19th North Pacific Albacore Workshop: Stock Assessment Conclusions[1]

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6. Stock Assessment Conclusions

6.1. Introduction

Following review of the preliminary VPA-2BOX (Porch 2003) runs presented by Japan and the United States, Workshop participants recommended that two model configurations (henceforth, referred to as Model Scenarios 1 and 2) be further evaluated. Each of these configurations included the suite of assumptions and methods that were presented in the preliminary assessments discussed above. Given the importance of the indices of relative abundance in such assessments, the participants recommended that these two Scenarios be based on similar biological assumptions, with one utilizing all of the indices of abundance (Model Scenario 1) and the other based on a subset of the indices (Model Scenario 2). Maturity schedules (Ueyanagi 1957), weight-at-age (Suda and Warashina 1961; Suda 1966), rates of natural mortality (*M* of 0.3 for all ages and years), and general estimation methods were consistent between the two Models. Model Scenario 1 was based on the following 16 indices: age-specific indices for ages 2-5 (U.S./Canada troll fishery); age-aggregated (assumed to represent ≥ 6-yr old fish) abundance index (U.S. longline fishery); age-specific indices for ages 2-5 (Japan pole-and-line fishery); and age-specific indices for ages 3 to ≥ 9 (Japan longline fishery). Model Scenario 2 was based on the following 10 indices: age-specific indices for ages 2-5 (U.S./Canada troll fishery); age-specific indices for ages 2-5 (Japan pole-and-line fishery); and age-aggregated indices for the U.S. and Japan longline fisheries.

The estimated trends for important management-based statistics (e.g., stock biomass, spawning stock biomass, and recruitment) were generally similar between the two Model Scenarios. Thus, for the purposes of assessing current stock status and projecting future stock conditions, Model Scenario 1 was chosen as the preferred model, given: (1) statistical fits and diagnostics were deemed generally satisfactory; and (2) Model Scenario 1 utilized more of the available sample information than Model Scenario 2. The Workshop members concluded that Model Scenario 1 represented a reasonable current understanding of the population dynamics of North Pacific albacore.

6.2. Input Data and Output Results From Model Scenario 1

The catch-at-age matrix used for the Workshop-based Model Scenario 1 run is presented in Table 2. Indices of abundance data and assumptions have been described generally in Section 5 above. The Model Scenario 1 estimates of numbers-at-age, and fishing mortality-at-age are presented in Tables 3 and 4, respectively. Finally, given VPA-based methods commonly produce highly uncertain (imprecise) estimates of young fish for recent years, the following calculations were conducted: (1) numbers of age-1 fish in 2003-04 reflected the mean estimate over the period 1992-99; and number of age-2 fish in 2004 reflected the exponential decline of age-1 fish in 2003 (i.e., e^{-Z} applied to the mean number of age-1 fish in 2003).

6.3. Results

6.3.1. Biomass and Spawning Stock Biomass Trends

Estimated stock biomass (*B*, ages ≥ 1 or 1+) decreased from about 360,000 mt in 1975 to about 270,000 mt in the late 1980s (see Figure 17). Stock biomass then increased to a peak of roughly 460,000 mt by the early-2000s and has remained at this level to date, likely, in large part, due to improved recruitment (see Figure 19). However, the estimate of stock biomass in recent years is imprecise and thus, should be interpreted accordingly. For example, the point estimate of the 2004 stock biomass is roughly 429,000 mt with 80% confidence limits (*CI* derived from a bootstrap method, based on 500 replications) ranging from roughly 329,000 to 563,000 mt (Figure 20).

Spawning stock biomass has experienced slight fluctuations since the late 1970s, but generally, it has remained relatively stable at roughly 90,000 mt over the last two decades (Figure 18). The historically high estimate observed in 2004 (approximately 165,000) was largely the outcome of a very successful year class in 1999 (i.e., age-1 fish in 2000); however, recruitment levels from 2001 to the present were considerably lower than this and thus, projected estimates of *SSB* declined to levels more typical of the historical time period. See section 6.3.3 for further discussion regarding projected estimates of these stock parameters.

For the purpose of comparison, *B* and *SSB* time series generated from the ADAPT model (also VPA-based) in 2002 are also shown (Figures 17 and 18). For the most part, the two modeling platforms were similar; however, some discrepancies exist, given the newer modeling platform incorporated numerical estimation methods not available in the older modeling software (e.g., *F* estimation for the oldest true age, age-group 8, and variance re-weighting methods were internally different between the two VPA modeling approaches).

6.3.2. Biological Reference Points

Determination of 'biological reference points' involved uncertainty analysis based on four model configurations. That is, inherent uncertainty surrounding current levels of both stock 'productivity' (i.e., recruitment) and fishing pressure (i.e., *F*) was evaluated as follows:

'Low productivity'/'Low *F*'
'Low productivity'/'High *F*'
'High productivity'/'Low *F*'
'High productivity'/'High *F*'

'Low productivity' represented the mean recruitment for the period 1975-89 (*R* = 22.5 million recruits), whereas 'high productivity' was defined as the mean *R* for the period 1990-00 (*R* = 31 million recruits), see Figure 19. For 'low *F*', fishing mortality was assumed to be 0.43 (i.e., arithmetic mean of ages 4-9+ in 2003), whereas the 'high *F*' hypothesis was based on a *F* of 0.68 (i.e., mean estimates of ages 7-9+ in 2003). These estimates of F at age are not adjusted for partial recruitment at age, but partial recruitment at age is applied to F in the forward projections (see section 6.3.3).

Equilibrium yield-per-recruit (*Y/R*) and spawning stock biomass-per-recruit (*SSB/R*) calculations were conducted using the same vital rates (growth, maturity, and natural mortality) used in Model Scenario 1 (Figure 21). The partial recruitment (*PR*) schedule (i.e., selectivity ogive) was taken from Model Scenario 1 results, i.e. *PR* used in the *Y/R* and *SSB/R* analyses was calculated as an arithmetic mean (normalized to maximum value) over the period 1995-03 (Figure 21). Results from *Y/R* and *SSB/R* analyses are presented in Figure 22.

6.3.3. Stochastic Stock Projections

The initial conditions for the projections were taken from Model Scenario 1 (see section 6.1). More specifically, the projections used terminal year (2004) stock numbers-at-age (N_a) and fishing mortality rate (F_{2003}) as estimated in the VPA-2BOX analysis, and partial recruitment (PR_a) reflected the mean from 1995-03 (see 6.3.2 and Figure 21). Constant *F* and *PR* were used for all projection years (2005-10). The natural mortality, weight-at-age, and maturity-at-age parameters used in the projections were identical to those used in the VPA-2BOX analysis (Model Scenario 1).

The projections were carried out based on the four-hypothesis uncertainty discussed above: (1) a 'high productivity'/'low *F*' regime, characterized by randomly sampling (with replacement) from the recruitments estimated for the 1990-00 period (Figure 19), based on a $F = 0.43$; (2) a 'high productivity'/'high *F*' regime, characterized by randomly sampling (with replacement) from the recruitments estimated for the 1990-00 period, based on a $F = 0.68$; (3) a 'low productivity'/'low *F*' regime, characterized by randomly sampling (with replacement) from the recruitments estimated for the 1975-89 period (Figure 19), based on a $F = 0.43$; and (4) a 'low productivity'/'high *F*' regime, characterized by randomly sampling (with replacement) from the recruitments estimated for the 1975-89 period, based on a $F = 0.68$.

The stochastic projections were linked with the bootstrap analysis that was carried out to estimate error associated with the VPA-2BOX-based parameters. Five hundred bootstrap replications were conducted using Model Scenario 1, i.e., VPA-2BOX analysis was run 500 times with resampled indices of abundance for each run. The respective estimates of terminal year N_a, F_{2003}, and PR_a (all of which differ by bootstrap replication number) were carried forward into a 6-year projection. Along each of these trajectories, annual recruitment (2005-10) was drawn randomly (with replacement) from the appropriate pool of VPA-2BOX-estimated recruitments (i.e., from 1975-89 or from 1990-00). Overall, the stochastic projection was designed to capture the variance in terminal year estimates (N_a, F_{2003}, and PR_a), as well as recruitment variability in all projection outputs.

Projections were made out to 2010 to illustrate the convergence of *B* and *SSB*, with the long-term mean (equilibrium) conditions expected under the assumptions of constant mortality and forecasted recruitment levels, based on the uncertainty analysis described above (*B*: Figures 23A-B for high productivity scenarios and Figures 24A-B for low productivity scenarios; *SSB*: Figures 25A-B for high productivity scenarios and Figures 27A-B for low productivity scenarios). The solid line with annual markers in the Figures is the mean of the 500 projections. The dashed lines represent the 10^{th} and 90^{th} percentiles from the 500 projections, i.e., nonparametric 80% *CI*s.

Under the 'high productivity'/'low *F*' scenario, *B* is projected to increase moderately from its current level (Table 5A and Figure 23A). Under the 'high productivity'/'high *F*' scenario, *B* is forecasted to remain at roughly its current level (Table 5B and Figure 23B). In the 'low productivity'/'low *F*' scenario, *B* is expected to decline slightly (Table 5C and Figure 24A). In the 'low productivity'/'high *F*' scenario, *B* is projected to decline substantially from its current level (Table 5D and Figure 24B).

As noted in section 6.3.1, the magnitude of *SSB* observed in 2004 (approximately 165,000) was essentially the result of a record high recruitment (*R*, age-1 fish) estimate in 2000 (i.e., the 1999 year class), with subsequent recruitment dropping to levels more characteristic of the annual average observed during the 'high productivity' time period. For the 'high *F*' scenarios under both the 'high' and 'low productivity' assumptions, *SSB* is projected to decrease substantially (Tables 5B and 5D; Figures 25B and 26B), whereas 'low *F*' scenarios generally resulted in *SSB* remaining constant (Table 5C and Figure 26A) or increasing slightly (Table 5A and Figure 25A). Finally, it is important to note that in all scenarios, the level of uncertainty is quite high and thus, predicting trends over the long-term is necessarily problematic to some degree.

6.3.4. Stock Condition in Relation to Biological Reference Points

In addition to estimating stock sizes in the past (i.e., see sections 6.3.1), it would be desirable to assess 'current' conditions of both fishing mortality and stock biomass in relation to biological reference points of interest. Although inclusion of such reference points is becoming a standard feature of stock status determinations, there is no agreement yet as to which reference points are appropriate for tuna stocks, including North Pacific albacore. Accordingly, participants continued to take the approach adopted at the *Eighteenth North Pacific Albacore Workshop* and simply compare current levels of fishing mortality and biomass with a familiar suite of reference points. Evaluation and selection of preferred reference points is a task for the future and should be done by consensus among scientists, fishery managers, and stakeholders.

The biological reference points considered here fall into two categories: (1) reference points that are potential candidates as *F*-based MSY proxies, namely $F_{40\%}$, $F_{30\%}$, and $F_{0.1}$; and (2) candidates to serve as *F*-based 'limit' proxies, namely $F_{20\%}$ and F_{Max}. While it is recognized that this list of reference points does not encompass all possible reference points for North Pacific albacore, it does include the most commonly used reference points for contemporary fisheries management.

Depending on the 'current' level of F assumed in the uncertainty analysis (see above), the population is being fished between roughly $F_{17\%}$ (i.e., $F_{2003} = 0.68$) and $F_{30\%}$ (i.e., $F_{2003} = 0.43$), see Figure 22. These results are generally similar to the previous assessment conducted in 2002 (i.e., *Eighteenth North Pacific Albacore Workshop*). This conclusion regarding the spawning potential ratio reference point (i.e., $F_{\%}$) is essentially based on Model Scenario 1 (and assumptions regarding current F), coupled with the per-recruit analyses. As such, it does not depend on knowing whether the North Pacific albacore population is presently in a 'high or low productivity' regime. However, in order to compare current levels of biomass with those at equilibrium that would result from fishing at any given F-based reference point, it is necessary to postulate the current productivity of the stock. That is, appropriate consideration of the status of the North Pacific albacore population necessarily involves assumptions regarding current levels of recruitment. In this context, important management-based statistics presented in Table 5 are summarized below:

(1) *High productivity (Table 5A-B)*: under this hypothesis, the level of productivity observed over the past decade continues to date. For the F_{MSY} proxies considered, B_{MSY} ranges from approximately 560,000 to 660,000 mt (49% to 57% of B_0). The estimate of stock biomass in 2004 (B_{2004}) is 22% below this range. Similarly, SSB_{MSY} ranges from roughly 220,000 to 290,000 mt (30% to 40% of SSB_0), with SSB_{2004} 25% below this range. Again, note that the high level of SSB in 2004 is largely driven by a historically high 1999 year-class (see the age-1 data point in 2000, Figure 19), with estimates of R since that time declining markedly (see Table 3); also see Figures 25A-B for projected (2005-10) estimates of SSB. Current catch (C_{2004}) is captured within the MSY range.

(2) *Low productivity (Table 5C-D)*: under this hypothesis, the level of productivity observed over the past decade would be replaced by the lower productivity observed during the 1975-89 period. For the F_{MSY} proxies considered, B_{MSY} ranges from approximately 410,000 to 480,000 mt (49% to 57% of B_0). The estimate of stock biomass in 2004 (B_{2004}) is near the middle of the MSY range. Similarly, SSB_{MSY} ranges from roughly 160,000 to 210,000 mt (30% to 40% of SSB_0), with SSB_{2004} at the lower-end of the MSY range. Again, note that the high level of SSB in 2004 is largely driven by a historically high 1999 year-class (see the age-1 data point in 2000, Figure 19), with estimates of R since that time declining markedly (see Table 3); also see Figures 26A-B for projected (2005-10) estimates of SSB. Current catch (C_{2004}) is approximately 34% above the MSY range and in excess of the catch 'limits' associated with $F_{20\%}$ and F_{Max}.

In summary, as noted above, the current level of spawning stock biomass (i.e., $SSB_{2004} = 165{,}000$ mt) is largely reflective of a very strong 1999 year-class that eventually became a major contributor in 2004 as part of 'mature' (spawning) biomass. However, subsequent recruitment (R) declined to levels more typical of the extended historical time series, which translated to reduced levels of forecasted SSB, particularly, assuming 'high F' scenarios (Figures 25B and 26B) within the overall uncertainty analysis. This coupled with a current fishing mortality rate (F_{2003}) that is high relative to commonly used reference points, may be cause for concern regarding the current stock status of North Pacific albacore. Future conditions are less well known, but if rates of *F* continue at assumed levels, it is unlikely that the *SSB* will rebuild to SSB_{MSY} levels within a 5-year time horizon; the only potential exception to this point is the 'low productivity/'low *F*' scenario, with projected *SSB* (2010) falling at the lower end of the estimated MSY range. Thus, participants of the North Pacific Albacore Workshop noted the critical need to closely monitor the population over the coming years, particularly, to validate SSB abundance in relation to MSY levels. In this context, it was recommended that another assessment be conducted in 2006.

Further, Workshop discussions reflected a growing concern about current and future stock condition and the uncertainties in stock assessments. It is particularly noteworthy that key biological parameters used in the overall stock status analysis, particularly growth and maturity rates, were based on studies conducted in the 1950-60s. While these remain the best available studies on which to base the analysis, it is not known to what extent vital rates of this species may have changed from those measures obtained over 40 years ago. These biological studies should be brought up-to-date as soon as possible. Concern was also expressed about the current lack of understanding of factors affecting recruitment and more generally, the processes affecting productivity (i.e., recruitment levels). Thirdly, retrospective analysis revealed a noticeable trend of over-estimation of stock parameters (e.g., *B* and *SSB*) in the ongoing Workshop-based assessments, which necessarily warrants consideration of precautionary management advice associated with the results generated from year-to-year. Finally, there is a general expectation that biological reference points will be needed to guide future fishery management discussions about North Pacific albacore. Accordingly, along with research to improve the accuracy and reliability of stock assessments, a high priority should be given to scientific studies of appropriate reference points for the stock, both with respect to fishing mortality and stock abundance. Participants agreed that provisional studies of candidate reference points should be undertaken during the intersessional period and presented at the next Workshop.

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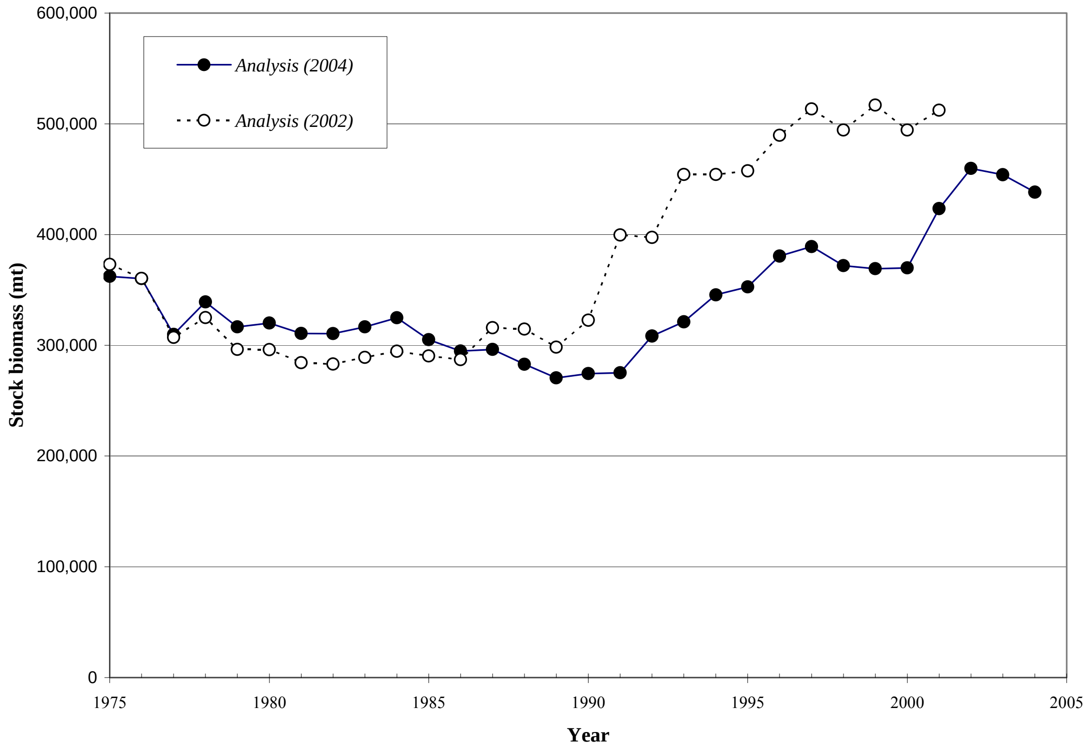


Figure 17. Total stock biomass (mt) time series (1975-04) for North Pacific albacore generated from Model Scenario 1 (Analysis 2004). Final estimated stock biomass time series from the previous North Pacific Albacore Workshop (2002) is also presented (Analysis 2002). Time series are based on January 1 estimates.

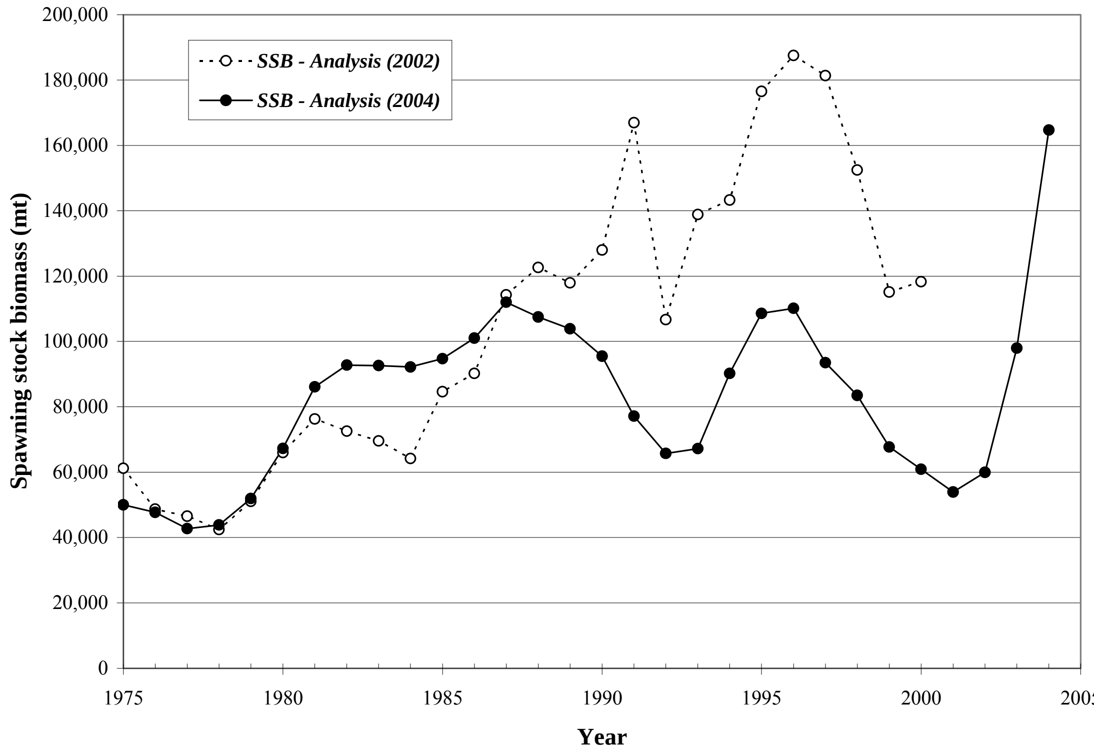


Figure 18. Total spawning stock biomass (mt) time series (1975-04) for North Pacific albacore generated from Model Scenario 1 (Analysis 2004). Final estimated spawning stock biomass time series from the previous North Pacific Albacore Workshop (2002) is also presented (Analysis 2002). Time series are based on January 1 estimates.

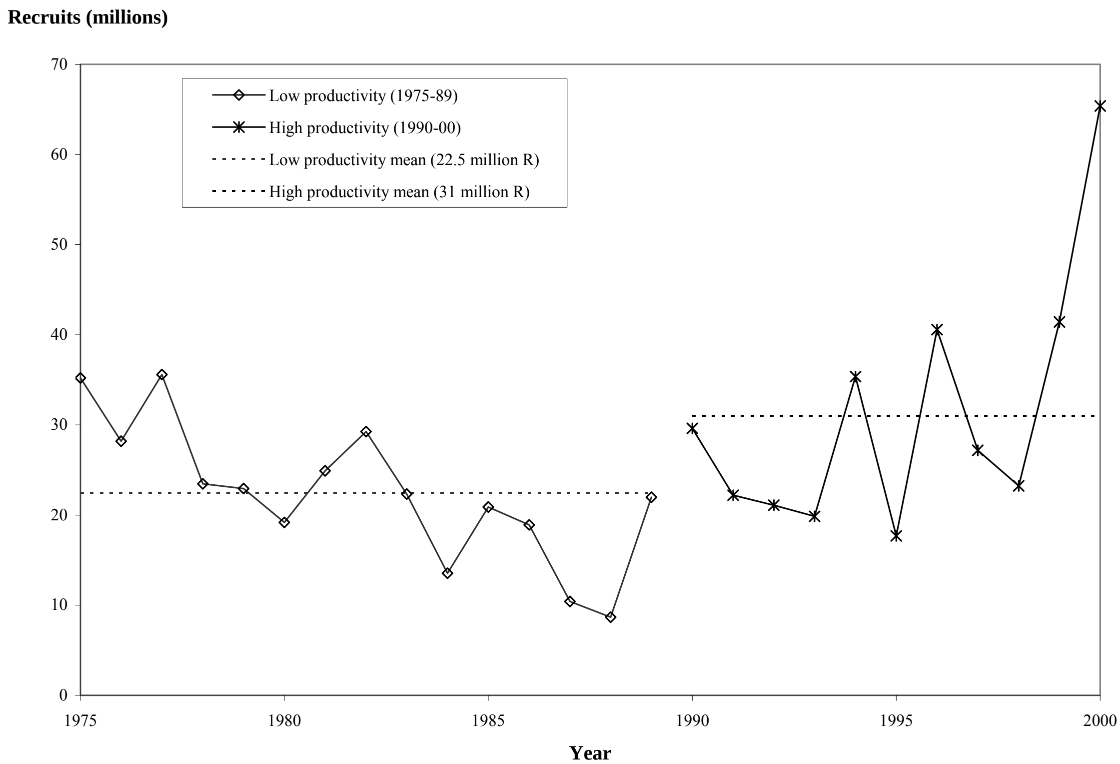


Figure 19. Recruitment (age-1 fish in millions) time series of North Pacific albacore generated from Model Scenario 1 illustrating low (1975-89) and high (1990-00) productivity scenarios. Recruitment from 2001-04 reflected the mean estimate for the low and high productivity scenario assumption, respectively (see section ?).

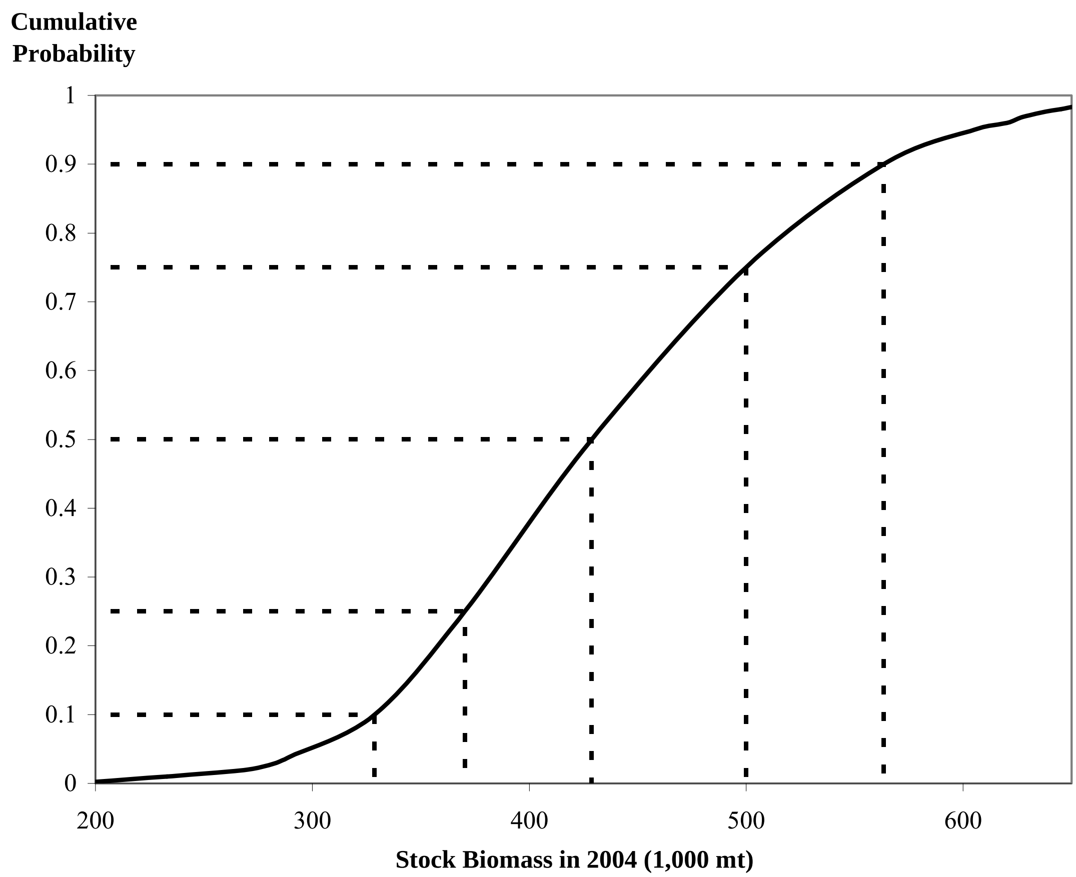


Figure 20. Probability 'profile' of total stock biomass (1,000 mt) of North Pacific albacore in 2004 generated from Model Scenario 1. The profile presents the probability that stock biomass is less than the values presented on the X-axis, e.g., there is a 90% probability that stock biomass is less than 563,400 mt. The drop lines indicate the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles.

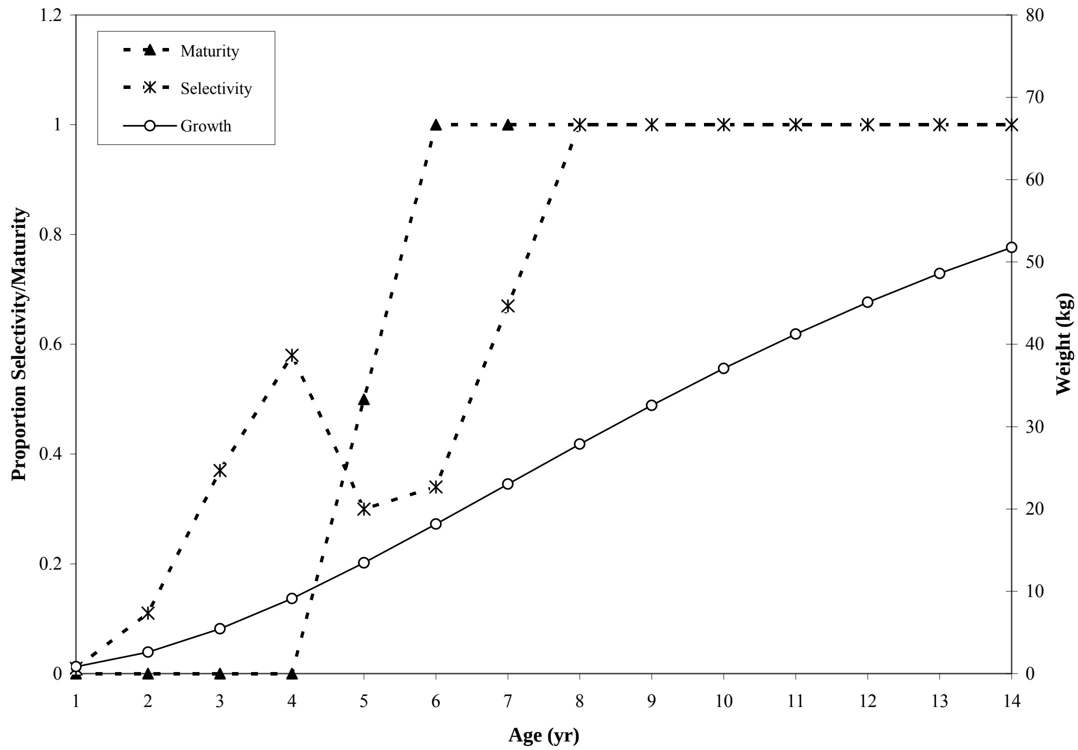


Figure 21. Partial recruitment (i.e., selectivity), maturity, and growth (in weight, kg) schedules used to determine biological reference points associated with Model Scenario 1. Maturity ogive is from Ueyangi (1957), weight-at-age time series reflects January 1 estimates and is based on Suda (1966) and Suda and Warashina (1961), and natural mortality-at-age (M) was 0.3.

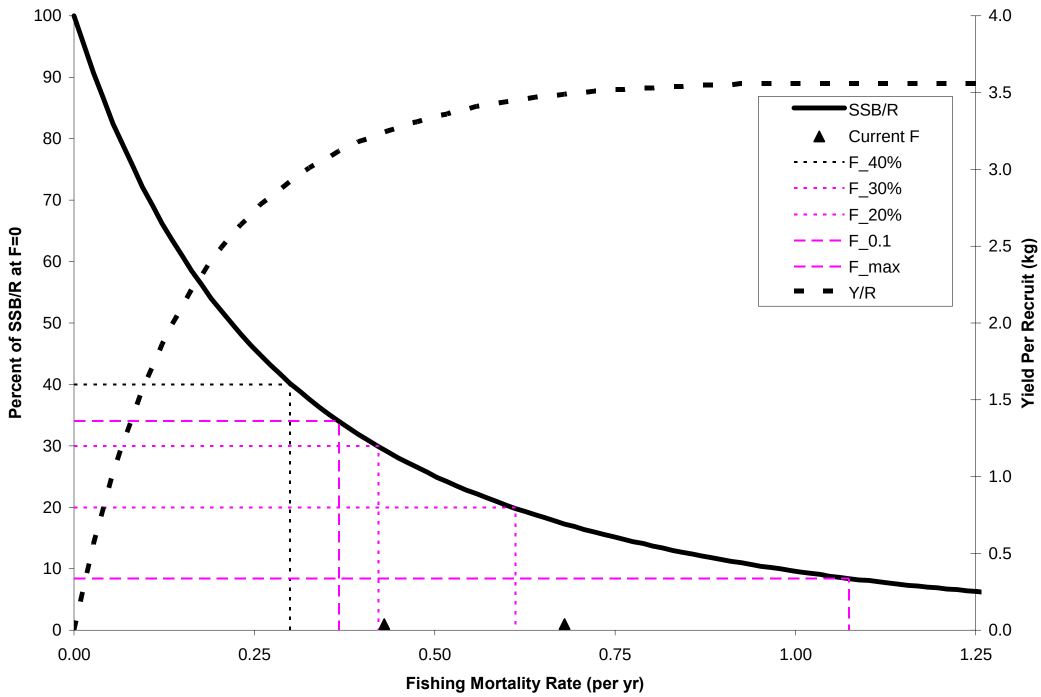


Figure 22. Equilibrium yield-per-recruit (Y/R in kg) and (% of SSB/R at F=0) and various F-based biological reference points for as a function of fishing mortality rate (F) for North Pacific albacore associated with Model Scenario 1. The current F (2003) reflects a 'range' based on a 'low' (0.43) and 'high' (0.68) assumption involved in uncertainty analysis (see section 6.3.2).

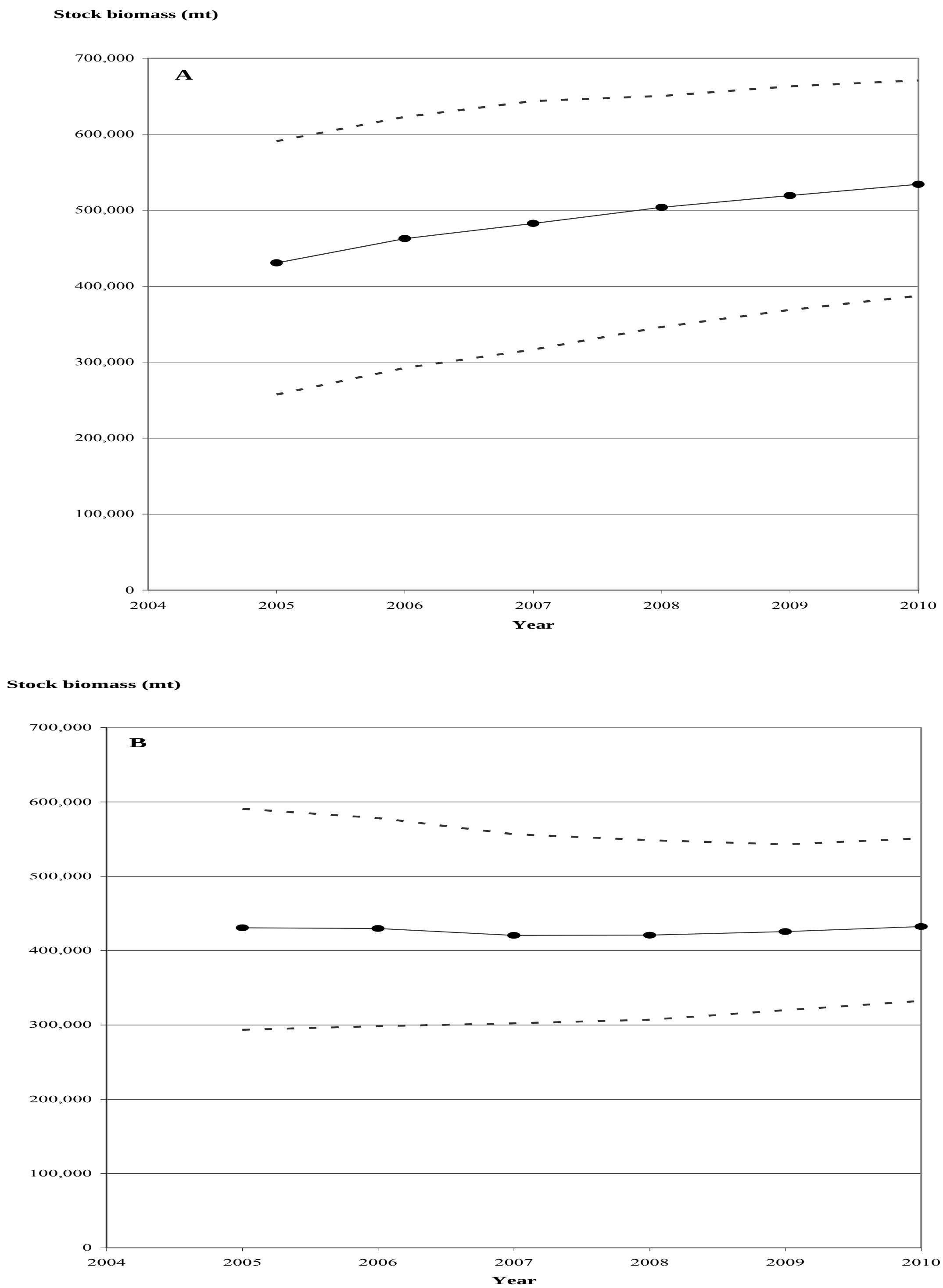
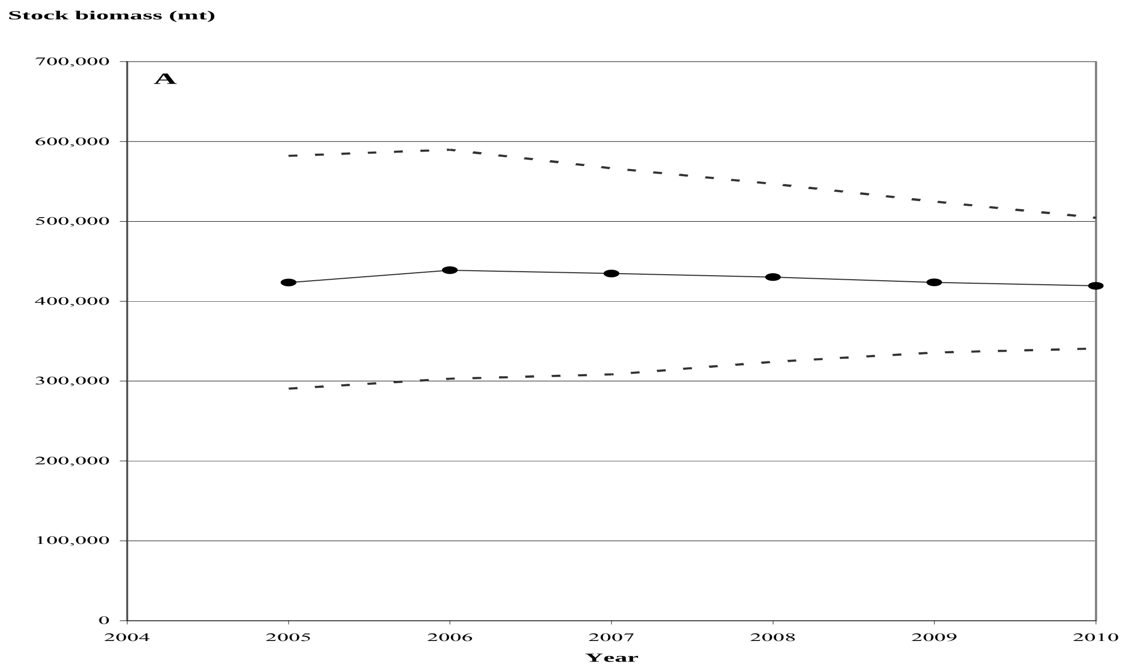


Figure 23. Stochastic projection of total stock biomass (mt) of North Pacific albacore based on the uncertainty analysis scenario 'high productivity/low F' – **A**, and 'high productivity/high F' – **B** associated with Model Scenario 1 (2005-10). Dashed lines represent 80% CI. See section 6.3.3.



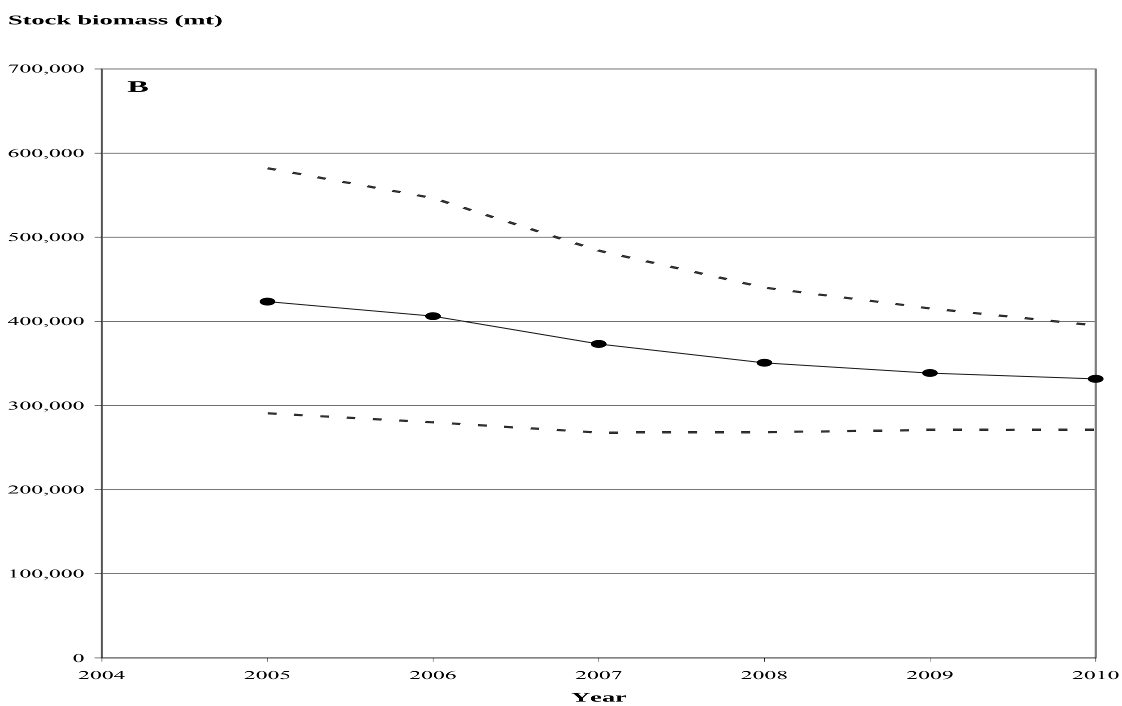
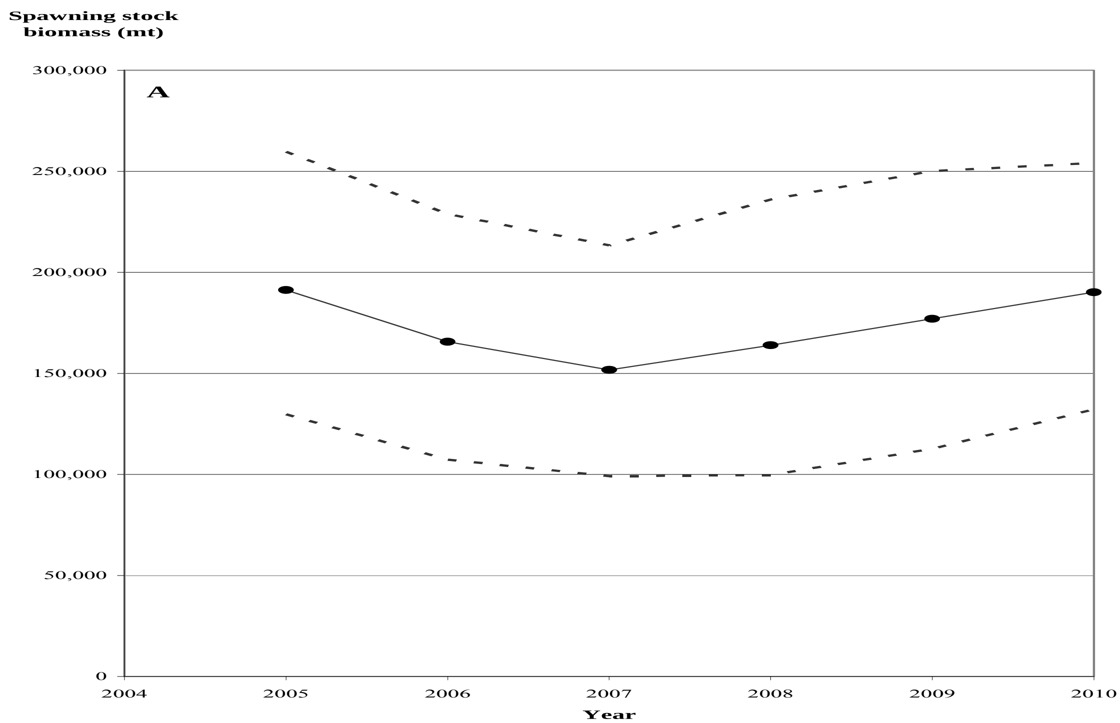


Figure 24. Stochastic projection of total stock biomass (mt) of North Pacific albacore based on the uncertainty analysis scenario 'low productivity/low F' – **A**, and 'low productivity/high F' – **B** associated with Model Scenario 1 (2005-10). Dashed lines represent 80% CI. See section 6.3.3.



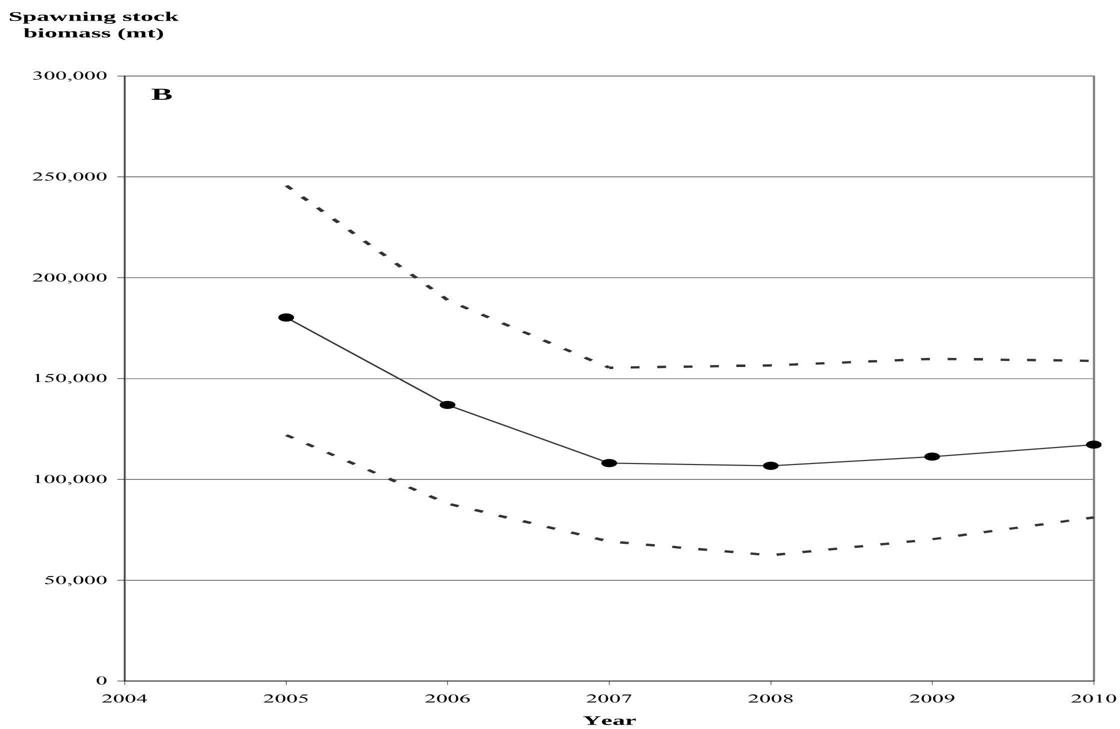


Figure 25. Stochastic projection of spawning stock biomass (mt) of North Pacific albacore based on the uncertainty analysis scenario 'high productivity/low F' – **A**, and 'high productivity/high F' **– B** associated with Model Scenario 1 (2005-10). Dashed lines represent 80% CI.

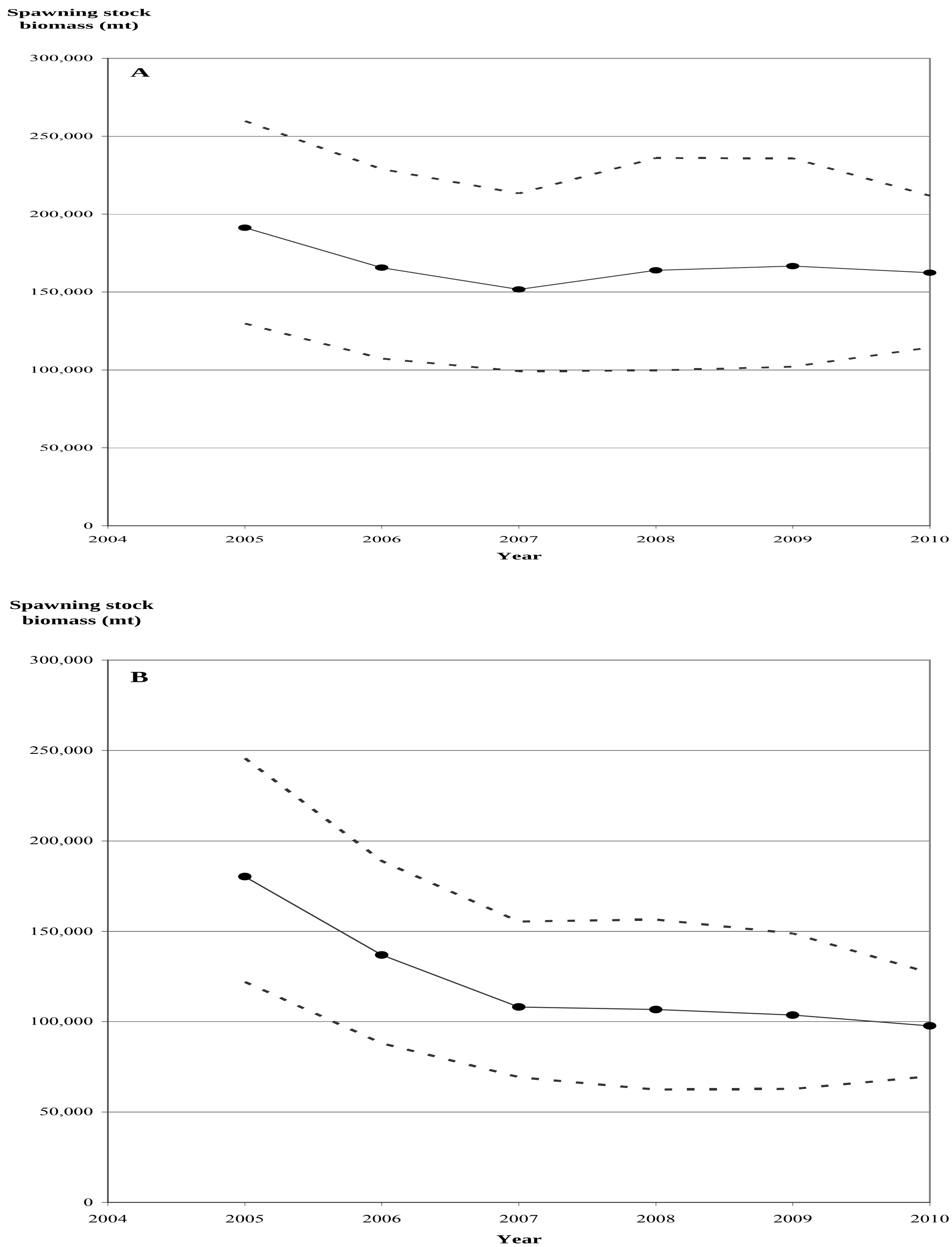


Figure 26. Stochastic projection of spawning stock biomass (mt) of North Pacific albacore based on the uncertainty analysis scenario 'low productivity/low F' – **A**, and 'low productivity/high F' – **B** associated with Model Scenario 1 (2005-10). Dashed lines represent 80% CI.

Table 2. North Pacific albacore catch-at-age (number of fish in 1,000s) matrix used for all VPA-2BOX model analysis conducted during the Workshop (1975-03).

YEAR	AGE (yr)									TOTAL
	1	2	3	4	5	6	7	8	≥9	
1975	0.0	792.1	4,931.1	2,958.5	1,680.5	261.8	99.3	74.0	207.6	11,004.8
1976	0.4	2,285.8	4,952.3	5,758.9	2,607.4	342.2	133.0	138.3	93.6	16,311.9
1977	0.2	765.4	3,042.5	1,991.1	1,026.5	452.2	101.8	99.8	87.6	7,567.1
1978	2.5	5,932.8	2,308.5	4,764.8	1,088.2	360.2	114.2	59.3	47.9	14,678.3
1979	0.1	582.6	1,289.0	3,707.2	1,121.7	329.3	131.7	67.1	46.1	7,274.7
1980	0.1	2,480.0	2,950.9	3,174.2	733.7	307.9	111.7	86.4	55.2	9,900.0
1981	3.8	927.4	1,653.6	2,764.7	1,182.1	340.8	264.2	85.7	76.5	7,298.6
1982	75.0	606.0	2,135.8	3,260.2	459.7	265.2	220.3	179.3	69.3	7,270.8
1983	2.0	1,185.8	2,657.9	2,305.9	271.3	161.2	142.0	186.1	87.4	6,999.5
1984	4.8	1,106.1	4,756.6	2,914.3	263.7	171.3	152.1	145.8	79.2	9,594.1
1985	1.7	318.5	1,332.6	2,782.4	627.6	140.5	183.5	144.6	216.2	5,747.7
1986	0.1	801.4	1,099.4	2,341.7	194.6	123.2	146.4	56.6	113.9	4,877.3
1987	0.6	275.6	2,203.4	1,282.1	465.9	251.0	173.6	98.4	151.4	4,902.0
1988	3.5	142.7	1,704.1	1,126.5	293.9	586.3	200.9	154.7	152.4	4,365.0
1989	106.3	441.0	390.0	1,242.8	1,039.1	322.8	217.5	120.0	129.7	4,009.1
1990	107.0	315.1	285.4	1,106.1	1,685.9	568.8	202.1	133.3	209.9	4,613.5
1991	77.7	695.2	1,740.8	409.0	319.2	270.8	172.8	92.7	220.8	3,999.0
1992	0.9	392.9	2,493.7	1,546.8	594.6	407.0	153.0	109.6	150.8	5,849.4
1993	0.0	494.0	1,263.2	1,970.3	622.6	176.0	185.4	135.7	252.4	5,099.5
1994	27.5	697.1	2,001.2	2,050.0	1,090.0	553.2	188.6	77.0	129.6	6,814.3
1995	1.5	531.3	1,964.3	2,451.9	320.7	393.5	404.2	76.8	83.0	6,227.2
1996	7.6	498.4	4,394.6	1,815.6	566.6	576.2	496.5	216.3	64.9	8,636.8
1997	0.1	2,342.4	1,888.9	4,433.8	397.6	188.3	457.3	536.7	212.4	10,457.6
1998	0.0	1,125.1	4,353.7	1,676.6	1,259.6	384.2	327.8	424.6	233.0	9,784.6
1999	76.6	826.7	3,982.2	5,885.3	475.4	436.3	416.3	326.1	174.1	12,599.1
2000	0.0	1,269.2	2,041.0	2,882.0	973.5	397.7	440.9	276.9	84.8	8,366.0
2001	4.1	1,511.9	4,510.5	1,585.7	1,078.1	467.8	370.2	234.0	51.6	9,813.9
2002	0.1	1,485.5	8,099.8	2,629.2	565.6	313.6	315.6	92.1	31.1	13,532.8
2003	0.0	3,049.9	4,204.2	3,326.6	706.1	346.9	282.1	133.8	42.0	12,091.7
TOTAL	504.0	33,878.0	80,631.3	76,144.3	23,711.3	9,896.2	6,804.9	4,561.7	3,554.4	239,686.2

Table 3. North Pacific albacore numbers-at-age (millions of fish on January 1) as estimated in Model Scenario 1 (1975-04). Recruitment (age-1 fish) from 2003-04 reflects mean estimate from 1992-99; and (2) age-2 fish in 2004 reflects exponential decline (e^{-Z}) of age-1 fish in 2003, see section 6.3.1.

YEAR	AGE (yr)								
	1	2	3	4	5	6	7	8	≥9
1975	35.215	19.034	19.325	9.338	3.082	0.903	0.534	0.159	0.446
1976	28.199	26.088	13.422	10.124	4.409	0.876	0.447	0.311	0.211
1977	35.588	20.890	17.371	5.754	2.684	1.089	0.359	0.218	0.191
1978	23.461	26.364	14.820	10.275	2.577	1.120	0.425	0.180	0.145
1979	22.938	17.378	14.481	9.009	3.600	0.991	0.525	0.218	0.150
1980	19.184	16.993	12.375	9.626	3.545	1.716	0.455	0.277	0.177
1981	24.912	14.212	10.472	6.657	4.441	2.001	1.009	0.242	0.216
1982	29.254	18.452	9.734	6.347	2.598	2.285	1.192	0.523	0.202
1983	22.343	21.608	13.150	5.393	1.965	1.533	1.466	0.695	0.326
1984	13.546	16.550	14.992	7.478	2.050	1.224	0.998	0.965	0.524
1985	20.889	10.031	11.314	7.073	3.077	1.294	0.761	0.609	0.911
1986	18.913	15.474	7.158	7.243	2.889	1.745	0.838	0.407	0.820
1987	10.413	14.011	10.777	4.365	3.381	1.974	1.187	0.496	0.764
1988	8.670	7.714	10.143	6.107	2.145	2.107	1.248	0.731	0.720
1989	21.967	6.420	5.592	6.061	3.564	1.338	1.063	0.753	0.814
1990	29.623	16.183	4.378	3.809	3.431	1.758	0.717	0.602	0.948
1991	22.189	21.853	11.718	2.999	1.883	1.125	0.820	0.359	0.856
1992	21.085	16.372	15.594	7.195	1.873	1.123	0.603	0.461	0.634
1993	19.851	15.619	11.792	9.425	4.013	0.883	0.487	0.317	0.589
1994	35.350	14.706	11.148	7.656	5.304	2.442	0.504	0.204	0.344
1995	17.664	26.164	10.298	6.552	3.930	3.001	1.338	0.214	0.231
1996	40.471	13.084	18.928	5.955	2.780	2.637	1.887	0.648	0.195
1997	26.971	29.975	9.266	10.283	2.871	1.577	1.463	0.976	0.386
1998	23.071	19.980	20.202	5.256	3.878	1.787	1.007	0.696	0.382
1999	40.511	17.091	13.839	11.259	2.472	1.805	0.997	0.469	0.250
2000	63.867	29.946	11.954	6.871	3.404	1.426	0.966	0.387	0.119
2001	28.223	47.314	21.097	7.115	2.658	1.695	0.719	0.345	0.076
2002	14.963	20.905	33.756	11.789	3.921	1.059	0.858	0.222	0.075
2003	28.122	11.085	14.215	18.117	6.495	2.422	0.518	0.369	0.116
2004	28.122	20.791	5.621	6.963	10.586	4.208	1.498	0.148	0.210

Table 4. Instaneous rates of fishing mortality-at-age (yr^{-1}) as estimated in Model Scenario 1 (1975-03).

YEAR	AGE (yr)								
	1	2	3	4	5	6	7	8	≥9
1975	0	0.049	0.346	0.45	0.959	0.404	0.241	0.753	0.753
1976	0	0.107	0.547	1.028	1.098	0.59	0.417	0.704	0.704
1977	0	0.043	0.225	0.503	0.574	0.64	0.393	0.735	0.735
1978	0	0.299	0.198	0.749	0.656	0.459	0.368	0.473	0.473
1979	0	0.04	0.108	0.633	0.441	0.478	0.34	0.434	0.434
1980	0	0.184	0.32	0.474	0.272	0.231	0.331	0.442	0.442
1981	0	0.078	0.201	0.641	0.364	0.218	0.357	0.519	0.519
1982	0.003	0.039	0.291	0.872	0.228	0.144	0.239	0.498	0.498
1983	0	0.066	0.265	0.667	0.173	0.129	0.118	0.367	0.367
1984	0	0.08	0.451	0.588	0.16	0.176	0.193	0.191	0.191
1985	0	0.037	0.146	0.595	0.267	0.134	0.324	0.318	0.318
1986	0	0.062	0.195	0.462	0.081	0.085	0.224	0.175	0.175
1987	0	0.023	0.268	0.41	0.173	0.159	0.185	0.259	0.259
1988	0	0.022	0.215	0.239	0.172	0.384	0.205	0.279	0.279
1989	0.006	0.083	0.084	0.269	0.407	0.324	0.268	0.203	0.203
1990	0.004	0.023	0.078	0.405	0.815	0.462	0.39	0.294	0.294
1991	0.004	0.037	0.188	0.171	0.217	0.324	0.277	0.351	0.351
1992	0	0.028	0.204	0.284	0.452	0.535	0.344	0.319	0.319
1993	0	0.037	0.132	0.275	0.197	0.26	0.57	0.669	0.669
1994	0.001	0.056	0.231	0.367	0.27	0.301	0.557	0.563	0.563
1995	0	0.024	0.248	0.557	0.099	0.164	0.425	0.528	0.528
1996	0	0.045	0.31	0.43	0.267	0.289	0.359	0.481	0.481
1997	0	0.095	0.267	0.675	0.174	0.148	0.443	0.972	0.972
1998	0	0.067	0.285	0.454	0.465	0.284	0.466	1.16	1.16
1999	0.002	0.058	0.4	0.896	0.25	0.325	0.646	1.502	1.502
2000	0	0.05	0.219	0.65	0.397	0.385	0.731	1.595	1.595
2001	0	0.038	0.282	0.296	0.62	0.38	0.876	1.426	1.426
2002	0	0.086	0.322	0.296	0.182	0.415	0.545	0.641	0.641
2003	0.002	0.379	0.414	0.237	0.134	0.18	0.956	0.535	0.535

Table 5. Rates of fishing mortality (*F*), annual catch (*C*), stock biomass (ages ≥1, *B*), and spawning stock biomass (*SSB*) for a range of F_{MSY} and F_{Limit} proxy biological reference points from uncertainty analysis associated with Model Scenario 1 (see section 6.3.2). Generated statistics are based on assumptions regarding current levels of productivity (recruitment) and *F*: (a) high productivity/low *F*; (b) high productivity/high *F*; (c) low productivity/low *F*; (d) low productivity/high *F*. Recent estimates of fishing mortality (F_{2003}), catch (C_{2004}), stock biomass on January 1 (B_{2004}), and spawning stock biomass at the beginning of the spawning season (SSB_{2004}) are highlighted in bold. Similarly, the corresponding projected estimates in 2010 are also shown in bold. See section 6.3.2.

A HiPro/LoF

		F **(per yr)**		***C*** **(1,000 mt per yr)**		***B*** **(1,000 mt)**	**Percent of unfished**		***SSB*** **at mid-yr (1,000 mt)**	**Percent of unfished**
	No Fishing	0.00	C_0 =	0	B_0 =	1,153	100	SSB_0 =	724	100
	F_{2003} =	**0.43**	**C_{2004} =**	**98**	**B_{2004} =**	**438**	38%	**SSB_{2004} =**	**165**	23%
Potential F_{MSY} Proxy Reference Points	$F_{40\%}$ =	0.30	C_{MSY} =	91	B_{MSY} =	656	57%	SSB_{MSY} =	291	40%
	$F_{30\%}$ =	0.42	C_{MSY} =	100	B_{MSY} =	562	49%	SSB_{MSY} =	216	30%
	$F_{0.1}$ =	0.37	C_{MSY} =	97	B_{MSY} =	600	52%	SSB_{MSY} =	246	34%
Potential F_{Limit} Reference Points	$F_{20\%}$ =	0.61	C_{Limit} =	107	B_{Limit} =	464	40%	SSB_{Limit} =	144	20%
	F_{Max} =	1.07	C_{Limit} =	110	B_{Limit} =	334	29%	SSB_{Limit} =	61	8%
			C_{2010} =	**92**	**B_{2010} =**	**534**		**SSB_{2010} =**	**190**	

B HiPro/HiF

		F **(per yr)**		***C*** **(1,000 mt per yr)**		***B*** **(1,000 mt)**	**Percent of unfished**		***SSB*** **at mid-yr (1,000 mt)**	**Percent of unfished**
	No Fishing	0.00	C_0 =	0	B_0 =	1,153	100	SSB_0 =	724	100
	F_{2003} =	**0.68**	**C_{2004} =**	**98**	**B_{2004} =**	**438**	38%	**SSB_{2004} =**	**165**	23%
Potential F_{MSY} Proxy Reference Points	$F_{40\%}$ =	0.30	C_{MSY} =	91	B_{MSY} =	656	57%	SSB_{MSY} =	291	40%
	$F_{30\%}$ =	0.42	C_{MSY} =	100	B_{MSY} =	562	49%	SSB_{MSY} =	216	30%
	$F_{0.1}$ =	0.37	C_{MSY} =	97	B_{MSY} =	600	52%	SSB_{MSY} =	246	34%
Potential F_{Limit} Reference Points	$F_{20\%}$ =	0.61	C_{Limit} =	107	B_{Limit} =	464	40%	SSB_{Limit} =	144	20%
	F_{Max} =	1.07	C_{Limit} =	110	B_{Limit} =	334	29%	SSB_{Limit} =	61	8%
			C_{2010} =	**104**	**B_{2010} =**	**432**		**SSB_{2010} =**	**117**	

Table 5. Continued.

C LoPro/LoF		***F*** (per yr)		***C*** (1,000 mt per yr)		***B*** (1,000 mt)	Percent of unfished		***SSB*** at mid-yr (1,000 mt)	Percent of unfished
	No Fishing	0.00	C_0 =	0	B_0 =	837	100	SSB_0 =	525	100
Potential F_{MSY} Proxy Reference Points	**F_{2003} =**	**0.43**	**C_{2004} =**	**98**	**B_{2004} =**	**438**	52%	**SSB_{2004} =**	**165**	31%
	$F_{40\%}$ =	0.30	C_{MSY} =	66	B_{MSY} =	476	57%	SSB_{MSY} =	211	40%
	$F_{30\%}$ =	0.42	C_{MSY} =	73	B_{MSY} =	408	49%	SSB_{MSY} =	157	30%
	$F_{0.1}$ =	0.37	C_{MSY} =	70	B_{MSY} =	435	52%	SSB_{MSY} =	178	34%
Potential F_{Limit} Reference Points	$F_{20\%}$ =	0.61	C_{Limit} =	78	B_{Limit} =	337	40%	SSB_{Limit} =	104	20%
	F_{Max} =	1.07	C_{Limit} =	80	B_{Limit} =	243	29%	SSB_{Limit} =	44	8%
			C_{2010} =	**76**	**B_{2010} =**	**419**		**SSB_{2010} =**	**162**	

D LoPro/HiF		***F*** (per yr)		***C*** (1,000 mt per yr)		***B*** (1,000 mt)	Percent of unfished		***SSB*** at mid-yr (1,000 mt)	Percent of unfished
	No Fishing	0.00	C_0 =	0	B_0 =	837	100	SSB_0 =	525	100
Potential F_{MSY} Proxy Reference Points	**F_{2003} =**	**0.68**	**C_{2004} =**	**98**	**B_{2004} =**	**438**	52%	**SSB_{2004} =**	**165**	31%
	$F_{40\%}$ =	0.30	C_{MSY} =	66	B_{MSY} =	476	57%	SSB_{MSY} =	211	40%
	$F_{30\%}$ =	0.42	C_{MSY} =	73	B_{MSY} =	408	49%	SSB_{MSY} =	157	30%
	$F_{0.1}$ =	0.37	C_{MSY} =	70	B_{MSY} =	435	52%	SSB_{MSY} =	178	34%
Potential F_{Limit} Reference Points	$F_{20\%}$ =	0.61	C_{Limit} =	78	B_{Limit} =	337	40%	SSB_{Limit} =	104	20%
	F_{Max} =	1.07	C_{Limit} =	80	B_{Limit} =	243	29%	SSB_{Limit} =	44	8%
			C_{2010} =	**83**	**B_{2010} =**	**332**		**SSB_{2010} =**	**98**	