Not to be cited without prior reference to the author

ICES C.M. 1993/D:10
Sess. P
Statistics Committee/
Ref. Theme Session P

Advice under uncertainty to managers for two fisheries of the northeastern Pacific

William H. Lenarz

National Marine Fisheries Service
3150 Paradise Drive
Tiburon, California, USA 94920

Introduction

Fisheries managers must base their decisions on information that has considerable uncertainty. Important population dynamic processes such as the spawn/recruit relationship are highly stochastic. The accuracy of quantitative descriptions of these processes is often low. Confidence limits about parameter estimates derived from fisheries dependent and fisheries independent data are often wide. While usually overlooked in the technical advice given managers, there also is considerable uncertainty in the political outcome of management decisions. For example, environmental groups may object to a decision and through the judicial or political system cause changes that could be costly to government agencies and fishing industry. Fisheries managers are very aware that they work in an uncertain field and desire, but often do not receive technical advice on the risks of alternative management options.

In this paper I describe results of two studies of Northeast Pacific fisheries that convey risk information to fishery managers. The first study was conducted on Pacific sardine (*Sardinops sagax*) fishery in 1970. The second study is on the widow rockfish (*Sebastes entomelas*) fishery and still is in progress.

Pacific Sardine Study

In 1970 the northern stock of the Pacific sardine was badly depleted. The biomass was estimated to have decreased from almost 4,000,000 tons in 1932 to between 1000 and 5000 tons in 1970. Landings were restricted to low levels. Reported 1970 landings were 221 tons. However, sardines had become very valuable for use as bait by recreational fishermen and there was anecdotal evidence of significant non-reported landings.

My colleague Paul Smith (National Marine Fisheries Service, La Jolla Ca.) and I became concerned that potential for stock recovery could be reduced by the fishery and decided to examine the possible effects of the fishery with a simulation model. I based the model on the results of Murphy's (1966) study of Pacific sardine population dynamics. The model used standard catch and growth equations and these were assumed to be deterministic. Since there was considerable uncertainty in the spawn/recruit relationship (SR) and the SR is extremely important in projections of future populations, I used a stochastic SR. I employed an autoregressive equation with a lognormal error term to model deviations from expected values of a Ricker SR.

We presented results of the modeling exercise to managers in the form of probability of recovery as a function of biomass in 1970 and average future catches, Figure 1. Two recovery levels were presented; 20,000 tons in ten years and 950,000 tons in 25 years. Simulations indicated that it would be safe to have a low intensity bait fishery if the population recovered to 20,000 tons and that maximum sustainable production occurs at about 950,000 tons. The results indicated that if the biomass was only 1000 tons that a reduction in catches from even the reported landings would improve the probability of recovery. The results also showed that if catches were kept at low levels there was a good chance for recovery within a reasonable time frame.

We presented the results to various levels of state government (the regulatory authority) and included the recommendation that a regulation be enacted to prevent use of Pacific sardines for bait. The administrators sent the paper out for review. Some scientific assumptions of the study were questioned and Paul Smith did an excellent job of presenting data that convinced the reviewers that the assumptions were reasonable. California enacted the recommendations in 1974. Landings averaged less than 10 tons for the next 5 years. We will never know either the exact levels of 1970 catch and biomass nor the exact nature of the SR, but the population is recovering. By 1986 the population had recovered sufficiently to allow a small directed fishery. The 1992 quota was set at 25,000 tons.

Widow Rockfish Study

Since 1970, fishery data have improved somewhat and our analytical techniques even more so. While the level of uncertainty in management advice is still high, the improvements in data and techniques allow us to describe better the uncertainties associated with stock assessments and management recommendations. Another change that has occurred is that groups with strong conservation ethics have become well organized and aggressive in attempts to meet their goals. In the past fisheries decisions were sometimes challenged in the judicial or political arena by user groups willing to take long term risks to obtain short term gains. Now fishery managers also encounter efforts by groups that are primarily interested in avoiding long term risks to natural populations. Management decisions made by judicial or political bodies can be more difficult and costly to implement, and/or subject the resource to greater risk than agency-made decisions. This study compares the results of management policy often used for northeastern Pacific groundfish with a more aggressive policy and a type of policy that might result from a judicial decision resulting from a challenge by an environmental group.

Specific management policies for groundfish fisheries off California, Oregon and Washington are recommended to the National Marine Fisheries Service (NMFS) by the Pacific Fishery Management Council (PFMC). The management duties and authorizations of NMFS and PMFC are specified by the Fisheries Management and Conservation Act (FMCA). The FMCA requires that overfishing to be defined for each fishery and that management policies contain measures to prevent overfishing. The PFMC defines overfishing for groundfish as the level of fishing mortality that reduces equilibrium spawning biomass per recruit to 20% of the unfished level ($F_{20\%}$).

The present management policy for widow rockfish (policy P) is to fish at the constant level of fishing mortality that reduces equilibrium spawning biomass per recruit to 35% of the unfished level ($F_{35\%}$). This management policy is based on the study by Clark (1991). Hightower and Lenarz (1990) estimated $F_{35\%}$ to be 0.21 for widow rockfish. An aggressive policy (policy A) would be to fish at a rate (F_{MYPR}) that produces close to maximum yield per recruit. I estimated F_{MYPR} to be 0.50. A court-ordered management policy (policy C) could take many forms. I chose a policy that would close the fishery if the population fecundity fell below 20% of an unfished population. The fishery would not be allowed to reopen until population fecundity recovered to 35% of an unfished population. I also assumed that management agencies and the industry would bear an additional annual cost when fishing was closed because of added monitoring and administrative costs. The cost was assumed to equivalent to 1000 tons of fish, which represents about 15% of recent annual landings. The cost was subtracted from the annual yield under policy C.

The model was age structured and used parameter estimates from Hightower and Lenarz (1990). Natural mortality (M) was assumed to be 0.15. Fishing selectivity was assumed to be domed shape with full selectivity at 8 years. Maximum age was 55 years. Fish were 70% mature at age 7. The Kimura (1988) formulation of the Beverton-Holt SR was assumed with shape parameter (A) set at 0.889. Under the assumed SR, recruitment is relatively high until population fecundity is reduced to less than 20% of unfished levels, Figure 2. Deviations of recruitment from expected values were assumed to have a log normal distribution. Runs were also made under the assumption that recruitment is independent of spawning stock. It was also assumed that fishing mortality and population fecundity estimates followed a log normal distribution. Each 200 year simulation began with an unfished population at equilibrium. 2000 replicates were run for each combination of management policy and 2 SR's.

I will first present results as I might to a technical audience. Both the management policy and SR had considerable influence on yield and population fecundity. For example, under policy P fishing mortality would be 0.21 and relative yield would be about 0.7 when recruitment is stock independent, and 0.6 under the Beverton-Holt SR; Figure 3. Relative population fecundity at the end of the 200 year period would be about 0.4 when recruitment is stock independent and 0.3 under the Beverton-Holt SR. There are even greater differences in the results when management policy A is followed (F=0.50). Relative yield would be about 1.0 when recruitment is density independent and 0.2 under the Beverton-Holt SR. Relative population fecundity at the end of the simulation would be about 0.15 when recruitment is stock independent and less than 0.001 when under the Beverton-Holt SR. When management policy C is used, I assume that F=0.5 when the fishery is open. Relative yield would be about 0.8 when recruitment is density independent and 0.6 under the Beverton-Holt SR. Under both SR assumptions relative yield would decrease by about 0.05 when adjusted for cost of years closed to fishing and the fishery was closed about 50% of the time. Fishery closures ranged from 1 to more than 10 years with typical closures being about 4 years. Under both SR assumptions relative population fecundity at the end of the simulation would be between 0.30 and 0.35.

The results shown in Figures 3 and 4 indicate that if management used policy A because it assumed that recruitment was density independent and the assumption was correct, yield would be relatively high, 1.0, but population fecundity would be lower than 0.2. If management had guessed wrongly, yield would be very low, 0.25, and the population would have collapsed by the end of the simulation period. However if management policy P was used, relative yield would only be 20% less than under management policy A when recruitment is density independent and yield would by 300% higher than under policy A when there is the assumed Beverton-Holt SR. Population fecundity at the end of the simulation period would be considerably higher under policy P than under policy A regardless of SR. Management policy C produces results that are similar to policy P except that the fishery would be closed about 50% of the time.

I think that for even a technical audience it would be easier to comprehend the important outcomes of the study, if they were presented as shown in Figure 5. It can easily be seen that the aggressive policy would result in low population fecundity under either SR and would also result in very poor yield under the Beverton-Holt SR. It is also easy to see that management policies P and C produce similar yields and population fecundities, but that fishery would be closed about 50% of the time under policy C.

Acknowledgements

I thank Paul Smith for many interesting discussions and for carrying more than his share of the burden of communicating the results of our sardine study. I also thank Alec MacCall for discussing the widow rockfish study with me and reviewing this paper.

Literature Cited

Clark, W. G. 1991. Groundfish exploitation rates based on life history parameters. Can. J. Fish. Aquat. Sci. 48(5):734-750.

Hightower, J. E. and W. H. Lenarz. 1990. Status of widow rockfish fishery in 1990. Appendix F *In* Status of Pacific coast groundfish fishery through 1990 and recommended acceptable biological catches for 1991. Pacific Fishery Management Council, Metro Center, Suite 420, 2000 S.W. First Ave., Portland OR 97201-5344.

Kimura, D. K. 1988. Stock-recruitment curves as used in the stock-reduction analysis model. J. Cons. int. Explor. Mer 44:253-258.

Murphy, G. I. 1966. Population biology of the Pacific sardine (Sardinops caerulea). Proc. Calif. Acad. Sci. XXXIV(1):84p.

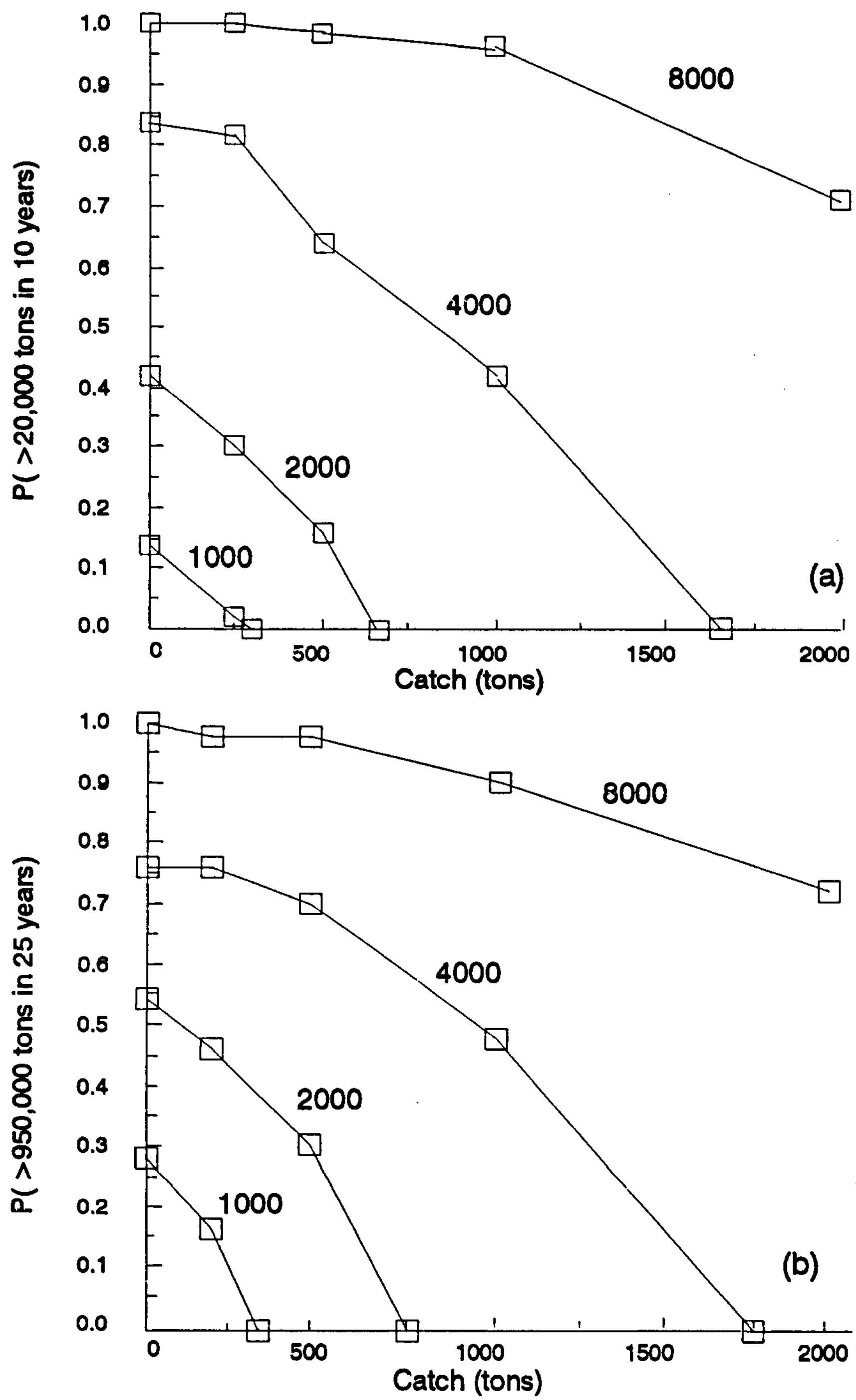

Figure 1. Probability of recovery of Pacific sardine population t0 20,000 tons in 10 years (a) and 950,000 tons in 25 years (b). 1970 population size (tons) isopleths are shown with annual catch and probability of recovery.

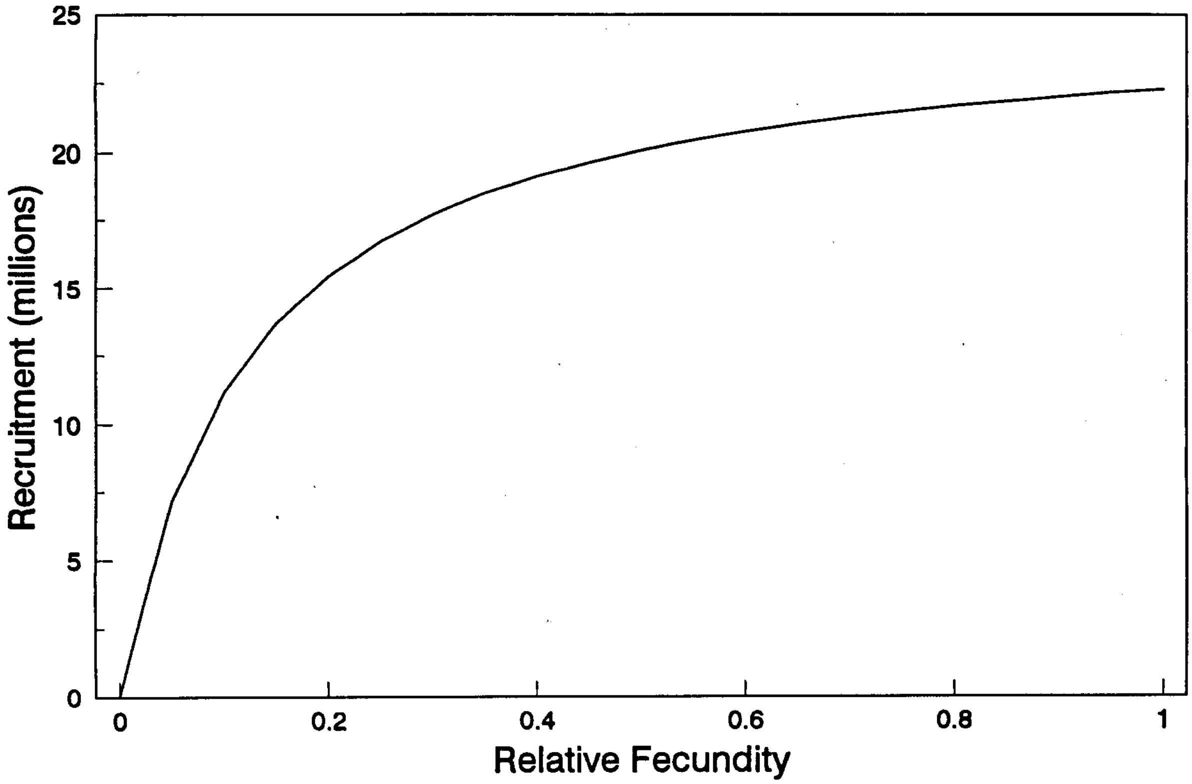

Figure 2. Simulated recruitment of 5 year old widow rockfish as a function of relative population fecundity.

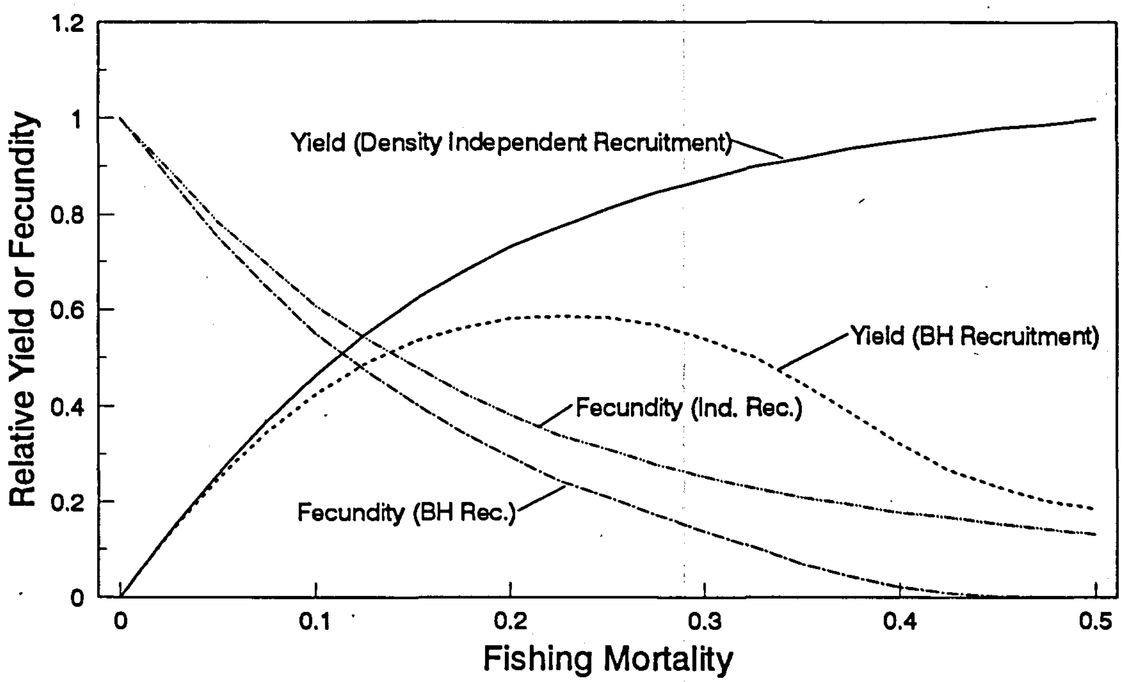

Figure 3. Relative yield and population fecundity of widow rockfish as a function of fishing mortality.

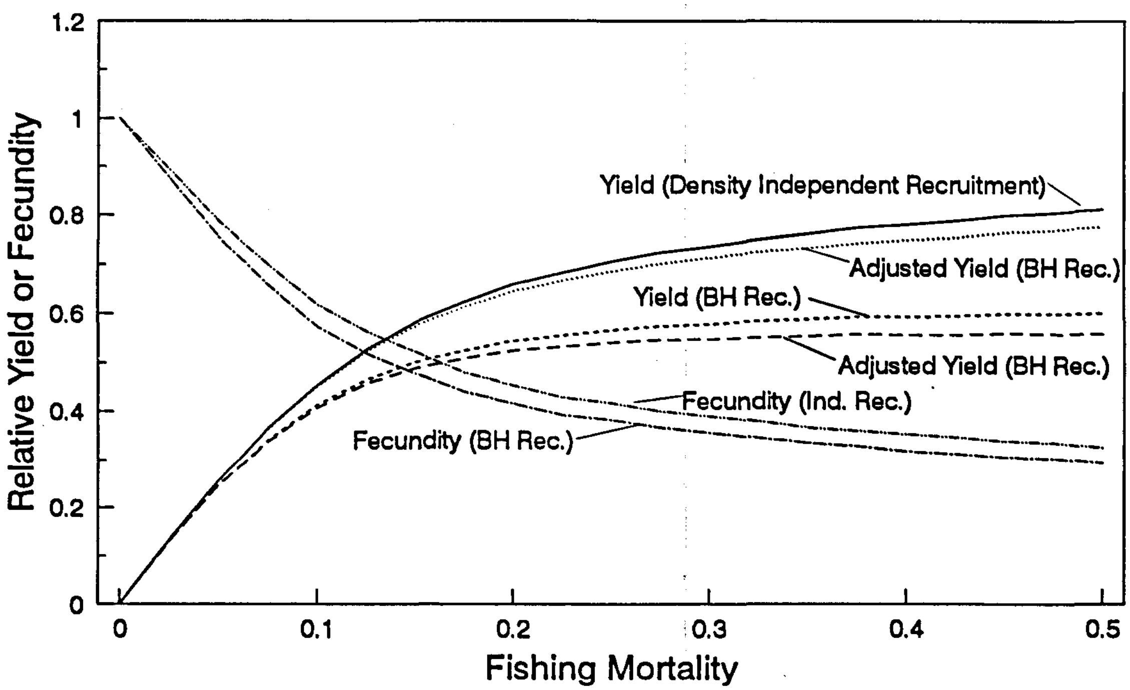

Figure 4. Relative yield and population fecundity of widow rockfish as a function of fishing mortality. Simulated fishery was closed if population fecundity dropped below 20% of unfished level and reopened when fecundity recovered to 35% of unfished level. Yield is relative to maximum yield of unclosed fishery. Adjusted yield reflects cost of closure.

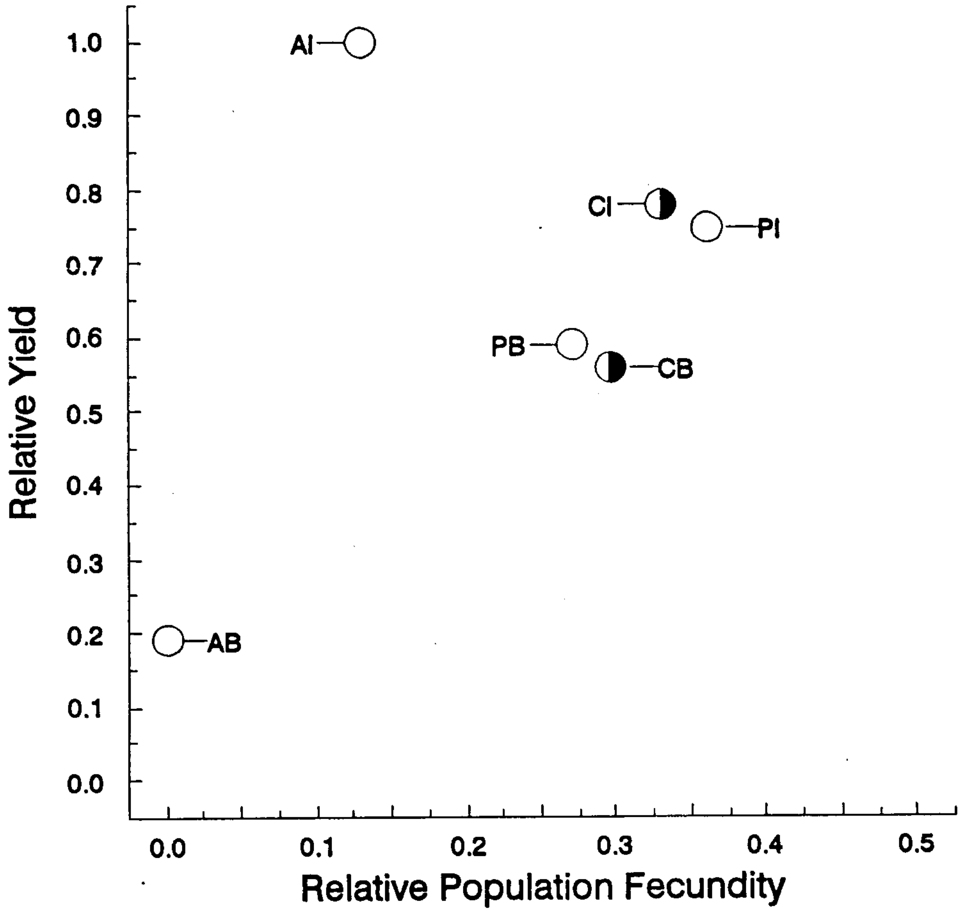

Figure 5. Relative yield and terminal population fecundity of simulated widow rockfish fishery under three types of management; agressive (A), court-ordered (C), and present (P); and two spawn/recruitement models; recruitment density independent (I) and Beverton-Holt (B). Filled portions of circles are proportional to portion of time that fishing is allowed. Yield under court-ordered management reflects additional costs.