

## Updated Rebuilding Analysis for Lingcod

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### Introduction

In 1997, an assessment of lingcod prepared for the PFMC found that female spawning biomass estimates were below 25% of the unfished biomass level for the northern portion of the stock (Jagiello et al 1997). An analysis was subsequently prepared which indicated that rebuilding to the  $B_{40\%}$  level was possible within 10 years at  $F=0$  (Jagiello 1999). Based on the analysis for the northern area, a 10 year rebuilding plan was implemented by PFMC for the entire West Coast (Washington-Oregon-California). The rebuilding plan began in 1999 and set the target date of the start of 2009 for achieving the  $B_{40\%}$  spawning stock size.

More recently, a new coastwide assessment for lingcod was conducted in 2000 (Jagiello et al 2000). The new assessment provides separate estimates of spawning stock biomass for the northern (LCN: US-Vancouver and Columbia) and southern (LCS: Monterey, Eureka, Conception) areas. Spawning stock size estimates have increased since 1997 in both areas, indicating progress toward the rebuilding target since the implementation of coastwide catch reductions (Figure 1). Recruitments are plotted by brood year in Figure 1a.

The present rebuilding analysis utilizes information from the most recent stock assessment and conforms to the SSC Terms of Reference for Groundfish Rebuilding Plans. This analysis provides new rebuilding trajectories for both the northern and southern areas that provide for lingcod rebuilding within the time frame originally established by PFMC in 1999.

### Data and Parameters

This analysis uses the SSC Default Rebuilding Analysis software developed by Punt (2001). For each area, data inputs included: 1) spawning output by age (the product of

the weight-at-age and % maturity-at-age vectors); 2) sex-specific natural mortality; 3) age specific weight (kg), selectivity, and numbers of fish for the year 2000; and 4) vectors of annual recruitment (age 2 fish) and spawning biomass estimates (1973-2000). Age specific data were input for ages 2-20+, with 20+ serving as an accumulator age. The population projection was configured to begin in 2001 with rebuilding occurring by the start of 2009 (year 10 from the original rebuilding start year of 1999). Catches were pre-specified for 2001, and were derived from the projections for the years 2002-2008.

### **Management Reference Points**

Separate estimates of  $B_0$  were computed using random draws from 1) the full time series of recruitment estimates (1973-1995), and 2) the time series of early recruitments (1973-1982) (Table 1). Distributions of the simulated  $B_0$  estimates under these alternative recruitment scenarios indicated a marked difference for the northern area, but little difference for the southern area (Figure 2). For both areas, the full recruitment time series  $B_0$  scenario was selected for the rebuilding projection analysis (Table 1 values shown in bold). Comparison of the spawning stock estimates for 2000 (Table 1) with the full recruitment time series estimates of  $B_0$  indicate that the recent coastwide spawning population size is approximately 15% of the unfished population size.

The median time to rebuild at  $F=0$  was determined by the previous lingcod rebuilding analysis to be 5 years, and the maximum time allowed to rebuild ( $T_{max}$ ) was established by PFMC to be 10 years (by the start of 2009) (Jagiello 1999). The present analysis confirmed that rebuilding could occur within 10 years with no fishing; the median time to rebuild at  $F=0$  was estimated to be 3.6 years for the northern area, and 4.8 years for the southern area.

### **Rebuilding Projections**

Population projections were conducted using the "recruits" in lieu of the "recruits-per-spawner" option provided by Punt (2001). The basis for this choice was the lack of a credible spawner-recruit relationship for lingcod (Figures 3 and 4). This is evidenced particularly for the northern area (Figure 3), where the ratio of recruit/spawning output increased substantially from 1987-1993 -- a period where the trend in spawning stock size was decreasing (Figure 1). Recruitments for the LCN and LCS projections were randomly drawn from the values estimated from the most recent years (1986-1995) in the assessment (Jagiello et al 2000).

### **Performance of alternative rebuilding policies**

Estimates of fishing mortality, median years to rebuild, and OY (mt) for 2002-2009 were computed for alternative probabilities of achieving the rebuilding target by start of 2009-- 50%, 60%, 70% and 80%--as well as the 40-10 and  $F=0$  policies (Table 2). The bottom panel of Table 2 shows the coastwide rebuilding OYs for each policy, which represent the combination of northern and southern yields. These trajectories are also portrayed in Figure 7. For comparative purposes, Figure 7 also depicts the 2000 harvest and the 2001

OY. The 2002 OY associated with a 60% likelihood of rebuilding is slightly lower than the OY adopted for 2001. Plots of the probability ogives for each of the alternative policies, including  $F=0$  and the 40:10 rule, are shown in Figures 5 and 6. Also shown in these figures are the median projected OYs through 2009, for each policy, and the trajectories of median ratios of spawner biomass to target biomass. For the alternative with 60% likelihood of rebuilding, Figure 8 portrays the variability in the ratio of spawner-to-target biomasses in the northern and southern areas. The median ratio is portrayed, along with the 5<sup>th</sup>, 25<sup>th</sup>, 75<sup>th</sup>, and 95<sup>th</sup> percentiles for the years 2001-2009. For figures relating to biomass, the year indices reflect the status at the beginning of the year.

## 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.
- Jagiello, T.H. 1999. Lingcod Rebuilding. Analysis submitted to Pacific Fishery Management Council, May 5, 1999. Attachment G.9.c June 1999, PFMC Briefing Book.
- Jagiello, T.H., D. Wilson-Vandenberg, J. Sneva, S. Rosenfield, and F. Wallace. 2000. Assessment of Lingcod (*Ophiodon elongatus*) for the Pacific Fishery Management Council in 2000. In Appendix to Status of the Pacific Coast Groundfish Fishery Through 2000 and Recommended Acceptable Biological Catches for 2001, Stock Assessment and Fishery Evaluation. 142 p. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, Oregon 97201, October 2000.
- Punt, A.E. 2001. SSC Default Rebuilding Analysis. Technical specifications and user manual. Ver. 1.000003 (July 2001).

## Tables and Figures

Table 1. Estimates of unfished spawning stock biomass ( $B_0$ ), Bmsy proxy ( $B_{40\%}$ ), and spawning stock size in 2000 ( $B_{2000}$ ) for the northern (LCN) southern (LCS) areas. Values in bold were used for rebuilding projections.

	Spawning Output (mt)				
	All Recruitments (1973-1995)		Early Recruitments (1973-1982)		Recent Estimate ( $B_{2000}$ )
	Unfished ( $B_0$ )	Target ( $B_{40\%}$ )	Unfished ( $B_0$ )	Target ( $B_{40\%}$ )	
LCN	<b>22,882</b>	<b>9,153</b>	31,033	12,413	3,527
LCS	<b>20,971</b>	<b>8,389</b>	22,799	9,120	3,220

Table 2. Rebuilding projection results; Top: northern area (LCN), Middle; southern area (LCS), Bottom: LCN and LCS Combined.

LCN							
Fishing rate	0.0607	0.0531	0.051	0.0474	40:10 Rule	F=0	
<b>Prob to rebuild by Tmax</b>	<b>50%</b>	<b>60%</b>	<b>70%</b>	<b>80%</b>	<b>55%</b>	<b>100%</b>	
Median years to rebuild	7.0	6.6	6.1	5.9	6.7	3.6	
OY (mt)							
2002	384	337	324	302	189	0	
2003	429	379	365	341	284	0	
2004	470	417	402	376	384	0	
2005	502	447	432	405	473	0	
2006	531	475	460	432	553	0	
2007	561	504	487	459	621	0	
2008	581	523	506	477	665	0	

LCS							
Fishing rate	0.0667	0.061	0.0533	0.0472	40:10 Rule	F=0	
Prob to rebuild by Tmax	50%	60%	70%	80%	68%	100%	
Median years to rebuild	7.0	6.7	6.3	6.0	6.5	4.8	
OY (mt)							
2002	262	240	211	187	91	0	
2003	296	273	241	214	150	0	
2004	345	319	283	253	232	0	
2005	399	370	329	295	332	0	
2006	448	416	371	334	434	0	
2007	494	460	412	371	534	0	
2008	536	500	448	405	644	0	

Coastwide OY (mt)	Prob to rebuild by Tmax:				40:10 Rule	F=0
	Year	50%	60%	70%		
2002	646	577	535	489	280	0
2003	725	651	606	555	434	0
2004	815	735	685	629	616	0
2005	901	817	761	701	805	0
2006	979	891	831	766	987	0
2007	1,055	963	899	830	1,155	0
2008	1,117	1,022	954	882	1,309	0

Figure 1. Time series of female spawning stock biomass estimates (mt).  
 Source: Jagielo et al. 2000.

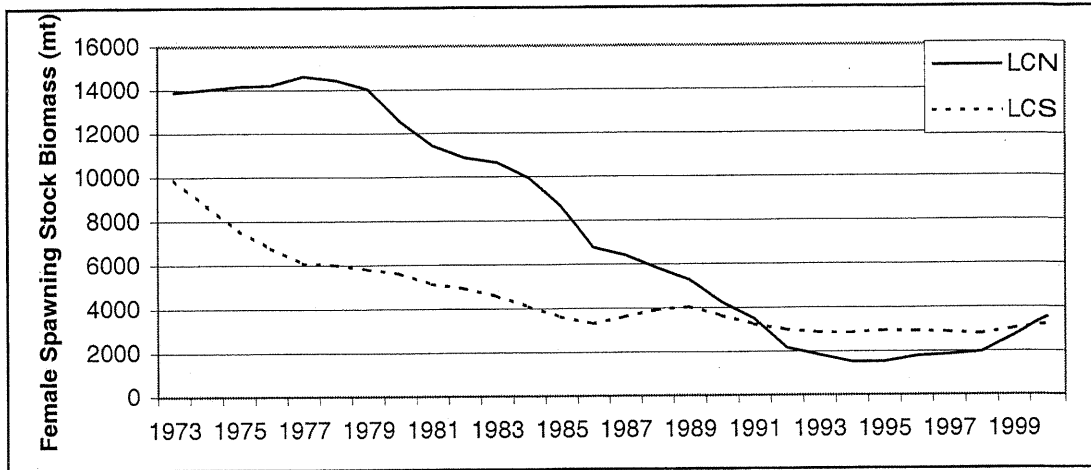


Figure 1a. Full recruitment time series by brood year (1971-1993) for LCN and LCS.

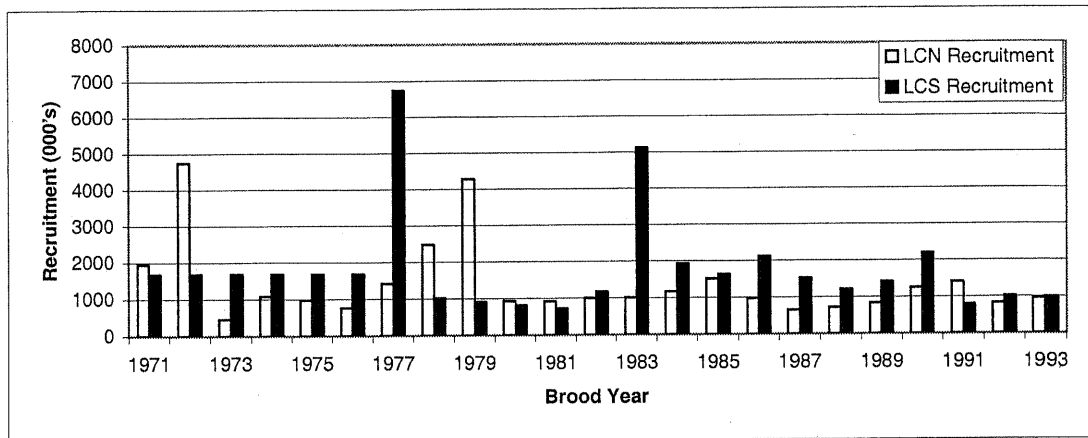


Figure 2. Distribution of Virgin Spawning Biomass ( $B_0$ ) estimates for 1000 simulation runs.  
Top: Northern area (LCN), Bottom: Southern area (LCS).

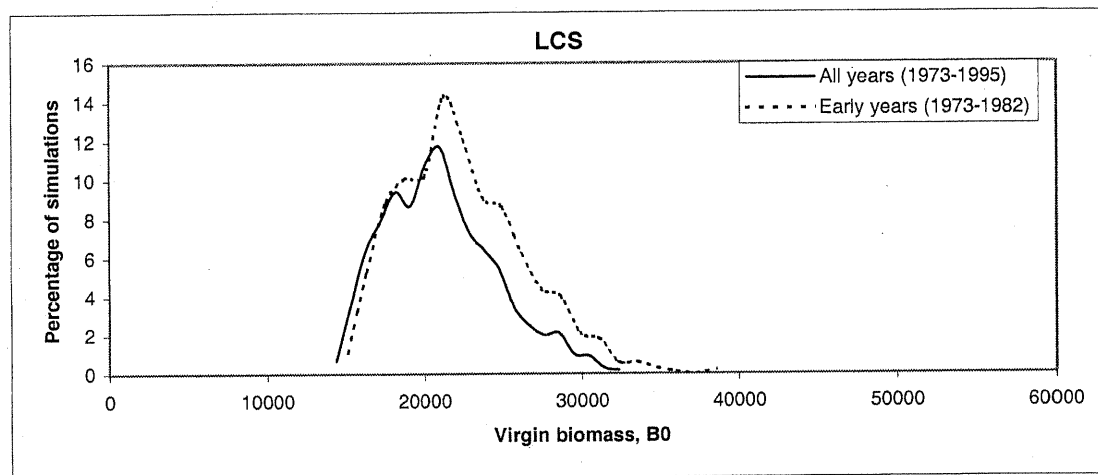
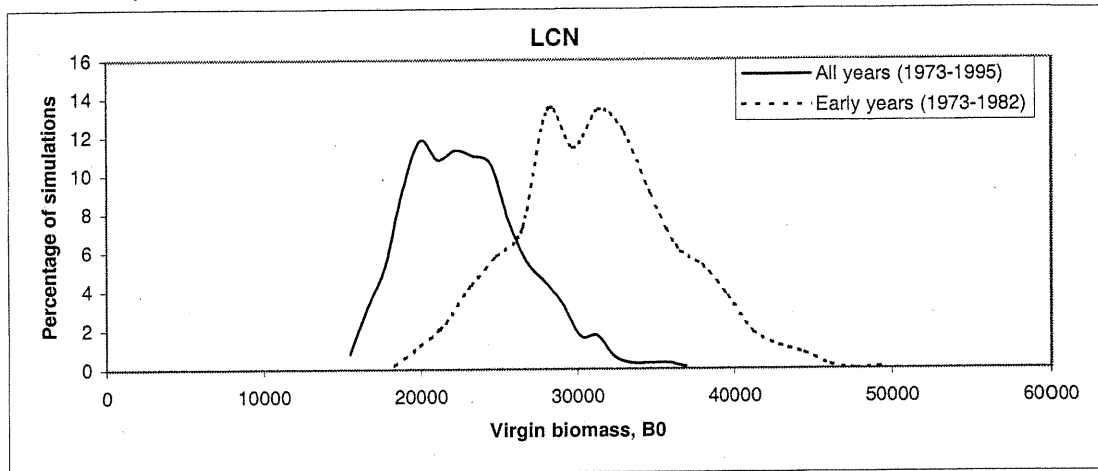


Figure 3. Recent northern area (LCN) recruitment and recruits/spawning output (R/S).

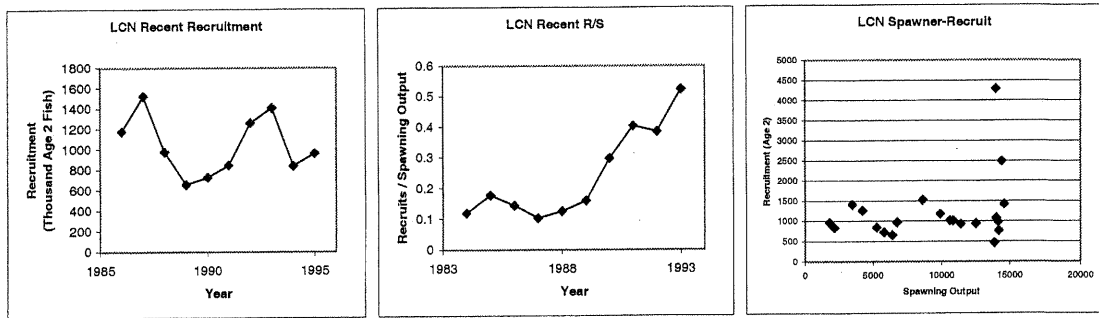


Figure 4. Recent southern area (LCS) recruitment and recruits/spawning output (R/S).

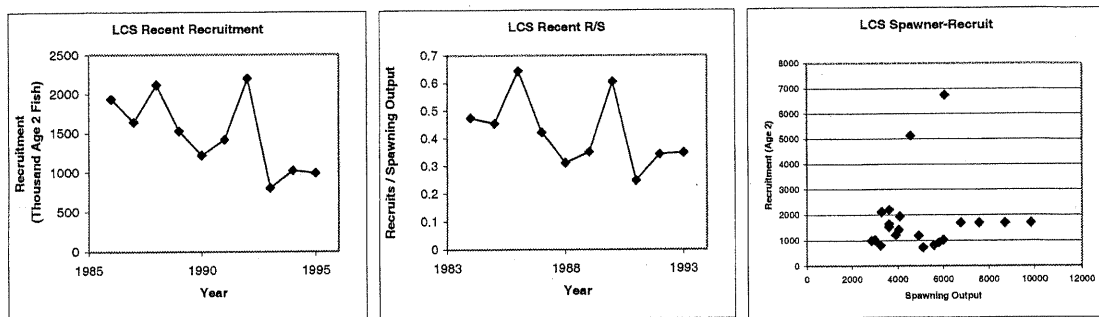


Figure 5.--Probability of limit attainment, median OY trajectories, and ratios of spawner biomass to target biomass, under six alternative harvest policies in the northern area (LCN).

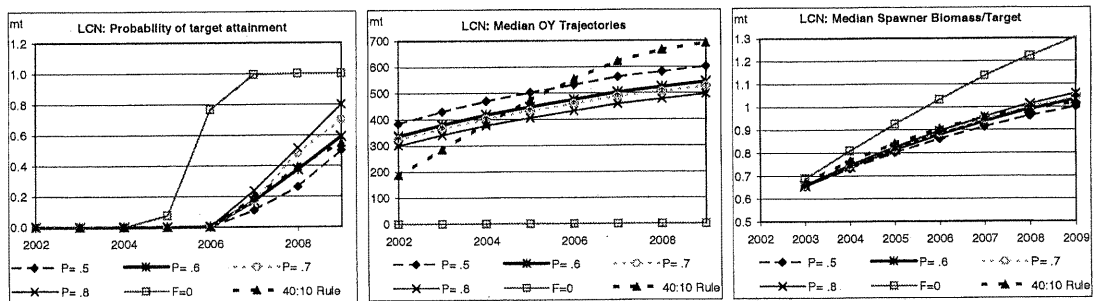


Figure 6.--Probability of limit attainment, median OY trajectories, and ratios of spawner biomass to target biomass, under six alternative harvest policies in the southern area (LCS).

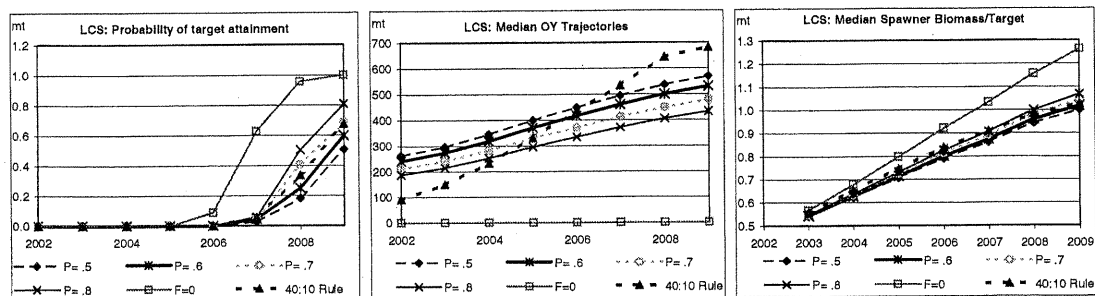


Figure 7.--Coastwide rebuilding OYs for lingcod, 2002-2008, based on the median projections, for six alternative harvest policies, and the 2000 harvest and 2001 OY.

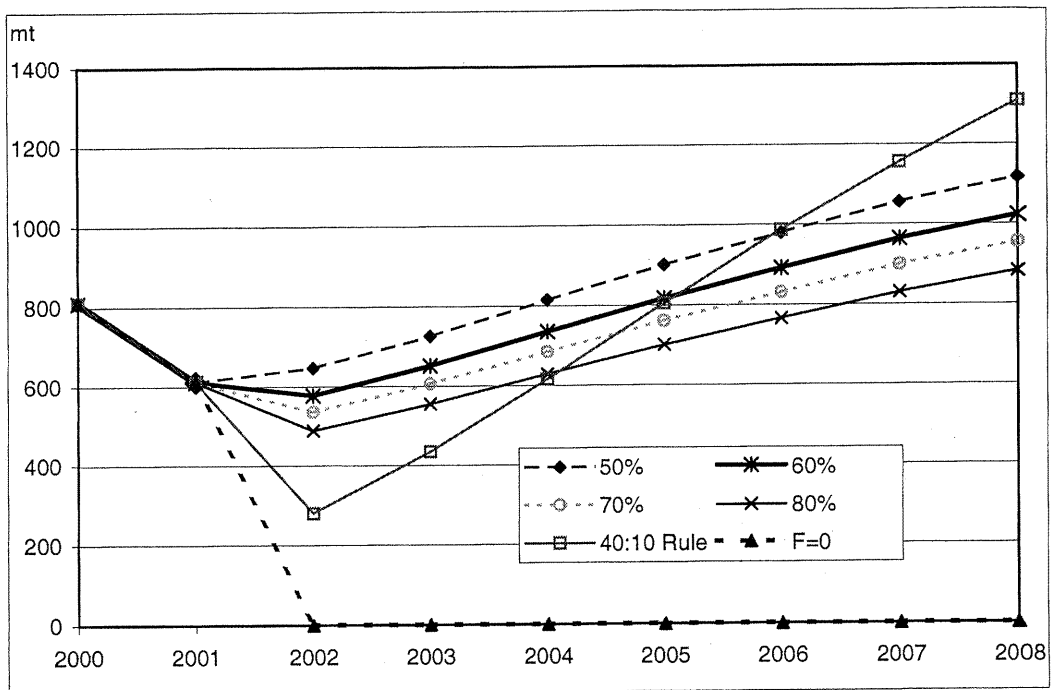
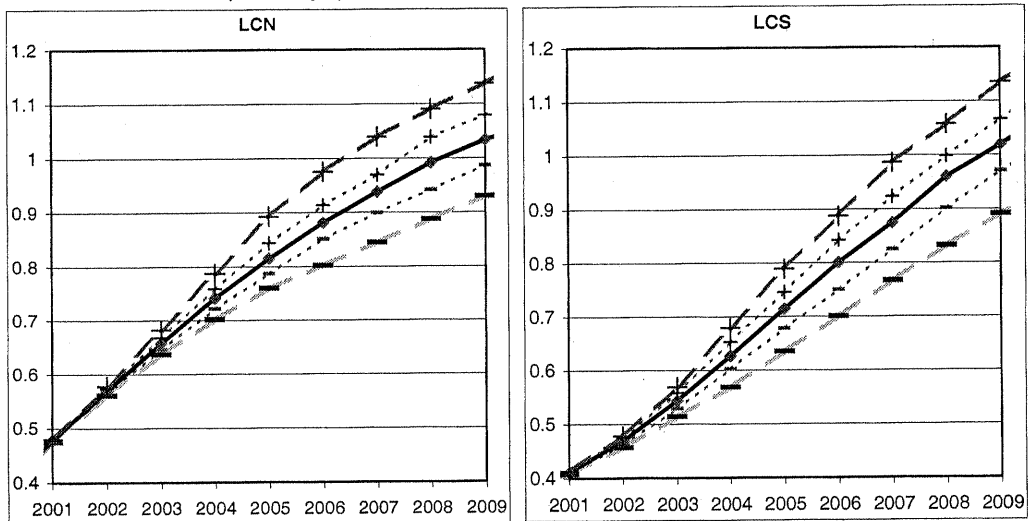


Figure 8.--Projected ratios of spawner biomasses to the targets, for the northern (LCN) and southern (LCS) areas under the 60% probability option.



Note: The central thick line represents the median ratio in each year. Other lines, from bottom to top represent the 5th, 25th, 75th, and 95th percentiles.