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

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Executive Summary

The 2014 winter Bogoslof pollock (*Gadus chalcogrammus*) acoustic-trawl (AT) survey increased relative to the 2012 survey by 67% but this remains at only 25% of the 1991-2014 mean. The following summarizes the 2014 ABC and OFL levels using Tier 5 values and assuming a natural mortality of 0.2:

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015	2016
M (natural mortality rate)	0.2	0.2	0.2	0.2
Tier	5	5	5	5
Biomass (t)	67,063	67,063	106,000	106,000
F_{OFL}	0.200	0.200	0.200	0.200
$maxF_{ABC}$	0.150	0.150	0.150	0.150
F_{ABC}	0.150	0.150	0.150	0.150
OFL (t)	13,413	13,413	21,200	21,200
maxABC (t)	10,059	10,059	15,900	15,900
ABC (t)	10,059	10,059	15,900	15,900
Status	As determined *this* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a

Response to SSC and Plan Team comments

General comments:

There were no general comments pertaining to this Tier 5 assessment

Comments specific to this assessment

The SSC noted that this stock has not been fished for a long enough time that catch curve analysis could be used to estimate recent natural mortality. This would be a useful check on the assumed value.

The age-structured model was updated which allowed for a more statistically sound approach to estimating natural mortality. A short summary of this is presented for contrast with the assumption of constant natural mortality of 0.2.

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).

Collectively, pollock found in the Donut Hole and in the Bogoslof region are considered a single stock, 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 (Fig. 1B.1). 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.

There are some characteristics that 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 information available for pollock in the Aleutian Basin and the Bogoslof Island area indicates that these fish may belong to the same “stock”. 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 there has been some indication that there are strong year classes appearing on the shelf that have not been as strong (in a relative sense) in the Bogoslof region (Ianelli et al., 2004).

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 were small in recent years (Table 1B.2). The increase in pollock bycatch in 2010 (9 t in 2008 to 73 in 2009 and 176 t in 2010) can be attributed to the non-pelagic trawl arrowtooth flounder target fishery. The majority of pollock bycatch in the Bogoslof region continues to be occurring in the non-pelagic trawl arrowtooth flounder target fishery. For all fisheries there were 57 t of pollock catch in 2013 and 428 t in 2014.

Data

Survey and fishery

NMFS acoustic-trawl survey biomass estimates are the primary data source used in this assessment. Since 2000, the values have varied between 292,000 t and 67,000 t. The most recent AT survey of the Bogoslof spawning stock was conducted in March of 2014 (McKelvey and Stienessen, in prep; Table 1B.3) and resulted in a biomass estimate of 112,070 t. The 2012 survey was the lowest observed. For supplemental studies (the age structured model) additional age-specific information was needed. This included the catch at age in the fishery (for only 1988) and mean weights at age (Tables 1B.4). Additionally, the survey age-specific data were used (Tables 1B.5 and 1B.6).

Analytical approach

Model Structure

Survey biomass averaging

The model for harvest recommendations was based on using a Tier-5 approach with some modifications based on Plan Team and SSC recommendations. First, used a process error model recommended by the Plan Team for estimating a mean biomass over a number of surveys was also explored. This model estimates biomass (B_t) over time as 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 2015 which weights the relative influence of past survey estimates between process error variances and that specified as observation errors.

Evaluation of natural mortality estimate

Another analysis was undertaken to evaluate the SSC’s recommendation to evaluate the natural mortality as used in the Tier 5 calculation. They suggested that a catch-curve analysis to examine mortality rates under the current bycatch-only status of Bogoslof pollock might be useful. However, since an age-structured stock assessment model has been constructed in the past (Ianelli et al. 2005) it was considered useful for this task since natural mortality can easily be estimated in that configuration and it, unlike a catch curve approach, requires fewer assumptions about the data and appropriateness of the likelihoods. Consequently a model configured similarly to that used for Aleutian Islands pollock (AMAK) was used with updated survey age data. For brevity, two model configurations were developed, one in which the assumed natural mortality was fixed at 0.2 and the other where it was freely estimated with a diffuse prior distribution.

More recently the SSC has requested an analysis of natural mortality rates since fishing in this region has been curtailed for some time and survey data are relatively plentiful. They suggested that a catch-curve analysis to examine mortality rates under the current bycatch-only status of Bogoslof pollock might be useful. Consequently, the original age-structured stock assessment model (Ianelli et al. 2005 updated with the same model configuration as Aleutian Islands pollock) was used with the new survey age data. For brevity, two model configurations were developed, one in which the assumed natural mortality was fixed at 0.2 and the other where it was freely estimated with a diffuse prior distribution. The catch data used are as reported from 1977-2014 and fit to one year of fishery age composition data (from 1988) and 20 years of survey age compositions:

Source	Type	Years
Fishery	Catch biomass	1977-2014
Fishery	Catch age composition	1988
Acoustic trawl survey	Population biomass (q=1)	1988-2003, 2005-2007, 2009, 2012, 2014
Acoustic trawl survey	Proportions at age	1988-2003, 2005-2007, 2009, 2012

Parameters Estimated Outside the Assessment Model

The model extended from ages 4-15+ pollock, assumed that the survey index catchability was constant and fixed at a value of 1.0, and that selectivity was also estimated at age but constant over time for both the survey and fishery. Mean weights were based on survey and fishery data when they were available and assumed to be constant otherwise and presented in the tables. The assumed proportion mature-at-age was:

Age	4	5	6	7	8	9	10+
	0.30	0.80	0.90	0.95	0.96	0.97	1.00

Results

Results clearly indicated that the fixed natural mortality did a much better job fitting the “plus group” (ages 15 and older) as observed in the 20 years of survey age composition data (Fig. 1B.2). The fit to the survey trend was also improved (Fig. 1B.3), but the impact on the current spawning biomass was relatively minor (Fig. 1B.4). Recent periods of recruitment, excluding the large 1978 year-class, were similar for both model configurations but had different scales with higher recruitment for the model with higher natural mortality (Fig. 1B.5). Running the model using MCMC over a chain of one million samples (keeping each 200th) provides a marginal posterior distribution in which the median and the mean were 0.2992, and 0.3000, respectively (Fig. 1B.6). The mode of the posterior distribution was 0.297, all nearly identical to the values assumed for the eastern Bering Sea pollock stock.

Results of the Plan Team recommended process error method gave nearly identical estimates as using the most recent survey (106,000 t of biomass for the process error model compared to 112,070 t; Fig. 1B.2). However, accounting for the 2012 survey (which was the lowest observed) the survey averaging approach provides a lower value of 106,000 t from which to make the Tier 5 calculations.

Regarding the age-structured model evaluation of natural mortality, the evidence suggests that a higher value is more consistent 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 2015 and 2016 under Tier 5 relies exclusively on the NMFS biennial acoustic trawl survey biomass estimate. Biomass was based on the survey averaging approach.

The Tier 5 ABC formula is:

$$ABC = B_{2014} \times M \times 0.75$$

Using the alternatives requested by the Plan Team and SSC (i.e., alternative survey averaging and examination of natural mortality) gives the following options for consideration:

Description	M	Biomass	ABC	OFL
Recent survey, M=0.2	0.2	112,070	16,811	22,414
Recent survey, M estimated	0.3	112,070	25,216	33,621
Survey average, M=0.2	0.2	106,000	15,900	21,200
Survey average, M estimated	0.3	106,000	23,850	31,800

For consistency with previous years calculations the recommended ABC is based on the survey average biomass and the natural mortality as in previous years. This results in a maximum permissible Tier 5 ABC of 15,900 t for 2015 and 2016 and an OFL of 21,200 t. The alternative recommendation which uses both the new survey average method and the revised estimate of M would give an ABC and OFL of 23,850 t and 31,800 t, respectively.

Ecosystem considerations

In general, a number of key issues for ecosystem conservation and management can be highlighted. These include:

- Preventing overfishing;
- Avoiding habitat degradation;
- Minimizing incidental bycatch (via multi-species analyses of technical interactions);
- Controlling the level of discards; and
- Considering multi-species trophic interactions relative to harvest policies.

For the case of pollock, the NPFMC and NMFS continue to manage the fishery on the basis of these issues in addition to the single-species harvest approach. The prevention of overfishing is clearly set out as a main guideline for management. Habitat degradation has been minimized in the pollock fishery by converting the industry to pelagic-gear only. Bycatch in the pollock fleet is closely monitored by the NMFS observer program, and individual species caught incidentally are managed on that basis. Discarding rates have been greatly reduced in this fishery and multi-species interactions is an ongoing research project within NMFS with extensive food-habit studies and simulation analyses to evaluate a number of “what if” scenarios with multi-species interactions.

As reported in Loughlin and Miller (1989) pups of Northern fur seals, *Callorhinus ursinus*, were first observed on Bogoslof Island in 1980. By 1988 the population had grown at a rate of 57% per year to over 400 individuals, including 80+ pups, 159 adult females, 22 territorial males, and 188 sub-adult males. They noted that the rookery is in the same location where solitary male fur seals were seen in 1976 and 1979 and is adjacent to a large northern sea lion rookery. On July 22, 2005 NMFS surveys resulted in counts of 1,123 adult males, a substantial increase over this time period (L. Fritz, AFSC, pers. comm.). The estimated number of Northern fur seal pups born on Bogoslof Island increased from 5,096 (SE = 33) to 12,631 (SE = 335) (Angliss and Allen, 2007). This suggests that conditions in the ecosystem have changed and appear to favor Northern fur seals. The extent that this is due to environmental conditions is unknown. However, pollock abundance may play only a small role since during peak abundance levels, the Northern fur seal abundance was at very low levels. Also, pollock are most concentrated in this region during winter months when Northern fur seals have migrated to more southern areas.

Data gaps and research priorities

Previous assessments (e.g., Ianelli et al. 2004) developed a full-age structure model which was further refined (Ianelli et al. 2005) to include the effect of Donut Hole catches in the 1980s. In that study they assumed that 75% of the Donut Hole catches came from the Bogoslof stock, which is in accord with past practices of international pollock workshops (which used a range from 60 to 80%). However, concerns about this assumption were raised due to the uncertain degree of interchange between Bogoslof fish and central BS fish. In the SSC's December 2006 minutes they noted that additional research is needed to better understand the extent of these linkages. Data to help understand these linkages are not forthcoming and substantial resources (e.g., tagging, extensive survey efforts) would be required. Hence the source and dynamics of recruitment to the Bogoslof region remains unclear.

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Table 1B.1 Catch in tons from the Donut Hole and the Bogoslof Island area, 1977-2014.

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

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	9
2013	< 1	56	57
2014	54	374	428

Table 1B.3. Biomass (tons) of pollock as surveyed in the Bogoslof region, 1988-2014. For additional details see McKelvey and Stienessen (in prep).

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	1,104,124	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	301,402	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	1,870	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%

Table 1B.4. Catch at age (top row, italics) and average weight at age assumed for fishery in the age-structured model for Bogoslof pollock.

	4	5	6	7	8	9	10	11	12	13	14	15
1988	*0.10*	*0.50*	*3.27*	*2.47*	*1.64*	*3.50*	*12.01*	*2.88*	*2.87*	*2.02*	*0.89*	*0.54*
1977	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1978	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1979	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1980	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1981	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1982	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1983	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1984	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1985	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1986	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1987	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1988	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1989	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1990	0.45	0.59	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1991	0.45	0.59	0.72	0.84	0.88	1.00	1.11	1.13	1.19	1.21	1.26	1.24
1992	0.45	0.59	0.66	0.74	0.90	0.96	1.15	1.17	1.20	1.13	1.18	1.30
1993	0.45	0.59	0.77	0.93	1.08	1.19	1.24	1.39	1.51	1.63	1.59	1.46
1994	0.45	0.59	0.73	0.71	0.99	1.29	1.23	1.20	1.33	1.31	1.28	1.28
1995	0.45	0.59	0.84	0.85	1.00	1.24	1.31	1.37	1.49	1.40	1.34	1.49
1996	0.45	0.59	0.82	0.96	0.97	1.06	1.14	1.37	1.45	1.49	1.68	1.46
1997	0.45	0.59	0.75	0.89	1.07	1.08	1.24	1.33	1.42	1.57	1.45	1.42
1998	0.45	0.59	0.64	0.77	1.04	1.19	1.26	1.32	1.35	1.50	1.52	1.63
1999	0.45	0.59	0.74	0.88	1.03	1.11	1.21	1.34	1.41	1.52	1.55	1.50
2000	0.45	0.59	0.74	0.84	1.00	1.12	1.21	1.29	1.37	1.42	1.43	1.42
2001	0.45	0.59	0.74	0.84	1.01	1.14	1.22	1.31	1.39	1.44	1.45	1.44
2002	0.45	0.59	0.75	0.85	1.02	1.16	1.23	1.32	1.41	1.47	1.47	1.46
2003	0.45	0.59	0.75	0.85	1.01	1.15	1.23	1.32	1.40	1.46	1.46	1.46
2004	0.45	0.59	0.75	0.86	1.02	1.14	1.23	1.33	1.41	1.47	1.48	1.48
2005	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2006	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2007	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2008	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2009	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2010	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2011	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2012	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2013	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2014	0.45	0.59	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47

Table 1B.5. Weight at age for the acoustic-trawl survey in age-structured model for Bogoslof pollock.

	4	5	6	7	8	9	10	11	12	13	14	15
1977	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1978	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1979	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1980	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1981	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1982	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1983	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1984	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1985	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1986	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1987	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1988	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1989	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1990	0.45	0.50	0.72	0.84	0.94	1.03	1.10	1.16	1.21	1.25	1.29	1.31
1991	0.45	0.50	0.72	0.84	0.88	1.00	1.11	1.13	1.19	1.21	1.26	1.24
1992	0.45	0.50	0.66	0.74	0.90	0.96	1.15	1.17	1.20	1.13	1.18	1.30
1993	0.45	0.50	0.77	0.93	1.08	1.19	1.24	1.39	1.51	1.63	1.59	1.46
1994	0.45	0.50	0.73	0.71	0.99	1.29	1.23	1.20	1.33	1.31	1.28	1.28
1995	0.45	0.50	0.84	0.85	1.00	1.24	1.31	1.37	1.49	1.40	1.34	1.49
1996	0.45	0.50	0.82	0.96	0.97	1.06	1.14	1.37	1.45	1.49	1.68	1.46
1997	0.45	0.50	0.75	0.89	1.07	1.08	1.24	1.33	1.42	1.57	1.45	1.42
1998	0.45	0.50	0.64	0.77	1.04	1.19	1.26	1.32	1.35	1.50	1.52	1.63
1999	0.45	0.50	0.74	0.88	1.03	1.11	1.21	1.34	1.41	1.52	1.55	1.50
2000	0.45	0.50	0.74	0.84	1.00	1.12	1.21	1.29	1.37	1.42	1.43	1.42
2001	0.45	0.50	0.74	0.84	1.01	1.14	1.22	1.31	1.39	1.44	1.45	1.44
2002	0.45	0.50	0.75	0.85	1.02	1.16	1.23	1.32	1.41	1.47	1.47	1.46
2003	0.45	0.50	0.75	0.85	1.01	1.15	1.23	1.32	1.40	1.46	1.46	1.46
2004	0.45	0.50	0.75	0.86	1.02	1.14	1.23	1.33	1.41	1.47	1.48	1.48
2005	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2006	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2007	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2008	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2009	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2010	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2011	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2012	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2013	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47
2014	0.45	0.50	0.74	0.86	1.02	1.13	1.22	1.33	1.40	1.48	1.50	1.47

Table 1B.6. Estimated survey numbers at age from the acoustic-trawl surveys used in the age-structured model for Bogoslof pollock.

	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

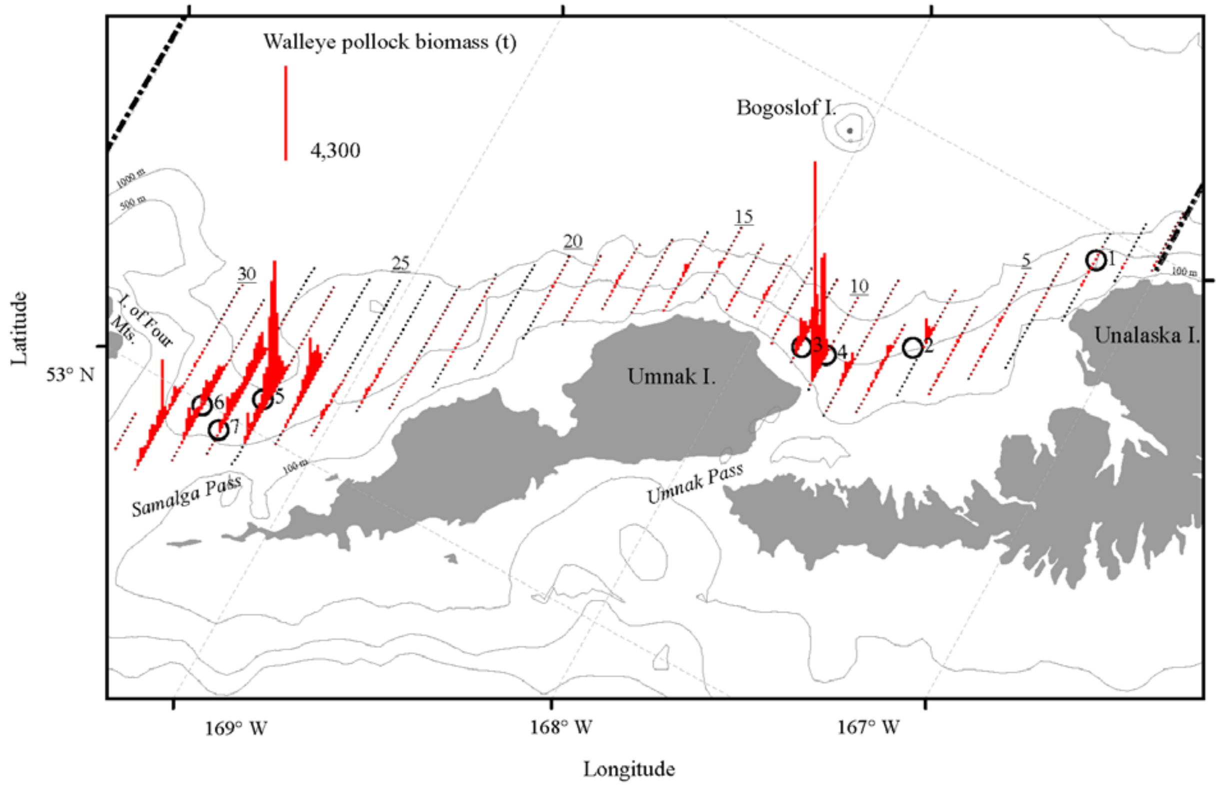

Figure 1B.1. Distribution of pollock biomass (t) observed along transects during the winter 2014 acoustic-trawl survey. Transect numbers are underlined; trawl haul locations are indicated by circles.

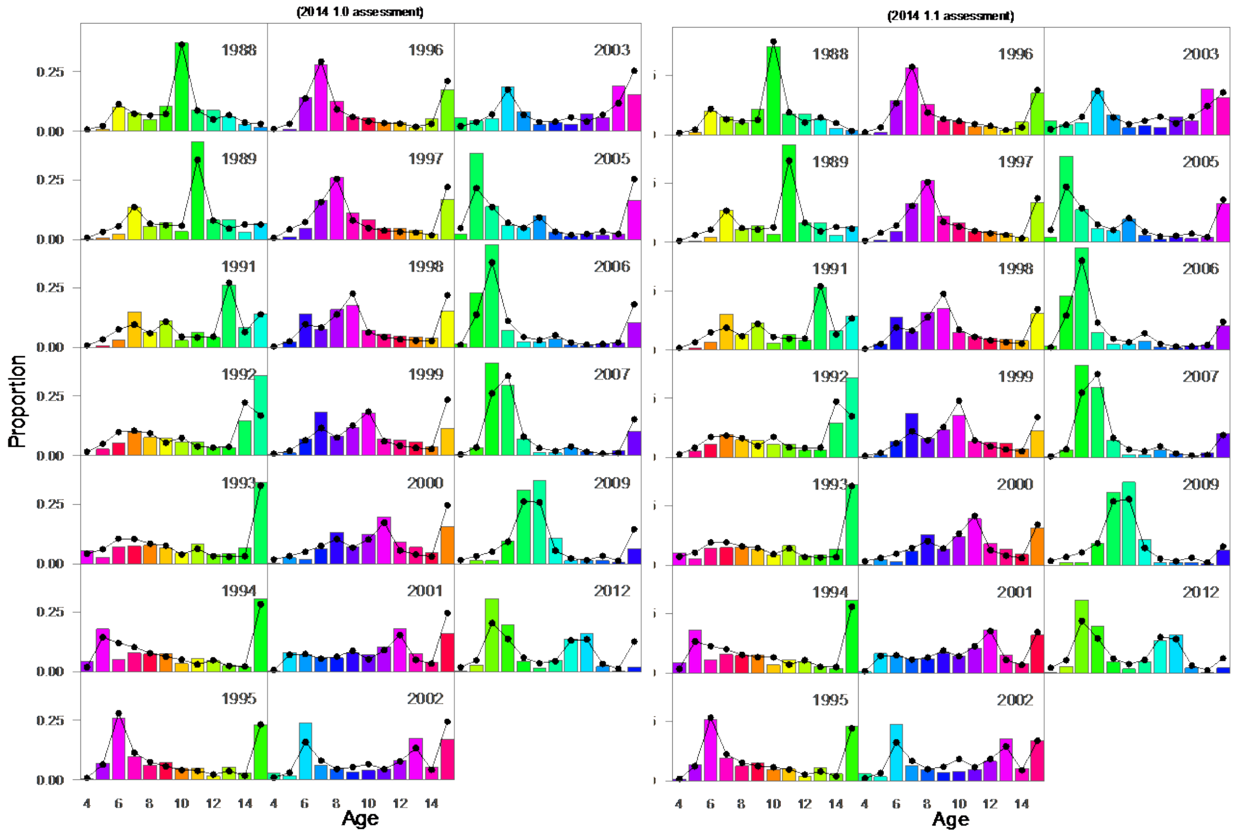

Figure 1B.2. Comparisons of the Bogoslof pollock age-structured model fits to the survey age compositions when natural mortality (M) was assumed to be 0.2 (left panels) compared to when M was freely estimated (right panels).

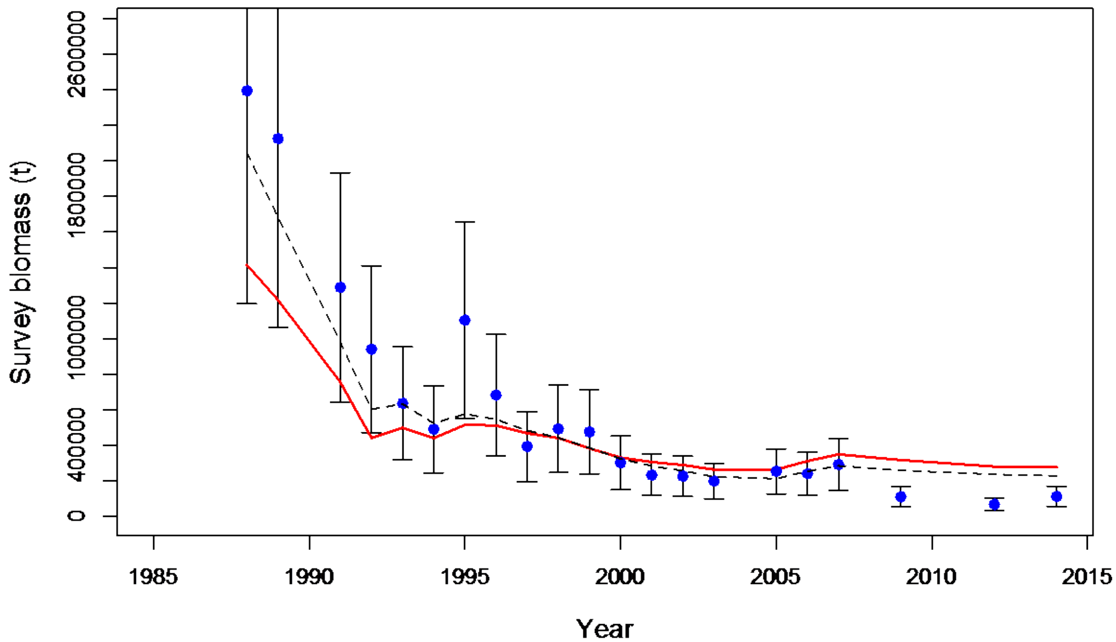

Figure 1B.3. Comparisons of the Bogoslof pollock age-structured model fits to the survey index data when natural mortality (M) was assumed to be 0.2 (solid line) compared to when M was freely estimated (dashed line).

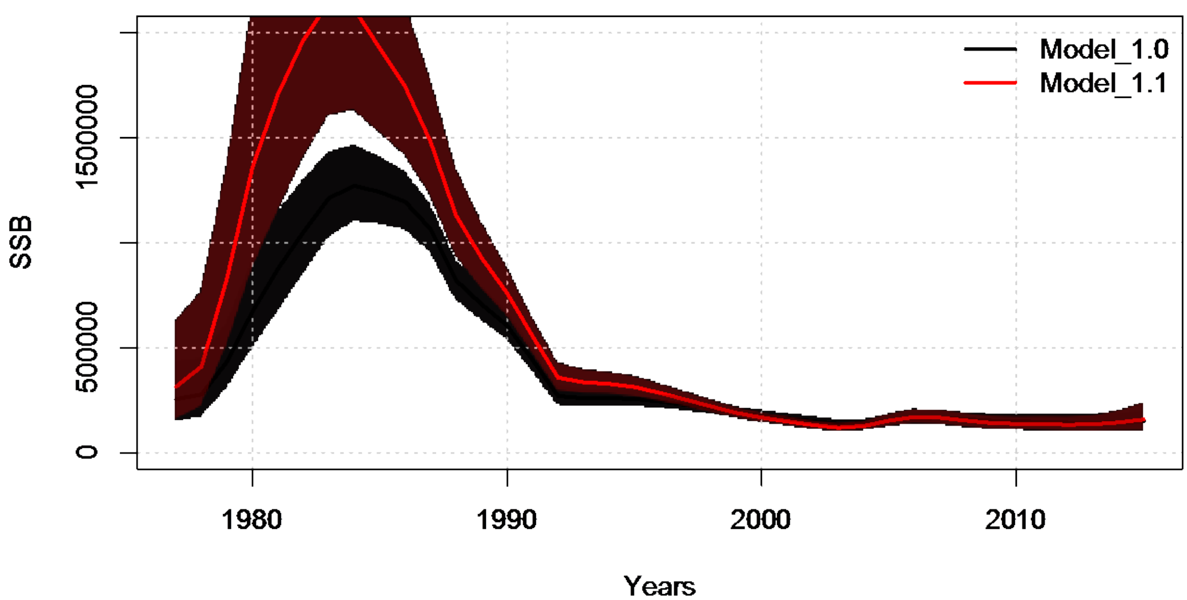

Figure 1B.4. Comparisons of the Bogoslof pollock age-structured model results in spawning biomass (SSB) in t when natural mortality (M) was assumed to be 0.2 (Model 1.0) compared to when M was freely estimated (Model 1.1).

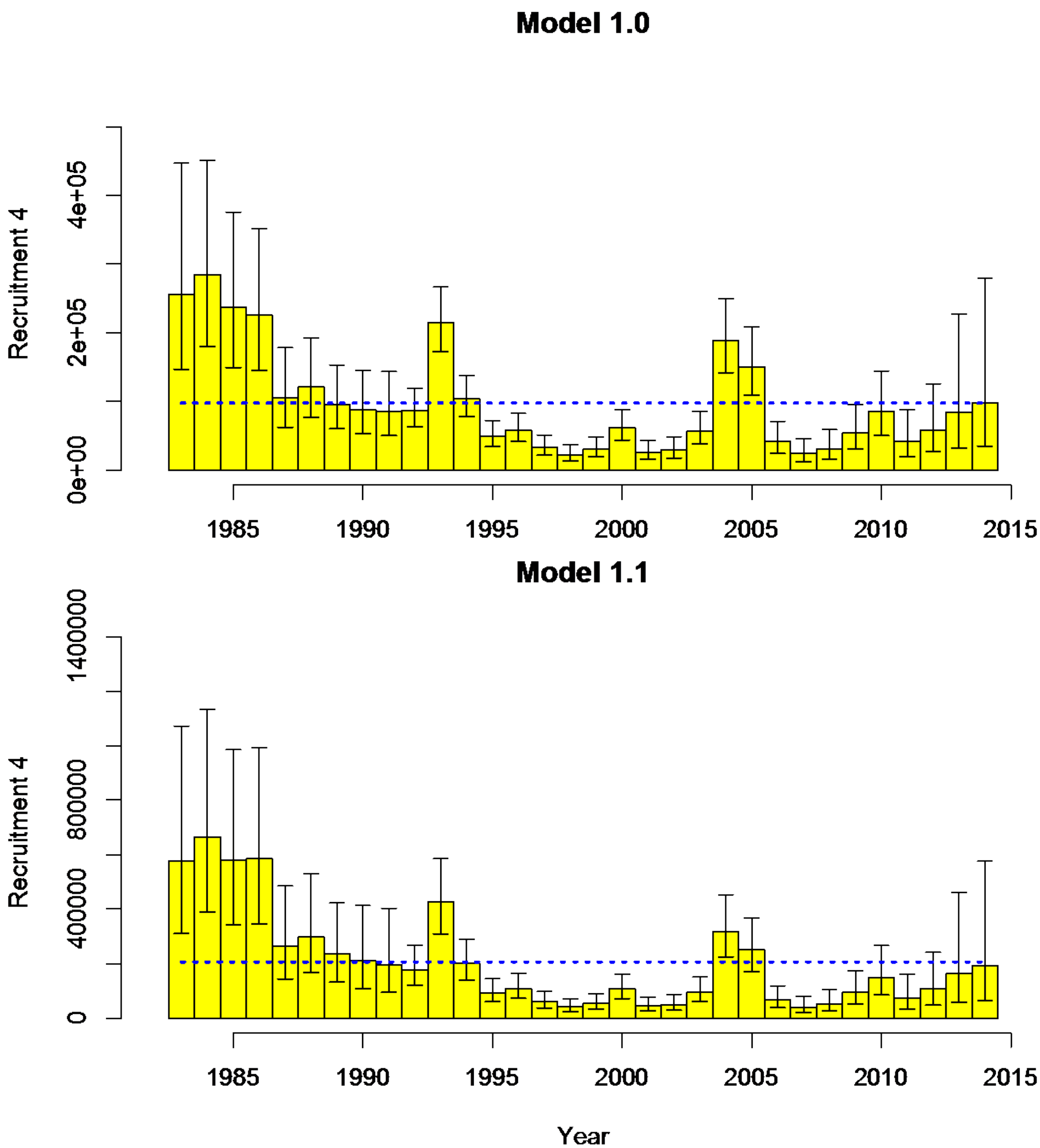

Figure 1B.5. Comparisons of the Bogoslof pollock age-structured model results in recruitment (at age 4) in t when natural mortality (M) was assumed to be 0.2 (Model 1.0; top) compared to when M was freely estimated (Model 1.1; bottom).

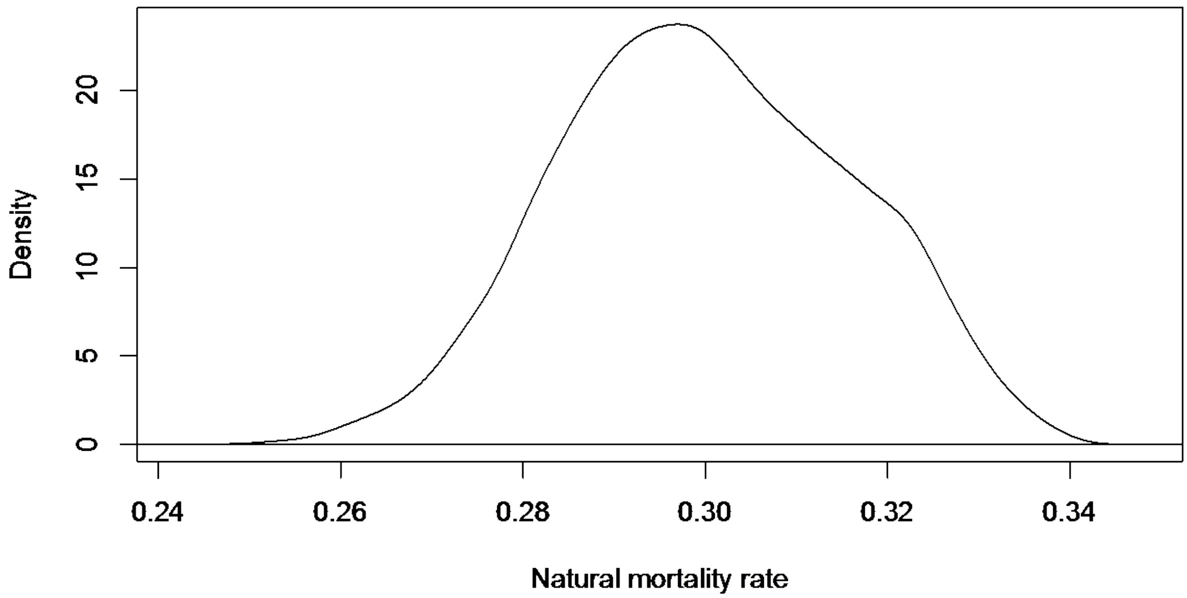

Figure 1B.6. Posterior marginal distribution of one million MCMC samples for the Bogoslof pollock age-structured model for natural mortality (M) under Model 1.1 configuration. The median and the mean were 0.2992, and 0.3000, respectively.

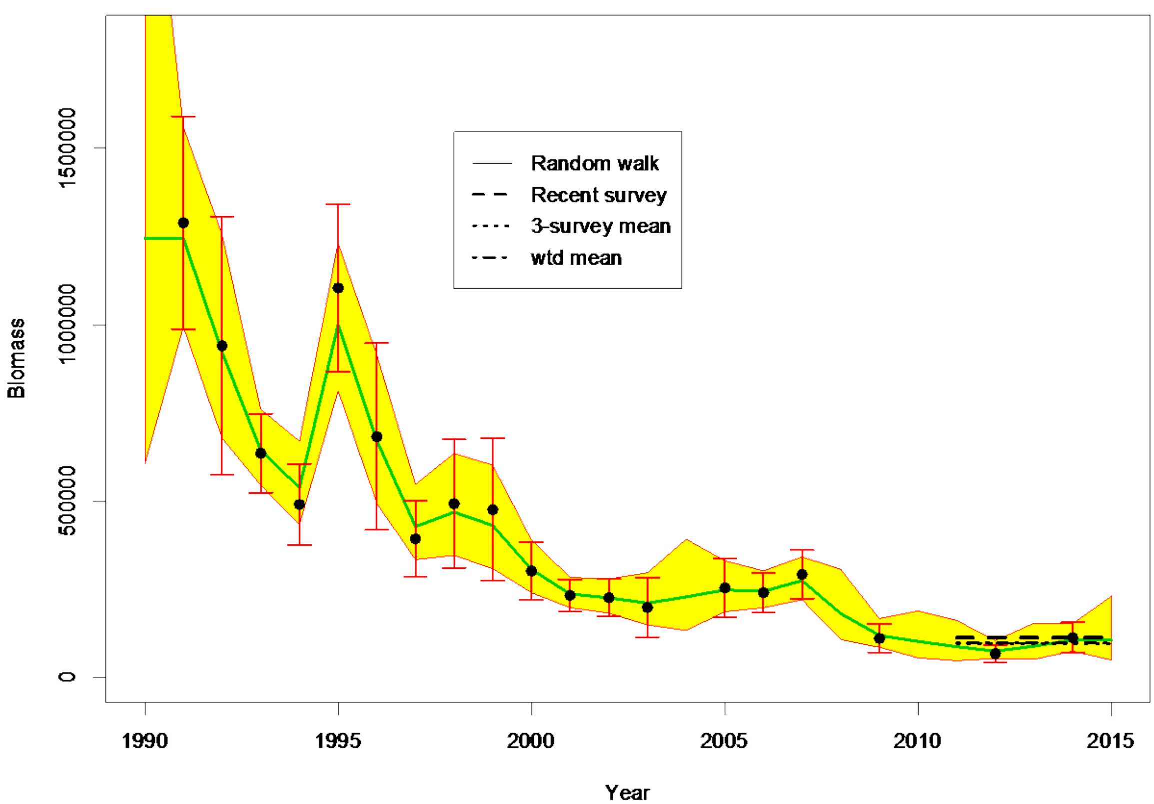

Figure 1B.7. Bogoslof Island pollock survey estimates fitted to a process error model for averaging recruitment. The shade represents the approximate 90% confidence interval from the model. Note that the lines described in the legend appear for the last few years and are difficult to distinguish given the scale.