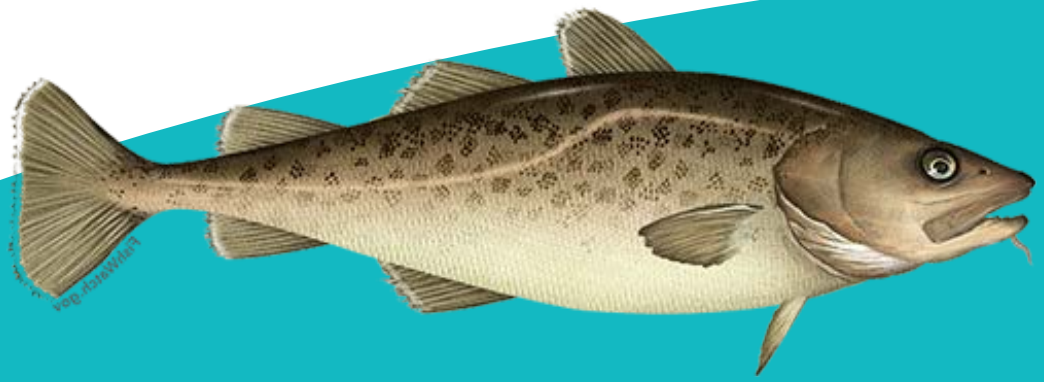

Gulf of Alaska Pacific cod

Steven Barbeaux, Bridget Ferriss, Wayne Palsson, Kalei Shotwell, Ingrid Spies, Muyin Wang, and Stephani Zador

Changes in the input data

- Federal and state catch data for 2019 were updated and preliminary federal and state catch data for 2020 were included;
- Commercial federal and state fishery size composition data for 2019 were updated, and preliminary commercial federal and state fishery size composition data for 2020 were included;
- AFSC bottom trawl survey Pacific cod conditional length-at-age data for the GOA for 2019 were included;
- AFSC longline survey Pacific cod abundance index and length composition data for the GOA for 2020 were included;
- All length composition samples with less than 30 fish for a particular area, year, quarter, and gear type were excluded from the dataset. This made up 2% of the data representing < 1% of the overall catch.

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Model changes

- Model 19.1 is Model 19.14.48c, last year's accepted management model with new data
- Model 20.1 is a environmentally-linked Model 19.1
  - Growth – temperature influenced von Bertananffy growth
    - L_∞ and K scaled to mean June SST anomaly
    - L_0 scaled to temperature dependent juvenile growth rate from Laurel *et al.* 2015
  - Recruitment
    - R_0 scaled to the cube of the spawning marine heatwave cumulative index (Feb-Mar HWCI)

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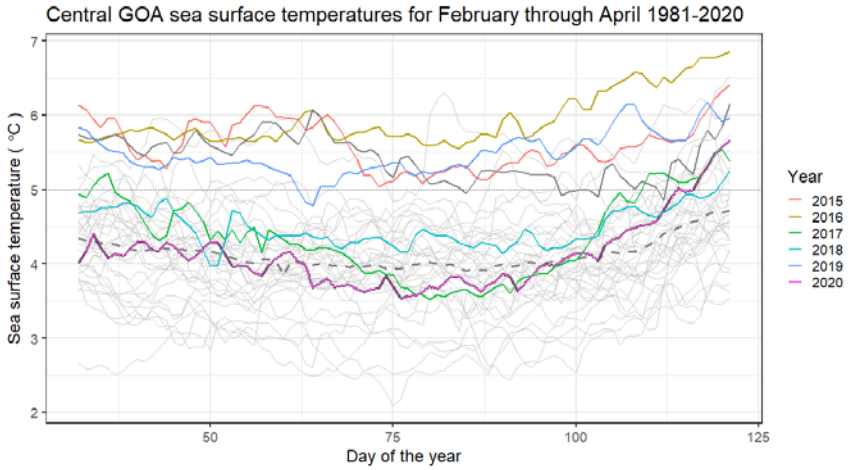
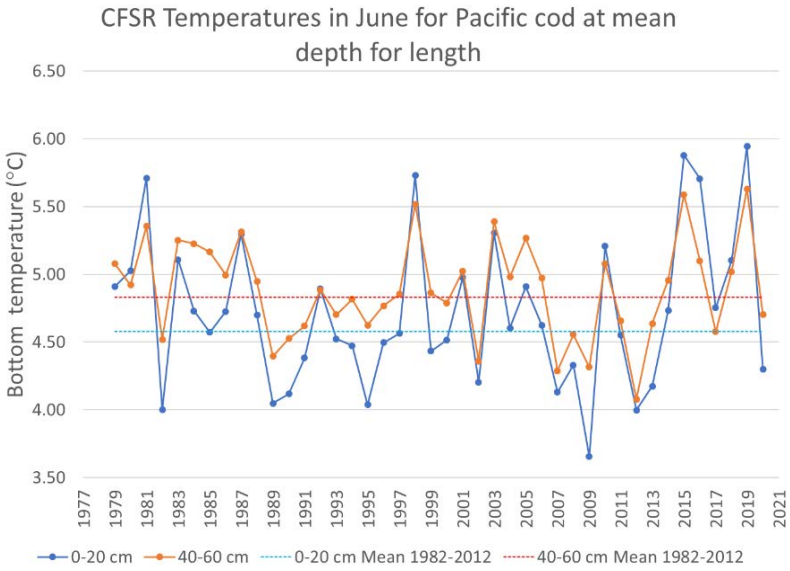


2019 heatwave conditions during spawning

2020 cooler SST during spawning season



2019 warmest June bottom temperatures

2020 cooler June bottom temperatures to below the 1982-2012 mean

Ecosystem data

Sea surface and bottom temperatures were cooler in 2020 Winter and Spring

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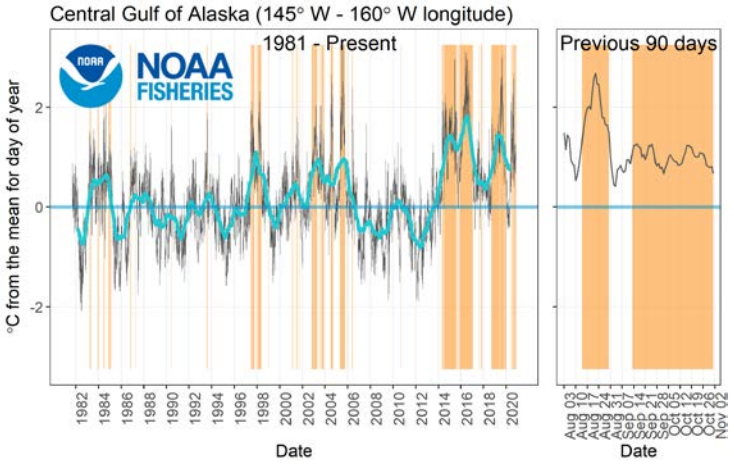
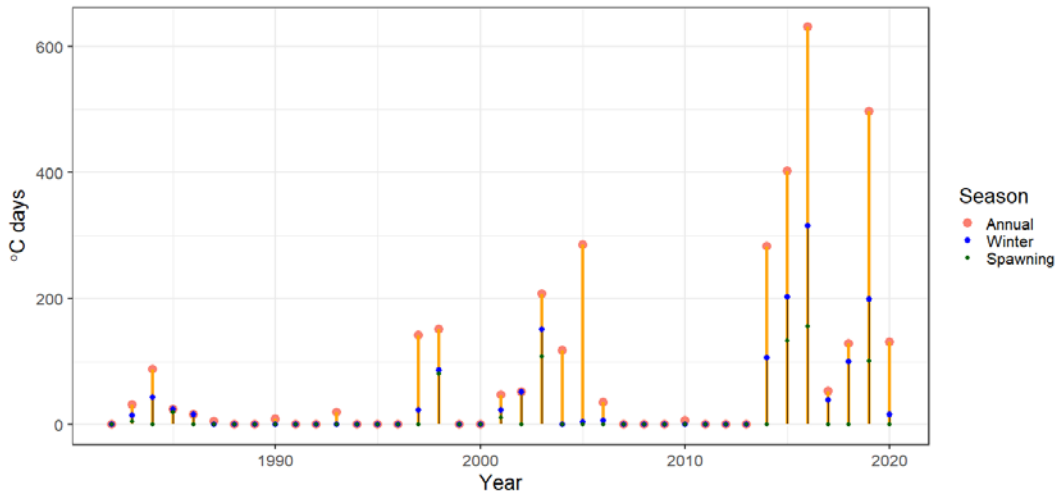
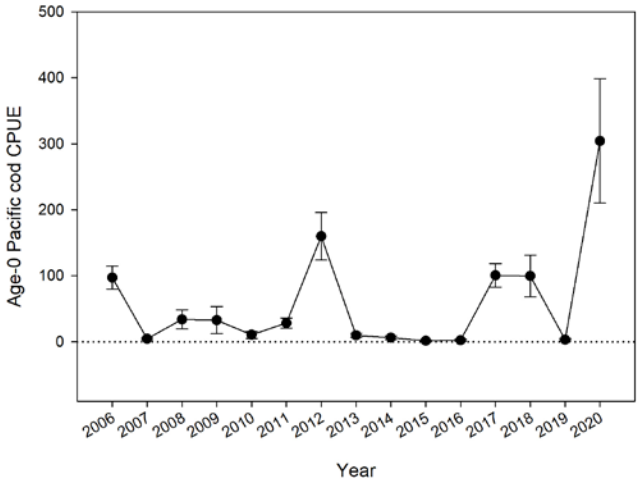




- 2019 heatwave conditions throughout the year
- 2020 heatwave conditions during summer and into fall

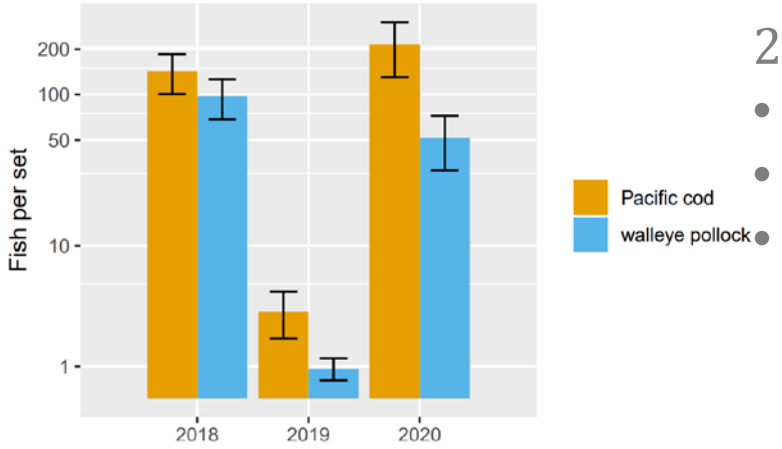
Ecosystem data

Temperatures and heatwave indices show a warm 2020 summer and fall



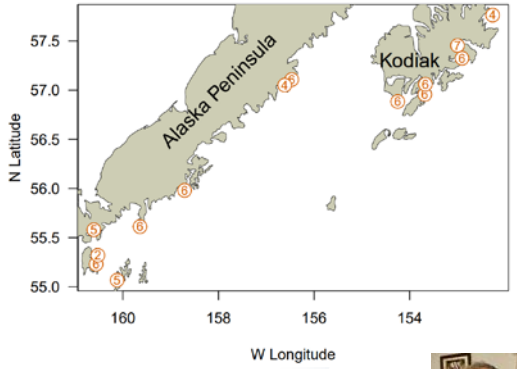
2006-2020 Kodiak beach seine survey

- Ben Laurel
- Relatively high 2020 age-0 Pacific cod
- 2019 similar to heatwave numbers



2018-2020 CGOA and WGOA beach seine survey

- Alisa Abookire and Mike Litzow
- 2020 higher than 2019 and 2018
- 2019 very low



YOY surveys: not used in assessment

2020 year class looks relatively high in both beach seine surveys.

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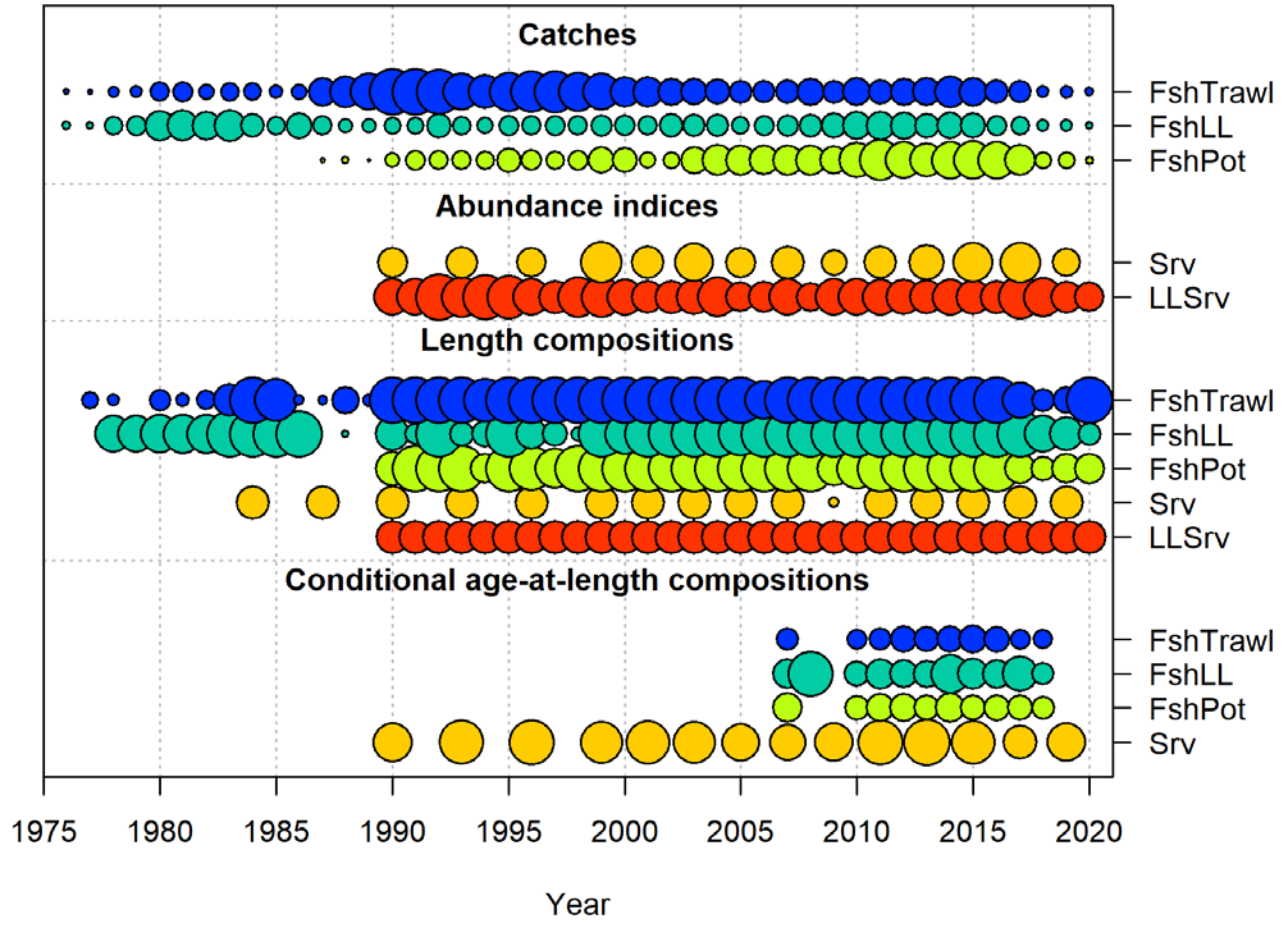

Same as 2019

- Three fisheries
- Two survey indices
- Length composition
- Conditional age-at-length

Data in the models

Three fisheries, two surveys, length composition from all, conditional age-at-length composition for Bottom trawl survey and three fisheries.

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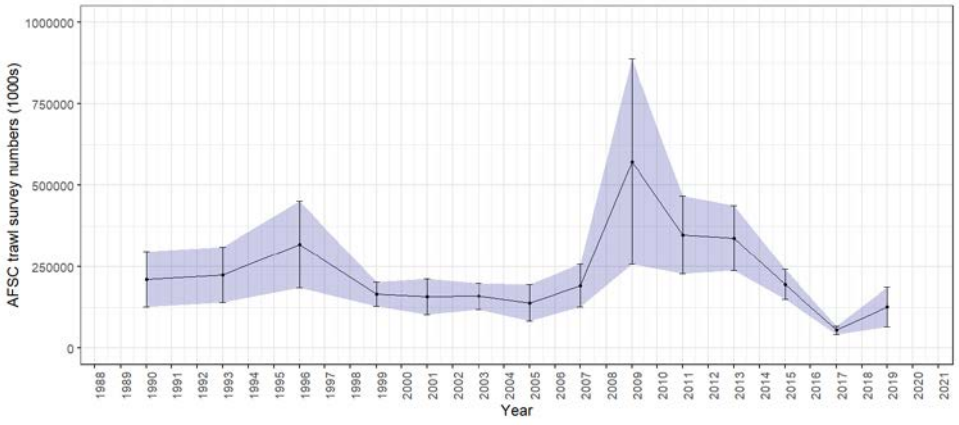
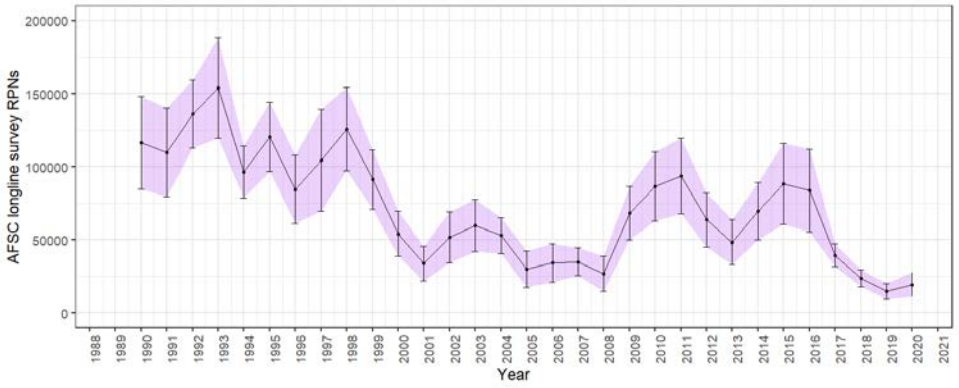


2019 AFSC Bottom trawl survey

- 126% increase in abundance from 2017
  - 5.6×10^7 to 12.7×10^7 fish
- Second lowest biomass estimate in time series
  - 69% increase to 181,581 t
  - Highest CV in time series (0.243)



2020 AFSC Longline survey

- 30% increase in abundance from 2019
  - Second lowest RPN in time series
  - 2019 lowest estimate in time series

Survey indices: used in model

AFSC bottom trawl and AFSC longline surveys still at low values

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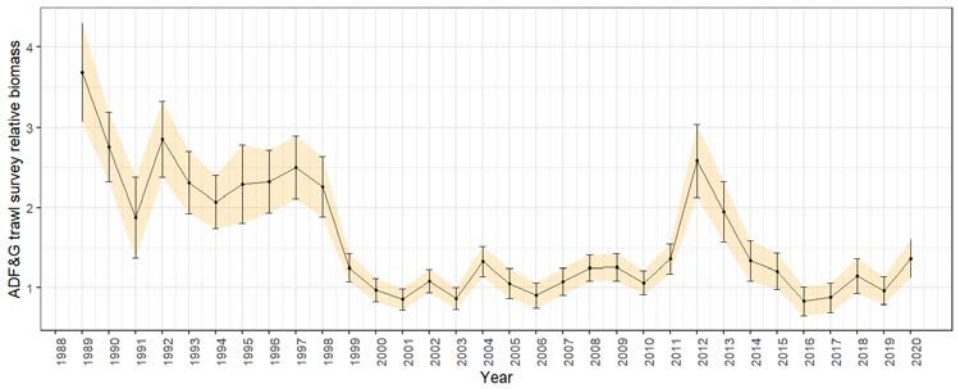
IPHC longline survey

- 2020 reduced survey area not including western GOA strata
  - Data not yet available
  - No Pacific cod lengths measured
- 2019 survey 4% decrease from 2018



2020 ADFG trawl survey

- 2020 survey 41% increase in abundance from 2019

Survey indices: not used in assessment

Some mixed signals, but continued lower abundance for both surveys

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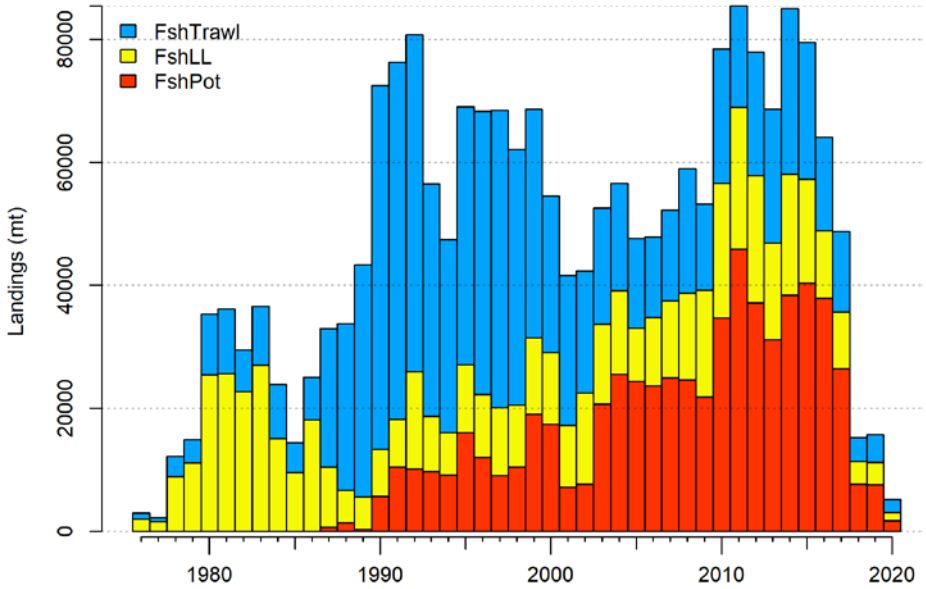

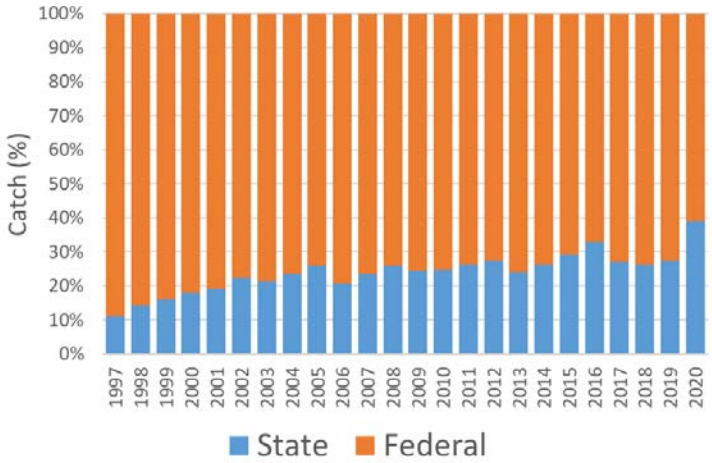

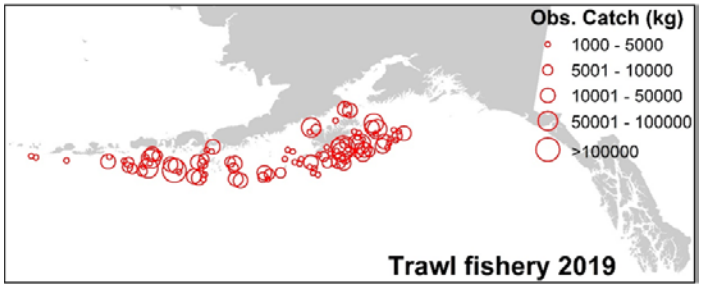

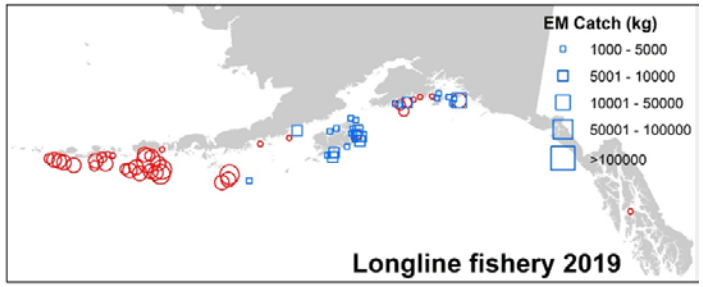

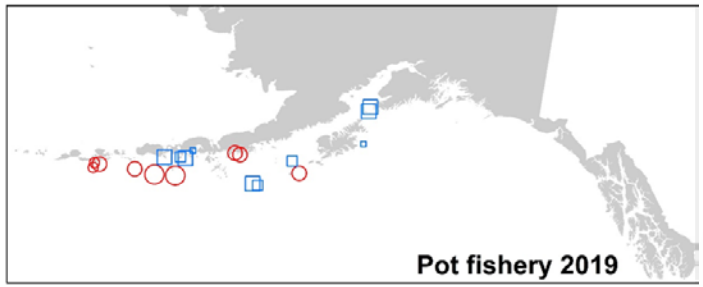

Fishery catch

5,742 t as of 10/14/2020

Drastically reduced catch starting in 2017. Larger proportion of longline and pot fishery monitored electronically. Increasing proportion of catch taken by the state.

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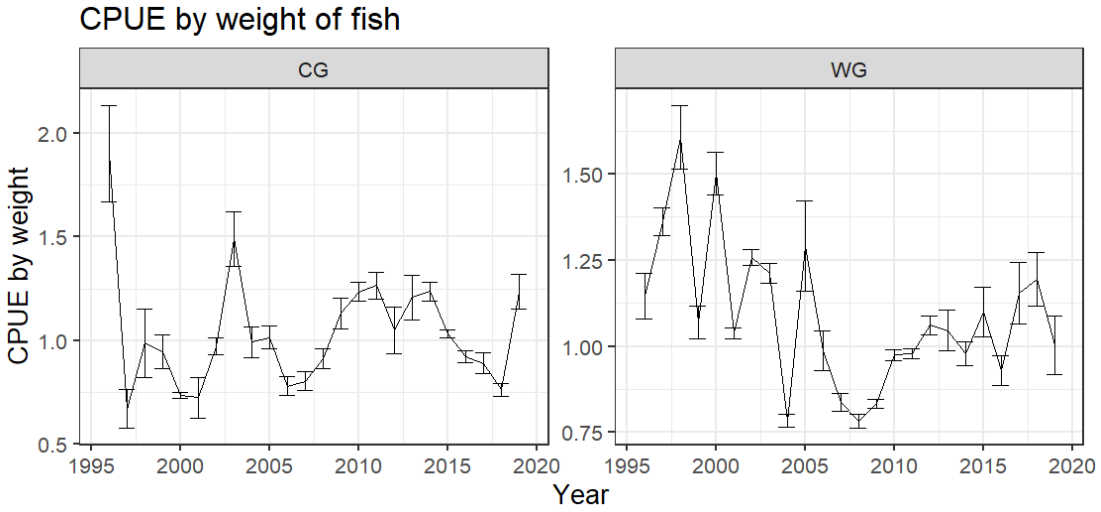
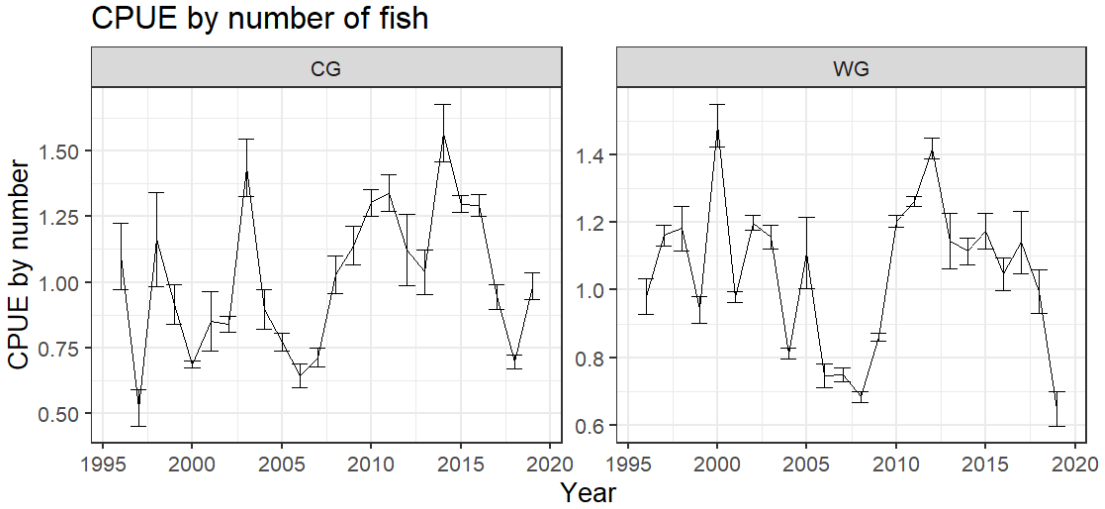


Catch weighted standardized combined gear CPUE



2019 has few longline and pot data in central GOA due to electronic monitoring coverage

Fishery CPUE through 2019

Mixed signal on CPUE but overall drop in CPUE from 2015-2018 in central GOA and variable signal in the western GOA.

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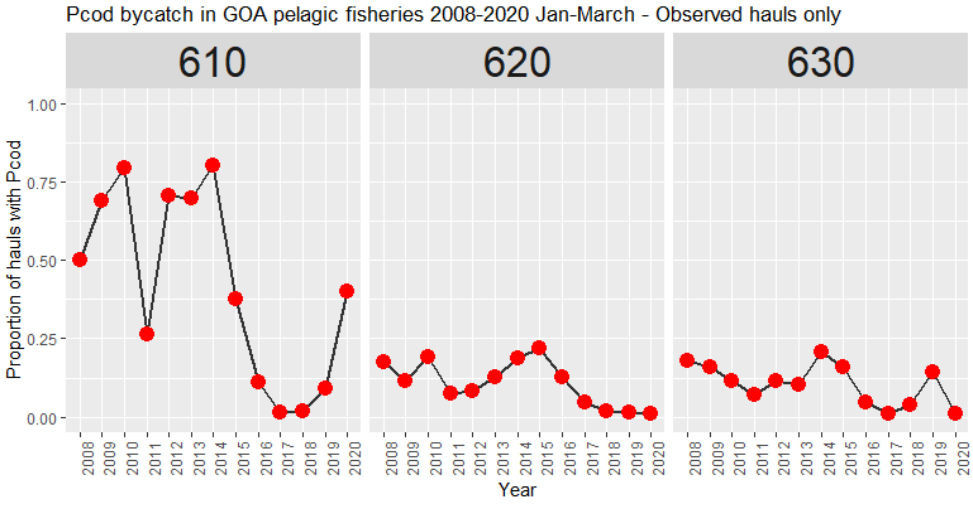
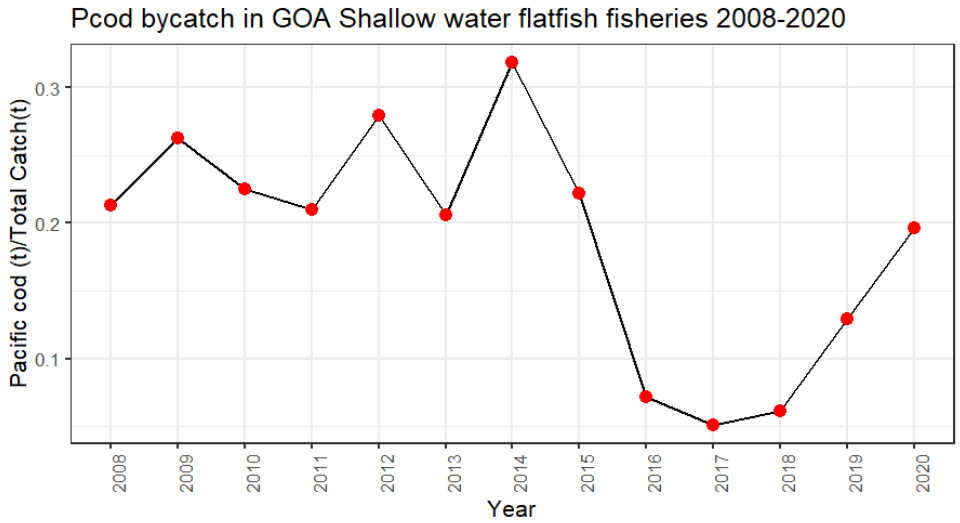


Encounter rate of Pacific cod in the pollock fishery indicates increases in the western GOA, but decreases in central GOA



Shallow water flatfish show a steady increase in bycatch of Pacific cod since 2017 low

Pacific cod bycatch indices

Mixed signals in Pacific cod bycatch

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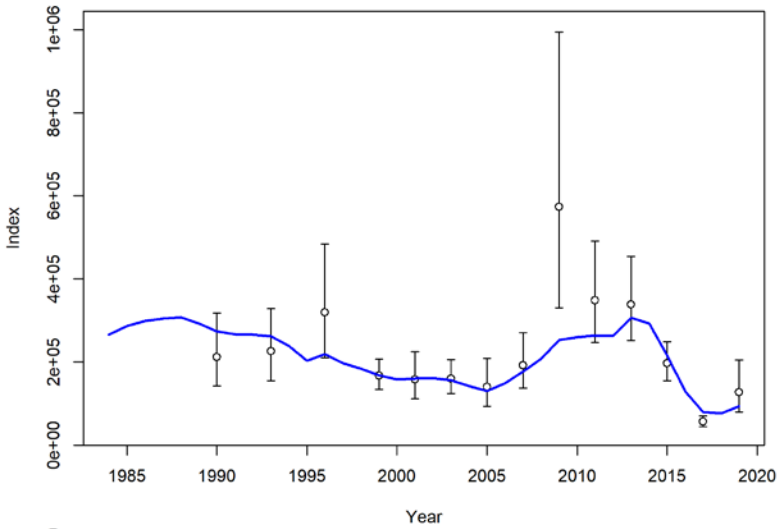

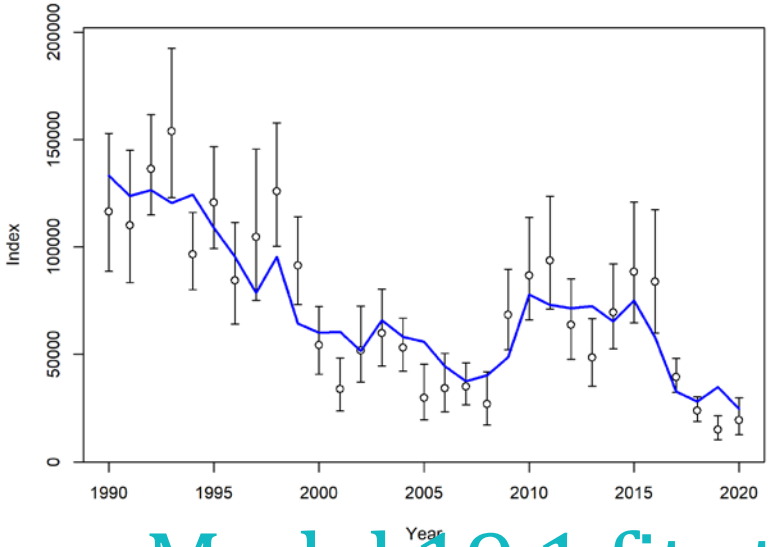

AFSC bottom trawl survey

- Poor fit to high 2009 estimate.

AFSC longline survey

- Catchability scaled to June CFSR temperatures
- Poor fit to low 2019 estimate

Model 19.1 fits to survey indices

Generally good fit to surveys, trawl survey difficulty fitting 2009 survey estimate, the longline survey has difficulty fitting 2019 estimate.

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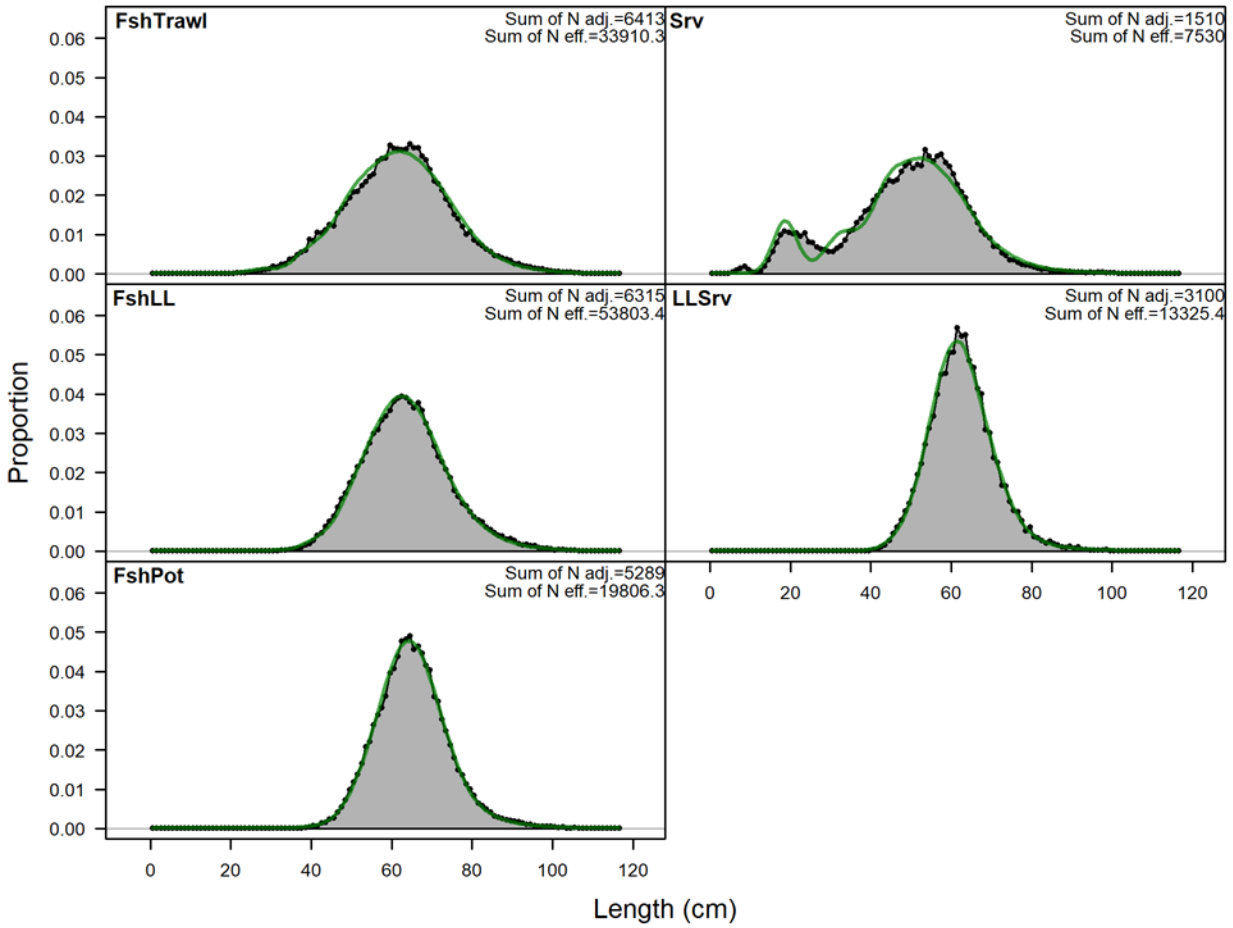

Model 19.1 fit to length composition

Overall good fit to length composition.

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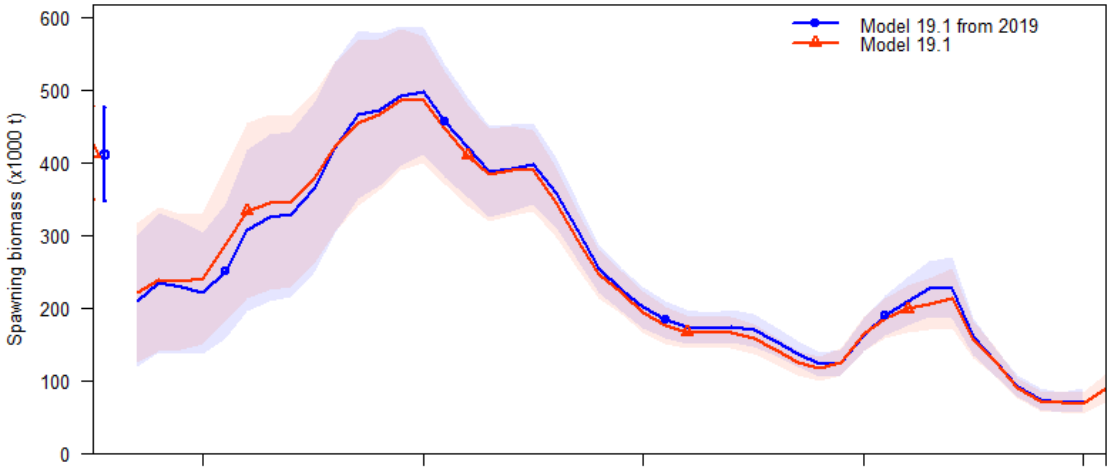

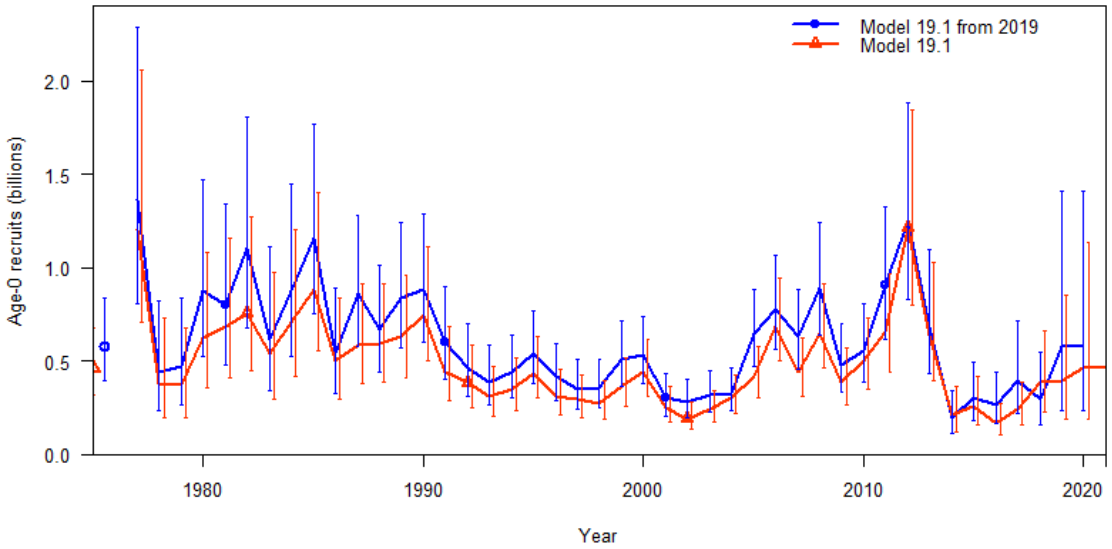

- Model 19.1 results in similar SSB to 2019 reference model

- Scale of recruitment differs for this years models due to change in natural mortality estimate.

Model 19.1 comparison with previous year

Slight reduction in peak SSB in 2012-2015 with lower natural mortality.

Lower recruitment with lower natural mortality estimate.

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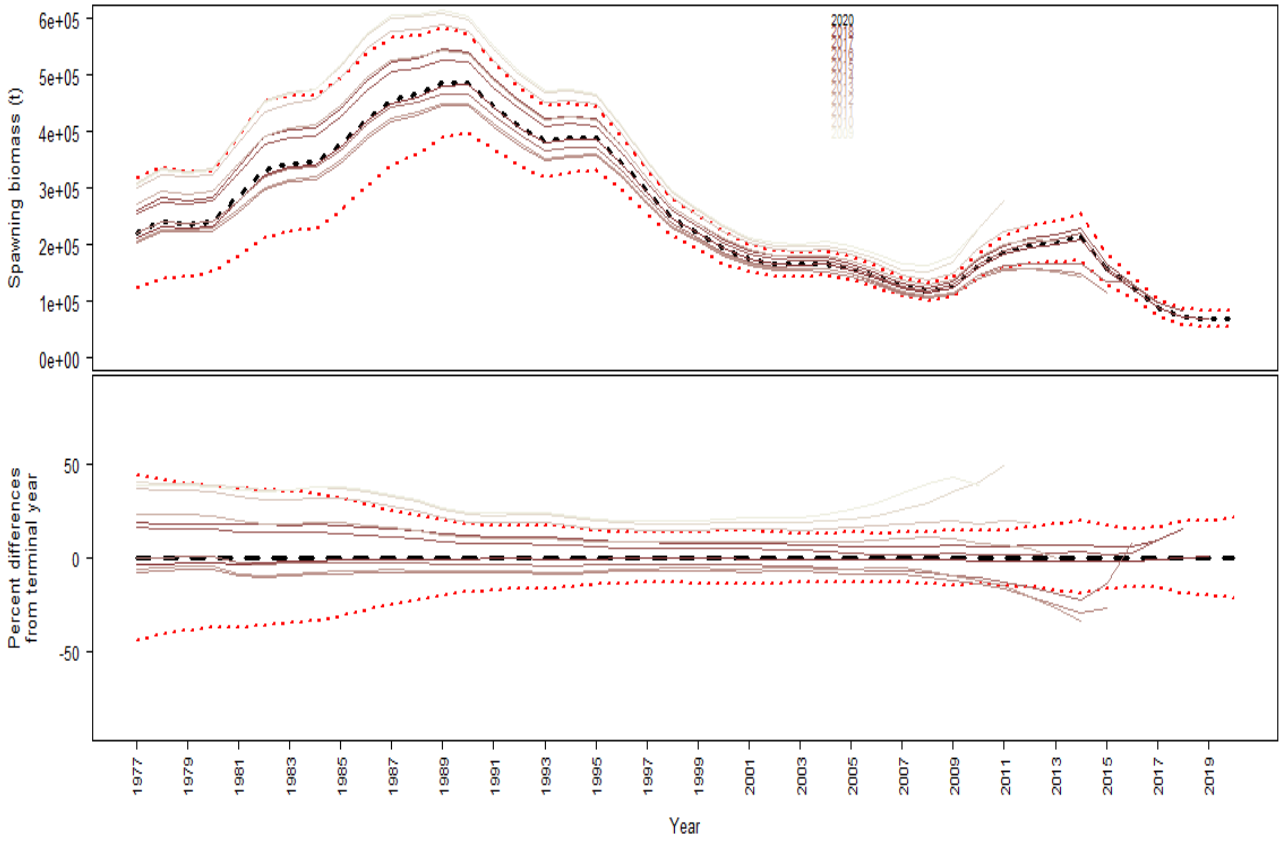

- SSB
  - Mohn's ρ = 0.08
  - WH ρ = 0.08
  - RMSE = 0.15
- Recruitment
  - Mohn's ρ = -0.06
  - WH ρ = 0.04
  - RMSE = 0.22

Model 19.1 retrospective bias

Low retrospective bias in both spawning biomass and recruitment

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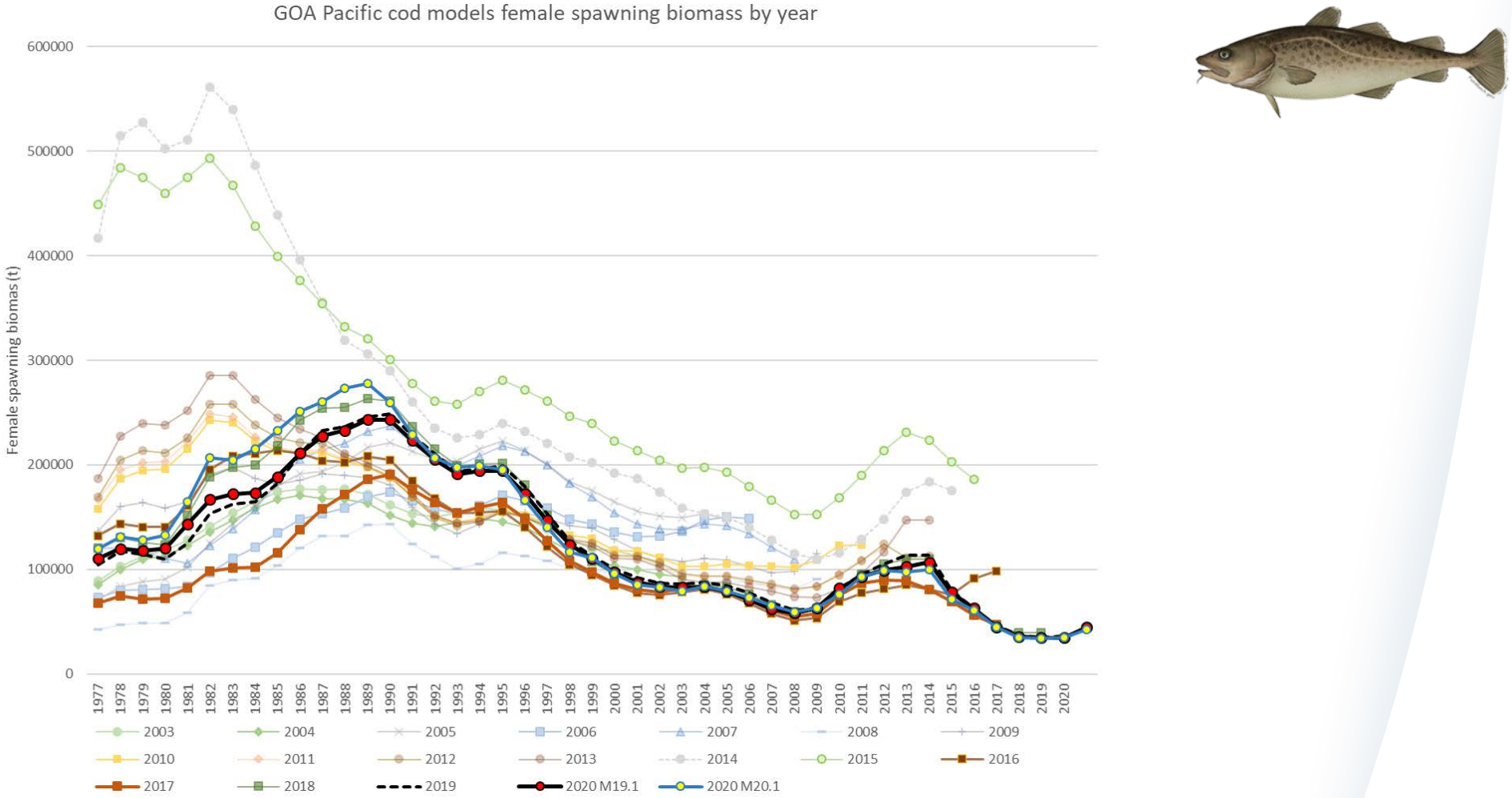

Model 19.1 compared to previous years

Model 19.1 similar results to previous 3 models.

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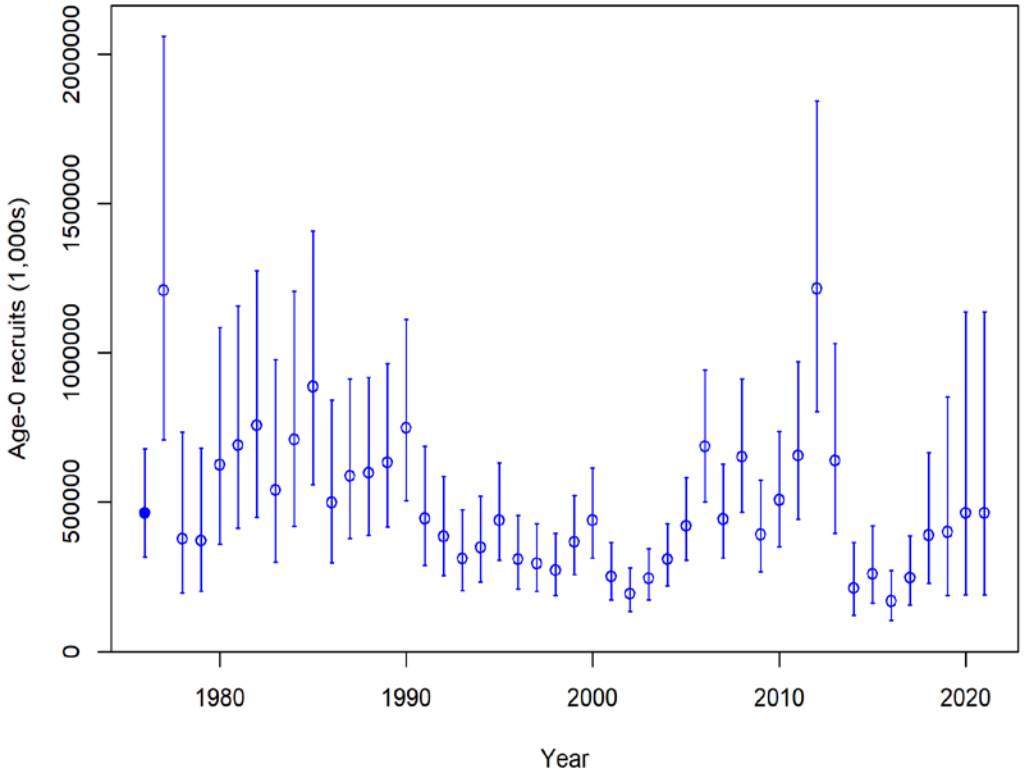

- Poor recruitment since 2014
- Recent fishery carried on 2010-2013 year classes
- 2018 recruitment better, but still projected to be below average recruitment
- 2019 recruitment modeled as near average even though most indicators suggest it is much lower
- Although modeled as average we have no data on 2020

Model 19.1 recruitment

Poor recent recruitment post-2013. 2018 better recruitment, but little data to inform 2019. Post-2019 is average recruitment.

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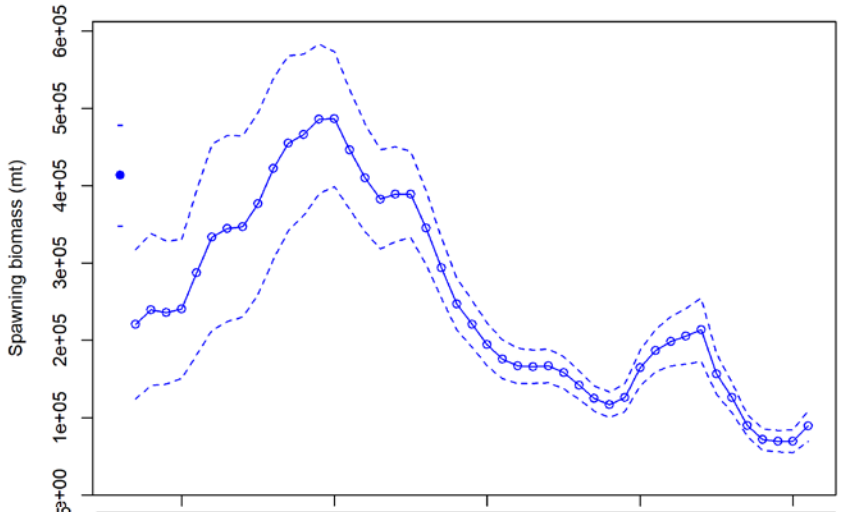

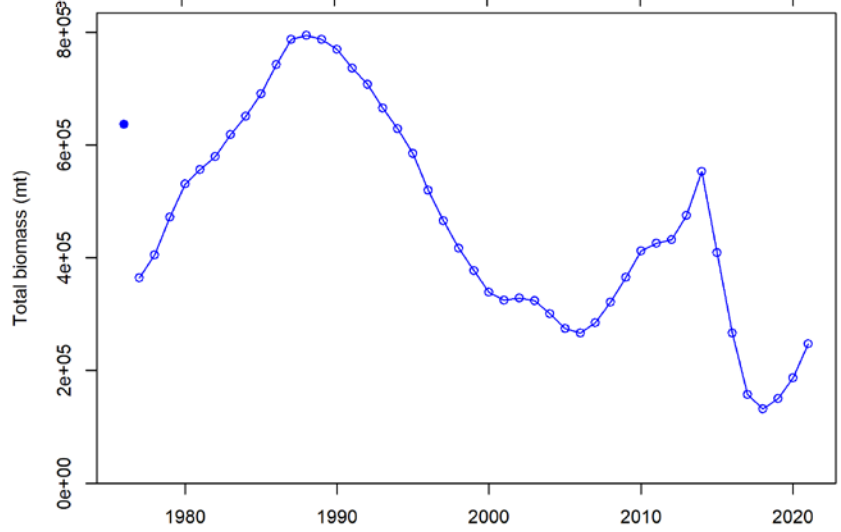

- 2020 lowest female spawning biomass at 34,631 t ($B_{19.2\%}$)
- 2021 15% increase in female spawning biomass to 39,977 t ($B_{22.2\%}$)
- Lowest total biomass in 2018 131,650 t
- 2021 biomass up 88% from 2018 to 247,415 t

Model 19.1 biomass trends

Increasing trend in both total biomass and spawning biomass.

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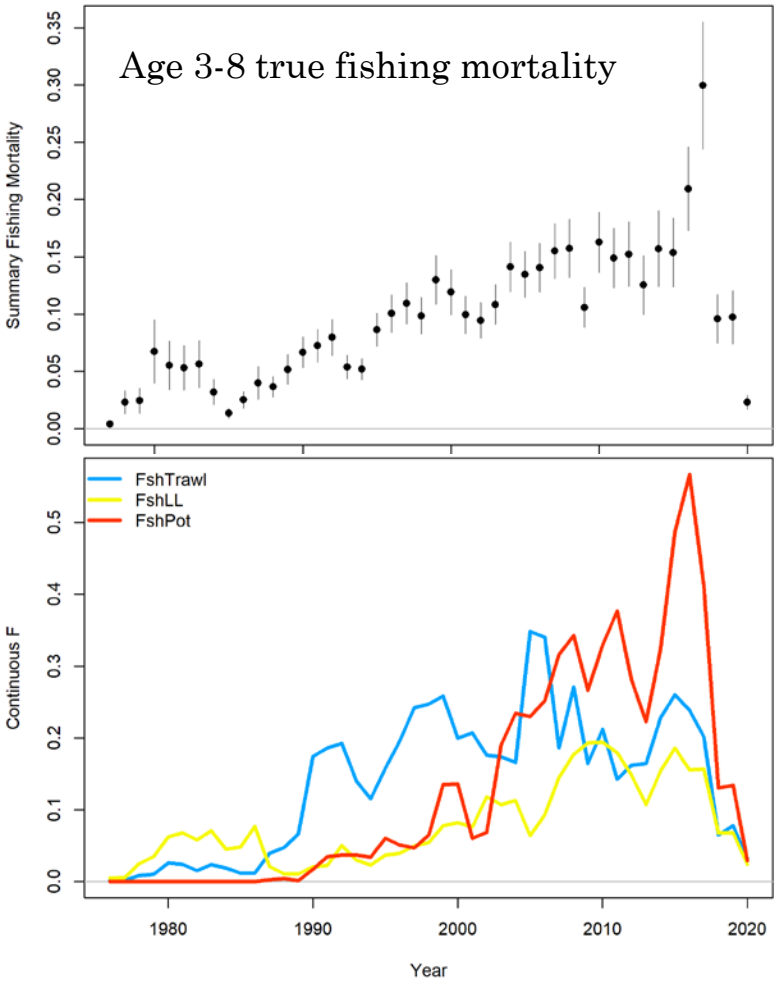

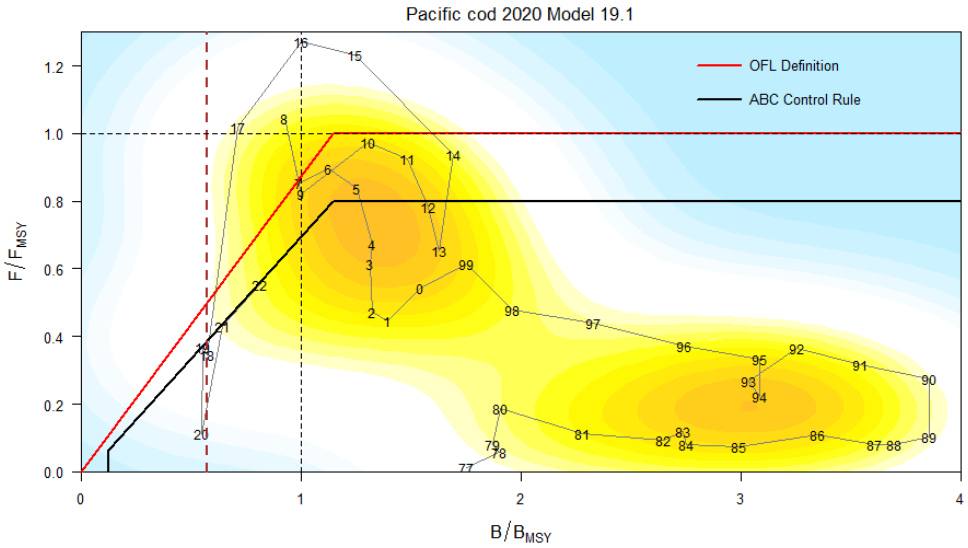

- Increasing F over time
- Highest F 2016-2017
- Below $B_{20\%}$ 2018-2020

Model 19.1 fishing mortality

Increasing trend in F over time until 2018 with relatively high F for 2016-2017. Below B20% for 2018-2020. Above $B_{20\%}$ in 2021.

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Quantity	As estimated or *specified last* year for: 2020	2021	As estimated or *specified this* year for: 2021	2022
M (natural mortality rate)	0.49	0.49	0.47	0.47
Tier	3b	3b	3b	3b
Projected total (age 0+) biomass (t)	203,373	261,484	265,661	312,783
Female spawning biomass (t)				
Projected	32,958	42,026	39,977	50,813
$B_{100\%}$	187,780	187,780	180,111	180,111
$B_{40\%}$	75,112	75,112	72,045	72,045
$B_{35\%}$	65,723	65,723	63,039	63,039
F_{OFL}	0.27	0.36	0.41	0.54
$maxF_{ABC}$	0.22	0.29	0.33	0.43
F_{ABC}	0.22	0.29	0.33	0.43
OFL (t)	17,794	30,099	28,977	46,587
maxABC (t)	14,621	24,820	23,627	38,141
ABC (t)	*14,621	*24,820	23,627	38,141

- **2021 above $B_{20\%}$**
- 2021 maxABC 23,627t
- 2022 maxABC 38,141t
- 2021 OFL 28,977t
- 2022 OFL 46,587t

- 2021 ABC is 5% lower than projected for 2021 last year
- 2021 OFL id 4% lower than projected for 2021 last year

Summary of results

Tier 3b stock status in 2021 estimated to be at $B_{22\%}$ and in 2022 at $B_{28\%}$.
No overfishing, not overfished, and not approaching overfished.

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Assessment-related considerations	Population dynamics considerations	Environmental /ecosystem considerations	Fishery Performance
Level 2: Substantially increased	Level 2: Substantially increased	Level 1: Normal	Level 1: Normal

- Assessment-related concerns
  - High uncertainty in 1977-1989 recruitment and SSB subject to assumptions on selectivity
  - Sub-27cm fish not well fit for AFSC bottom trawl survey

- Population dynamics considerations
  - 2019 year class appears much lower in ancillary data and ecosystem-linked model than projected in the reference model

Risk Table

No reduction in maxABC recommended for 2021 and 2022.

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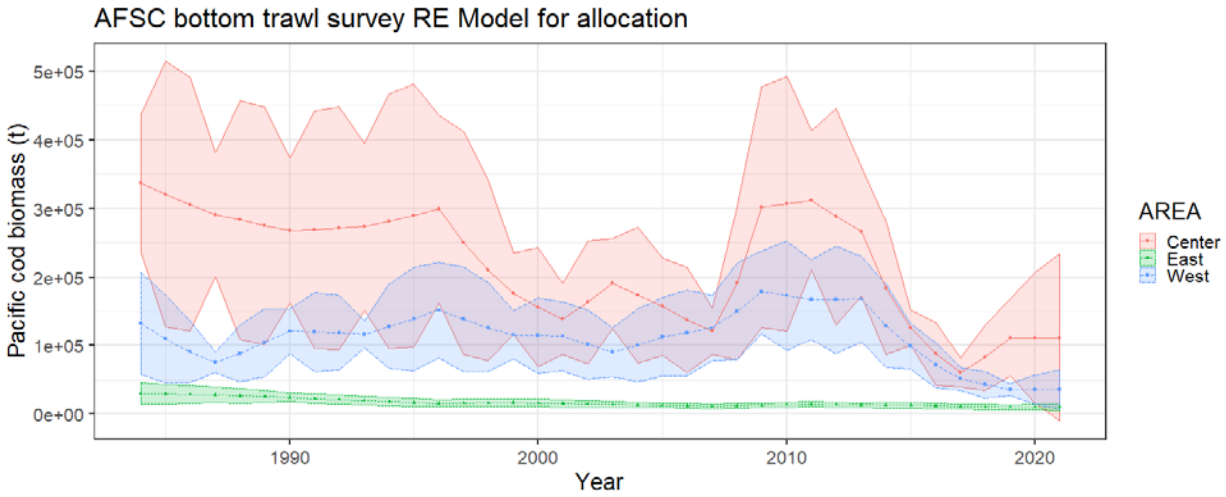

- In 2019 the SSC chose a stair-step approach as the mean between 2018 and 2019 random effects model apportionment proportions

Random Effects model apportionment

	Western	Central	Eastern	Total
Random effects area apportionment	22.7%	70.6%	6.7%	100%
2021 ABC	5,363	16,681	1,583	23,627
2022 ABC	8,658	26,928	2,555	38,141

Stair-step apportionment

	Western	Central	Eastern	Total
Stair-step area apportionment	33.8%	57.8%	8.4%	100%
2021 ABC	7,986	13,656	1,985	23,627
2022 ABC	12,892	22,045	3,204	38,141

Apportionment

Random effects model used 2013-2018, in 2019 SSC recommended a stair-step approach due to the large change from 2018.

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Model 20.1

- Ecosystem-linked model

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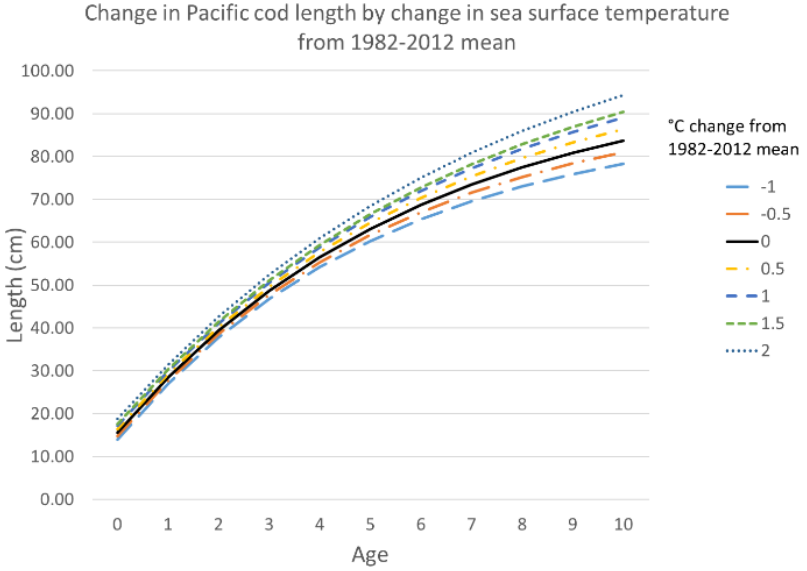

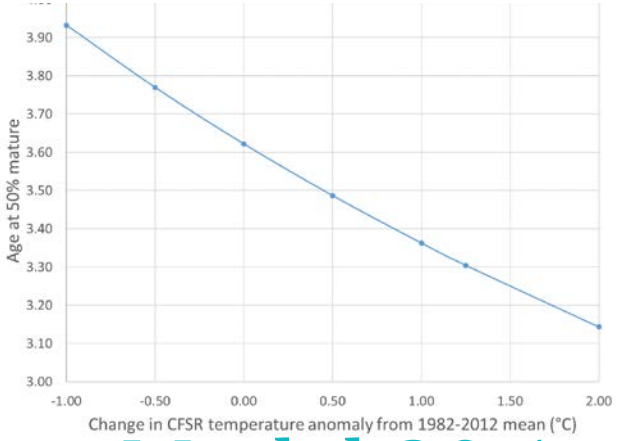

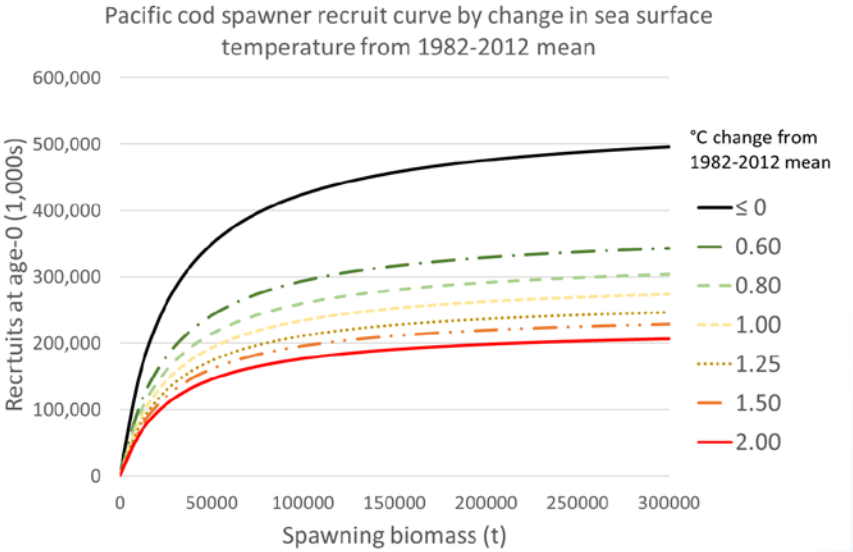

Model 20.1

Ecosystem-linked growth and recruitment shows increased growth with increased temperature and lower recruitment with increased spawning season marine heatwave conditions.

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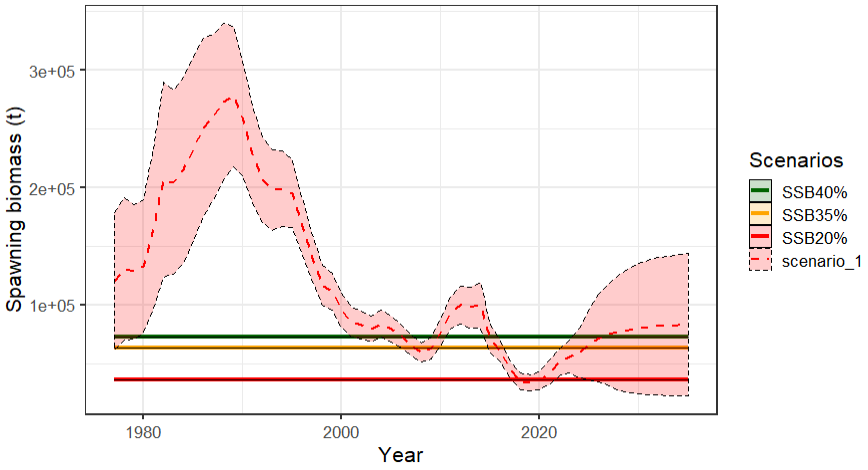

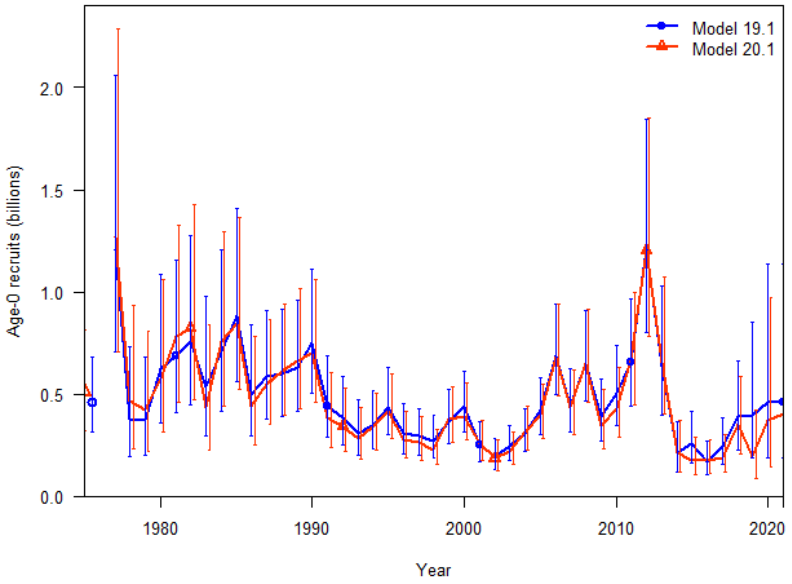

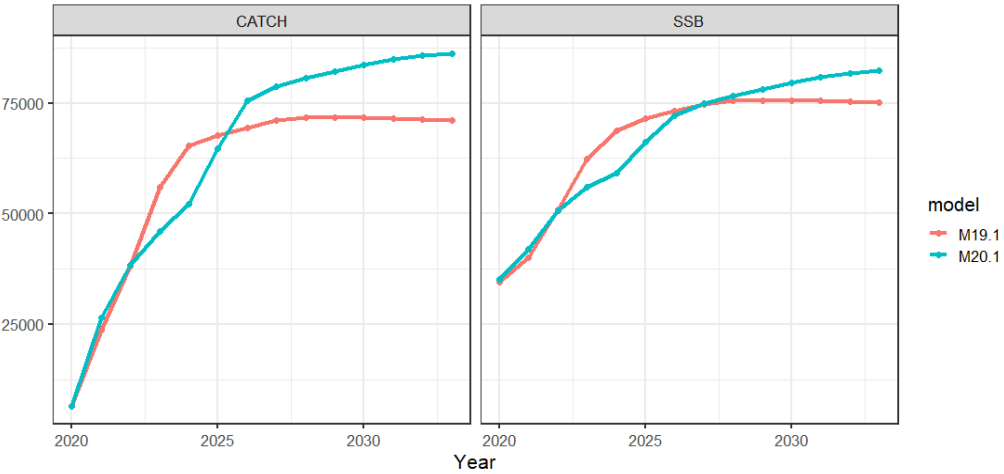

Model 20.1 Projections

Short-term projections shows difference due to difference in estimated 2019 recruitment.

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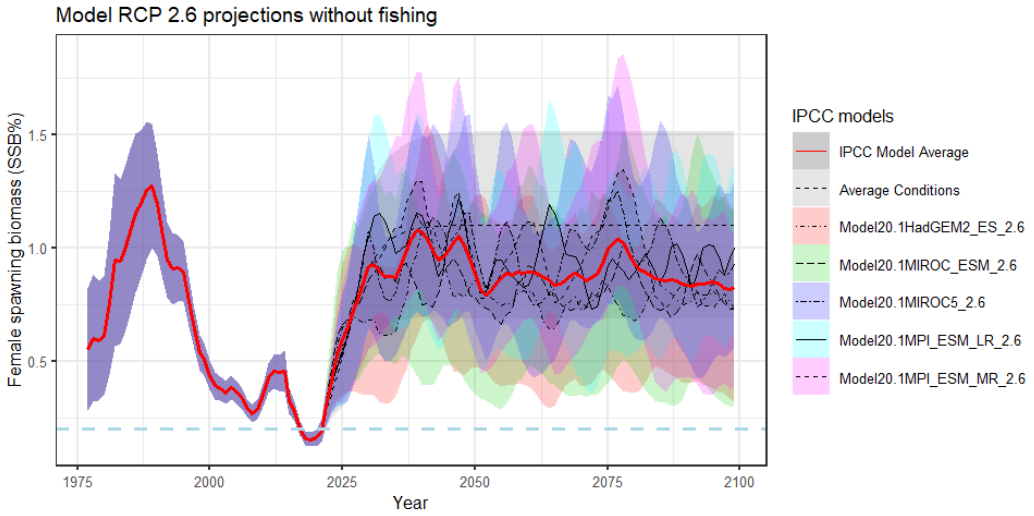

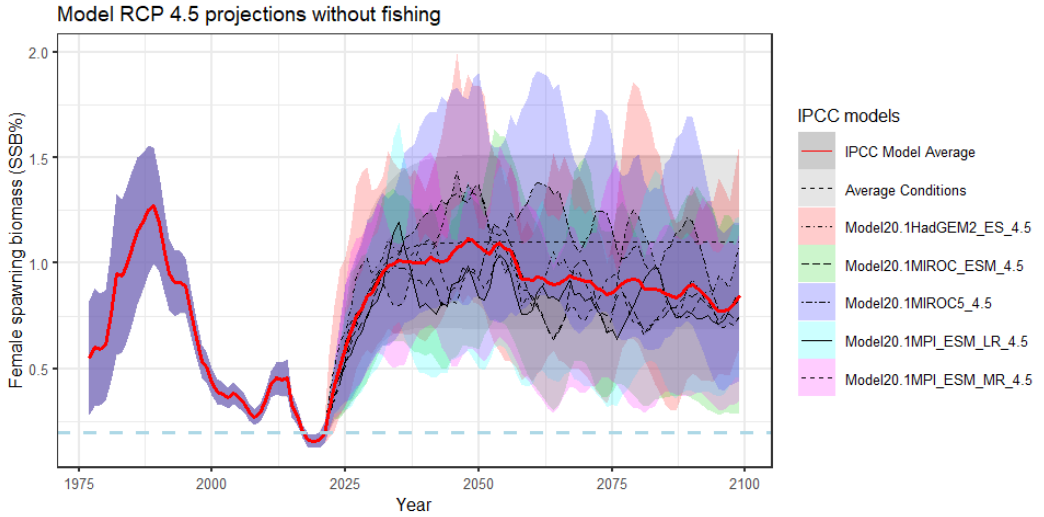

Model 20.1 IPCC model projections

Five IPCC models under RCP 2.6 and RCP 4.5, the most optimistic IPCC scenarios. Both scenarios result in reduction in productivity.

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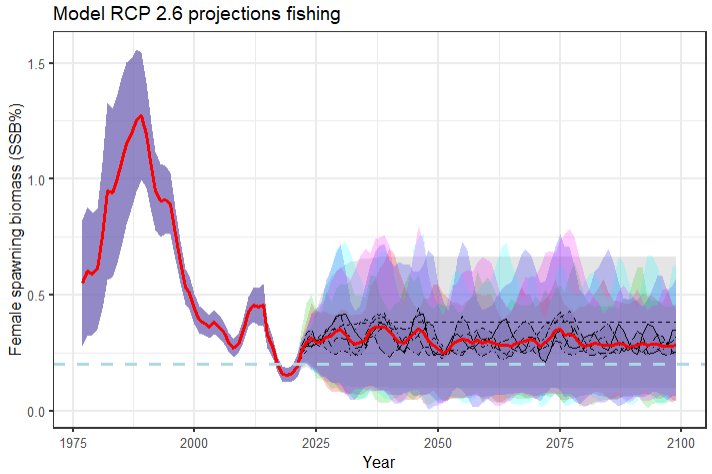

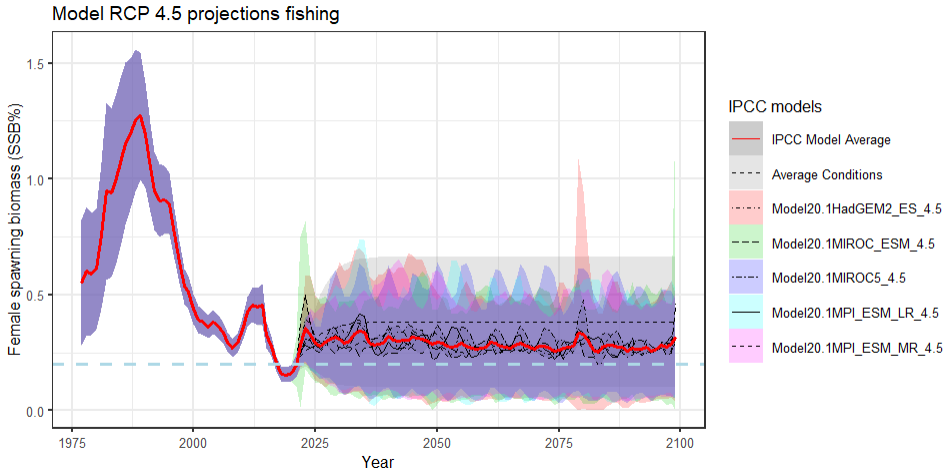

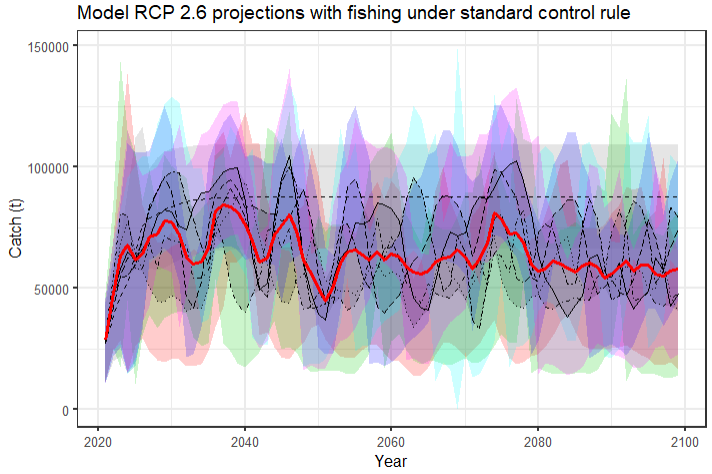

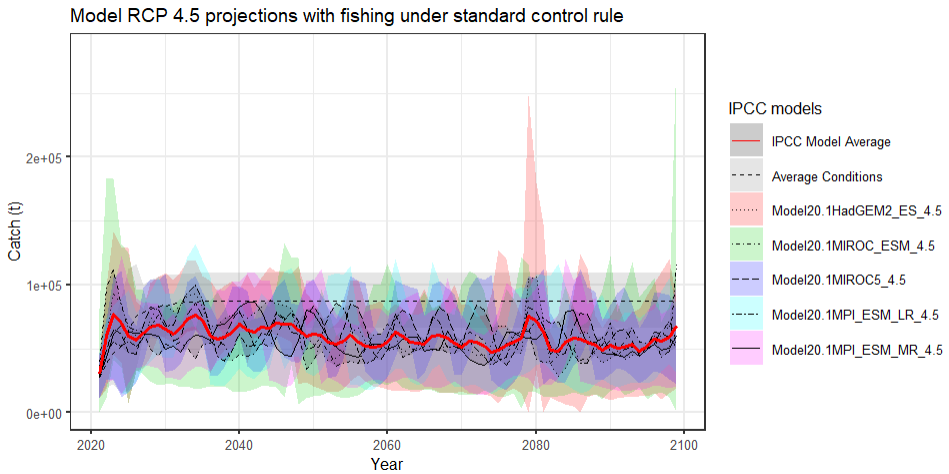

Model 20.1 IPCC model projections

23-27% reduction in spawning biomass with fishing

30-36% reduction in catch 2050-2099

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Quantity	As estimated or *specified last* year for: 2020	2021	As estimated or *specified this* year for: 2021	2022
M (natural mortality rate)	0.49	0.49	0.47	0.47
Tier	3b	3b	3b	3b
Projected total (age 0+) biomass (t)	203,373	261,484	265,661	312,783
Female spawning biomass (t)				
Projected	32,958	42,026	39,977	50,813
$B_{100\%}$	187,780	187,780	180,111	180,111
$B_{40\%}$	75,112	75,112	72,045	72,045
$B_{35\%}$	65,723	65,723	63,039	63,039
F_{OFL}	0.27	0.36	0.41	0.54
$maxF_{ABC}$	0.22	0.29	0.33	0.43
F_{ABC}	0.22	0.29	0.33	0.43
OFL (t)	17,794	30,099	**28,977**	**46,587**
maxABC (t)	14,621	24,820	23,627	38,141
ABC (t)	*14,621	*24,820	**23,627**	**38,141**

	Western	Central	Eastern	Total
Stair-step area apportionment	33.8%	57.8%	8.4%	100%
2021 ABC	7,986	13,656	1,985	23,627
2022 ABC	12,892	22,045	3,204	38,141

Summary of results/recommendations

Recommending Model 19.1 OFL and maxABC with no reduction from risk table adjustments and continued use of the stair-step area apportionment for 2021 and 2022.

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