Management options for the South Australian rock lobster (*Jasus edwardsii*) fishery: a case study of co-operative assessment and policy design by fishers and biologists

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Abstract: A modelling workshop process was used to bring biologists and commercial fishers together to develop a spatial model for population dynamics and harvest regulation of the South Australian rock lobster (*Jasus edwardsii*) fishery. The resulting model provided a credible reconstruction of how the space, time, and size structures of the stock have changed over the history of the fishery, and offers a rich variety of regulatory policy options for exploration of how the stock might have behaved (and might behave in the future) if managed differently. Initial use of the model has been to test options for reducing risk of recruitment overfishing by increasing spawning stock and egg production. A number of regulations ranging from increased size limits to large spatial refuges could accomplish this risk reduction aim. One option is to simply reduce the fishing season length dramatically. The model predicts that short-term yield loss under this strategy would eventually be regained through increased survival and higher catch rates of larger lobsters, and offers the economic advantage of greatly reduced fishing costs. This policy hypothesis can be tested in the field by a management experiment allowing fishers to see for themselves whether an area with a short season does indeed result in catch rates high enough to compensate for fishing time loss.

Résumé : La formule de l'atelier de modélisation a été utilisée pour réunir des biologistes et des pêcheurs commerciaux pour élaborer un modèle spatial dans le but d'examiner la dynamique des populations et les règlements régissant la récolte dans la pêcherie de langouste (*Janus edwardsii*) du sud de l'Australie. Le modèle qui a résulté a fourni une reconstruction crédible de la façon dont le stock a évolué du point de vue du temps, de l'espace et de sa structure de taille au cours de l'histoire de la pêcherie et offre une gamme très riche d'options du point de vue de la politique de réglementation permettant de se faire une idée du comportement passé et futur du stock s'il était géré différemment. Le modèle a été utilisé initialement pour vérifier des options visant à réduire les risques de surpêche au niveau du recrutement en augmentant le stock de géniteurs et la production d'oeufs. Un certain nombre de mesures réglementaires variant de l'augmentation de la limite de taille à la création de grandes réserves pourraient permettre d'atteindre cet objectif de réduction du risque. Une des options consiste simplement à écourter de manière substantielle la saison de pêche. Le modèle prévoit que la perte de rendement à court terme découlant de cette stratégie finirait par être récupérée grâce à une survie accrue et à des taux de capture plus élevés de langoustes de plus grande taille, sans compter que cette stratégie présente l'avantage économique de réduire considérablement les coûts de la pêche. Cette hypothèse de politique peut être vérifiée sur le terrain par une expérience de gestion permettant aux pêcheurs de constater par eux-mêmes si une zone soumise à une courte saison de pêche entraîne effectivement des taux de capture suffisamment élevés pour compenser la réduction du temps de pêche. [Traduit par la Rédaction]

Introduction

Traditional approaches to fishery management have frequently created deep divisions between fishers and regulatory agencies. Fishers take as much as they can, show remarkable inventiveness at finding ways around regulatory measures, and often provide only as much information as absolutely required. Biologists try to make sense of this information for assessment, then regulators often adopt openly paternalistic attitudes when forced to discuss assessments and regulatory options with fishers. No one wins in these situations; assessments are dangerously unreliable; opportunities for better information gathering and co-operative experiments are missed; and regulatory systems are usually ineffective due to both immediate enforcement problems and technological innovations to circumvent them.

There has been an opportunity in the South Australian (SA) lobster fishery to begin moving toward a more co-operative approach to management, building upon the shared goal of both fishers and regulators to ensure a sustainable future for the fishery. The SA lobster fishery is relatively small, with licensing and regulation split into two zones (northern,

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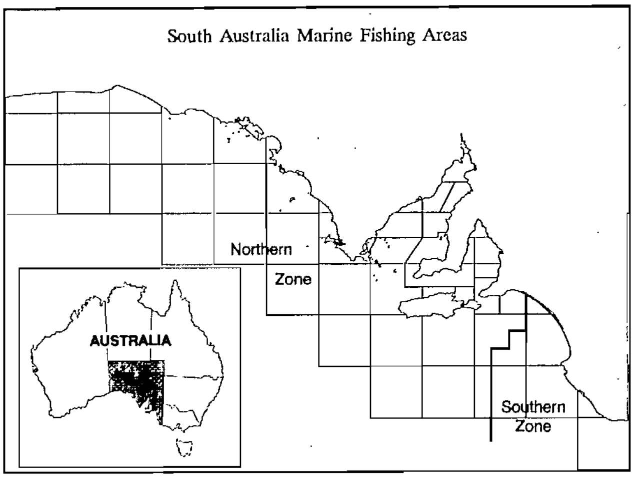
Fig. 1. South Australian rock lobster marine fishing areas (as 1° square blocks) and the two management zones. Southern zone is currently managed through individual transferable quota (ITQ) system, northern zone through traditional effort controls (pot number, season length).



78 vessels; and southern, 187 vessels). Most fishers are relatively prosperous, well-educated, and keenly aware of the biology and population dynamics of the lobster. Many have been in the fishery since its major development in the early 1960's, and have seen very substantial changes in the stock since then. They have also been part of a relatively dynamic management system that has adjusted season length, reduced pot numbers, and in the southern zone actively reduced the number of vessels licensed. The license buy-back was paid for by the remaining fishers with the help of a state government loan, a policy that has since been widely commended by fishers.

Recently southern zone fishers opted to move to a quota management system, albeit one with the same effort regulations (pot limits, seasons, size limits) still in force. As before, there has been much concern about how this new regulatory measure will protect the spawning stock. Most fishers agree that fishing mortality rates are very high; perhaps dangerously high in the southern zone, as evidenced by the scarcity of larger mature lobsters. Northern zone fishers have opted to remain with effort controls to manage their fishery. However, many northern zone fishers fear that the stock may be in danger of being overfished due to improved fishing technology. In 1994, fishers sought a means of compensating for an anticipated increase of 5% in effective effort. A model was developed leading to the adoption of an increase in minimum size and a series of 8–9 day closures (McGarvey and Prescott 1998). Concerned fishers in both zones helped initiate and have backed a research program through financial support and direct participation in a data collection program in place since 1991 to provide data for a robust stock assessment.

One aspect of the research program that was specifically requested by fishers was a spatial model of the fishery with good visual output. Some fishers had seen models of an abalone fishery, AbaSim (Sluczanowski and Prince 1994), and the southern shark fishery, SharkSim (Sluczanowski 1994), and recognized their value for conveying complex information in a way fishers could understand. We intended to produce a model of the lobster fishery with such an interface but decided also to use the model development as a way to provide further motivation for co-operative information gathering. At the same time we tried to capitalize on fishers' knowledge of factors such as distribution of lobster habitat, by involving both fishers and biologists co-operatively in a computer model building process.

The explicit objective of building the model was to provide a device for synthesizing existing data into a useful format for policy analysis. However, the more important objectives were to foster better communication (trying to build a working simulation model requires precise definition of terms and use of information), to demonstrate to fishers exactly how data are used for biological assessment, and hence why much better data (and management experiments) are needed. We saw the model development as a level playing field for all stakeholders, with information and policy analysis suggestions from fishers being potentially just as critical as anything provided by professional biologists. We did not expect that the simulation model produced during this first co-operative effort would be particularly useful for policy analysis, but we did hope it would provide a concrete starting point for further cooperation and development. The ultimate aim would be to develop a policy screening tool that can deal not only with obvious policies such as pot reduction and quotas, but also a wide variety of other regulatory tactics such as size limits, fishing season pattern, etc.

Surprisingly, just a few days spent on model development led to both a very useful policy screening model, and to a possible win-win policy option for both increasing fishers' incomes and providing better protection for the spawning stock. Here we describe the model and policy analysis results obtained to date, and speculate on how co-operative management will develop in the future of the fishery.

We used an Adaptive Environmental Assessment (AEA) workshop process (Holling 1978; Walters 1986) to structure involvement by biologists and fishers in the model development process. AEA workshops proceed from definition of precisely what policy options and performance indicators are to be evaluated, through a series of data analysis and submodel development sessions for developing the actual simulation code, to gaming sessions where workshop participants "test" the model and its predicted policy options and suggest ways to improve it. In this case, the workshop included twenty biologists with a range of experience in lobster fisheries and population dynamics from across Australia and New Zealand, and twenty fishers from various fishing ports and the two South Australian management zones. The model reviewed in the following section thus represents the experience (and consensus) of a remarkably diverse participant/development group.

Spatial model description

The same model accounting structure for spatial population and fishing effort dynamics was chosen as had been developed in a previous analysis of the Western Australian rock lobster fishery (Walters et al. 1993). Here we review only the main features of that structure, which represents population and harvest processes on a spatial grid of cells (1° blocks in this case) laid over the fishing grounds corresponding to statistical reporting blocks for the fishery (Fig. 1). Various policy parameters (license access, refuge closures) and biological parameters (growth patterns, proportions of annual total recruitment, proportions of ocean bottom of suitable habitat for lobsters) are allowed to vary across cells. The cells are linked through three main processes: (*i*) allocation of total fishing effort among cells, (*ii*) larval settlement pattern (allocation of total recruitment over space), and (*iii*) movement of lobsters.

A key initial part of the model development was to have experienced fishers provide rough maps of benthic habitat type within each model spatial cell based on their past fishing success, using the simple classification: suitable for lobsters at all pot setting sites, sparse with small suitable patches requiring careful pot location, and not suitable for lobsters. This classification allowed us to capture some known differences among spatial cells in the effective area for lobsters (and fishing); in particular, much of the northern zone is either unsuitable or sparse habitat, while most of the southern zone cells have very high proportions of suitable habitat. All recruitment and fishing effort calculations for model cells were made relative to the estimated suitable habitat rather than cell size; thus in some cells with relatively little habitat, even a low total fishing effort can generate high simulated fishing mortality rate, while much higher efforts are needed to generate similar fishing rates in a cell with much good habitat.

The lobster subpopulation in each spatial cell is represented in terms of length (rather than age) structure, with the number of lobsters having 82 mm carapace length and larger divided into 8-mm (typical moult increment) categories. In each model cell, growth is represented by size-specific tables of moult frequencies (the proportion of animals moulting in each season/size category is then moved to the next larger size category).

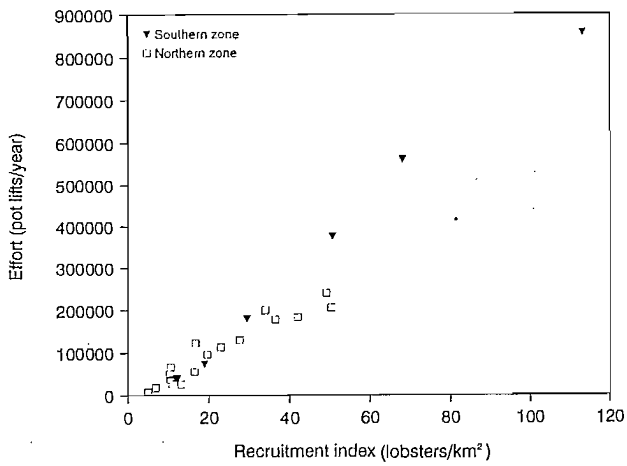
Recruitment to the smallest category (82–90 mm) is calculated from simulated puerulus settlement 3–4 years earlier (using a Beverton-Holt stock-recruit relationship between egg production and total settlement). The Beverton-Holt recruitment relationship was included in the simulation to represent the possibility of recruitment overfishing should the population egg production be reduced sufficiently. The phyllosoma larvae spend a year or more in a pelagic phase in the open ocean, potentially traversing distances of perhaps 1000 km based on typical current speeds in these waters of the Southern Ocean south of the Great Australian Bight. We presume that this precludes development of local subpopulation structure, so that total recruitment for each simulated year is calculated as a grand pool of settling puerulus dependent on antecedent egg production throughout South Australia. But we soon found that no hypothesis or model involving declining recruitment as the fishery developed would predict the observed pattern of catches and relative abundance (as indicated by catch per unit effort, CPUE); this suggests that recruitment has been relatively stable since the early 1970's. The recruitment relationship is left in the model as a functional form with parameter values set so that simulated recruitment is impaired only if egg production is reduced substantially from current (early 1990's) levels. This is not a serious limitation of the model, since there was a very clear consensus among biologists and fishers that they were only interested in exploring "safer" policy options involving regulations to increase egg production and hence move away from that uncertain point on the recruitment relationship where recruitment begins to fail.

For survival, growth, and harvest calculations, each simulated year is divided into 2-week time steps. Two fortnights in the middle of the moulting periods, summer and winter, are designated as the seasonal moulting times. Using a 2-week time step is of course not really necessary for the survival/growth calculation; its value is to allow model users to vary fishing season patterns and season length widely, and to allow more realistic representation of the annual fishery depletion and spatial effort movement process. Discard mortality from undersized lobsters and females bearing spawn which are returned to the water, as well as losses from illegal fishing and a small recreational sector, are also incorporated in the harvest submodel.

Spatial variation in recruitment rate (proportions of total recruits settling in different spatial cells) appears to be critical to the structure of the fishery. We noticed that catches in most spatial cells have been stable for the past decade. This implies that annual recruitment rate per cell (or per unit suitable habitat within each cell) can be estimated from the average catch and estimated yield per recruit (average recruitment in a near-equilibrium situation must be yield divided by yield per recruit). We used fishing effort, natural mortality, and growth estimates to estimate yield per recruit for each cell. The catchability coefficient (fishing mortality rate per unit effort) needed for the fishing mortality part of the yield per recruit calculation was estimated by running the overall simulation model while varying the catchability parameter and historical fishing effort, to find catchability and total fishing mortality that would match changes from early in the fishery to the present in observed length frequencies. The resulting recruitment (yield/yield per recruit) calculation is admittedly crude, but it provides at least a more realistic estimate of spatial variation in recruitment rate than would crude catch or catch-per-effort statistics alone. Catch-per-effort does not in fact vary much over the whole fishing area, indicating that effort is attracted to areas of high lobster density and recruitment quickly enough to cause strong exploitation competition among fishers.

We found a very close relationship between recruitment rate estimated as above and annual fishing effort (averaged for 1989–1993), apparently indicating that effort is strongly responsive to spatial variations in recruitment rate (Fig. 2). Unfortunately we cannot be certain that the strong relationship in Fig. 2 does in fact represent attraction of fishing effort to areas where recruitment is concentrated. The observed pattern could be produced in at least two other ways. First, recruitment could be the same in all cells, but effort could be distributed in some way related to factors like access from port. Then if fishing mortality rate were in fact low in all cells, our recruitment calculation (catch divided by yield per recruit) would be dominated by catch variation due only to effort variation, with some spurious correction in yield per recruit from incorrectly assuming high fishing rates in some areas. The main evidence against this explanation is that length frequencies in areas with high effort indicate that fishing mortality rates are definitely not low in such areas. Second, recruitment could again be the same in all areas, but catchability could vary greatly so as to make the apparent or vulnerable stock look much larger in some areas (and attract more fishing to those areas). We see no way to reject this explanation using data from the fishery; there could indeed be substantial abundances of lobsters that are for some reason "invisible" to the fishery, but it would be plainly unwise

Fig. 2. Estimated relationship between recruitment rate per unit usable habitat and fishing effort for statistical subareas within the South Australian lobster fishery. Recruitment rate is estimated as observed average catch for each statistical subarea divided by estimated yield per recruit for the subarea.



to count on such invisible animals as a source of protection against overfishing (egg and recruitment source).

The model uses the approach of Walters et al. (1993) and Allen and McGlade (1986), simulating the spatial redistribution of fishing effort each biweekly time step according to the desirability for vessels to fish in each cell. This variable, the effort "attractivity" of each cell, is directly proportional to the expected profitability from fishing there and is hypothesized in the model to be a function of spatial patterns in expected fishing success as measured by CPUE. For each simulation fortnight, the model calculates expected attractivity for each cell as a weighted average of the CPUE experienced the previous fortnight that same year and the historical value of the previous year's CPUE for the cell that fortnight of the season, with each predictor weighted equally. Effort is then allocated to each cell according to the attractivity proportion, the attractivity for the cell divided by the sum of expected attractivities over all cells. Over a fishing season of several months, repeating this redistribution calculation results in the pattern shown in Fig. 2; high effort is attracted to areas with high recruitment early in the season where it drives CPUE down. Later, effort spreads out to cells with lower initial recruitment as the more attractive cells are depleted. This effort redistribution submodel is critical for evaluating impacts of a variety of policy options, including spatial refuges that concentrate effort into remaining open areas and reductions in fishing season length that may reduce the tendency for effort to move into less attractive areas later. In addition to abundance, model effort responds to variations in price, both through the season, and as it varies with the supply, taken as the catch in South Australia overall.

Fractions of larger lobsters migrating between the spatial cells will be obtained directly from the results of a large mark-recapture study now being completed. Rates of migration in the model are assumed to be proportional to the density of animals in each cell. The proportion of lobsters leaving a cell is also assumed to decrease with increasing lobster size, so that lobsters with 120+ mm carapace length are not moved in the model. Preliminary tagging data suggest that movements are principally offshore and in distance are generally less than the width of a model cell, so only movement to adjacent cells is simulated. As it turns out, varying the small proportions of lobsters moving between cells does not alter model policy predictions, since increasing simulated movement simply causes simulated fishing effort to move as well. We were concerned about the movement parameters in initial workshop discussions, since we had found in the West Australian model (Walters et al. 1993) that offshore movement rate is critical to assessments of population egg production. Historically, offshore areas in Western Australia receive much less effort than inshore, providing a partial refuge for the spawning population. However, this is not the case in South Australia, where fishers are apparently much more willing to fish offshore than their Western Australian counterparts.

Model user interface and gaming procedures

The model is programmed to provide a series of spreadsheet-like interfaces for changing model parameters and policies, and a complex visual display of reference data and simulation results as each simulation or gaming trial proceeds. When we first presented this interface, biologists were concerned that it would be too complex for fishers to understand. In fact, fishers learned very quickly how to read the display screen that resembles the instrument panel of a modern fishing vessel, where several display blocks each show some relatively simple part of the results. The upper left area of the display shows color-coded maps of overall density changes from year to year, for juvenile and adult (egg producing sizes) lobsters. The yearly simulated size distributions are compared with recent data in two panels in the left center of the screen. The right side of the screen has four panels showing time series plots of long-term change in egg production, effort as pot lifts per year, catch, and CPUE outputs for both zones showing historical data and simulation time series.

Simulation time begins in 1950 (when the fishery started to develop rapidly), so that cumulative effects over time of any biological parameter changes made by the model user are immediately evident in terms of how well the model matches 45-year historical catch/effort and size distribution trends. This protocol helps to avoid the risk of confusing biological parameter changes made in one simulation run with changes made during subsequent runs in a policy evaluation session. The model can be stopped in any simulated year to introduce parameter changes. Normally only policy changes would be made, then the model would be restarted so the effects of change can be evaluated by comparing predicted outcomes to actual experience and to previous model outputs simulating historical policy. This method of comparing policy options is easier to understand (and far more credible) for both biologists and fishers than the usual modelling approach of just simulating alternative futures.

The model was deliberately run with a constant catchability chosen to match recent catch, CPUE estimates, and fishing mortality rate (as evidenced by length frequency) since 1980. Using this parameter value for early simulation years results in predicted catches that are much higher than reported for the

Fig. 3*a*. Predicted catch under four alternative management scenarios in the southern zone (SZ). Scenarios plotted include the baseline model (i.e., the historical management simulation), immediate reduction in fishing season length from seven to two months, gradual reduction in season over eight years, increased minimum size limit from 98 to 144 mm, and a refuge area of 1° square, i.e., one model cell in the zone.

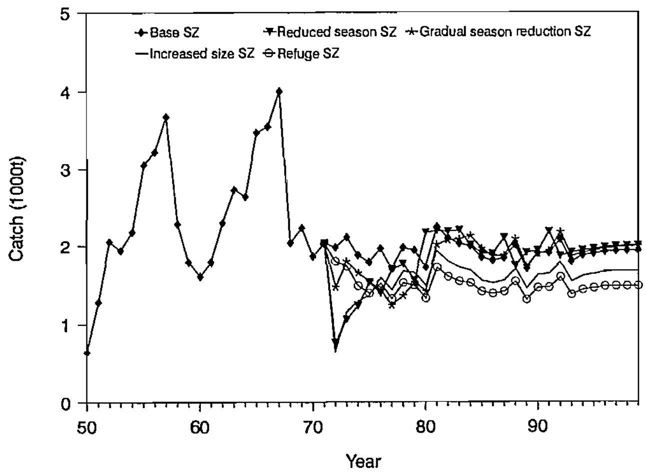
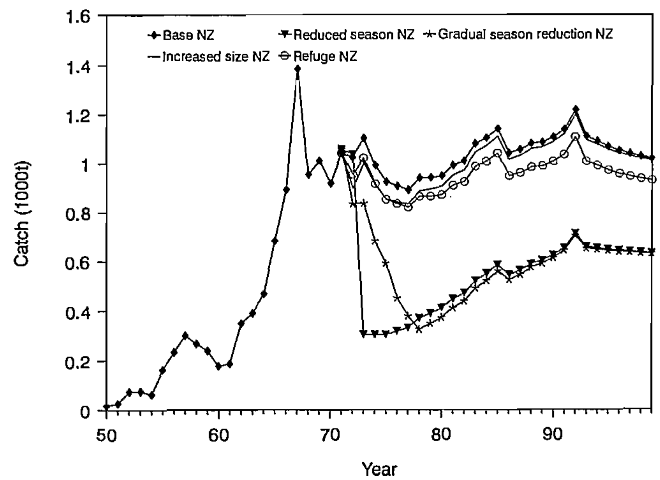


Fig. 3*b*. Predicted catch under four alternative management scenarios in the northern zone (NZ). Scenarios plotted include the baseline model (i.e., the historical management simulation), immediate reduction in fishing season length from seven to two months, gradual reduction in season over eight years, increased minimum size limit from 98 to 144 mm, and a refuge area of 1° square, i.e., one model cell in the zone.



southern zone and lower than reported for the northern zone. We believe that two factors contributed to this result. Conflicting results between the two zones are thought to be the result of the way that total effort was ascribed to each zone prior to their creation in 1968. However, we attribute most of the difference between reported and predicted catch rates in the southern zone to the increase in fishing power that has occurred over time. Basically, the model results with constant catchability indicate that the modern fishing fleet would have achieved roughly three times the catch (and population impact) of its early (1950–1970) counterpart. We could obviously vary the catchability parameter by including an arbitrary time effect to improve the fit to historical data, but in this instance the prediction-data discrepancy was very easily understood by fishers and in fact appeared to make the whole model more credible to them.

Options for reducing risk of recruitment overfishing

Fishers participating in the AEA workshop were given an opportunity to "play" with the model in a session where no biologists were present. They quickly tested a variety of surprisingly intrusive and potentially effective options for reducing risk of recruitment overfishing by increasing average annual egg production. Among these options were: (*i*) very large and immediate reduction in fishing season lengths, (*ii*) very large but more gradually imposed reduction in fishing season lengths, (*iii*) large increases in legal minimum size limits, and (*iv*) establishment of permanent closed areas (egg production "refuges"). Many simpler and more modest options were also examined by fishers, and the history-reference simulation approach described above appeared to help them very quickly grasp why such modest options would not likely have a significant effect.

The most interesting option examined to date is the very simple one of drastically reducing the season length, from seven to two or even one month. Fishers first tried this option as a perturbation test on the southern zone, to see what the model would do with an extreme policy change. They then brought this to the attention of the model development biologists and said that they had found a mistake in the code. The model predicted a dramatic decrease in catch in the years immediately after reducing the season, as expected. However, catch slowly built back to historical levels (Fig. 3*a*) over a period of eight years. We agreed that there must be an error, and had a frantic workshop session trying to find it. We finally realized that there was no mistake, and we were looking at the transient dynamics for a very classical prediction in the yield-per-recruit theory of fishing: starting at zero, equilibrium yield increases rapidly with fishing rate (F), then the relationship becomes very flat or slightly decreasing (provided recruitment overfishing is not a factor) over a wide range of higher F values. This undiminished catch rate is due primarily to increase in yield-per-recruit since the stock-recruitment relationship is effectively flat through the range of model egg production. One qualifier on this prediction of a recovery in catch to near preseason reduction levels with a large reduction in effort is the assumption of no density dependence in growth or adult mortality, or of recruitment. The history-reference display interface became critical in helping to explain this prediction to fishers; we simply pointed out how the model CPUE and length-frequency structure would recover under reduced fishing time to values near what the fishery produced in early years when total fishing effort was much lower. One uncertainty that fishers raised was whether lobsters can survive to larger sizes today as they did historically when F was lower. To test this critical assumption fishers suggested a planned experimental reduction in fishing mortality in a few spatial areas. They also quickly found a policy involving progressive reduction in season length over about 10 years that would result in substantial increase in population egg production with minor catch

Fig. 4*a*. Effect of alternative southern zone policies shown in Fig. 3*a* on total population egg production: comparison of the baseline output with immediate and gradual fishing season reduction, increased minimum size, and refuge area.

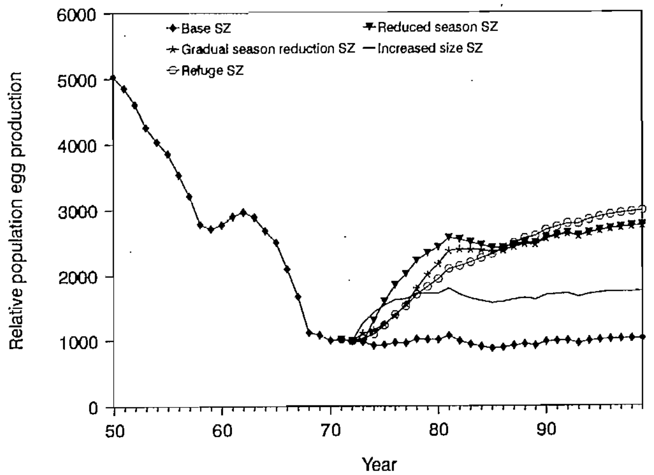
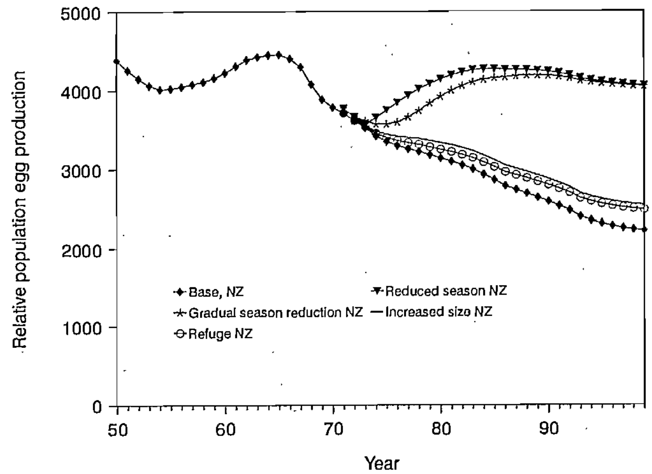


Fig. 4*b*. Effect of alternative northern zone policies shown in Fig. 3*b* on total population egg production: comparison of the baseline output with immediate and gradual fishing season reduction, increased minimum size, and refuge area.



reductions (of the order of 10–20% per year) along the way (Fig. 3*a*, gradual reduction case). Note in Fig. 3*b* that the recovery effect is not predicted to occur in the northern zone, where F is apparently much lower in the first place.

The model predicts large impacts on egg production of closing even a few model grid cells (1° square blocks) to fishing. Figures 4*a* and 4*b* show simulated egg production impacts of closing one southern zone and one northern zone cell, with the northern zone closed cell in a high recruitment area west of Kangaroo Island. In the southern zone, this policy has roughly the same simulated impact as drastically shortening the fishing season. However, this policy disadvantages southern zone fishers by closing a larger percentage of their fishing area, and it intensifies competition within the remaining open areas thereby increasing fishing mortality rate in these areas. Fishers suggested that instead of moving immediately to such refuges, potential refuge areas could instead be subject initially to substantially reduced fishing seasons. This staged approach to refuge area development would then also provide an experimental test of the predictions about season length reduction. The decision to proceed to complete closure of a refuge could then be made on the basis of experimental evidence. Unfortunately, the model and data analysis of Fig. 2 predicts that fishers will respond to any initial increase in CPUE in the experimental areas by shifting effort to them, preventing stock size and CPUE from increasing much. Under regulation this shift could presumably be restrained. Hence it appeared that the policy was failing when, in fact, it would work if these effort shifts could be restrained.

Another policy suggestion from fishers was to substantially shorten the fishing time allowed each license or quota holder, while allowing individual fishers to select their own fishing "seasons." A similar policy was adopted by northern zone fishers in the months following the workshop. Its effect is like a reduced fishing season, but with less gear competition for available pot setting locations. It would also be much like a policy of greatly reducing the total number of licensed fishing pots, since the number of pots fishing in any part of the overall season would be much reduced. The model does not keep track of individual fishing patterns, but we did try simulations of major reductions in number of pots fishing for each 2-week time step. A supplementary spreadsheet model was developed to test the consequences of fisher-chosen season reductions (McGarvey and Prescott 1998) and was used to decide the lengths and months of closures in the 1994/1995 season. This option is very popular with fishers in the northern zone so it may be worth testing the concept further, if fishers are willing to cooperate in establishing and maintaining experimental areas where the annual number of pot lifts is drastically reduced.

With quota management established in the southern zone, it should be possible, in principle, to establish a sequence of quotas over time that would cause the same ramping down in fishing mortality as would shortening fishing seasons. But implementation of this policy has inherent risks when annual assessments of stock size are subject to large errors. Quotas could trigger a decline in stock abundance rather than an increase if stock size were overestimated and quotas initially allocated were too large, because an absolute level of removal is an increasing fraction as the stock declines. However, the southern zone is unusual in that the fishery has maintained the same effort controls, pot number limits, and seven-month season, that were in place prior to quotas being introduced. Without effort controls, to be relatively sure of obtaining the same reduction in risk of severe stock decline as a season reduction policy, quotas would have to be reduced much more, and for much longer, than would catches under season reduction. The dilemma of how to reconcile quota management with need for direct and simple regulation of exploitation rate has not been resolved, and will likely be a matter of much future discussion between biologists and fishers.

Discussion

We entered the modelling exercise thinking that a detailed and realistic spatial model would be needed to link long-term population dynamics considerations with an analysis of specific regulatory options. Indeed, it was perhaps necessary to proceed with the analysis in detail so as to make it credible to biologists and fishers alike. But in the end, the most important policy findings, including reduced season lengths and experimental tests of season length reduction perhaps leading to refuge areas, involve only very simple predictions about the impact of reduced fishing mortality rate on population size structure, CPUE, and fecundity due to changes in yield- and egg-per-recruit. While it seems that we did more analysis than was really necessary, we view the overall findings as a very fortunate outcome. Had the policy exploration and testing uncovered only a few specific policy alternatives whose efficacy depended on particular local and highly uncertain estimates of population parameters, the model would have been a much less useful tool. We would have been left with the tired old complaint that the data are inadequate and more research is needed.

During the model development and testing, we repeatedly found the most critical data to be length-frequency patterns sampled from the fishery. Beyond the obvious use of these data for quantitative assessment of fishing mortality and catchability, we found them necessary in "credibility checks" on policy alternatives. Our only real justification for model predictions that lobsters would on average increase in size under reduced fishing mortality is that, in fact, lobsters were larger when effort was lower. However, it did not take fishers long to find the basic flaw in this argument, and to recognize the strong assumption of stationarity implied by arguing that historical data are good predictors of the effects of future policy change. They noted that the difference in size structure could be due to recent growth rates being lower or unusually high recruitment some years before the early samples were taken. They further noted that we cannot reliably use northern/southern zone size frequency comparisons for mortality assessment, because the higher frequency of large lobsters in the northern area, where effort is lower, could be due simply to large areas in the far western regions and offshore where fishing in the past was rare, leaving substantial numbers of near virgin stock to be harvested now. In the end, we cannot reject these counter arguments and criticisms of the model assumptions by using only available data, or by continued monitoring. The arguments are instead perhaps the best case we can make for the need to immediately establish at least some small, experimental refuge areas to provide reference or baseline information on how population size structure should look under reduced fishing mortality.

Somewhat surprisingly, there was strong support in principle by fishers for setting up management experiments to directly test for such effects as shifts in abundance and size distributions under reduced fishing effort. The same experiments could also reveal if there are significant increases in gear efficiency when fewer pots are in competition. Usually there is a tacit assumption by fishers, and many biologists, that just gathering more data will somehow permit analyses to resolve key uncertainties. But in this case, most stakeholders recognized immediately that the critical uncertainties involve circumstances that no longer occur naturally in the fishery, and must be deliberately created if policy evaluations are to be rigorously tested. Laying the groundwork for a co-operative program to design and conduct real adaptive management experiments is perhaps the most important single achievement of our efforts to date.

We believe that our AEA workshop will serve as a stimulus for other such workshops in fisheries. Participants were quick to appreciate how the data they collected were used to develop an understanding of such a complex and dynamic system. Participants were also able to use the model to test policies almost as soon as they had access to it because of the model's relatively simple graphical interface. Models with such easy-to-use and understand graphical output are relatively rare. This may be because most scientists are able to gain sufficient understanding of model outputs using methods familiar to them such as tables of results and static graphs. While the biologists may understand the results fishers often do not. The power of this type of graphical interface for communicating results was clearly obvious to every biologist in attendance.

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