1.B. Assessment of walleye pollock in the Bogoslof Island Region

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Executive Summary

Summary of Changes in Assessment Inputs

The 2020 acoustic-trawl survey conducted in February was included in the analysis along with age composition estimates. As in the 2018 assessment, natural mortality was re-evaluated given the additional age composition data from the survey and the fact that the stock has had only minor fishery catches (as bycatch in other directed fisheries) since 1992.

Summary of Results

The ABC and OFL levels using Tier 5 values and assuming the random-effects model:

Quantity	As estimated or specified last year for:		As estimated or recommended this year for:	
	2020	2021	2021	2022
M (natural mortality rate)	0.3	0.3	0.3	0.3
Tier	5	5	5	5
Biomass (t)	610,267	610,267	378,262	378,262
F_{OFL}	0.300	0.300	0.300	0.300
$maxF_{ABC}$	0.225	0.225	0.225	0.225
F_{ABC}	0.225	0.225	0.225	0.225
OFL (t)	183,080	183,080	113,479	113,479
maxABC (t)	137,310	137,310	85,109	85,109
ABC (t)	137,310	137,310	85,109	85,109
Status	As determined *this* year for:		As determined *this* year for:	
	2018	2019	2019	2020
Overfishing	No	n/a	No	n/a

Response to SSC and Plan Team comments

General and specific comments:

There were no comments pertaining to this Tier 5 assessment

Introduction

Alaska pollock (*Gadus chalcogrammus*) are broadly distributed throughout the North Pacific with largest concentrations found in the Eastern Bering Sea. The Bogoslof region is noted for having distinct spawning aggregations that appear to be independent from pollock spawning in nearby regions. The Bogoslof management district (INPFC area 518) was established in 1992 in response to fisheries and surveys conducted during the late 1980s, which consistently found a discrete aggregation of spawning pollock in this area during the winter. The degree to which this aggregation represents a unique, self-recruiting stock is unknown but the persistence of this aggregation suggests some spawning site fidelity that called for independent management. The Bogoslof region pollock has also been connected with the historical abundance of pollock found in the central Bering Sea (Donut Hole) due to concentrations of pollock that appeared to be moving toward this region prior to spawning (Smith 1981). For the purpose of management within the US zone, pollock from this region are managed separately.

Collectively, pollock found in the Donut Hole and in the Bogoslof region are by convention, considered to be part of the Aleutian Basin stock. Currently, based on an agreement from a Central Bering Sea convention meeting, it is assumed that 60% of the Aleutian Basin pollock population spawns in the Bogoslof region. The actual distribution of Aleutian Basin pollock is unknown and likely varies depending on environmental conditions and the age-structure of the stock. The Bogoslof component of the Aleutian Basin stock is one of three management stocks of pollock recognized in the BSAI region. The other stocks include pollock found in the large area of the Eastern Bering Sea shelf region and those in the Aleutian Islands near-shore region (i.e., less than 1000m depth; Barbeaux et al. 2004). The Aleutian Islands, Eastern Bering Sea and Aleutian Basin stocks probably intermingle, but the exchange rate and magnitude are unknown. The degree to which the Bogoslof spawning component contributes to subsequent recruitment to the Aleutian Basin stock also is unknown. From an early life-history perspective, the opportunities for survival of eggs and larvae from the Bogoslof region seem smaller than for other areas (e.g., north of Unimak Island on the shelf). There is a high degree of synchronicity among strong year-classes from these three areas, which suggests either that the spawning source contributing to recruitment is shared or that conditions favorable for survival are shared. From a biological perspective, the degree to which these management units are reasonable definitions depends on the active exchange among these stocks. If they are biologically distinct and have different levels of productivity, then management should be adjusted accordingly. Bailey et al. (1999) present a thorough review of population structure of pollock throughout the north Pacific region. They note that adjacent stocks were not genetically distinct but that differentiation between samples collected on either side of the N. Pacific was evident.

Some characteristics distinguish Bogoslof region pollock from other areas. Growth rates appear different (based on mean-lengths at age) and pollock sampled in the Bogoslof Island survey tend to be much older. For example, the average percentage (by numbers of fish older than age 6) of age 15 and older pollock observed from the Bogoslof AT surveys (1988-2012) is 18%; in the EBS region (from model estimates), the average from this period is only 2%. The pollock found in winter surveys are generally older than age 4 and are considered distinct from eastern Bering Sea pollock. Further study on stock structure (relating age compositions in adjacent regions) should help understand this possibility. Although data on the age structure of Bogoslof pollock show that a majority of pollock originated from year classes that were also strong on the shelf, 1972, 1978, 1982, 1984, 1989, 1992, 1996, 2000, and 2006. A more recent pattern appears to be that the year-classes differ slightly. There are strong year classes appearing on the shelf that may not be occurring the Bogoslof region. For example, the 2008 year-class in the EBS was not abundant in the Bogoslof region yet there seems to be a strong 2009 year-class in the Bogoslof region. This may be due to age-determination discrepancies or that spawning and subsequent survival rates are diverging. Indications suggest that the 2012 year-class appeared in this survey (4 year-olds in 2016) and were also observed in the EBS shelf region.

Fishery

Prior to 1977, few pollock were caught in the Donut Hole or Bogoslof region (Low and Ikeda 1978). Japanese scientists first reported significant quantities of pollock in the Aleutian Basin in the mid-to-late 1970's, but large-scale fisheries in the Donut Hole only began in the mid-1980's. By 1987 significant components of these catches were attributed to the Bogoslof Island region (Table 1B.1); however, the actual locations were poorly documented. The Bogoslof fishery primarily targeted winter spawning-aggregations but in 1992, this area was closed to directed pollock fishing.

In 1991, the only year with extensive observer data, the fishery timing coincided with the open seasons for the EBS and Aleutian Islands pollock fisheries (the Bogoslof management district was established in 1992 by FMP amendment 17). However, after March 23, 1991 the EBS region was closed to fishing and some effort was re-directed to the Aleutian Islands region near the Bogoslof district. In subsequent years, seasons for the Aleutian Islands pollock fishery were managed separately. Bycatch and discard levels were relatively low from these areas when there was a directed fishery (e.g., 1991). Updated estimates of pollock bycatch levels from other fisheries has varied with a high of over 1,000 t in 2016 (Table 1B.2). The majority of pollock bycatch in the Bogoslof region continues to be occurring in the non-pelagic trawl arrowtooth flounder target fishery. Catches have dropped to below 200 t in the last two years. The history of management measures since 1992 is provided in Table 1B.3.

Data

Survey

NMFS acoustic-trawl (AT) survey biomass estimates are the primary data source used in this assessment and are conducted in February and March time frames. Since 2000, the values have varied between a low 67,000 t to a high of over 600 kt estimated in 2018. This year's AT survey estimate was 345 kt, a 48% decrease from the 2018 estimate (Table 1B.4). The area covered by surveys 2016, 2018, and 2020 including tow locations, and relative pollock densities are depicted in Fig. 1B.1. The time series of age composition data from this survey is provided in Tables 1B.5.

Analytical approach

Model Structure

Survey biomass averaging

The model for harvest recommendations was based on using a Tier-5 approach which requires survey estimates of biomass (B_t). In Ianelli et al. (2015) the SSC accepted application of a random effects model of the form:

$$B_t = B_{t-1} e^{\epsilon_t} \qquad \epsilon_t \sim N\left(0, \sigma_{\epsilon}^2\right)$$

with process errors ϵ_t estimated as random effects and σ_{ϵ}^2 also estimated with the observations and errors from Table 1B.3 included in the likelihood. The model was fit using ADMB (Fournier et al. 2012). This model provides alternative estimates of survey biomass in 2016 which weights the relative influence of past survey estimates between process error variances and that specified as observation errors.

Age structured assessment

To follow-up on the approach developed by Ianelli et al. (2015), a re-evaluation of natural mortality was conducted.

Parameter estimates

The fits to the random-effects model results in a 2021 biomass estimate of 378,262 t (Fig. 1B.2).

Applying the age-structured assessment model fit the survey biomass estimates reasonably well except for the period from 2009-2014 (Fig. 1B.3). Fits to the age composition also showed some inconsistencies (e.g., over-estimating the 8-year old pollock and under-estimating the 2010 and 2009 year-classes in 2020; Fig. 1.B4).

In the 2015 assessment (Ianelli et al. 2015) the estimate of natural mortality was re-evaluated and the value of 0.3 was determined to be a reasonable estimate for this stock given the time series of survey age composition data. Using the same approach in 2018 and again this year with updated age data confirms this based on the posterior distribution of natural mortality (Fig. 1B.5)

Results

The random-effects method of survey averaging resulted in 378,262 t (Fig. 1B.2). As an alternative method, the three-survey average approach gives an estimate of 505,261 t from which to make the Tier 5 calculations. Regarding the age-structured model evaluation of natural mortality, the evidence suggests that a value of 0.3 is with the data should be considered as an alternative for use in the Tier 5 calculation. All options are presented in the Harvest Recommendations section below.

Harvest Recommendations

Maximum permissible ABC and OFL estimates for 2021 and 2022 under Tier 5 relies exclusively on the NMFS biennial acoustic trawl survey biomass estimate. Biomass was based on two survey averaging approaches: simple 3-survey mean and a mean estimated from a random-effects model gives:

Description	M	Biomass	ABC	OFL
Random-effects survey average	0.3	378,262	85,109	113,479
3-survey average	0.3	505,261	151,578	113,684

For consistency with past approaches, the maximum permissible ABC is based on the random effects survey average biomass and the natural mortality as estimated in 2020. This results in a maximum permissible Tier 5 ABC of 85,109 t for 2021 and 2022 and an OFL of 113,479 t. Given there have been two recent surveys that indicate a relatively high biomass, this seems appropriate for the current stock estimates.

Risk table summary
NOTE: this section was added during the Plan Team meetings.

This stock is managed under Tier 5 and depends on acoustic-trawl surveys that have been conducted regularly over a long period. With respect to the columns related to the assessment, two approaches have been applied as cross checks (i.e., a Tier 3-like age-structured assessment to estimate natural mortality along with the Tier 5 method). The data and information are well fit and seem consistent over time so the assessment side warrants a level 1—no concern. Regarding the population dynamics, stock structure uncertainty remains an issue but genetic studies are underway which should help resolve this outstanding issue. We also chose a level 1—no concern.

With respect to the ecosystem column, pollock in this area (Southern Bering Sea survey area) are generally found between 3.7 and 5.2°C in the AI survey, while in 2016 they were found in waters up to 6.5°C. GODAS temperature anomalies for the 100-250m depth range show that significantly warmer temperatures have remained since 2016; the GODAS estimates are supported by the water column temperatures indicator for the AI (AI ESR Physical factors 2020). In general, higher ambient temperatures incur bioenergetic costs for ectothermic fish such that, all else being equal, consumption must increase to maintain fish condition. Thus, the persistent higher temperatures may be considered a negative indicator for pollock, although not as strongly as for other species, such as Pacific cod and arrowtooth flounder which fared poorly during the extended heatwave of 2014-2016 in the Gulf of Alaska. The higher temperatures increasing consumption demands beyond what is available, along with higher competition and increasing biomass of POP and Kamchatka pink salmon, may jointly explain why the observed body condition for pollock >25 cm has been lower than the survey mean since 2012 in the southern Bering Sea region of the AFSC bottom trawl survey (Fish Condition, AI ESR). Due to lack of 2020 surveys, fish condition and diet indicators were not measured this year. Sea surface temperatures are forecast to be near normal to slightly above normal in the AI this coming winter.

Although we don't have direct abundance estimates of copepods, which comprise 53% of juvenile (<20cm) pollock diet, along with euphausiids and pelagic gelatinous filter feeders, we can infer that this year copepods experienced lower predation pressure based on the biannual cycle and record abundance of Kamchatka pink salmon during 2019. The biannual cycle and cascading effects of pink salmon predation on copepods has been documented before by Springer 2014, Batten et al 2018 and in the width of Atka mackerel otolith growth (Matta et al 2020). Competition for copepods does not seem to drive abundance of pollock however, as time-series of either young ages or total population in this region do not show alternate years of high numbers of fish. Other inferences we can make about zooplankton prey availability are from the Continuous Plankton Recorder (CPR) sampling, for which the most recent data are from 2019. Data from CPRs that sample near the Aleutian chain show anomalously small copepod taxa from 2016-2018, but larger in 2019, which may indicate a recent increase in the quality of zooplankton prey available to pollock.

Both Pacific ocean perch (particularly juvenile <20 cm), Kamchatka pink salmon, and Atka mackerel are primary consumers of copepods, with the first two showing biannual signals in their abundance. Diets of large (>20 cm) pollock in the southern Bering Sea survey area are composed of 44% euphausiids, 17% myctophids and 11% copepods. In contrast, small pollock (<20 cm) from this area consume 42% copepods and 27% euphausiids as primary prey, making juvenile pollock more susceptible to prey competition for copepods. The increased consumption of copepods by the increasing POP population and high abundance years of Kamchatka pink salmon might be limiting the availability of prey for small pollock through competitive pressure. Some fishery-related evidence might be the increased bycatch of pollock on rockfish fisheries. Walleye pollock are a key prey for Steller sea lions in the eastern AI and northern fur seals at Bogoslof, along with Pacific cod, arrowtooth flounder, and Pacific Halibut (AFSC Groundfish Food Habits database). Recent data suggest that Steller sea lion populations have continued to decline in the Aleutians (AI ESR), suggesting that their predatory impact on pollock has not increased. However, Northern fur seals at Bogoslof and Pacific cod have been consistently increasing after a steady decline from 2000 to 2012; over half the biomass of AI Pacific cod is estimated to be in the eastern Aleutians. Arrowtooth flounder biomass peaked in 2006 and has been decreasing since, as has Pacific halibut since 1997 based on AI survey biomass estimates. Taken together, these indicators suggest that the current level of concern is level 1—no apparent environmental/ecosystem concerns. However, continued trends in poor fish condition as well as the potential for competition with the expanding Pacific Ocean perch stock may warrant further exploration when more data are available.

Finally, under "fishery performance" there is no concern since this directed fishery has been closed since 1992.

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Tables

Table 1B.1 Catch in tons from the Donut Hole and the Bogoslof Island area, 1977-2020.

Year	Donut Hole (t)	Bogoslof Island (t)	Total (t)
1977		11,500	11,500
1978		9,600	9,600
1979		16,100	16,100
1980		13,100	13,100
1981		22,600	22,600
1982		14,700	14,700
1983		21,500	21,500
1984	181,200	22,900	204,100
1985	363,400	13,700	377,100
1986	1,039,800	34,600	1,074,400
1987	1,326,300	377,436	1,703,736
1988	1,395,900	87,813	1,483,713
1989	1,447,600	36,073	1,483,673
1990	917,400	151,672	1,069,072
1991	293,400	316,038	609,438
1992	10,000	241	10,241
1993	1,957	886	2,843
1994		556	556
1995		334	334
1996		499	499
1997		163	163
1998		8	8
1999		29	29
2000		29	29
2001		258	258
2002		1,042	1,042
2003		24	24
2004		<1	<1
2005		<1	<1
2006		<1	<1
2007		<1	<1
2008		9	9
2009		73	73
2010		176	176
2011		173	173
2012		79	79
2013		57	57
2014		428	428
2015		733	733
2016		1,005	1,005
2017		186	186
2018		133	133
2019		8	8
2020		8	8

Table 1B.2. Estimated retained, discarded, and total pollock catch (t) from the Bogoslof region. Source: NMFS Regional office Blend database and catch accounting system.

Year	Discarded	Retained	Total
1991	20,327	295,711	316,038
1992	240	1	241
1993	308	578	886
1994	11	545	556
1995	267	66	334
1996	7	492	499
1997	13	150	163
1998	3	5	8
1999	11	18	29
2000	20	10	29
2001	28	231	258
2002	12	1,031	1,042
2003	19	5	24
2004	< 1		< 1
2005	< 1	< 1	< 1
2006	< 1	< 1	< 1
2007	< 1	< 1	< 1
2008	< 1	9	9
2009	6	67	73
2010	53	124	176
2011	23	150	173
2012	5	74	79
2013	< 1	56	57
2014	54	374	428
2015	138	595	733
2016	7	997	1,005
2017	2	184	186
2018	2	131	133
2019	0	8	8
2020	2	6	8

Table 1B.3. ABC, OFL, and TAC by year for Bogoslof region pollock, 1992—2020.

Year	ABC	OFL	TAC	Catch
1992	25,000	25,000	1,000	241
1993	42,000	42,000	1,000	886
1994	31,750	31,750	1,000	556
1995	22,100	22,100	1,000	334
1996	121,000	121,000	1,000	499
1997	32,100	43,800	1,000	163
1998	6,410	8,750	1,000	8
1999	15,300	21,000	1,000	29
2000	22,300	30,400	1,000	29
2001	8,470	60,200	1,000	258
2002	4,310	46,400	100	1,042
2003	4,070	45,300	50	24
2004	2,570	39,600	50	0
2005	2,570	39,600	10	0
2006	5,500	50,600	10	0
2007	5,220	48,000	10	0
2008	7,970	58,400	10	9
2009	7,970	58,400	50	73
2010	156	22,000	50	176
2011	156	22,000	150	173
2012	16,500	22,000	500	71
2013	10,100	13,400	100	57
2014	10,059	13,413	75	427
2015	15,900	21,200	100	733
2016	23,850	31,906	500	1,005
2017	60,800	130,428	500	185
2018	60,800	130,428	450	14
2019	137,310	183,080	75	8
2020	137,310	183,080	75	8

Table 1B.4. Biomass (tons) of pollock as surveyed in the Bogoslof region, 1988-2020. For additional details see McKelvey and Levine (In review).

Year	Survey biomass estimates (t)	Survey area (nmi^2)	Relative error
1988	2,395,737	NA	22%
1989	2,125,851	NA	22%
1990			No survey
1991	1,289,006	8,411	12%
1992	940,198	8,794	20%
1993	635,405	7,743	9%
1994	490,077	6,412	12%
1995	1,104,118	7,781	11%
1996	682,277	7,898	20%
1997	392,402	8,321	14%
1998	492,396	8,796	19%
1999	475,311	NA	22%
2000	301,390	7,863	14%
2001	232,170	5,573	10%
2002	225,712	2,903	12%
2003	197,851	2,993	22%
2004			No survey
2005	253,459	3,112	17%
2006	240,059	1,803	12%
2007	291,580	1,871	12%
2008			No survey
2009	110,191	1,803	19%
2010			No survey
2011			No survey
2012	67,063	3,656	10%
2013			No survey
2014	112,070	1,150	12%
2015			No survey
2016	508,051	1,400	11%
2017			No survey
2018	663,070	1,500	43%
2019			No survey
2020	344,663	1,455	16%

Table 1B.5. Estimated survey numbers at age (millions) from the acoustic-trawl surveys used in the age-structured model for Bogoslof pollock (from McKelvey and Levine, in review).

	Age											
Year	4	5	6	7	8	9	10	11	12	13	14	15
1988	-	27.94	326.71	246.84	163.68	350.07	1,200.88	287.82	287.33	201.95	89.24	53.89
1989	6.00	15.00	58.00	363.00	147.00	194.00	91.00	1,105.00	222.00	223.00	82.00	180.00
1991	2.00	12.00	46.00	213.00	93.00	160.00	44.00	92.00	60.00	373.00	119.00	202.00
1992	2.00	27.00	54.00	97.00	74.00	71.00	55.00	57.00	33.00	34.00	142.00	327.00
1993	33.00	17.00	44.00	46.00	48.00	42.00	28.00	51.00	25.00	27.00	42.00	209.00
1994	21.00	86.00	26.00	38.00	36.00	36.00	17.00	27.00	23.00	13.00	9.00	146.00
1995	6.00	75.00	278.00	105.00	68.00	80.00	53.00	54.00	19.00	59.00	32.00	248.00
1996	0.50	6.00	96.00	187.00	85.00	40.00	37.00	24.00	24.00	12.00	36.00	117.00
1997	0.50	4.00	16.00	55.00	88.00	38.00	28.00	16.00	16.00	13.00	7.00	57.00
1998	0.50	11.00	61.00	34.00	70.00	77.00	32.00	25.00	21.00	19.00	18.00	67.00
1999	2.00	5.00	29.00	77.00	34.00	50.00	75.00	29.00	27.00	25.00	16.00	48.00
2000	1.00	6.00	4.00	14.00	30.00	16.00	28.00	45.00	21.00	16.00	11.00	36.00
2001	1.00	14.00	12.00	10.00	10.00	14.00	12.00	18.00	31.00	13.00	7.00	27.00
2002	5.00	3.00	41.00	11.00	8.00	6.00	7.00	8.00	14.00	30.00	9.00	29.00
2003	8.00	6.00	7.00	25.00	11.00	4.00	5.00	4.00	10.00	8.00	26.00	21.00
2005	5.00	81.00	31.00	13.00	11.00	22.00	7.00	3.00	5.00	4.00	5.00	37.00
2006	4.00	55.00	104.00	18.00	6.00	6.00	9.00	3.00	2.00	4.00	5.00	25.00
2007	1.00	8.00	92.00	70.00	17.00	3.00	3.00	8.00	4.00	1.00	5.00	24.00
2009	-	1.00	1.00	7.00	23.00	26.00	8.00	1.00	1.00	1.00	0.44	4.78
2012	0.14	1.38	14.96	9.65	2.24	0.89	2.36	6.74	7.85	1.12	0.20	1.06
2014	1.00	34.00	31.00	11.00	14.00	7.00	3.00	0.50	1.00	5.00	4.00	2.5
2016	170.25	40.69	161.41	366.88	98.69	16.84	9.30	1.03	0.00	0.00	0.00	0.00
2018	0.00	58.93	152.37	80.74	381.08	247.39	27.42	13.77	2.67	0.00	0.00	0.00
2020	3.11	0.44	4.39	22.62	27.90	54.77	104.08	95.58	21.46	5.00	0.27	0.00

Figures

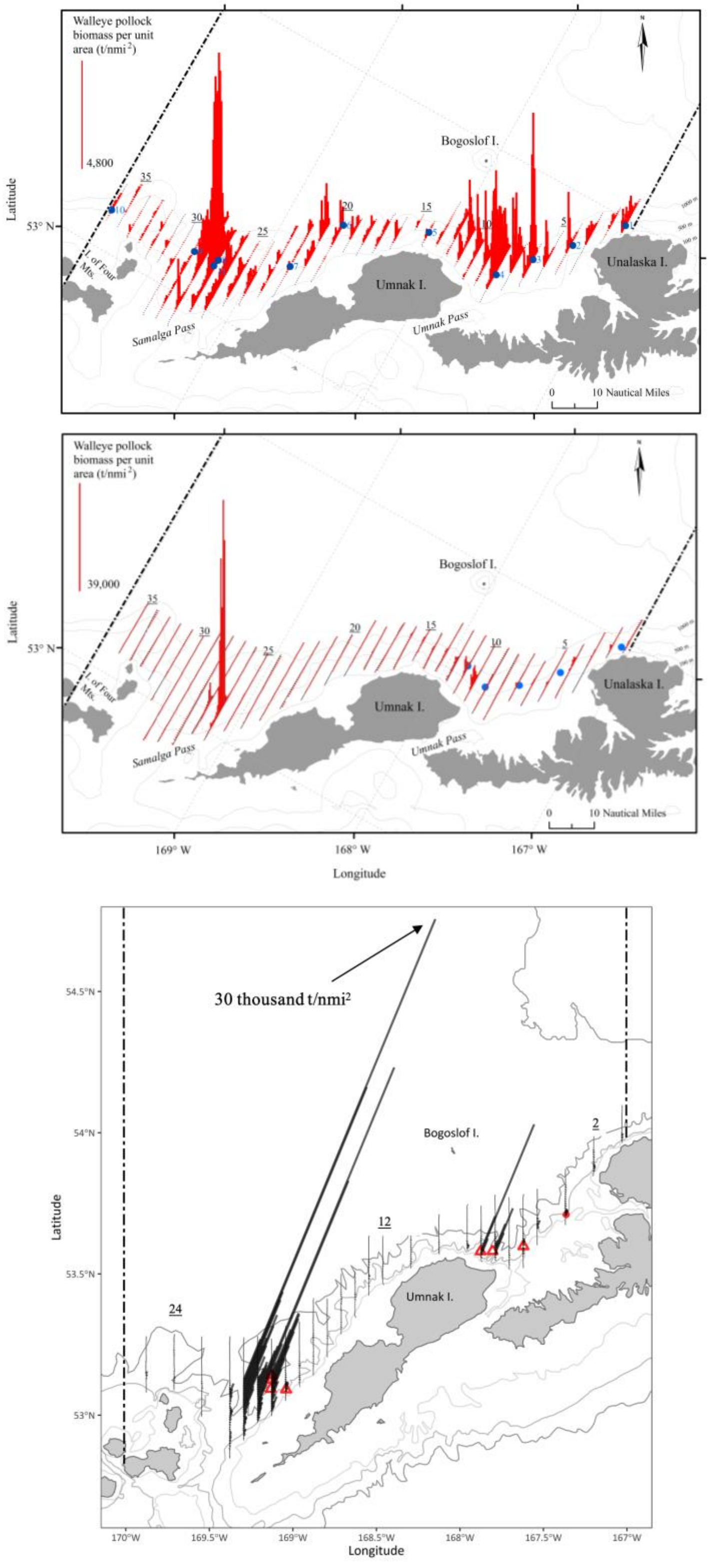


Figure 1B.1. Distribution of pollock biomass (t/nmi^2) observed along transects during the winter 2016 (top), 2018 (middle), and 2020 (bottom) acoustic-trawl survey. Transect numbers are underlined; trawl haul locations are indicated by circles or triangles.

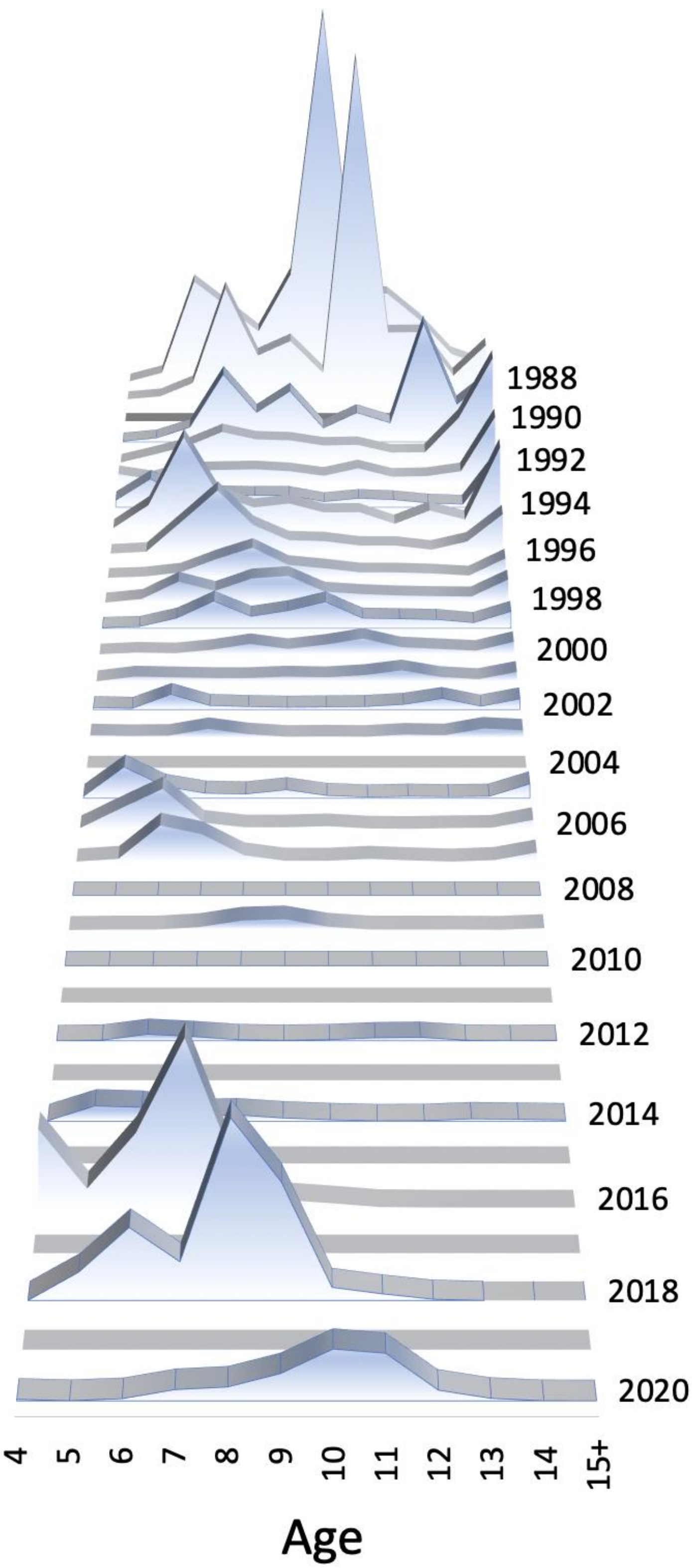


Figure 1B.2. Age composition estimates (numbers) during the winter surveys for Bogoslof region pollock, 1988-2020.

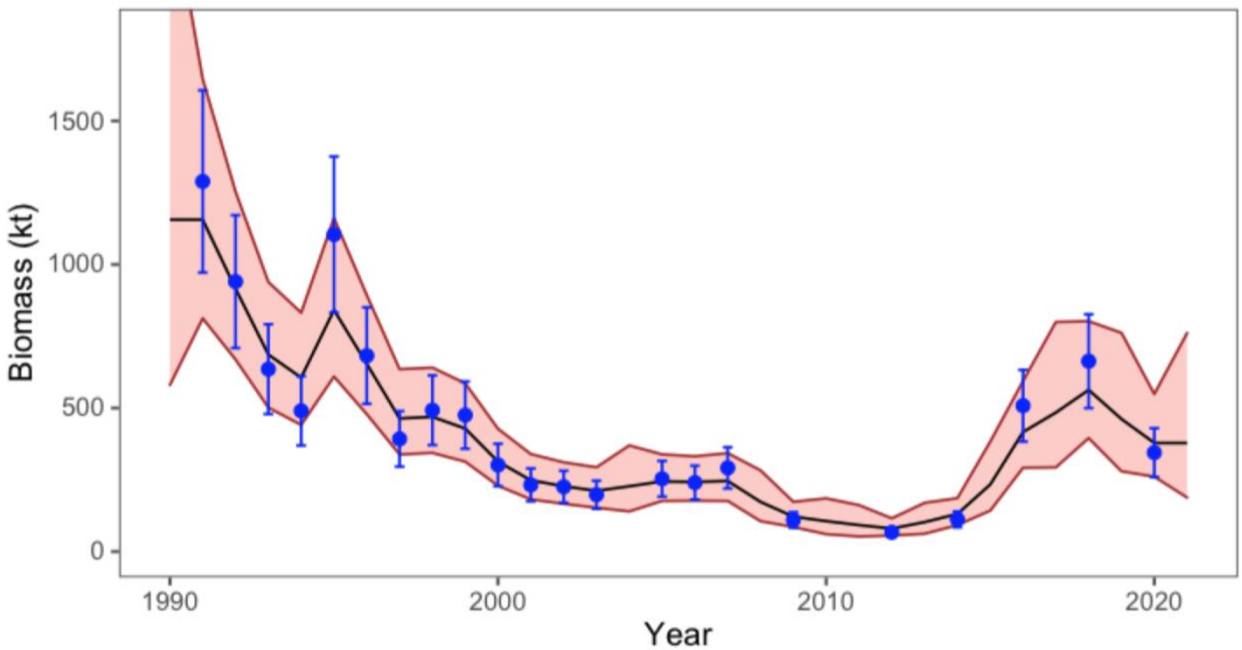


Figure 1B.3. Bogoslof Island pollock survey estimates fit to a process error model for averaging biomass. The shade represents the approximate 90% confidence interval from the model.

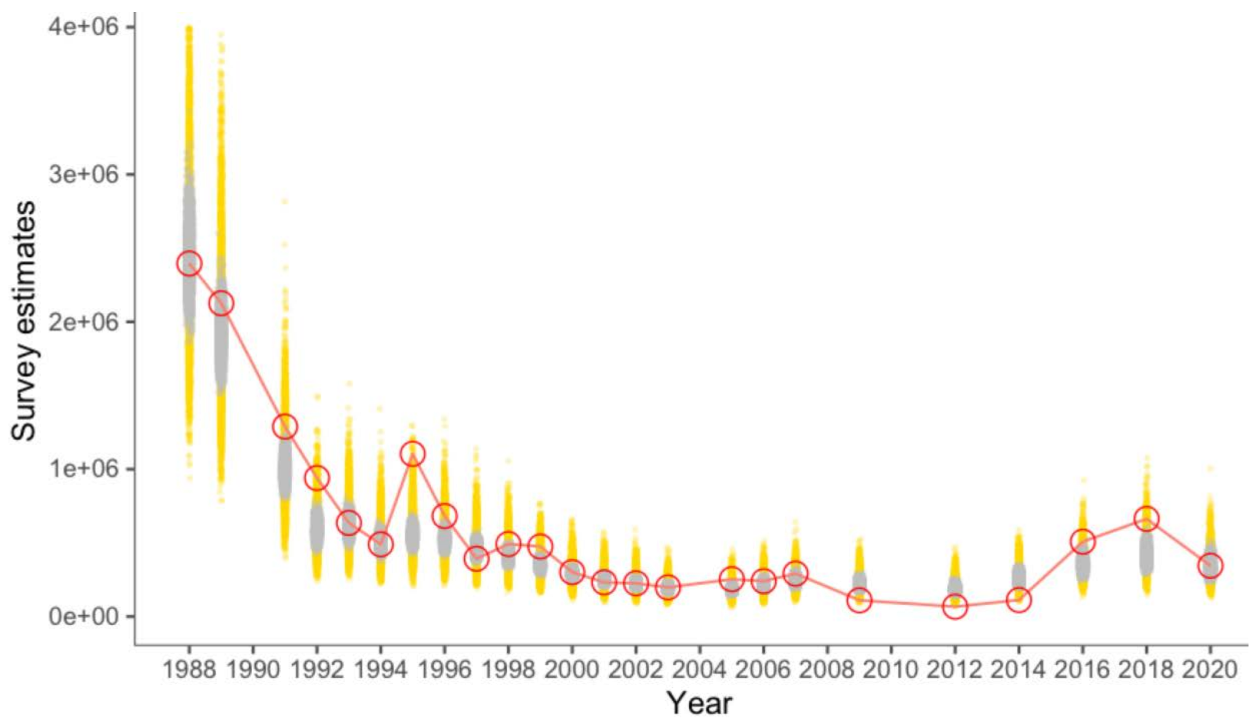


Figure 1B.3. Pollock age-structured model fit to Bogoslof region acoustic-trawl survey biomass estimates, 1988-2020. Open circles and line represents survey point estimates, grey dots represent the posterior mean, and yellow dots represents the posterior predictive values.

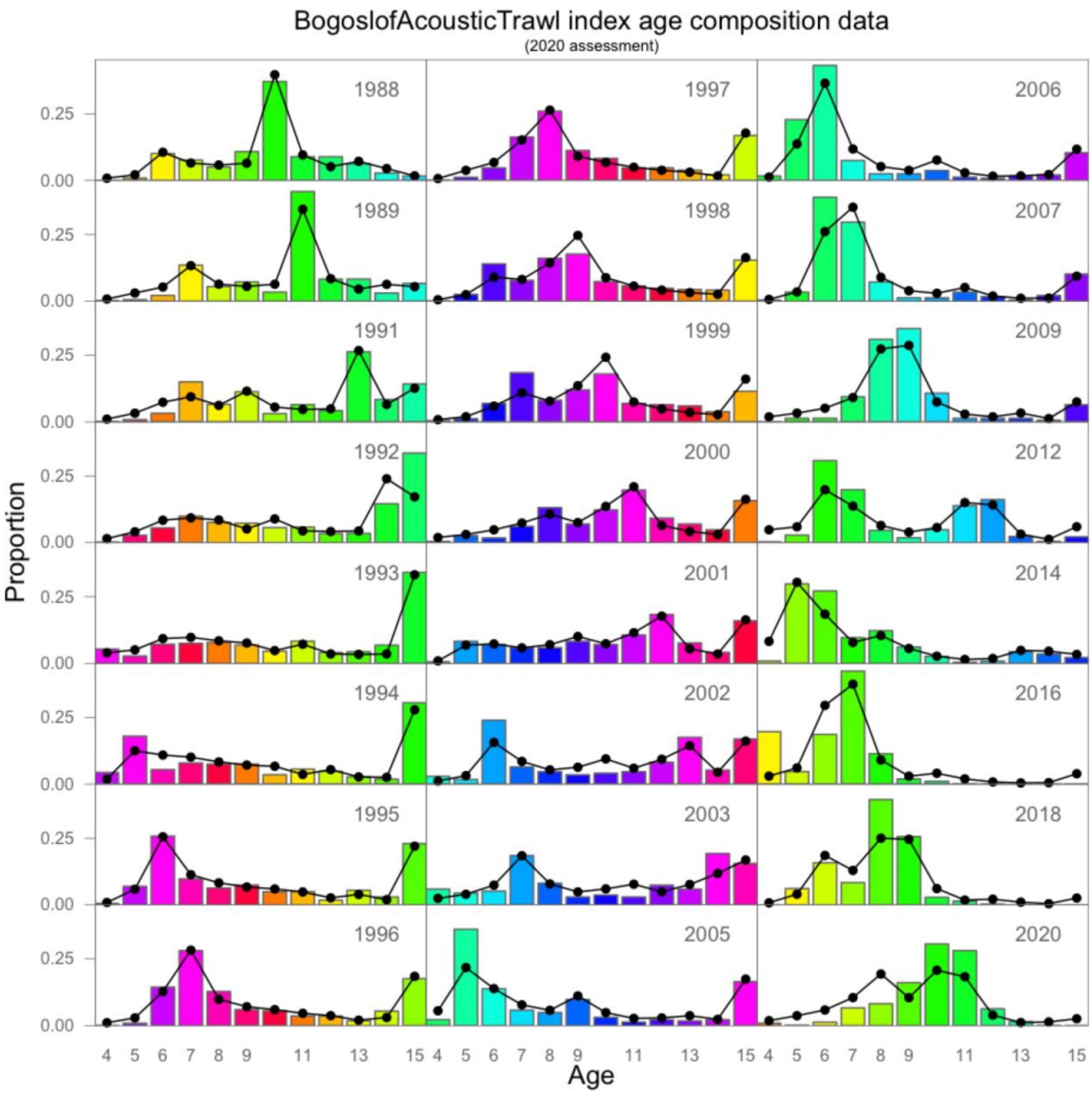


Figure 1B.4. Pollock age-structured model fit to the Bogoslof region acoustic-trawl survey age composition estimates, 1988-2020.

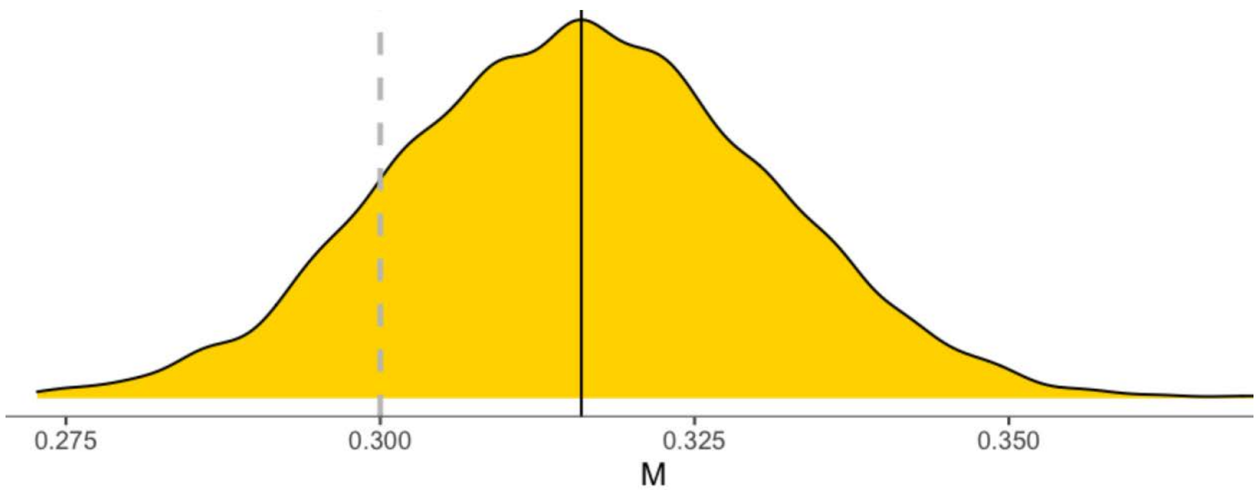
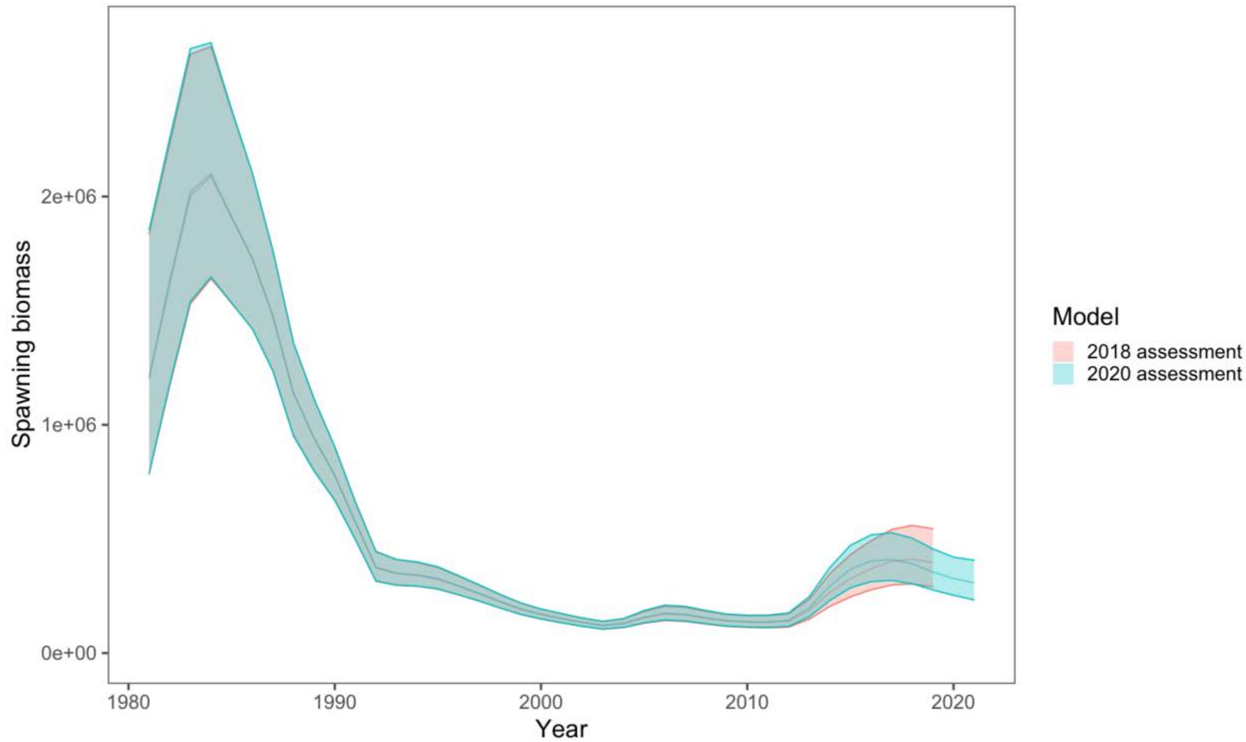


Figure 1B.5. Pollock age-structured model fit marginal distribution for natural mortality based on 9000 samples of an MCMC chain (after warmup).



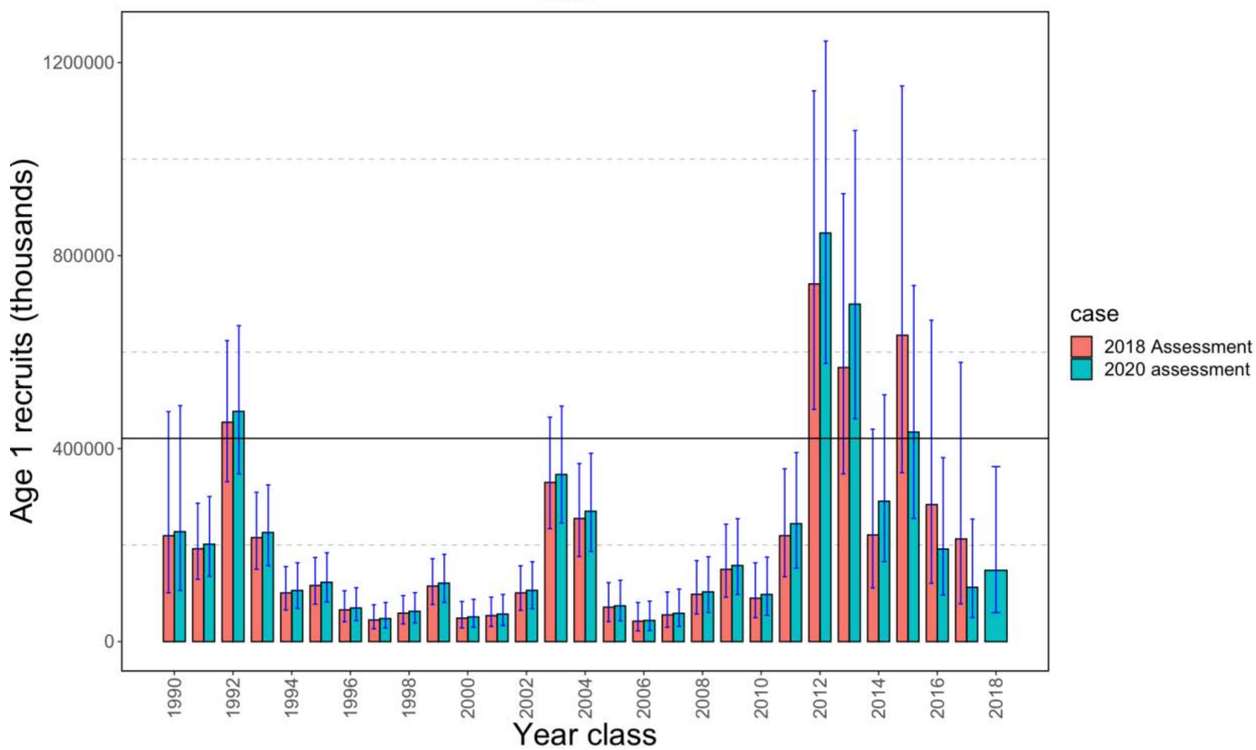


Figure 1B.6. Estimates from the age-structured model of spawning biomass (top) and recruitment for Bogoslof region pollock, 1988-2020.