

## Lingcod Rebuilding

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### Background

This analysis was prepared, at the request of PFMC, to get a preliminary estimate of harvest constraints for lingcod rebuilding under the requirements of the Magnuson-Stevens Fishery Management Act (MSFMA). The results presented here are based on information from the most recent PFMC lingcod assessment (Jagielo et al 1997), which covered the Columbia and Vancouver INPFC areas through area 3C-N in Canada. A new assessment for southern lingcod is scheduled for this year, and a new coastwide assessment is planned for 2000. These assessments are expected to provide new and updated information for a revised rebuilding plan in the future.

### Rebuilding Target

The goal of rebuilding is to increase abundance to  $B_{msy}$ . For the purposes of this analysis,  $B_{40\%}$  and  $B_{35\%}$  were arbitrarily selected as potential proxies for  $B_{msy}$ , where:

$$\begin{aligned} B_{40\%} &= 0.40 B_{unfished} \\ B_{35\%} &= 0.35 B_{unfished} \end{aligned}$$

$B_{unfished}$  is the unfished equilibrium female spawning biomass in metric tons, calculated as the product of female lingcod numbers at age ( $n_a$ ), weight at age ( $w_a$ ), and proportion mature at age ( $p_a$ ), where:

$$B_{unfished} = \sum_{a=2}^{14} n_a w_a p_a$$

$n_{a=2}$  = median recruitment (1975-1994) (Jagielo et al 1997),

$$n_{a=3..13} = n_{a-1} e^{(-0.18)}, \text{ and}$$

$$n_{a=14} = n_{a=13} e^{(-0.18)} / (1 - e^{(-0.18)}).$$

The vectors of  $w_a$  and  $p_a$  were obtained from Jagielo et al (1997). The resulting estimates were:

$$B_{unfished} = 27,228 \text{ mt}; B_{40\%} = 10,891 \text{ mt}; \text{ and } B_{35\%} = 9,530 \text{ mt}.$$

## Projection of Population Abundance

The forecasting model that was originally constructed to project 1998-2000 yield for the 1997 assessment (Jagiello et al, 1997) was modified to serve the needs of this analysis. Inputs to the projection are, for both sexes, 1) full selection fishing mortality ( $f_{\max}$ ), selectivity-at-age, and weight-at-age in each fishery, 2) estimates of natural mortality, 3) the 1997 estimated population numbers at age, and 4) recruitment for each future year in the projection.

One key modification to the original model was to incorporate stochastic (random) recruitment, to better characterize uncertainty due to natural variability. For each realization of the stochastic model, recruitment was drawn randomly from the most recent 10 years of estimated recruitments. The model was run 1000 times for each level of  $F$  evaluated, which ranged from  $F=0$  to  $F=0.6F_{\max}$ . The value of  $F_{\max}=0.323$  ( $F_{35\%}$ ) was obtained from Jagiello et al 1997; the corresponding exploitation rate was 0.14.

### Time to Rebuild if $F=0$

In the absence of fishing, rebuilding times ranged from 4 to 8 years with a median of 5 years for the  $B_{40\%}$  target, and 3 to 7 years with a median of 4 years for the  $B_{35\%}$  target (Figure 1).

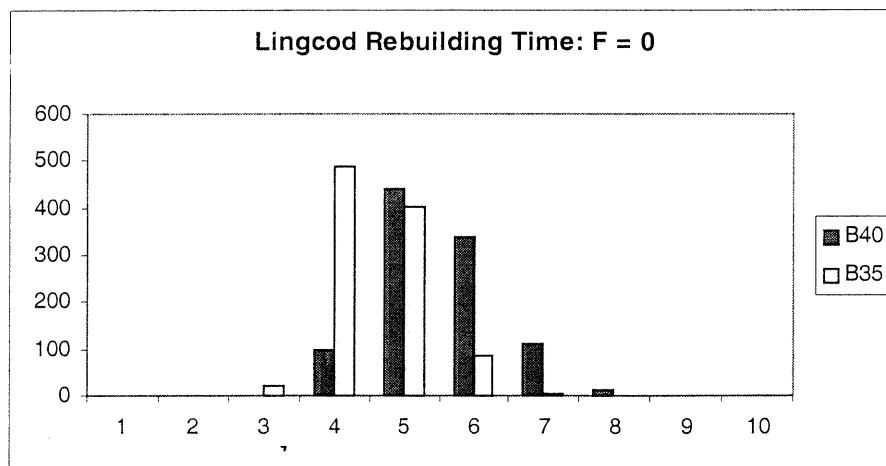


Figure 1. Distribution of rebuilding time estimates (years) for 1000 model runs for  $B_{40\%}$  and  $B_{35\%}$  rebuilding targets, in the absence of fishing.

### Maximum $F$ for Rebuilding

Estimates of rebuilding times with increasing levels of fishing were evaluated by conducting model runs ranging from  $0.2 f_{\max}$  to  $0.6 f_{\max}$ , where  $f_{\max}$  is the  $F_{35\%}$  fishing rate (0.323) obtained from Jagiello et al (1997).

For the B<sub>40%</sub> target, rebuilding within 10 years occurred 74% of the time with an average exploitation rate of 6.1% and average catch of 782 mt. (Table 1; Figure 2).

Table 1. Estimates of rebuilding time to reach the B<sub>40%</sub> target, with increasing levels of fishing.

Lingcod Rebuilding: Target = B 40%						
F <sub>max</sub> Multiplier	Exploitation Rate	Avg. Catch (mt) for Median Years	Years to Rebuild			Percent Rebuilt Within 10 Years
			Min	Median	Max	
0	0.0%	0	4	5	8	100%
0.2	3.2%	395	4	7	12	99%
0.3	4.7%	586	4	8	20	92%
0.4	6.1%	782	5	9	26	74%
0.5	7.3%	964	5	12	41	35%
0.6	8.3%	1167	7	21	41	6%

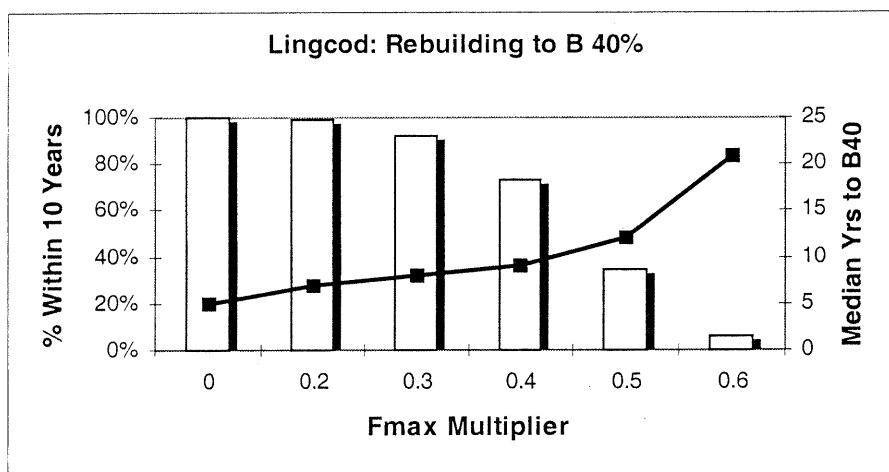


Figure 2. Estimates of median time to rebuild, and probability of rebuilding within 10 years for the B<sub>40%</sub> target, at increasing levels of fishing.

For the  $B_{35\%}$  target, rebuilding within 10 years occurred 97% of the time with an average exploitation rate of 6.2% and average catch of 734 mt. (Table 2; Figure 3).

Table 2. Estimates of rebuilding time to reach the  $B_{35\%}$  target, with increasing levels of fishing

Lingcod Rebuilding: Target = B 35%							
Fmax Multiplier	Exploitation Rate	Avg. Catch for Median Years	Years to Rebuild			Percent Rebuilt Within 10 Years	
			Min	Median	Max		
0	0.0%	0	3	4	7	100%	
0.2	3.2%	382	4	5	10	100%	
0.3	4.7%	558	4	6	16	100%	
0.4	6.2%	734	4	7	15	97%	
0.5	7.6%	905	4	8	25	84%	
0.6	8.9%	1072	5	10	33	53%	

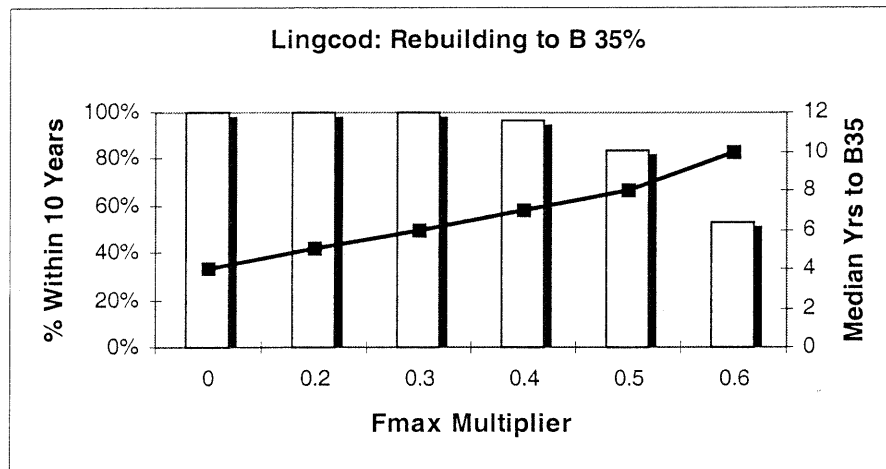


Figure 3. Estimates of median time to rebuild, and probability of rebuilding within 10 years, for the  $B_{35\%}$  target at increasing levels of fishing.

## Discussion

This rebuilding analysis relies on many assumptions including 1) the validity of the input data, mostly derived from the 1997 assessment, 2) a strong population response to reductions in fishing, and 3) a population that has already been partially rebuilt due to catch reductions already put in place since the 1997 assessment. It should also be noted that the value of  $B_{msy}$  estimated here is uncertain, being derived from the assumptions of 1) an equilibrium age structure, and 2) a median recruitment value obtained from model estimates for only the past 20 years. The true value of  $B_{msy}$  for instance, may be considerably higher if the long term recruitment median is higher than the estimated

value. Higher values of  $B_{msy}$  would imply longer rebuilding times than are reflected in this analysis.

### References

Jagiello, T., P. Adams, M. Peoples, S. Rosenfield, K. Silberberg, and T. Laidig. 1997. Assessment of lingcod (*Ophiodon elongatus*) for the Pacific Fishery Management Council in 1997. In: Status of the Pacific Coast groundfish fishery through 1997 and recommended biological catches for 1998. Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, Oregon.