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

James N. Ianelli, S. J. Barbeaux, Ivonne Ortiz, and D. McKelvey

Alaska Fisheries Science Center
National Marine Fisheries Service

Executive Summary

Summary of changes in the assessment

The 2020 acoustic-trawl survey results were updated and the natural mortality estimate 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. The revisions to the survey data involve corrections to how nearest-tow data were assigned to pollock backscatter.

The age-structured model developed in 2015 was updated and applied. Revised estimates of natural mortality were obtained given the available survey age composition data over a period where fishing has been effectively zero.

Summary of results

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

Quantity	As estimated or specified last year for:		As estimated or recommended this year for:	
	2022	2023	2023	2024
M (natural mortality rate)	0.3	0.3	0.313	0.313
Tier	5	5	5	5
Biomass (t)	378,262	378,262	367,880	367,880
F_{OFL}	0.300	0.300	0.313	0.313
$maxF_{ABC}$	0.225	0.225	0.23475	0.23475
F_{ABC}	0.225	0.225	0.23475	0.23475
OFL (t)	113,479	113,479	115,146	115,146
maxABC (t)	85,109	85,109	86,360	86,360
ABC (t)	85,109	85,109	86,360	86,360
Status	As determined *this* year for:		As determined *this* year for:	
	2020	2021	2021	2022
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) was 18% but since then (2014-2020) this proportion only average 1%. Interestingly this pattern more closely aligns with pollock age distributions from the EBS.

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 been low but increased to 256 t in 2022. 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. The 2020 AT survey estimate was 353 kt, a 47% 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 and in Fig. 1B.2.

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:

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

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 2022 which weights the relative influence of past survey estimates between process error variances and that specified as observation errors.

Age structured assessment alternative

To follow-up on the approach developed by Ianelli et al. (2015), a re-evaluation of natural mortality was conducted (based on an SSC request). This model uses the same ADMB code and structure applied for the Aleutian Islands pollock assessment (Barbeaux et al., this volume). Key differences are that recruitment is specified to start age 4, only a winter spawning survey is used index abundance, and natural mortality is freely estimated.

Results

The random-effects model resulted in a 2023 biomass estimate of 367,880 t (Fig. 1B.3).

For the age-structured model, the survey selectivity-at-age is shown in Fig. 1.B4. The model fit the survey biomass estimates reasonably well except for the period from 2009-2014 (Fig. 1B.5). Fits to the age composition 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.B6). The recruitment and spawning biomass estimates compared to the 2020 version of the model are shown in Fig. 1.B7.

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, 2020, and again this year with updated age data confirms this based on the posterior distribution of natural mortality (Fig. 1B.8). The results from the age-structured model indicated natural mortality slightly larger than previously assumed: 0.313 compared to 0.3. This was provided as an alternative for Tier 5 calculations.

Harvest Recommendations

Maximum permissible ABC and OFL estimates for 2023 and 2024 under Tier 5 relies exclusively on the NMFS biennial acoustic trawl survey biomass estimate. The biomass estimate was based on the random-effects model gives:

Description	M	Biomass	ABC	OFL
Status quo	0.300	367,880	82,773	110,364
Estimated M	0.313	367,880	86,360	115,146

We recommend the ABC be set to the maximum permissible using the estimated natural mortality from the age structured model. Under Tier 5 this results in an ABC of 86,360 t for 2023 and 2024 and an OFL of 115,146 t.

Risk table summary

Assessment considerations
The Bogoslof pollock assessment has been managed under Tier 5 of the FMP and is based on survey trends. In addition, a Tier-3 type age-structured model has been applied to track spawning biomass trends and consider survey age composition data to estimate natural mortality since fishing mortality has been near zero since 1992 due to directed fishing closures in this region. Genetic studies are underway which may require reconsidering the stock structure assumptions; however, we consider the assessment adequate given the limited fishing (level 1).

Population dynamics considerations
As with the assessment considerations, there are questions about the stock structure for this region. However, it appears that the spawning characteristics in this area continue to be consistent and until more details on the interactions with other areas are understood, we consider issues related to uncertainty in the population dynamics to be risk averse given there is no directed fishing in this region (level 1).

Environmental/Ecosystem considerations
Environment: In the Southern Bering Sea, pollock have been found in temperatures ranging from 2.9 7.3°C. The average bottom temperature from the Aleutian Islands bottom trawl survey (AIBTS, (165°W – 170°W) in the Southern Bering Sea was ~4.4·C, similar to 2018 and cooler than the highest observed in 2016 but still above the long term mean, as have the last four surveys (2014 onwards). Mid-depth (100-300m) and water column temperature (surface to bottom) from the longline survey (165°W to 170°W) and bottom trawl survey, respectively show a similar pattern, with warmer temperatures throughout the water column starting 2014. The longline survey in particular shows warm water between 150 – 250 m depth, with cooler waters towards the surface and below. Surface temperature both from the AIBTS, as well as satellite data for the Eastern Aleutians, show an increasing trend in temperatures, during both summer and winter with 2022 being one of the warmest years in summer for the eastern Aleutians. Most of summer through August has been under a moderate heatwave in the eastern Aleutians (Bond et al, 2022).

Pollock spawns March through June, their larvae stay in surface waters (top 40 m) before they shift to deeper waters (Smart et al., 2013). This timing means the eggs are vulnerable to MHW penetrating the top of the water column as was the case particularly in 2015, 2016, and 2019 when surface temperatures exceeded 6°C – 7°C based on data from the longline (Bond et alSewicke, 2022) and bottom trawl survey (O'Leary and Laman, 2022)

Prey: Although we don't have direct abundance estimates of copepods, which comprise juvenile (<20cm) pollock diet, along with euphausiids and pelagic gelatinous filter feeders, we can infer that copepods experienced lower predation pressure based on the biannual cycle and record abundance of Kamchatka pink salmon during 2021. The biannual cycle and cascading effects of pink salmon predation on copepods has been documented before by Springer and van Vliet (2014), Batten et al. (2018), and Matta et al. (2020). Time-series of either young ages or total population do not show alternate years of high number of pollock. Based on the Kamchatka pink-salmon – copepods relationship, we assume that copepod prey availability to pollock in 2022 would be higher than in odd years when pink salmon abundance is high. Other inferences we can make about zooplankton prey availability are from the reproductive success of Leach's storm petrels at Aiktak which feed on zooplankton as well as invertebrates and had good reproductive success this year, fork tailed storm petrels and Ancient murrlets also had average reproductive success, as did puffins and murres, suggesting that both zooplankton and forage fish were sufficiently abundant during these years to support successful production of chicks and possibly indicative of abundant zooplankton prey in that area. Data from the Continuous Plankton Recorders that sample near the Aleutian chain show average size anomalously small copepod taxa from 2016-2018, increasing in size in 2019 and 2021. which may indicate a recent increase in the quality of zooplankton prey available to pollock.

Recent condition indices (2014 onwards, even years) taken during surveys have been lower than the long-term survey mean, and while the condition of pollock stayed below the mean this year, it did improve slightly in the Southern Bering Sea. The recent higher water temperatures increasing consumption, along with higher competition and increasing biomass of Pacific ocean perch, may jointly explain the negative body condition observed in the past years in walleye pollock. – Pacific ocean perch and northern rockfish which were heavily fished by the foreign fishery in the 1960s and 1970s and have subsequently been increasing since the 1980s to its peak biomass (age 3+) in 2011-2012. Since then POP have decreased but remain at a high biomass and along with northern rockfish dominate over Atka mackerel and pollock within the pelagic forgers guild. Pollock and Atka mackerel were the dominant species based on survey data) in the early 1990s.

Competitors and predators: Both Pacific ocean perch (particularly juvenile POP <20 cm), Kamchatka pink salmon, and Atka mackerel are primary consumers of copepods, with the first two showing biannual signals in their abundance. Both the western and central Aleutians have shown decreased survey biomass estimates of pollock not observed in the eastern Aleutians. 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 pollock through competitive pressure. Some fishery-related evidence might be the increased bycatch of pollock in rockfish fisheries.

Walleye pollock are a key prey for northern fur seals which are increasing in Bogoslof, offsetting the decreasing population in the East St Paul Island rookery complex. Pollock in this area is also consumed by Steller sea lions (increasing also in this area), Pacific cod, arrowtooth flounder (decreasing), and Pacific Halibut (diet for fish from AFSC Groundfish Food Habits database). Pollock are also consumed by harbor seals. Recent data suggest that Steller sea lion populations are increasing in the eastern Aleutians as part of the Rookery Cluster Area 6 (Sweeney and Gelatt, 2020) where most of the pollock is distributed, suggesting that their predatory impact on pollock may increase in this region. Offsetting this potential increase in predation, Pacific cod decreased compared to 2018, as did arrowtooth flounder based on AI survey biomass estimates. These trends suggest no large changes in predation pressure on AI pollock.

Taken together, these indicators suggest that the current level of concern is level 1—no apparent environmental/ecosystem concerns.

The sustained high biomass of POP, which may be outcompeting pollock in other areas, is a return to conditions before POP was heavily fished by the foreign fleet. The trends in fish condition and seabird reproductive success would seem to support prey is available, so other factors may be limiting it from improving its condition further.

Data Gaps and Research Priorities

Genetic work should be developed further to distinguish this spawning aggregation from other studies. In particular, samples from the spawning grounds should be compared with nearby areas in other periods.

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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
2021		9	9
2022		256	256

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	67	334
1996	7	492	499
1997	13	150	163
1998	3	5	8
1999	11	18	29
2000	20	10	29
2001	28	231	259
2002	12	1,031	1,043
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	177
2011	23	150	173
2012	0	71	71
2013	0	56	57
2014	54	373	427
2015	138	595	733
2016	7	997	1,004
2017	1	184	185
2018	2	11	14
2019	0	8	8
2020	2	7	9
2021	4	4	8
2022	25	231	256

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
2021	85,109	113,479	250	9
2022	85,109	113,479	250	256

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	353,069	1,455	16%
2021		No survey	
2022		No survey	

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 20XX).

	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	3.31	0.39	4.04	14.29	27.19	56.40	107.44	88.56	21.00	4.60	0.39	0.00

Figures

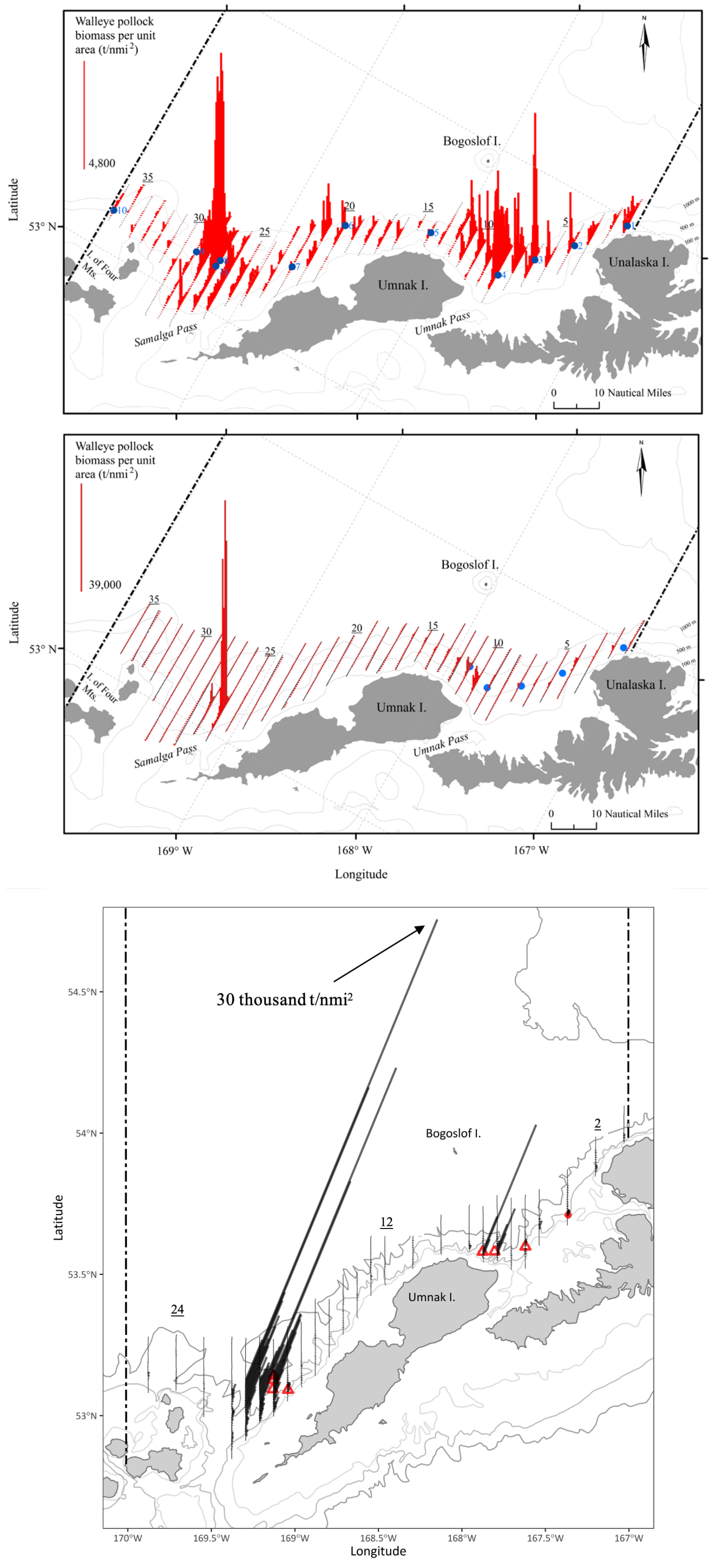

Figure 1B.1. Distribution of pollock biomass (t/nmi^2) observed along transects during the winter 2016 (top), 2018 (middle), and 2020 (bottom) acoustic-trawl survey. Transect numbers are underlined; trawl haul locations are indicated by circles or triangles.

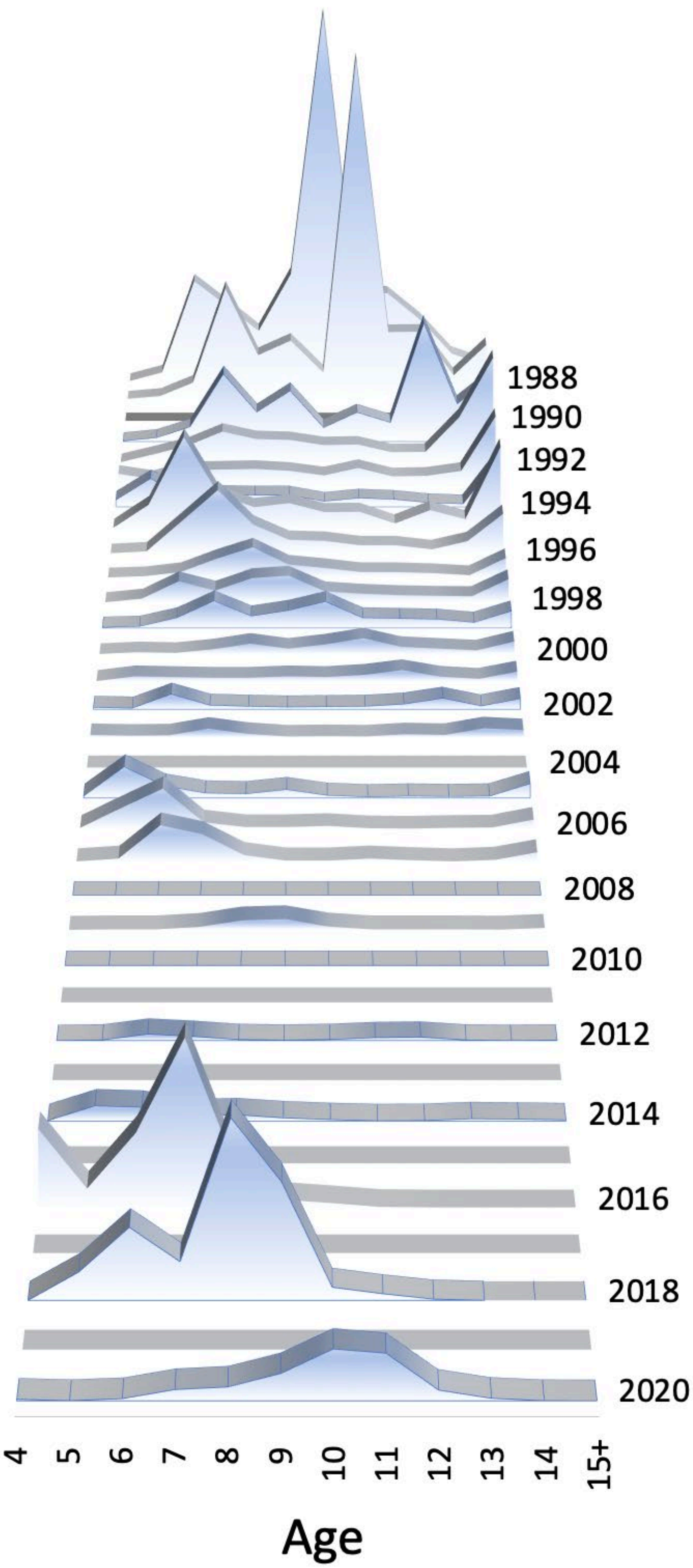

Figure 1B.2. Age composition estimates (numbers) during the winter surveys for Bogoslof region pollock, 1988-2020.

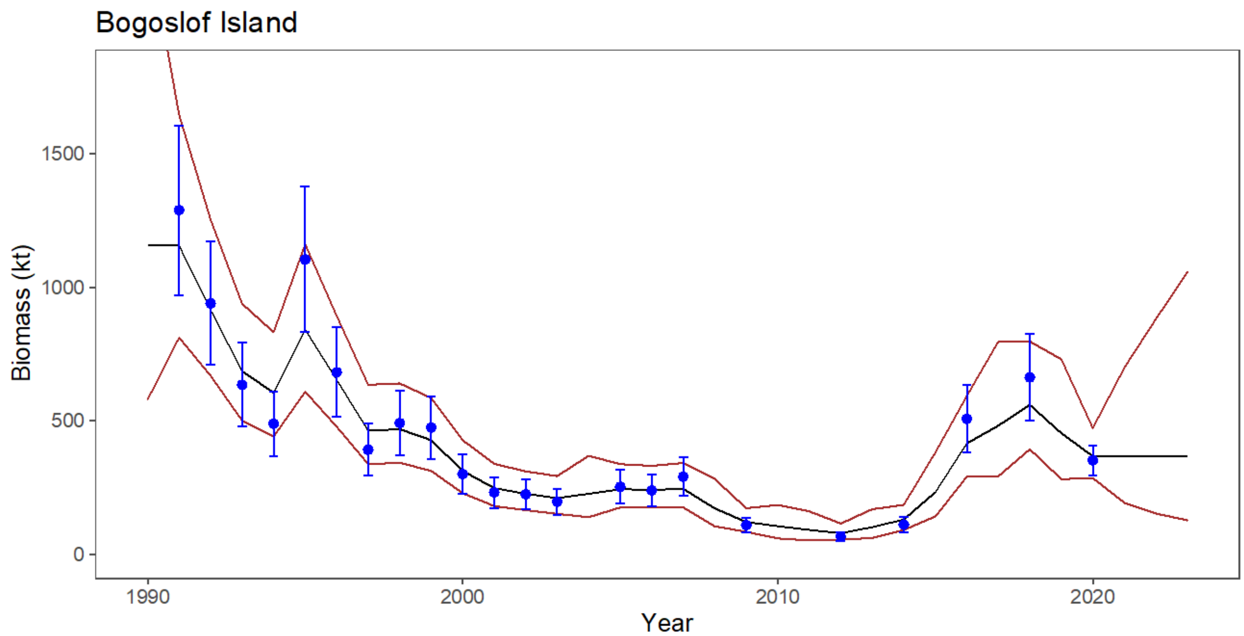

Figure 1B.3. Bogoslof Island pollock survey estimates fit to a process error model for averaging biomass. The shade represents the approximate 90% confidence interval from the model.

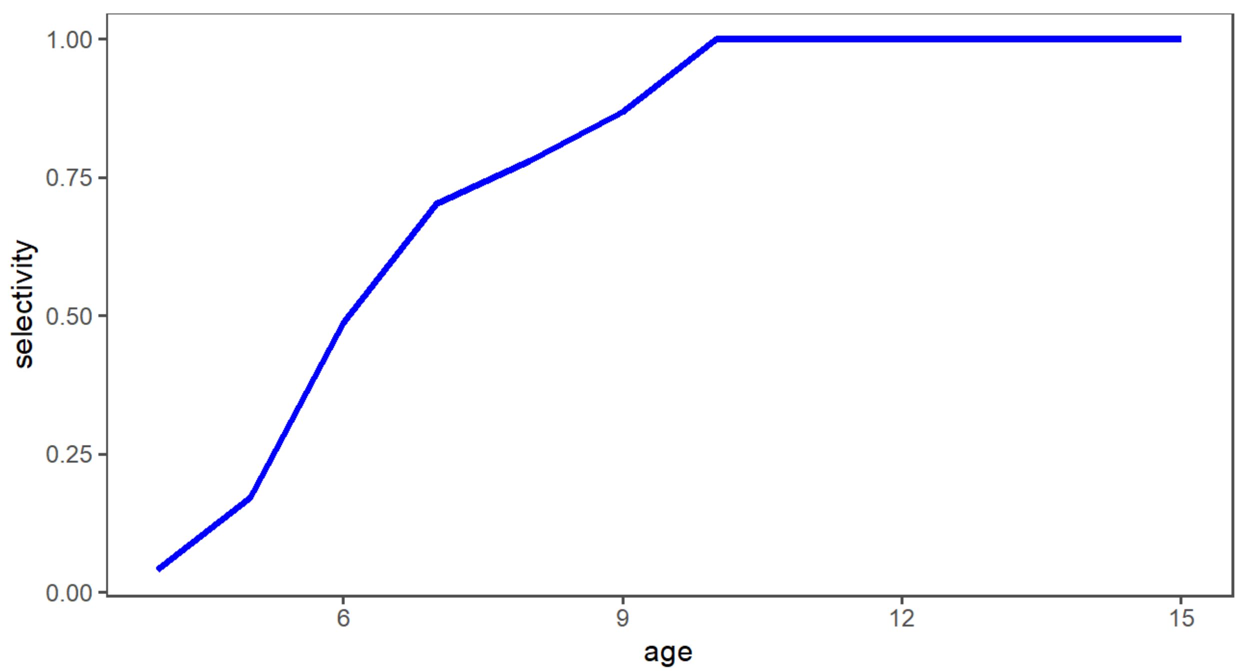

Figure 1B.4. Pollock age-structured model estimate of survey selectivity.

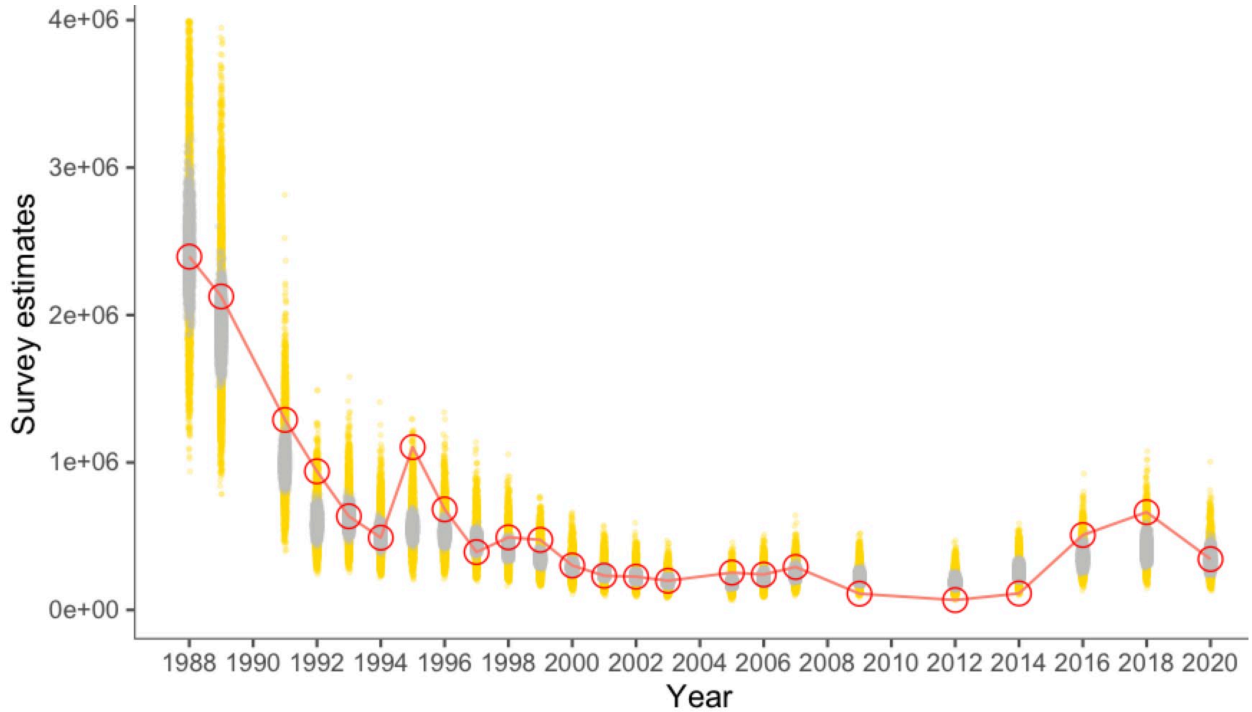

Figure 1B.5. Pollock age-structured model fit to Bogoslof region acoustic-trawl survey biomass estimates, 1988-2020. Open circles and line represents survey point estimates, grey dots represent the posterior mean, and yellow dots represents the posterior predictive values.

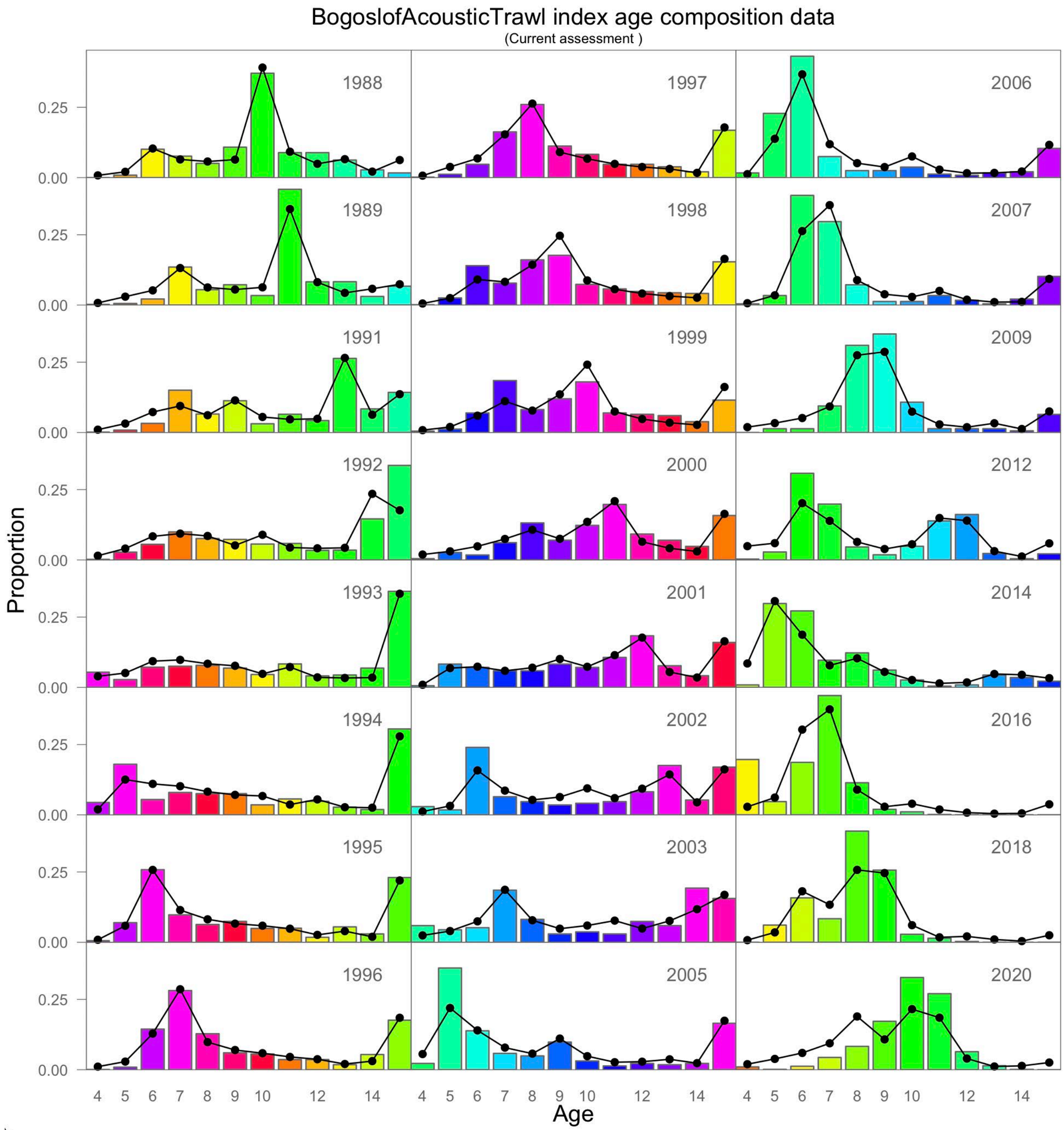

Figure 1B.6. Pollock age-structured model fit to the Bogoslof region acoustic-trawl survey age composition estimates, 1988-2020.

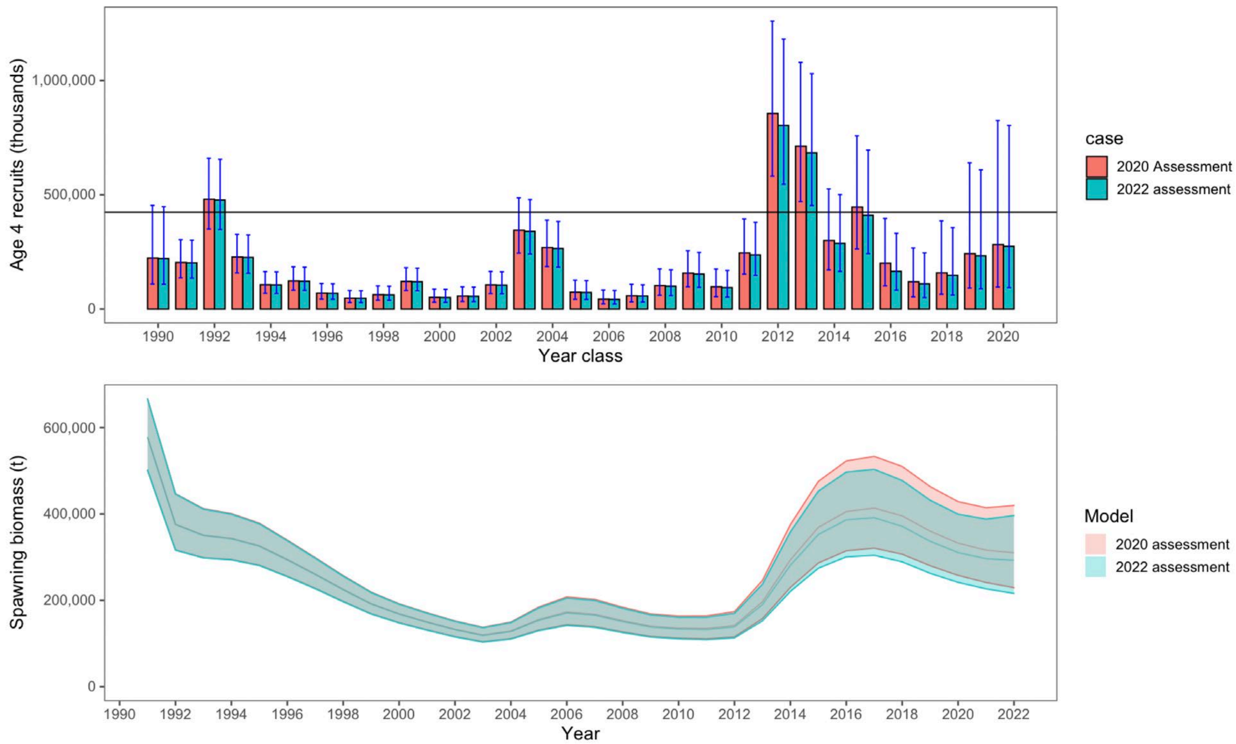

Figure 1B.7. Bogoslof Island pollock age-structured assessment model comparison with the 2020 assessment (bars and bands represent approximate 90% credible interval from the model.

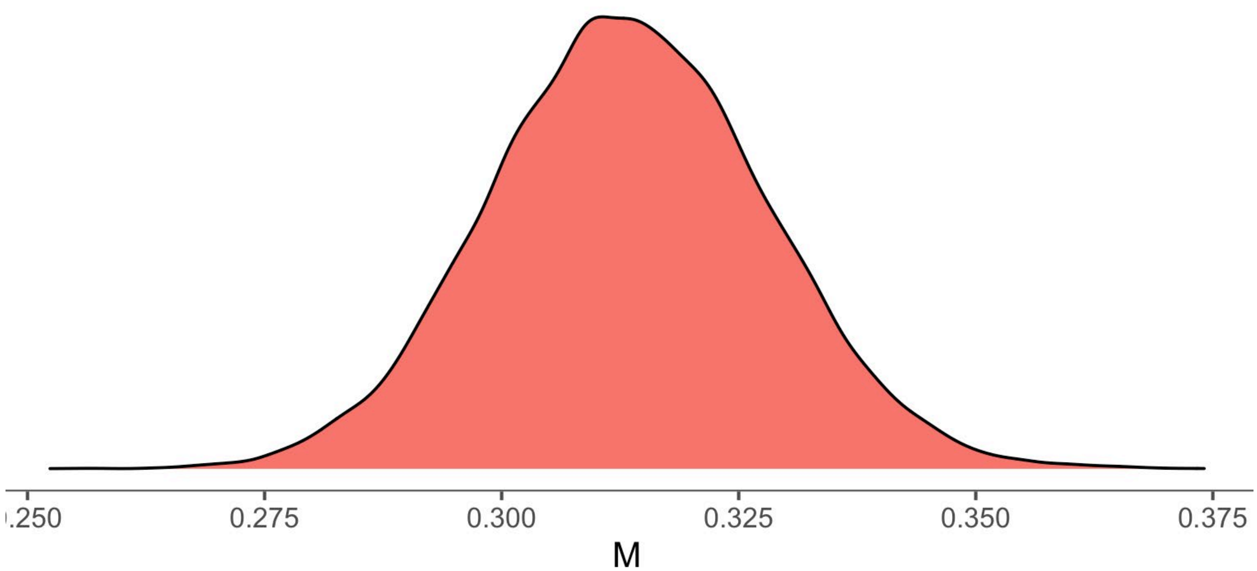

Figure 1B.8. Pollock age-structured model posterior marginal distribution for natural mortality from MCMC sampling.