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Graduate Student Symposium on Fish Population Dynamics and Management

Fisheries Centre, University of British Columbia, Canada

edited by

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and
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Director's Foreword

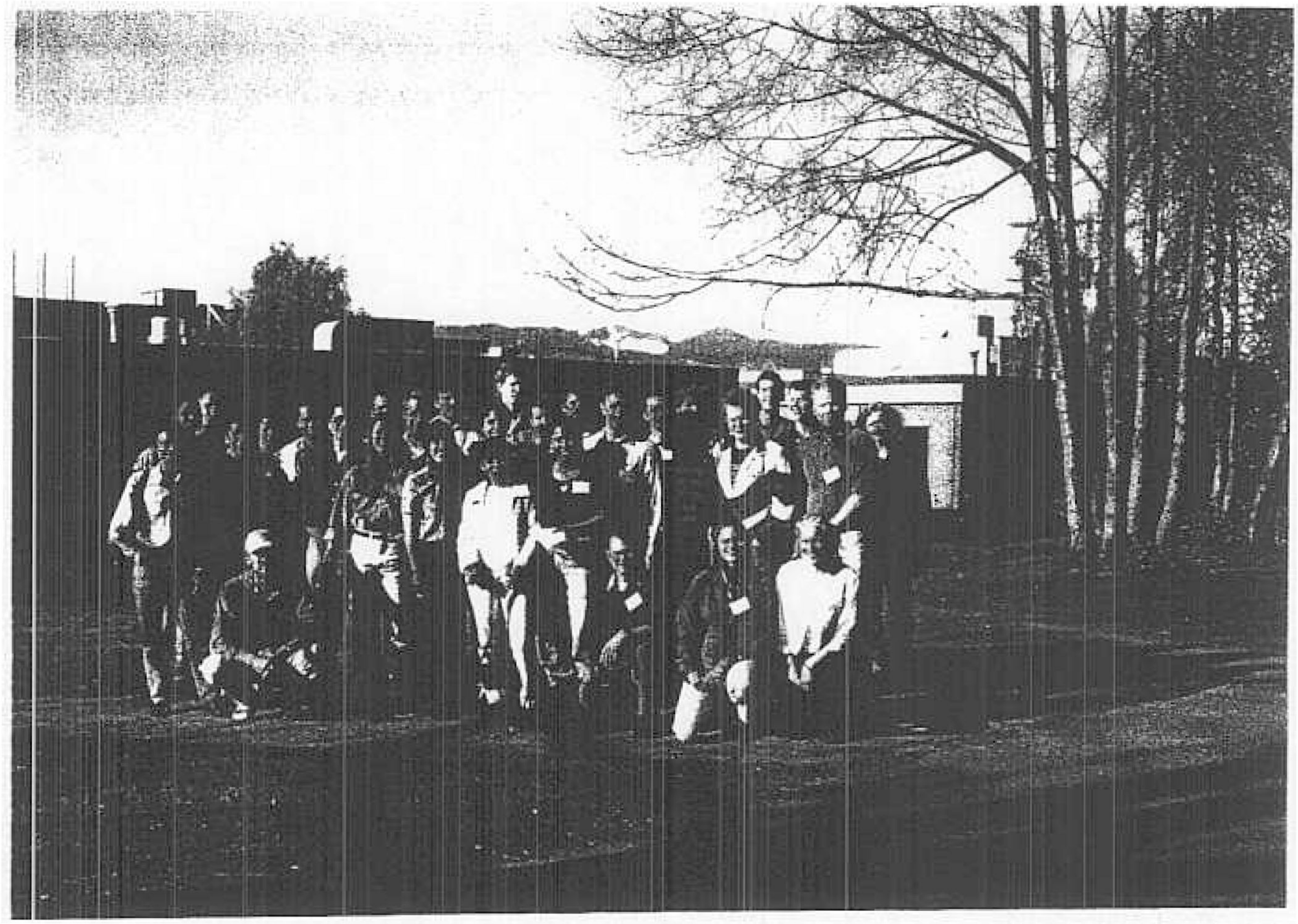
From April 22-23 1995 the UBC Fisheries Centre was delighted to host over 30 fishery graduate students from the Universities of British Columbia, Minnesota, Washington, Oregon State and Simon Fraser University who met in order to participate in the first Graduate Fisheries Symposium on Fish Population Dynamics and Management. It is hoped that this is the first of an annual series.

The Symposium was jointly organised by Alida Bundy from the Fisheries Centre, UBC and Elizabeth Babcock from the School of Fisheries, UW. These proceedings consist of extended abstracts of papers presented at the Symposium together with a list of participants and a summary of discussion items.

Fishery science is in a state of dynamic flux today. Old ideas are being re-visited and re-vitalised using new tools of the computing and information explosion. Graduate students are the life blood of any research institute and so we are making this record of the Symposium more widely available to communicate important discussion themes that we think are at the frontiers of fishery science.

The Graduate Student Symposium on Fish Population Dynamics and Management constitutes the 2nd in a series of meetings/workshops held at the UBC Fisheries Centre in 1995 and was partially sponsored by the Fisheries Centre. The workshop series aims to focus on broad multidisciplinary problems in fisheries management, provides a synoptic overview of the foundation and themes of current research, and attempts to identify profitable ways forward. Edited reports of the workshops are published in Fisheries Centre Research Reports and are distributed to all participants and to selected international fisheries libraries. Further copies are available on request.

Tony J Pitcher
Professor of Fisheries
Director, UBC Fisheries Centre



Standing, from left to right:
Ted Tien-hsiang Tsai, Patrick McConney, James Scandol, Jesus Jurado-Molina, Sherry Larkin, Ricardo Torres, Leonardo Huato, Chris Tuninga, Lisa Thompson, Trevor Hutton, Stacey Rassmussen, Chris Costello, Silvia Salvas, Lorraine Read, Warren Schlechte, Christina Robb, Ying Chuenpagdee, Martin Esseen, James Lady, Ramón Bonfil, Michiyo Shima, Richard Porter, Calvin Peters, Tim Liermann, Milo Adkison, Derek Ogle, Marianne Johnson.

Kneeling, from left to right:
Judson Venier, Murdoch McAllister, Beth Babcock, Alida Bundy.

Organisers' Introduction

The first of an intended annual series of Graduate Fisheries Symposia for North American West Coast Universities was held at the Fisheries Centre, UBC, 22-23 April 1995. The aims of the Symposium were to provide a venue for fisheries students to make contact with one another, for students to formally and informally discuss their work and to foster knowledge and communication links between fisheries students in different universities and departments. The Symposium was very successful, with many participants voicing interest and stimulation in papers presented and in formal and informal discussion.

Alida Bundy
Fisheries Centre
University of British Columbia

Elizabeth A Babcock
School of Fisheries
University of Washington

Summary of the Symposium

Thirty five students from the Fisheries Centre, UBC, the Department of Fisheries and Wildlife, UM (University of Minnesota), the School of Fisheries (SOF) and the Center for Qualitative Science (CQS), UW, the Department of Agriculture and Resource Economics, OSU (Oregon State University), and the School of Resource and Environmental Management (REM), SFU (Simon Fraser University) attended the meeting. 18 papers were presented. The meeting began on the Saturday morning with 'Modelling in Fisheries Assessment', followed by two shorter sessions in the afternoon, 'Decision Analysis' and 'Policy'. The two sessions on Sunday morning, 'Estimation and Survey Methods' and 'Ecosystem Management' ended the meeting. The quality and interest of all the papers was high, stimulating many questions and discussions which extended into the coffee and lunch breaks. In addition, we ended Saturday with an informal discussion session.

The discussion concerned the interdisciplinary nature of fisheries science. It was first noted that the sessions and papers in the Symposium covered a wide number of disciplines, including biology, modelling, economics, socio-economics, law and social science. However, it was questioned how well these disciplines are integrated into fisheries management, science and teaching and how effective communication between disciplines is. This was followed by a question about how much the individual fisheries scientist should know of other disciplines. Opinion was mixed. Some expressed the view that fisheries biologists should have a reasonable knowledge of the social, economic and political aspects of fisheries to enable them to better understand fisheries problems and issues and place them in an advantaged position to advise managers. Considerable discussion ensued concerning the view that effective fisheries management depends on understanding the behaviour of fishers, but whether fisheries biologists should or could study fisher's behaviour was questioned. Many discussants considered overspecialisation and discipline isolation to be negative. However, others disagreed. They felt that biologists should stay within their own discipline, in order that biological advice to management be independent and objective. They also considered that the social aspects of fisheries should be studied by the appropriate specialists. They did not however negate the role of the other disciplines in fisheries science.

The majority considered the social and economic side of fisheries to be very important. It was generally agreed that fisheries science must be multidisciplinary and that in order for fisheries science, and therefore management of fisheries to be successful, scientists from different disciplines must have a sufficient knowledge of the other "fisheries" disciplines to enable effective communication and understanding. The lack of communication and understanding between disciplines was identified as key problem area in today's science, which seems to consist of a tripartite, but separate, structure of biology, economics and sociology. Although this is an improvement on the old unitary biological approach, effective links need to be further built and maintained.
The implications of the multidisciplinarity of fisheries science for graduate teaching programs was also discussed. Again it was generally agreed that programs need improvement, that they should include discipline options and that the connection

between disciplines should be explicitly considered.

The final event of the Saturday was a evening boat trip aboard the MW Invader, a 1930s steam yacht. It was a beautiful evening with a bit of a breeze and we cruised the Burrard Inlet and False Creek. For those from out of town it was a great chance to see Vancouver in its majestic setting, but even for those from Vancouver the boat trip was a great treat. It provided a further chance for people to get to know each other and relax in an informal atmosphere, while taking in the scenery.

The Symposium was funded by registration fees (CA$20) and a very useful contribution from the Fisheries Centre, UBC.

Next Years Symposium

It was proposed at the conclusion of the meeting that an organising committee, with a member from each of the West Coast universities, should be formed to organise next years symposium and that this committee should have an annual rolling membership. The 1996 committee are:

Elizabeth A Babcock (UW)
Christina Robb (SFU)
Silvia Salas (UBC)
Christopher J. Costello (OSU)

and the 1996 Symposium will be held at the School of Fisheries, University of Washington.

It would be very beneficial for the 1996 organising committee if attendees (and others interested) started to consider the themes they might like to see discussed at 1996 meeting. The Symposium provides a unique opportunity for graduate students involved in fisheries research to criticise (without their advisors distracting them) issues affecting their discipline. Some initial areas ripe for discussion might include:

What does graduate education in fisheries lack in 1996 ?
Are we really preparing for fisheries management for the 21st century ?
What is the best balance between qualitative and quantitative fisheries science ?
What is the best balance between social and ecological research in fisheries ?

For further information and copies of this report, please contact either Beth Babcock or Alida Bundy, or any of the 1996 committee (addresses at the end of this report).

Schedule

Fisheries Centre, Ralf Yorque Room
Saturday 22 - Sunday 23 April

Saturday

8.30 - 9.00 Registration, Coffee and Muffins

9:00-9:10 Introduction

Modelling in Fisheries Assessment

9:10 Babcock, Elizabeth. UW. A dynamic model of fisher effort allocation in a multispecies trawl fishery.

9:35 Bonfil, Ramón. UBC. Monte Carlo testing of fisheries models for sharks.

10:00 Huato, Leonardo. UBC. Optimal migratory paths for returning sockeye salmon.

Break: 10:25-10:50

10:50 Lady, James. UW. Mark-recapture models for estimating stream life of spawning salmon.

11:15 Schlechte, Warren. UW. Investigations into the dynamics of the Pacific razor clam along the Washington coast.

11:40 Scandol, James. UBC Application Strategies for Biophysical Models of Salmon Migration and Production in the Northeast Pacific.

Lunch 12:05-1:15

Decision Analysis

1:15 Larkin, Sherry. OSU. Social welfare impacts of alternative recruitment specifications: implications for Pacific whiting management using bioeconomic analysis.

1:40 Peters, Calvin. SFU. An analysis of stocking and research programs in two British Columbia lakes using a quantitative decision- support model.

2:05 Robb, Christina. SFU. A method for determining when to declare a surplus in the Nass River sockeye salmon fishery.

Break 2:30-2.50

Policy

2:50 Hutton, Trevor. UBC. Fisheries management policy and practice in South Africa: the present and the future.

3:15 McConney, Patrick, UBC. Social networks and tropical small-scale fisheries management and planning.

3:40 Porter, Richard. UBC. Exploring liability in the context of pollution and the fishery

4:05 - 5:00 Open Discussion

6.00 - 10.30 - Boat Trip
Leave here at 5.30pm, to board at 6.00pm. We depart at 6.30, returning to port at 10.30pm. There will be a buffet dinner aboard, but unfortunately we could not run to drinks as well, so you are going to have to buy your own, Sorry!

Sunday

Estimation and Survey Methods

9:30 McAllister, Murdoch K. UW. Evaluating the bias and variance from fish migration in trawl estimates of abundance

10:20. Tsai, Ted Tien-hsiang. UW. Standardization of fishing effort and abundance trends of the major groundfish resources in the southern part of the East China Sea.

10.45 - 11.05 Break

Ecosystem Management

11:05 Bundy, Alida. Fisheries Assessment and Management in a data sparse, multispecies, multigear fishery

11:30 Shima, Michiyo. UW. Marine mammal- fishery interactions in the Gulf of Alaska and comparisons to other ecosystems.

11:55 Thompson, Lisa. UBC. Effects of nutrient additions to Kootenay Lake, B. C., on zooplankton and kokanee salmon (*O. nerka*) biomass and productivity.

Lunch 12:20 pm⇒

One Page Summaries

A dynamic model of effort allocation in the West Coast groundfish trawl fishery

Elizabeth A Babcock,
SOF, UW.

For fisheries management to be effective, it is necessary to understand the behavior of fishermen, particularly how they choose a target species, gear or fishing grounds. This problem can be addressed using dynamic programming models, assuming that fishermen make the decision that will maximize net profit over a trip.

The U. S. West Coast shore-based trawl fishery is a multispecies fishery in which vessels generally target more than one species during a trip. The targeted species groups have been categorized into five "strategies" -- midwater trawling for widow rockfish, deepwater Dover sole trawling, bottom rockfish trawling, nearshore mixed species trawling and shrimp trawling. The fishery is managed with trip limits, which are quotas on the amount of each species that can be landed by an individual vessel, per trip or per week. Vessels can change their fishing strategy in response to changes in trip limits and other regulations, market conditions or fish distribution.

A stochastic dynamic model was developed to simulate a fishing trip for an individual vessel, and predict the strategy choices the vessel would make. The input parameters for the model were calculated using an observer database developed by Pikitch et al. (e.g. Pikitch et. al. 1990, Fisheries Research Institute Publication FRI-UW-9019). The model requires information on the cost of fishing each strategy, probability of some random event such as weather or gear damage in each strategy, the probability distribution of catches in each strategy, and the trip limits on each species. The vessel skipper is assumed to know the costs and probability distributions without error.

During each hour of the modeled trip, the vessel chooses the activity that will maximize the expected increase in net profit between the current time and the end of the trip. A trip is modelled backward in time to calculate the optimal choice for every possible vessel state. The optimal choices are then used to model a trip forward in time, and calculate the probability that the vessel is fishing each strategy at each time.

The model was used to predict the strategy choice of a vessel a vessel with various trip limits. For example, the model was run for a vessel choosing between the Bottom Rockfish and Deepwater Dover strategies, with varying trip limits on yellowtail rockfish (*Sebastes flavidus*), an important component of the Bottom Rockfish strategy. The model predicted that without a yelllowtail trip limit, the vessel would always fish BRF; with a trip limit of zero, the vessel would always fish DWD; with an intermediate trip limit, the vessel would fish BRF until the limit is reached, then switch to DWD. These results are qualitatively consistent with observed fisher behavior. The model will also be used to predict strategy choice with more complex trip limits, and with various gear regulations.

Dynamic programming seems to be effective in predicting fisher strategy choice with respect to trip limits. The approach has the potential to be useful both as a means of studying fisher behavior theoretical and as a management tool.

Monte Carlo testing of fisheries models for sharks.

Ramón Bonfil,
Fisheries Centre, UBC

Surplus production models have been disregarded for assessing elasmobranch fisheries due to perceived model misspecification The more sophisticated age-structured models might not be an alternative solution due to present poor understanding of elasmobranch biology and ecology and the level of precision in the data required by such models. Recent studies on fisheries modelling suggest that many of the problems with catch/abundance models lie in the data rather than model inadequacy.

In the present study, the Schaefer and the Fox dynamic surplus production models and the delay-difference model of Deriso-Schnute are compared through Monte Carlo simulation to test their performance in estimating assessment and management parameters. A full age-structured stochastic simulation model of a shark population is built and a fisheries submodel generates 100 yearly replicates of artificial catch and CPUE data from this population. Six different operating models are considered, including all possible combinations of the Ricker and the Beverton-Holt stock-recruitment models and spatial distribution as characterised by hyperstability, hyperdepletion or proportionality between CPUE and biomass. Each model being tested is fitted to these data using the Total Least Squares fitting procedure, which takes account of observation as well as process errors in order to find parameter estimates.

Preliminary results indicate that assuming multiplicative observation errors in the estimating models improves the performance of all models as opposed to assuming additive observation errors. For simulations under the Beverton-Holt recruitment model and proportionality in the CPUE-biomass relationship, there is a particularly bad performance by the Fox models for optimal effort estimation, and by the Deriso model for both management parameters and for expected discrepancy. The estimates from the Schaefer model, if not particularly good, are at least within acceptable limits as compared to similar studies. When the Ricker recruitment model is considered most models cannot estimate properly or reliably the optimal effort, and the Deriso model keeps failing at estimating optimal catch and has high expected discrepancies.

The further assumption that the system was at equilibrium when the fishery started (B_0=K assumption) did not seem to benefit the estimating procedures. This strategy helped improve optimal effort estimates ins some cases, but at the cost of a deterioration on stock biomass estimates. When the hyperdepletion and hyperstability operating models are considered, all three fishery models show dismal performance in parameter estimation. Hyperdepletion situations seem to be particularly difficult for estimation.

Further research will focus on improving values of parameters that are fixed constant for the Deriso-Schnute model, as errors in this area might account for the bad performance of the model. This however only highlights the probably impossible level of accuracy and precision needed in real situations to make this type of model useful for practical purposes. The robustness of the models will be tested by carrying out more simulations under a different effort regime (with less contrast in the data) and using a less productive population.

Fisheries assessment and management in a data sparse, multispecies, multigear fishery

Alida Bundy,
Fisheries Centre, UBC.

San Miguel Bay in the Philippines has been heavily fished for 2 to 3 decades and exhibits classic over fishing symptoms such as decreasing catch-per-unit-effort, increasing effort and diversity of effort, changes in species composition and reduced profits. The multispecies, multigear fishery catches some 108+ species and is comprised of 18+ small scale gears and 4 trawling sectors and has a history of conflict, typical of many fisheries where large and small-scale sectors co-exist. Fisheries management and monitoring are minimal and consequently, fisheries data are sparse. There are only two well documented periods in time, 1980-1981 and 1992-1993 when comprehensive surveys took place. No time series of catch and effort or other fisheries related data exists thus rendering standard fisheries assessment methods inoperable.

There are 2 main issues to be addressed in SMB: multispecies management and management to mitigate conflict, both in the face of large uncertainty. A simplified adaptive management approach is developed here as a means to address both these necessities in the fishery. This paper describes the first step of this multistage process where hypotheses about the multispecies resource are developed.

Ecopath 2 (Christensen and Pauly 1992), a steady-state ecosystem model was used to investigate the resource dynamics. The model is based on a series of balanced linear equations which are solved by matrix algebra where,

Production by (i) - all predation on (i) - non-predation losses of (i) - export of (i) = 0, for all (i). That is,

$$B_iPB_i - \Sigma_j B_j * QB_j * DC_{ji} - PB_i * B_i(1-EE_i) - EX_i = 0$$

where,
B_i = biomass of (i),
P/B_i = Production/Biomass ratio of (i),
Q/B_i = Consumption/Biomass ratio of (i),
DC_{ji} = Proportion of (i) in the diet of (j),
$(1-EE_i)$ = other mortality of (i),
EX_i = Export of (i).
The 3 parameters B, P/B, Q/B where estimated from the trawl survey data and diet was taken mainly from the representative data on the literature.

From the results of the model and an analysis of the fishery data, the following hypotheses were made:

1. Competitive and predatory interactions influence the impact of fishing on the resource. most competition occurs at trophic level 3 and predation at higher levels.

2. San Miguel Bay acts as a nursery area, continually re-stocked from outside. Significant import and export appear to exist

3. Large flow to detritus has a positive impact on the resource.

The ensuing problems and ideas for modelling these hypotheses were briefly discussed.

References

Christensen, V. and D. Pauly (1992) A Guide to the ECOPATH II program (version 2.1). ICLARM Software 6, International Centre for Living Aquatic Resources Management, 72 pp.

Optimal migratory paths for returning sockeye salmon

Leonardo Huato
and
Carl J. Walters,
Fisheries Centre, UBC

Research on salmon migration has focused on the mechanisms salmon may use for navigation and orientation, and the effect of the oceanographic conditions on arrival time and condition of the fish. In this paper we hypothesize that salmon should choose returning trajectories that minimize ocean travel costs in order to maximize reproductive output at their home stream. We then investigate how such trajectories are related to salmon distribution prior to migration, time to arrival and costs of migration.

We develop a spatially explicit optimality model to calculate cost-effective travel trajectories for returning Fraser sockeye salmon, *Oncorhynchus nerka,* over a grid of starting points covering the Northeast Pacific Ocean. Because we were interested in the oceanic part of the returning migration, we made the migration goal the mouth of the Fraser river.

Travel costs, expressed as total metabolism, are calculated from a bioenergetics model. We used sea surface temperature data taken from the COADS data set to calculate optimal swimming speed and metabolic cost at that speed, and surface current estimates from the OSCURS model to calculate ground speed of salmon and swimming time to next gridpoint. Optimal trajectories were then calculated over the entire grid with a dynamic programming algorithm. Total metabolic cost was set as the state variable to minimize, and compass bearing was the decision variable.

Modeled trajectories show that optimal paths are position-dependent, and suggest that salmon should use currents as an aid to migration. Bioenergetics shows that currents are the main factor in the selection of the trajectories since the cost of swimming outweigh the effect of temperature in the metabolism of the fish. Nonetheless, as salmon get closer to home, environmental factors are less likely to affect the trajectory due to the fixed nature of their goal. Trajectory patterns show that complexities in coast line configuration can also affect trajectory choice, as happen when salmon reach the northern tip of Vancouver Island, where only two trajectories are possible.

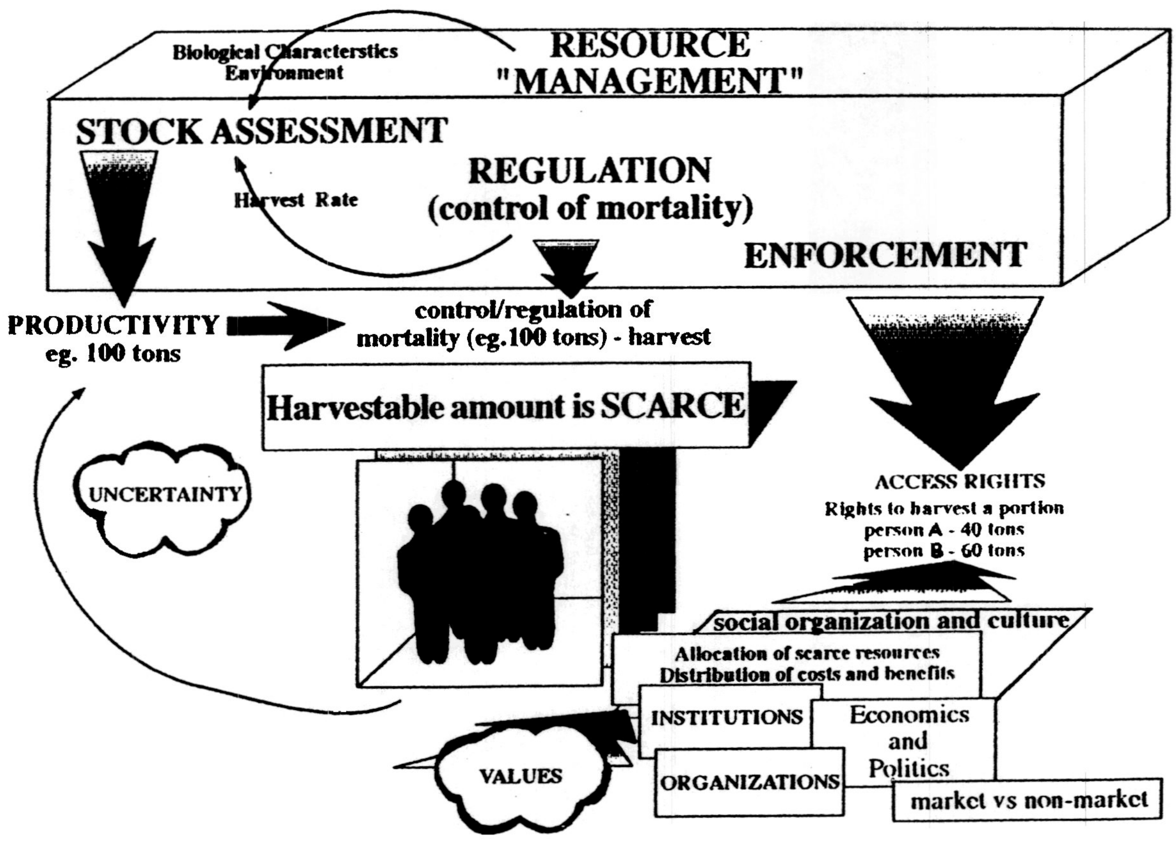
Modeled trajectories also shown that under the oceanographic conditions of the Alaskan Gyre, a 2 kilogram sockeye salmon can cover the area from 155□ W up to the river (122□ W) in less than three months, requiring 300-500 grams of body mass (depending on the starting point) in energy units to cover such distance. This sets an outer boundary to where salmon can be at the onset of the migration in order to arrive to the Fraser river in the required time.

Fisheries Management Policy and Practice in South Africa: the Present and the Future.

Trevor Hutton,
Fisheries Centre, UBC.

South Africa has an array of highly integrated fisheries including commercial, recreational and subsistence fisheries. Commercial catches are dominated by hake and anchovy. There are also fisheries for rock lobster, abalone and various linefish. In the last few decades the central government has played an ever-increasing role in management, administering its regulatory policy through the Sea Fishery Act. Most of the fisheries have developed in a way that is typical world-wide, from open access to restricted open access fisheries to restricted and regulated access. The main tools used by the state to restrict and regulate access include technical conservation measures (mesh restrictions) and effort or catch control which are expressed in the regulations as limited licences and permits.

The move towards regulated access in the major commercial fisheries occurred before the current political changes in the country. Presently, one of the most contentious issues being considered is access rights; past practices have been questioned and re-distribution has been called for. A review of the fisheries, the current management structure, the policy and various laws, and the key issues that are being debated were presented. The issue is complicated because of the very nature of fishing: resource management and the allocation of scarce resources are linked in a very complex way. A conceptual model of the components and the linkages was presented (see figure below). The aim was to consider the factors which play a role in management. Controlling the harvest of the productivity is inextricably linked to the principle objectives of management, that is, an efficient allocation of the resource and equitable distribution of the result. Understanding these linkages is crucial to determining the possible consequences of major changes in the current policy. The form of the access rights and how they are defined is of critical importance in determining whether the objectives mentioned above will be met.



Mark-Recapture models for estimating stream life of spawning salmon

James Lady,
CQS, UW.

One widely used method for measuring escapement for populations of Pacific Salmon is the area-under-the-curve (AUC) method, by which the estimate of total escapement is calculated by dividing an estimate of total fish-days by an estimate of the average stream residence time, or stream life. In order to estimate escapement accurately using the AUC method, an accurate estimate of stream life must first be obtained. The goal of my research is to develop mark-recapture models to estimate stream life. I am using computer simulation studies to study the statistical properties of stream life estimates based on these mark-recapture models.

A mark-recapture model that uses counts of live individuals can be used to estimate the conditional survival probabilities from one sampling occasion to the next. An estimate of stream life can then be obtained from these conditional survival probabilities. I propose to develop more precise estimates of stream life in two ways: By using the Weibull distribution to model the stream survival process, and by incorporating counts of dead individuals as well as live individuals into the mark-recapture model.

One motivation for incorporating the Weibull distribution is that it decreases the number of parameters that must be estimated in order to estimate stream life. In a mark-recapture model that does not incorporate the Weibull distribution, the conditional survival probabilities from one sampling occasion to the next are separate parameters that must be estimated. However, if the stream survival process is assumed to follow the Weibull distribution, only the two parameters of the distribution need to be estimated in order to describe the entire stream survival process, and subsequently to estimate the stream life. The need to estimate fewer parameters should increase the precision of the estimate of stream life.

One possible disadvantage of incorporating the Weibull distribution is that the actual distribution may not follow the Weibull distribution. Therefore, the robustness of Weibull-based estimates to deviations from the Weibull must be explored.

Preliminary simulations have been performed to compare two separate estimates of stream life: A nonparametric estimate based on the estimates of the conditional survival probabilities, and an estimate obtained by incorporating the Weibull distribution. Both estimates are based on models which incorporate the detection of live individuals. The results show that the nonparametric estimate consistently has a lower sample variance than the Weibull estimate, and the Weibull model did not perform well with "little information" (low probabilities of detection, small initial release size, and small number of sampling occasions). However, the mean squared error (MSE) for the Weibull estimate is often less than the MSE for the nonparametric estimate, suggesting that the Weibull estimate is less biased. Also, the Weibull estimate seems fairly robust to deviations from the Weibull distribution, provided there are high probabilities of detection, a large enough release size, and a sufficiently large number of sampling occasions.

Future research will involve the incorporation of counts of dead individuals as well as counts of live individuals into the mark-recapture model. This provides more information on the survival process that should increase the precision of the estimate of stream life, but it also increases the number of parameters that must be estimated (e.g., probability of carcass detection, probability of the retention of a carcass from one sampling occasion to the next). I am interested in looking at the trade-off between these two factors, and determining whether incorporating counts of dead individuals can be used to increase the precision of the estimate of stream life.

Social Welfare Impacts of Alternative Recruitment Specifications: Implications for Pacific Whiting Management using Bioeconomic Analysis

Sherry Larkin,
Department of Agriculture and Resource Economics, OSU.

Pacific whiting, *Merluccius productus*, is ecologically and commercially one of the most important fish species on the North American west coast. The stock is exploited by both the U.S., which captures approximately 75% of the allowable catch, and Canada. The stock is managed triennially in the U.S.; every three years biologists with the National Marine Fisheries Service recommend the total allowable catch for each of the upcoming three years assuming recruitment (number of age-2 fish) remains constant at the historical median. Like the gadoids, however, recruitment variation is a major component of stock dynamics for this pelagic specie; it can have a greater impact on production than either variability in mortality or growth. Consequently, fluctuations in stock abundance caused by interannual recruitment variation can significantly impact social welfare.

A fundamental principle regarding the management of renewable resources states that the sustainable yield depends on the size of the parent stock. Obviously, some minimum level of spawning stock is necessary, and maximum recruitment is limited by total fecundity, however, this relationship does not appear to be strong for Pacific whiting. There are several hypothesis regarding the source of variation in whiting recruitment, the most enduring is the effect of environmental conditions (e.g., ocean upwelling and surface temperatures). To examine the effect of alternative recruitment specifications on recommended yields and social benefits, a 3-year bioeconomic model is employed. This management-level, optimal control model integrates population dynamics, intrinsic product quality (via proximate analysis) and industry economics to develop optimal intra- and interseason harvest patterns (i.e., short-term property rights allocations). This age-structured (14 cohort) model tracks the stock over time (across months and into successive years) and between geographic regions (U.S. and Canada). In addition, the optimal temporal allocations depend on the harvest sector (onshore or at-sea) and product form (surimi, fish meal, headed and gutted, or fillet) produced.

Results of the sensitivity analysis reveals that using a constant level of recruitment can mask the importance of a large year-class. When a constant level of recruitment is changed, the change in social welfare (i.e., net present value based on a 5% real discount rate) will be proportionately equal to the change in average annual yield (MSY). If recruitment is variable, both the existence and magnitude of a large year-class can significantly impact welfare and total yield. More importantly, these figures depend on when the large cohort entered the model; for example, welfare and yields each increase by approximately 50% if a large cohort occurs in the second year, as opposed to the third, in this 3-year model. In terms of the existing management structure, these results suggest significant potential benefits from incorporating recruitment estimates. These estimates could be obtained from either (1) prediction (which is possible given the 2-year lag between spawning and recruitment) or (2) survey methods. These results were also supported using a 15-year planning horizon. In addition, discounting only affected the net present value and not the MSY (when measured in thousands of metric tons). These results are, therefore, robust to changes in the both the time horizon and use of discounting.

Source Paper:

Larkin, Sherry and Gilbert Sylvia. 1995. "Intraseason Product Quality and Fisheries Management: A Bioeconomic Analysis of the Pacific Whiting Fishery." Oregon State University, Department of Agriculture and Resource Economics, Corvallis.

Evaluating the bias and variance from fish migration in trawl estimates of abundance

Murdoch K McAllister,.
School of Fisheries, UW.

Estimates of fish abundance from trawl surveys are typically imprecise and may often by biased because of uncontrollable factors such as fish migration. In this paper I formulate a vector-based approach for modeling the bias in area swept estimates of biomass when fish migration occurs as the survey is conducted. I evaluate the magnitude and direction of bias from fish migration in systematic transect survey designs. The effects on variability in biomass estimates of interannual variation in migration and vessel speeds are evaluated using Monte Carlo simulation. For even low fish migration velocities (<0.5m/s) bias in estimated fish biomass can be very large (>500%) in trawl surveys. Furthermore, relatively small interannual variability in fish migration rates and vessel speeds (e.g. CV=0.1 for each) can result in very large interannual error variability in biomass estimates (e.g. CV>0.5). Of the alternatives considered, designs with the least bias and variability in biomass estimates had the fastest vessel speeds along transects, shorter transects, transects aligned roughly parallel to the direction of fish migration, and the survey vessel proceeding slightly against the direction of migration as it proceeds between transects.

Social networks and tropical fisheries management planning

P.A. McConney,
Resource Management and Environmental Studies, UBC.

This presentation posed for consideration the extent to which social factors should and could be incorporated into fishery management and planning. It explored the need for an empirically grounded bio-socio-economic fishery management framework.

State-structured regulatory and market-based management measures are based largely on bioeconomic models that typically assume social atomism. That is, individual decisions and actions are assumed to be taken independently—free from the influence of social relations and organizations. However, social scientists have argued that social atomism is an analytical construct not supported by empirical evidence. Some argue that the concepts of social embeddedness and social networks (Figure 1) are more empirically valid and theoretically relevant than the more simple notion of social atomism. From this perspective, the decisions and actions of people are influenced by access to social capital and the exercise of social power (represented by the lines connecting the social actors in Figure 1). These concepts do not fit easily, if at all, into existing quantitative fishery models.

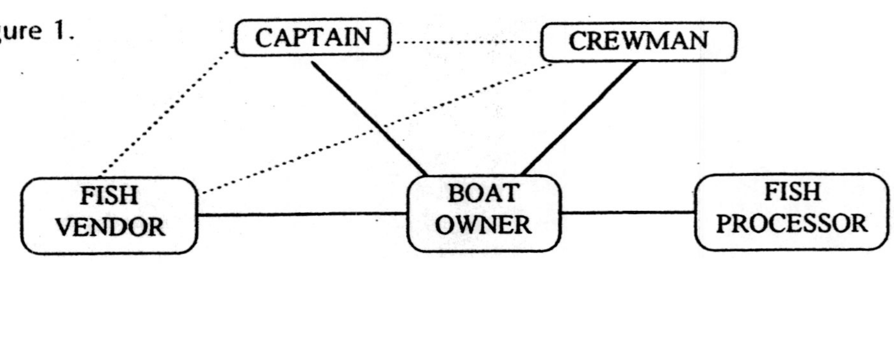
The presentation outlined the ways in which social relations and organizations may complicate the introduction of planning and management to the Barbados tropical, open access, small-scale commercial fishery for migratory pelagics. This fishery was the subject of an applied interdisciplinary research case study focused on social action.

The study revealed little empirical evidence of social atomism, although social networks with an individualistic orientation were found, especially among fishers. Formal social organizations were weakly developed partly because of this individualism, but social networks were used for cooperative purposes, particularly among small-scale buyers.

In the harvest sector, social networks influenced patterns of information exchange between fishers using different boat types and from different locations. Consequently, fishing behaviour, catches and catch rates were systematically affected. In addition to economic factors, social relations between the harvest and postharvest sectors influenced selection of target species, amounts landed and ex-vessel sales transactions. These are only a few of the complex and pervasive effects of social networks.

Knowing the characteristics of social relationships among stakeholders in the fishing industry, and between them and state officials, was invaluable for determining the most appropriate means for introducing and operating a cooperative system of fishery management planning in the case of Barbados. While integration of biological, social and economic considerations is possible in qualitative terms and in specific cases, the absence of a more formal and general integrating framework remains a serious constraint on fisheries management planning.

Figure 1.



The temporal signature technique in a Bayesian Framework

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Temporal signatures in calcified structure growth can be used to accurately assign age to fish that have ceased to record growth. A temporal signature is a characteristic pattern of growth found on the calcified structures of all fish alive during the period of pattern formation. Skilled scale analysts have often informally identified and used temporal signatures to assign age to fish. By identifying a particular temporal signature on the calcified structure of an individual fish, the year-class of that fish can be accurately determined. The age of the fish is then the difference between the year of capture and the predicted year-class.

However, identification of the temporal signatures on the calcified structure is difficult because of the confounding effect of age on incremental width. When we quantified the temporal signature technique (Ogle et al. 1994), we removed the effect of age and constructed a series of age-corrected growth increments, called a master chronology, with a linear growth model (Weisberg 1993). The temporal signature technique can be automated by comparing the age-corrected growth increments of a fish to all possible year-classes in the master chronology. We used a minimum sum-of-squared differences to determine year-class membership of a fish (Ogle et al. 1994).

Analysts might find the temporal signature technique more useful in a Bayesian framework because (1) prior information about the sample (e.g., length or known year-class strengths) and interpretations about the scale margin (i.e., degree of resorption or number of ambiguous annuli) can be coherently incorporated into the analysis and (2) probabilities of year-class membership can be obtained. In a Bayesian analysis, methods for developing a likelihood function and expressing prior information and beliefs into a probability function are needed. In this presentation, we developed a likelihood function under the assumptions that the year-coefficients in the master chronology are normally distributed and a fish's age-corrected increments are independent. Development of the likelihood function can be easily generalized to other distributions of the year-coefficients and to simple relationships between the age-corrected increments. We chose parameters for the Beta probability function to model our prior beliefs. We concluded by using real fish to depict several possible results of this new technique.

Finally, because this technique can be used to assign age to fish, we feel that it is imperative that historical collections of scales be preserved. Historical collections can be used to develop master chronologies for which (1) very old individuals in contemporary samples can be aged and (2) age information under past environmental or management conditions can be more accurately inferred.

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An analysis of stocking and research programs in two British Columbia lakes using a quantitative decision support model.

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Freshwater fisheries are managed by the Fisheries Branch of the B.C. Ministry of the Environment. The objectives of the Fisheries Branch are to provide a wide variety of angling opportunities and to maintain CPUE, fish body size, and other components of anger success. To achieve these objectives, the Fisheries Branch sets regulations and operates an intensive stocking program using hatchery-reared rainbow trout to support recreational fisheries in many lakes around the province.

Stocking rates are linked to angler success through a series of density-dependent and size-dependent processes, including growth and vulnerability. The number of rainbow trout to stock annually in individual lakes is therefore an important policy consideration for fisheries managers in British Columbia. Excessively high or low stocking rates can result in unacceptably low catch rates for recreational anglers. Managers seeking to maximize social benefits derived from recreational fisheries thus need a way to choose among alternative stocking programs.

Stocking rates are currently set using a stocking formula that relates optimal stocking densities to lake productivity and lake size. Recently, a computer simulation model of rainbow trout population dynamics and recreational fishery processes has been developed that allows the effects of different management strategies to be simulated. The objective of my research is to use this simulation model to develop a quantitative decision-theoretic approach to setting rainbow trout stocking rates in British Columbia.
Two lakes in the interior of B.C. are used to illustrate the application of these methods.

This approach simulates the effects of different stocking rates on catch statistics given uncertainties in density-dependent growth and in size-dependent vulnerability relationships. The simulation results are then incorporated into a decision-theory framework to provide a relative ranking of different stocking rates. Rankings are assigned based on the relative ability of alternative stocking rates to optimize selected performance criteria such as CPUE and fish length. Preliminary runs of the model suggest that increases in CPUE cannot be achieved through higher stocking rates without decreasing the body size of caught fish. Resolution of this trade-off will depend on the values and objectives of fishery managers.

The decision-theory framework can also be used to quantify the value of additional research into biological and vulnerability relationships. Reducing uncertainties in these processes can lead to better-informed management decisions. Improvements in angling success that result from managing with better information thus represent the benefits of collecting additional information. These benefits will be used to evaluate alternative stocking and research programs.

Exploring liability in the context of pollution and the fishery

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Liabilities represent claims against persons, corporations and things. Liability affixes responsibility and establishes 'probable' prices for economic externalities. Institutional arrangements will determine the amount of externality, technical conditions will affect its existence. The assignment of liability expands the rights of others, and renders externalities pecuniary.

Torts are private wrongs, resulting from the injurious trespass of the property or rights of others. Tort is an ex post legal solution to an a priori economic problem; however, the threat of tort is sufficient to begin pricing or internalizing externalities. Were property rights well specified, liability would be equally well specified and all externalities internalized at their established prices. Wherever goods and services remain held in common, property rights, and hence liability, remain ambiguous; the unpriced externalities will bring users into conflict.

The legal history of pesticide pollution cases, clearly establishes liability for the damages to personal and private property by pollutants as the responsibility of the polluter. The tort system operates well, when private interests are damaged by nuisance. However, where pollution results in public nuisance, as in the pollution of bodies of water, so long as no private rights are adversely affected, the responsibility to prosecute the polluter remains with the Crown. The ambiguous status of rights in the fishery, implies a duty on the part of the Crown enforce any liability for pollution that deteriorates the productive capacity of the fishery.

The objective of fishery management is to manage access, not just to fish, but to the ecosystem itself. Pollution of the fishery habitat is a form of access which remains unmanaged. Conservation policies which reserve production can be used to build biomass. Such policies emphasis the regulated taking of biomass, and generally involve the gradual enclosure of the fishery. Conservation policies which are restorative, emphasis investment in the productive capacity of the ecosystem □ they expand the intrinsic growth rate of stock, and the carrying capacity of the system. Expanding fishers rights so that they represent a private interest in the biomass and the environment, will provide incentives for voluntary investments in restoration, only so long as they are protected by liability.

A method for determining when to declare a surplus in the Nass River sockeye salmon fishery.

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Inseason salmon management provides a clear example of decision making under uncertainty. Managers of salmon fisheries attempt to achieve an optimal number of fish onto the spawning grounds and thus maximise returns to the fishery. Managers must make daily decisions that affect final escapement, despite incomplete knowledge of the number of fish still to return and the response of harvesters to both salmon abundance and management decisions. A further uncertainty is the stock-recruitment relationship and hence the impact on future abundance of either not reaching or exceeding the target escapement.

I developed a decision mechanism for declaring a surplus in the Nass River sockeye salmon fishery that explicitly accounts for uncertainty in stock-recruitment parameters and for interannual variability in run size, run timing and catches. A surplus occurs when fish in excess of the escapement target escape the commercial fishery. The declaration of a surplus in the Nass permits the opening of an in-river fishery using a fishwheel. The method employs Monte Carlo simulation within a Bayesian decision theory framework. I used Bayesian statistics to place probabilities on parameter combinations of the Shepherd stock-recruitment model. Escapement and commercial catch were simulated using an empirically based relationship between run size and the ability of managers to achieve escapement goals, thus avoiding complex in-season modelling of the commercial fishery. Run timing curves were selected at random from historical data. The catchability co-efficient for the fishwheel varied with daily abundance of fish passing the wheel site.

I structured the management decision rule so that a surplus is declared once a set percentage of the escapement target has been measured at the fishwheel. I assessed the performance of possible rules against four management objectives: maintain stock health, maximise catches (both commercial and "surplus"), minimise the variability in catches and improve ability to achieve management goals. Expected values of appropriate indicators were determined for rules ranging from 40 to 100% of the target escapement. Results indicate that the optimal decision depends on the relative importance of the four objectives. The Bayesian decision framework provides an appropriate avenue to communicate the implications of the management decision for each of the four objectives.

My next step is to compare the performance of the decision rules developed using this approach to decisions made using three alternative approaches to uncertainty: a deterministic model, a model that accounts for interannual variability in components but not uncertainty about the stock-recruitment relationship and a model that uses conservative estimates of all parameters. This analysis should show the potential benefits of including uncertainties in a rigorous and quantitative manner.

Application strategies for biophysical models of salmon migration and production in the Northeast Pacific

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Pacific salmon (*Oncorhynchus spp.*) have complex life cycles involving both freshwater and marine phases. The marine phase is characterised by extensive feeding in the North Pacific Ocean followed by precise homing to the natal stream. The mechanisms used by the salmon to realise these migrations are not completely understood, therefore the migration route and return times of the salmon stocks are difficult to predict. Furthermore, the production of salmon (the product of salmon abundance and individual weight) is associated with biophysical oceanic conditions such as sea surface temperature and zooplankton abundance. Managers are very interested in estimates of both production and return migration route/timing.

Computer modelling techniques have the ability to easily and inexpensively explore a range of hypotheses regarding Pacific salmon migration and production. Our interdisciplinary project aims to draw together existing knowledge about salmon biology, zooplankton production and physical oceanography into a set of models that have important interpretations in salmon ecology with potential application to long and short term Pacific salmon management.

However the conclusion that published models "are applicable to management" is often a non sequitur. Management is a complex process involving historical, subjective and emotive factors. New ideas (especially those based upon computer or mathematical models) are often treated with appropriate skepticism, and many studies end up being best classified as "shelfware". We are exploring a range of strategies to facilitate model application. These include:

Scientific visualisation and gaming: The iterative loop of hypothesis formulation, hypothesis testing and then hypothesis reformulation lies at the very core of scientific investigation. However, within modelling studies, often the rate determining step is the speed at which useful information can be obtained from models (hypotheses). By constructing models which immediately display output information on computer screens, scientists have the opportunity to rapidly adjust their thinking about specific sets of ideas. In this sense the scientist "games" with the model, playing with input parameters, and getting a feel for the dynamics of the system. The same model/visualisation system might then be used to allow decision makers to gain an understanding of the system dynamics. Although the results from the model might never be used in a quantitative fashion, additional qualitative appreciation of a system is a desirable result for a modelling study and an example of model application.

Decision theoretic interpretations: Often decision processes are well established, and decisionmakers are shy of making large changes to their procedures. However results from modelling studies have the potential to improve the effectiveness of decision makers. What is required is a systematic method with which information from models can be "bled" into decision procedures so that the makers maintain a sense of control of the procedure. Bayesian methods provide one such mechanism. The application of uninformative prior probability distributions to estimates of unknown parameters should not alter the analysis than if it were performed using maximum likelihood methods. If results from (say simulation) models were be interpreted as informative prior probability distributions of specified parameters, these have the potential to change (often by reducing variance) estimates of unknown parameters using the same data. The degree of credibility that a decision maker attaches to a model can be reflected in how informative they choose to make the prior. Technical difficulties exist towards implementing such schemes, however such methods may provide another effective mechanism for applying the results of modelling studies.

Investigations into the Dynamics of the Pacific Razor Clam along the Washington Coast.

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Historical stock assessment data was combined with survival data collected over a three year period to assess the population dynamics of the Pacific Razor Clam. The analysis was completed in two steps: a) survival analysis, and b) recruitment analysis. The investigation began after 1983 when the Washington Department of Fisheries thought that the disease NIX might be reducing survival, and that future management should include this factor in their decision-making process.

Survival analysis of the adult population was undertaken using SURPH (Survival Under Proportional Hazards), a statistical package for analyzing survival under a proportional hazards assumption when the data are from either release-recapture or telemetry studies. The survival analysis indicated low adult survival (Probability of Yearly Survival = 0.10), especially during the summer months. The survival of adults decreased with increasing length. Survival analysis of the juveniles was undertaken using a simple regression relationship between juvenile and adult densities with data from the stock assessment. This analysis indicated that the survival of the juveniles was higher (Probability of Yearly Survival = 0.70) than that of adults. No temporal aspect of survival is possible in the juvenile stage because of the structure of the data. The decrease in adult survival during the summer months cannot be attributed to the influence of NIX.

Stock and recruitment were modelled using variations of the Ricker model, the Schaefer equation and a Stage-Structured Ricker Model. The temperature of the surrounding seawater was included as a predictor variable, with the thought that changes in seawater temperature might affect the stock-recruitment relationship. Similarly, the impact of the disease NIX was also investigated in the stock-recruitment relationship. Of the models that were investigated, many of them indicated that the inclusion of temperature would improve the statistical properties of the model. Qualitatively, for all of the models that included temperature except the Stage-Structured Ricker Model, the inclusion of temperature did little. For the Stage-Structured Ricker Model, the inclusion of temperature helped to explain the large recruitments in the early 1970's. All models indicated that a strong density-dependent relationship existed between the current density and future densities. The inclusion of NIX did not improve the fit of any of the models.

The decrease in 1983 that was observed in the population time series is adequately explained by the stock density and temperature variables. This implies that the decrease in the population in 1983 was caused by poor environmental conditions and high adult stock densities on the beach.

Marine mammal-fishery interactions in the Gulf of Alaska.

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In the Gulf of Alaska ecosystem, Steller sea lion (*Eumetopias jubatus*) populations have declined dramatically in the past 2-3 decades. Due to the large-scale nature of the decline, hypotheses to explain the reduced rates of juvenile and/or adult female survival have focused on factors that potentially have widespread effects, such as disease and changes in prey resources. This study examines how Steller sea lion prey resources have changed over time and how that change may have (or is) affecting the sea lions.

In the GOA, walleye pollock (*Theragra chalcogramma*) have been the most important prey species in both number and volume since the 1970's. Our study explores how the declines may not be related to changes in abundance of pollock alone but may also be affected by changes in the availability of the prey resource. Two modeling approaches were taken to examine the timing and possible mechanisms responsible for changes in availability of pollock to juvenile sea lions that would result in the observed decline in Steller sea lions.

The first approach consisted of a simple life table model constructed to explore the timing of changes in juvenile mortality necessary to reproduce the observed decline in the sea lion population, and to project future population trends. We modeled Steller sea lion population numbers over time starting with the initial age composition in 1975 (which assumes a stable age distribution, York 1994). Successive generations of sea lions were produced based on the fecundity and mortality values (calculated from survival) taken from York (1994) with slight alterations. Sea lion numbers were fit to observed values by adjusting natural mortality of juvenile sea lions (ages 1-3) only. The adjustment was determined by minimizing the square of the difference between the observed and the expected total number of sea lions. The fecundity schedule was assumed to be constant throughout all years.

The second modeling approach explored the dependence of Steller sea lion population fluctuations on pollock numbers. The model converted the number of pollock observed into the number available to juvenile sea lions. The theoretical number of juveniles supported by the biomass of pollock was then calculated using average annual kilocalorie requirements of juvenile sea lions (Castellini 1993). The ratio of the theoretical number supported over the observed number of sea lions was used to adjust survival of the simulated juvenile sea lion population to the next generation. If this ratio was greater than one, the simulated juvenile sea lions advanced to the next age class experiencing only baseline natural mortality. That is, we assumed that if the number of juveniles theoretically supported by the available pollock was greater than the observed numbers then there were enough pollock to support juvenile sea lions. If the ratio was less than one, the juvenile survival rate was reduced by multiplying by the ratio. All adult age-classes advanced to the next year, affected only by baseline natural mortality.

The models suggest possible hypotheses about the timing and magnitude of events that would have caused changes in pollock abundance and /or distribution. Our results suggest that the observed Steller sea lion population decline could be explained by a) increased mortality of juvenile sea lions alone, due to changes in the availability of pollock to juveniles linked to shifts in the environmental conditions occurring in the late 1970's or b) the combined increased mortalities of juvenile and adult female sea lions since the mid-1980's.

Effects of nutrient additions to Kootenay Lake, BC on zooplankton and kokanee salmon (<u>Oncorhynchus nerka</u>) biomass and productivity.

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Nutrient additions to Kootenay Lake began in April 1992 in an effort to halt the decline in abundance of kokanee salmon. Kokanee are an important sport fish, and the primary food of adult Gerrard rainbow trout (*Oncorhynchus mykiss*), which often attain trophy size. Natural phosphorus loading to the lake is one-third of historical levels, following the construction of the Libby and Duncan dams, and the closure of a fertilizer plant upstream at Kimberley. Fertilizer is being added at the north end of the lake to promote a gradient of phosphorus and nitrogen concentrations, and of algal concentrations, along which the responses of zooplankton, mysid shrimp (*Mysis relicta*) and kokanee are studied. The main uncertainties to be tested are whether zooplankton will respond positively to the anticipated increases in grazeable algal abundance, and whether kokanee will respond positively to increased zooplankton abundances. Since Mysis competes with kokanee for zooplankton, potential changes in the competition between kokanee and mysids for zooplankton at different trophy levels may also be important. The monitoring program includes collection of data on: macrozooplankton species composition, density, biomass and productivity; kokanee abundance, growth, diet and fecundity; and rainbow trout abundance, size, diet and fecundity. Data from 1992 and 1993 suggest that the proportion of cladoceran zooplankton has increased in the fertilized part of the lake (Fig. 1). Kokanee escapement (Fig. 2), and spawner size and fecundity also increased. Fertilization and monitoring will continue through 1995 to study the effect of nutrient enhancement on at least one kokanee cohort through its entire lifespan.

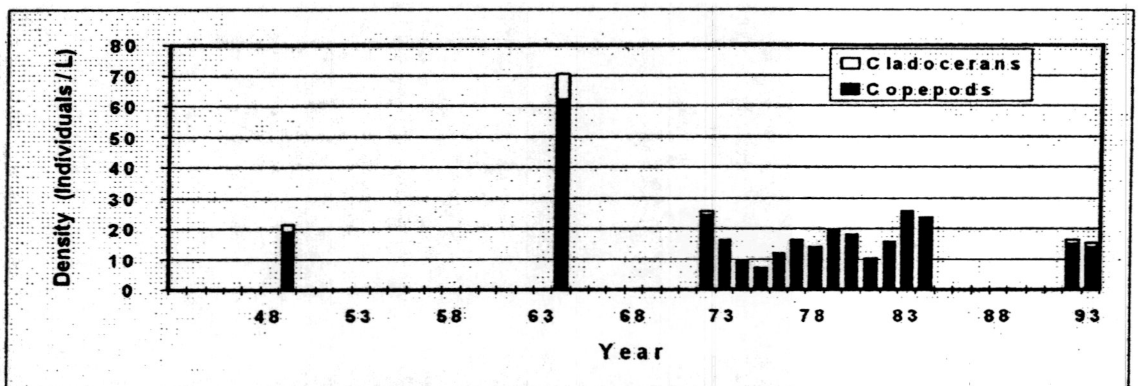

Fig. 1 Zooplankton abund

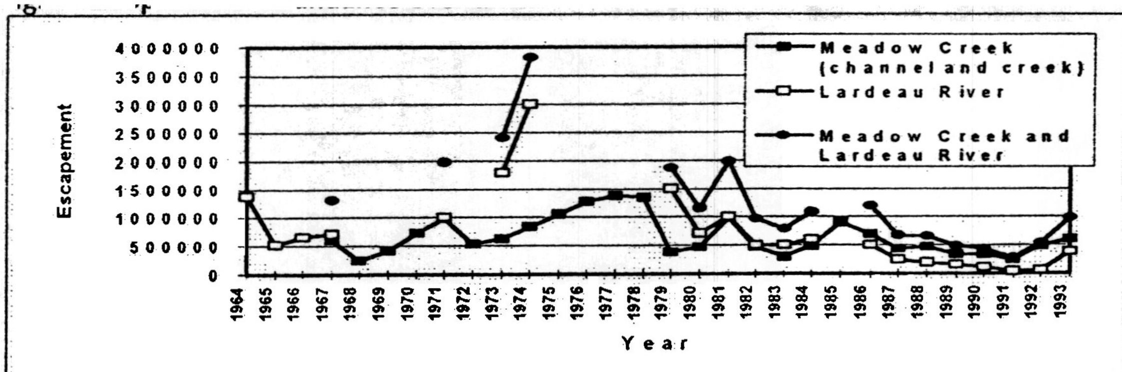

Fig. 2. Kokanee spawner escapement over time.

Standardization of fishing effort and abundance trends of the major groundfish resources in the southern part of the East China Sea

Ted Tien-hsiang Tsai,
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Fishing effort data from commercial catch statistics for Taiwanese trawlers are standardized in two steps. The data are from the East China Sea from 1974-1987. In the first step, the fishing effort data are transformed from number of hauls into towing hours by an interpolation method. In the second step, the towing hour data are standardized with respect to the relative fishing power of the individual vessels. The relative fishing power of the vessels is estimated by a regression analysis that includes the two vessel classes: 100-150 and 151-250, gross registered tonnage and the two gear types: otter and pair trawls.

Using the standardized effort, catch per standard unit of effort (CPUE) is used as an index of abundance for the five major species, or associated species assemblages. The species are: sea eel (*Muraexesox cinereus*), hair tail (*Trichiurus haumela*), white croaker (*Argyrosomas macrocephalus*) and the species assemblages are: squid (*Loligo spp.*) and cuttlefish (*Sepia spp.*) The results illustrate that CPUE derived from standardized effort is a more realistic representation of variation in abundance than CPUE derived from nominal effort (Figure 1.) The individual abundances of sea eel, hair tail, white croaker, and the pooled assemblage of all of the five species show similar trends of annual decline, except the cuttlefish which do not appear to be in decline.

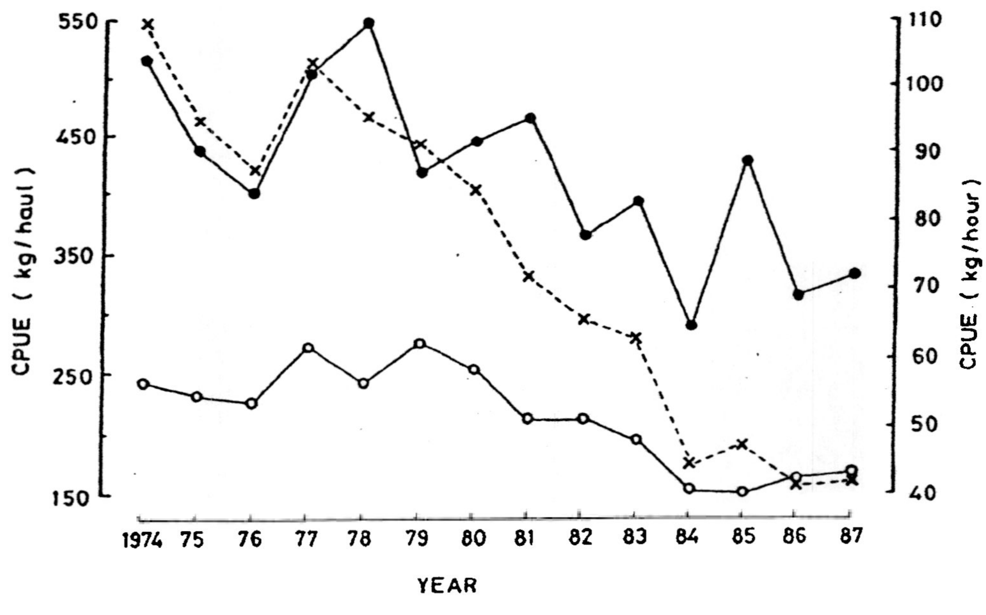

Fig. 1. Comparision among standardized CPUE (x in kg/hour) and unmodified ones (o for otter and • for pair in kg/haul) for pooled species caught by Taiwanese trawlers, which operated in the southern East China Sea.

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