7 Gulf of Alaska Pacific ocean perch (Executive Summary)

Dana Hanselman, Jonathan Heifetz, Jeffrey T. Fujioka, and James N. Ianelli

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7.1 Introduction

For 2005, GOA rockfish have been moved to a biennial stock assessment schedule to coincide with new survey data. On alternate (even) years we will present an executive summary with last year's harvest parameters and projection for this year, and this year's harvest parameters and projection for next year with updated catch information. Last year's full stock assessment is on the web (Hanselman et al. 2003, http://www.afsc.noaa.gov/refm/docs/2003/GOAPOP.pdf). We recommend the use of ABCs presented from the model with updated catch and projections.

We continue to use the generic rockfish model as the primary assessment tool. This model was developed in a workshop held at the Auke Bay Laboratory in February 2001, and refined to its current configuration in 2003. The model was constructed with AD Model Builder software. The model is a separable age-structured model with allowance for size composition data that is adaptable to several rockfish species. The data sets used included total catch biomass for 1961-2004; size compositions from the fishery for 1963-77 and 1990-97; survey age compositions for 1984, 1987, 1990, 1993, 1996 and 1999; fishery age composition for 1998-2002; and survey biomass estimates for 1984, 1987, 1990, 1993, 1996, 1999, 2001 and 2003. The only new data in the model were the updated 2002 (11,734 mt) and 2003 (10,861 mt) catches and an estimated 2004 (11,800 mt) fishery catch.

7.2 Summary of Major Changes

There are no major changes in the this year's model from last year. There is a slight downward change in spawning biomass and a small upward change in ABC. This is due to the fishery selectivity curve being relatively steep. A larger year class moved into the fishery, so the exploitable biomass has increased slightly. However, the older fish that make up the bulk of the spawning biomass were on a slight downward trend, as indicated by last year's projection. Thus, a slightly larger ABC resulted, even though spawning biomass decreased slightly. For next year's full assessment, an age sample of 1,021 otoliths from the 2003 trawl survey and new survey biomass estimates for 2005 will be included.

For the 2005 fishery, we recommend the ABC of 13,575 mt from the updated model. This ABC is similar to last year's ABC of 13,336 mt. The corresponding reference values for Pacific ocean perch are summarized below. The stock is not overfished, nor is it approaching overfishing status. The primary reference values are shown in the following table, with the recommended values in bold.

	Last year's projection-not updated		This year's projection-updated	
	2004	2005	**2005***	2006
$B_{40\%}$ (mt)	89,699	89,699	86,162	86,162
Female Spawning Biomass (mt)	95,762	93,397	92,421	90,572
$F_{50\%}$	0.04	0.04	0.04	0.04
F_{ABC} (maximum allowable= $F_{40\%}$)	0.06	0.06	**0.06**	0.06
F_{OFL} ($F_{35\%}$)	0.07	0.07	**0.07**	0.07
$ABC_{F50\%}$ (mt yield at $F_{50\%}$)	9,410	9,137	9,564	9,365
$ABC_{F40\%}$ (mt yield at $F_{40\%}=F_{max}$)	13,336	12,949	**13,575**	13,292
OFL(mt, yield at $F_{35\%}$)	15,924	15,477	**16,266**	15,887

7.3 Area Apportionment

The apportionment percentages are identical to last year, because there is no new survey information. The following table shows the recommended apportionment for 2005.

	Western	Central	Eastern	Total
Area Apportionment	19%	63%	18%	100%
Area ABC (mt)	**2,567**	**8,535**	**2,473**	**13,575**
Area OFL (mt)	3,076	10,226	2,964	16,266

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is the same as last year at 0.34. This results in an apportionment of ABC to the W. Yakutat area of 841 mt, which would leave 1632 mt of ABC east of 140° W longitude unharvested.

7.4 Responses to SSC Comments

The SSC has cited the Goodman report (2002) which specifically raises questions about the harvest rates for rockfish. To partially answer this question, we adapt methods from Dorn (2002) and a draft manuscript from Spencer and Dorn (2003) to present a Bayesian spawner-recruit analysis in Appendix 7A.1. This appendix suggests that the optimum harvest rate is between $F_{26\%}$ and $F_{28\%}$ depending on the spawner-recruit relationship used. This appendix suggests that a harvest rate of $F_{40\%}$ for Gulf of Alaska Pacific ocean perch is sufficiently conservative.

The SSC also stated general concerns about age-distribution truncation in rockfish, because fecundity and larval success for older rockfish may be much higher (Bobko and Berkeley 2004, Berkeley et al. 2004). In Appendix 7A.2 we present a simple analysis applying data for black rockfish from Berkeley et al. (2004) to Gulf of Alaska Pacific ocean perch, where we adjust the maturity curve to reflect better larval survival from older mothers. This analysis shows a 3% decrease in spawning biomass and a 14% decrease in projected ABC. Research similar to the recent work conducted for black rockfish should be initiated for other rockfish such as Pacific ocean perch.

The SSC has requested that additional analysis be provided on the possibility of localized depletion in rockfish stocks. These analyses will be conducted for the next full stock assessment cycle in 2005. In conjunction with these analyses, we will examine the data requirements for potentially disaggregating ABCs in the future.

The SSC also suggested additional exploration of the confounding of catchability and natural mortality. The analysis presented in an appendix to the 2002 GOA slope rockfish SAFE examined this relationship in detail. However, the Pacific ocean perch model has been refined substantially since then, and we will reexamine the parameters' confounding again for the full assessment in 2005.

7.5 Other analysis

Recently, there has been a heightened interest in management strategy evaluation and better ways to capture the real uncertainty in projections of future spawning biomass and catches. In Appendix 7A.3, we present two preliminary alternative methods of projecting the GOA Pacific ocean perch stock into the future and compare it to the standard method used by AFSC scientists.

7A Appendix. Evaluation of management parameters using Bayesian stock-recruit analysis

7A.1 Introduction and Methods

In a recent review of the harvest policy used in the North Pacific, particular attention was given to the consideration of lower harvest rates for rockfish because of their "low productivity" (Goodman et al. 2002). In this appendix, we conduct a Bayesian stock-recruit analysis for Gulf of Alaska Pacific ocean perch using methods developed by Dorn (2002) and applied to GOA pollock in Dorn et al. (2003).

7A.1.1 Bayesian stock-recruit model

The Beverton-Holt curve was re-parameterized using R_0 , the expected recruitment for an unfished stock size of S_0, and a parameter that measures the resiliency of the stock, h, defined as the proportion of R_0 that recruits when the stock is fished to 20% of unfished biomass (i.e., the "steepness" parameter of Mace and Doonan (1988)). The Beverton-Holt curve with these new parameters is given by

$$R = \frac{0.8 R_0 h S}{0.2 \varphi_0 R_0 (1-h) + (h-0.2) S}$$

where $S_0 = \varphi_0 R_0$, and φ_0 is spawning biomass per recruit for an unfished stock, which is estimated independently using conventional spawning biomass per recruit equations. Steepness ranges between 0.2 (recruits related linearly to spawning biomass) to 1.0 (recruits independent of spawning biomass).

Variability around the stock-recruit relationship was assumed lognormal. The assumption of lognormal errors in S-R models is based on both theoretical considerations (Hilborn and Walters 1992) and empirical studies (Peterman 1981, Myers et al. 1995). A lognormal probability density for recruitment is

$$p(R \left| \hat{R}(S, R_0, h), \sigma^2 \right.) = \frac{1}{R\sqrt{2\pi}\sigma} \exp\left[\frac{-1}{2\sigma^2} \left(\log R - \log \hat{R} + \frac{\sigma^2}{2} \right)^2 \right]$$

where $\hat{R}(S, R_0, h)$ is the expected recruitment as a function of the S-R parameters and spawning biomass, and σ^2 is a shape parameter. Note that the mean of the lognormal variate is used here rather than the usual parameterization with the median, $m = \hat{R}\exp(-\sigma^2/2)$.

There are three parameters for which priors need to be developed *R_0, h* and σ^2. The prior for steepness was modeled by assuming the logit of *h* was normally distributed (after rescaling *h* into the interval (0,1), $(h_k - 0.2)/0.8$, and simplifying),

$$\beta = \log\left(\frac{h-0.2}{1-h}\right), \beta \sim N(\mu, \xi^2)$$

For *h* in the interval (0.2, 1.0), the logit β ranges from -∞ to +∞. The use of the logit transformation makes it straightforward to specify a prior mean and variance.

A normal prior was used for R_0,

$$R_0 \sim N(\overline{R}_0, \omega^2)$$

where $\overline{R}_0$ is the prior mean, and ω^2 is the prior variance. For σ^2, a locally uniform prior for σ on a log scale was used. The negative log-likelihood is proportional to

$$-\log L_1 = \sum_i \frac{(\log R_i - \log \hat{R}_i(S_{i,} R_0, h) + \sigma^2/2)^2}{2\sigma^2} + n\log\sigma$$

Note that we assume no correlation in recruitment and no error in estimates of spawning biomass, i.e., the usual simplifying assumptions in analyses of S-R data.

The negative log-prior is proportional to

$$-\log L_2 = \frac{1}{2\zeta^2}(\beta-\mu)^2 + \frac{1}{2\omega^2}(R_0 - R_0)^2$$

The log joint posterior distribution is the sum of the log-likelihood and the log prior,

$$L = \log L_1 + \log L_2$$

The mode of the joint posterior distribution was obtained using the AD Model Builder nonlinear optimization software (Otter Research 1996).

7A.1.2 Obtaining posterior distributions using the Markov Chain Monte Carlo algorithm

To estimate F_{MSY}, the marginal posterior distribution of the stock-recruit parameters is needed, obtained by integrating joint posterior distribution with respect to the other parameters. Rather than attempting to evaluate this integral analytically, we used a MCMC algorithm to obtain random samples from the joint distribution. From these samples it is an easy matter to obtain empirical histograms that approximate the marginal distribution of any parameter of interest. The MCMC algorithm generates a Markov chain of random samples (i.e., each sample is conditionally dependent on the preceding sample) whose stationary distribution is the joint posterior distribution. Gelman (1995) provides a good introduction to MCMC methods, including the Hastings-Metropolis algorithm provided in the AD Model Builder software (see 30 January 1998 *http://otter-rsch.com/cc/cctoc.html* for additional details). Marginal posterior distributions were obtained by subsampling every 200th sample from a chain of length 1,000,000 of the MCMC algorithm after discarding the first 50,000 cycles.

7A.1.3 Estimates of FMSY

Let $h_{(C)}$, $R_{0(C)}$ be a sample of the stock-recruit parameters from the joint posterior distribution generated by the MCMC algorithm. For each sample, the equilibrium recruitment $R^{EQ}(p)$ is obtained for a sequence of harvest rates where SPR is reduced to a fraction p of unfished SPR

$$R^{EQ}(p) = \max\left(0, R_{0(C)} \frac{0.8h_{(C)}p - 0.2(1-h_{(C)})}{p(h_{(C)} - 0.2)}\right).$$

Some combinations of SPR rate and sampled stock-recruit parameters result in negative equilibrium recruitment, indicating that the SPR rate is not sustainable--hence the use of the *max* function in the above equation.

Equilibrium yield, $Y^{EQ}(p)$, and equilibrium spawning biomass , $S^{EQ}(p)$, at SPR rate p are

$$Y^{EQ}(p) = \eta_p R^{EQ}(p)$$
$$S^{EQ}(p) = p\varphi_0 R^{EQ}(p)$$

where η_p is the yield per recruit when SPR is reduced to a fraction p of unfished SPR.

F_{MSY} can be regarded as the fishing mortality rate at which expected yield is maximized,

$$SPR_{F_{MSY}} = \max_p E\left(Y^{EQ}(p)\right)$$

The expected yield at a particular SPR rate is obtained by averaging the equilibrium yield for each of the MCMC samples drawn from the joint posterior distribution. Of course, the relationship of the SPR rate to yield is also of interest, in addition to the point estimates.

7A.1.4 Extension to the Ricker stock-recruit curve

While Pacific ocean perch are not usually considered a candidate species for a dome-shaped S-R relationship, we present the Ricker curve for contrast to the Beverton-Holt model. Kimura (1988) re-parameterized the Ricker curve in relation to R_0, the expected recruitment for an unfished stock size of S_0, and a curvature parameter, α. The Ricker curve with parameters R_0 and α is

$$R = \frac{S}{\varphi_0} \exp\left[\alpha\left(1 - \frac{S}{R_0\varphi_0}\right)\right]$$

Note that e^{α} is the potential increase in reproductive success relative to an unfished stock, so that additive changes in α imply multiplicative changes in reproductive success at low stock size. Steepness is not a useful parameter for the dome-shaped Ricker model because recruitment at 20% of unfished biomass can be greater than unfished recruitment (steepness >1). We modeled the similarity of stocks in their response to harvesting by assuming that the curvature parameter for the kth stock was normally distributed,

$$\alpha_k \sim N(\mu, \tau^2).$$

Priors for μ and τ^2 were the same as those developed for the Beverton-Holt curve.

Equilibrium recruitment for the Ricker curve is given by

$$R^{EQ}(p) = \frac{R_0}{p}\left(\frac{1+\log p}{\alpha}\right).$$

7A.1.5 Specification of prior means and variances

A Bayesian analysis is a formal process for combining prior knowledge with data, with the data dominating posterior distribution when they are highly informative. We developed priors for β and α that are consistent with the perceived productivity of rockfish; the prior for R_0 was based upon the estimated parameter in the most recent assessment. Posterior distributions were estimated to evaluate whether available stock-recruit data support the use of tier 3 proxies, or whether other management parameters would be more appropriate for Gulf of Alaska rockfish.

7A.1.6 Prior for β

The derivation of $F_{35\%}$ as a proxy for F_{MSY} is from a theoretical analysis by Clark (1991). Clark initially considered S-R curves the Beverton-Holt and Ricker models that differed by the potential increase in reproductive success (R/S at the origin) relative to an unfished stock (R_0/S_0). Potential increases in reproductive success (Clark terms D) by factors of 4, 8, and 16 (steepness = 0.50, 0.67, and 0.80, respectively) were considered plausible, while factors of 2 and 32 (steepness = 0.33, and 0.89, respectively) were considered implausible. In Clark (2002), the original analysis is revisited to consider D values as low as 1.5 (steepness = 0.27). These deterministic results showed that at such a low level of potential reproductive success, the optimum harvest rate would be well above $F_{50\%}$. Dorn et al. (2003) generated prior distributions from these considerations by using a potential increase in reproductive success of 8 (β = 0.34) as the midpoint of the distribution, and setting the prior variance so that factors 4 and 16 were located at the 10th and 90th percentiles of the distribution (Table 7A-1). For GOA POP, the same variance was used but the midpoint of the distribution was lowered to a potential increase of reproductive success of 4 (β = -0.51), which reflects the perceived lower productivity of rockfish (Goodman et al. 2002). This midpoint of this distribution corresponds to a steepness of 0.50, closer to the value of 0.39 found for five rockfish stocks in a meta-analysis by Myers et al. (1999). The variance of the prior for α was also taken from Dorn et al. (2003), with the midpoint lowered to correspond to a potential increase of reproductive success of 4 rather than 8, yielding an α value of 1.386.

7A.1.7 Prior for R_0

The estimated number of age-2 recruits in the first year of the 2003 GOA POP assessment was 0.0422 billion fish and was used as the midpoint of the prior distribution for R_0. We used a relatively large coefficient of variation of 0.22 for this prior as used by Dorn et al. (2003).

7A.2 Results

Fits of the Beverton-Holt and Ricker models to the stock-recruit estimates were similar (Fig. 7A-1). The Ricker curve is slightly dome-shaped, and has a slightly lower slope at the origin than the Beverton-Holt curve. The Ricker curve predicts larger recruitment between spawning stock biomasses between 25-200 kilotons. The estimates of steepness and R_0 were 12% and 15% higher, respectively, for the Beverton-Holt model over the Ricker model (Table 7A-2).

The posterior distribution of β for the Beverton-Holt curve has a higher mean but is only marginally narrower than the prior, indicating that the S-R estimates are informative, but uncertain for the Beverton-Holt curve (Figure 7A-2A). The posterior of α for the Ricker curve has a higher mean and is much narrower than the prior, which would indicate it is informative and more certain under the Ricker model (Figure 7A-2B). These results are likely caused by the large recruitments at low stock sizes in 1988 and 1989.

Posterior distributions of R_0 *for* both the Beverton-Holt and the Ricker model are shifted upwards from the prior mean (Figure 7A-3). Both estimates of R_0 are consistent with the estimated recruitment of the years of the highest spawning biomass in 1961 and 1962 as seen in Figure 7A-1.

Posterior model probabilities were 0.499 and 0.501 for the Beverton-Holt and the Ricker models, respectively, indicating that the data is nearly equally consistent with the Beverton-Holt and the Ricker models.

The expected yield was maximized at $F_{28\%}$ for the Beverton-Holt curve and $F_{26\%}$ for the Ricker curve. Expected yield is extremely flat, especially for the Beverton-Holt curve, in the range of F20%-F50%, suggesting at least 80% of the expected maximum yield could be obtained by fishing mortality rates in this range (Table 7A-2, Figure 7A-4).

Although the Beverton-Holt and Ricker curves are similar, there are significant differences between the two models in the population response to harvesting. The Ricker model produces estimates of expected yield that are higher, and maximum occurs at a higher stock size in comparison to the Beverton-Holt curve (Figure 7A-5). The two models also produce different estimates of equilibrium stock size when fishing at $F_{40\%}$ (Figure 7A-7). For the Beverton-Holt model, equilibrium stock size is approximately 35% of unfished abundance, while for the Ricker model, equilibrium stock size is 56% of unfished abundance.

7A.3 Preliminary Conclusions

Based on the Bayesian stock recruit analysis, $F_{35\%}$ appears to be an appropriate proxy for F_{MSY} for Gulf of Alaska Pacific ocean perch, when examining the current recruitment estimates. These results are inconsistent with Ianelli and Heifetz (1995) who recommend $F_{44\%}$ for a harvest rate for POP. Their findings correspond to a fishing mortality of approximately 0.08 which is 33% higher than the current harvest rate. The data may have changed enough in a decade to result in much different rates, or the more fully Bayesian technique presented here allows more insight into the stock. Dorn (2002) found harvest rates exceeding $F_{30\%}$ to be lower than F_{MSY} for the Gulf of Alaska POP stock, apparently due to higher resilience. Of all rockfish stocks examined, GOA POP had the highest steepness parameter indicating strong compensation. In a parallel analysis, the BSAI POP stock (Spencer and Dorn 2003), had very similar results overall (see Table 7A-2), but the steepness was higher in the GOA stock. Both analyses of the Alaskan stocks contrast to the results in Dorn (2002) for West Coast, in which steepness was quite low.

This observed resiliency of GOA POP is largely influenced by several large recruitments in the late 1980's when spawning stock biomass was quite low. Whether this indicates density independent recruitment or favorable environmental conditions in those years is unknown. Dorn (2002) suggests that perhaps British Columbia and Gulf of Alaska are the optimal range for Pacific ocean perch and have higher resilience than stocks on the periphery of the range like the Bering Sea and West Coast that may be more influenced by changing environmental conditions.

The main conclusion of this harvest policy analysis is to illustrate that the current harvest rate is likely within a reasonable range, but the harvest policy is robust to small upward or downward changes. If the Beverton-Holt curve is accepted as reasonable, which is the more likely relationship for the life-history strategy of POP (Ianelli and Heifetz 1995), then the harvest policy is robust; harvest rates between $F_{20\%}$ and $F_{50\%}$ would capture roughly 80% of MSY. The use of priors reflecting that rockfish are less productive than other fish managed by the $F_{40\%}$ policy did not affect the outcome, indicating that the stock-recruitment data are informative. One caveat is that the conclusions of this analysis are based on several, large, recent recruitments which are uncertain and unpredictable. Since the stock assessment is updated yearly, adjustments will be made if new data indicates a downturn in the population.

Table 7A-1. Prior values used in a Bayesian analysis of GOA Pacific ocean perch stock-recruit data

S-R Model	β or α mean	β or α s.d.	R_0 mean	R_0 CV
Beverton-Holt	-0.51	0.63	0.0422	0.22
Ricker	1.386	0.54	0.0422	0.22

Table 7A-2. Posterior means of S-R and management parameters for a Bayesian analysis of GOA and BSAI stock-recruit data. For the Ricker model, the reported steepness is given by h=exp(α)/(exp(α) +4), which is the steepness of a Beverton-Holt (B-H) curve with the same slope at the origin as the Ricker curve. F_{MSY} is defined as the fishing mortality rate at which expected yield is maximized, considering uncertainty in the S-R relationship.

	BSAI		GOA	
Model	B-H	Ricker	B-H	Ricker
R_0	0.045	0.037	0.055	0.049
Steepness	0.84	0.76	0.78	0.68
Beta/Alpha	~1.2	~2.5	1.02	2.15
%SPR at F_{MSY}	26	20	28	26
% unfished stock size at F_{MSY}	22	36	23	33
% unfished stock size at $F_{40\%}$	37	64	35	56

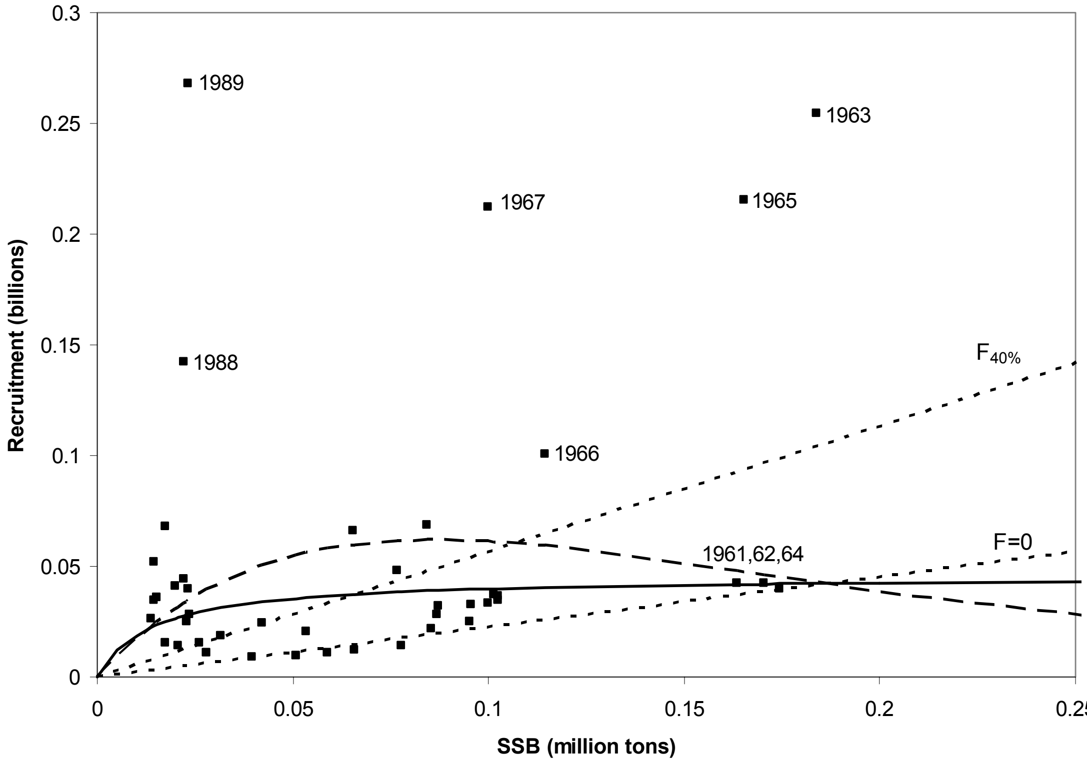

Figure 7A-1. GOA stock-recruit estimates, and mean stock-recruit curves based on posterior parameter means for Beverton-Holt (solid line) and Ricker (dashed line) models. The replacement lines for no fishing (F=0) and $F_{40\%}$ are shown with dotted lines. Labels are year class of 2-year old recruits.

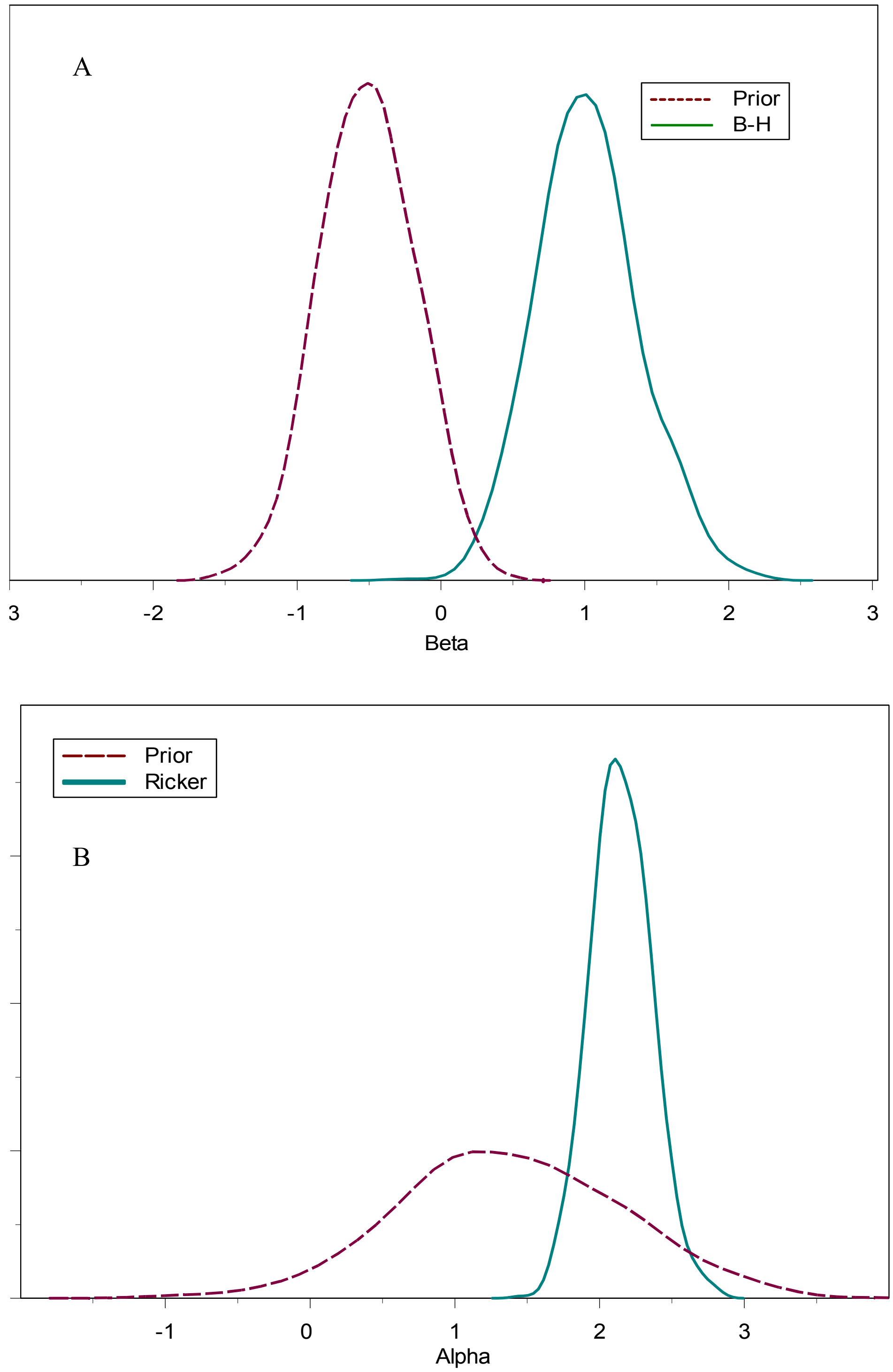

Figure 7A-2. Prior and posterior distributions of β (logit-transformed steepness) for the Beverton-Holt (B-H) curve (A) and α for the Ricker curve (B).

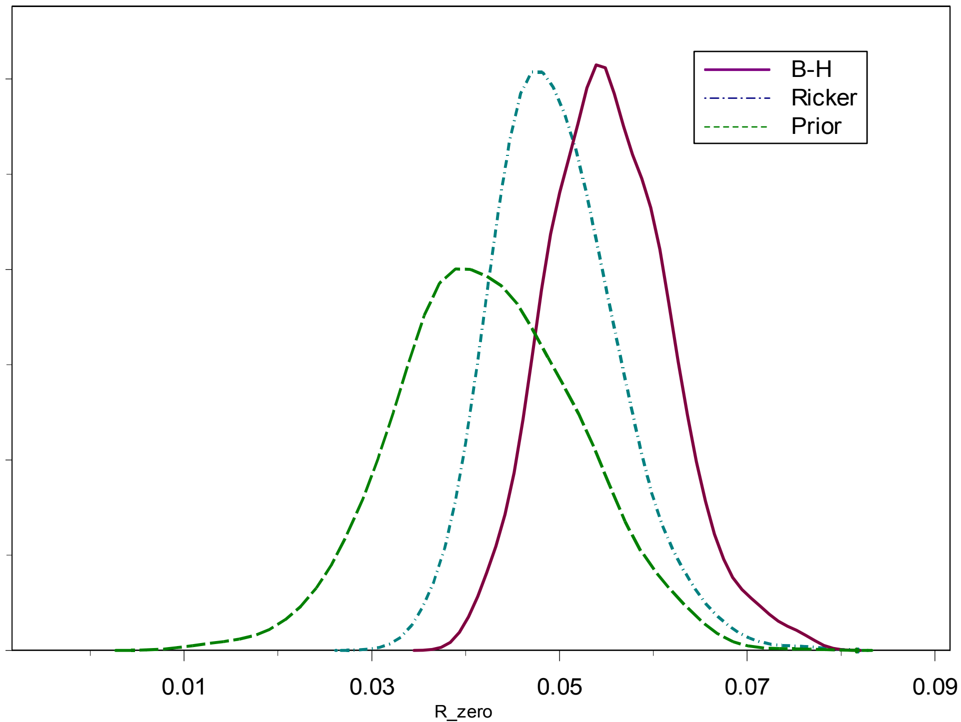

Figure 7A-3. Prior and posterior distributions of R_0 for the Beverton-Holt (B-H) and Ricker curves.

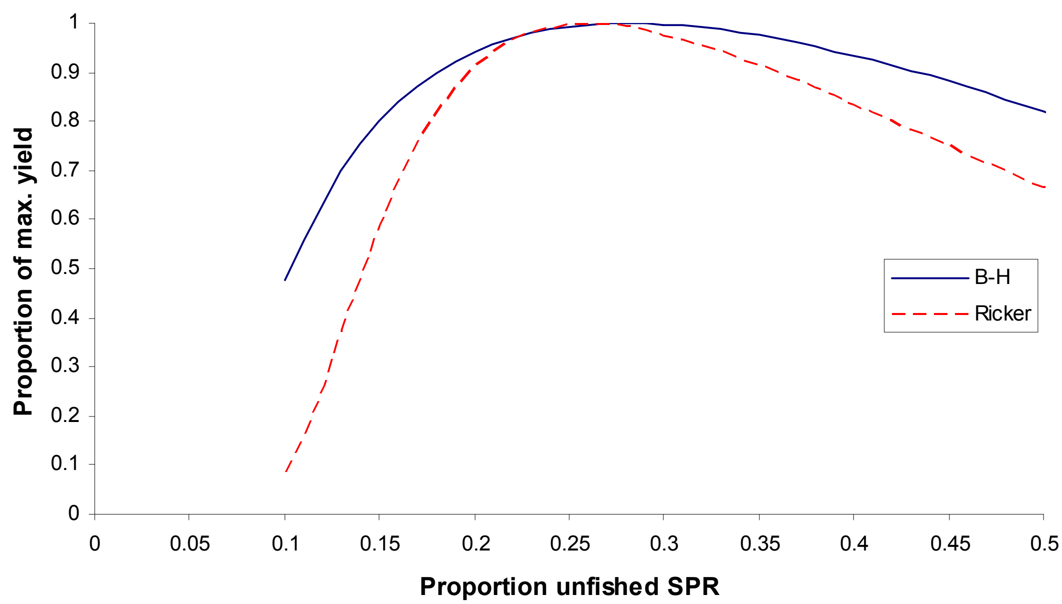

Figure 7A-4. Percent of expected maximum yield as a function of F_{SPR} harvest rates based on MCMC samples from the posterior distribution. Dashed line is Ricker model, solid line is Beverton-Holt (B-H) model.

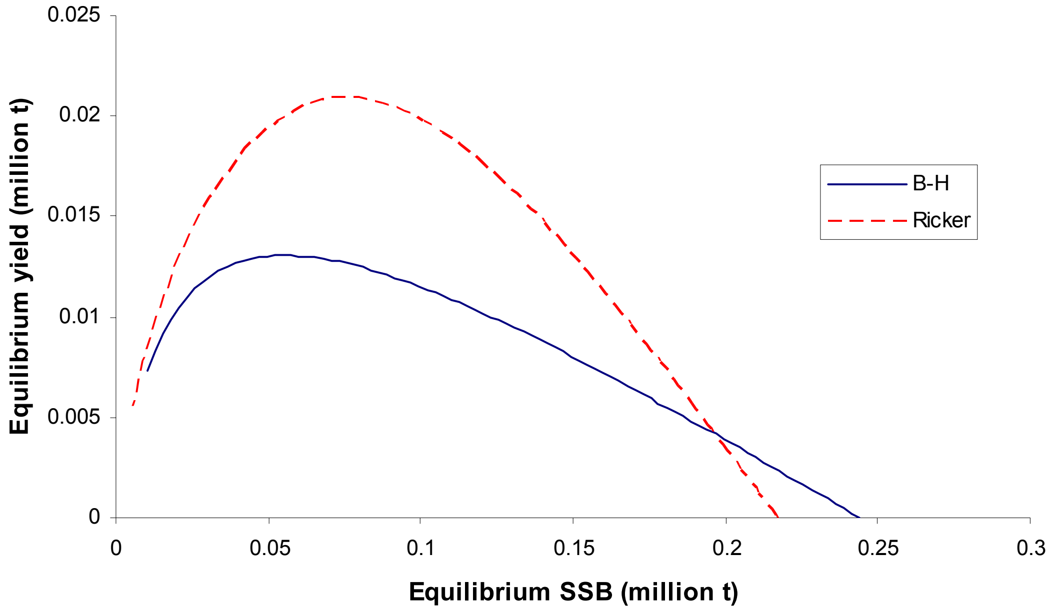

Figure 7A-5. Equilibrium yield as a function of equilibrium spawning biomass based on MCMC samples from the posterior distribution. Dashed line is Ricker model, solid line is Beverton-Holt (B-H) model.

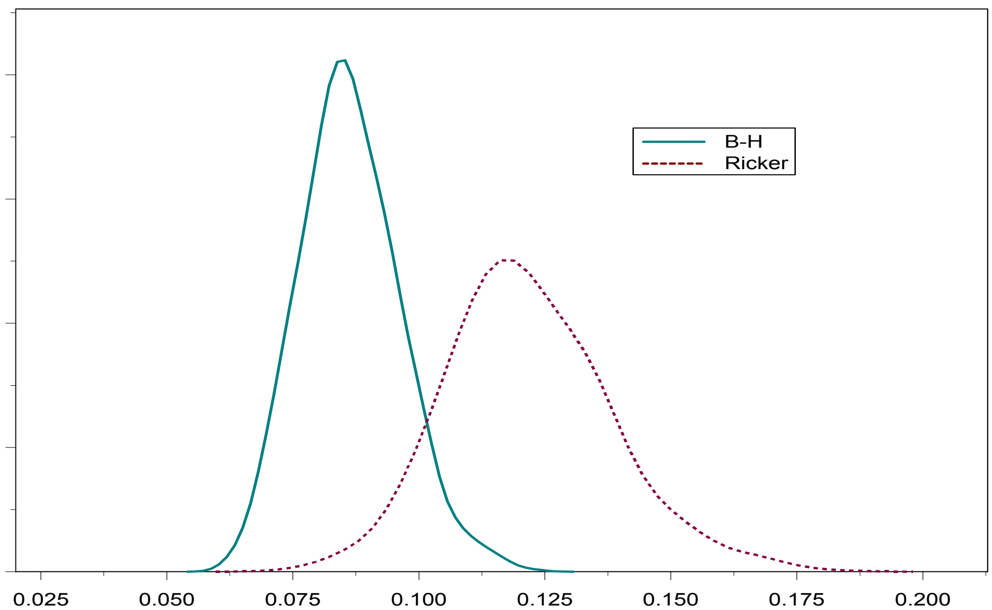

Figure 7A-6. Posterior distribution of equilibrium biomass when fishing at $F_{40\%}$ for Beverton-Holt and Ricker curves based on MCMC sampling from the posterior distribution. Dashed line is Ricker model, solid line is Beverton-Holt (B-H) model.

7B Appendix: Age-truncation and its effects on spawning biomass

7B.1 Introduction

Rockfish are some of the longest living vertebrates on the planet. This evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-truncation could be ruinous to a population with highly episodic recruitment like rockfish (Longhurst 2002).

Recent work on black rockfish (*Sebastes melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. De Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and rougheye rockfish (*S. aleutianus*) for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. In this appendix, we examine the level of age-truncation in the Gulf of Alaska Pacific ocean perch and simplistically apply the results of Berkley et al. (2004) to the maturity curve of the stock assessment for Pacific ocean perch to estimate what the effect of older fish producing larvae with a higher larval survival would have on its biomass estimates.

The earliest accurate age estimates for GOA Pacific ocean perch start in 1984 for the NMFS surveys and in 1987 for the fishery. The average age in both the fishery and survey have generally declined over the last two decades (Figure 7B-1). The proportion of old fish (40 years and older) has declined rapidly in both the fishery and survey. The larger decline in average age and proportion of old fish for the fishery would suggest targeting and depleting the oldest fish in the population by the fishery. One caveat of this figure is that some of the age samples are relatively small (~300). If larvae from these oldest fish have much better survival than the larvae produced by younger fish, then these data could indicate a potential problem.

7B.2 Methods and Results

We use data from Berkeley et al. (2004) for *S. melanops* and extrapolate it to Pacific ocean perch. We use their estimated curve of larval survival as a proxy for fecundity, or enhanced maturity. To reflect the different life history of Pacific ocean perch, we reduced the slope by 50% (POP have approximately twice the maximum age), and started the curve at age 10.5 instead of 6.5 (POP have an age of 50% maturity of 10.5, black rockfish are 50% mature at 6.5). The resulting larval survival curve is shown in Figure 7B-2. We multiplied this curve with the POP maturity curve to come up with a new curve and standardized it to the same average maturity. This yielded a new maturity curve showing a higher maturity at older ages (Figure 7B-3). The maturity curve at this point becomes a surrogate for fecundity or recruits-per-spawner as it no longer directly corresponds to proportion mature (it exceeds one at the oldest ages).

We then ran the stock assessment model, using this new maturity curve. The resulting estimates of spawning biomass are about 3% lower and the projected ABC is about 15% lower because the change in maturity results in a decreased $F_{40\%}$ (Table 7B-1). The spawning biomass estimates were affected more recently than in the past (Figure 7B-4), because of the decline in older fish that has occurred in the last few decades.

7B.3 Preliminary Conclusions

It appears that the age distribution for Pacific ocean perch is currently undergoing truncation. Whether older Pacific ocean perch have much higher larval success like black rockfish is currently unknown. This simple analysis suggests that if Pacific ocean perch larvae do experience much higher survival when reared from older mothers, the stock should be harvested at a lower rate.

Table 7B-1. Changes in key parameters for examining age-truncation in Gulf of Alaska Pacific ocean perch.

	Standard Model	Higher larval survival at older maternal age
B_{2004}	97,197	94,408
F_{40}	0.060	0.052
ABC	13,575	11,568

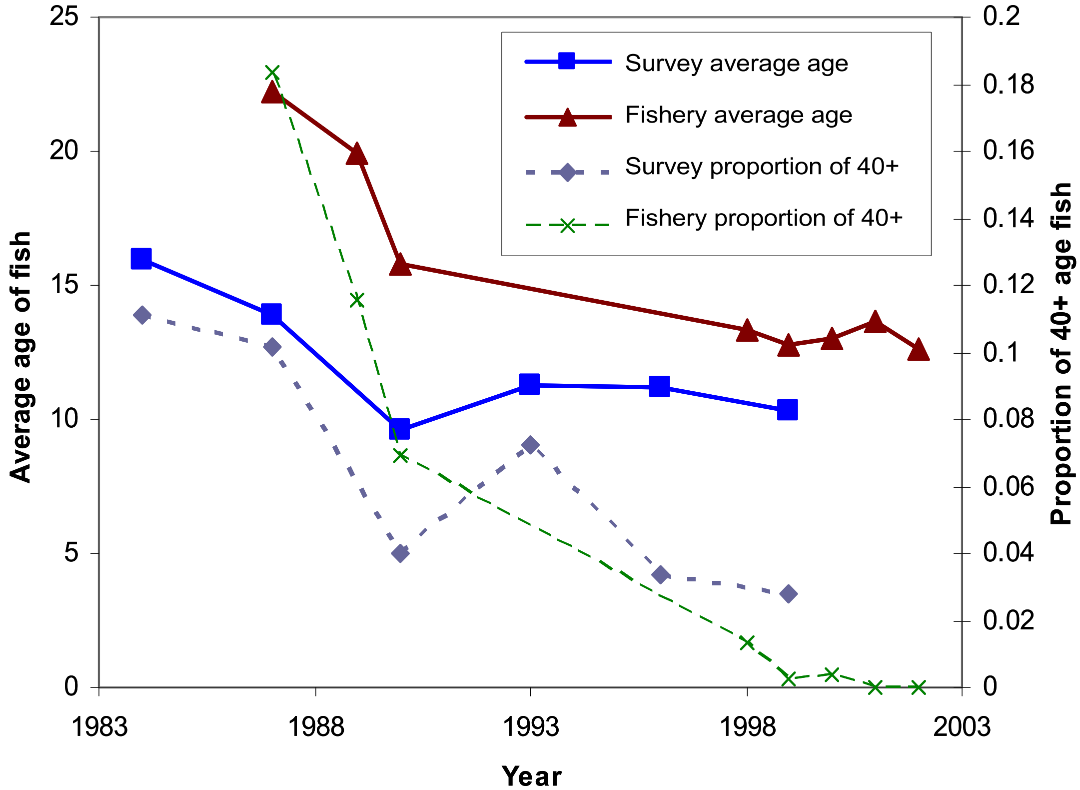

Figure 7B-1. Changes in average age and proportion of 40+ aged fish for of Gulf of Alaska Pacific ocean perch for the NMFS survey and fishery ages.

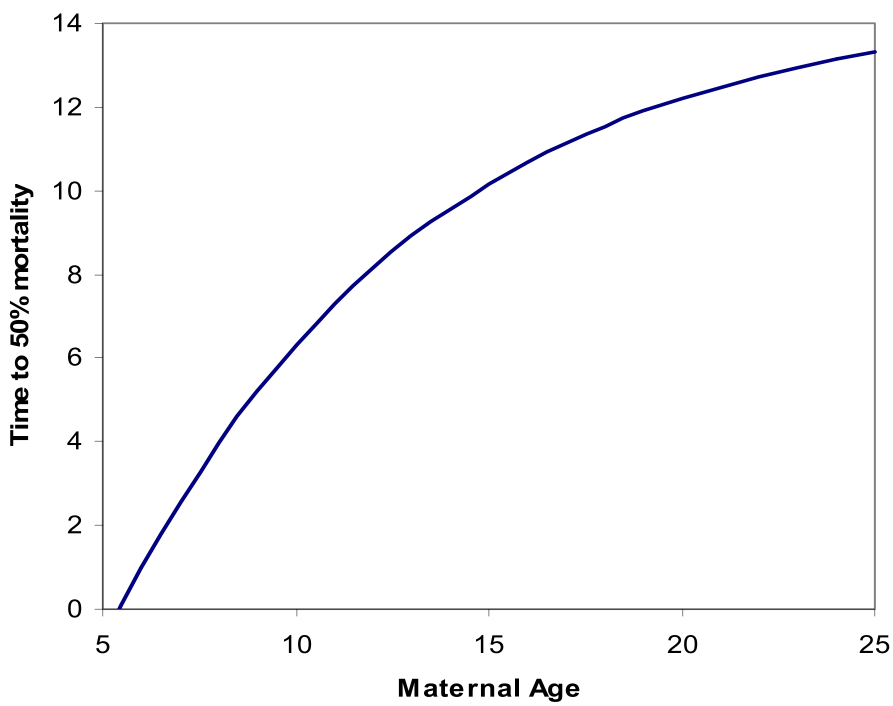

Figure 7B-2. Time to 50% larval mortality adapted for Pacific ocean perch from Berkeley et al. (2004) results for *S. melanops*.

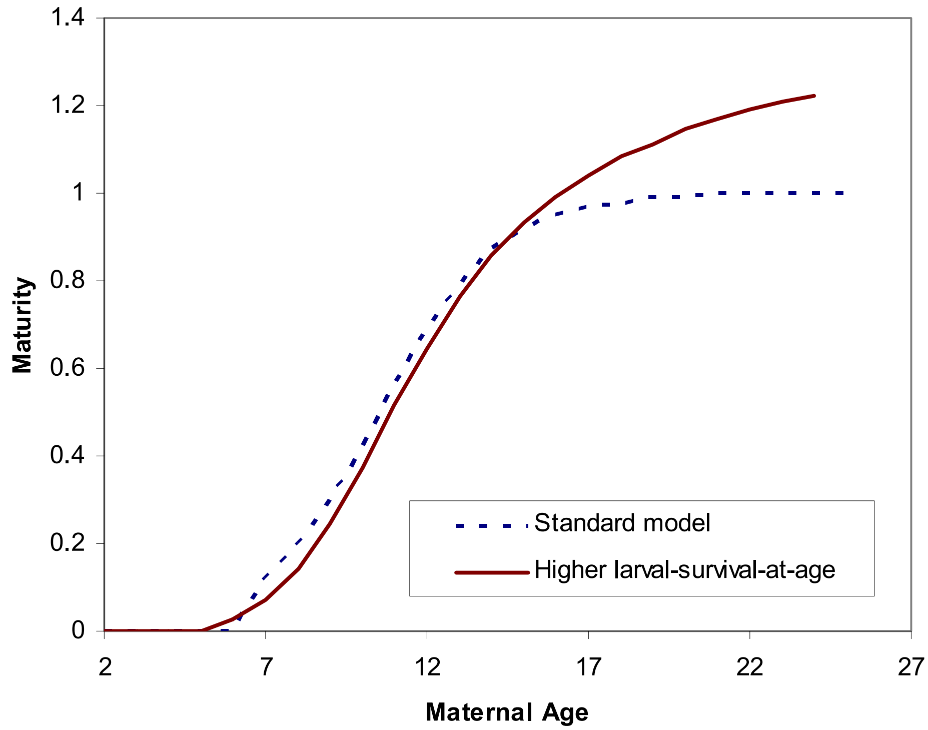

Figure 7B-3. Comparison of new maturity curve from inclusion of modified Berkeley et al. (2004) larval survival curve to standard maturity for Gulf of Alaska Pacific ocean perch. Dashed line equals normal maturity schedule, solid line is a proxy for a higher larval survival from older female fish.

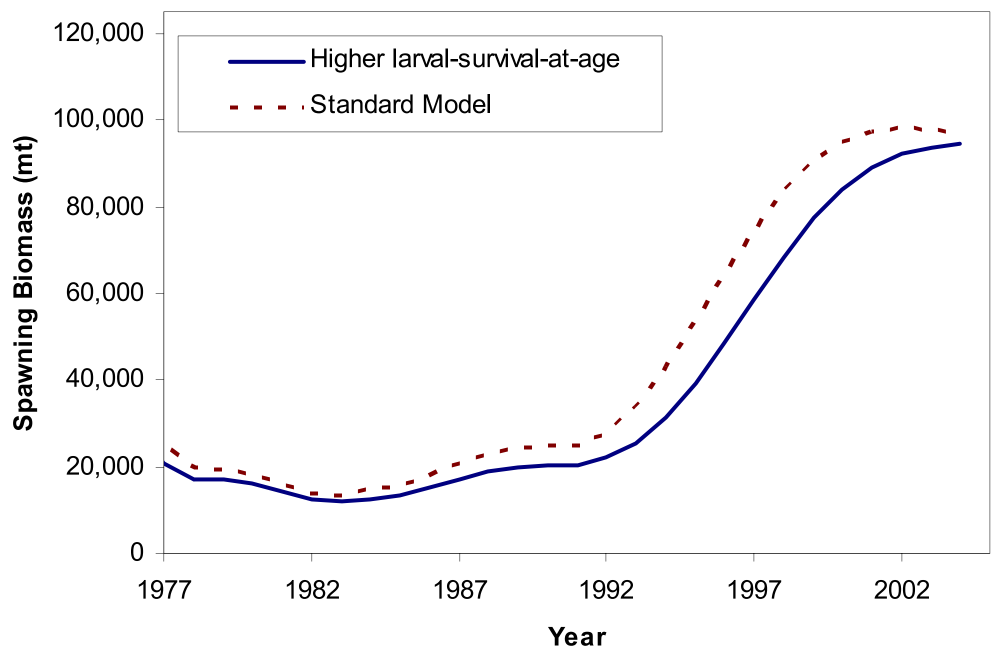

Figure 7B-4. Comparison of spawning biomass estimates of model with higher enhanced maturity-at-age compared to the standard maturity curve for Gulf of Alaska Pacific ocean perch. Dashed line equals spawning biomass with normal maturity schedule, solid line is a spawning biomass using a proxy for a higher larval survival from older female fish.

7C Appendix: Alternate projection strategies for Gulf of Alaska Pacific ocean perch

7C.1 Introduction

A standard set of projections is required for stocks managed under Tier 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56 of the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). In this appendix, we present two other methods to project stock status and yield into the future and compare them to the standard approach used by most Alaska Fisheries Science Center authors (Case 1).

7C.2 Methods and Results

7C.2.1 Case 1

For each scenario, the projections begin with the 2004 numbers at age as projected by the assessment model. In each year, the fishing mortality rate is determined by the spawning biomass in that year and the respective harvest scenario. Recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments during 1977-1999 as estimated by the assessment model. Spawning biomass is computed in each year based on the time of peak spawning (March) using the maturity-at-age and weight-at-age in Hanselman et al. (2003). This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches. Under this standard projection scenario, it would seem that we are remarkably confident about where the spawning stock biomass will be in a decade (Figure 7C-1). Over the last decade, stock assessment scientists have been starting to recognize the value of accounting for the vast uncertainty in our stock assessment estimates (Patterson et al. 2001, NRC 1998, Hilborn et al. 1994). To further explore uncertainty, we present two new methods of projection spawning biomass and catch into the future.

7C.2.2 Case 2

For our Case 2 projection, we use a simple "feedback" scenario where the model is run for the next year and catch is taken at 92% of projected ABC (full ABC has not been taken since 1996 due to the closure of the eastern Gulf of Alaska). This is repeated until 2017, where MCMC sampling is performed (Gelman et al. 1995, also see section 7A.1.2) to estimate the posterior distribution of spawning biomass from 2004-2017. The mean and 95% confidence intervals of the posterior distribution are shown in Figure 7C-2a. The mean is much lower than the Case 1 projection with very wide confidence intervals. The maximum likelihood values are more similar to the Case 1 projection (Figure 7C-2b), but the Hessian confidence intervals are wider than the MCMC confidence intervals.

7C.2.3 Case 3

For our case 3 projections, we use a more complex "feedback" approach, where the model, like Case 1, is given new recruitments generated from the lognormal distribution with the mean log-recruitment and standard deviation estimated by the stock assessment model. This recruitment is used as a proxy for new survey data coming in each year. The model is then run 200 times for each projection year to 2017, allowing a fully stochastic starting point as well as ending point. For each year and iteration, the log-recruitment and standard deviation is re-estimated and used to generate random recruitments for the following year. This differs from Case 1 in several important ways: (1) The starting points are not fixed; (2) The recruitment distribution can change through time; (3) Natural mortality, catchability and other parameters can change through time. This method results in a small upward migration of the projection time series from Case 1, with considerable more uncertainty. This method, though more stochastic than Case 2, provided more certainty, presumably because data was added each year.

7C.2.4 Projecting Yield

The three projection methods give different results in terms of expected yield and the uncertainty of future yield (Figure 7C-4). Case 1 gives the highest immediate yields but the lowest estimate of future yields. Case 2 gives a slightly higher trajectory of yields, but exhibits a cyclical pattern. Case 3 exhibits the highest trend, which moves steadily upward. Cases 1 and 3 because of their simulation nature can give percentile confidence bounds. The lower bounds of the two techniques are similar, but the upper bound is much higher for Case 3.

7C.3 Preliminary Conclusions

Our additional projection methods show that population status into the future may not be as certain as shown by the standard projection method. By starting the current projection model at a fixed parameter space, it ignores the great uncertainty in those starting biomass estimates and gives an unreasonable perception of certainty in the future.

Case 2 shows the situation in which data collection ceased for the species and only added catches to the stock assessment each year. It indicates a retrospective pattern that increases spawning biomass at the beginning of the projection model as each new year is added. The MLE estimates in Case 2 (Figure 7C-2b) show the same mean biomass but a downward trend, while the MCMC estimates in Case 2 show the lowest of the spawning biomass estimates with a downward trend.

Case 3 represents the situation of surveys returning with variable results continuing into the future by simulating recruitment events. Cases 1 and 3 show about the same trend, but Case 3 projects that the trend will be higher overall. This is a similar retrospective pattern to Case 2. The Case 3 results indicate more upward uncertainty in the spawning biomass estimates, indicating a skewed distribution.

Yield is surprisingly uncertain in Case 1, given the certainty of the spawning biomass projection. The mean estimate for Case 1 is stable and the most conservative. Case 2 projects a cyclical, but increasing trend in catches. Case 3 suggests that harvesting at less than ABC will eventually lead to larger harvests in the future, but with considerable uncertainty.

Overall these two new projection methods show a different way to look at the future prospects of the Pacific ocean perch stock and should be considered as another information source in future management decisions.

Figure 7C-1. Standard projection method (Case 1) used in projecting future consequences on spawning biomass of a harvest rate of 0.92*$F_{40\%}$.

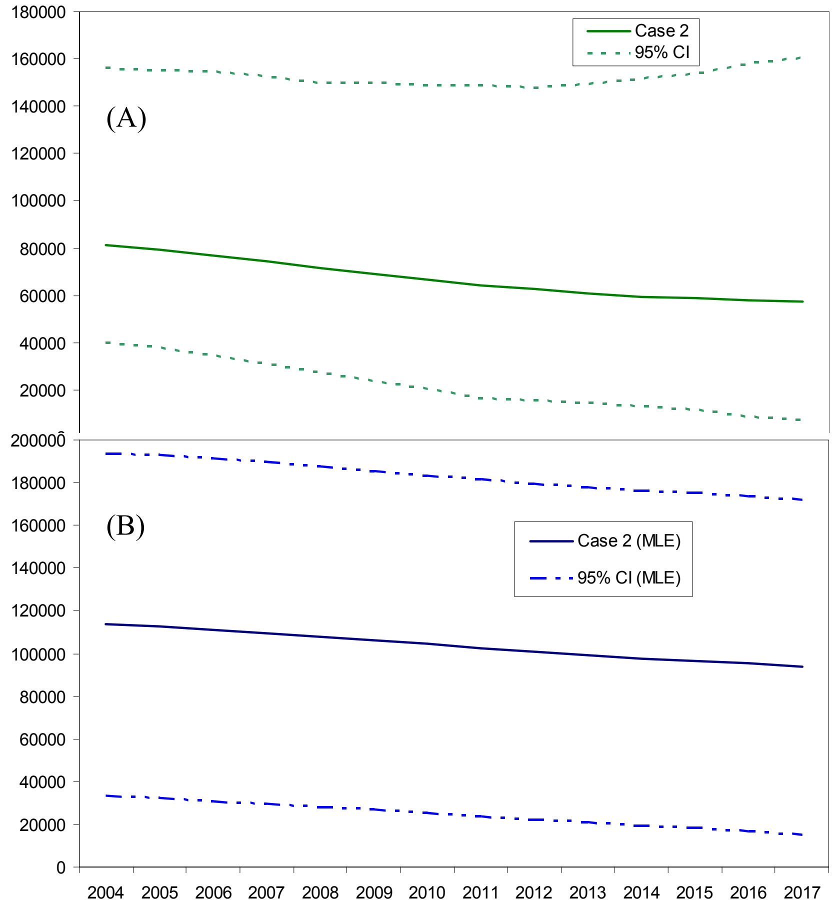

Figure 7C-2. Simple feedback projection method (Case 2) used in projecting future consequences on spawning biomass of a harvest rate of 0.92*$F_{40\%}$. (A) is posterior estimates using one million MCMC samples. (B) is MLE estimates with confidence interval estimates from the Hessian.

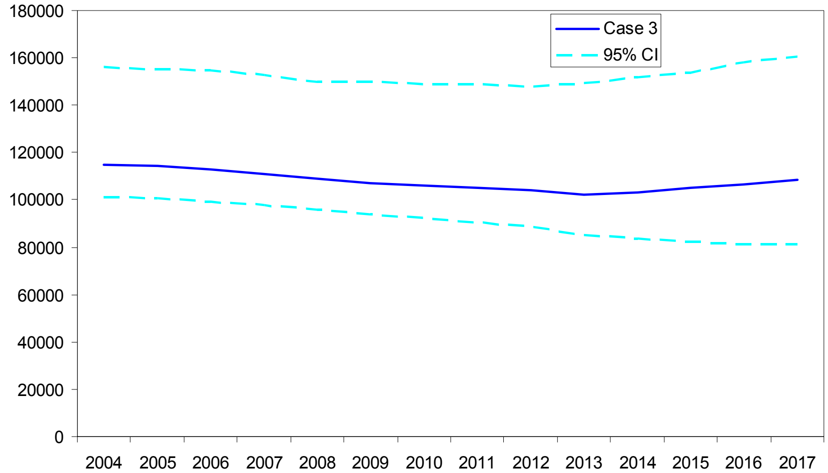

Figure 7C-3. Full feedback projection method (Case 3) used in projecting future consequences on spawning biomass of a harvest rate of 0.92*$F_{40\%}$.

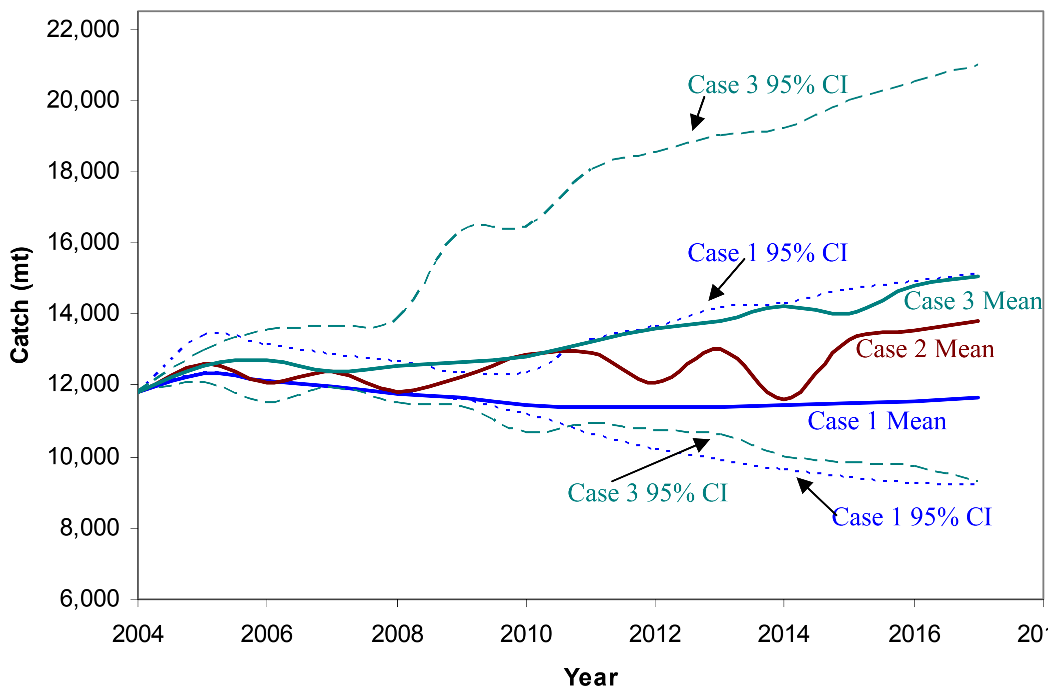

Figure 7C-4. Comparisons of yields and confidence bands for three different projection scenarios at a harvest rate of 0.92*$F_{40\%}$.

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