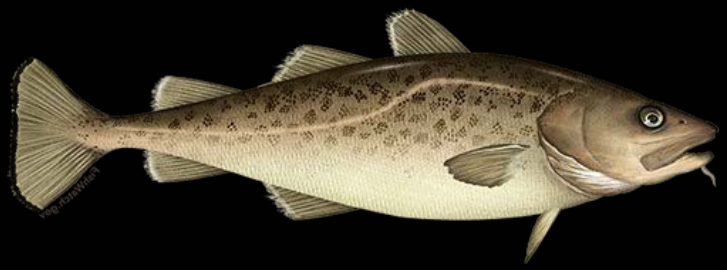


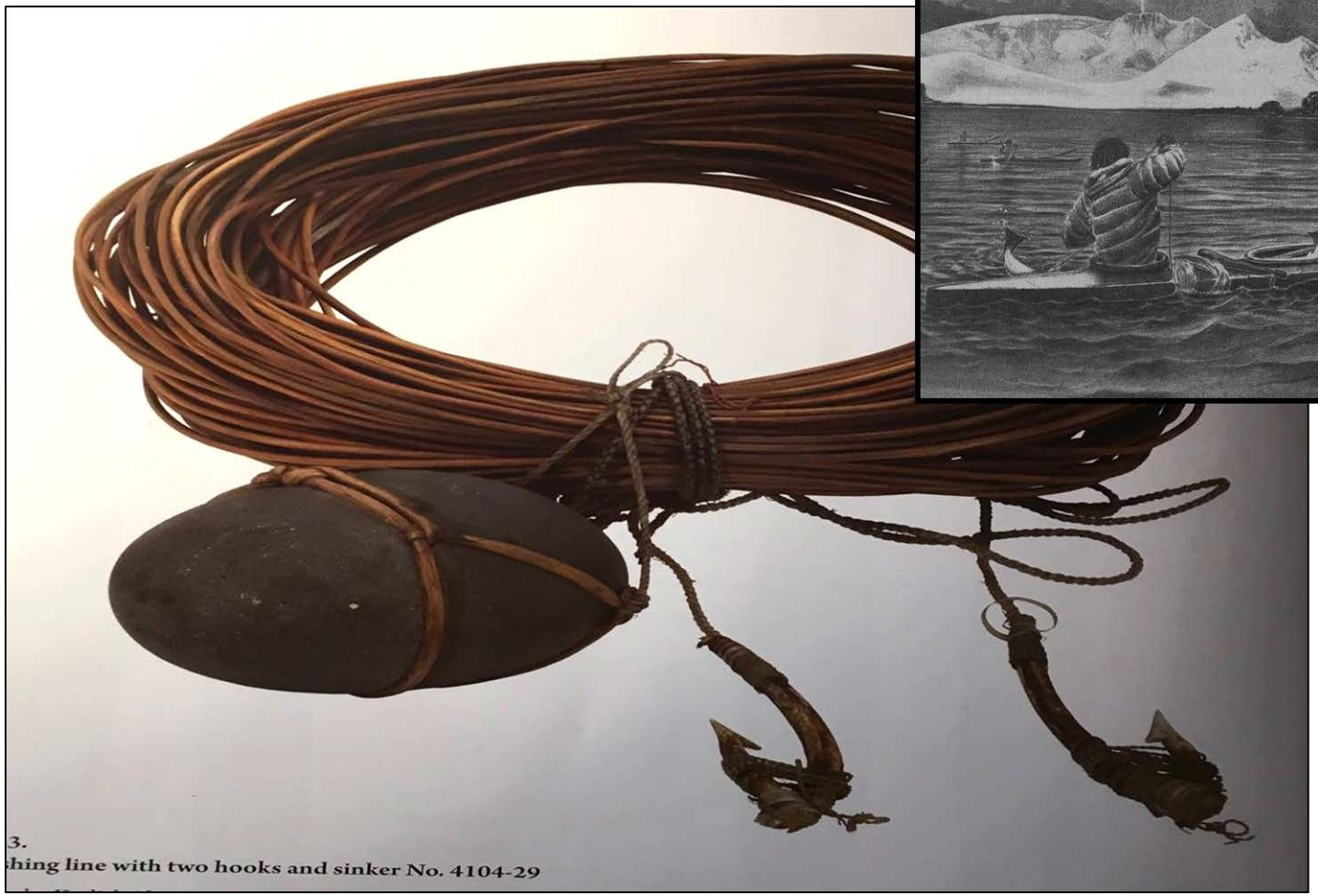
2020 Gulf of Alaska Pacific cod September addition

Steve Barbeaux, Kerim Aydin, Ben Fissel,
Kirstin Holsman, Ben Laurel, Wayne Palsson,
Lauren Rogers, Kalei Shotwell,
Muyin Wang, and Stephani Zador

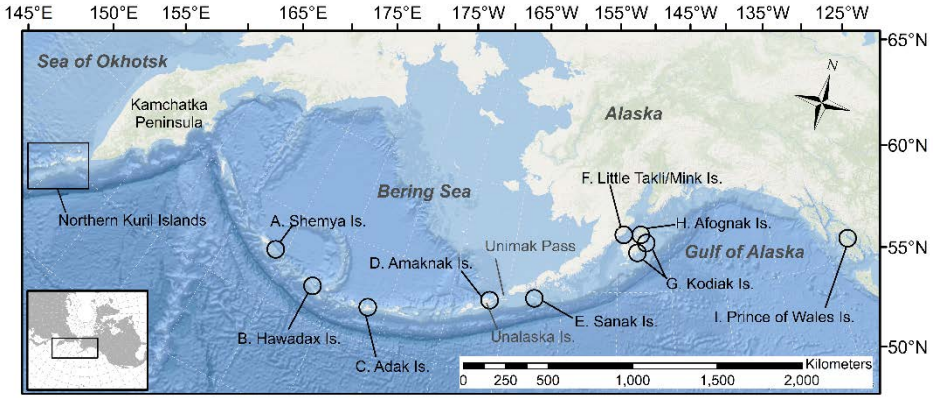
September 9, 2020

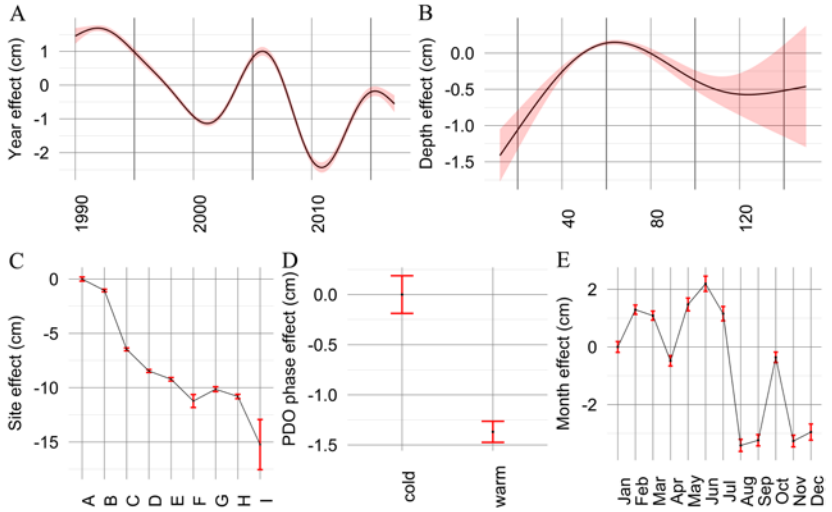
More than 6,000 years as an important resource to Alaskan coastal communities

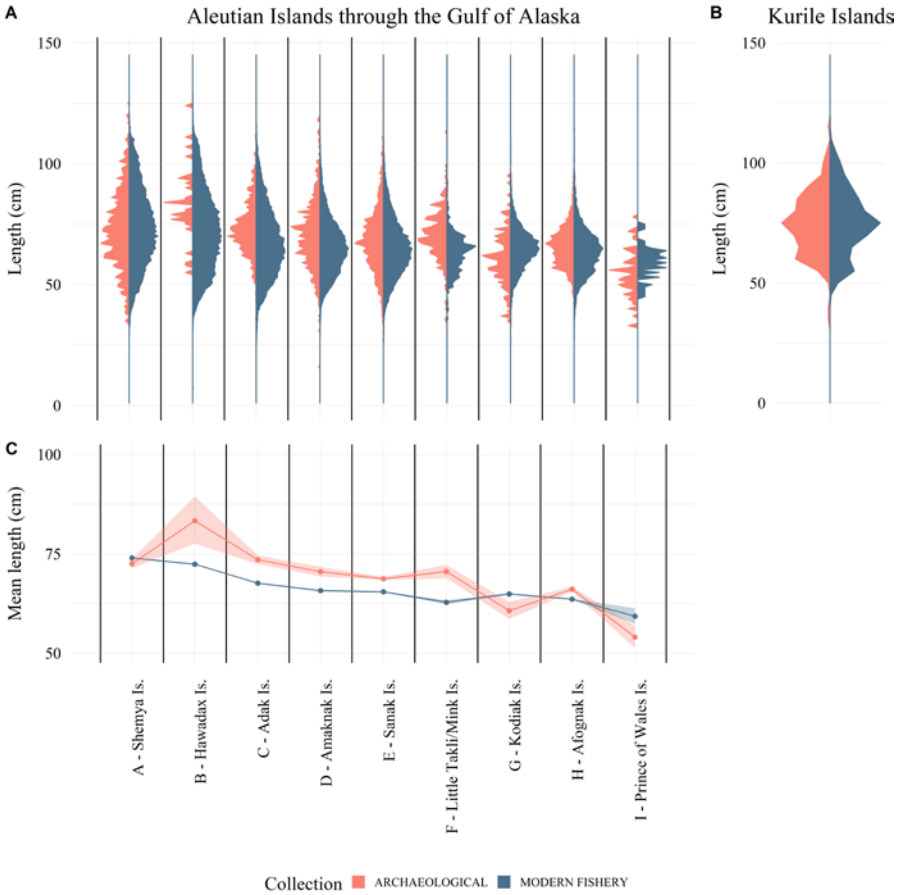
Atxidax̂ – The fish that stops



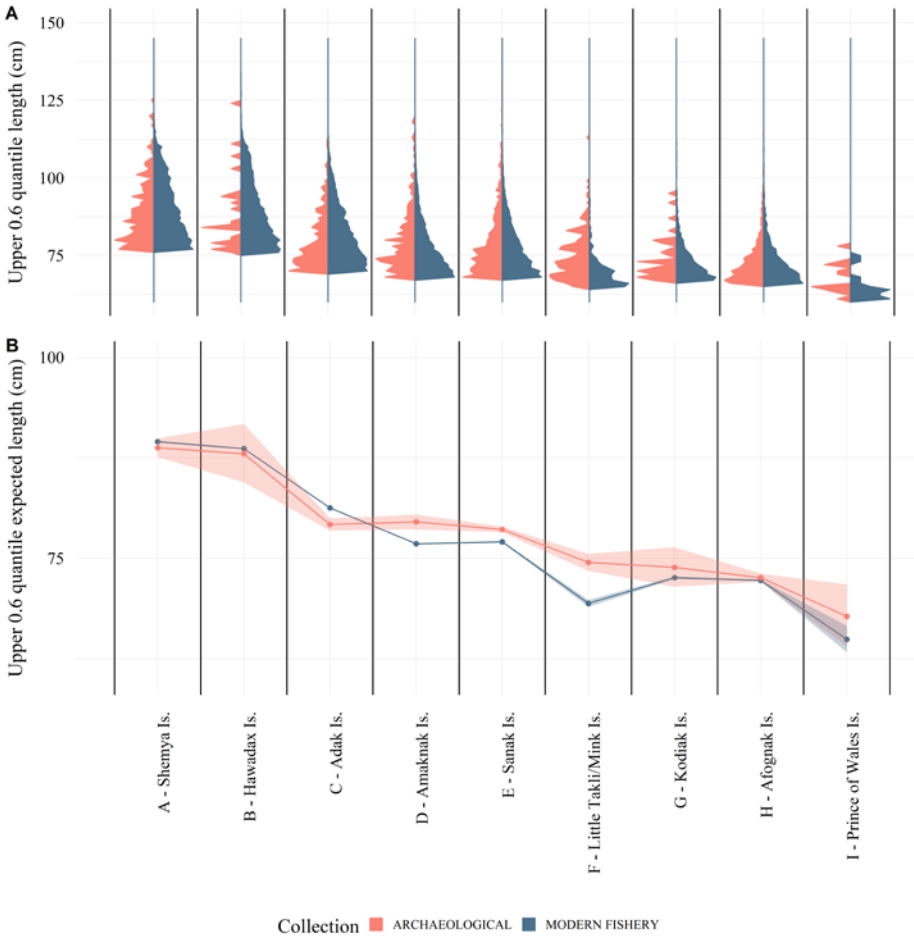
West et al. (In press)‘Size distribution of Pacific cod in the North Pacific Ocean over 6 millennia’

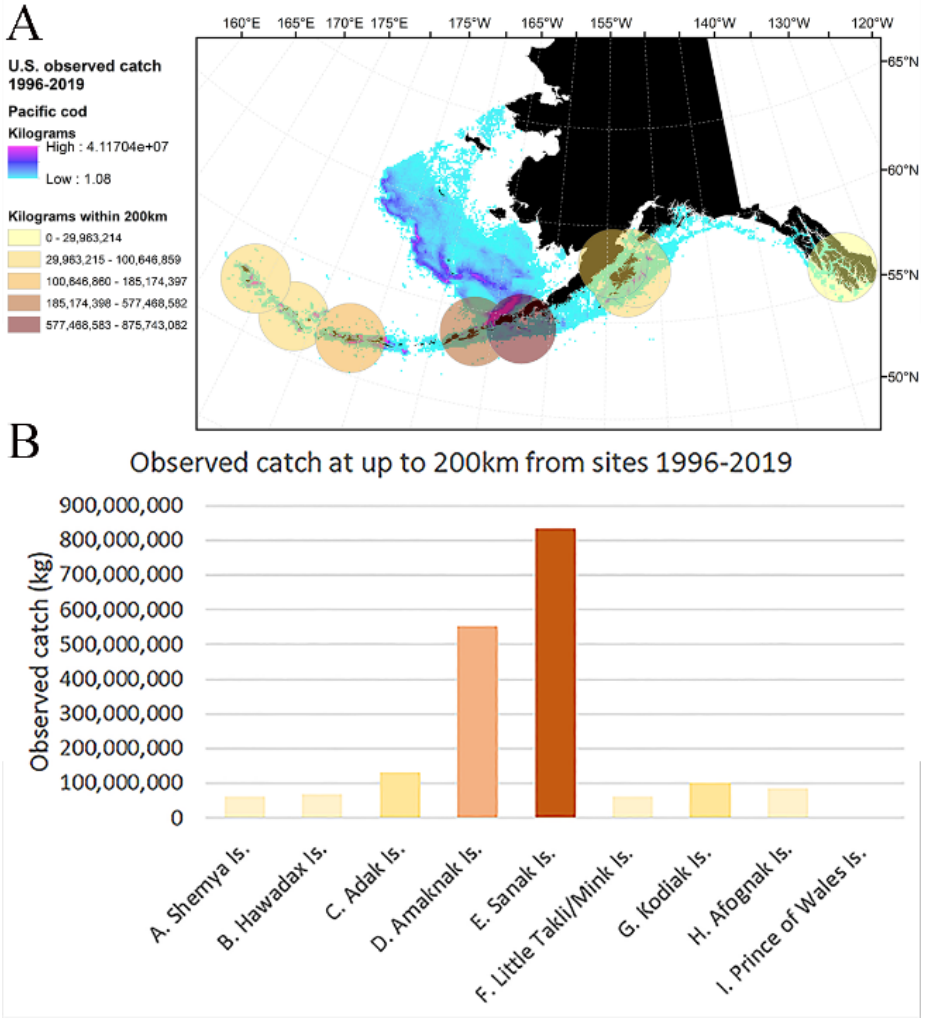






West et al. (In press)‘Size distribution of Pacific cod in the North Pacific Ocean over 6 millennia’





Salt cod fishery – Gulf of Alaska commercial cod fisheries began in 1863, collapsed in 1930's-1940's

The reason for the collapse is unknown.

Image from Mackovjak (2019)

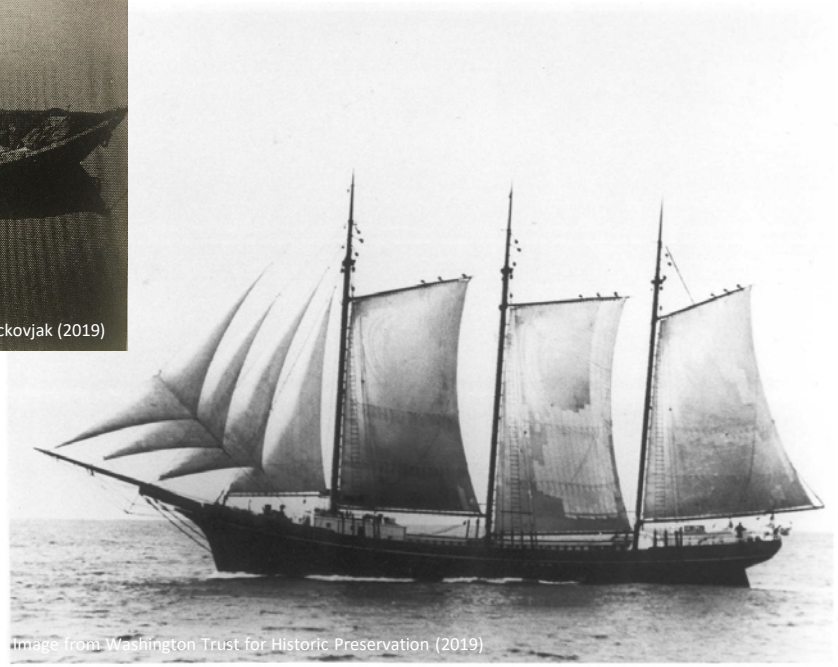


Image from Washington Trust for Historic Preservation (2019)

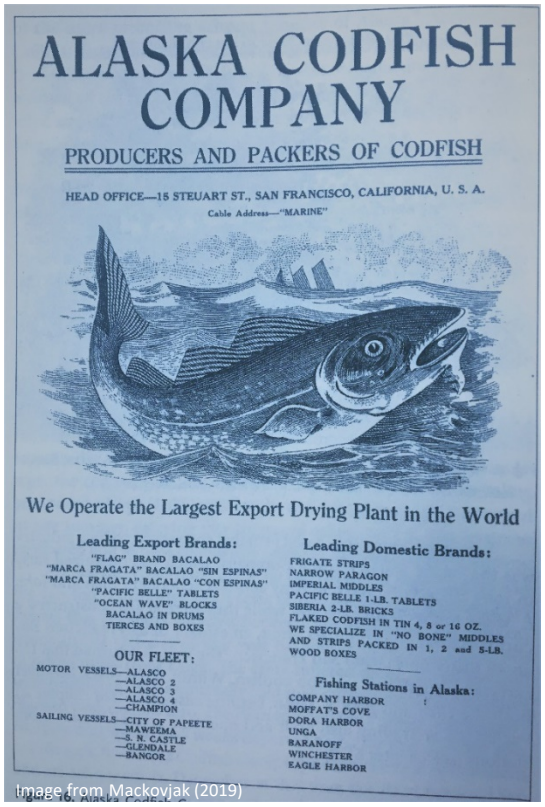
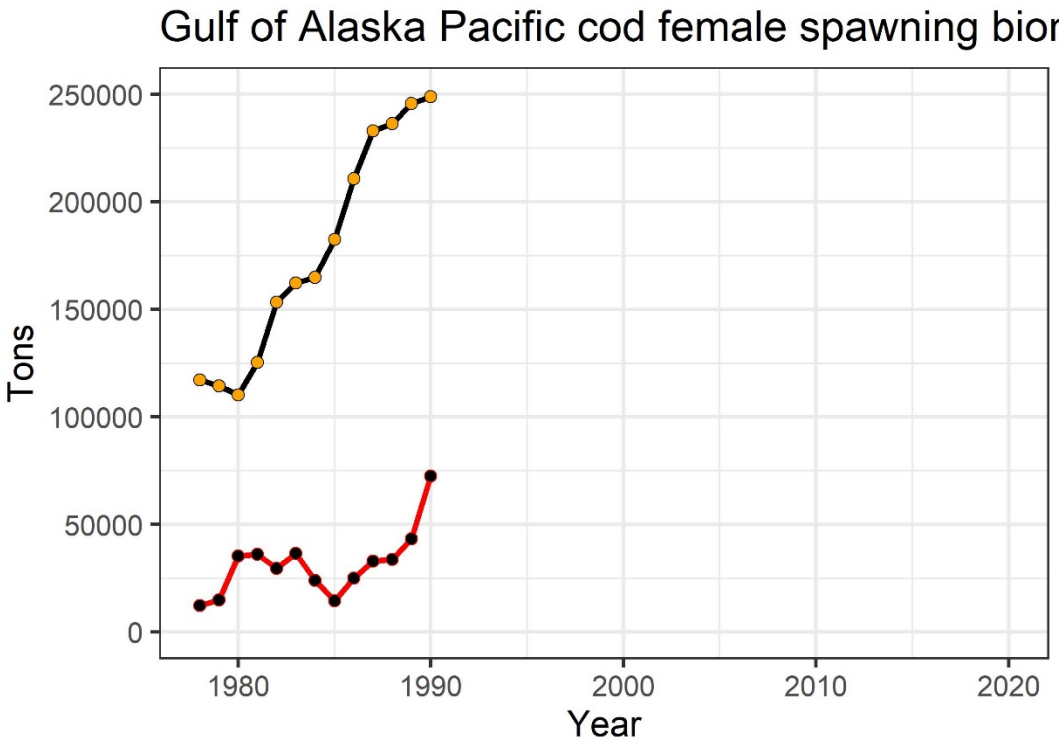
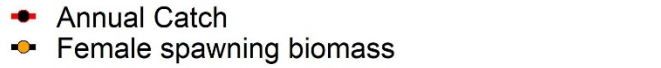


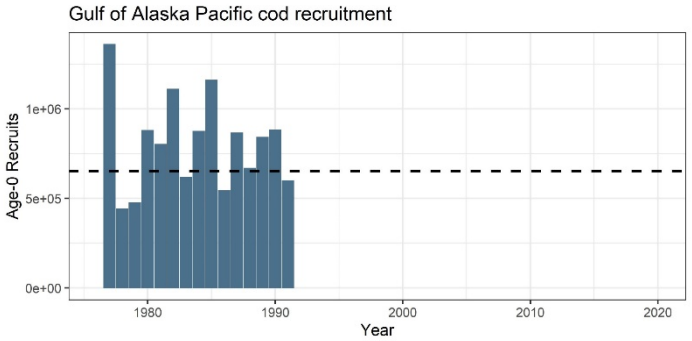
Image from Mackovjak (2019)

Gadid bloom and the development of the modern domestic cod fishery – 1980's

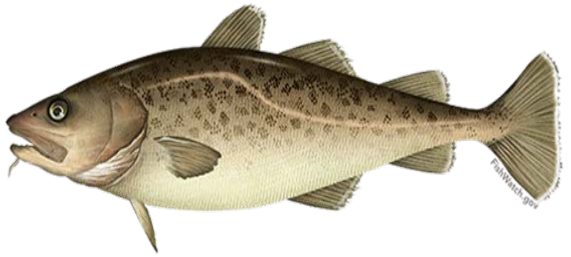
- Early 1980's saw a sharp increase in the Gulf of Alaska Pacific cod stock peaking in 1990 with a female spawning stock biomass of 250Kt



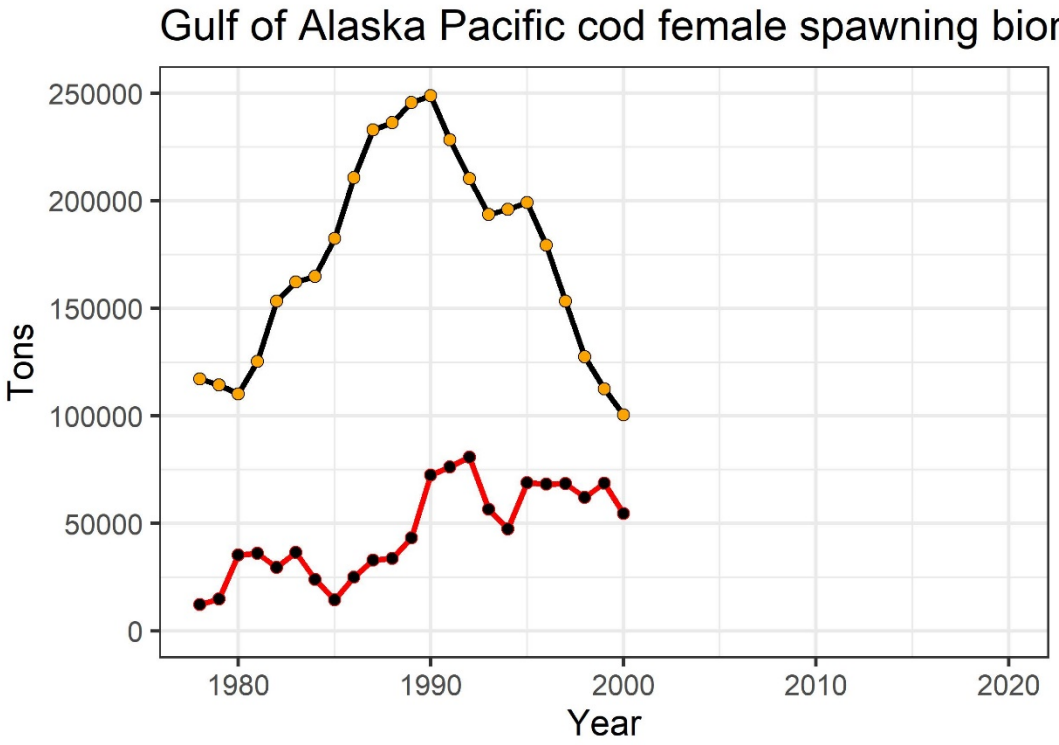




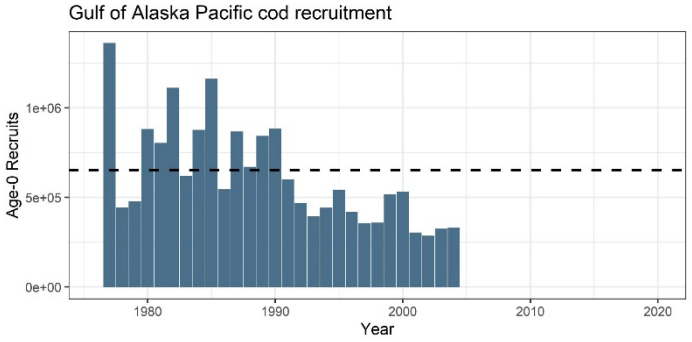
1990-2000's



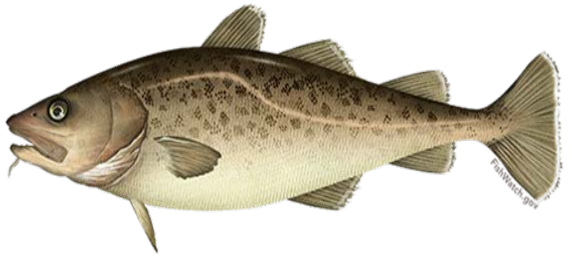
- Continuous decline despite relatively low fishing pressure
- Poor recruitment 1991-2004
- 61Kt female spawning biomass in 2008, lowest to date



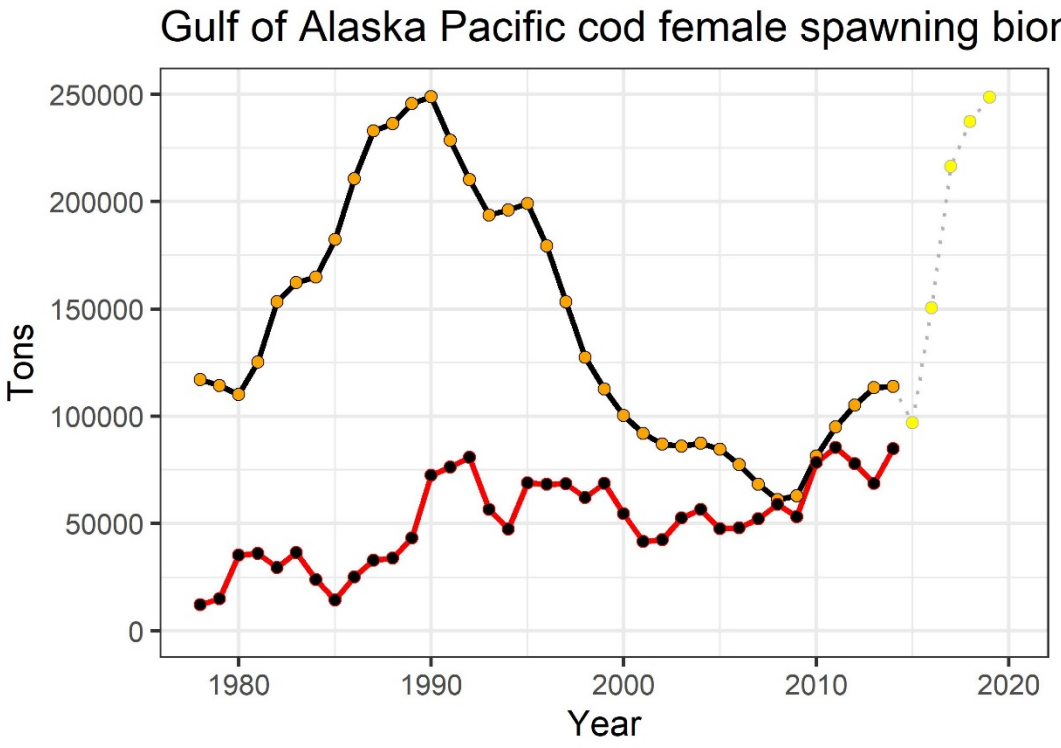
Annual Catch
Female spawning biomass

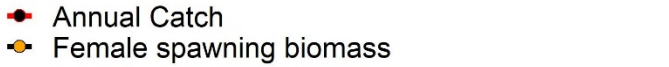


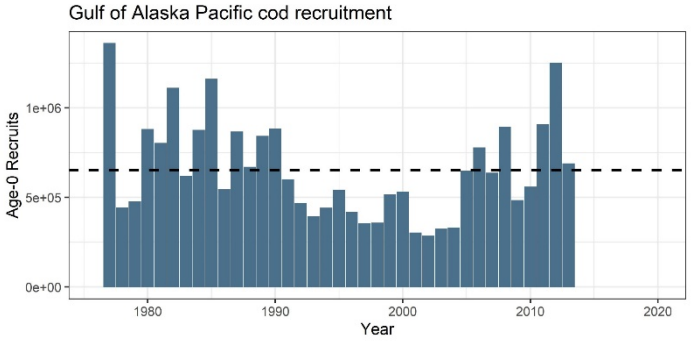
2008-2014



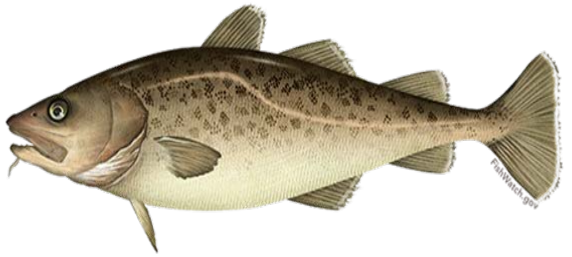
- High recruitment in 2006 through 2012 resulted in a sharp increase in spawning biomass in 2008-2014
- $103 million US in first wholesale value annually



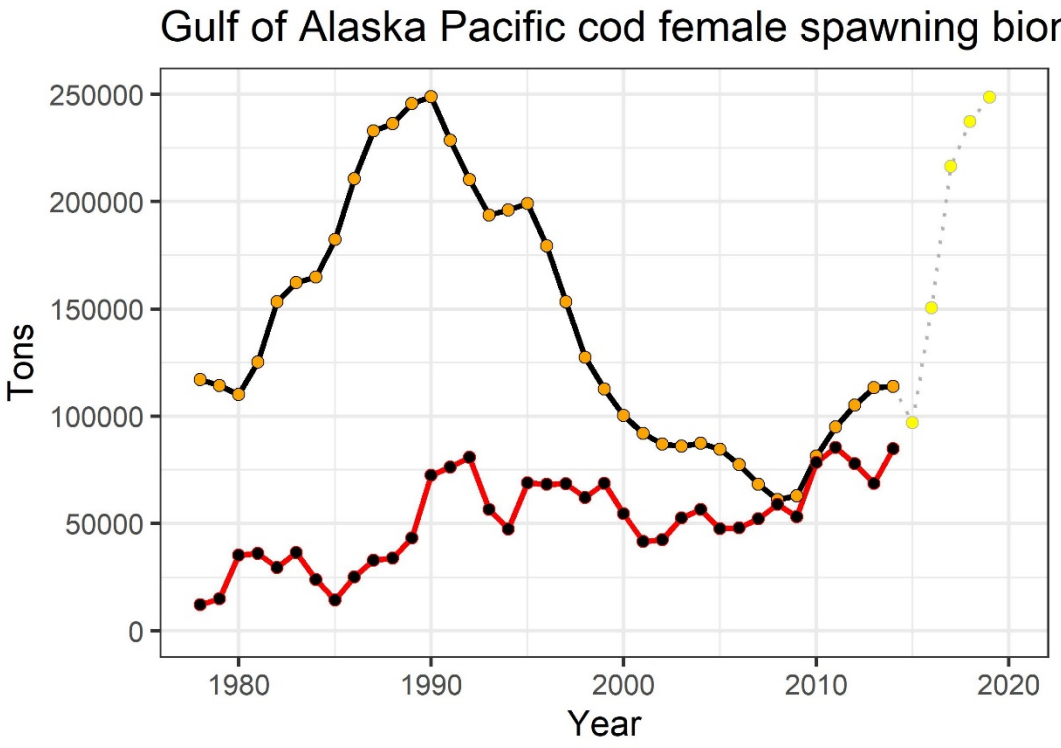


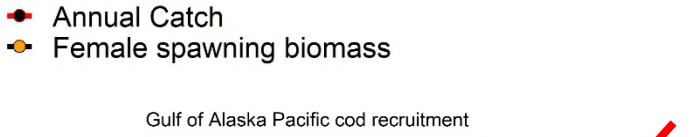


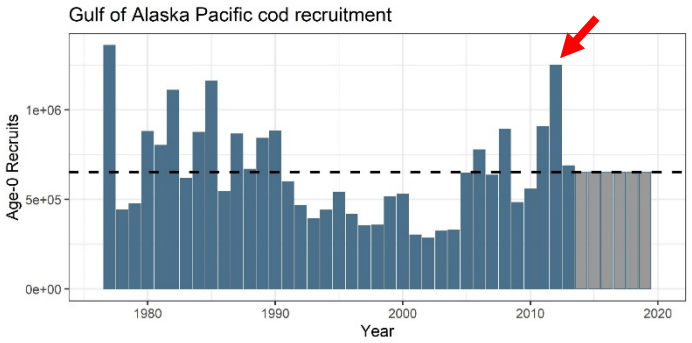
2015-2019 Projections



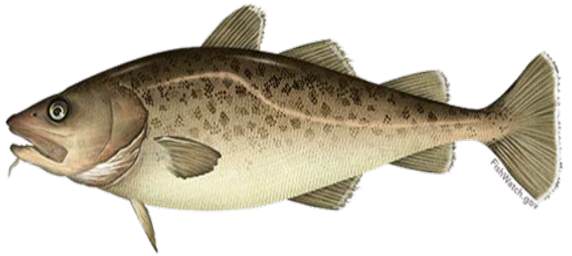
- 2012 year class estimated to be largest since 1977
- Under average conditions spawning stock projected to rise steeply



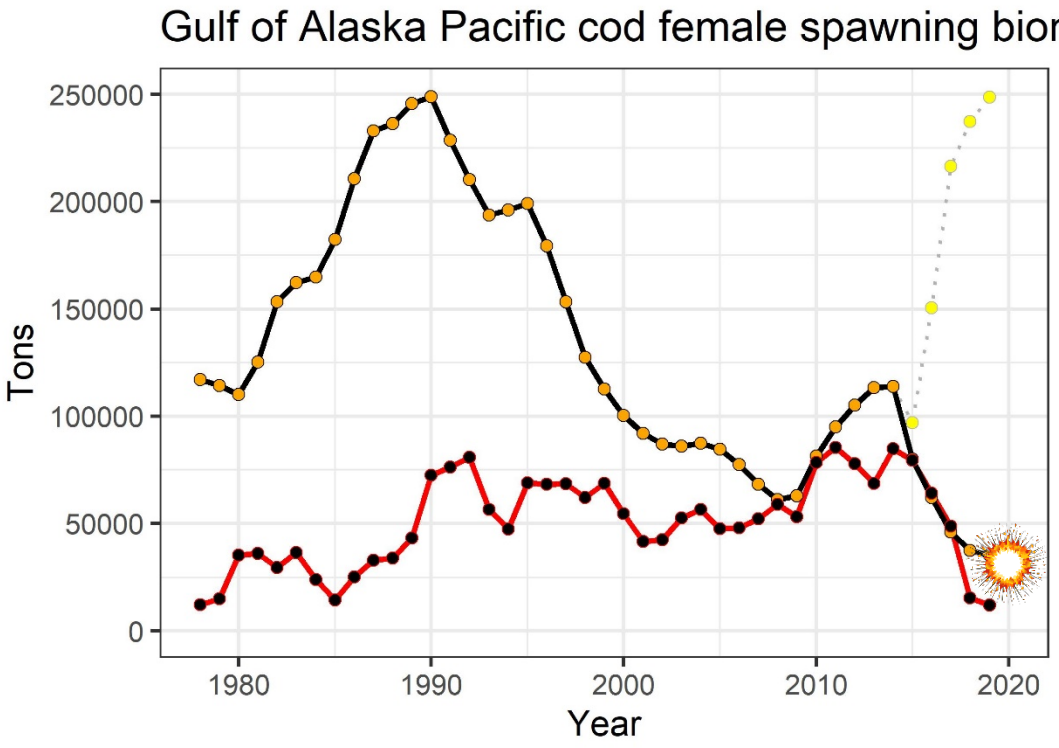


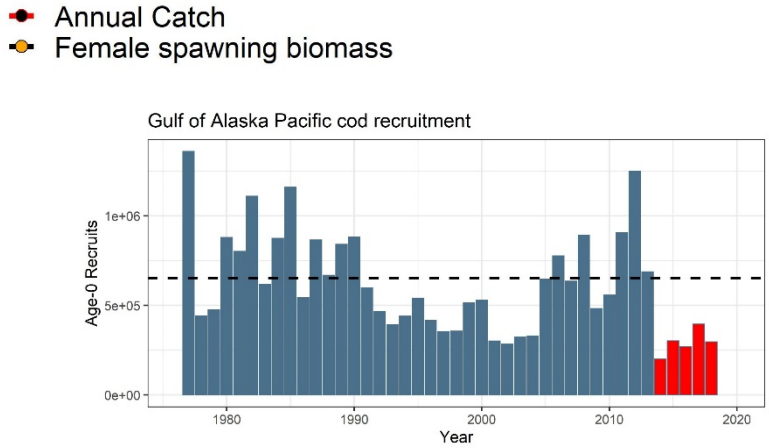


2015-2019 Reality

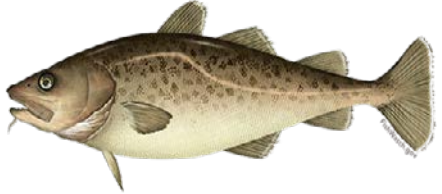


- Poor recruitment 2014-2018
- Sudden collapse of the stock
- 2019 lowest female spawning biomass in timeline (33Kt)

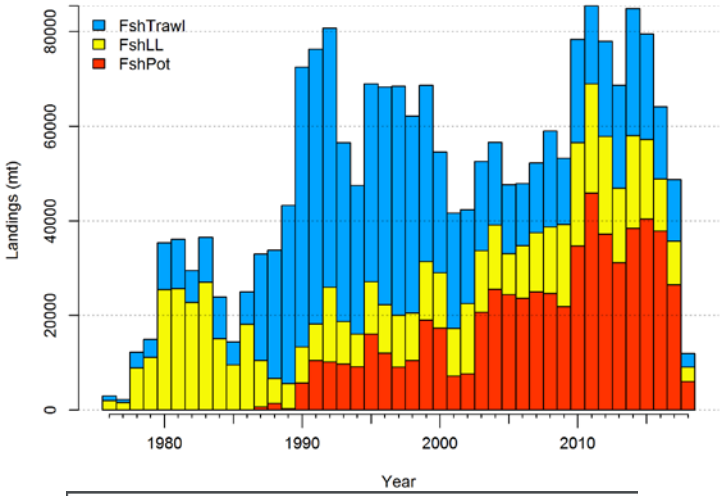


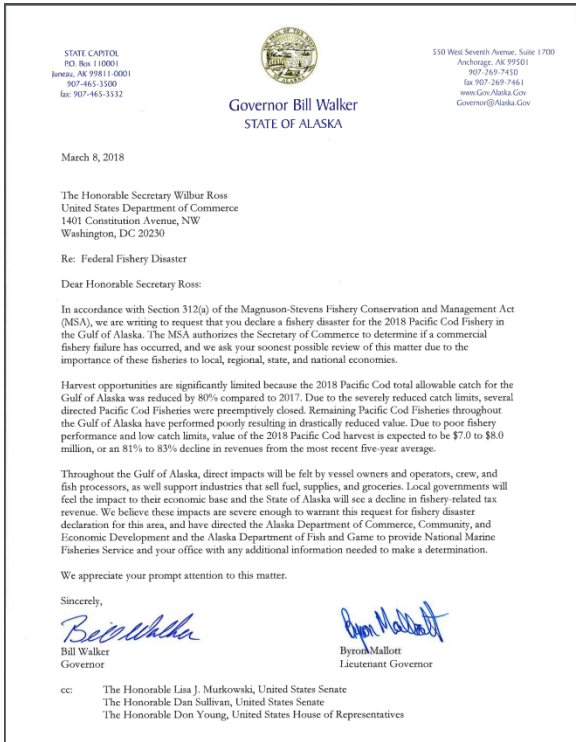


Management response



- 2018
  - 80% reduction in ABC
    - 88 Kt in 2017 to 18 Kt in 2018
    - Realized catch in 2018 was 15Kt
      - 69% reduction from 2017
    - Reduction from $75 to $32 million in first wholesale value
- 2019
  - ABC further reduced to 17 Kt
    - Realized catch of 15Kt
  - Fishery disaster declared 25 September 2019
- 2020
  - Closure of the directed federal fishery as stock status descended below 20% of unfished spawning biomass





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Governor@Alaska.Gov

Governor Bill Walker
STATE OF ALASKA

March 8, 2018

The Honorable Secretary Wilbur Ross
United States Department of Commerce
1401 Constitution Avenue, NW
Washington, DC 20230

Re: Federal Fishery Disaster

Dear Honorable Secretary Ross:

In accordance with Section 312(a) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), we are writing to request that you declare a fishery disaster for the 2018 Pacific Cod Fishery in the Gulf of Alaska. The MSA authorizes the Secretary of Commerce to determine if a commercial fishery failure has occurred, and we ask your soonest possible review of this matter due to the importance of these fisheries to local, regional, state, and national economies.

Harvest opportunities are significantly limited because the 2018 Pacific Cod total allowable catch for the Gulf of Alaska was reduced by 80% compared to 2017. Due to the severely reduced catch limits, several directed Pacific Cod Fisheries were preemptively closed. Remaining Pacific Cod Fisheries throughout the Gulf of Alaska have performed poorly resulting in drastically reduced value. Due to poor fishery performance and low catch limits, value of the 2018 Pacific Cod harvest is expected to be $7.0 to $8.0 million, or an 81% to 83% decline in revenues from the most recent five-year average.

Throughout the Gulf of Alaska, direct impacts will be felt by vessel owners and operators, crew, and fish processors, as well support industries that sell fuel, supplies, and groceries. Local governments will feel the impact to their economic base and the State of Alaska will see a decline in fishery-related tax revenue. We believe these impacts are severe enough to warrant this request for fishery disaster declaration for this area, and have directed the Alaska Department of Commerce, Community, and Economic Development and the Alaska Department of Fish and Game to provide National Marine Fisheries Service and your office with any additional information needed to make a determination.

We appreciate your prompt attention to this matter.

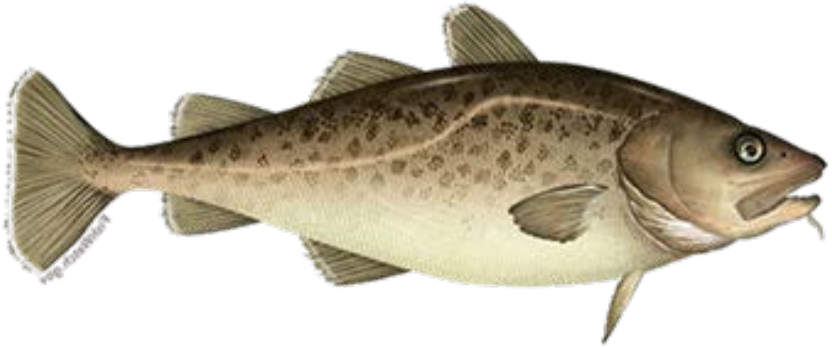
Sincerely,

Bill Walker
Governor

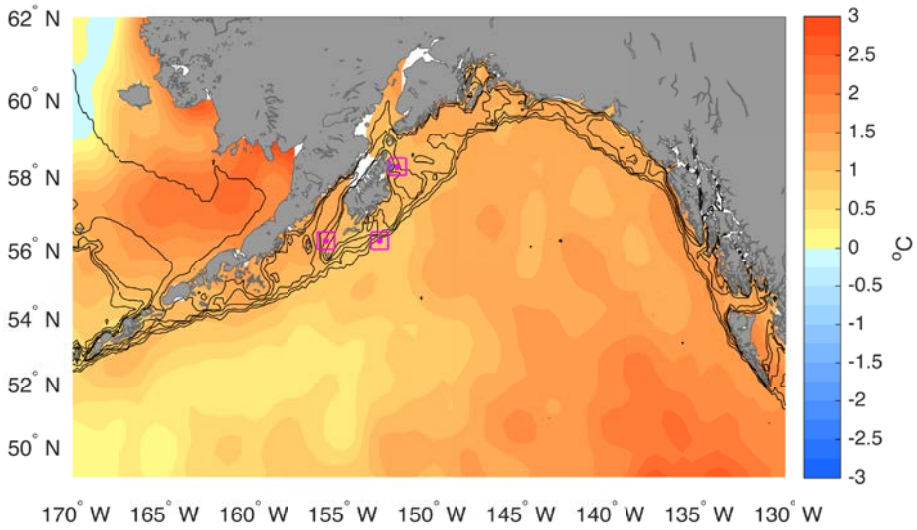
Byron Mallott
Lieutenant Governor

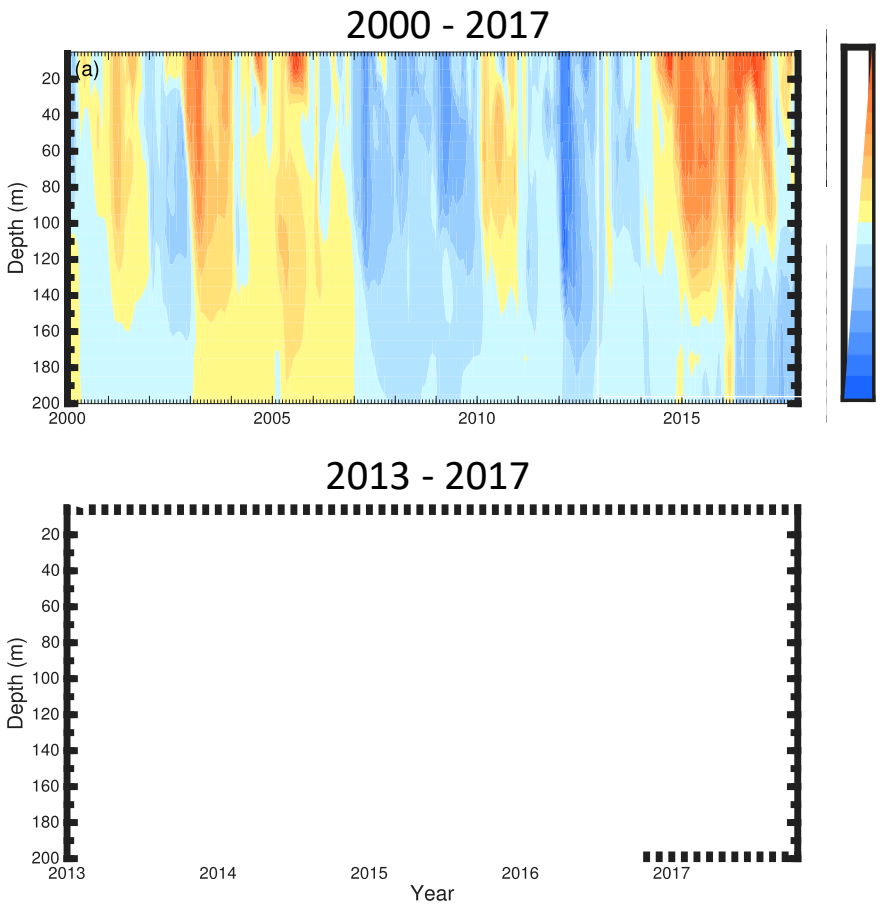
cc: The Honorable Lisa J. Murkowski, United States Senate
The Honorable Dan Sullivan, United States Senate
The Honorable Don Young, United States House of Representatives

Why did this happen?



Anomalously warm ocean conditions in the NE Pacific Ocean during 2014-2016 (“The Blob”)

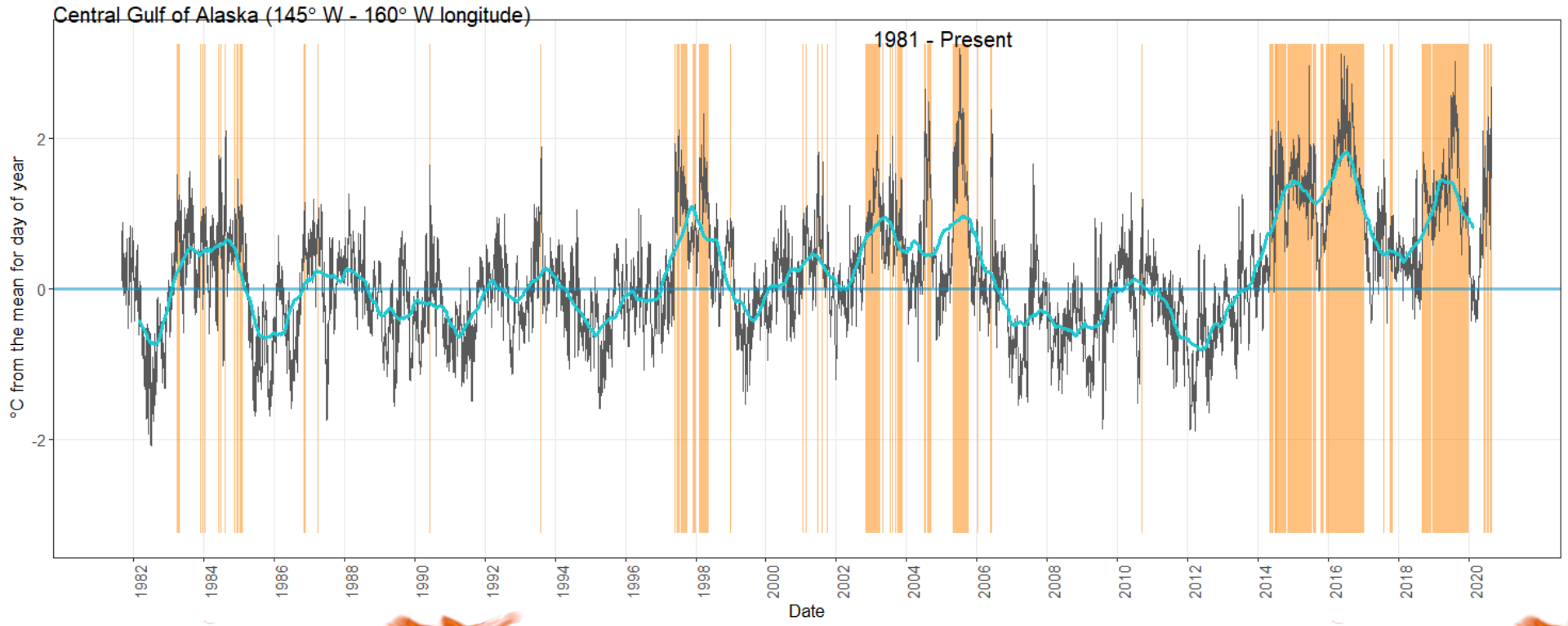




- During the period of 2014-2016, the NE Pacific experienced strong SST warming (Bond et al. 2015).
- Within the topmost 100 m, a region of $\sim 2 \times 10^6$ km^2 was more than 2.5ºC warmer with a peak anomaly exceeding 3 standard deviations compared to the long-term mean averaged from 1982-2012.
- Warming extended to ~300m.

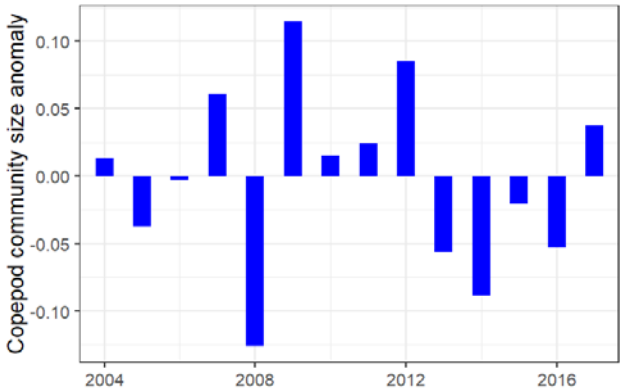
2014-2016 marine heatwave central Gulf of Alaska

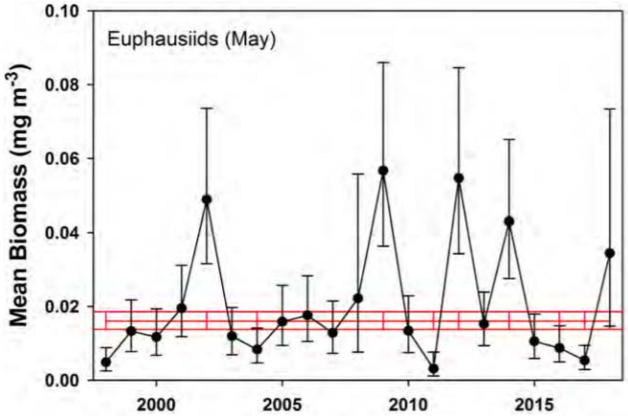
- Nearly 3°C above the seasonally corrected mean
- Nearly 2°C above the seasonally corrected 90th percentile



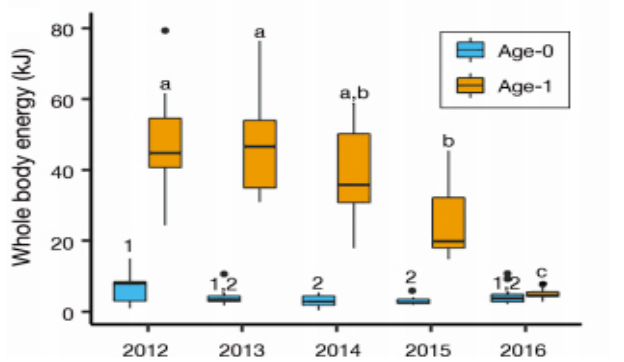
Ecological impacts of the 2014-2016 marine heatwave

- Higher mesozooplankton abundance





- Fewer large lipid-rich copepods
- Low euphausiid abundance
- Low forage fish abundance
- Lower forage fish energy density*



*von Biela, V.R., et al., 2019. Extreme reduction in nutritional value of a key forage fish during the Pacific marine heatwave of 2014-2016. *Marine Ecology Progress Series*, *613*, pp.171-182.

Ecological impacts of the 2014-2016 marine heatwave

- Large-scale seabird die-offs and reproductive failure
- Increase in large whale strandings

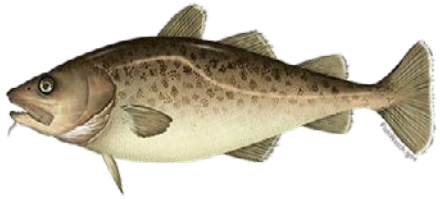
PLOS ONE

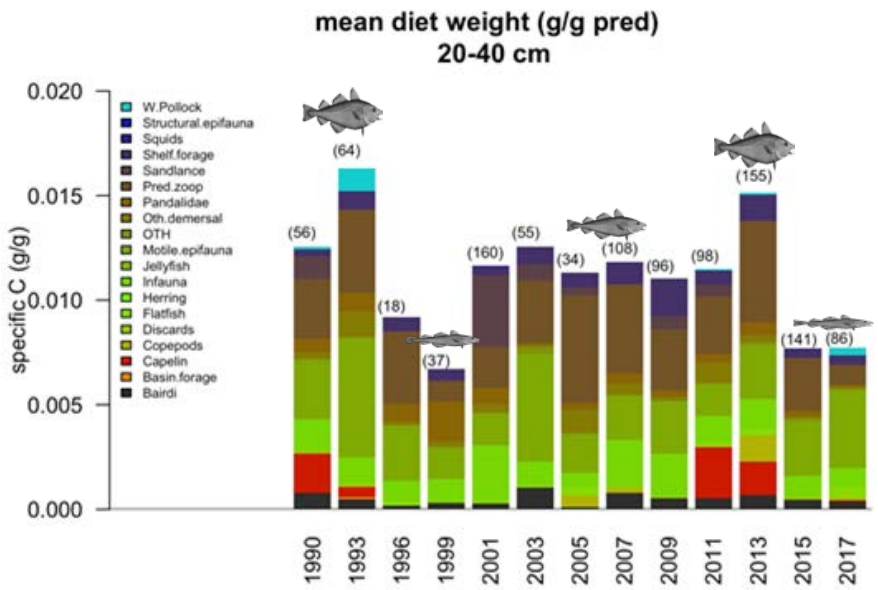
RESEARCH ARTICLE

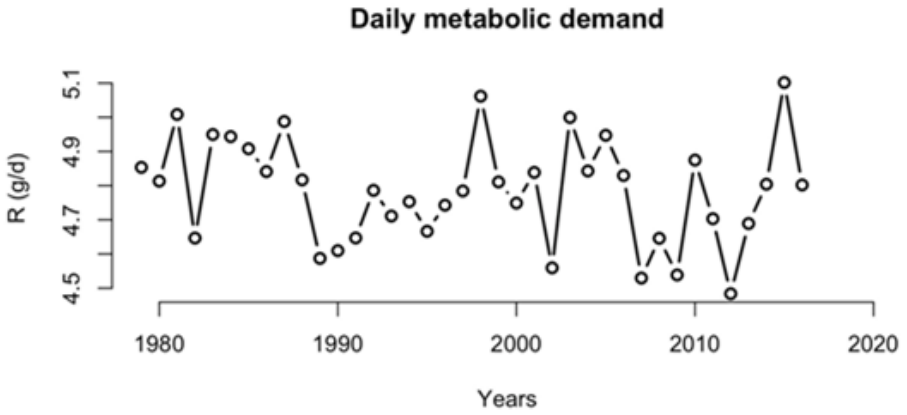
Extreme mortality and reproductive failure of common murres resulting from the northeast Pacific marine heatwave of 2014-2016

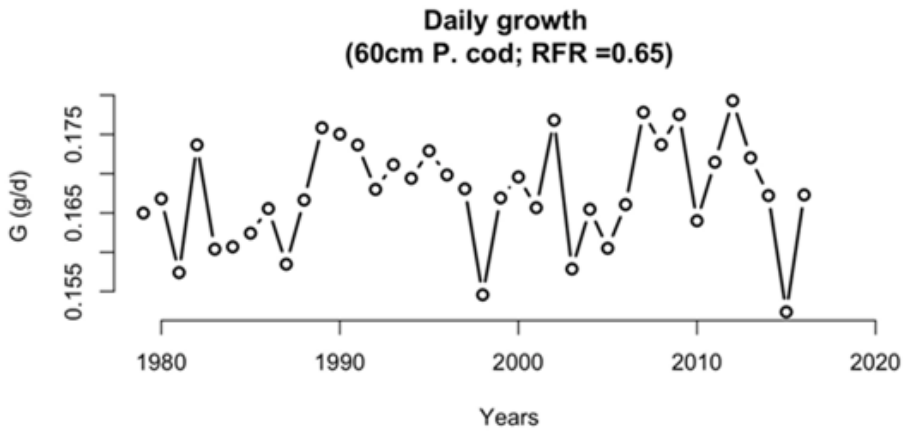
John F. Piatt[1]*, Julia K. Parrish[2], Heather M. Renner[3], Sarah K. Schoen[1], Timothy T. Jones[2], Mayumi L. Arimitsu[4], Kathy J. Kuletz[5], Barbara Bodenstein[6], Marisol García-Reyes[7], Rebecca S. Duerr[8], Robin M. Corcoran[9], Robb S. A. Kaler[4], Gerard J. McChesney[10], Richard T. Golightly[11], Heather A. Coletti[12], Robert M. Suryan[13], Hillary K. Burgess[2], Jackie Lindsey[2,14], Kirsten Lindquist[15], Peter M. Warzybok[16], Jaime Jahncke[16], Jan Roletto[15], William J. Sydeman[7]

Low forage and increased metabolism



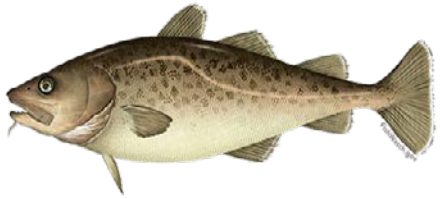


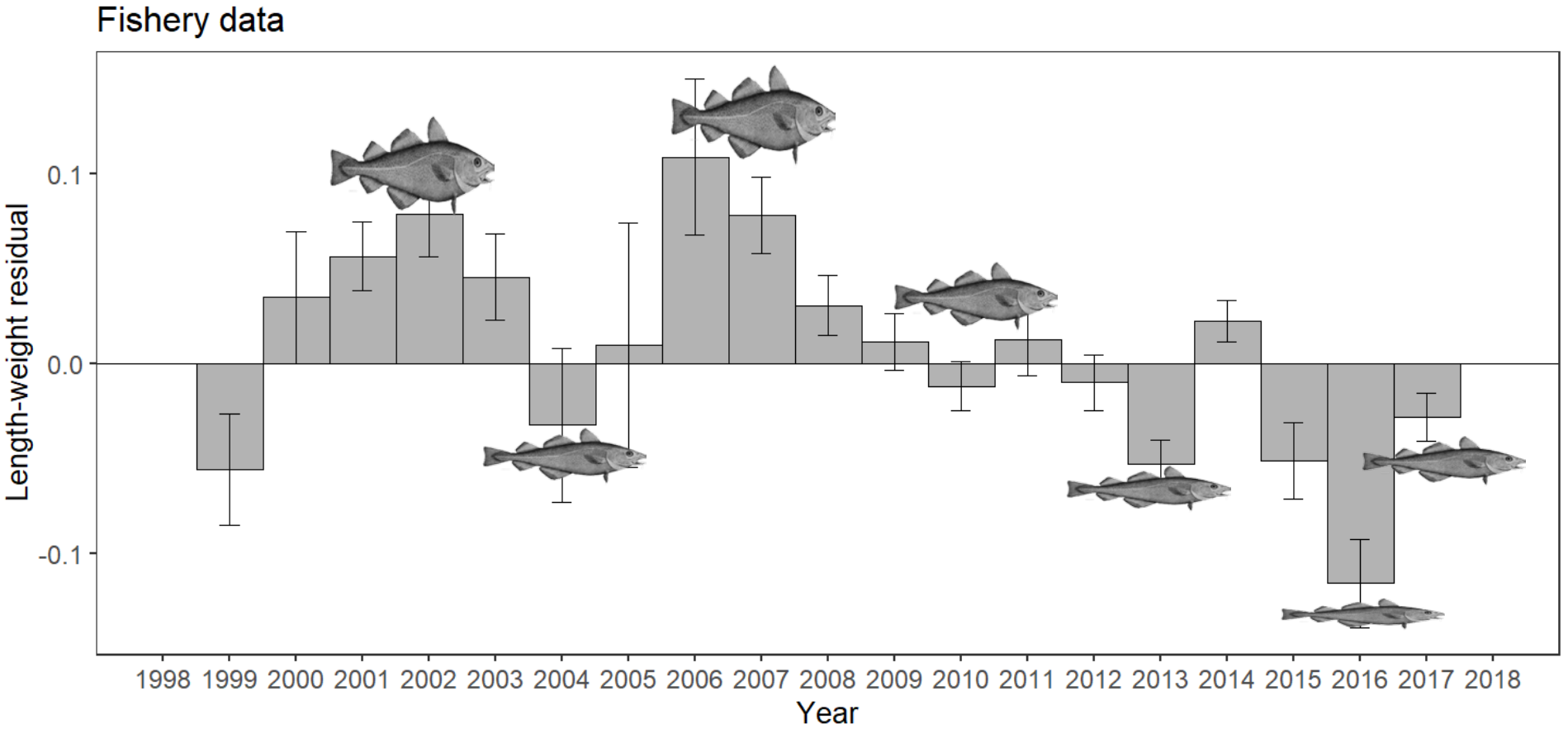




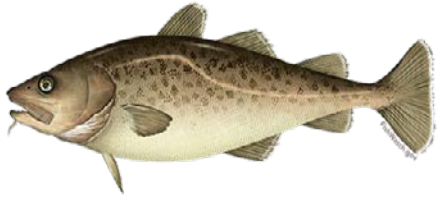
Bioenergetics analysis by Kirsten Holsman

Poor condition and increased natural mortality for juveniles and adults





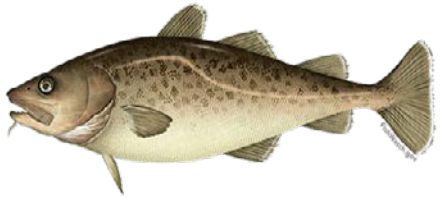
Bio-energetics summary



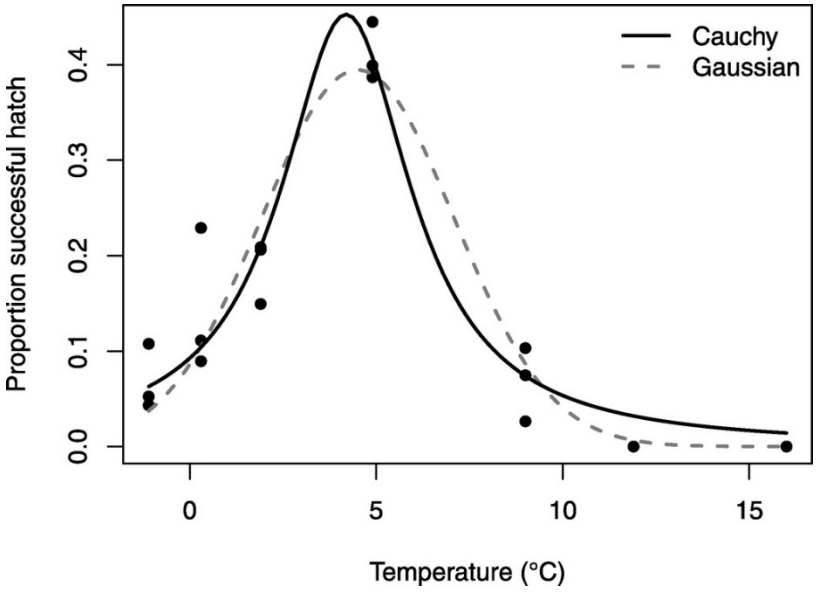
- Warmer temperatures were throughout the year and water column
- Higher metabolism in warmer temps lead to higher forage requirements
- Indications of lower forage amounts in 2015-2016
- Combination likely lead to higher Pacific cod natural mortality for these years.

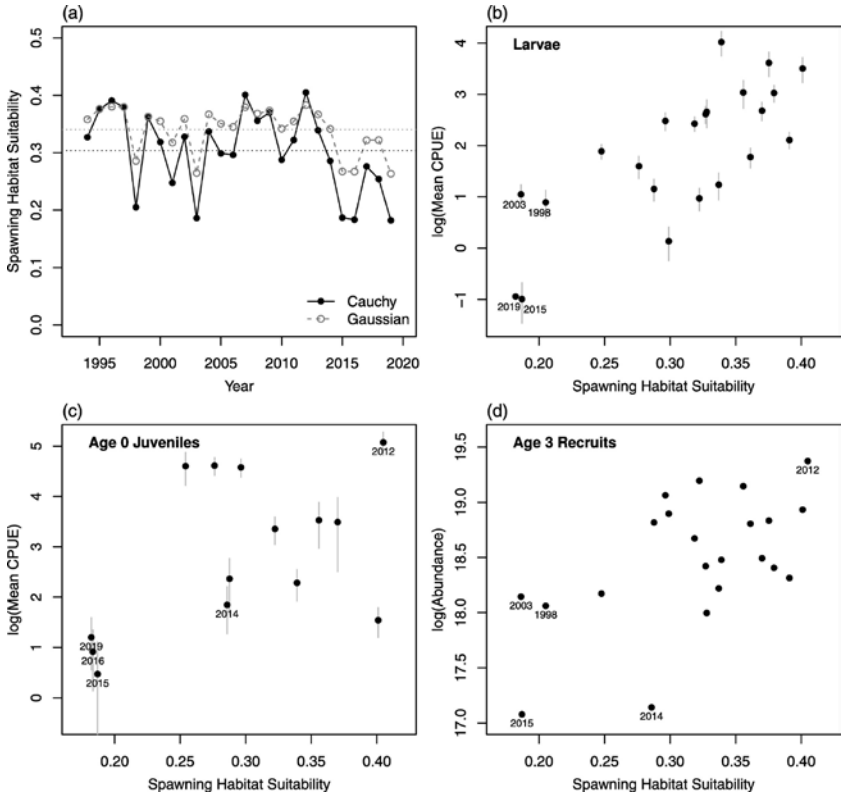
Piatt *et al.* (2020)'s ectothermic vice

Lower Pacific cod recruitment



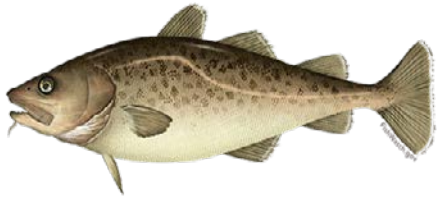
- Increased temperature results in lower egg survival and fewer larvae

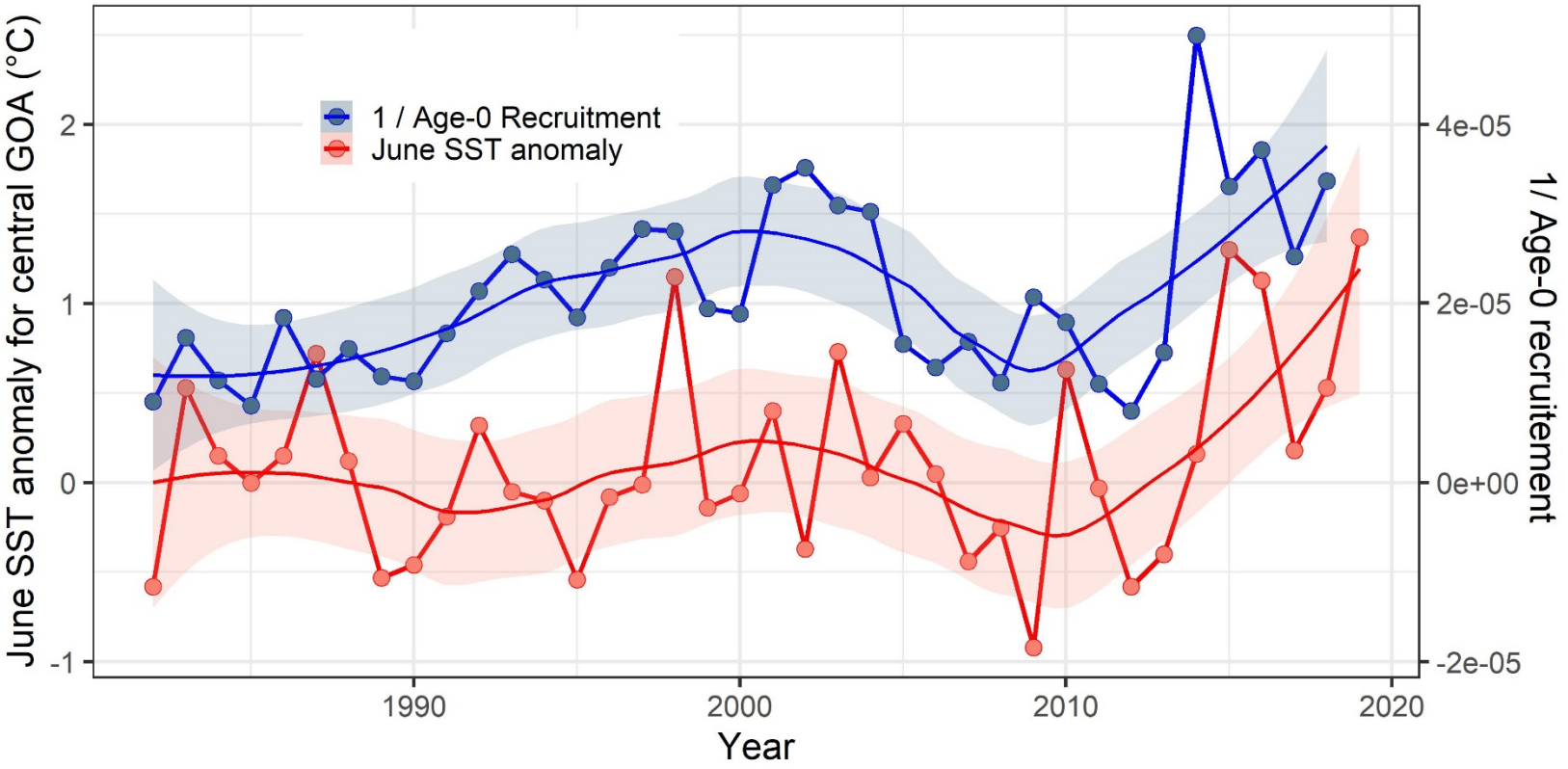




Laurel, B.J. and Rogers, L.A., 2020. Loss of spawning habitat and prerecruits of Pacific cod during a Gulf of Alaska heatwave. Canadian Journal of Fisheries and Aquatic Sciences, 77(4), pp.644-650.

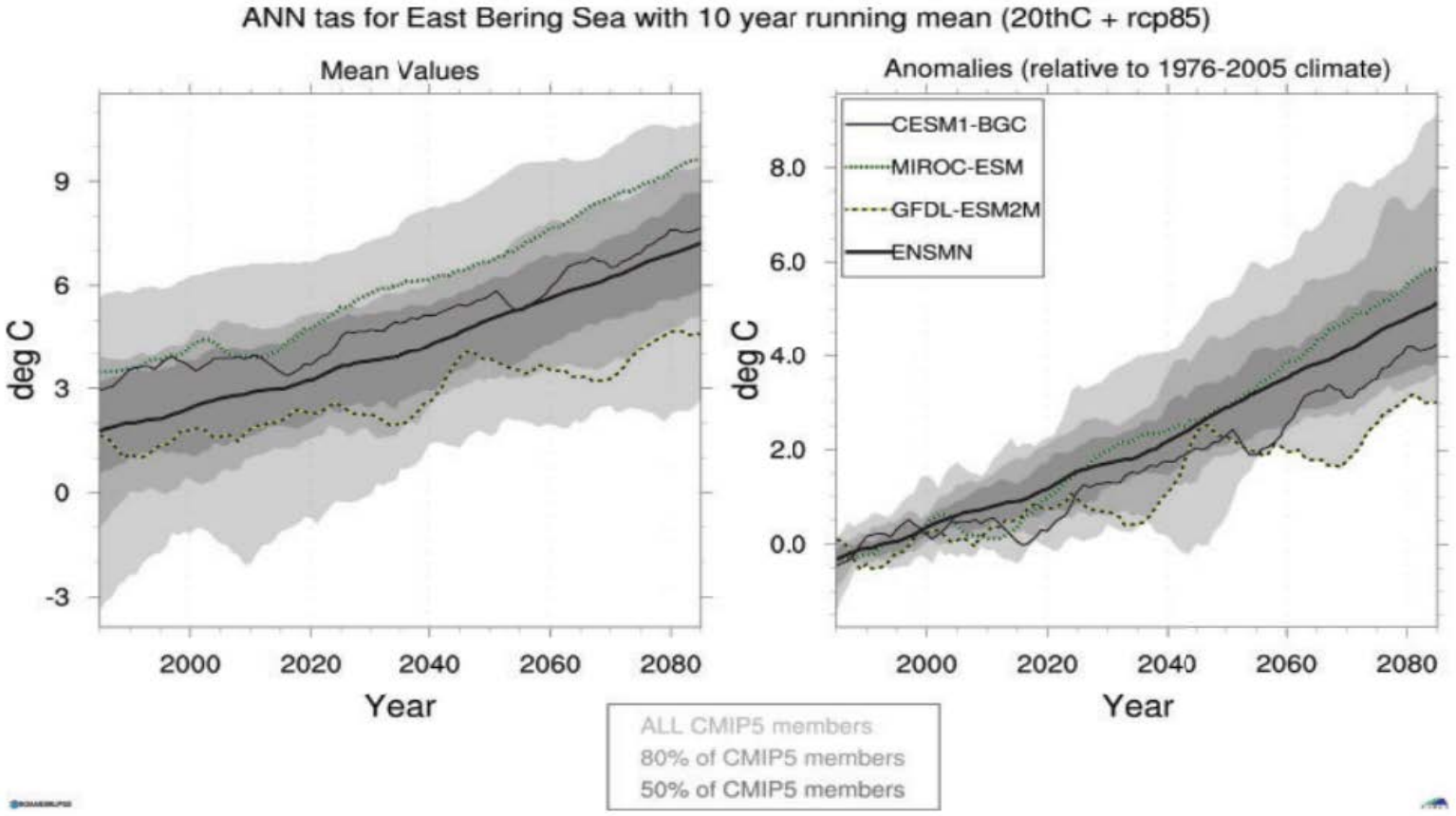
Recruitment trends with temperature





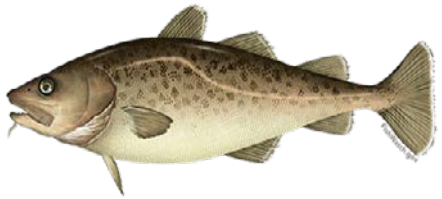
Looking to the future

- Sea temperatures are expected to rise and marine heatwaves become more common



Hermann, et al. 2019. Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. *ICES Journal of Marine Science*. 76: 1280-1304. DOI: 10.1093/icesjms/fsz043

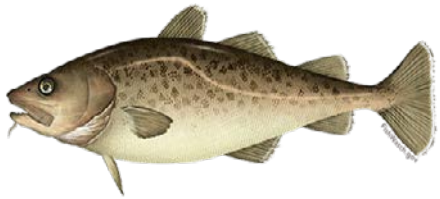
Climate-enhanced stock assessment model



- Marine heatwave cumulative index
  - Natural mortality at age
  - Recruitment

- Sea surface temperature
  - Growth
  - Maturity

Climate-enhanced stock assessment model

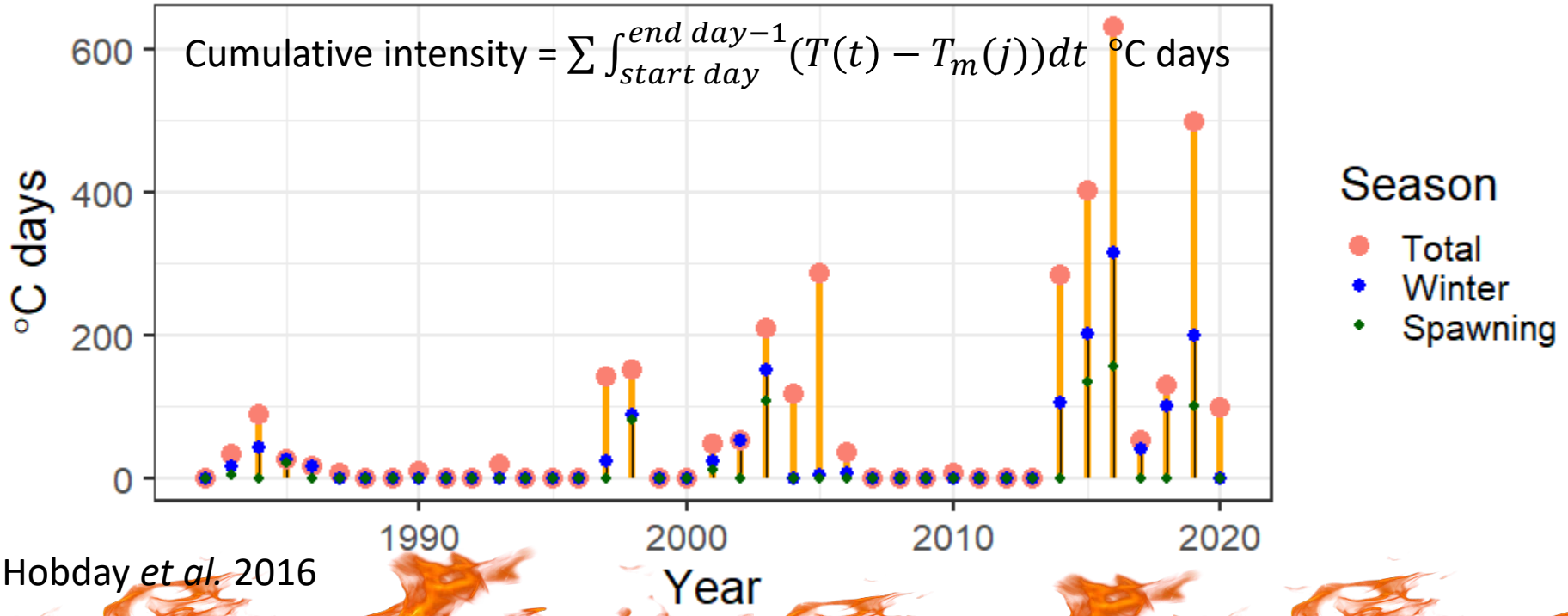


- Marine heatwave cumulative index
  - Natural mortality at age
  - Recruitment
- Sea surface temperature
  - Growth
  - Maturity

Not proposed for management this year!

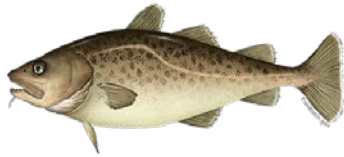
Marine heatwave cumulative index (MHCI)

- Sum of cumulative heat above the mean for days warmer than the 90th percentile for more than 5 sequential days
- 'Winter' is November through March
- 'Spawning' is February through March

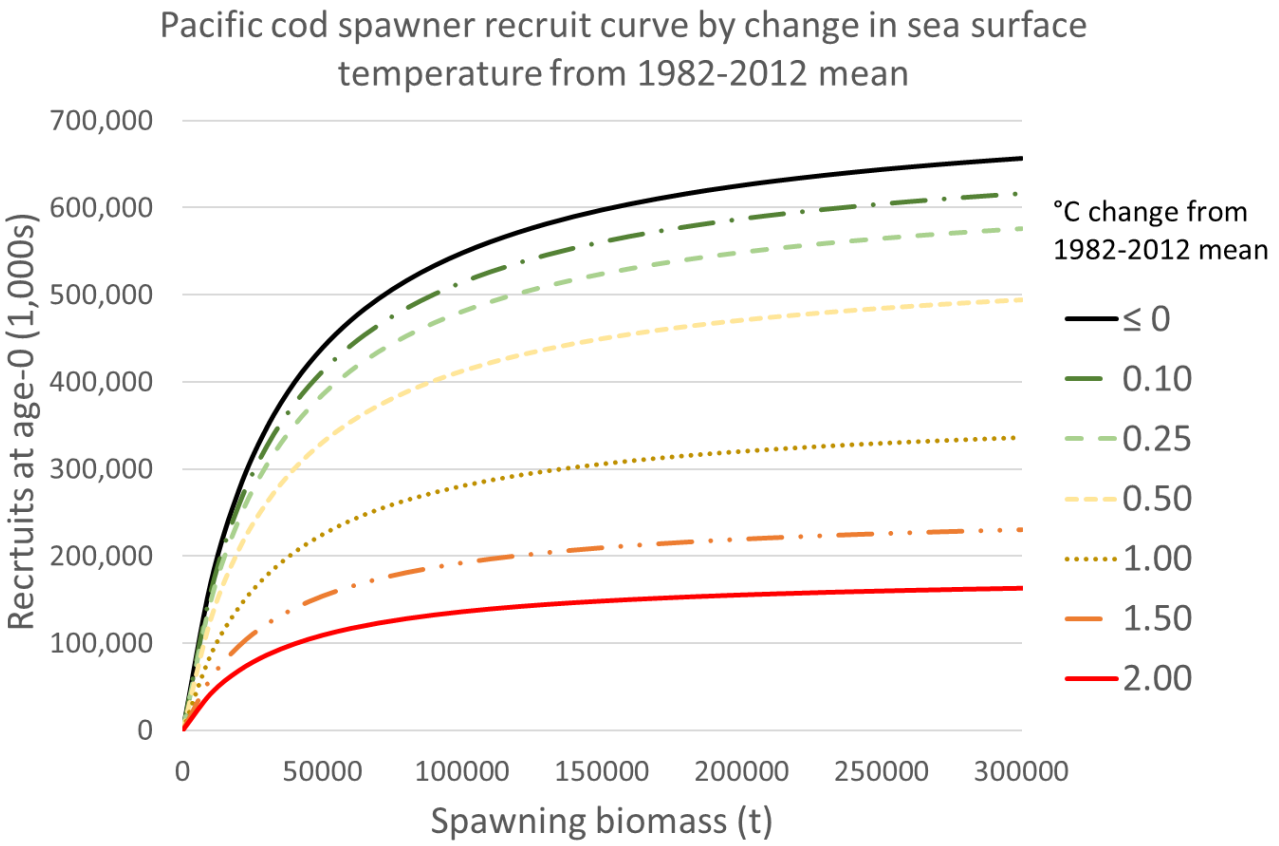


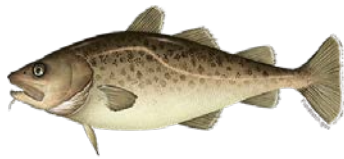
Hobday *et al.* 2016

Recruitment



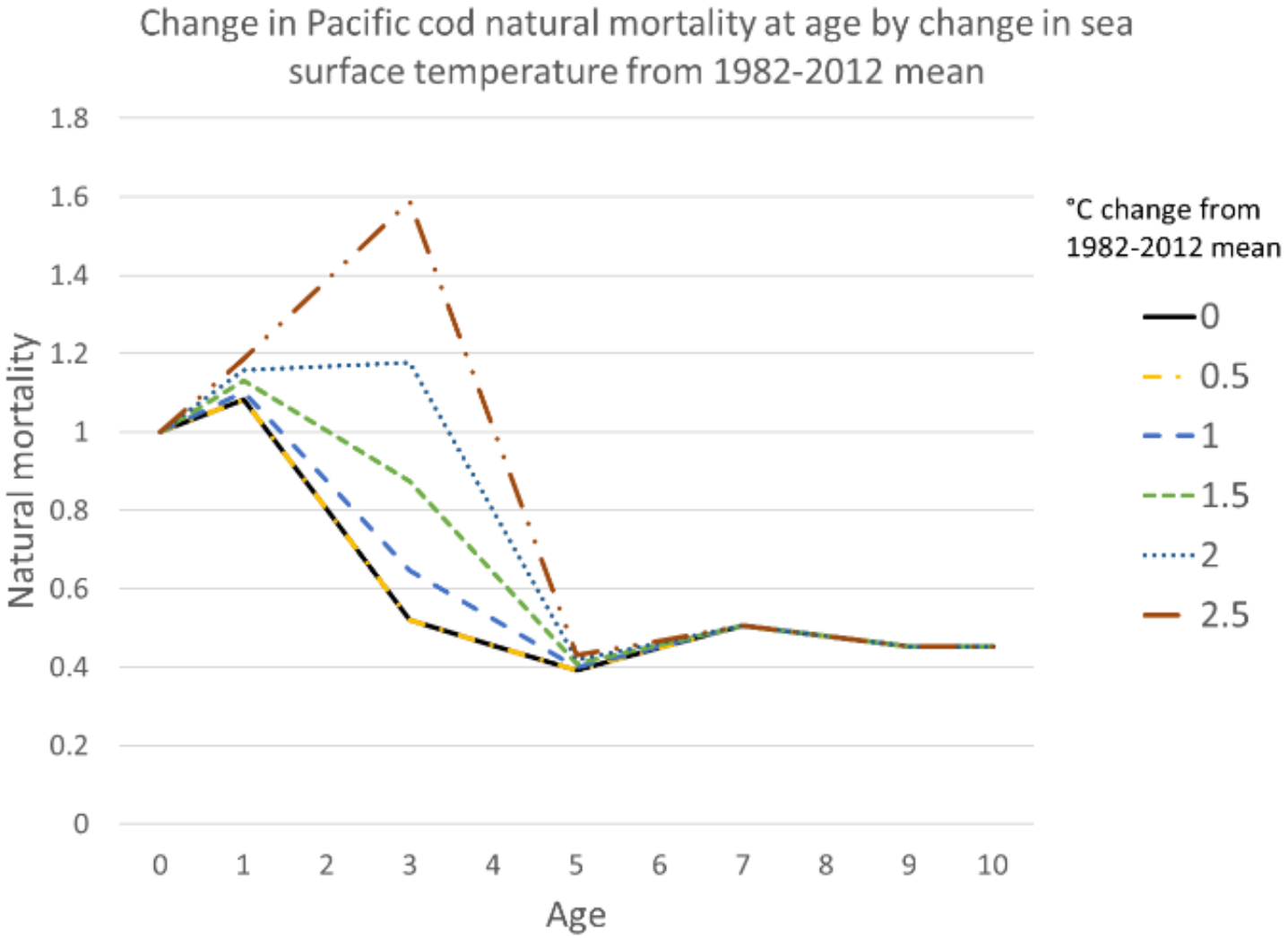
Beverton-Holt recruitment with R_0 scaled to winter MHCI





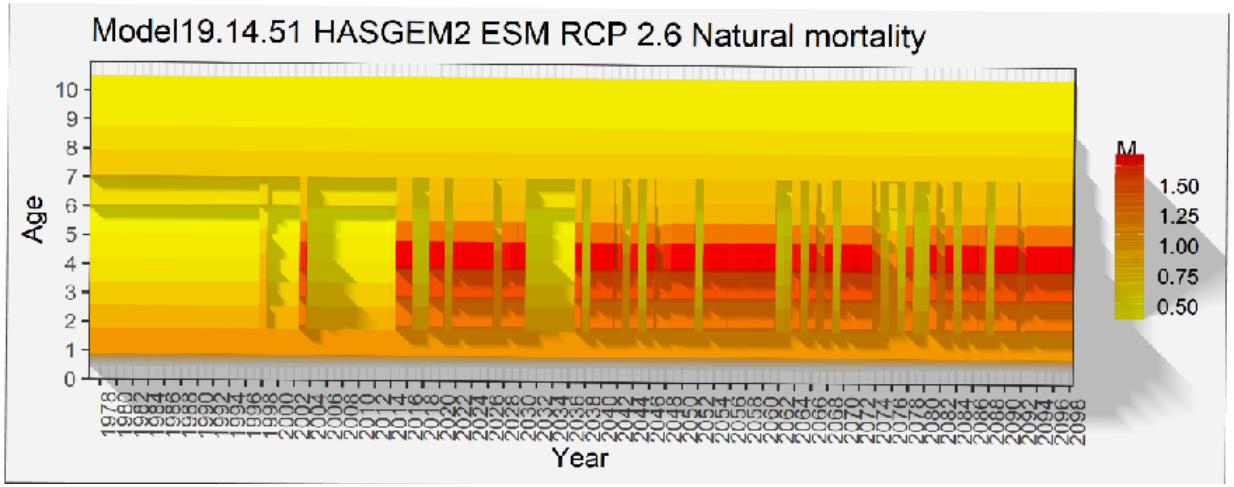
Natural mortality

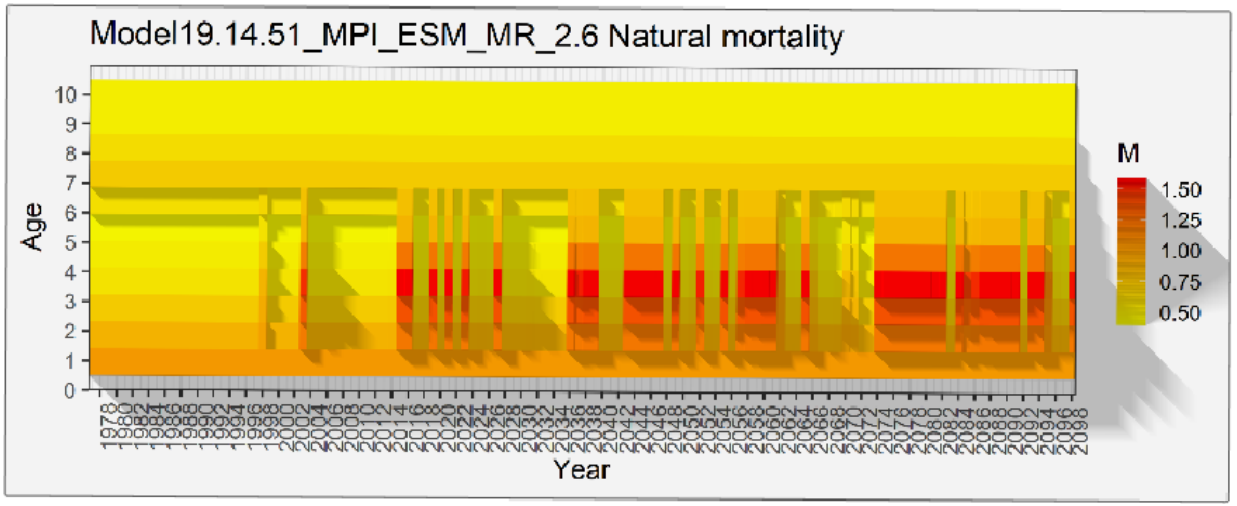
Natural mortality by age scaled to winter MHCI



Natural mortality

Natural mortality by age scaled to winter MHCI and projected forward in two climate scenarios

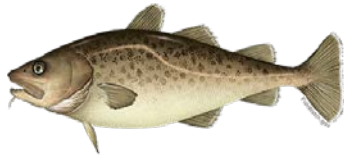




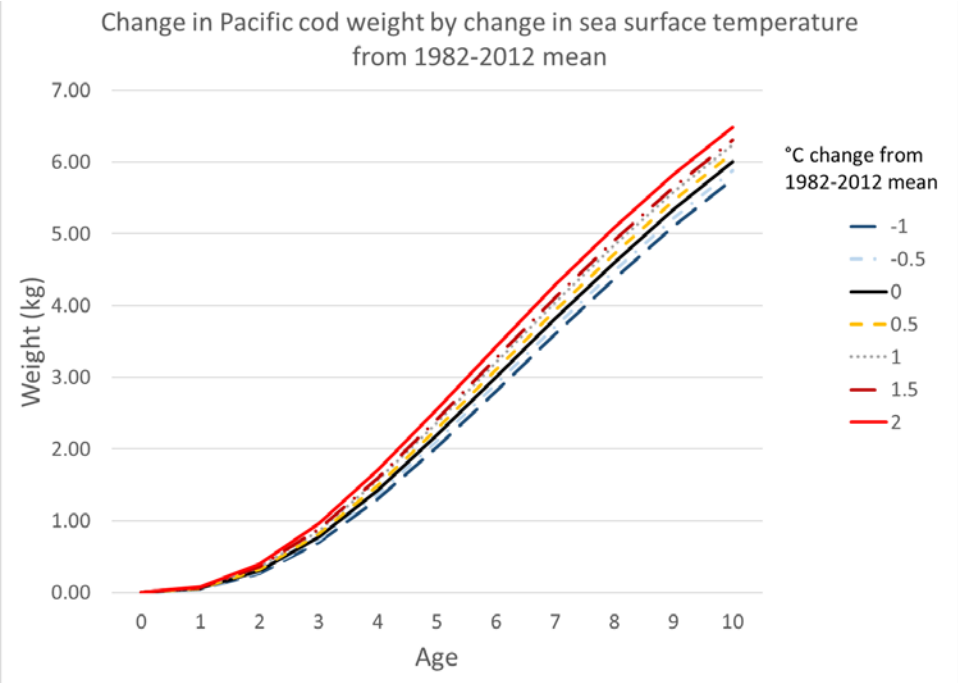
Temperature dependent growth models (based on Schnute model)

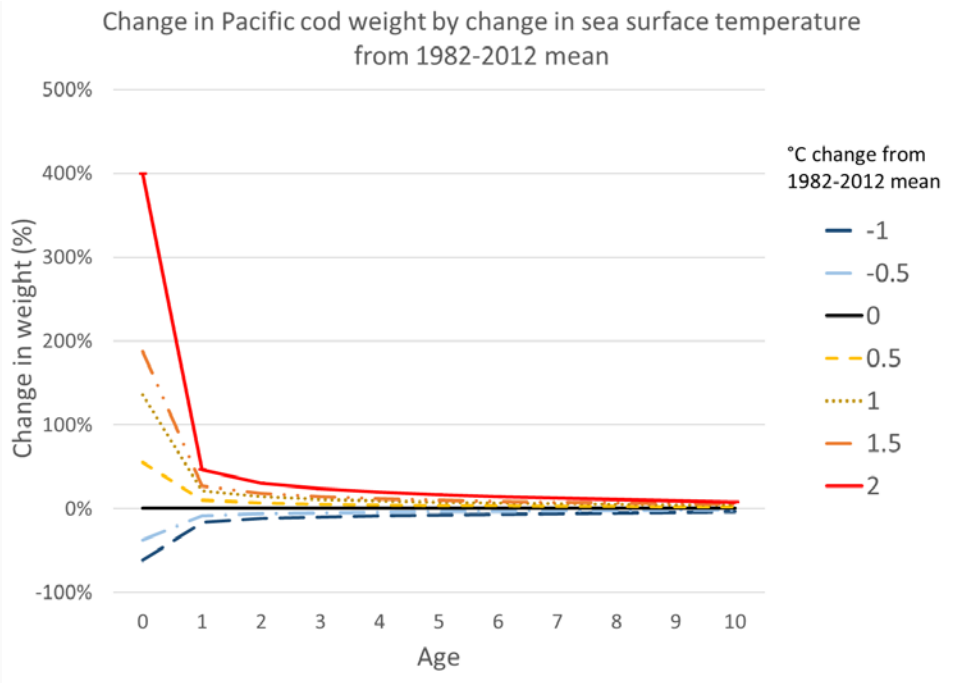
Model	L1	L3	K	t1	t2	a	b	d	LL	AIC	ΔAIC	w_i
L1 + (L3 - L1) * ((1 - exp(-K * (t - t1)))/(1 - exp(-K * (t3 - t1))))	11.17	91.31	0.142	0.5	10					340703	361.0	0.000000
(L1+a*I1) + (L3- (L1+a*I1)) * ((1 - exp(-K * (t - t1)))/(1 - exp(-K * (t3 - t1))))												
I1= Growth Model - Year Class	9.42	91.29	0.142	0.5	10	1.706			-170341	340691	349.5	0.000000
I1= Temp. anomaly - Year Class	11.13	91.29	0.142	0.5	10	0.368			-170342	340694	352.0	0.000000
I1= Growth Model - Year	3.54	91.37	0.141	0.5	10	7.523			-170184	340378	36.5	0.000000
I1= Temp. anomaly - Year	11.09	91.37	0.141	0.5	10	1.760			-170192	340393	51.7	0.000000
(L1+a*I1) + ((L3+b*I2)- (L1+a*I1)) * ((1 - exp(-K * (t - t1)))/(1 - exp(-K * (t3 - t1))))												
I1= Growth Model - Year Class, I2= Temp. anomaly - Year Class	5.78	91.40	0.142	0.5	10	5.314	-1.458		-170294	340599	257.7	0.000000
I1= Growth Model - Year Class, I2= Growth Model - Year	9.18	85.35	0.141	0.5	10	1.984	5.921		-170249	340510	168.3	0.000000
I1= Growth Model - Year, I2= Growth Model - Year	4.17	90.40	0.141	0.5	10	6.904	0.963		-170183	340378	35.8	0.000000
I1= Growth Model - Year, I2= Growth Model - Year Class	3.64	93.53	0.140	0.5	10	7.438	-2.109		-170175	340362	20.3	0.000039
I1= Growth Model - Year, I2= Temp. anomaly - Year	3.99	91.36	0.141	0.5	10	7.087	0.163		-170183	340361	19.0	0.000075
(L1+a*I1)+ (L3- (L1+a*I1)) * ((1 - exp((-K+(b*I2)) * (t - t1)))/(1 - exp((-K+(b*I2)) * (t3 - t1))))												
I1= Growth Model - Year Class, I2= Temp. anomaly - Year Class	2.13	91.29	0.143	0.5	10	8.884	0.016		-170284	340579	237.7	0.000000
I1= Growth Model - Year, I2= Temp. anomaly - Year Class	3.60	91.37	0.141	0.5	10	7.472	0.002		-170183	340377	35.5	0.000000
L1 + ((L3*exp(a*I1))- L1) * ((1 - exp((-K*(exp(b*I2))) * (t - t1)))/(1 - exp((-K*exp(b*I2)) * (t3 - t1))))												
I1= Growth Model - Year Class, I2= Growth Model - Year Class	11.19	98.09	0.112	0.5	10	-0.070	0.230		-170327	340665	323.7	0.000000
I1= Growth Model - Year Class, I2= Temp. anomaly - Year Class	11.19	97.42	0.141	0.5	10	-0.063	0.046		-170329	340670	328.3	0.000000
I1= Growth Model - Year, I2= Temp. anomaly - Year	11.17	94.45	0.140	0.5	10	-0.033	0.117		-170219	340450	108.2	0.000000
I1= Growth Model - Year Class, I2= Temp. anomaly - Year	11.20	93.51	0.140	0.5	10	-0.023	0.083		-170214	340440	97.9	0.000000
(L1+a*I1) +((L3+b*I2)- (L1+a*I1)) * ((1 - exp((-K+(d*I2)) * (t - t1)))/(1 - exp((-K+(d*I2)) * (t3 - t1))))												
I1= Growth Model - Year Class, I2= Temp. anomaly - Year Class	2.65	91.32	0.142	0.5	10	8.381	-0.407	0.013	-170283	340579	237.4	0.000000
I1= Growth Model - Year , I2= Temp. anomaly - Year Class	3.54	91.48	0.140	0.5	10	7.540	-1.524	-0.008	-170164	340342	0.0	0.999886
I1= Growth Model - Year , I2= Temp. anomaly - Year	2.76	91.36	0.141	0.5	10	8.296	0.547	0.005	-170182	340378	35.8	0.000000

Growth
Temp. dependent Schnute model

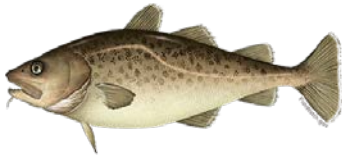


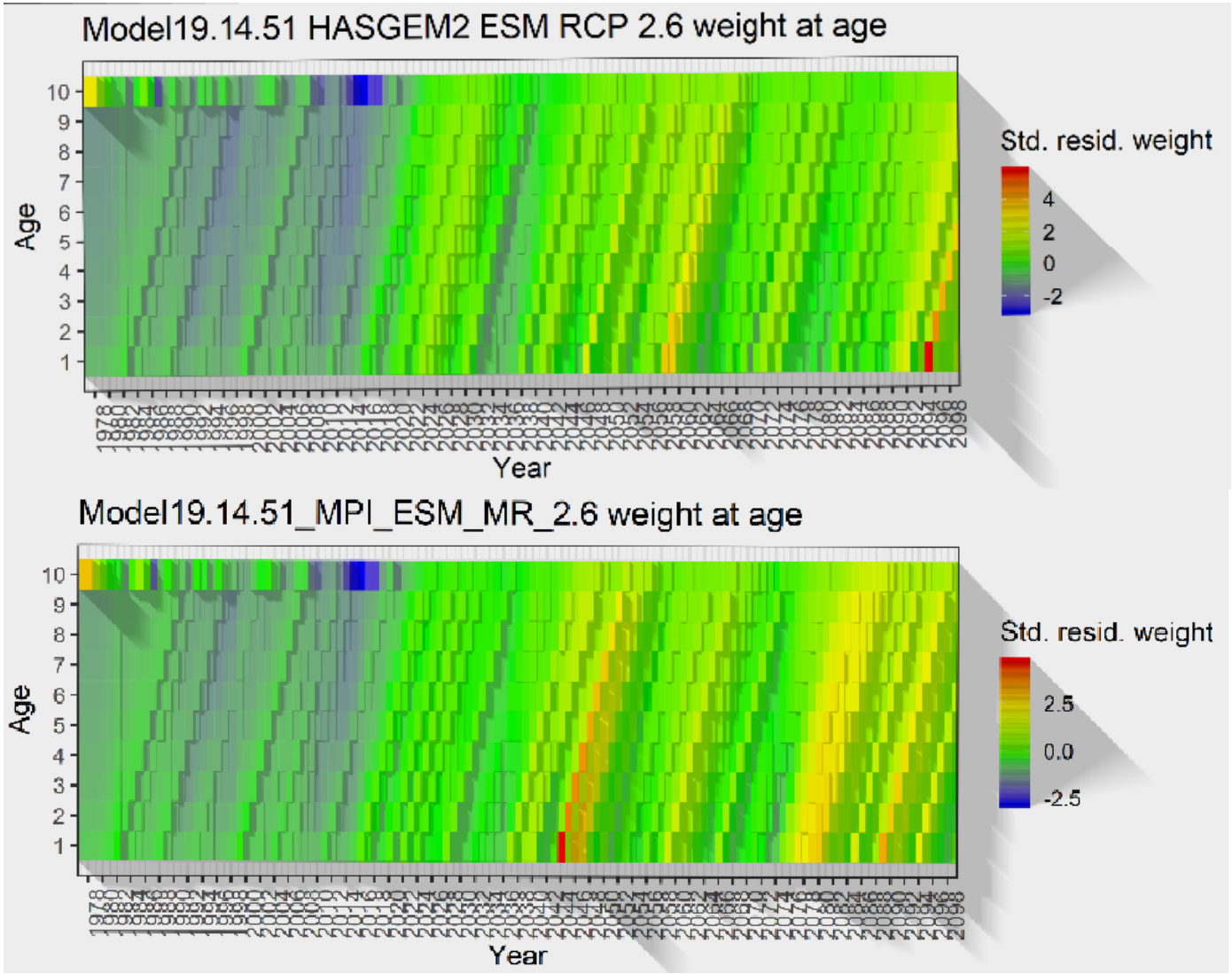
$$(L1+a*I1)+ (L3- (L1+a*I1)) * ((1 - \exp((-K+(b*I2)) * (t - t1)))/(1 - \exp((-K+(b*I2)) * (t3 - t1))))$$

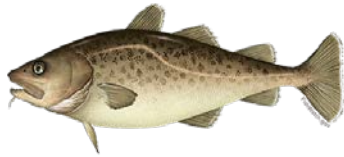




Growth
Weight by age residuals examples

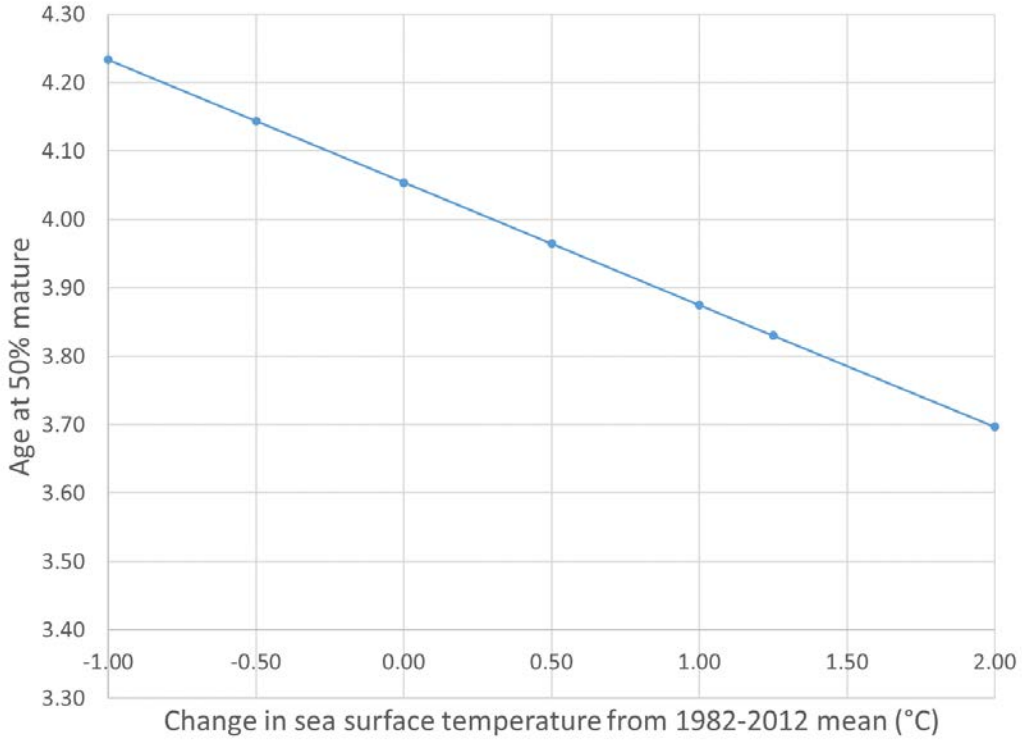


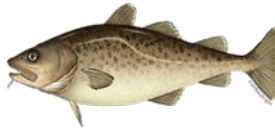




Maturity

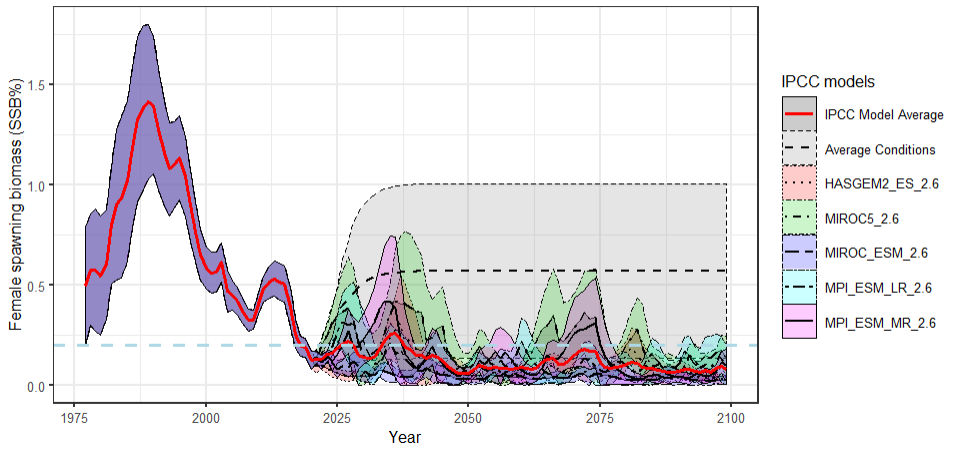
- Maturity is fixed as a function of length in the model with L_{50} at 53.7cm
- Age at maturity goes down with higher temperatures



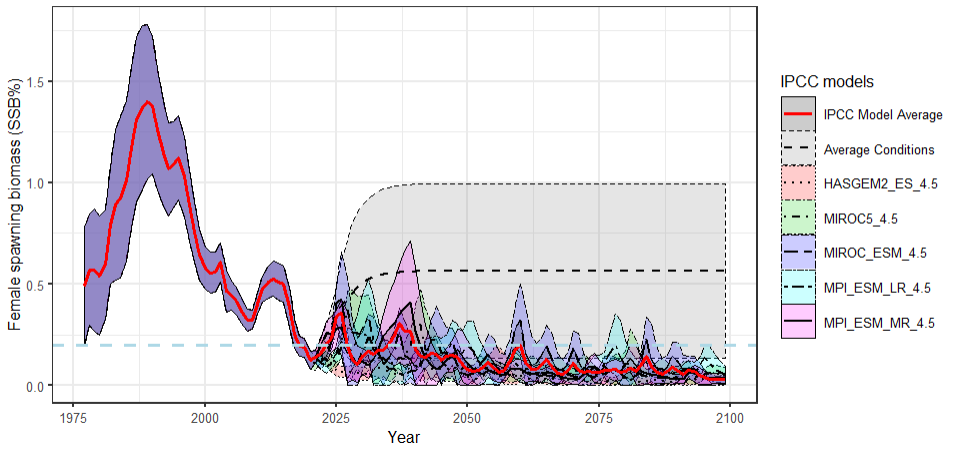


Projected female spawning biomass (MHCI driven natural mortality)

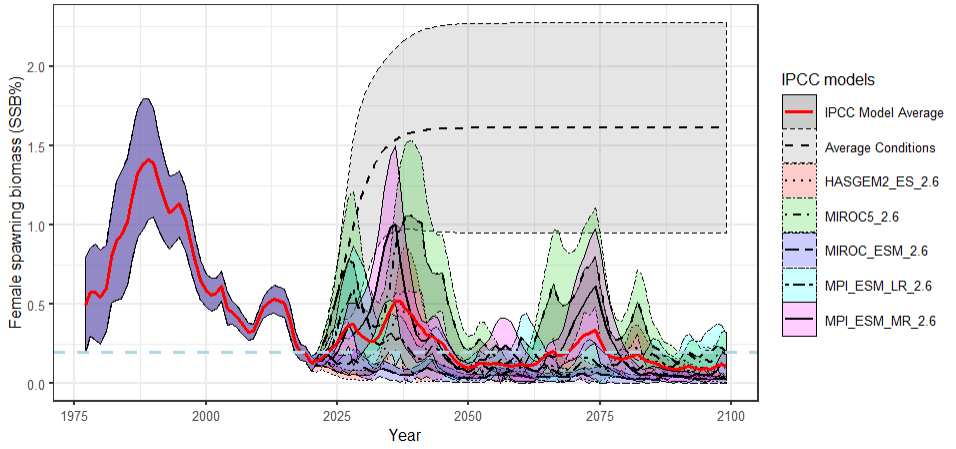
Model RCP 2.6 projections with fishing under standard control rule



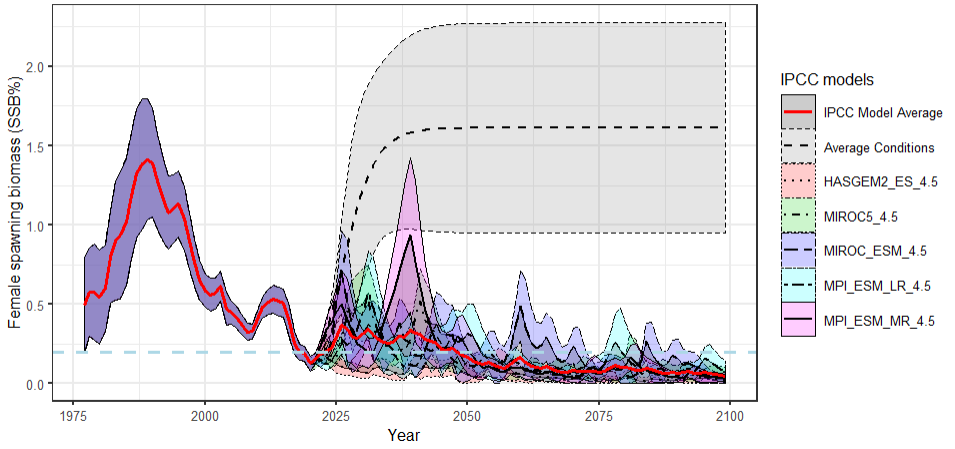
Model RCP 4.5 projections with fishing under standard control rule

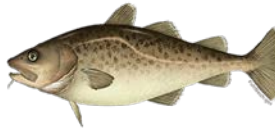


Model RCP 2.6 projections without fishing

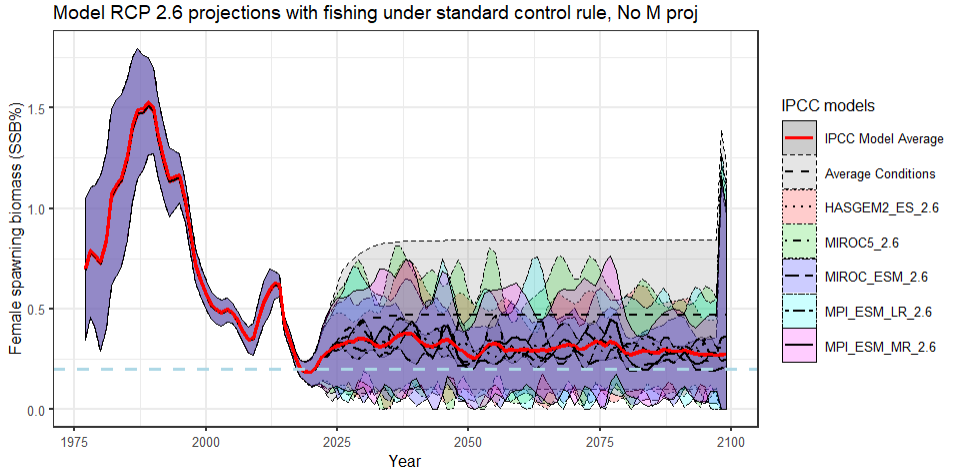


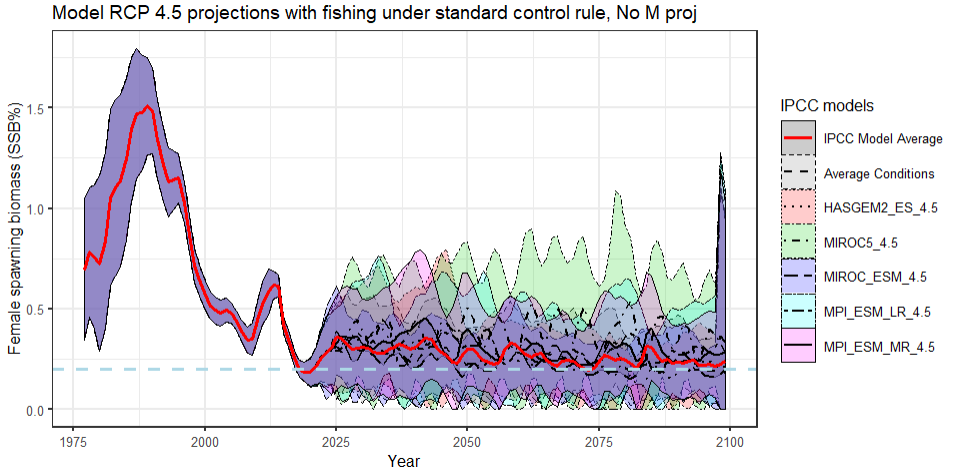
Model RCP 4.5 projections without fishing

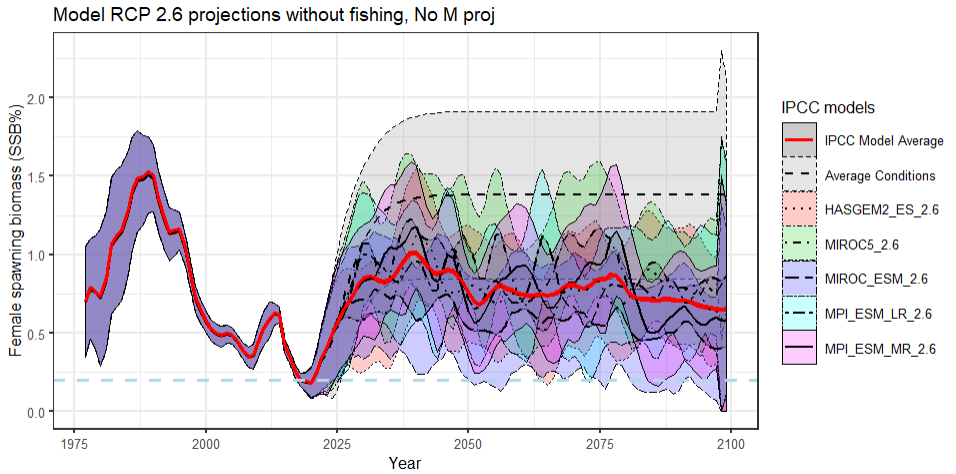


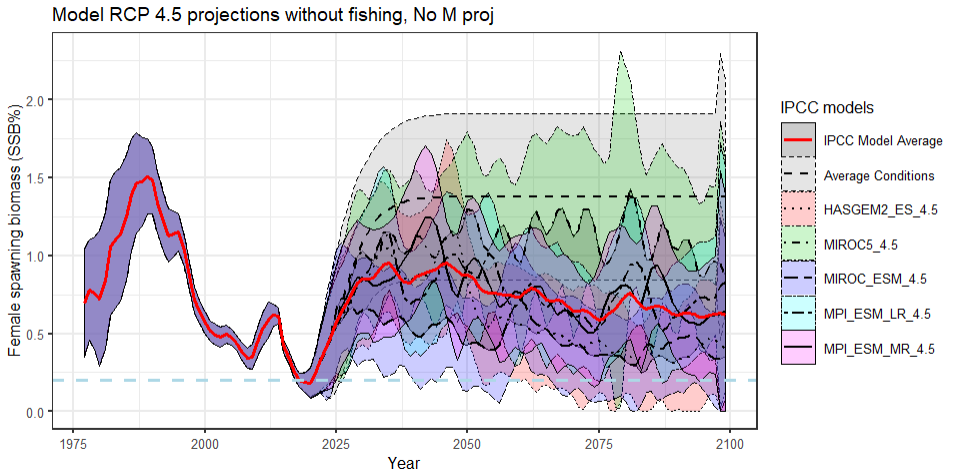


Projected female spawning biomass (average natural mortality)



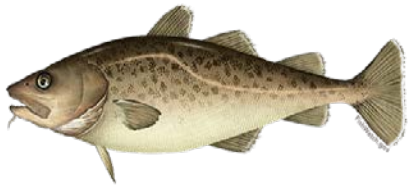




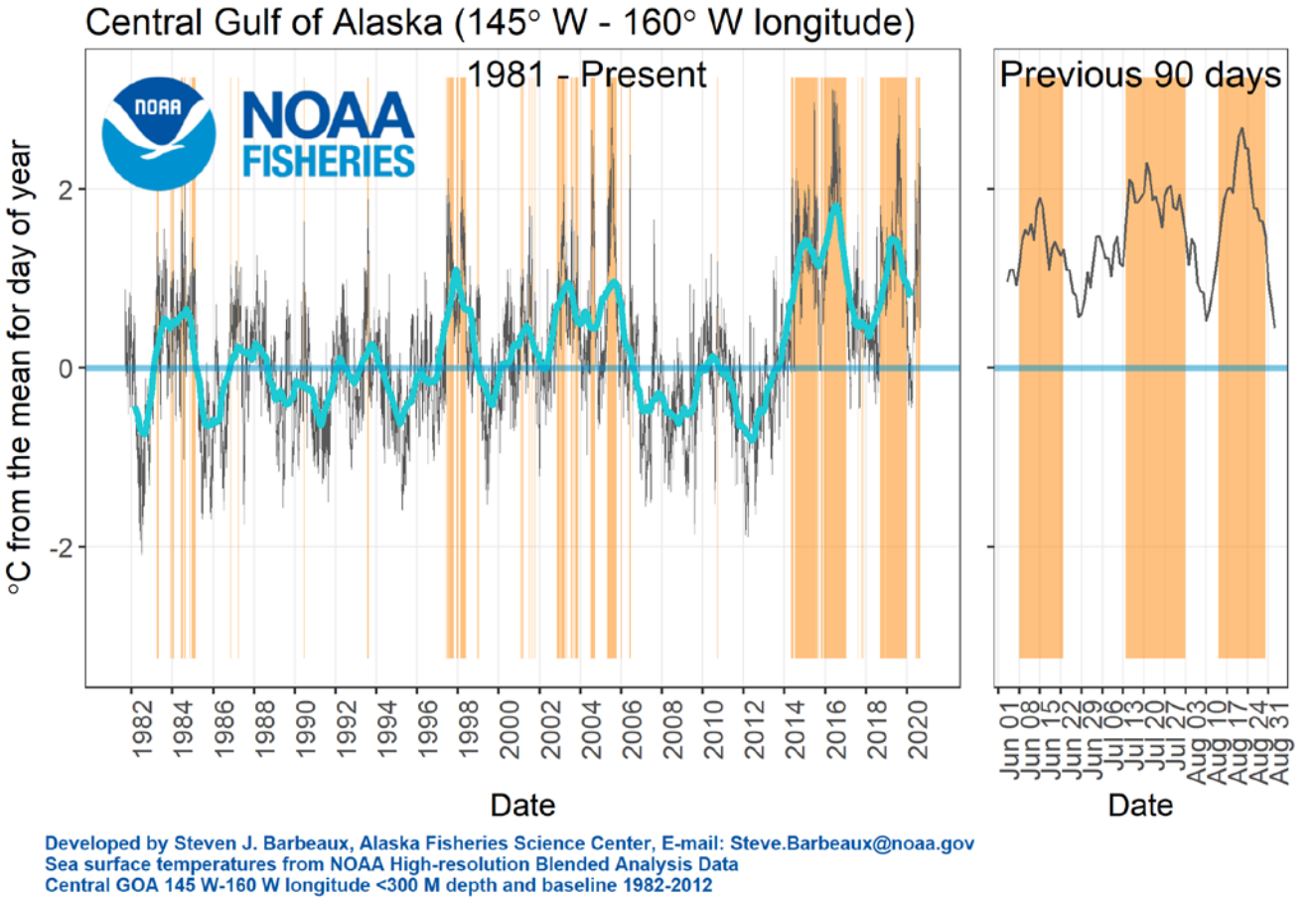


What’s happening now?

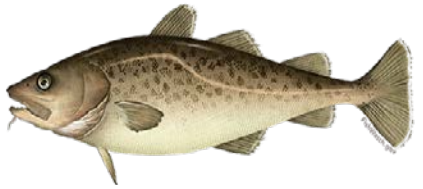
Anomalously warm waters continue in the Central GOA



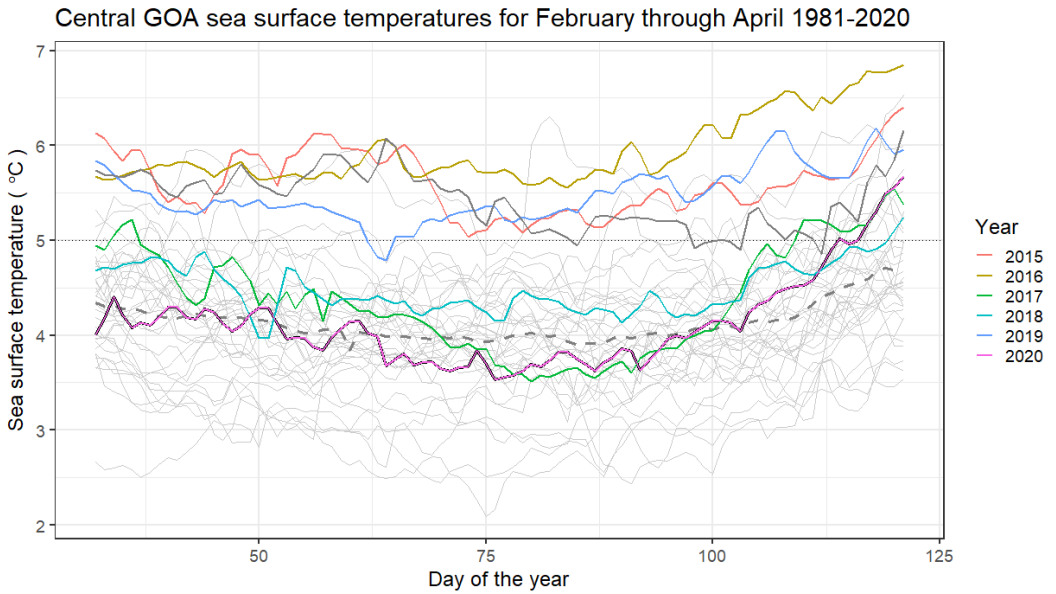
- Heatwaves have continued in the Central GOA since the ‘Blob’
- 17-18 cooler, but generally above the 82’-12’ mean
- 18’-19’ heatwave began September 10, 2018 and ended December 23, 2019
- Three marine heatwaves so far in 2020



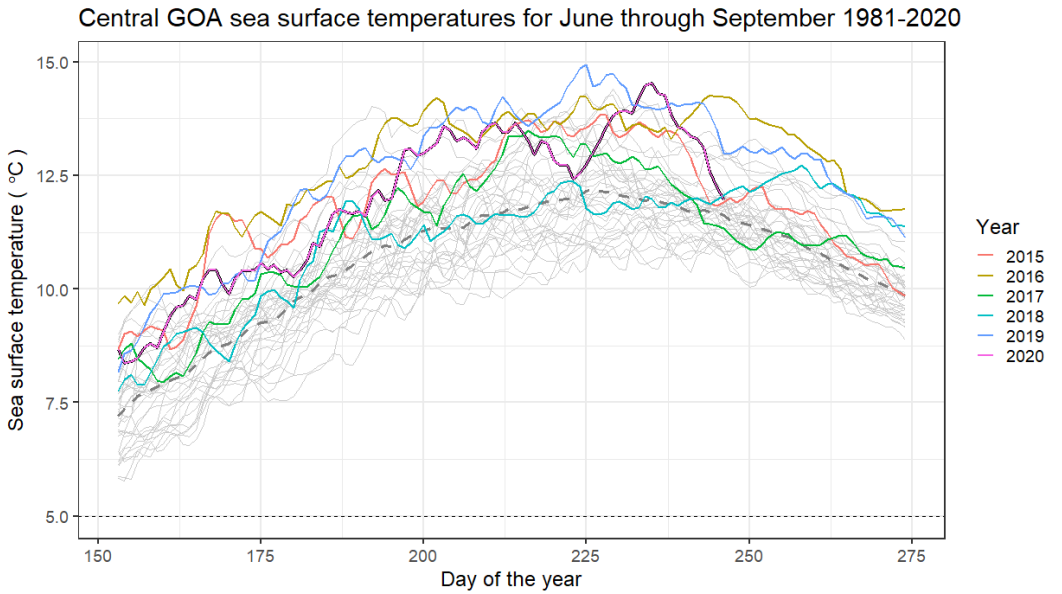
Anomalously warm waters continue in the Central GOA



- Early winter 2020 was cooler than average.



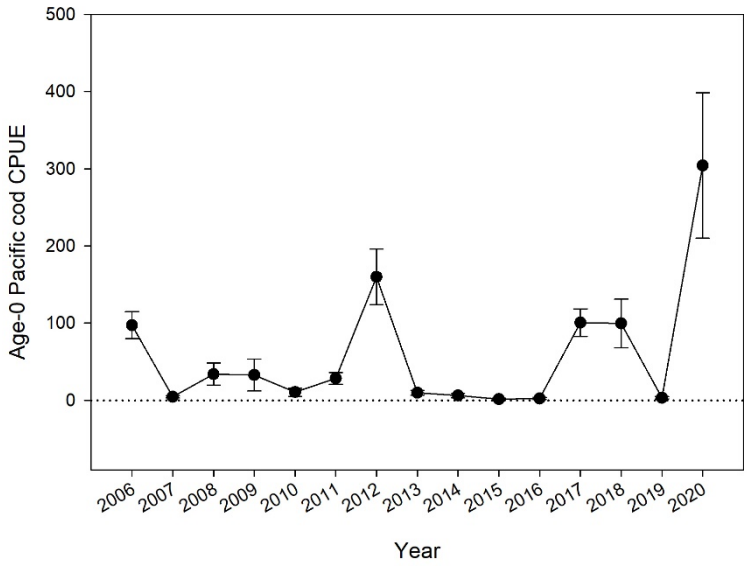
- Summer of 2020 surface temps were warmer than average with several smaller marine heatwaves.



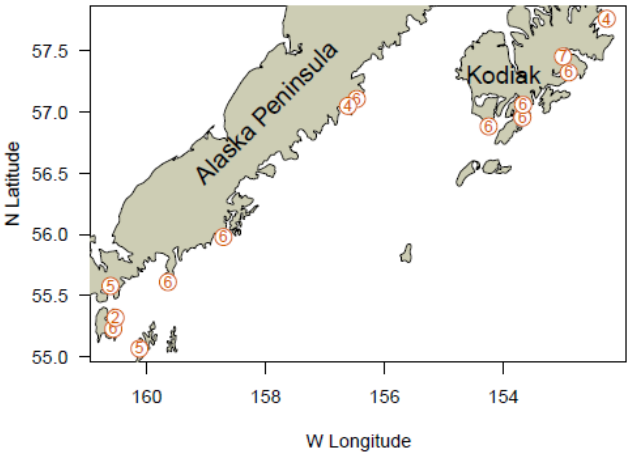
2020 Age-0 beach surveys

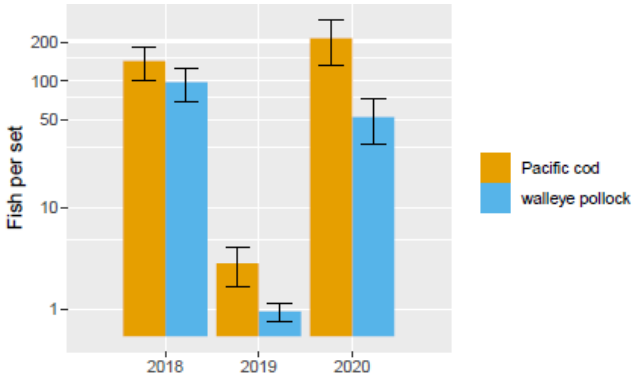
- Kodiak and wider Gulf of Alaska beach seine surveys saw increased abundance of age-0 Pacific cod.
- 2020 had the highest densities in both survey timelines

Ben Laurel Kodiak beach seine survey

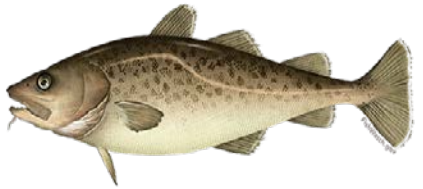


Alisa Abookire and Mike Litzow Kodiak and AK Peninsula beach seine survey

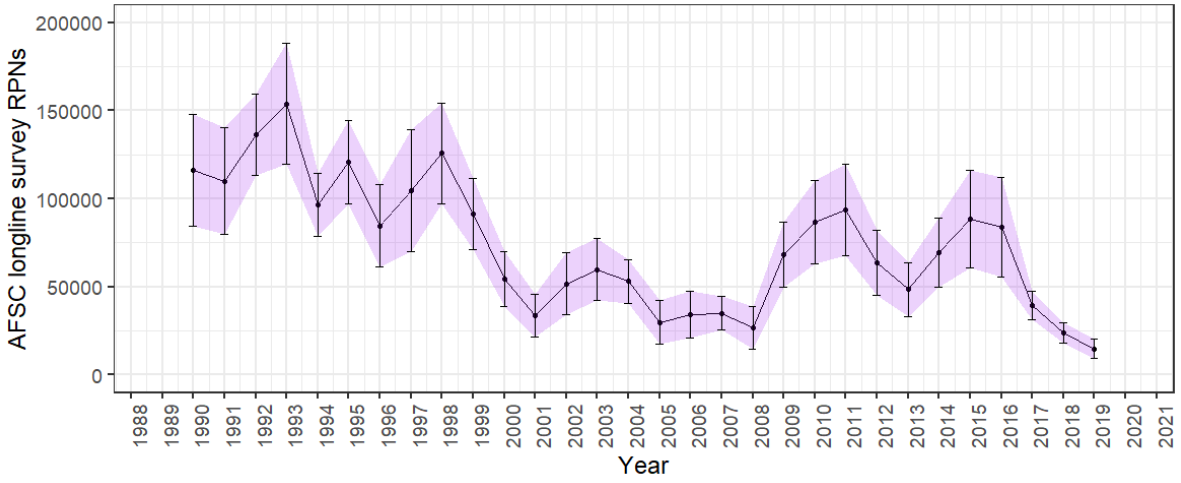


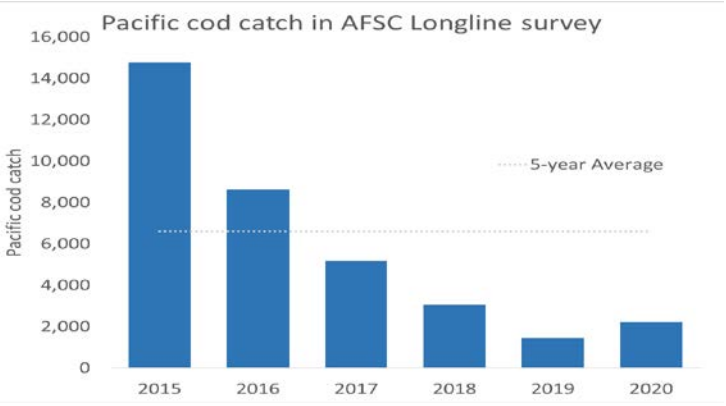


AFSC longline survey



- 2019 historic low (37% decrease from 2018)
- 2020 raw catch numbers higher than 2019, but still lower than 2018 (corrected for added hooks).
- With warm temperatures should have encountered more fish…

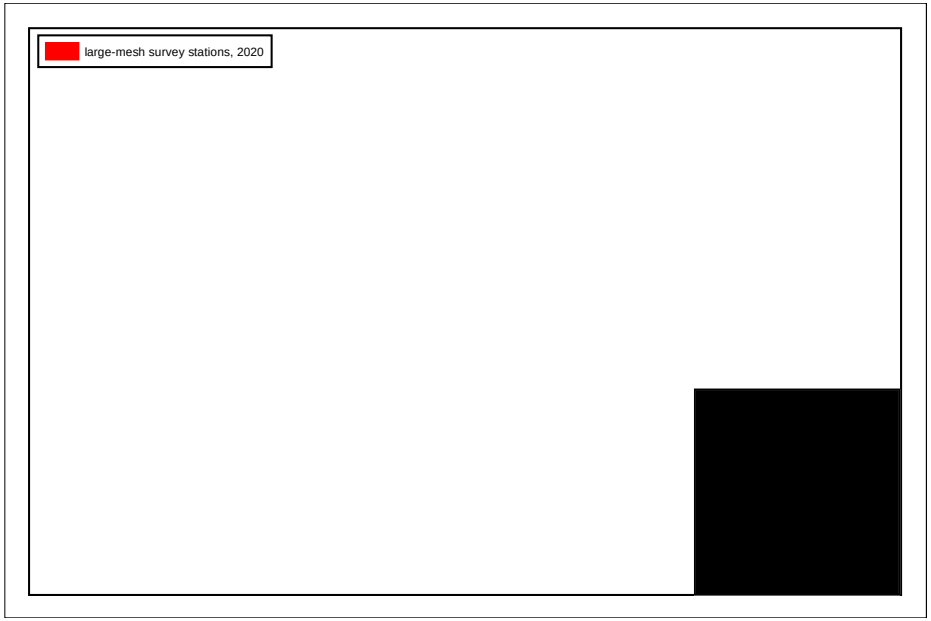




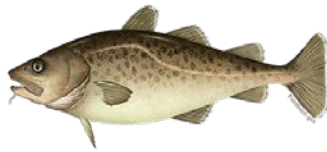
ADF&G Large-Mesh Trawl Survey

- 2020: 348 stations from Cape Douglas to False Pass
- R/V *Resolution*, 95 feet
- 400-Eastern otter trawl is towed for 1.0 nmi

- A subsample is taken to determine species composition
- Commercially-important species are measured

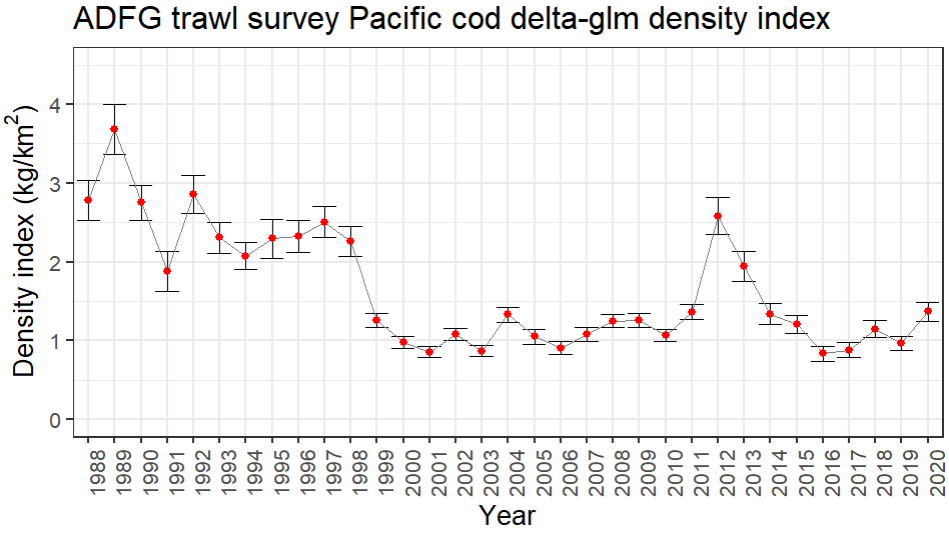


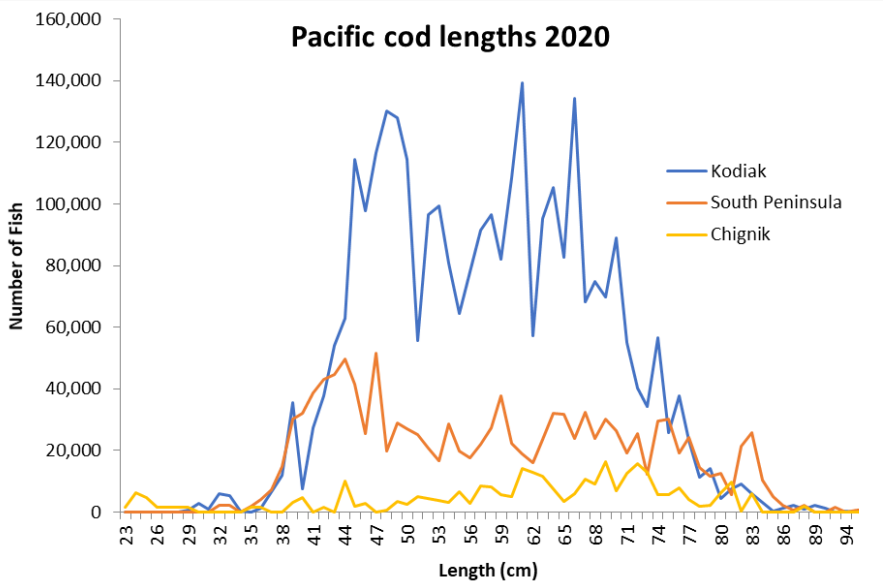
ADF&G Large-Mesh Trawl Survey

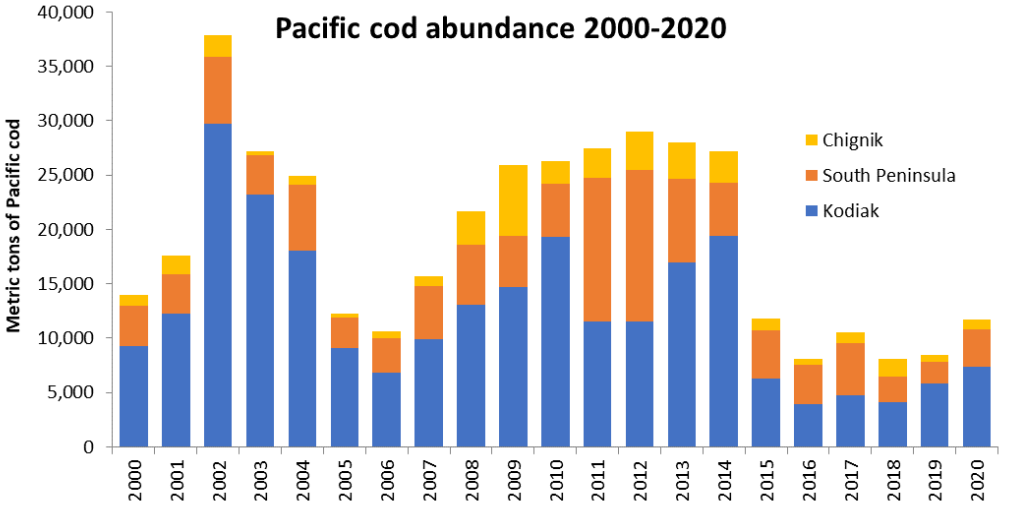


Preliminary Pacific cod results

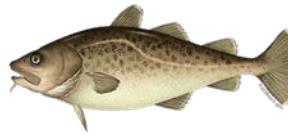
- 2020 P. cod CPUE and abundance remains low, but did show increases from 2019
- P. cod length distribution was similar across areas, and showed few cod smaller than 40 cm

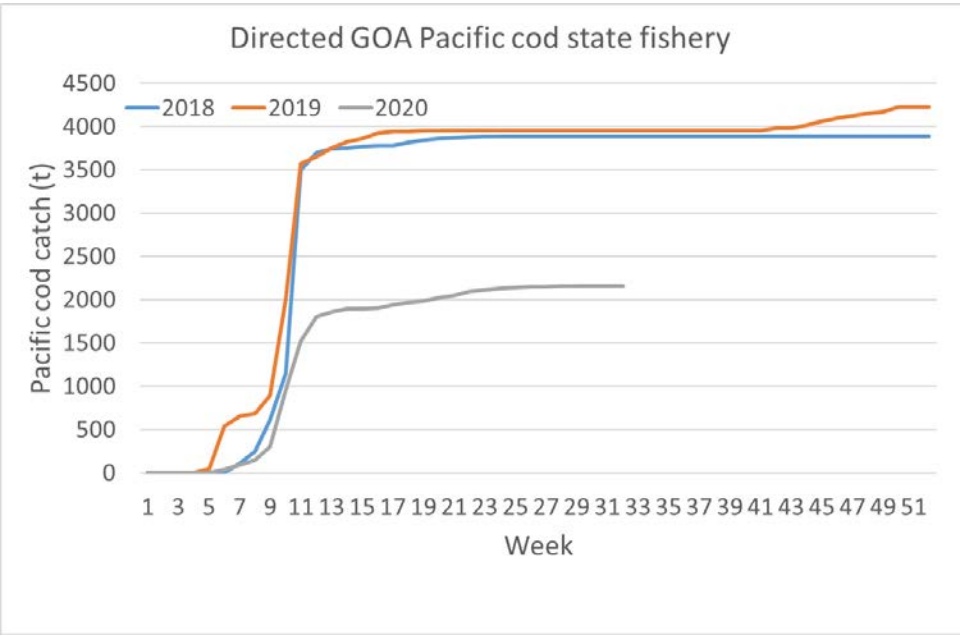


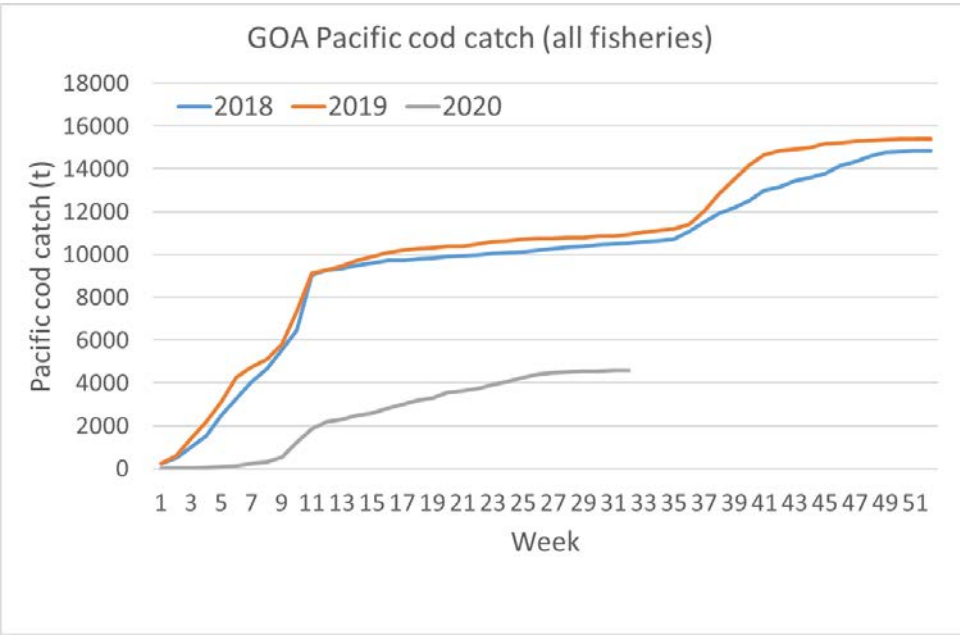




GOA Pacific cod catch

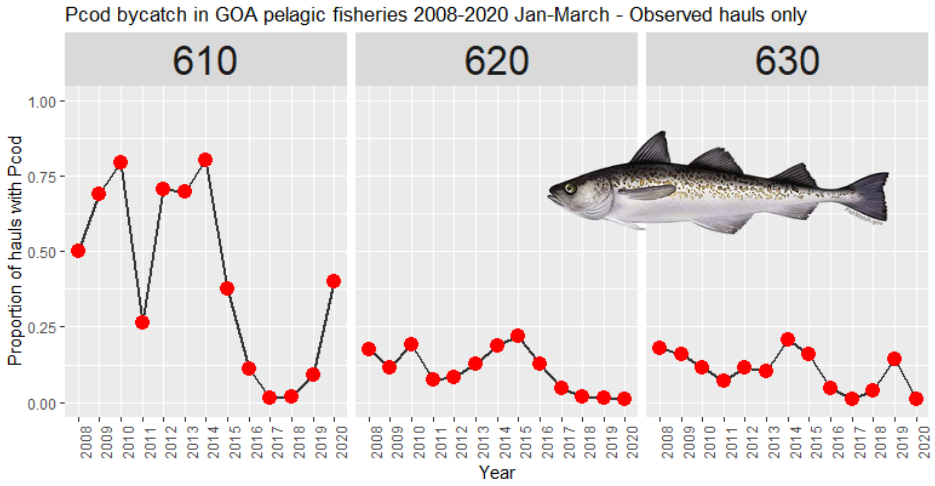




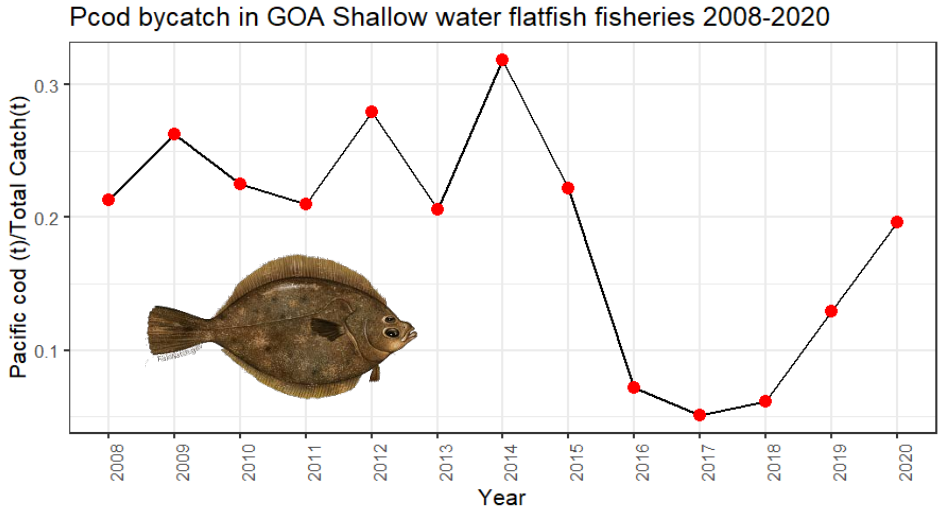


Bycatch rates in pollock and shallow-water flat fisheries

- Encounter rate in pelagic pollock fishery is a mixed signal depending on area
- Up in 610, down in 620 and 630

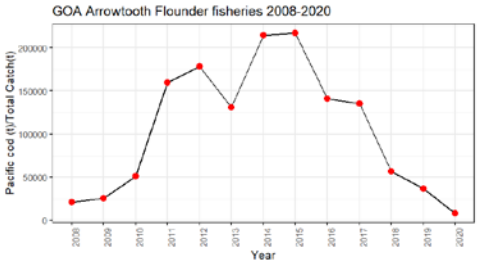


- Bycatch rate in shallow water flatfish fishery appears higher in 2020 compared to 2016 through 2019



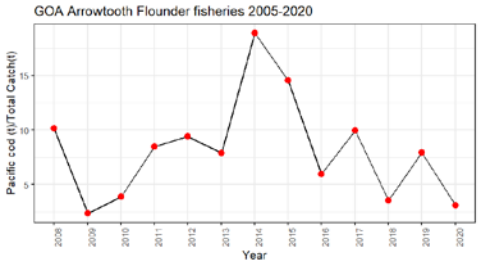
Bycatch rates in arrowtooth and rockfish fisheries

- Bycatch rate in GOA arrowtooth target fishery dropped in 2020.

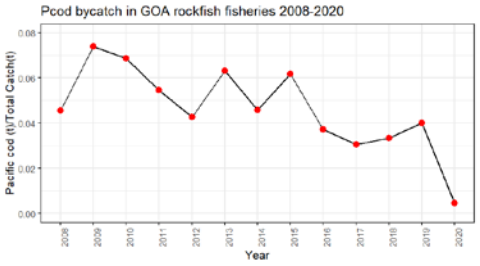


Observer Data

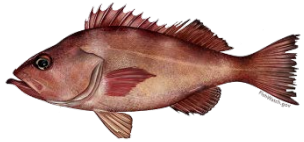
Catch Accounting



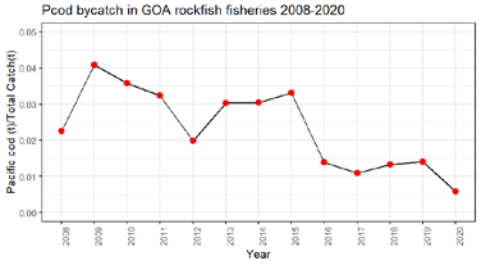
- 2020 bycatch rate in rockfish target fisheries lowest since 2008.



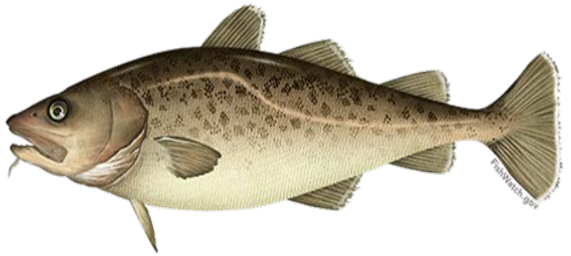
Observer Data



Catch Accounting



Questions?



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