Chapter 1b: An age-structured assessment of pollock (*Theragra chalcogramma*) from the Bogoslof Island Region

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Executive Summary

In 1987 pollock catch peaked in the Bogoslof region (INPFC area 518) with over 370,000 tons reported. During the period from 1985 to 1991, a total of 932,996 t of pollock were caught in this region. NMFS subsequently closed this area to directed pollock fishing (1992-2005) due in part to agreements under the Convention on the Conservation and Management of the Pollock Resources in the Central Bering Sea. Under this convention, the Bogoslof spawning aggregations are linked to the abundance of pollock found in international waters of the Aleutian Basin. As part of the monitoring program for the Convention, 17 annual Echo Integration Trawl (EIT) surveys of Bogoslof pollock abundance have been undertaken since 1988. This document presents an integrated analysis of these data through an age-structured assessment. Results from these analyses suggest that the survey data are very informative and that the current spawning stock size may be nearly 2-fold higher than the $B_{40\%}$ level (or about 77% of the $B_{100\%}$ level). Estimates of natural mortality from these data are somewhat higher than previously assumed values for pollock in this region (0.256 compared to 0.20). The extent to which this stock is vulnerable to fisheries in other regions (e.g., the EBS shelf and in Russian waters) is a key question. As with pollock observed in the US, Russian, and international zones, the 1978 year class dominated the Bogoslof population; its strength is more than 10 times the average year class strength. Favorable environmental conditions are thought to play a major role in the production of year-classes of this magnitude. This high level of natural variability should be considered in management recommendations, particularly in setting realistic target stock levels.

Summary of Major Changes

<u>Changes to the input data</u>

In the winter of 2006 an echo-integration trawl (EIT) survey was conducted and the biomass estimate from this research was included in this assessment. The relative estimation errors as presented in the survey reports were included as part of the likelihood weighting (previously, a constant CV was assumed).

A separate catch time series was compiled which assumed that 60% of the Donut Hole catches could be attributed to the Bogoslof region stock.

Changes in the assessment methodology

The same model as presented in 2005 was used for these analyses.

Changes in the assessment results

The age structured model estimates indicate that this stock is above the $B_{40\%}$ level and hence could qualify for Tier 3a recommendations under Amendment 56 of the FMP. This results in maximum permissible ABC values of:

Year	ABC	OFL
2006	138,800 t	173,200 t
2007	173,000 t	216,300 t

These values are based on assuming that the Aleutian Basin catch time series is the most appropriate value and that the strong 1978 year class was anomalous (i.e., not solely from the Bogoslof Island spawning stock but also from other regions). Given the continued uncertainty about stock structure and lack of understanding on where Bogoslof pollock pre-recruits reside, it seems prudent to continue to set the ABC at levels suitable for bycatch in other fisheries.

Response to SSC comments

In their December 1999 minutes, the SSC commented:

> "*The SAFE contains an interesting [Bogoslof region] age-structured model for this stock using only data from the Bogoslof surveys. If we were willing to ignore the connection of Bogoslof pollock to the Aleutian Basin, then this model could provide a basis for determining ABC. However, we continue to believe that Bogoslof pollock are related to the Aleutian Basin stock, and therefore, ignoring data from the entire stock does not constitute use of best available information for this stock.*"
>
> *In their December 2005 minutes the SSC notes that the authors have not yet been able to explore the effect of Donut Hole catches in the 1980s on the stock assessment results. Therefore, the SSC agrees with the Plan Team to postpone acceptance of the model until this research is done.*

Adding the reported catches from the Donut hole to the Bogoslof catches and analyzing results was attempted. Since the Central Bering Sea convention assumes that 60% of the Aleutian Basin pollock spawns in the Bogoslof region, the catches from the Donut hole were discounted by 60%. This results in values of $B_{40\%}$ that are between 77% and 130% higher depending assumptions about whether the 1978 year class is included. Using $B_{35\%}$ as a proxy for B_{msy}, the corresponding values range from 193 - 456 thousand t of female spawning biomass. This is substantially lower than past "target" values used by the SSC of 2 million t of total biomass.

Introduction

Alaska pollock (*Theragra chalcogramma*) 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 spawning in adjacent 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 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 successively moving toward this region prior to spawning (Smith 1981, Shuntov et al. 1993). 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. 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 EIT survey since 1988 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. 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, and 2000, 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). Strong year classes of pollock in Bogoslof may be functionally related to abundance on the shelf.

Fishery

Prior to 1977, few pollock were caught in the Donut Hole or Bogoslof region (Low and Akada 1978). Japanese scientists first reported significant quantities of pollock in the Aleutian Basin in the mid-to-late 1970's, but large scale fisheries did not occur until the mid-1980's in the Donut Hole. By 1987 significant components of these catches were attributed to the Bogoslof Island region (Table 1b.1), although the actual locations are poorly documented. The Bogoslof fishery primarily targeted winter spawning-aggregations. Since 1992, the Bogoslof management district has been closed to directed pollock fishing. During summer months, pollock distribution is diffuse and no directed pollock fishery has occurred.

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 (recall that the Bogoslof management district was not yet established). However, after March 23, 1991 the EBS region was closed to fishing and some effort was re-directed to the Aleutian Islands region but adjacent to 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). Pollock retention levels are variable and have increased as bycatch levels from other fisheries in this area have increased (Table 1b.2).

Data

Fishery

We estimate the catch-at-age composition using the methods described by Kimura (1989) and modified by Dorn (1992). Age-length keys were constructed from length-stratified age data by stratum and sex, then applied to randomly sampled length frequency data. Length sample sizes are low except during 1985-1991 (Fig. 1b.1; Table 1b.3). The resultant catch-at-age compositions show the strong 1978 year-class through the population as it grew over time. Indeed, in the one year where sufficient age-determination samples were collected and processed (1987) the number of 9-year olds dominated the catch (Table 1b.4).

Echo-integration trawl (EIT) surveys

The National Marine Fisheries Service has conducted echo-integration-trawl (EIT) surveys for Aleutian Basin pollock spawning in the Bogoslof Island area annually since 1988, except that the survey was not conducted in 1990 or 2004, and in 1999, the survey was conducted by the Fisheries Agency of Japan. Survey reports have appeared in various publications (see list in Ianelli et al., 2005). The impact of strong year-classes, particularly for 1978 can be seen in the time series of survey length frequencies (Fig. 1b.2).

The timing of the survey has varied in different years but has generally occurred in late February and/or early March (Fig. 1b.3). Sample sizes for lengths, weights, and ages have been quite high (Table 1b.5).

Survey abundance declined between 1988 and 1994, was stable and variable, then dropped again to the level it has maintained since 2000 (Fig 1b.4; Table 1b.6). The 1989 year class recruited to the Bogoslof Island area and was partly responsible for the 1995 increase (Table 1b.7), but the abundance of all ages increased between 1994 and 1995. The decrease between 1995 and 1996 was followed by a continued decline in 1997, suggesting that the 1995 estimate may be high, or that conditions in that year affected the apparent abundance of pollock. The 1996 year class has appeared to some degree in the 2005 survey, while the 1999 and 2000 year classes appear to be strong. The locations of pollock concentrations seen in the 2006 survey is similar to that of recent years (Fig. 1b.5).

Analytic approach

Model structure

The age-structured analysis was conducted using the AMAK model (as is used for the Aleutian Islands pollock and BSAI Atka mackerel stocks). The technical aspects of this model are presented in these reports (Barbeaux et al. 2004, Lowe et al. 2004). Briefly, the model structure is developed following Fournier and Archibald's (1982) methods, with a number of similarities to Methot's extension (1990). The model is implemented using automatic differentiation software developed as a set of libraries under the C++ language (AD Model Builder). The catch-equation was formulated assuming fishing mortality occurred instantaneously at the mid-point of the year. The first age of recruitment was set at age 5 since younger fish are rarely found in the survey or the fishery. Fish of age 15 and older were pooled into a single age group (labeled 15+).

Parameters estimated independently

Natural Mortality and maturity at age
Wespestad and Terry (1984), estimated natural mortality to be about 0.2. Here, this assumption was relaxed and estimated within the model. Maturity at age was assumed to be (Ianelli et al. 2004):

Age	5	6	7	8	9	10	11	12	13	14	15+
Prop. Mature	0.842	0.902	0.948	0.964	0.970	1.000	1.000	1.000	1.000	1.000	1.000

Length and Weight at Age
EIT survey estimates of mean body-weight at age by year, sexes combined (Table 1b.8) were used to convert model estimates of catch-at-age (in numbers) to model estimates of total annual harvests (by weight). The mean body weight values were computed by dividing the EIT estimated biomass-at-age by the estimated population numbers-at-age. The 2004 data were computed as averages from the 2005 and 2003 average weights at age.

EIT survey catchability
For the models presented here, survey catchability was assumed to equal 1.0—implying that the survey represents an absolute abundance index.

Parameters estimated conditionally

In total, 61 parameters were estimated. These include vectors describing recruitment variability in the first year (as ages 5-15 in 1977) and the recruitment deviations (at age 5) from 1977-2006. Additionally, projected recruitment variability was also estimated (using the estimated variance of past recruitments) for 10 years (2006-2015). The two-parameter stock-recruitment curve is included in addition to a term that allows the average recruitment before 1977 (that comprises the initial age composition in that year) to have a mean value different from subsequent years. With the value for recruitment variability about the curve, the total for recruitment-related parameters is 53.

Fishing mortality is parameterized to be the same for all ages greater than age 6 since this fishery comprises mainly spawning aggregations and only one year of fishery age composition data is available. As with the survey data, the ages 5 and 6 occur less commonly in this area and hence the vulnerability for these ages is estimated (resulting in 6 parameters, 3 each for the survey and fishery). As noted above, natural mortality is estimated as a free parameter.

The likelihood components can thus be partitioned into the following groups:

- Log-normal indices of abundance for the EIT survey (values of σ=0.2 were assumed)

- Fishery and survey proportions-at-age estimates (multinomial with effective sample sizes presented in Table 1b.9).
- Slight selectivity constraints on ages 5 and 6 for both the survey and fishery, constant value for ages 7 and older
- Stock-recruitment: non-informative prior distribution assumed to fit the stochastic stock-recruitment relationship within the integrated model

Model evaluation

In 2005 seven alternative models were evaluated. These examined assumptions about stock-recruitment productivity, natural mortality, survey catchability, and the extent of the survey index area. Rather than completely repeat those analyses here, a single model where the stock-recruitment parameters and natural mortality were estimated and survey catchability was assumed to equal 1.0 was used. From initial model runs, this latter assumption proved important since with the added Donut Hole catch, the population levels tended towards unreasonably high levels (when survey catchability was estimated, it went to very small values). For evaluation purposes, the impact of adding in historic Donut-hole catches to the Bogoslof region catches was considered. As shown below, two alternative assumptions about projections are also considered since they have large implications on biomass reference points and maximum permissible ABC levels.

Results

The main model results are summarized in Table 1b.10. Natural mortality was similar to last year's estimate but slightly higher for model 1 and slightly lower for model 2. The impact of the 2006 survey information was small relative to last year's assessment but the effect of adding the Aleutian Basin catches was quite high, more than doubling the estimated peak biomass levels (Fig. 1b.6). While the fits for Model 2 (including the Aleutian Basin catches) were somewhat worse than for Model 1, it was adopted since assigning the Aleutian Basin catches to the Bogoslof region seems most relevant given current stock-structure hypotheses.

The estimated selectivity patterns are similar for both the survey and fishery (Fig. 1b.7), which is unsurprising because the timing and location of the fishery and the EIT survey largely overlap.

The overall trend in abundance relative to the EIT survey time series shows a series of positive residuals during the late 1980s and early 1990s (Fig. 1b.8). The fit to the EIT survey age composition data shows some variability in the estimates of above-average year-classes (Fig. 1b.9). The proportions-at-age observed in the survey are generally consistent with what appeared in the fishery from 1987 (Fig. 1b.10).

Estimated numbers-at-age are presented in Table 1b.11 and estimated catch-at-age presented in Table 1b.12. Estimated summary biomass (age 5+), female spawning biomass, age 5 recruitment, and full-selection fishing mortality for Model 2 is given in Table 1b.13. A comparison of these biomass levels, together with the predicted and observed survey estimates, is given in Figure 1b.11.

Abundance and exploitation trends

The abundance and exploitation pattern estimated from Model 2 shows that the fishing mortality rate was high during the late 1980s when the largest removals reported from this region occurred (Fig. 1b.12). Biomass levels increased from 1979 to the mid-1980's (Fig. 1b.13; Table 1b.13) primarily due to the recruitment of the strong 1978 year class (Table 1b.11). Compared to last year's assessment, the peak stock size this year is estimated to be substantively higher, while the recent stock levels are very similar (Table 1b.14).

Recruitment

As with pollock observed in the US, Russian, and international zones, the 1978 year class dominated the Bogoslof population as a major event. For the Bogoslof region the magnitude of this year-class is more than 10 times the average (Fig. 1b.14). Favorable environmental conditions are thought to play a major role in the production of year-classes of this magnitude. For the Bogoslof region, density dependent processes affecting subsequent recruitment likely occur outside of this region since the area is relatively small and the winter spawning aggregations appear to disperse or move to other regions. Since this and issues related to stock structure remain uncertain, harvest recommendations based on a fitted stock-recruitment relationships were avoided (Fig. 1b.15).

Projections and harvest alternatives

Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Reference points related to maximum sustainable yield (MSY) were estimated but considered inappropriate. Therefore, reference points for pollock in the Bogoslof region are based solely on Tier 3 of Amendment 56. The reference point estimates varied widely depending on the model and the inclusion of the 1978 year class (Table 1b.15; Fig. 1b.16). Since such a large part of the removals from the Aleutian Basin consisted of the 1978 year class, and that this year-class is the largest on record for the EBS shelf region, it seems that assuming all of the production arose from the Bogoslof spawning stock (or at least 60% of it) is too high. Therefore, the 1978 year class as estimated in the present model is treated as an anomalous event and not included for projection purposes. The reference points (excluding the 1978 year class estimate) are thus:

$B_{100\%}$ = 551,825 thousand t female spawning biomass

$B_{40\%}$ = 220,730 thousand t female spawning biomass

$B_{35\%}$ = 193,139 thousand t female spawning biomass.

Standard Harvest Scenarios and Projection Methodology

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3, of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2006 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2006 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2006. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2007, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2006 recommended in the assessment to the *max* F_{ABC} for 2007. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.) The results from this scenario were omitted since they are the same as Scenario 1.

Scenario 3: In all future years, F is set equal to the 2002-2006 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 4: In all future years, F is set equal to F75%. (Rationale: This scenario was requested from public comment on the DSEIS proposed in 2006.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2006 or 2) above ½ of its MSY level in 2006 and above its MSY level in 2017 under this scenario, then the stock is not overfished.)

Scenario 7: In 2007 and 2008, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2018 under this scenario, then the stock is not approaching an overfished condition.)

Projections and status determination

For the purposes of these projections, we present results based on selecting the $F_{40\%}$ harvest rate as the max F_{ABC} value and use $F_{35\%}$ as a proxy for F_{msy}. Scenarios 1 through 7 were projected 14 years from 2006 (Table 1b.16). Under Scenario 1, the expected spawning biomass is projected to increase to above the $B_{40\%}$ by the year 2007. Under this scenario, the yields are expected to vary between 50 – 200 thousand tons. If the highly conservative catch levels (estimated from the last 5 years) are to continue, then the stock is projected to increase.

Any stock that is below its minimum stock size threshold (MSST) is defined to be overfished. Any stock that is expected to fall below its MSST in the next two years is defined to be approaching an overfished condition. Harvest scenarios 6 and 7 are used in these determinations as follows:

Is the stock overfished? This depends on the stock's estimated spawning biomass in 2007:

a) If spawning biomass for 2007 is estimated to be below ½ $B_{35\%}$ the stock is below its MSST.
b) If spawning biomass for 2007 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c) If spawning biomass for 2007 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest scenario 6 (Table 16). If the mean spawning biomass for 2018 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario 7:

a) If the mean spawning biomass for 2009 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b) If the mean spawning biomass for 2009 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c) If the mean spawning biomass for 2009 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2018. If the mean spawning biomass for 2018 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

For scenarios 6 and 7, we conclude that pollock is not below MSST for the year 2007, nor is it expected to be approaching an overfished condition based on Scenario 7.

Specification of OFL and Maximum Permissible ABC

In this section standard age-structured results are presented for a Tier 3a (amendment 56) ABC calculation. Past methods and a recommendation are presented in the subsequent section. For Model 2, the year 2006 female spawning biomass is estimated to be 198,446 thousand tons (at the time of spawning, assuming the stock is fished at F40%). This is slightly below the $B_{40\%}$ value of 220,730 but above the $B_{35\%}$ value of 193,139. The maximum-permissible ABC and OFL levels are thus 138,800 t and 173,200 t, respectively. The values for 2008 (assuming 2007 catches are similar to 2006) gives ABC and OFL of 173,000 t and 216,300 t, respectively

ABC Recommendation

Since 1999 the North Pacific Fishery Management Council (NPFMC) has generally been presented with a number of alternative methods for computing ABC values for the Bogoslof region. These have included:

1. Using a biomass-adjusted harvest rate rule (with 2,000,000 ton estimate as a target stock size) with an estimate of a F_{ABC} based on growth, natural mortality, and maturation rate.
2. Using a harvest rate as a simple fraction of natural mortality rate (e.g., F_{ABC} =0.75M).
3. An approach using the age-structured model presented in this document.

Historically, the NPFMC Science and Statistical Committee (SSC) considered the third approach using the age-structured model to be inappropriate since it was thought this region only covered part of the stock. While this may still be the case, the analysis carried out here is intended to provide some contrast and provides a more complete evaluation of the data from this region.

The approach 1) and 2) above are provided below for comparison (along with alternative assumptions about F_{ABC} level for 1). Using method 1) above and given the 2006 survey estimate of exploitable biomass of 0.253 million t and M = 0.2 and considering of a target stock size of 2 million tons, the F_{ABC} level is computed as:

$$F_{abc} \le F_{40\%} \bullet \left(\frac{B_{2006}}{B_{\text{Target}}} - 0.05 \right) \Big/ (1 - 0.05) \ .$$

Assuming that $F_{40\%}$ = 0.27 (as in past assessments), this gives a fishing mortality rate of 0.0217 that translates to an exploitation rate of 0.0215. This value multiplied by the most recent survey estimate (240,000 t), gives a **2007 ABC of 5,218 t for the Bogoslof region.** The value assumed for $F_{40\%}$ that is critical for this calculation was based on uncertain assumptions about selectivity, natural mortality, growth, and maturation. Some of these assumptions were reevaluated here using a simple knife-edged selectivity at age 4 and age 5. Female pollock were specified to be 50% mature by age 5 and immature for younger pollock and 100% mature for older pollock with a natural morality of 0.3. This results in an $F_{40\%}$ level of 0.22 for the age-4 knife edge assumption and $F_{40\%}$ = 0.33 for the age-5 knife-edge assumption. These two scenarios provide ABCs for 2007 that would be 4,252 t or 6,378 t for the age-4 and age-5 knife edge assumptions, respectively. Clearly, these rules are sensitive to assumptions about expected selectivity, assumed growth, natural mortality, and maturation rates.

The approach for computing ABC levels under 2) above (a Tier 5 computation) simply uses the most recent survey biomass estimate applied to an adjusted natural mortality. Given a value of $M=0.3$ then the ABC level would be (2006 survey biomass $\times M \times 0.75$) of **54,000 t** at a biomass of 240,000 t. With $M = 0.2$, the ABC would be 36,000 t.

The age-structured model presented here provides a number of new results. First, the value estimated for $F_{40\%}$ (assuming the selectivity and natural mortality are as estimated and given the assumed proportion mature at age) is higher than that assumed above (although the exploitation rate—catch over total biomass—is about 30%). Also, the reference points are quite different. Assuming that the 2,000,000 t "target" represents ~1 million t of female spawning biomass, then the target of 220,730 t of female spawning biomass presented above is substantially smaller. The current Bogoslof stock size is about nearly two times the target level ($B_{40\%}$) and about 77% of the "unfished" level (which given observed recruitment at age 5 to this region is 551,825 t of female spawning biomass). The maximum-permissible ABC using the age-structured model gives a 2007 ABC level of 138,800 t.

In summary, there is a broad range of ABC levels that have been calculated under the NPFMC guidelines. The third approach (age-structured model) results in the highest ABC levels. The age-structured model, while currently under review by the SSC, could be argued to represent an alternative method to set ABCs and subsequent TACs. Given the current uncertainty about stock structure and our lack of understanding on where Bogoslof pollock pre-recruits reside, it seems prudent to set the ABC at levels suitable for bycatch in other fisheries. This would be closest to the recent 5-year average fishing mortality level (Scenario 4) which indicates an ABC level of 471 t. A summary of the results is given in Table 1b.17.

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%/yr to over 400 individuals, including 80+ pups, 159 adult females, 22 territorial males, and 188 subadult males. They noted that 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 survey efforts counted 1,123 adult males, a substantial increase over this time period (L. Fritz, AFSC, pers. comm.). 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.

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Tables

Table 1b.1 Catch in tons from the Donut Hole, the Bogoslof Island area, and the Bogoslof region assuming 60% of the Donut Hole catch was part of the stock corresponding to the Bogoslof region, 1977-2006.

Year	Donut Hole (t)	Bogoslof Island (t)	Total (t)	Bogoslof Island + 60% of Donut Hole catch
1977		11,500	11,500	11,500
1978		9,600	9,600	9,600
1979		16,100	16,100	16,100
1980		13,100	13,100	13,100
1981		22,600	22,600	22,600
1982		14,700	14,700	14,700
1983		21,500	21,500	21,500
1984	181,200	22,900	204,100	131,620
1985	363,400	13,700	377,100	231,740
1986	1,039,800	34,600	1,074,400	658,480
1987	1,326,300	377,436	1,703,736	1,173,216
1988	1,395,900	87,813	1,483,713	925,353
1989	1,447,600	36,073	1,483,673	904,633
1990	917,400	151,672	1,069,072	702,112
1991	293,400	316,038	609,438	492,078
1992	10,000	241	10,241	6,241
1993	1,957	886	2,843	2,060
1994		556	556	556
1995		334	334	334
1996		499	499	499
1997		163	163	163
1998		136	136	136
1999		29	29	29
2000		29	29	29
2001		258	258	258
2002		1,042	1,042	1,042
2003		24	24	24
2004		100	100	100
2005		100	100	100
2006		100	100	100

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

Year	Discard	Retained	Total	Percent Discard
1991	20,327	295,711	316,038	6%
1992	240	1	241	100%
1993	308	578	886	35%
1994	11	545	556	2%
1995	267	66	334	80%
1996	7	492	499	1%
1997	13	150	163	8%
1998	3	133	136	2%
1999	11	18	29	39%
2000	20	10	29	67%
2001	28	231	258	11%
2002	12	1,031	1,042	1%
2003	19	5	24	79%
2004	0.01	0	0.01	-
2005	0.016	0.002	0.018	-

Table 1b.3. Numbers of fishery samples used for lengths (measured), otoliths collected ("Collected") and number of age determinations (Aged) made for 1978-2004. These represent pollock as sampled by the NMFS observer program. Note that all otolith collections included a body weight measurement.

Lengths

Year	Male	Female	Unsexed	Total
1978	25	47	2	74
1979	80	65		145
1980	42	49		91
1981	408	557		965
1982	151	267		418
1983	231	239		470
1984	239	513		752
1985	470	318		788
1986	7,593	10,467		18,060
1987	77,860	98,333	10	176,203
1988	52,848	40767	3	93,618
1989	391	322		713
1990				
1991	73,550	67257	365	141,172
1992			12	12
1993				
1994				
1995	101	156		257
1996	511	486		997
1997	146	115		261
1998	93	78		171
1999	30	36	20	86
2000	41	60		101
2001	4	16		20
2002	8	12		20
2003				
2004	11	11		22
Total	214,833	220,171	412	435,416

Otoliths

Year	Aged	Unaged	Total collected
1978	10		10
1981	18		18
1982	1		1
1983	21		21
1987	683		683
1991	188	1,637	1,825
1996		10	10
1997	17	2	19
1998	5	5	10
	943	1,654	2,597

Table 1b.4. Bogoslof Region walleye pollock catch at age (in thousands of fish) estimates based on observer data, 1987.

Year	6	7	8	9	10	11	12	13	14	15+	Total
1987	18,727	28,386	65,466	228,550	60,057	44,416	34,412	23,612	12,416	10,454	526,495

Table 1b.5. Number of hauls and sample sizes for age and length data taken during the Bogoslof pollock EIT surveys, 1988-2006. The 1999 survey effort from the Japanese vessel is not included.

Year	Number of hauls	Number of pollock sampled for length	Number of pollock sampled for ages
1988	20	5,708	888
1989	11	3,238	643
1991	16	3,639	818
1992	13	3,312	1,004
1993	13	3,173	1,056
1994	13	3,162	890
1995	19	6,003	1,213
1996	17	5,161	1,271
1997	16	5,066	1,121
1998	14	4,013	1,182
2000	11	2,782	621
2001	14	3,993	815
2002	11	3,276	988
2003	5	1,804	346
2005	19	4,095	1,000
2006	14	3,681	593

Table 1b.6. Abundance at age (millions) of pollock as surveyed in the Bogoslof region (standard area), 1988-2005. Note that in 1999 the Fishery Agency of Japan conducted the survey.

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
1	0.0	0.0		0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
2	0.0	0.0		3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0		0.0
3	0.0	0.0		0.0	1.0	0.7	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	9.5	0.0		0.0
4	0.0	5.8		2.2	1.7	33.3	21.5	6.4	0.4	0.2	0.2	1.8	0.5	0.8	4.9	8.4		5.4
5	27.9	15.2		11.7	26.6	16.7	86.2	74.9	5.6	3.7	11.4	5.4	5.7	14.1	2.7	6.0		81.0
6	326.7	58.4		46.3	54.0	43.8	25.8	278.3	96.1	15.8	60.7	28.7	4.4	12.4	40.7	6.5		30.7
7	246.8	362.8		213.1	96.8	46.4	37.7	104.7	187.3	55.5	34.0	77.0	14.1	9.7	11.3	24.7		12.5
8	163.7	147.0		93.5	74.2	48.3	36.5	67.7	85.3	87.5	69.5	34.3	30.3	9.8	7.6	10.6		11.3
9	350.1	194.3		160.0	71.3	42.2	36.1	80.1	40.2	38.2	77.0	49.7	15.7	14.0	6.4	4.1		21.8
10	1200.9	90.7		44.1	54.8	28.3	16.9	53.4	37.0	27.7	32.1	74.8	28.4	12.0	6.6	4.5		7.1
11	287.8	1105.4		92.0	56.6	51.1	26.8	54.1	24.1	16.2	24.5	29.2	44.9	17.6	7.9	4.0		3.4
12	287.3	222.3		59.7	33.1	25.1	23.1	19.1	24.3	15.8	20.7	26.9	20.8	31.3	14.3	10.1		4.9
13	201.9	223.1		372.9	34.4	26.8	12.8	58.8	12.4	12.6	18.6	24.6	16.2	12.7	29.8	7.9		4.3
14	89.2	81.8		119.1	142.1	42.1	8.5	31.6	36.4	7.2	18.5	15.6	11.1	7.0	8.8	25.5		5.2
15	27.3	90.4		40.5	164.2	91.6	45.3	12.3	17.6	13.0	9.4	11.7	10.7	8.9	7.3	6.2		10.6
16	16.6	30.1		38.5	59.3	47.5	36.4	31.0	4.4	4.7	15.0	10.5	9.3	8.2	9.2	4.6		12.0
17	6.5	59.8		28.9	7.9	25.1	27.7	103.5	16.1	3.9	5.3	8.0	3.4	4.9	5.1	3.0		6.0
18	3.5	0.0		31.6	15.5	10.8	15.9	60.0	35.0	12.5	8.1	5.8	5.6	1.5	3.8	5.3		4.1
19	0.0	0.0		55.7	21.8	11.3	3.6	17.9	26.0	12.2	9.6	2.8	3.0	3.5	2.3	1.2		2.8
20	0.0	0.0		3.6	42.4	11.1	4.5	5.0	12.2	6.6	14.6	3.6	1.8	1.3	1.7	0.5		0.7
21	0.0	0.0		1.9	13.4	9.6	7.7	4.5	3.4	1.5	4.4	3.0	1.3	0.0	0.0	1.1		0.2
22	0.0	0.0		0.0	3.2	1.1	2.0	6.5	1.7	0.7	1.0	2.2	1.3	0.0	0.0	0.0		0.0
23	0.0	0.0		0.0	1.1	0.5	2.2	6.3	0.6	0.3	0.0	0.4	0.0	0.4	0.4	0.0		0.0
24	0.0	0.0		0.0	0.0	0.0	0.6	2.1	0.0	0.7	0.0	0.0	0.3	0.4	0.4	0.0		0.3
25	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0		0.0
Total	3,236	2,687		1,419	975	613	478	1,081	666	337	435	416	229	170	181	134		225

Table 1b.7. Biomass (tons) of pollock as surveyed in the Bogoslof region, 1988-2006. Note that in 1999 the Fishery Agency of Japan conducted the survey. These estimates are based on the biomass from the entire vicinity surveyed in each year rather than the specified “convention area” (see Ianelli et al. (2005) for a list of references documenting these surveys). “Relative Error” is the coefficient of variation assumed in fitting the model. Note that for 1988, 1989, and 1999 values were unavailable, hence they were set to the maximum value found from the other years. Source: McKelvey et al. 2006.

Year	Survey biomass estimates (t)	Survey area (nmi2)	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	240,000	1,803	12%

Table 1b.8. Annual average pollock weights-at-age (kg) used for the Bogoslof region assessment model. These values are used in the model for computing the predicted fishery catch (in weight) and for computing biomass levels for Bogoslof pollock. The italicized values used for 1977-1990 are the average from 1991-1995 whereas the values in 1999 and 2004 are averages from the year before and the year after. The weight at age in 2006 is the average from 2003-2005.

	5	6	7	8	9	10	11	12	13	14	15+
1977-1990	*0.677*	*0.744*	*0.827*	*0.942*	*1.043*	*1.105*	*1.151*	*1.148*	*1.170*	*1.155*	*1.113*
1991	0.520	0.538	0.671	0.798	0.931	0.986	1.022	0.993	1.012	0.976	0.969
1992	0.806	0.705	0.693	0.801	0.944	1.039	1.086	1.096	1.083	1.057	1.082
1993	0.716	0.893	0.927	0.971	1.042	1.084	1.161	1.078	1.118	1.116	1.122
1994	0.695	0.835	1.054	1.073	1.096	1.214	1.178	1.192	1.327	1.282	1.161
1995	0.650	0.749	0.790	1.068	1.201	1.203	1.306	1.383	1.312	1.343	1.229
1996	0.659	0.719	0.883	0.887	1.138	1.227	1.294	1.370	1.370	1.344	1.221
1997	0.560	0.673	0.894	1.081	1.152	1.367	1.415	1.420	1.434	1.482	1.373
1998	0.593	0.621	0.872	1.060	1.226	1.261	1.456	1.407	1.438	1.422	1.332
1999	*0.652*	*0.642*	*0.863*	*1.031*	*1.182*	*1.333*	*1.434*	*1.472*	*1.490*	*1.502*	*1.417*
2000	0.710	0.662	0.854	1.002	1.137	1.404	1.411	1.536	1.542	1.582	1.501
2001	0.819	0.900	1.003	1.180	1.287	1.358	1.502	1.593	1.583	1.565	1.513
2002	0.734	0.837	0.893	1.179	1.254	1.385	1.563	1.599	1.609	1.663	1.508
2003	0.897	0.952	1.057	1.150	1.469	1.847	1.805	1.815	1.815	1.842	1.752
2004	*0.771*	*0.886*	*1.069*	*1.218*	*1.399*	*1.635*	*1.780*	*1.831*	*1.824*	*1.864*	*1.833*
2005	0.645	0.819	1.081	1.285	1.328	1.422	1.755	1.846	1.832	1.885	1.914
2006	*0.771*	*0.886*	*1.069*	*1.218*	*1.399*	*1.635*	*1.780*	*1.831*	*1.824*	*1.864*	*1.833*

Table 1b.9. Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, and EIT surveys, 1987-2005.

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Fishery	200																		
EIT Survey		50	50		50	50	50	50	50	50	50	50	50	50	50	50	50		50

Table 1b.10. Results comparing fits for Models 1 and 2 with the analogous model from the 2005 assessment. Note that the relative error from McKelvey et al. (2006) was used in the current assessment. In 2005, a CV=0.20 was assumed for all survey years (hence, likelihood values for the survey index are not comparable).

		2005 Assess	Model_1	Model_2
Likelihood components				
	Fishery age composition	2.51	2.33	2.63
	Survey index	26.34	41.46	52.96
	Survey age composition	32.84	34.75	34.76
	Fishery selectivity smoothness	0.25	0.23	0.23
	Survey selectivity smoothness	56.28	59.04	99.89
	Recruitment likelihood	0.00	0.00	0.00
	Survey q prior	0.05	0.06	0.05
	Other priors	0.15	0.16	0.46
	Total -ln likelihood	120.02	139.68	192.18
	Number of parameters	60	61	61
Key parameters				
	Survey q	1.000	1.000	1.000
	Natural Mortality	0.262	0.271	0.257
	Steepness	0.365	0.343	0.348
	σ_R	0.854	0.867	1.045
Estimates				
	Age 5+ 2007 Biomass		458,000	491,000
	CV		12%	12%
	$F_{40\%}$	0.484	0.519	0.442
	$F_{35\%}$	0.654	0.706	0.588

Table 1b.11. Estimates of numbers at age for the Bogoslof region pollock stock under Model 2 (thousands).

Year	5	6	7	8	9	10	11	12	13	14	15+
1977	380,670	291,669	239,526	194,573	156,145	122,213	90,741	67,550	50,540	38,021	234,644
1978	782,782	293,716	224,437	183,565	149,114	119,665	93,660	69,541	51,768	38,732	208,962
1979	2,395,570	604,201	226,198	172,259	140,889	114,447	91,845	71,886	53,374	39,733	190,109
1980	2,836,810	1,847,750	464,581	173,114	131,834	107,826	87,589	70,291	55,016	40,848	175,903
1981	3,626,420	2,190,450	1,424,180	357,115	133,070	101,338	82,884	67,328	54,031	42,290	166,613
1982	2,835,570	2,799,470	1,687,410	1,093,670	274,239	102,188	77,820	63,649	51,703	41,492	160,422
1983	9,482,430	2,190,880	2,160,740	1,300,390	842,825	211,340	78,750	59,972	49,050	39,845	155,604
1984	1,684,650	7,326,290	1,690,900	1,664,960	1,002,020	649,439	162,848	60,681	46,211	37,796	150,603
1985	801,036	1,297,010	5,610,330	1,284,420	1,264,720	761,142	493,320	123,701	46,094	35,103	143,109
1986	578,767	615,265	988,023	4,220,710	966,282	951,462	572,614	371,130	93,062	34,677	134,071
1987	873,127	437,915	453,110	697,745	2,980,680	682,392	671,926	404,382	262,093	65,720	119,170
1988	350,877	643,221	303,186	283,601	436,718	1,865,600	427,108	420,558	253,102	164,044	115,723
1989	314,588	257,205	440,134	185,307	173,336	266,921	1,140,250	261,048	257,044	154,696	170,993
1990	169,835	225,774	167,264	241,801	101,804	95,228	146,641	626,432	143,414	141,215	178,927
1991	126,282	119,592	140,075	82,788	119,681	50,388	47,133	72,581	310,056	70,984	158,456
1992	114,497	86,634	69,403	59,107	34,934	50,502	21,262	19,889	30,627	130,834	96,817
1993	132,770	88,285	66,566	53,045	45,176	26,700	38,599	16,251	15,201	23,408	173,994
1994	302,655	102,581	68,138	51,292	40,874	34,810	20,574	29,742	12,522	11,713	152,109
1995	142,042	233,980	79,278	52,633	39,621	31,573	26,890	15,893	22,975	9,673	126,546
1996	70,149	109,825	180,878	61,269	40,677	30,621	24,401	20,781	12,282	17,756	105,275
1997	80,394	54,234	84,886	139,748	47,338	31,428	23,658	18,853	16,056	9,490	95,055
1998	42,007	62,164	41,932	65,621	108,033	36,594	24,295	18,289	14,574	12,412	80,819
1999	29,080	32,482	48,064	32,417	50,730	83,518	28,290	18,782	14,139	11,267	72,075
2000	37,897	22,487	25,117	37,165	25,066	39,227	64,580	21,875	14,523	10,933	64,443
2001	79,923	29,305	17,389	19,421	28,737	19,382	30,332	49,935	16,915	11,230	58,283
2002	37,297	61,791	22,651	13,435	15,006	22,204	14,975	23,436	38,582	13,069	53,709
2003	44,343	28,815	47,685	17,451	10,351	11,561	17,106	11,537	18,055	29,724	51,447
2004	70,173	34,290	22,281	36,871	13,493	8,003	8,939	13,227	8,921	13,961	62,763
2005	230,784	54,259	26,510	17,223	28,500	10,430	6,186	6,910	10,224	6,896	59,305
2006	156,590	178,450	41,951	20,493	13,314	22,032	8,063	4,782	5,341	7,903	51,176
Median	200,310	202,112	153,670	111,268	104,919	67,010	55,856	54,953	42,338	34,890	130,309
Average	960,334	744,000	568,761	427,107	313,840	222,006	154,109	103,364	67,583	43,515	125,571

Table 1b.12. Estimated catch numbers-at-age of Bogoslof region pollock for Model 2 (thousands).

	5	6	7	8	9	10	11	12	13	14	15+
1977	851	1,442	2,157	1,752	1,406	1,100	817	608	455	342	2,113
1978	1,459	1,211	1,684	1,378	1,119	898	703	522	389	291	1,568
1979	6,169	3,440	2,345	1,786	1,461	1,186	952	745	553	412	1,971
1980	4,219	6,077	2,782	1,037	789	646	524	421	329	245	1,053
1981	6,279	8,386	9,927	2,489	928	706	578	469	377	295	1,161
1982	2,425	5,293	5,809	3,765	944	352	268	219	178	143	552
1983	8,387	4,285	7,695	4,631	3,001	753	280	214	175	142	554
1984	7,472	71,850	30,192	29,729	17,892	11,596	2,908	1,083	825	675	2,689
1985	5,472	19,592	154,296	35,324	34,783	20,933	13,567	3,402	1,268	965	3,936
1986	13,022	30,611	89,496	382,318	87,527	86,185	51,868	33,617	8,430	3,141	12,144
1987	45,652	50,630	95,380	146,875	627,433	143,643	141,440	85,122	55,171	13,834	25,085
1988	20,397	82,683	70,957	66,373	102,208	436,619	99,959	98,426	59,235	38,392	27,083
1989	26,516	47,939	149,356	62,882	58,820	90,577	386,934	88,584	87,226	52,495	58,025
1990	18,642	54,800	73,916	106,855	44,989	42,082	64,803	276,830	63,377	62,405	79,071
1991	18,756	39,276	83,757	49,502	71,562	30,129	28,183	43,399	185,395	42,444	94,747
1992	333	557	812	692	409	591	249	233	358	1,531	1,133
1993	117	172	237	189	161	95	137	58	54	83	619
1994	82	61	74	56	45	38	22	32	14	13	166
1995	21	76	47	31	24	19	16	9	14	6	75
1996	15	54	161	54	36	27	22	18	11	16	94
1997	6	10	27	45	15	10	8	6	5	3	30
1998	3	10	12	19	31	11	7	5	4	4	23
1999	1	1	3	2	4	6	2	1	1	1	5
2000	1	1	2	3	2	3	5	2	1	1	5
2001	17	14	15	16	24	16	25	42	14	9	49
2002	35	127	85	50	56	83	56	88	145	49	201
2003	1	2	5	2	1	1	2	1	2	3	5
2004	7	8	10	16	6	3	4	6	4	6	27
2005	20	10	9	6	10	4	2	2	3	2	20
2006	13	34	14	7	5	8	3	2	2	3	18
Median	592	884	1,248	864	599	471	258	216	176	142	586
Average	6,213	14,288	26,042	29,929	35,190	28,944	26,478	21,139	15,467	7,265	10,474

Table 1b.13. Estimated Bogoslof region pollock Model 2 age 5+ begin-year biomass (with CV), female spawning biomass, age-5 recruitment (numbers), and full-selection fishing mortality rates, for 1977-2007.

Year	Age 5+	CV	Female spawning biomass	Age 5 Rec.	Full selection F
1977	1,890,100	18%	863,794	380,670	0.009
1978	2,091,000	19%	940,897	782,782	0.008
1979	3,328,200	18%	1,442,514	2,395,570	0.010
1980	4,709,700	16%	2,033,610	2,836,810	0.006
1981	6,464,700	13%	2,797,969	3,626,420	0.007
1982	7,517,900	11%	3,299,304	2,835,570	0.003
1983	12,792,000	8%	5,494,649	9,482,430	0.004
1984	12,329,000	7%	5,467,257	1,684,650	0.018
1985	11,178,000	6%	5,080,784	801,036	0.028
1986	9,940,800	5%	4,531,864	578,767	0.091
1987	8,384,500	4%	3,759,877	873,127	0.211
1988	6,004,600	4%	2,715,458	350,877	0.234
1989	4,238,800	3%	1,885,598	314,588	0.339
1990	2,664,700	3%	1,165,860	169,835	0.442
1991	1,531,400	4%	652,200	126,282	0.598
1992	796,560	6%	369,027	114,497	0.012
1993	734,060	5%	338,604	132,770	0.004
1994	802,310	4%	362,584	302,655	0.001
1995	765,070	4%	347,801	142,042	0.001
1996	690,140	3%	317,464	70,149	0.001
1997	636,000	2%	293,591	80,394	0.000
1998	561,840	1%	260,961	42,007	0.000
1999	485,580	1%	227,544	29,080	0.000
2000	426,760	2%	200,123	37,897	0.000
2001	403,250	3%	186,949	79,923	0.001
2002	355,600	4%	165,227	37,297	0.004
2003	319,790	5%	148,444	44,343	0.000
2004	309,420	6%	142,149	70,173	0.000
2005	407,000	10%	180,260	230,784	0.000
2006	446,890	13%	198,482	156,590	0.000
2007	491,490	12%	-	-	-

Table 1b.14. Estimated Bogoslof region pollock Model 2 age 5+ begin-year biomass (with CV), compared to the estimate from 2005 (Ianelli et al. 2005).

Year	Current Age 5+ Biomass	CV	2005 Assessment Age 5+ biomass	CV
1977	1,890,100	18%	1,051,600	19%
1978	2,091,000	19%	1,104,100	19%
1979	3,328,200	18%	1,461,600	19%
1980	4,709,700	16%	1,864,400	18%
1981	6,464,700	13%	2,373,000	16%
1982	7,517,900	11%	2,658,000	15%
1983	12,792,000	8%	4,283,900	14%
1984	12,329,000	7%	4,107,100	13%
1985	11,178,000	6%	3,755,500	12%
1986	9,940,800	5%	3,424,100	11%
1987	8,384,500	4%	3,125,900	10%
1988	6,004,600	4%	2,327,600	11%
1989	4,238,800	3%	1,977,700	10%
1990	2,664,700	3%	1,688,500	10%
1991	1,531,400	4%	1,299,200	11%
1992	796,560	6%	789,630	15%
1993	734,060	5%	725,830	14%
1994	802,310	4%	780,310	14%
1995	765,070	4%	739,960	13%
1996	690,140	3%	666,280	13%
1997	636,000	2%	614,050	13%
1998	561,840	1%	546,060	12%
1999	485,580	1%	476,980	12%
2000	426,760	2%	427,820	12%
2001	403,250	3%	421,330	13%
2002	355,600	4%	381,040	13%
2003	319,790	5%	355,120	13%
2004	309,420	6%	370,550	15%
2005	407,000	10%	591,490	20%
2006	446,890	13%	627,760	19%
2007	491,490	12%	-	-

Table 1b.15. Summary reference points for the two Bogoslof pollock models under different projection scenarios (sub-models 1b and 2b include the 1978 year class in the projections).

Model	*B100%%*	$B_{40\%}$	$B_{35\%}$	B_{2006}	Mean Recruitment	CV Recruitment
Model_1	312,185	124,874	109,265	187,305	170,064	0.928
Model_2	551,825	220,730	193,139	198,446	281,293	1.431
Model_1b	566,101	226,440	198,135	187,305	308,386	1.496
Model_2b	1,303,520	521,408	456,232	198,446	664,469	2.430

Table 1b.16. Projections of Model 2 catch, fishing mortality, and female spawning biomass for Bogoslof pollock for the 6 scenarios.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	B_{2006}
551,825	220,730	193,139	198,446

Catch	Max. Perm. ABC	Avg. F	$F_{75\%}$	No Fishing	Status Determ. 1	Status Determ. 1
2006	100	100	100	100	100	100
2007	138,830	362	32,251	0	173,193	138,830
2008	118,872	435	36,404	0	133,904	118,872
2009	119,740	527	42,162	0	132,957	153,200
2010	122,796	608	46,933	0	133,891	142,609
2011	124,340	680	50,786	0	133,795	137,140
2012	123,935	734	53,290	0	131,257	132,463
2013	122,884	779	55,200	0	130,379	130,790
2014	124,759	816	56,720	0	132,203	132,327
2015	126,377	850	58,253	0	135,185	135,215
2016	126,485	875	59,163	0	134,530	134,533
2017	125,549	893	59,757	0	132,703	132,701
2018	122,412	899	59,482	0	128,597	128,595
2019	119,907	903	59,223	0	126,689	126,688
Fishing M.	Scenario 1	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2006	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.400	0.001	0.082	0.000	0.526	0.400
2008	0.362	0.001	0.082	0.000	0.456	0.362
2009	0.344	0.001	0.082	0.000	0.442	0.467
2010	0.342	0.001	0.081	0.000	0.440	0.451
2011	0.343	0.001	0.081	0.000	0.441	0.445
2012	0.345	0.001	0.081	0.000	0.438	0.440
2013	0.343	0.001	0.081	0.000	0.437	0.437
2014	0.347	0.001	0.081	0.000	0.438	0.438
2015	0.344	0.001	0.081	0.000	0.440	0.440
2016	0.345	0.001	0.081	0.000	0.441	0.441
2017	0.345	0.001	0.081	0.000	0.438	0.438
2018	0.344	0.001	0.081	0.000	0.433	0.433
2019	0.340	0.001	0.081	0.000	0.432	0.432
Spawning biomass	Scenario 1	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2006	198,446	198,446	198,446	198,446	198,446	198,446
2007	237,593	250,450	247,807	250,479	233,710	237,593
2008	231,576	300,529	284,076	300,718	215,576	231,576
2009	235,027	346,348	316,049	346,706	214,719	231,436
2010	238,964	387,897	343,254	388,441	215,579	222,550
2011	237,527	419,722	360,985	420,458	212,308	215,002
2012	234,673	445,030	373,146	445,953	208,637	209,621
2013	237,468	470,573	386,991	471,670	211,498	211,833
2014	240,158	490,995	397,455	492,247	214,192	214,294
2015	243,485	509,057	407,094	510,445	217,409	217,435
2016	239,551	517,242	408,174	518,749	212,982	212,985
2017	237,914	524,975	410,085	526,584	211,261	211,259
2018	231,852	525,563	405,996	527,256	205,552	205,550
2019	229,937	527,337	404,308	529,098	204,237	204,236

Table 1b.17. Summary results for Model 2, Bogoslof region pollock. ABC and OFL levels for 2007 and 2008 are shown assuming catch to be the same as in recent years.

Age	5	6	7	8	9	10	11	12	13	14	15
M	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255
Prop mature females	0.421	0.451	0.474	0.482	0.485	0.500	0.500	0.500	0.500	0.500	0.500
Fish. Selectivity	0.196	0.488	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	Base model	Model 2
	Tier	3a
	Age 5+ 2007 begin-year biomass	484,140
	2007 Spawning biomass	198,446
	$B_{35\%}$	193,139
	$B_{40\%}$	220,730
	$B_{100\%}$	551,825
Full Selection F's		
	$F_{40\%}$	0.442
	$F_{35\%}$	0.589

Year	Catch	Max. Perm ABC	OFL	SSB
2007	100	138,800	173,200	250,500
2008		173,000	216,300	300,500

Figures

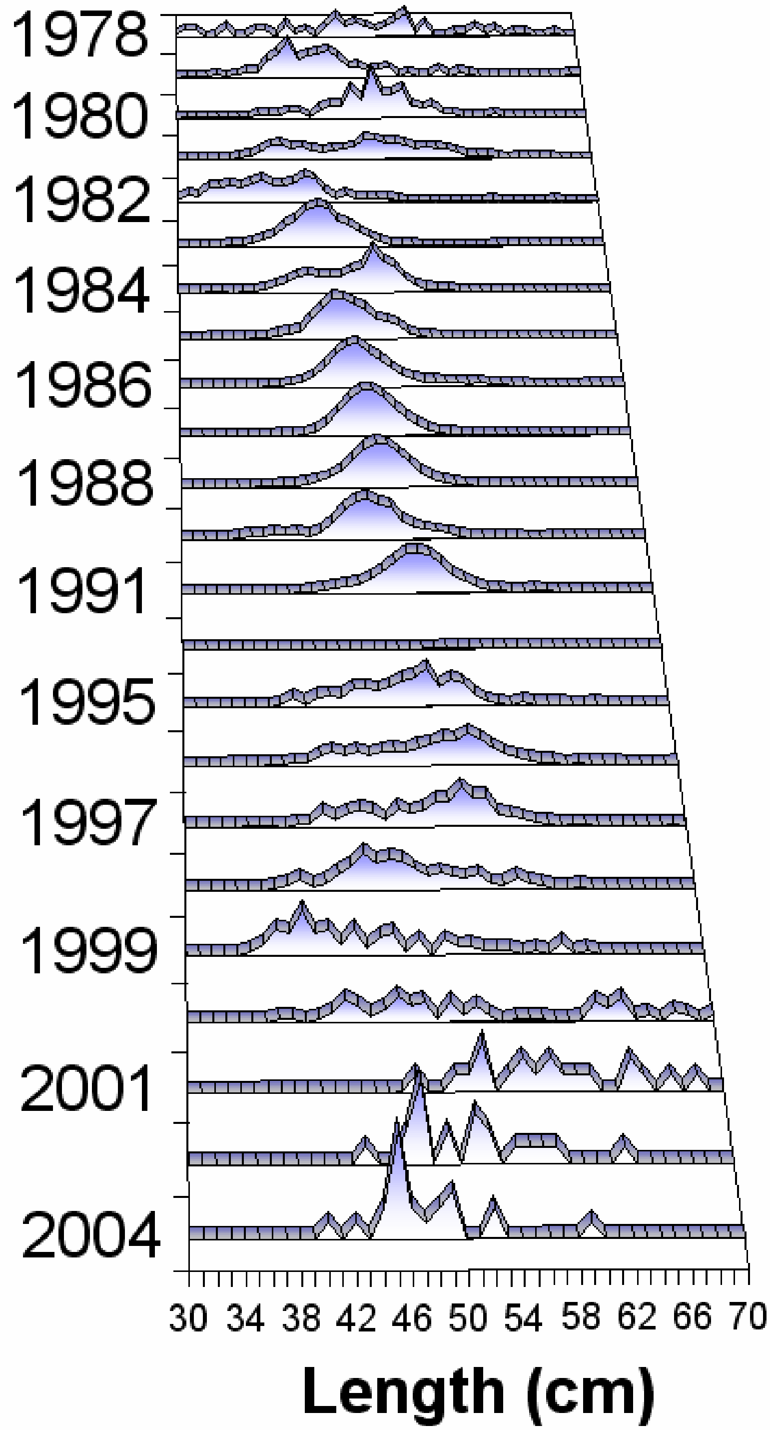

Figure 1b.1. Length frequency proportions of Bogoslof pollock based on observer data from fishery catches for 1978-2004. Note that sample sizes for most years (except 1985-1991) are very small.

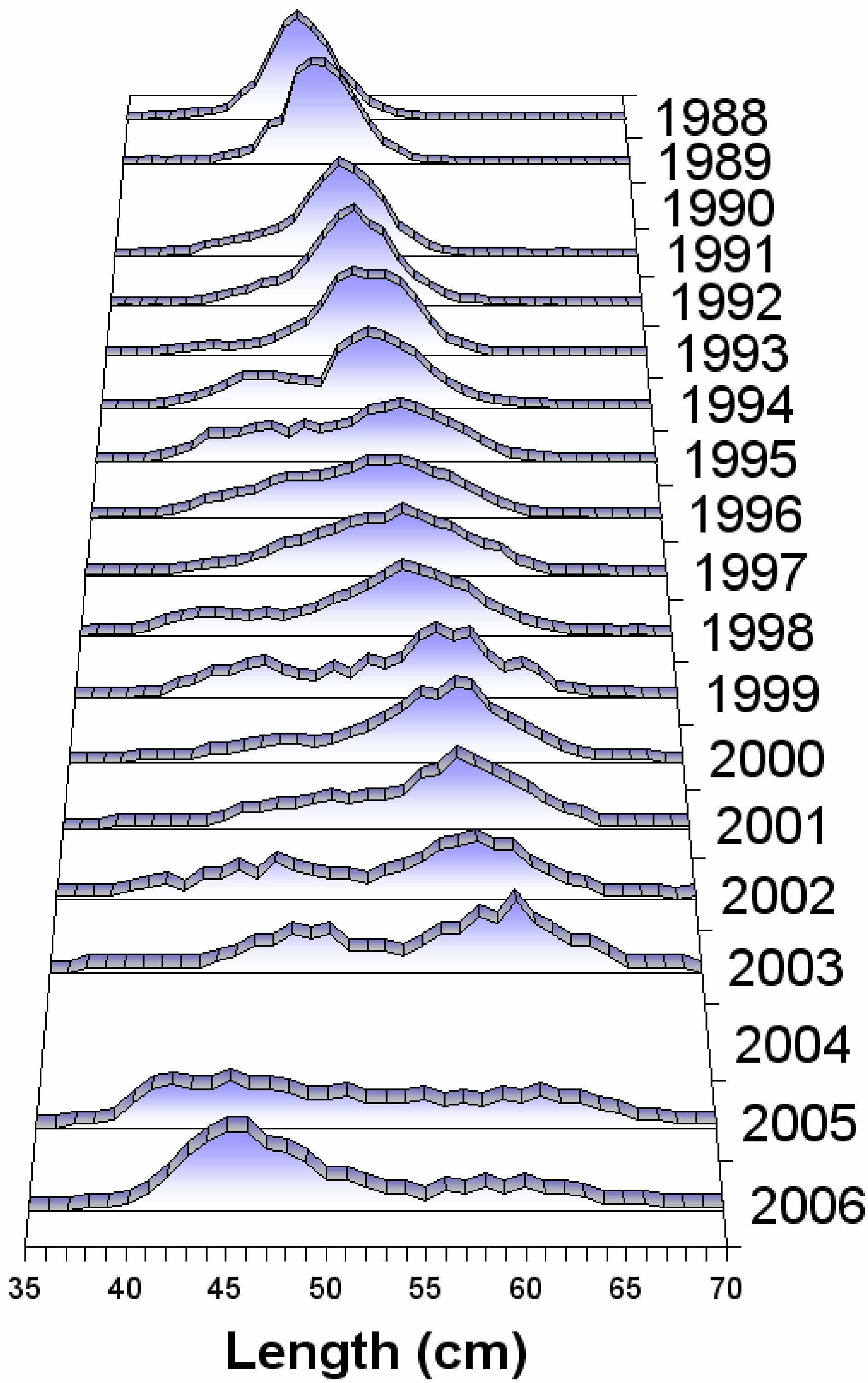

Figure 1b.2. Pollock proportion-at-length estimates from the 1988-2006 Bogoslof Area (INPFC area 518) EIT surveys. There were no surveys in 1990 and in 2004.

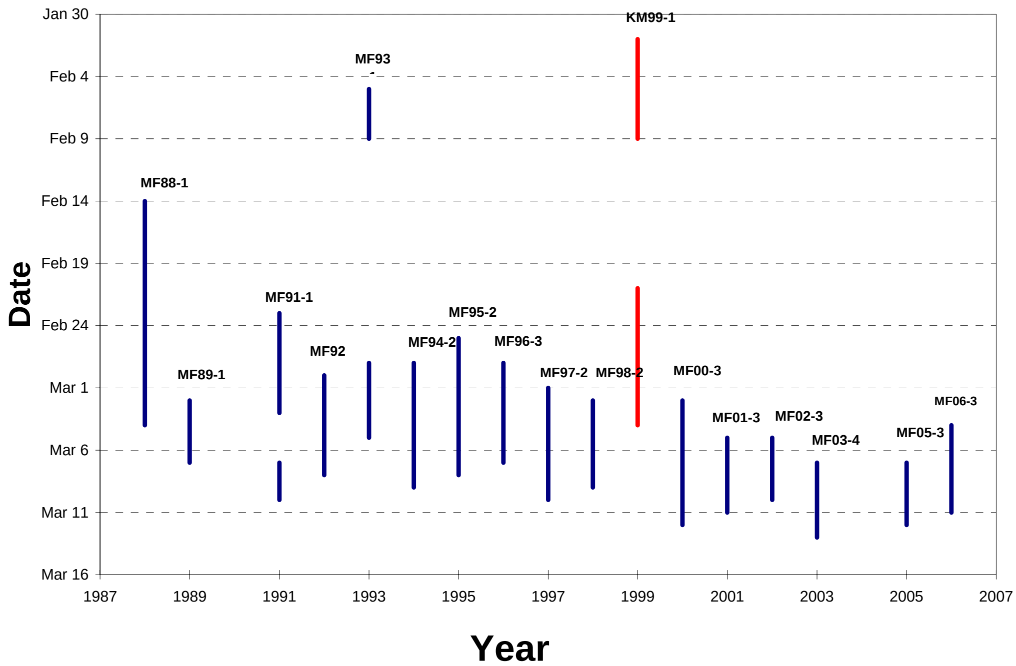

Figure 1b.3. Time periods of Bogoslof EIT surveys as conducted by AFSC (except in 1999 when the survey was conducted by the Japan Fishery Agency). Cruise names are listed at the beginning of each survey period.

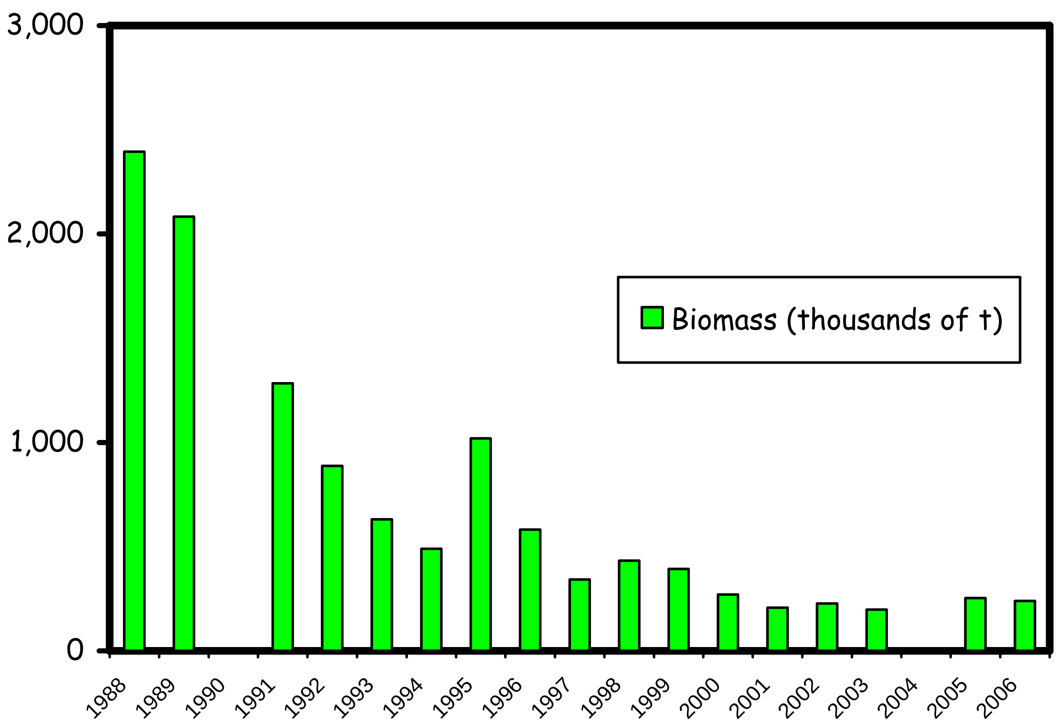

Figure 1b.4. Pollock biomass estimates from the 1988-2006 Bogoslof Area (INPFC area 518) EIT surveys in thousands of tons. There were no surveys in 1990 and in 2004.

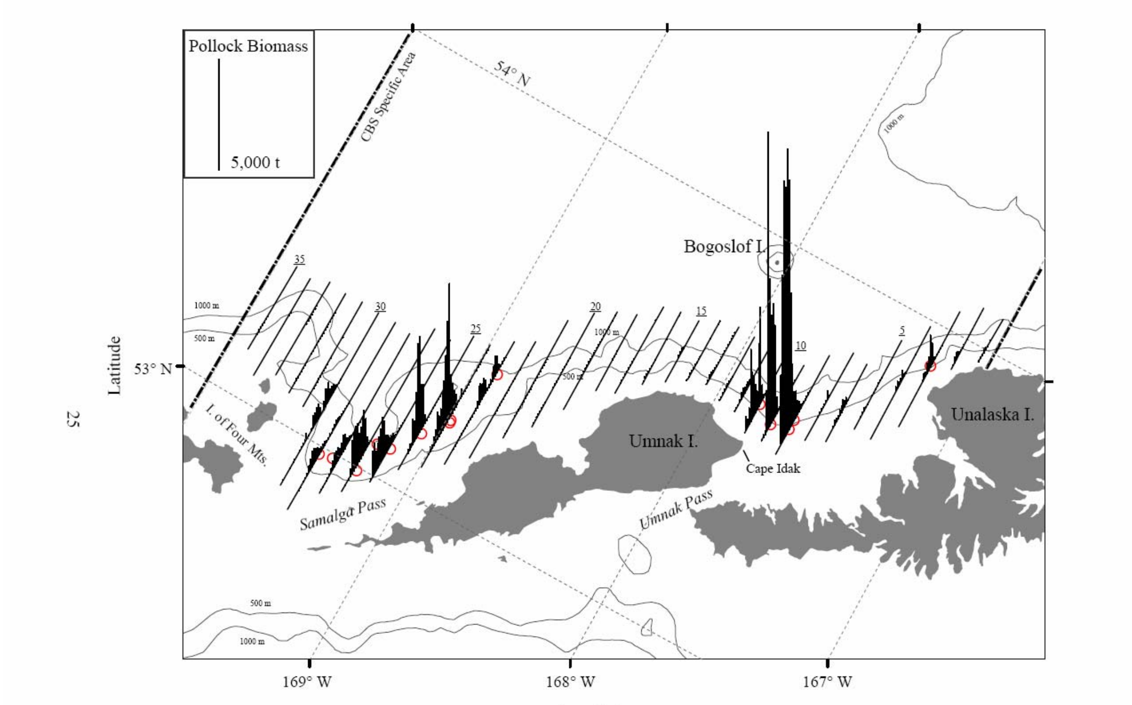

Figure 1b.5. Pollock biomass in metric tons (t) (vertical lines) and trawl hauls (circles) along tracklines from the winter 2006 echo integration-trawl survey of walleye pollock in the Bogoslof Island area. The Central Bering Sea Convention area is indicated by a dash-dotted line (from McKelvey et al. 2006).

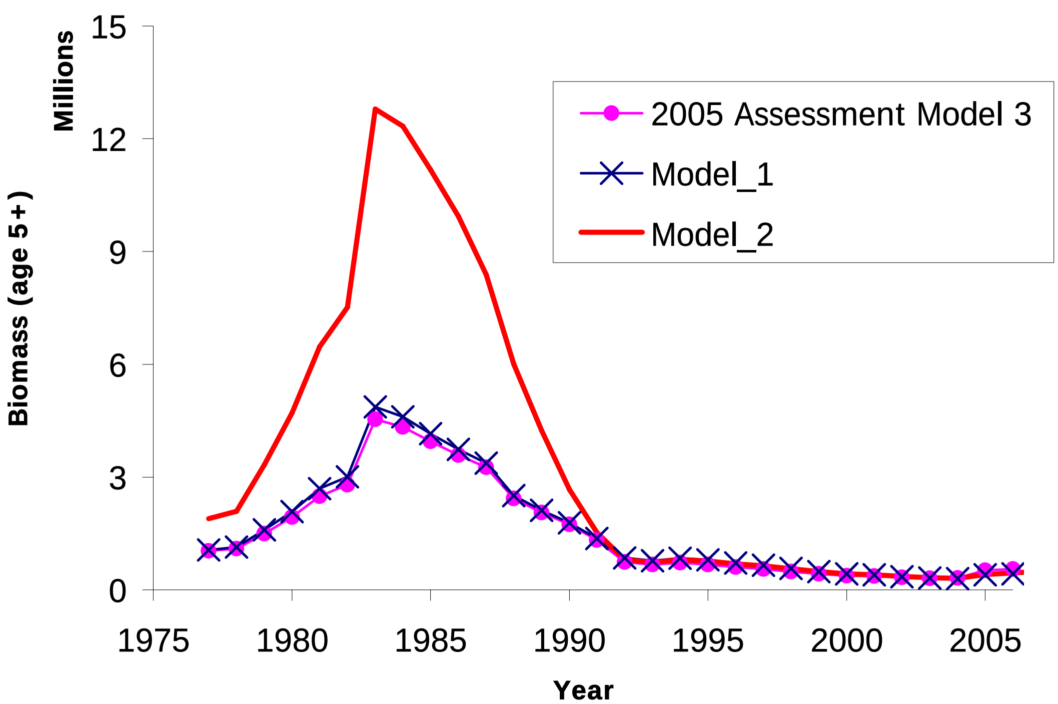

Figure 1b.6. Comparisons of different model specifications on estimates of age 5 and older Bogoslof region pollock biomass (tons). See text for explanation of different model assumptions.

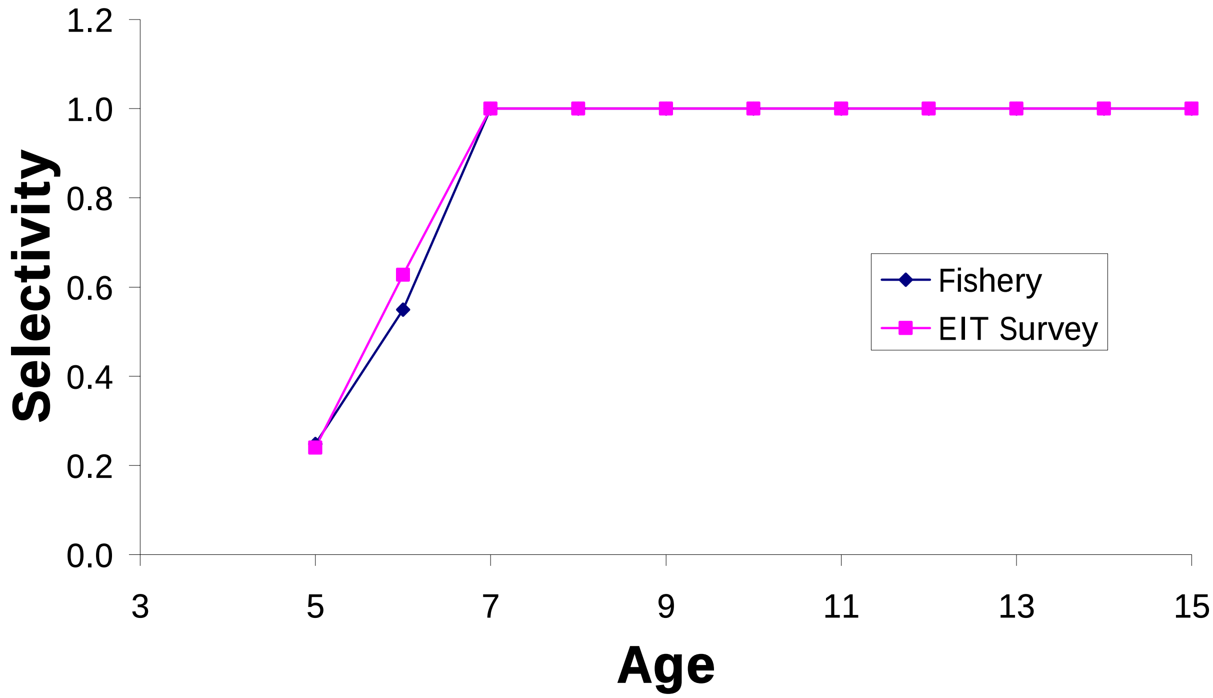

Figure 1b.7. Selectivity patterns estimated (and assumed for ages 7 and older) for the Bogoslof pollock survey and fishery under Model 2.

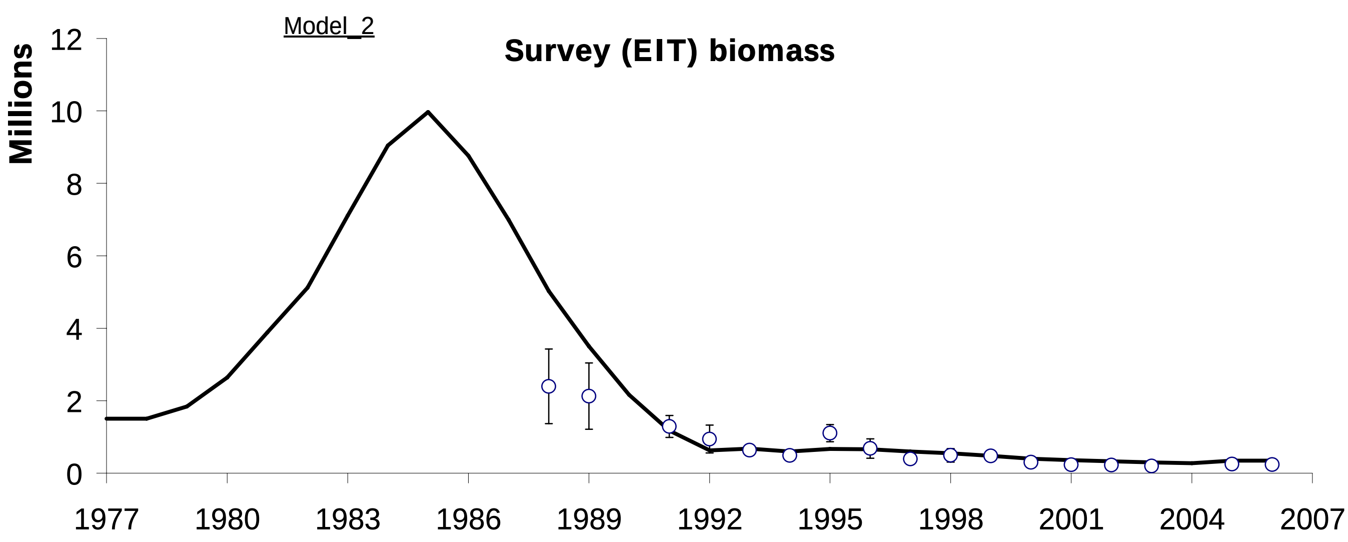

Figure 1b.8. Predicted Model 2 EIT survey biomass (line) versus observed survey estimates (circles) biomass (tons) of Bogoslof region pollock, 1988-2006. Vertical bars represent two times the annual standard deviations assumed for fitting the survey abundance index.

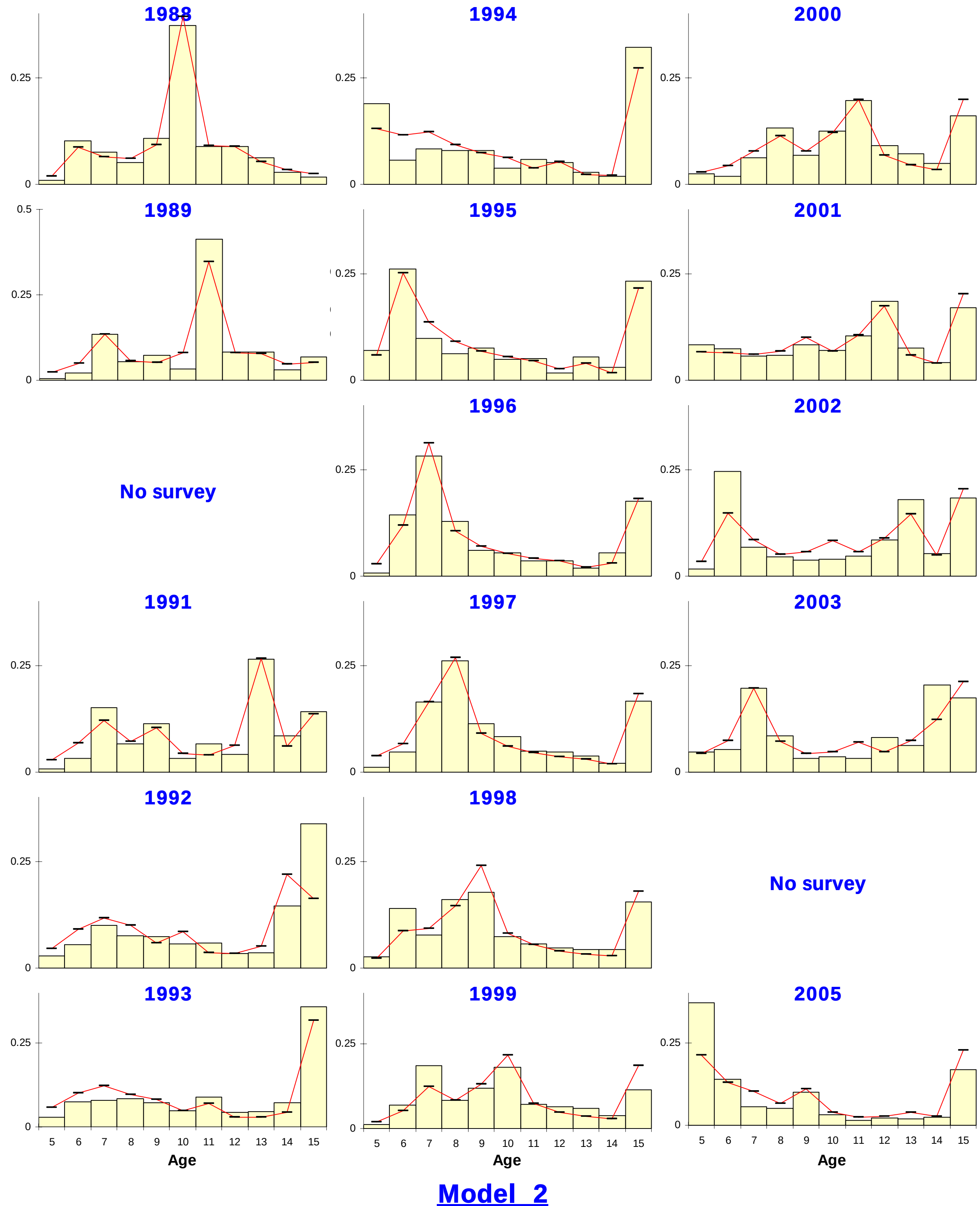

Figure 1b.9. Model 2 estimates (lines) versus observed EIT survey (bars) proportions-at-age of Bogoslof region pollock, 1988-2005.

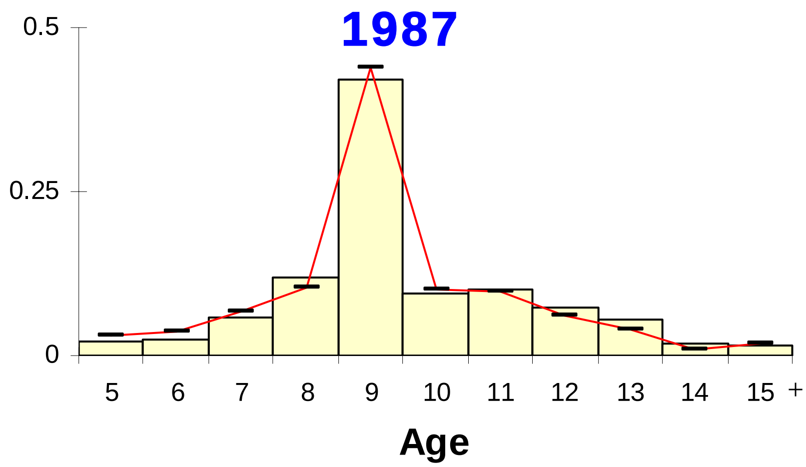

Figure 1b.10. Model 2 estimates (lines) versus observed fishery (bars) proportions-at-age of Bogoslof region pollock, 1987 (the only year where age-data are available).

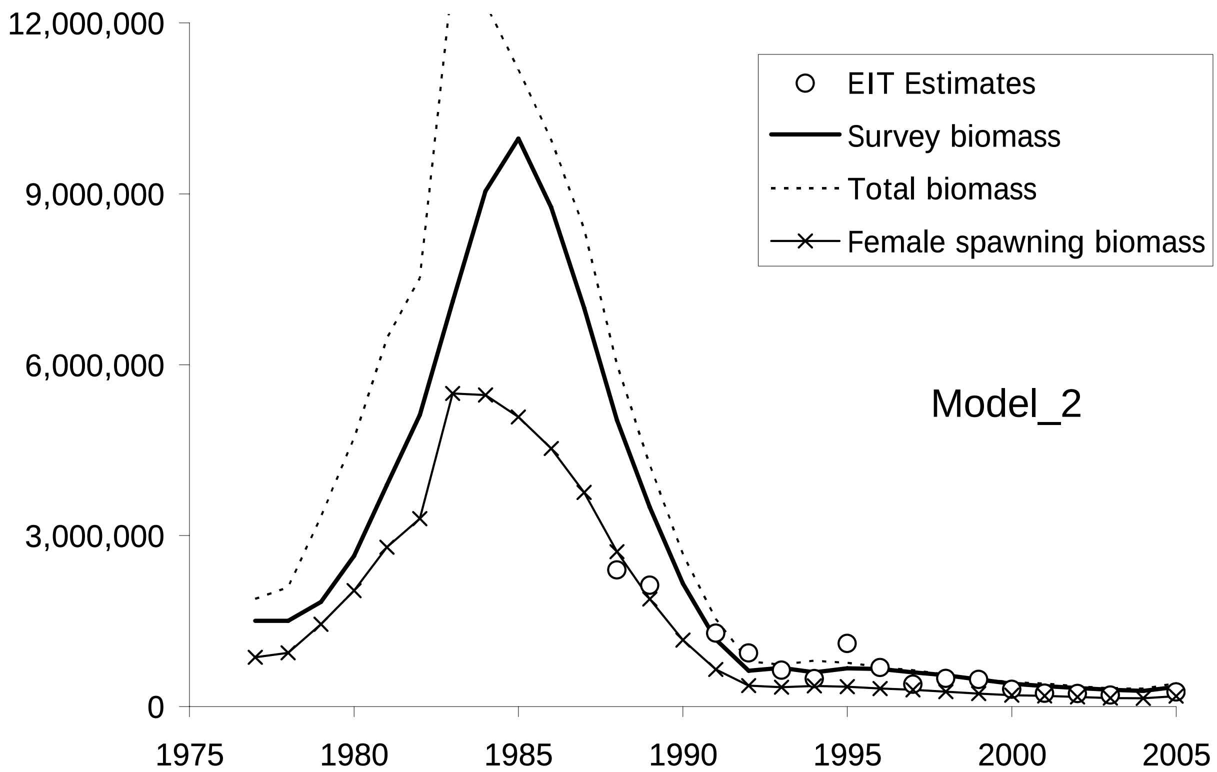

Figure 1b.11. Bogoslof pollock biomass measures as estimated for Model 2, 1977-2006. Units are in tons. The thick line represents the model prediction of the survey biomass. Note that 50:50 sex ratio is assumed for estimates of female spawning biomass.

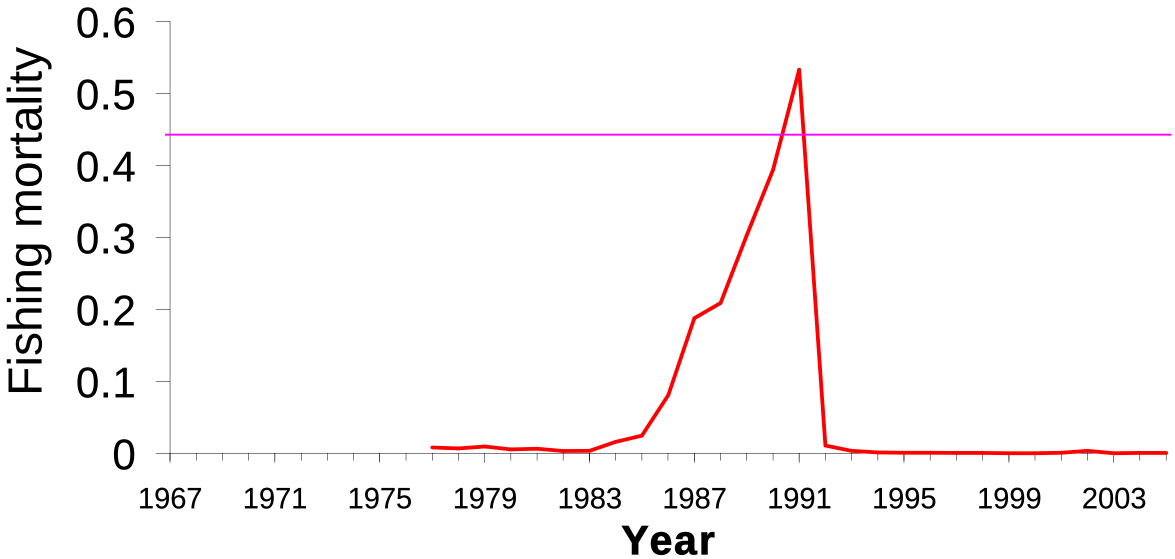

Figure 1b.12. Estimated Model 2 historical fishing mortality rates (age 5-15) for Bogoslof pollock, 1977-2005. The horizontal line represents the estimate of $F_{40\%}$.

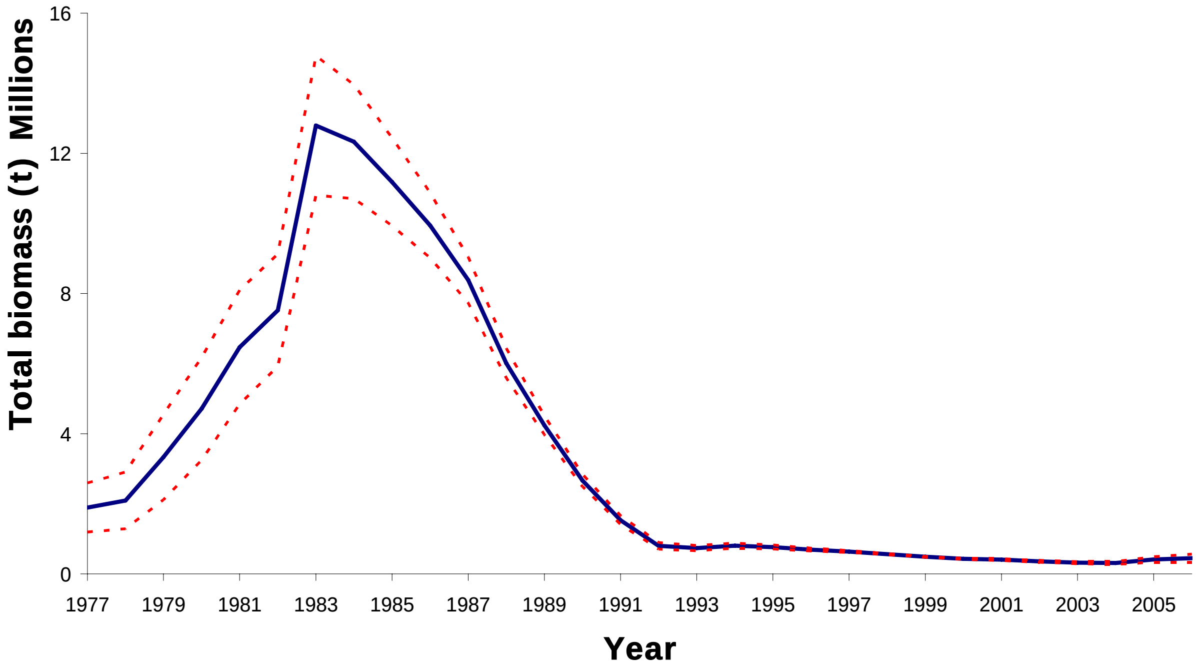

Figure 1b.13. Total age 5+ Model 2 Bogoslof pollock biomass estimated by the model with $\pm$ 2 standard deviations of the estimates (dashed lines).

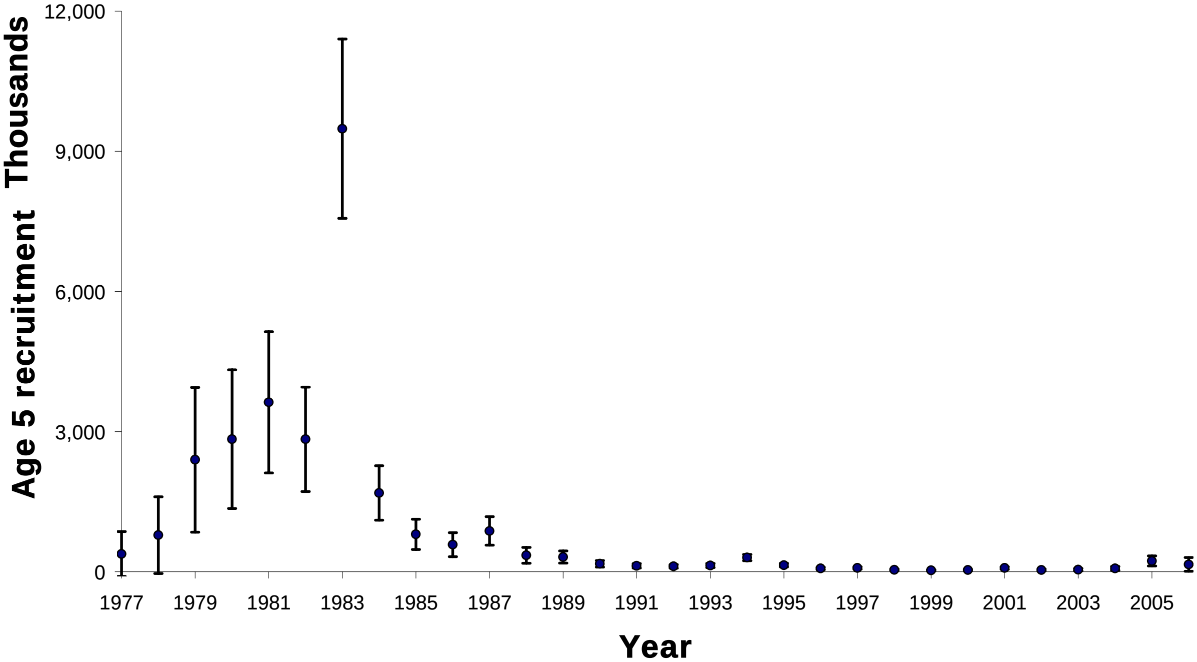

Figure 1b.14. Age-5 recruitment with + 2 standard deviations of the estimates for Bogoslof region pollock.

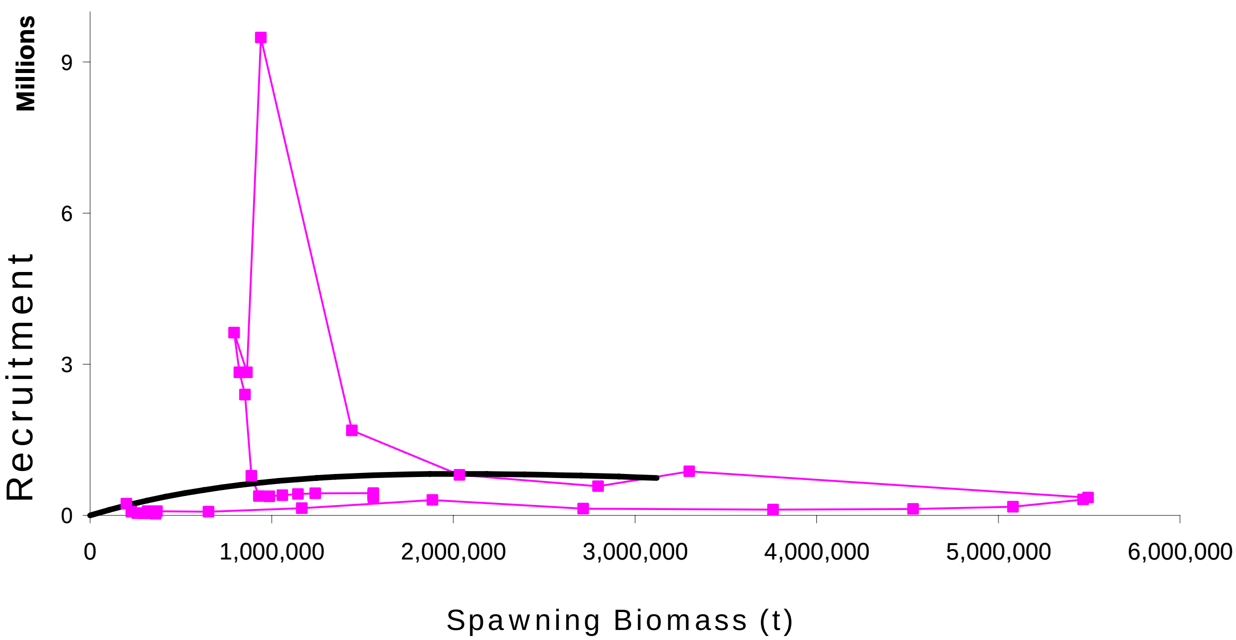

Figure 1b.15. Bogoslof pollock age-5 recruitment vs female spawning biomass 1977-2006. The curve represents the estimated stock-recruitment relationship.

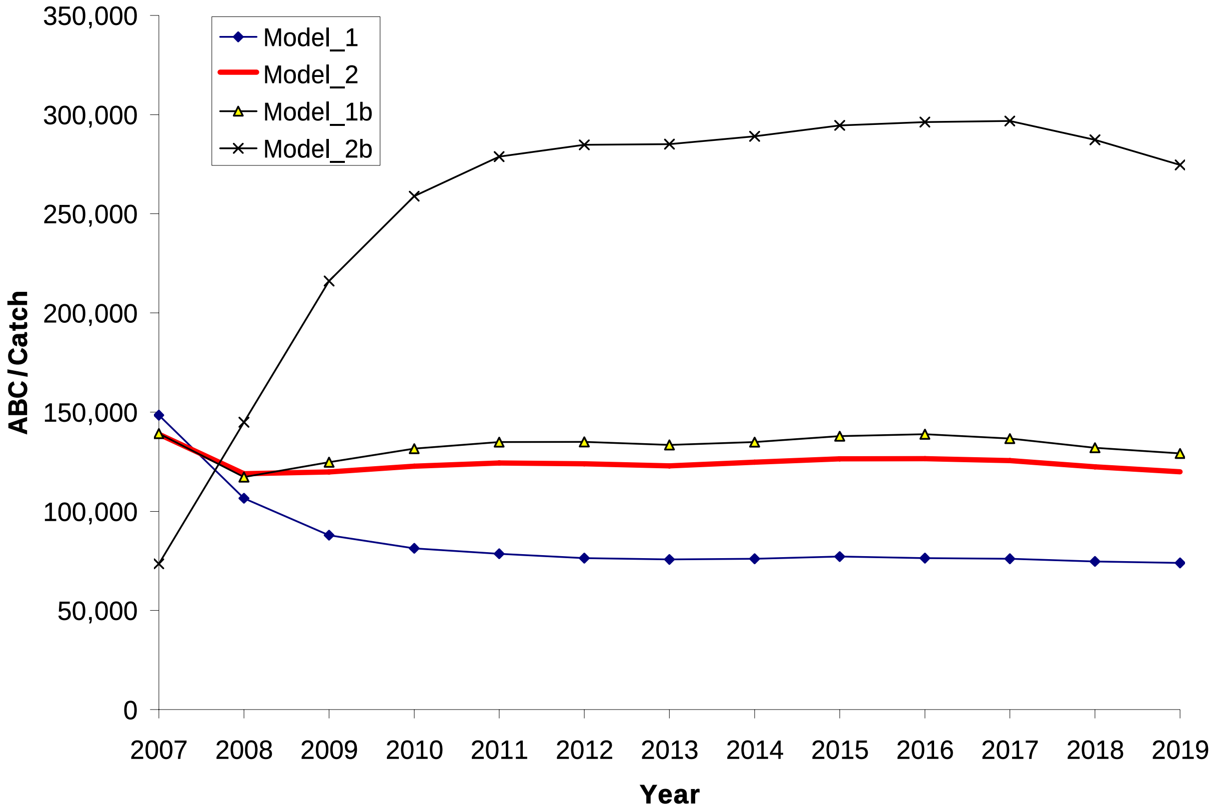

Figure 1b.16. Bogoslof pollock projected catch at ABC for the two models (Model 1 with Bogoslof catches only, Model 2 with Aleutian Basin catches included) and under different assumptions about the included recruitment time series—the “b” option includes the 1978 year class in the biological reference points and in the simulations whereas the others are based on recruitments from 1979-2006 only.

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