j1

Billfish Working Group
Stock Status and Conservation Advice
For ISC 18

ISC Billfish Working Group

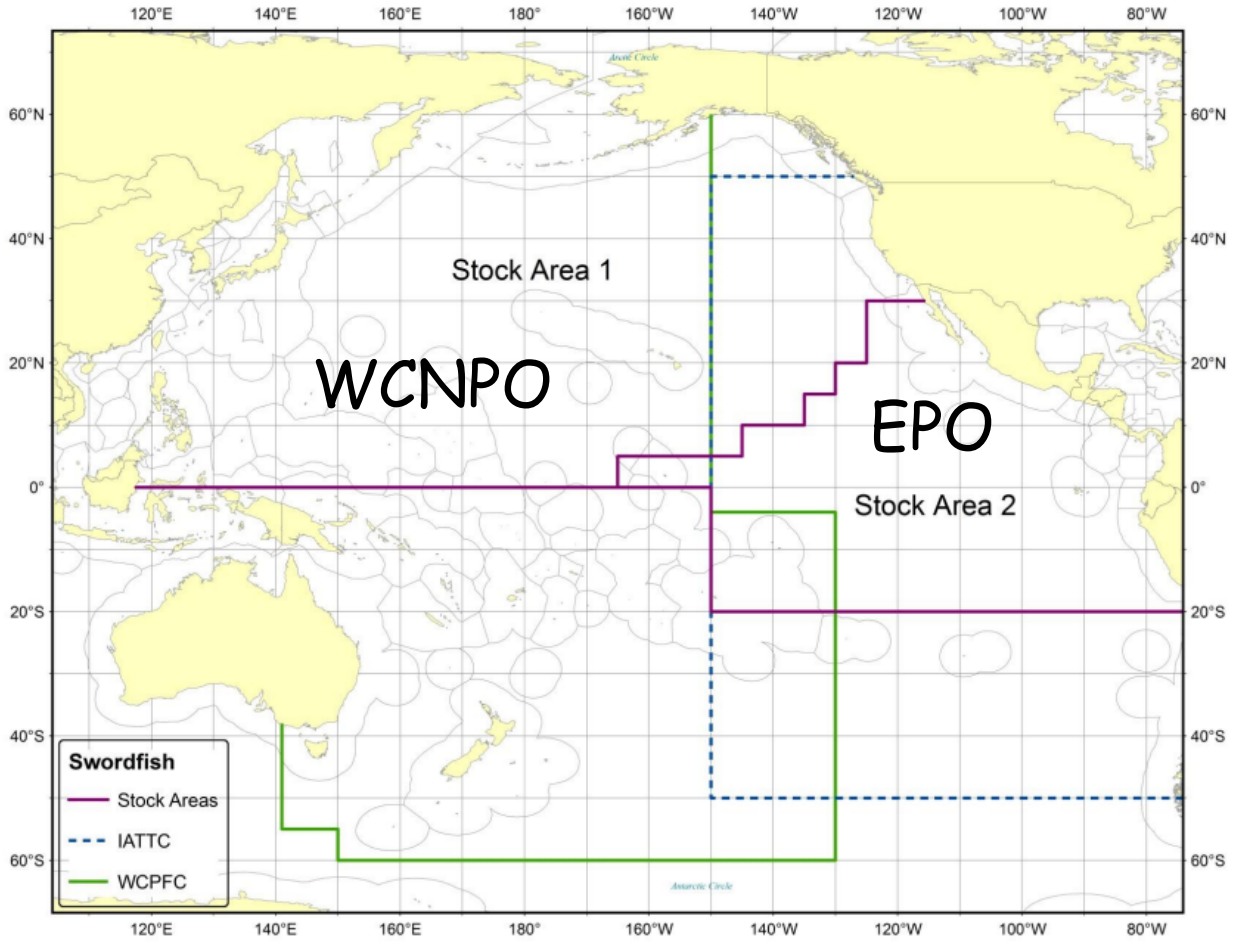
Jon Brodziak, Chair

Email: Jon.Brodziak@NOAA.GOV

Western and Central North Pacific Swordfish 2018 Benchmark Stock Assessment

ISC Billfish Working Group

North Pacific Swordfish Stock Areas

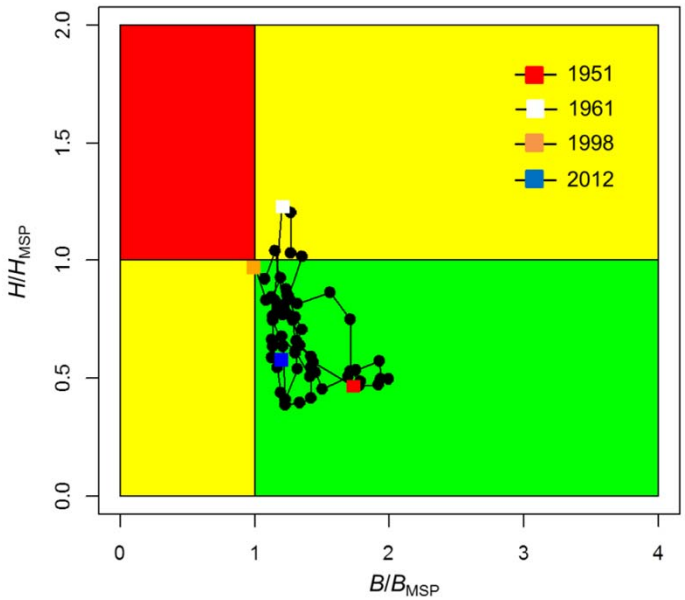


WCNPO Swordfish Assessment:
Chang et al. (2014) ISC/14/BILLWG-1/02

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

Overview of the 2014 Stock Assessment

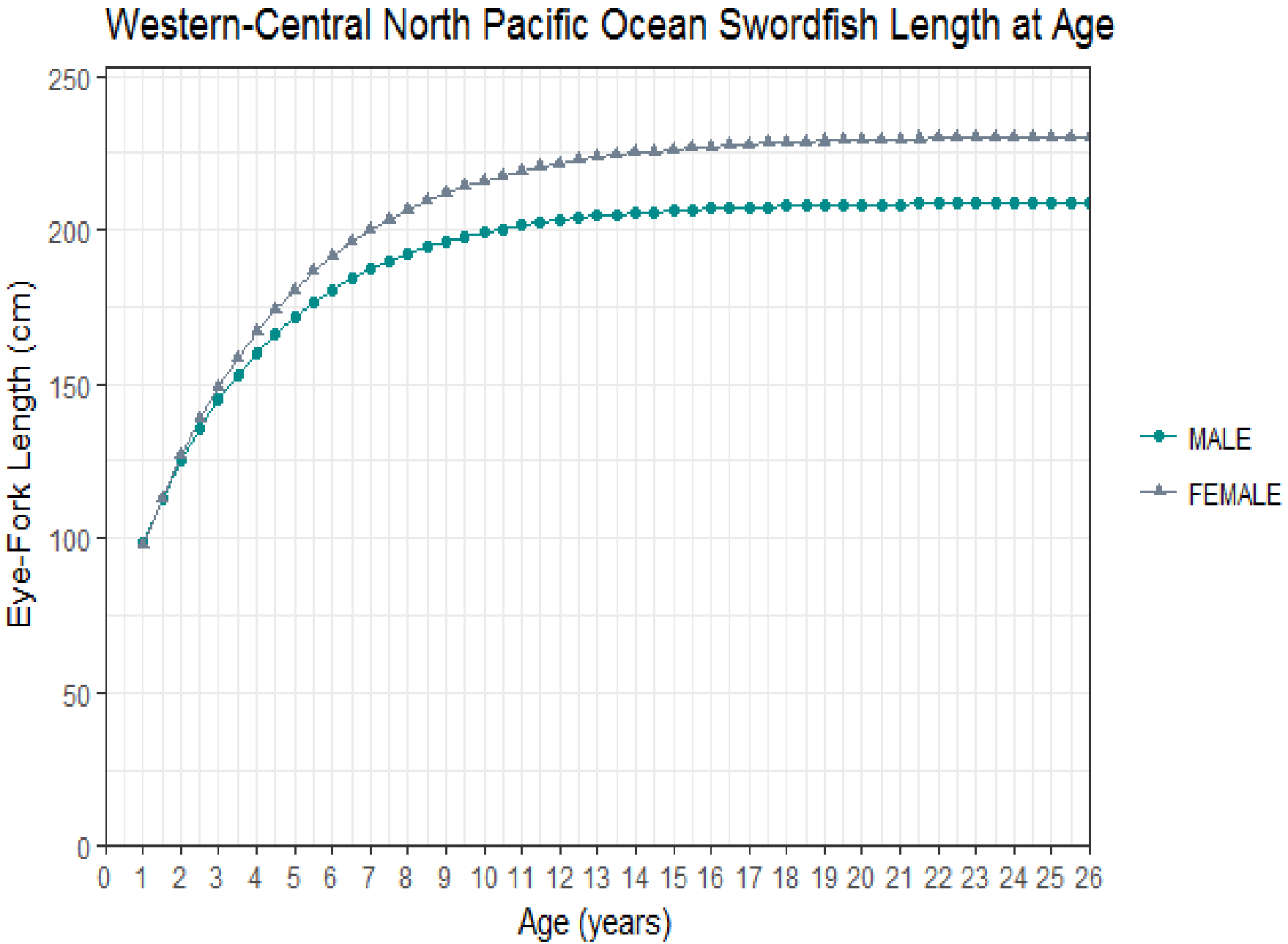
- **2014 Stock Assessment Summary**
  - Bayesian surplus production model (ISC 2014)
  - B_{2012} = mt (19 % above B_{MSY})
  - H_{2012} = (40% below H_{MSY})
  - **WCNPO swordfish was not experiencing overfishing and was not overfished relative to MSY-based reference points**



Western and Central North Pacific Swordfish 2018 Benchmark Stock Assessment

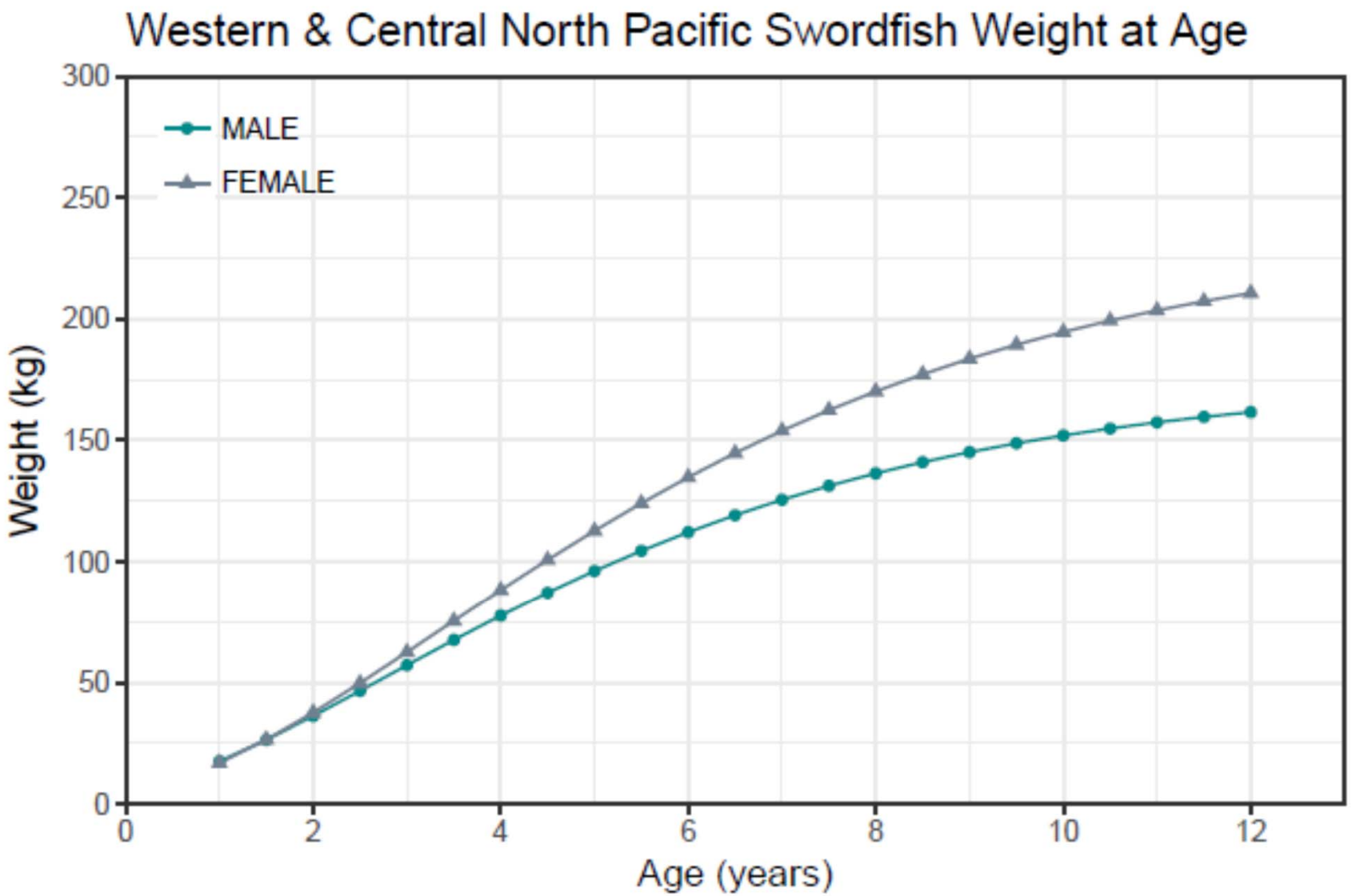
Assessment Data and Model

WCNPO Swordfish Life History Information


Western-Central North Pacific Ocean Swordfish Length at Age
Eye-Fork Length (cm)
250
200
150
100
50
0
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

Maximum Age and Length

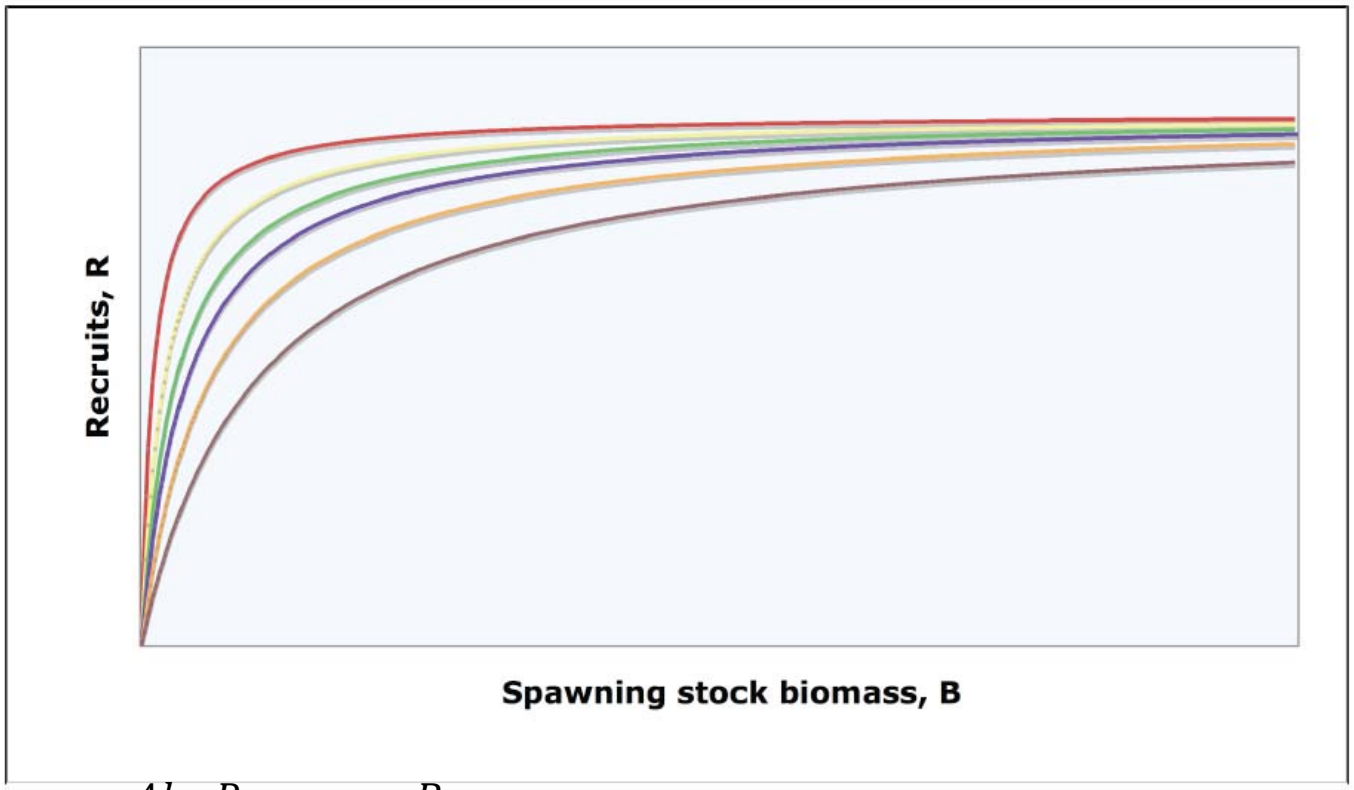
- Females: Amax = 12 years
- Males: Amax = 11 years
- Females: Lmax ≈ 260 cm EFL
- Males: Lmax ≈ 230 cm EFL


Western & Central North Pacific Swordfish Weight at Age
MALE
FEMALE
Weight (kg)
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Age (years)

Swordfish Stock-Recruitment Resilience

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

$$R = f(B)$$



$$R = f(B) = \frac{4h \cdot R_{unfished} \cdot B}{B_{unfished}(1-h) + B(5h-1)}$$

Definition of WCNPO Swordfish Fisheries

WCNPO Swordfish Fleets

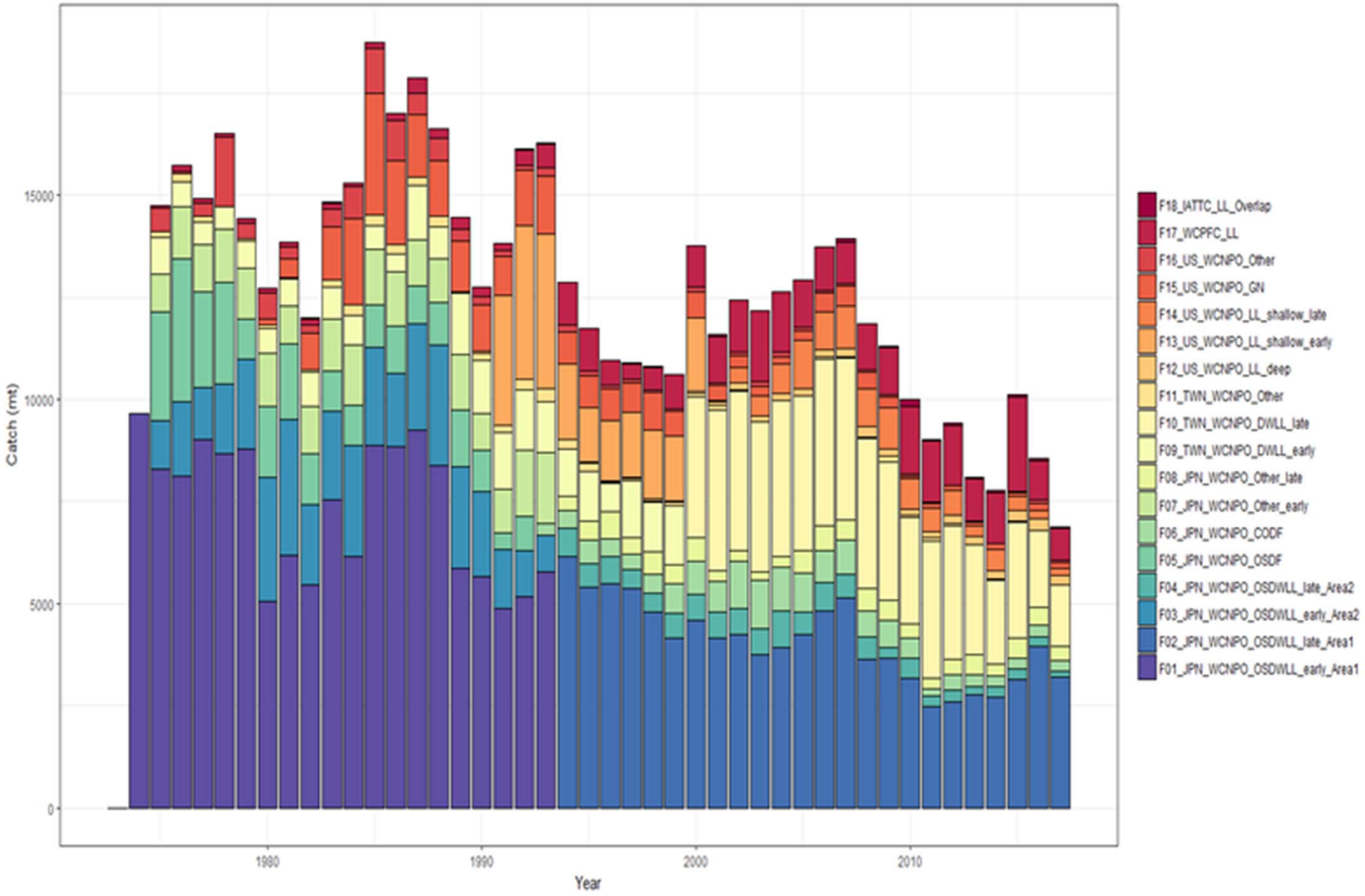
Fleet Code	Flag	Fleet Name	Catch Time Period	Quarterly Data ?	Catch Units	Standardized CPUE Available ?	Size Composition Data Available ?
F1	JPN	JPN_WCNPO_OSDWLL_early_Area1	1952-1993	Yes	Numbers	Yes, 1975-1993	Yes, 1970-1993, 1cm
F2	JPN	JPN_WCNPO_OSDWCOLL_late_Area1	1994-2016	Yes	Numbers	Yes, 1994-2016	Yes, 1994-2016, 1cm
F3	JPN	JPN_WCNPO_OSDWLL_early_Area2	1952-1993	Yes	Numbers	Yes, 1975-1993	No, Mirror F15
F4	JPN	JPN_WCNPO_OSDWLL_late_Area2	1994-2016	Yes	Numbers	Yes, 1994-2016	No, Mirror F15 or F11
F5	JPN	JPN_EPO_OSDWLL	1952-2016	Yes	Numbers	EPO, 1952-2016	Yes, Low coverage , 1cm
F6	JPN	JPN_WCNPO_OSDF	1960-1992	No	Weight	No	Yes, 1991-1992, 1cm
F7	JPN	JPN_WCNPO_CODF	1993-2014	No	Weight	No	Yes, Low coverage, 1cm
F8	JPN	JPN_WCNPO_Other_early	1952-1993	No	Weight	No	No, Mirror F1
F9	JPN	JPN_WCNPO_Other_late	1994-2014	No	Weight	No	No, Mirror F2
F10	TWN	TWN_WCNPO_DWLL _early	1959-1999	No	Weight	Yes, 1975-1999	No, Mirror F11 or F1
F11	TWN	TWN_WCNPO_DWLL _late	2000-2016	No	Weight	Yes, 2000-2016	Yes, 2004-2016, 1cm
F12	TWN	TWN_WCNPO_Other	1959-2016	No	Weight	No	No, Mirror F11 or F2
F13	TWN	TWN_EPO_OSDWLL_early	1967-1999	No	Weight	EPO, 1967-1999	No, Mirror F14
F14	TWN	TWN_EPO_OSDWLL_late	2000-2016	No	Weight	EPO, 2000-2016	Yes, 2004-2016, 1cm
F15	US	US_WCNPO_LL_deep	1995-2016	Yes	Weight	Yes, 1995-2016	Yes, 1995-2016, 1cm
F16	US	US_WCNPO_LL_shallow_early	1990-2000	Yes	Weight	Yes, 1995-2000	Yes, 1995-2000, 1cm
F17	US	US_WCNPO_LL_shallow_late	2005-2016	Yes	Weight	Yes, 2005-2016	Yes, 2005-2016, 1cm
F18	US	US_WCNPO_GN	1980-2016	No	Weight	Yes, 1985-2006	No, Mirror F15 or F16
F19	US	US_WCNPO_Other (Harpoon, Other)	1970-2016	No	Weight	No	No, Mirror F15 or F16
F20	MEX	MEX_LL_EPO	2011-2016	Yes	Weight	No	Yes, 2006-2016, 1 cm
F21	WCPFC	WCPFC_LL	1970-2016	Yes	Weight	No	No, Mirror F11 or F15
F22	IATTC	IATTC_LL	1975-2016	Yes	Weight	No	Yes, Low coverage, 1 cm
F23	IATTC	IATTC_LL_Overlap	1975-2016	Yes	Weight	No	No, Mirror F14 or F5

WCNPO Swordfish Catch Data

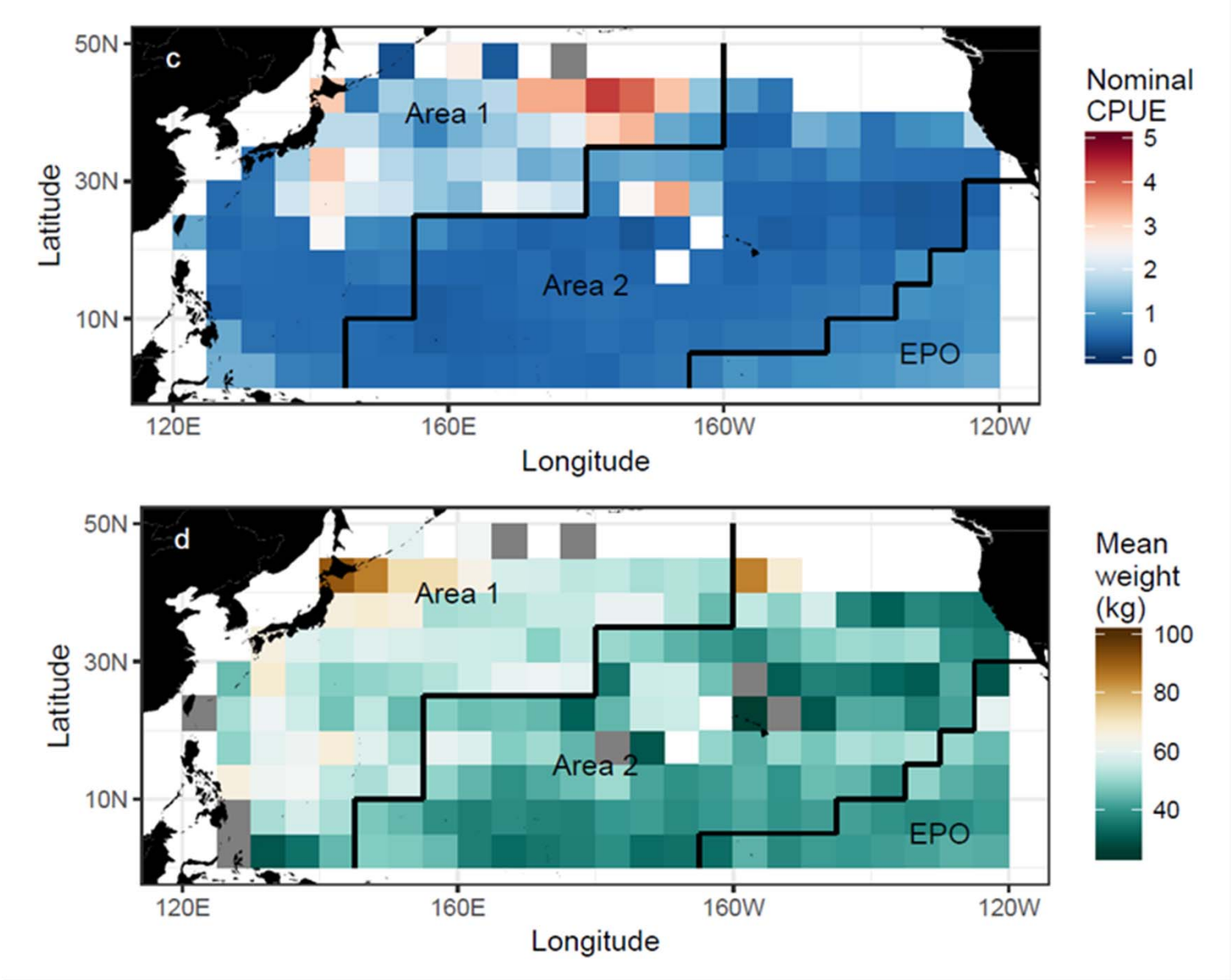
- Catch data for 1975 to 2016 were gathered from all available fleets and sources in the North Pacific

- Swordfish catches are assumed to be well reported

Finalized WCNPO Swordfish Catch Data by Fleet



Area Stratification for Japanese Longline Fleets in WCNPO



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

Standardized CPUE by Fleet

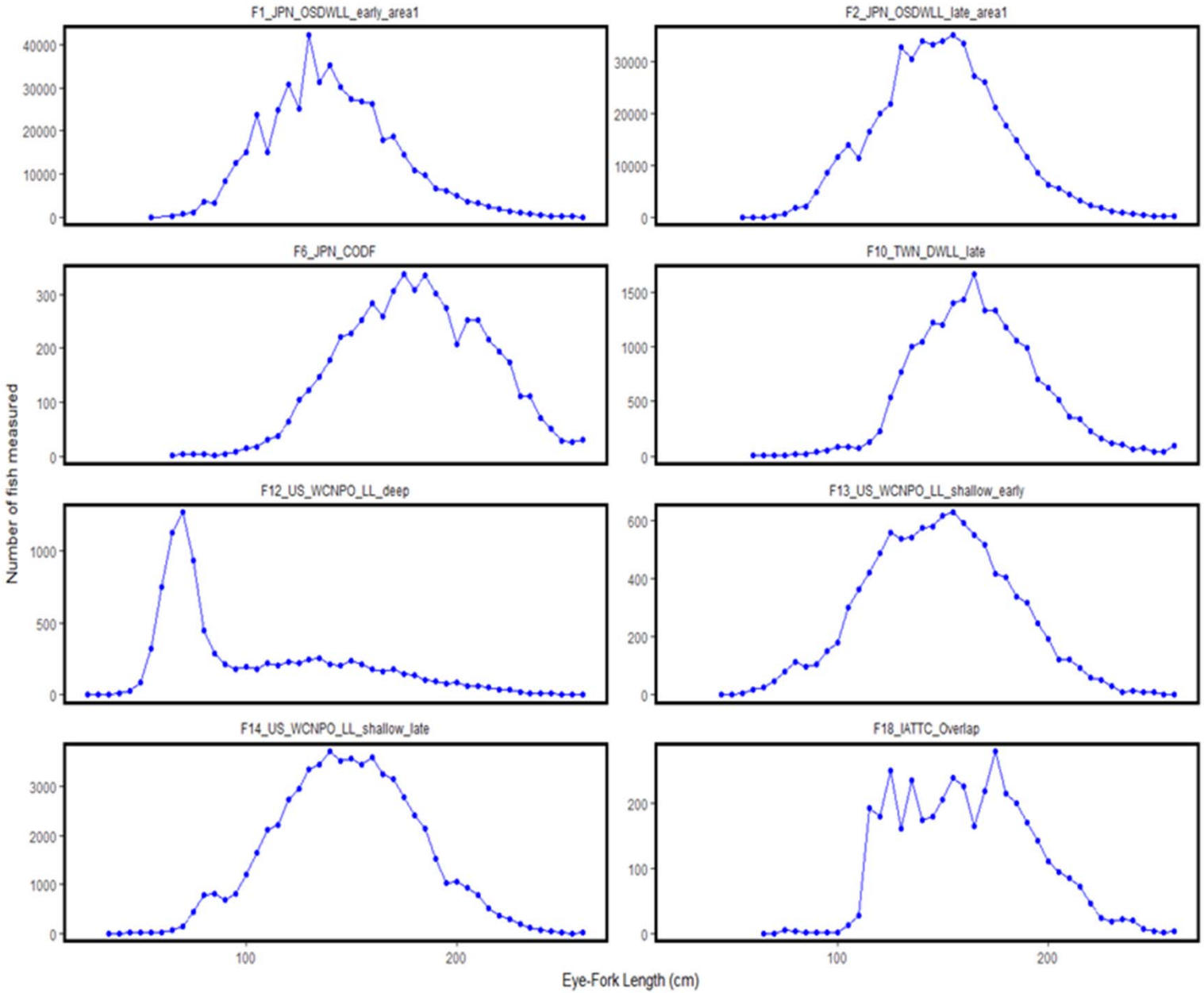
Size Data	CPUE	Fleet Name	Time Series	Source
F1 – N	S1 – Y	JPN_WCNPO_OSDWLL_early_Area 1	1975-1993	Kanaiwa and Ijima 2018
F2-Y	S2 – Y	JPN_WCNPO_OSDWLL_late_Area1	1994-2016	Kanaiwa and Ijima 2018
F3	S3 – Y	JPN_WCNPO_OSDWLL_early_Area 2	1975-1993	Kanaiwa and Ijima 2018
F4	S4 – Y	JPN_WCNPO_OSDWLL_late_Area2	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.

Size Composition Data

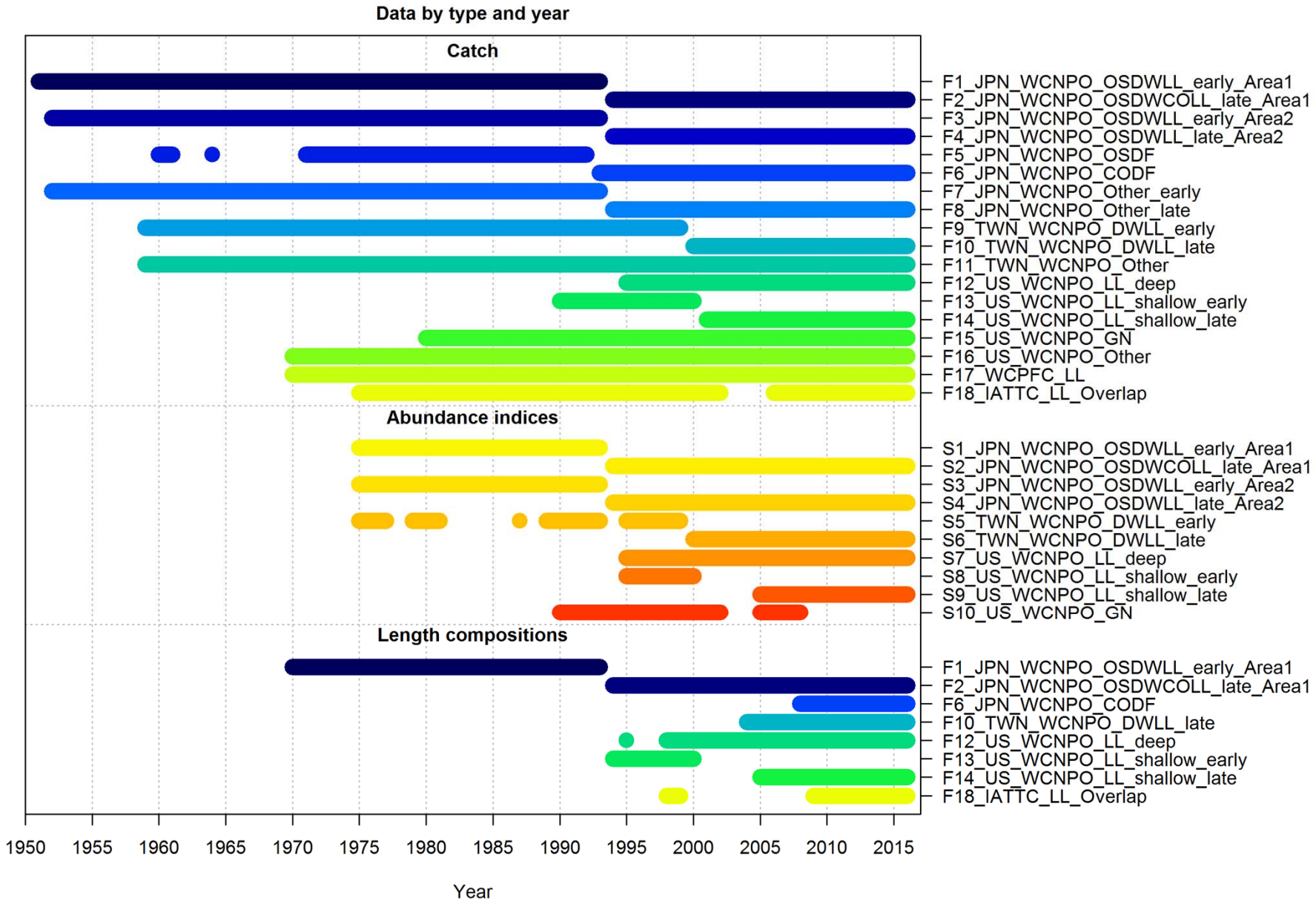
Size Composition Data by Fleet

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.

Aggregated Size Composition Data By Fleet



Temporal Coverage of Catch, Abundance Index, and Size Composition Time Series 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 the 2018 WCNPO swordfish assessment

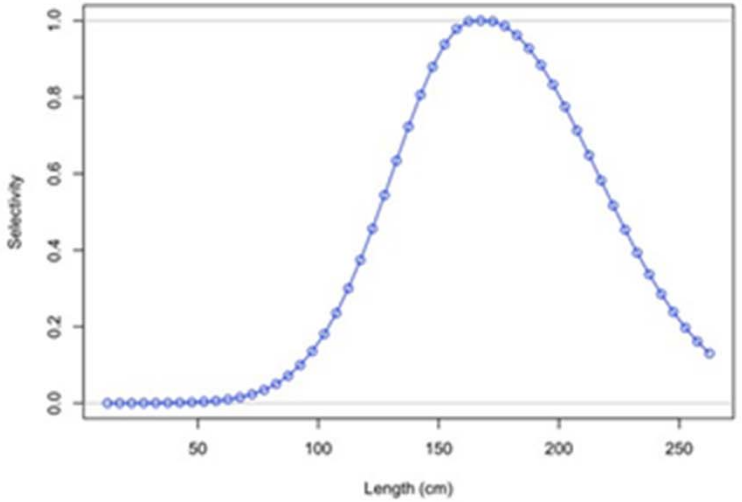
- ✓ Uncertainty in the initial stock numbers at age by gender was estimated using parametric bootstrapping of the fitted base case assessment model

- ✓ Uncertainty in future recruitment was incorporated by randomly sampling from the fitted stock-recruitment model as estimated in the base case assessment model.

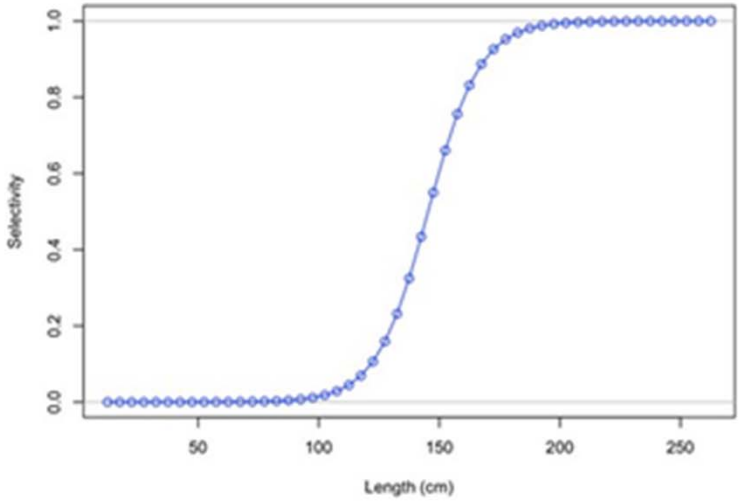
Model Diagnostics and Goodness of Fit

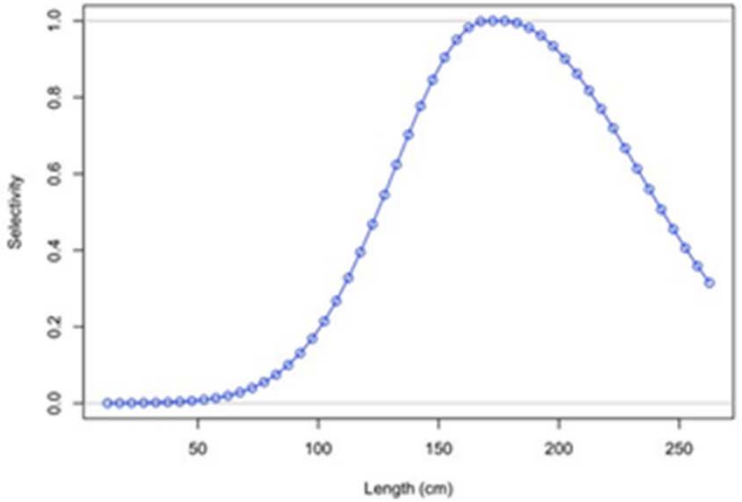
Fishery Selectivities by Fleet

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

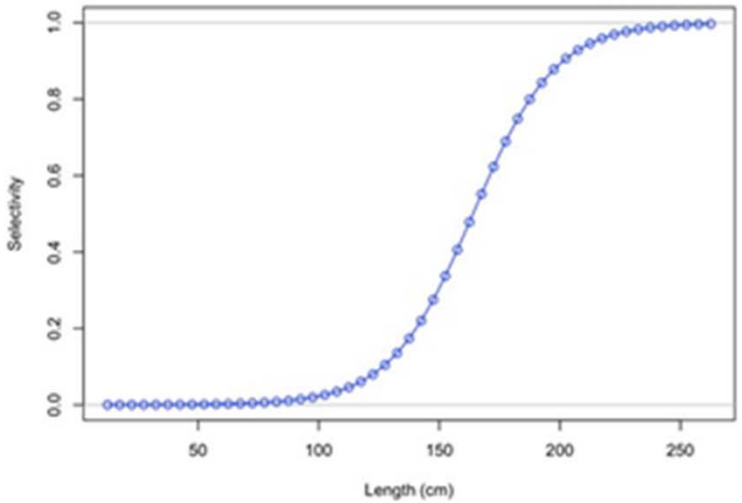


Taiwanese Distant Water Longline for 2000-2016



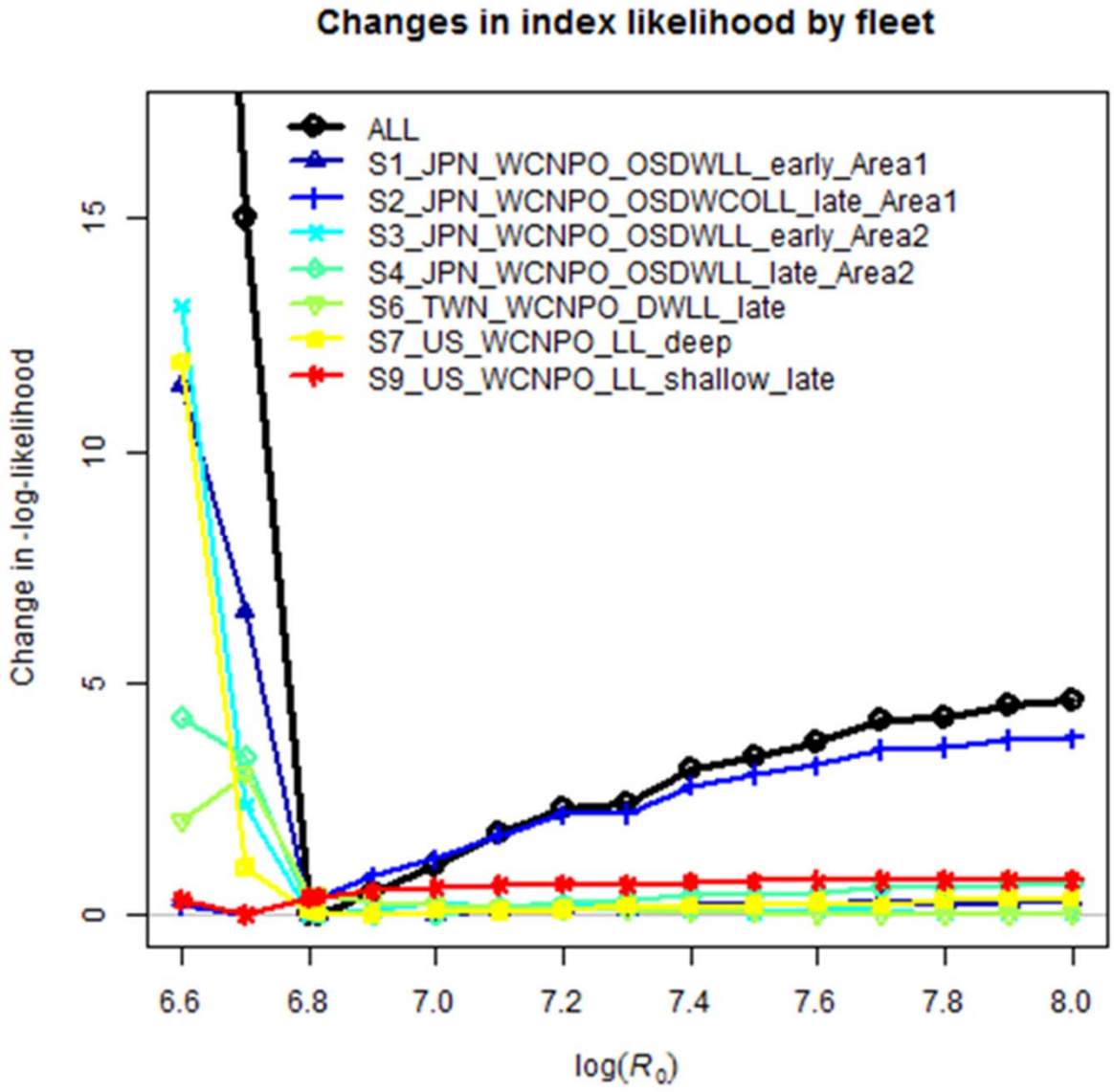


USA Shallow-Set Longline for 2005-2016



IATTC Longline in RFMO Overlap Area for 1975-2016

Results of Likelihood Profiles by CPUE Index for Unfished Recruitment R0

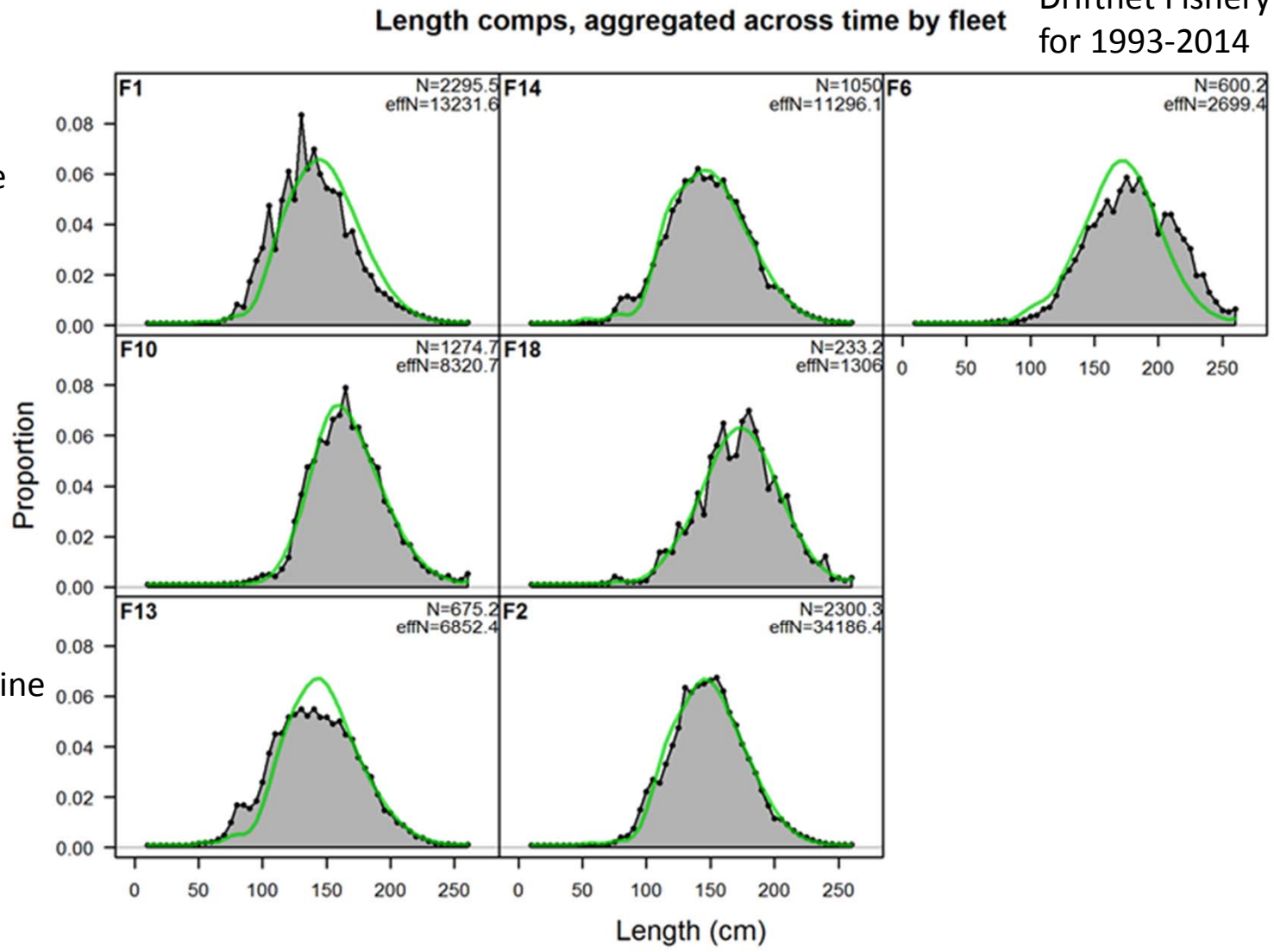


Fits to Size Composition Data by Fleet

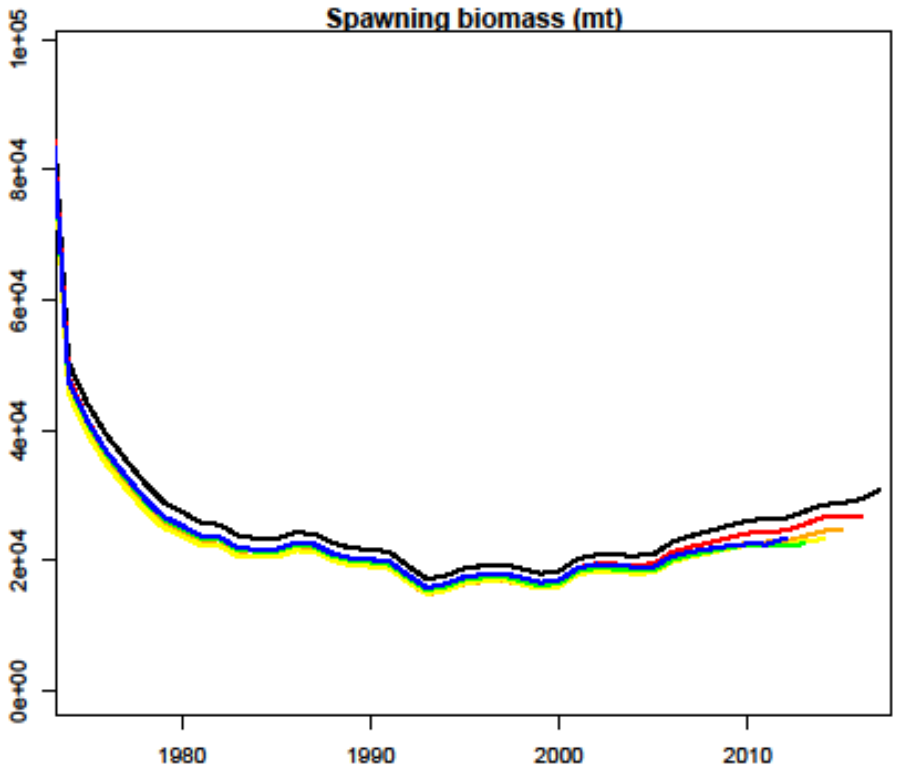
Japanese Coastal Driftnet Fishery for 1993-2014

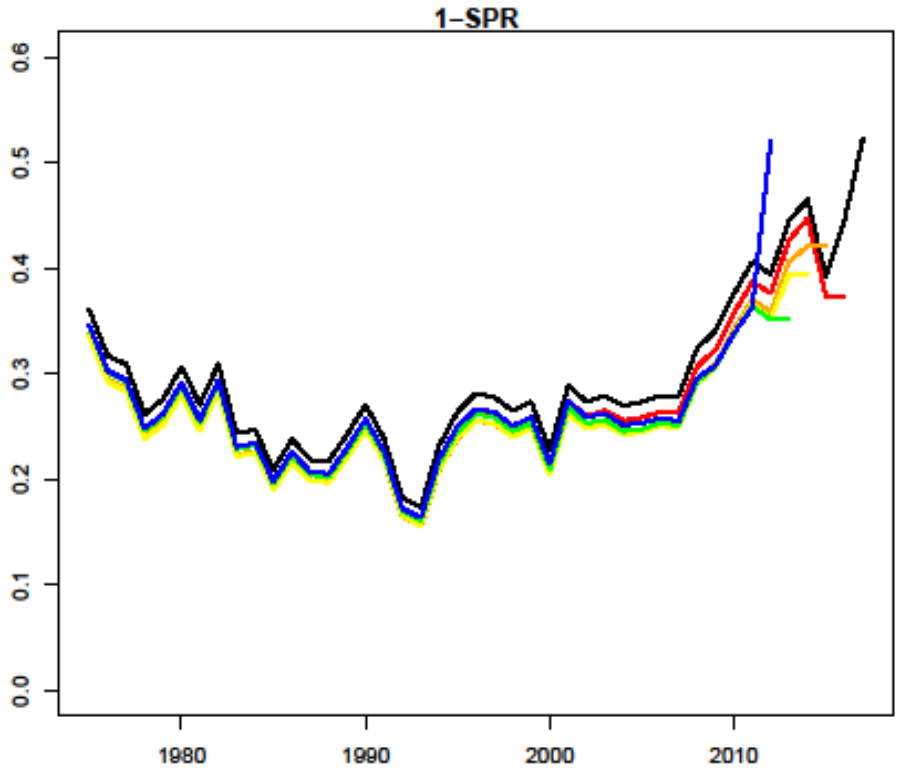
Japanese Offshore Distant Water Longline in Area 1 for 1975-1993

USA Shallow-Set Longline for 1995-2000

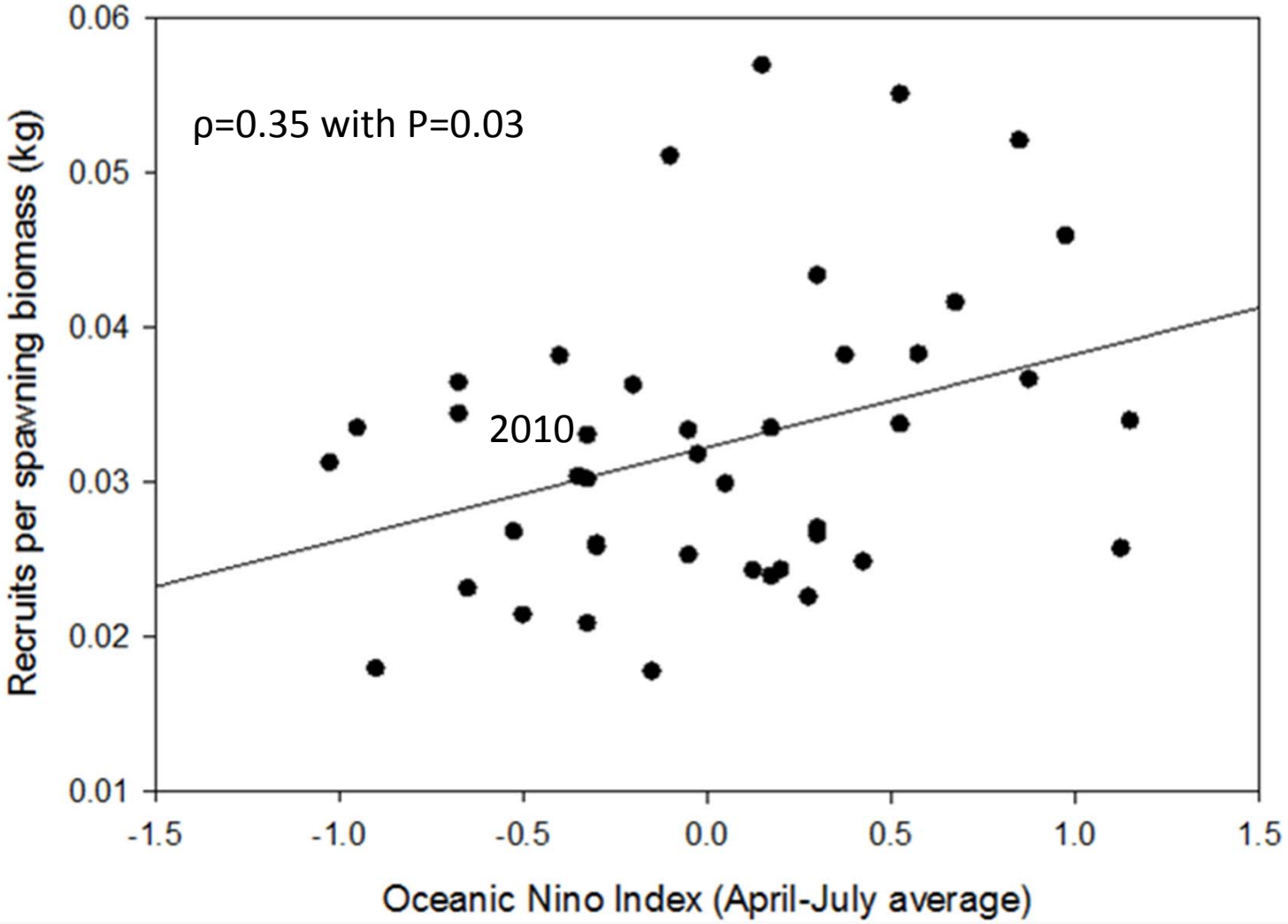


WCNPO Swordfish Retrospective Analyses





WCNPO Swordfish El Nino Forcing on Recruitment Success



R2010=789000 recruits, highest since 2004

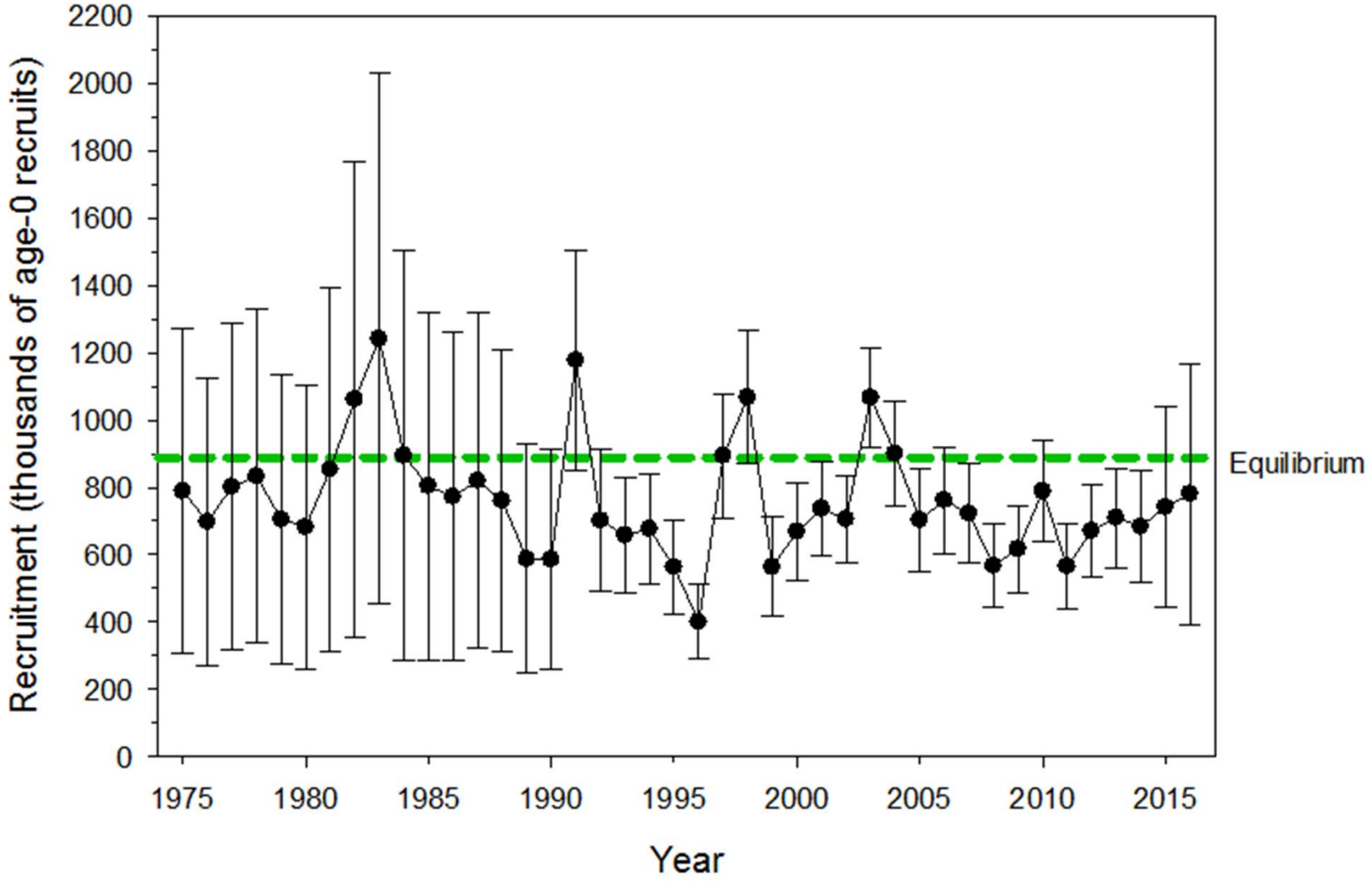
Western and Central North Pacific Swordfish 2018 Benchmark Stock Assessment

Stock Status and Conservation Information

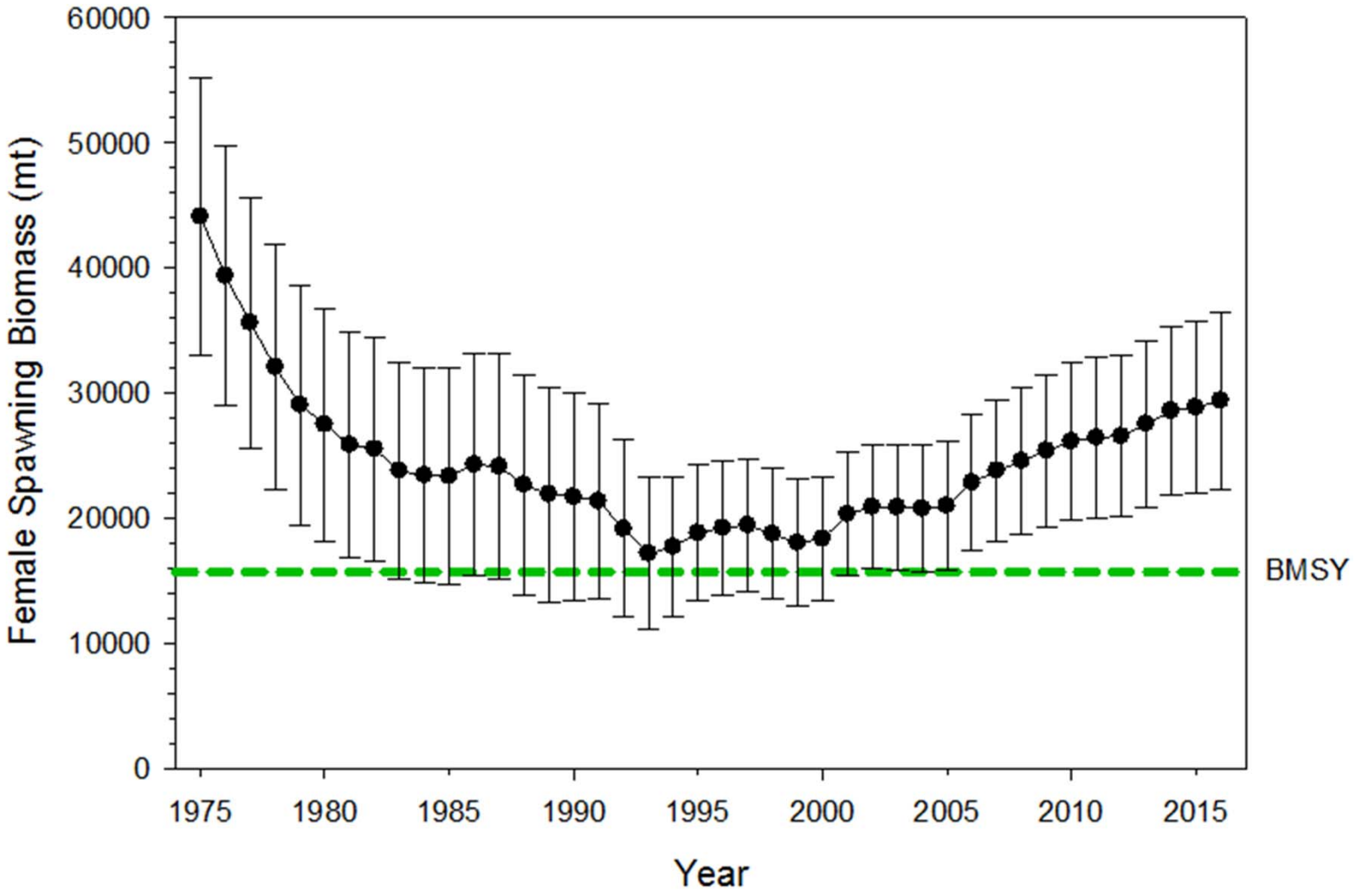
WCNPO Swordfish Reference Points

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

WCNPO Swordfish Recruitment



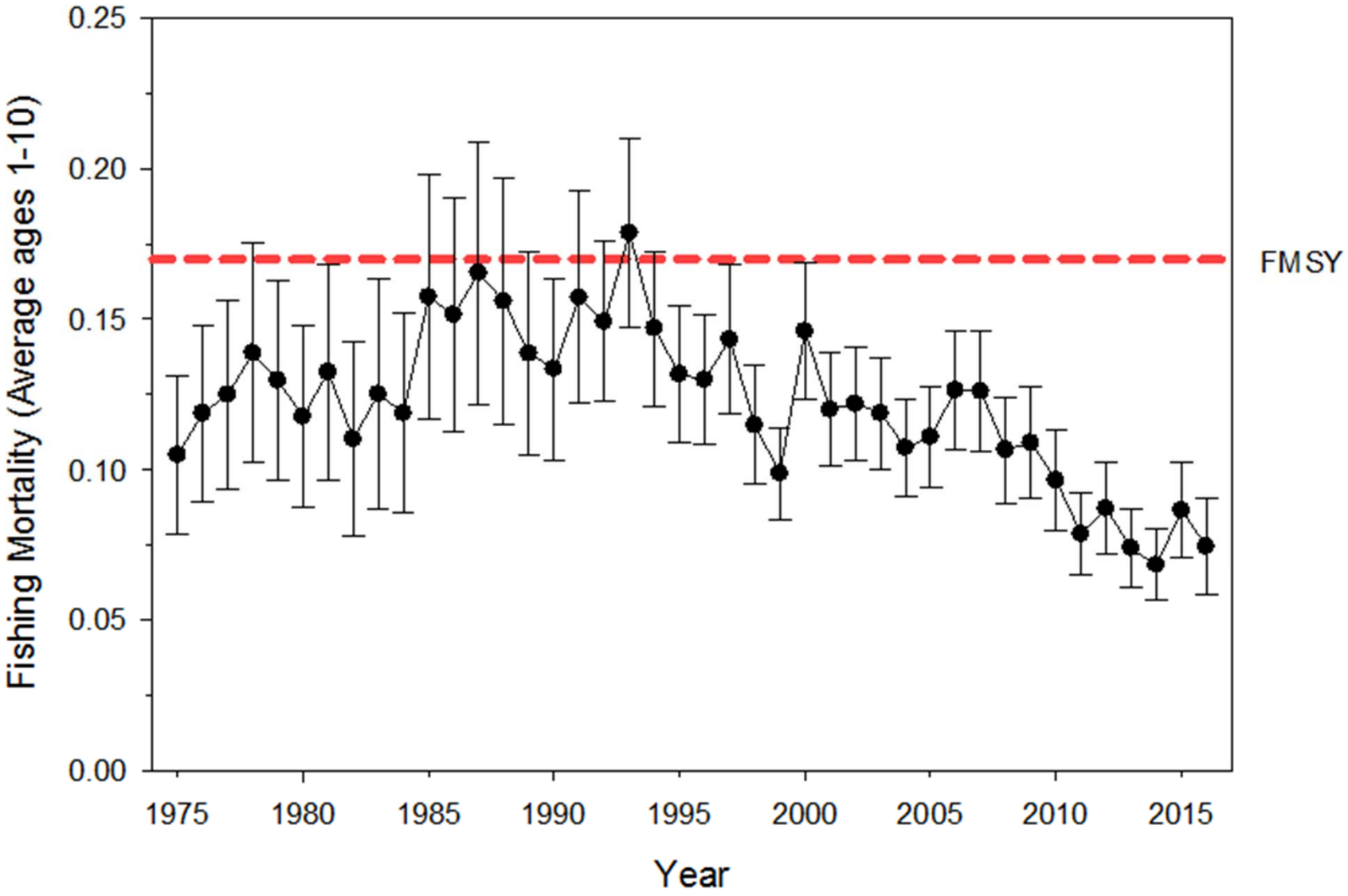
WCNPO Swordfish Spawning Biomass



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}

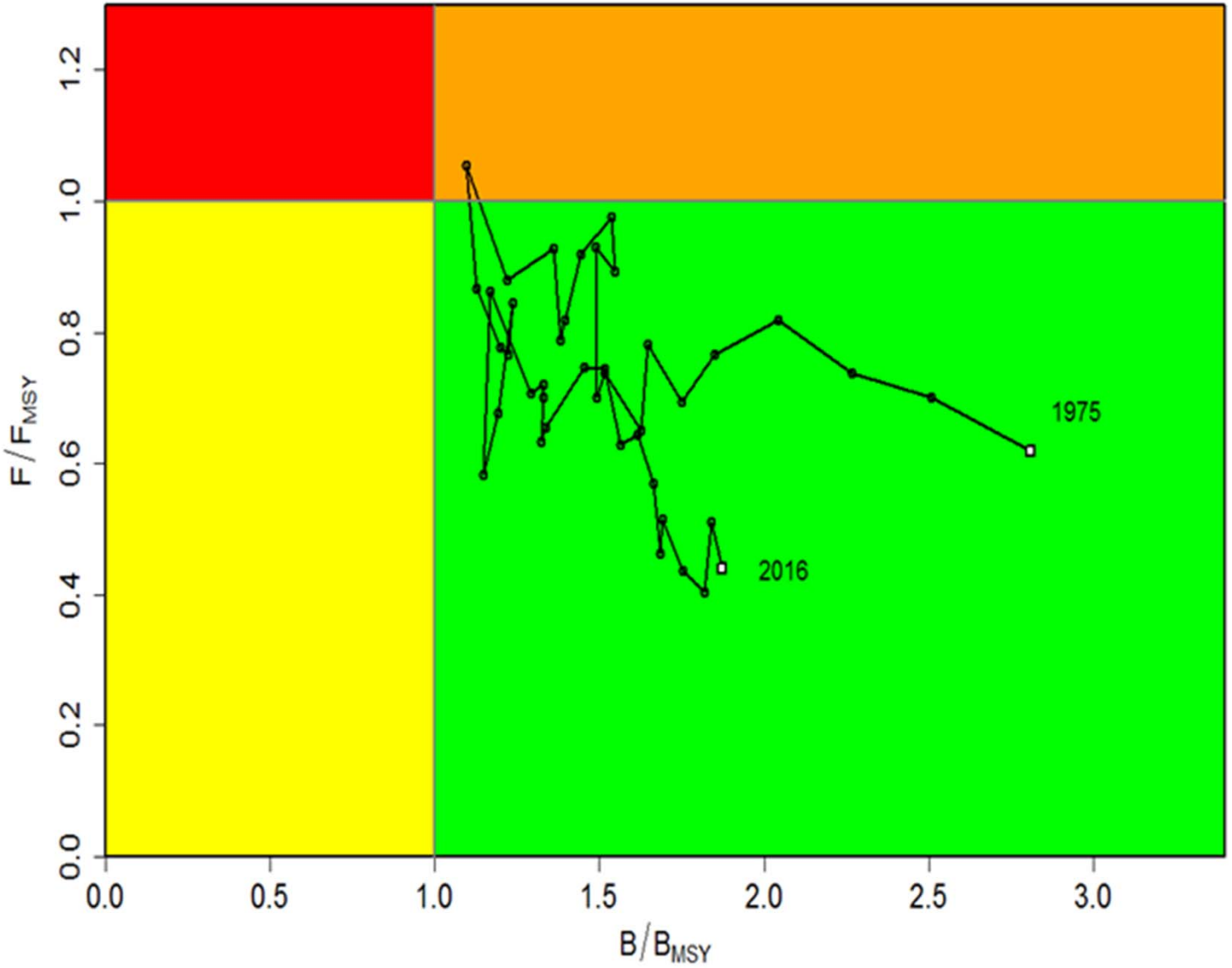
WCNPO Swordfish Fishing Mortality



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 $F_{20\%SSB(F=0)}$

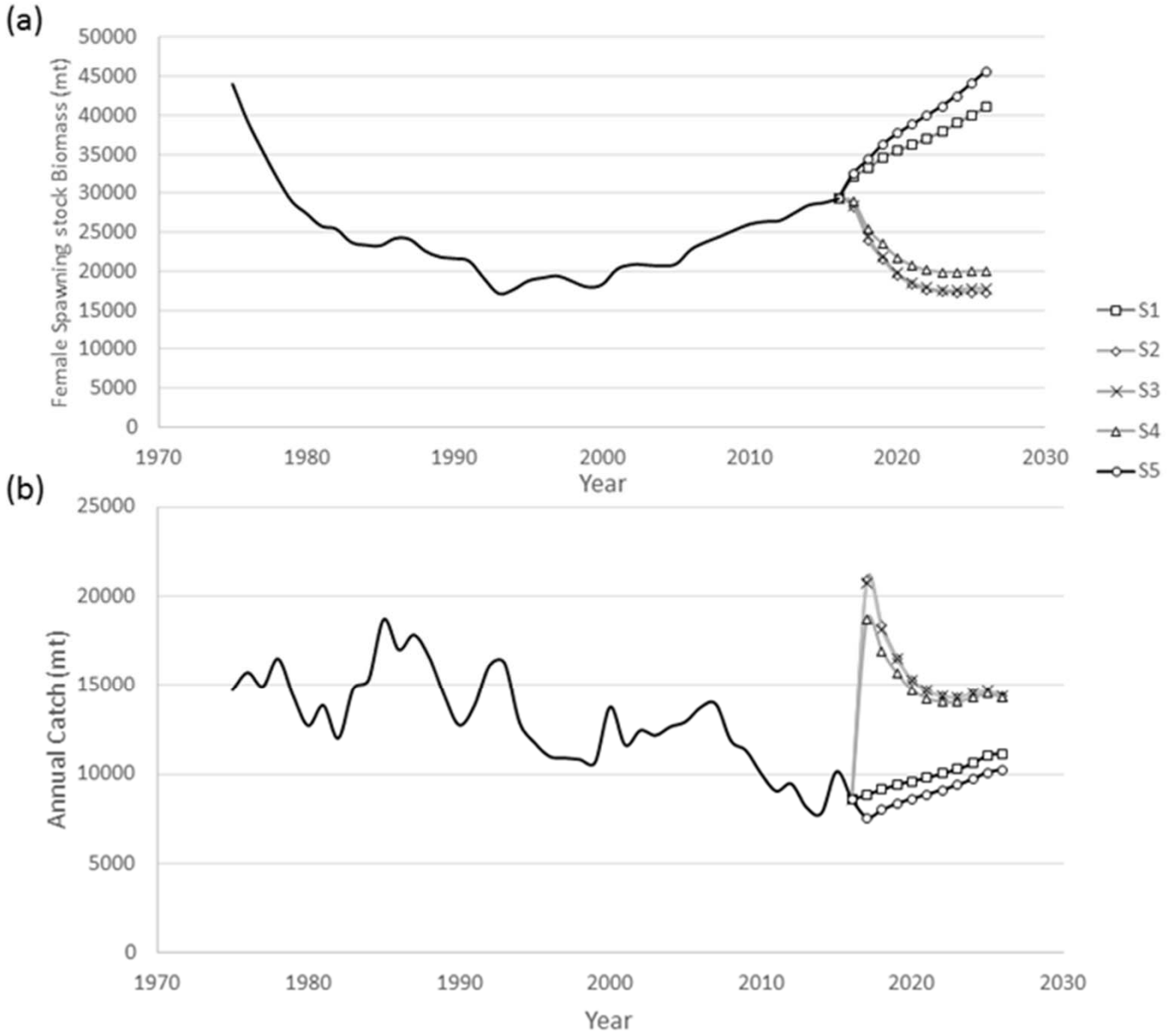
WCNPO Swordfish Kobe Plot
Relative to MSY-Based Reference Points



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 = $F_{20\%SSB(F=0)}$ = $F_{18\%}$
  - 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

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

Conservation Information

- 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)

Conservation Information

- 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.

Conservation Information

- Swordfish stock status is positive with 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}).

- It was also noted that retrospective analyses show that the assessment model appears to underestimate spawning potential in recent years.

Conservation Information

- 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

Western and Central North Pacific Swordfish 2018 Benchmark Stock Assessment

The End