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GRADUATE STUDENT SYMPOSIUM ON FISH POPULATION DYNAMICS AND MANAGEMENT

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Approved

Submitted 20 December 1996

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FOREWORD

This report summarizes the second in a series of symposia. The first conference was the result of a collaboration between students from the University of British Columbia (UBC) and University of Washington (UW). At the time of the initial conference, the only comparable student collaboration in the Pacific Northwest was the Pacific Ecology Conference; there were no student conferences for fisheries research.

Both the UBC Fisheries Centre and UW School of Fisheries (SoF) have a long history of graduate student initiative in planning conferences and seminars. At the SoF, the students run an annual Graduate Student Symposium, in which talks and posters are presented by SoF students only. There is also a student-run seminar series in fisheries quantitative methods.

As noted in the first conference proceedings, "Graduate students are the lifeblood of any research institution." The SoF, through its Fisheries Research Institute, is committed to supporting graduate student research and publications, and is committed to disseminating information on current research, such as that contained in this report.

This report contains abstracts or summaries presented by each speaker at the second annual conference. In addition, a summary of the discussion session is provided. The purpose of this report is to disseminate information on contemporary research in a timely manner. Thus, the publication process was limited to internal review by the organizers, sponsors, and the SoF Publications Office, and the result is akin to the "Notes" format various journals provide to speed up the process when timely dissemination is warranted. As such, responsibility for the content of this report lies solely with the organizers and the individual speakers.

On behalf of the School of Fisheries, and the Fisheries Research Institute, I am pleased to present this symposium proceedings. I hope and expect that this fruitful and collaborative forum continues.

Ellen K. Pikitch

PREFACE

When Alida Bundy (University of British Columbia Fisheries Centre) and I started this conference series 2 years ago, we were mainly motivated by a desire to attend a conference like this, to discuss our research, and interact with our peers at the other Pacific Coast universities. Both years, I have learned a great deal from the talks and discussions, and I have benefited from insightful comments on my own work. I am very happy to have been a part of this, and I am delighted that others have volunteered to continue the conference series.

I thank everyone who made the event a success this year, especially Claribel Coronado, Alida Bundy, and everyone who helped with the food and lodging. Thanks also to the University of Washington School of Fisheries for funding the conference with a generous donation. Thanks especially to Ellen Pikitch, Director of the Fisheries Research Institute, for supporting the conference and helping the organizers to secure funding. Finally, on behalf of all those who have partticipated in these symposia, I also thank next year's organizing committee for volunteering.

Elizabeth A. Babcock
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KEY WORDS

Authors are listed in parentheses immediately following the key words that pertain to their research: ocean carrying capacity (Aydin); dynamic programming, fisher behavior (Babcock); spatial structure, value of information (Buckworth); multispecies models, ecosystem models (Bundy); survial estimation (Coronado); growth estimation, mortality estimation (Ernst); fisheries management, Mexican shrimp fisheries (Fernandez); acoustic methods, Bayesian methods (Hammond); genetic modeling (Harada); tagging (Johnson); Bayesian methods, stock–recruit models (Liermann); stock–recruit relationships, queueing theory (Maunder); survival models, bycatch (Oddsson); individual transferable quotas, fisheries economics (Porter); bioeconomics, predator–prey interactionss (Sumaila); observer programs (Turk).

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OVERVIEW

The second annual Graduate Student Symposium in Fisheries Population Dynamics and Management met on April 20–21, 1996, in the Fisheries Center of the University of Washington (UW) School of Fisheries. More than 45 graduate students attended from the University of British Columbia (UBC) Fisheries Centre, the UBC department of the Resource Economics, Oregon State University (OSU), and the UW School of Fisheries, Center for Quantitative Science, School of Marine Affairs, and Department of Applied Math. Also, UW Fisheries faculty Ray Hilborn and Ellen Pikitch attended, with Ellen delivering the opening address. She expressed the School's support of the conference and encouraged the students to continue organizing these annual meetings.

The morning session of April 20th was devoted to papers presented on population dynamics, including stock–recruit relationships, survival models and stock assessments. The afternoon session entailed more presentations on population dynamics and a short session on multispecies models. The day ended with a discussion session that covered the role of fisheries science and the nature of cooperation, debate, and objectivity in science (see Discussion Session Summary). The April 21st session was focused on management. In total, 16 papers were presented.

The conference was an excellent opportunity for students from UBC, UW and OSU to meet and discuss our research interests informally and for students to make contacts with colleagues at other schools. We agreed that the conference series should continue and named an organizing committee for next year.

FURTHER INFORMATION

In 1995, the first graduate symposium in fisheries population dynamics and management met at the UBC Fisheries Centre. At that meeting, a committee was selected to organize the next conference. This year, we agreed to have the next meeting in 1 year at the University of British Columbia Fisheries Centre. The organizing committee members for next year are as follows:

Marcello Vasconcellos, UBC
Ellen Waible, OSU
Geir Oddsson, UW

If you have questions or suggestions regarding next year's meeting contact the organizing committee. Copies of the report from the 1995 meeting may be obtained from Alida Bundy (UBC) or Elizabeth Babcock (UW). Copies of this year's report may be obtained through the UW School of Fisheries Publications Office (tel: 206 543 4678; fax: 206 685 7471; email: mduke@ fish.washington.edu). In addition, a list of author email addresses is provided under Participants (in the preliminary pages) to enable readers to seek further information on the topics discussed herein.

ABSTRACTS

High Seas Carrying Capacity: A Mechanistic Approach

Kerim Aydin, UW School of Fisheries

A recent decrease of individual size-at-maturity, coupled with overall population size increases, has raised the issue of density-dependent growth in North Pacific salmonid (*Oncorhynchus* spp.) stocks. Since over 90% of salmonid somatic growth occurs while salmon feed in the open ocean, the apparent trade-off between final size and numbers has raised the question of a possible ecosystem-wide carrying capacity for salmonid growth on the high seas.

A brief review of the concept of carrying capacity is presented, along with perspectives exploring ecosystem organization using network and individual-based models. In addition, metrics that may assess the nearness of stocks to an ecosystem carrying capacity are outlined. Finally, alternate hypotheses to high-seas limitation for the recent decrease in salmon size are presented.

Given the current scale of various countries' hatchery salmon releases, a high-seas carrying capacity would have profound effects on management decisions throughout the Pacific region.

A Dynamic Programming Model of Fisher Target Species Assemblage Choice in the Oregon Bottom Trawl Fishery

Elizabeth A. Babcock, UW School of Fisheries

Vessels in the Oregon Coast groundfish fishery target on distinct species assemblages such as the deep-water Dover sole (*Microstomus pacificus)* complex (DWD) and the bottom rockfish (*Sebastes* spp.) complex (BRF). Individual vessels can pursue more than one strategy, or target species complex, during a trip. The fishery is managed by trip limits, which are restrictions on landings of individual species or species complexes by any individual vessel in a trip, week, or month.

Dynamic programming was used to model the strategy choices of an individual trawler through the course of one fishing trip (i.e., a series of hourly decisions). The vessel can fish either DWD or BRF. Data from a mesh size study (MSS) by Pikitch et al. (1988–1990) were used to calibrate the model. The model was then used to predict the actual landings of vessels in the Oregon fishery from 1988 to 1990. The model was run for vessels between 400 and 900 hp that fished both the BRF and DWD strategies during the MSS, between 43.37° and 45.5°N latitude. These vessels were chosen because they had fairly similar catch compositions, expenses, and other inputs. The MSS data was used to calculate (1) the median length of hauls in each strategy, (2) the median time between hauls with and without switching strategies, (3) the probability by strategy of a random event such as gear damage or weather ending the trip, (4) the cost per hour of fishing each strategy, and (5) an empirical distribution of possible catches in each strategy.

The model assumes that fishers make decisions that will maximize the net profit from a trip. The expected profit from a decision and, hence, the optimal decision depend on how many fish from each trip-limited species are already onboard. Therefore, we must calculate the optimal choices for all

possible previous catches of the trip-limited species. The trip-limited species are widow rockfish (*Sebastes entomelas*), Pacific Ocean perch (*S. alutus*), yellowtail rockfish (*S. flavidus*), the rockfish complex (all *Sebastes* except widow and POP), sablefish (*Anoplopoma fimbria*) and deep-water fishes (sablefish, thornyheads [*Sebastolobus* spp.], Dover sole, and arrowtooth flounder (*Asterethes stomias*). The model loops backward in time through all possible previous catches of each species, calculating the optimal decision at each time. Trips are then simulated forward in time, beginning with no fish in the hold, and assuming that the vessel always makes the (previously calculated) optimal choice for the catch onboard.

The simulation results showed that without any trip limits, the vessel would fish exclusively BRF because the expected value of a BRF haul is higher than that for a DWD haul. With trip limits, the vessel would begin in the DWD strategy and then switch to BRF. The switching time depended on the exact trip limits in place. Higher limits on the DWD complex caused the vessel to stay in DWD longer, and higher limits on BRF caused the vessel to switch sooner. Lower trip limits caused an increase in discarding. These results are qualitatively accurate. The dynamic programming approach appears to be a realistic way to model fisher strategy choice.

Spatial Structure, Stock Assessment, and Spanish Mackerel in Northern Australia

Rik Buckworth, UBC Fisheries Centre

Despite the increasing sophistication of assessment and management tools, fisheries throughout the world are in crisis. Particularly for fisheries that cannot support an extensive research base, more robust approaches to fisheries management supported by cost-effective research are needed. Where there is spatial structuring in a fished stock, the classical approaches to stock assessment may be uninformative or misleading. Relative values of different types of information collected about a fishery and resilience of management strategies depend largely on the spatial structuring of the population.

I propose to compare the relative values of research information for four types of spatially structured fisheries with the consequences of erroneous assumptions about spatial structuring. A case study is the troll fishery for Spanish mackerel (*Comberomorus commerson*) in waters off Australia's Northern Territory. A research program for this fishery concentrated on collection of data usually recommended in a classical approach. Stock assessment has been largely uninformative, and the necessary management response has been to maintain a conservative management regime that constrains effort.

Dynamic Ecosystem Modeling, Prediction and Experimental Management in a Multispecies, Multi-gear, Overexploited Tropical Fishery

Alida Bundy, UBC Fisheries Centre

The multispecies tropical fishery of San Miguel Bay, the Philippines, was captured in earlier work using ECOPATH, a static mass-balance model. The ECOPATH model described an ecosystem heavily dependent on detrital and benthic flows where most fished species were aggregated around trophic

level 3. Although the model indicated likely competition and predation between and within trophic levels, it was not possible to predict the impact of these interactions through time or in response to management strategies.

The recent development of ECOSIM (C. Walters, Univ. British Columbia Fisheries Centre, unpubl. ms.) has enabled the theoretical exploration of the ecosystem and fishery dynamics of San Miguel Bay. ECOSIM used the parameters from the mass-balance ECOPATH model. The ECOPATH equilibrium equations were reset to the non-equilibrium state of changing biomass with time (dB/dT), and different assumptions were made about consumption estimates between components of the ecosystem. ECOSIM was thus able to emulate the two main theories about flows in ecosystems (i.e., top–down or bottom–up control). The two main operational modes of the model allowed the user to (1) run a simulation through time with changing fishing mortality, and (2) run an equilibrium simulation where equilibrium biomass is estimated over a range of fishing mortalities.

Initial results indicated that, whatever assumptions are made about the consumption flows between pools, the fishery was heavily overexploited. Increasing fishing mortality would lead to a massive simplification of the ecosystem. A reduction in fishing mortality would allow recovery and diversification of the system. Single-pool yield curves indicated that all species, other than the three extant crustacean groups, are overfished.

Examining the impacts of different gears led to some surprising results. The much maligned large-scale trawling sector had little impact on the ecosystem, especially when compared with the impacts of the gillnet sector. Increasing effort in the latter sector led to substantial decreases in two medium predator groups, while allowing the recovery of top predators and intermediate groups in the system. The results indicated that, especially under stronger top-down assumptions, medium predator groups exert a strong repressive effect on other components of the ecosystem.

Experimental strategies to distinguish between different model assumptions could include a 50% reduction in gillnet effort; under top–down assumptions, this would lead to a 100% increase in medium predator biomass and an 80% reduction in large crustacean groups within about 5 years. Under bottom–up assumptions, a small increase in medium predator groups but no change in large crustacean biomass would result. ECOSIM, coupled with an experimental and adaptive management approach to fisheries management, could lead to a greatly improved knowledge of fisheries dynamics.

Spatial and Temporal Factors Affecting Survival of Hatchery-Reared Chinook and Coho Salmon in the Pacific Northwest

Claribel Coronado, UW School of Fisheries

It has been noted that abundance and survival rate of Pacific salmon (*Oncorhynchus* spp.) have been declining. Several hypotheses have been advanced to explain the observed declines. The major hypotheses relate declines to genetic deterioration, disease accumulation, variations in oceanic conditions, and density-dependent mortality.

To test some of these hypotheses, I estimated the survival rate of hatchery releases for all CWT groups of coho (*O. kisutch*) and chinook (*O. tshawytscha*) salmon. Survival rates were calculated for 8,596 and 11,051 tag groups for coho and chinook salmon, respectively. The performance of 258 coho hatcheries and 305 chinook hatcheries was compared.

The data series consisted of mark-recapture of coded-wire tagged fish from the northeastern Pacific Ocean. Tag recoveries were standardized to age-3 for all runs and species except for spring and summer chinook, which were standardized to age-4 using a virtual population analysis. Survival by tag code was calculated as the ratio between the standardized number of tags recovered and the total number of fish released with tags. The mean survival by hatchery and location was analyzed using charts, a generalized linear model, and cluster analysis.

The results indicated that salmonid populations continue to decline in most of the geographical range. The declines are particularly notorious from the late 1970s to the early 1980s and from the late 1980s to the most recent years available (e.g., mid-1990s).

The number of years a hatchery has been operating is of minor or no importance. This result also indicates that disease accumulation and genetic changes are not the causes of the observed survival declines. Some hatcheries continue to have good survival rates for long periods.

The hypothesis suggesting that the cause of declines is an increase of production from hatcheries located in areas believed to be less favorable to salmonid survival was also rejected. The overall results indicated that changes in ocean conditions could be at least partially responsible for the survival declines of coho and chinook in the Pacific Northwest. Density-dependent mortality could also play an important role, but it is confounded by ocean changes, and no attempt to test this hypothesis was made for this study.

An Overview of Two Chilean Crustacean Fisheries and the Estimate of Natural Mortality for the Squat Lobster Population

Billy Ernst, UW School of Fisheries

A quick overview of the historical landings of the two most important benthic crustacean resources of Chile (pandalid shrimp *Heterocarpus reedi* and squat lobster *Pleuroncodes monodon*) is presented. Some insights in the distribution, environmental conditions, and recruitment of both populations are also given.

On the basis of total mortality estimates from size distributions for a collection of years and different schedules of growth, estimates of natural mortality by sex (and their confidence limits) were computed by using an intensive resampling technique (parametric bootstrapping).

The Evolution of Shrimp Management in Mexico: A Case Study

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Shrimp are the most economically important fishery in Mexico, representing more than US$400 million in export revenues per year. While shrimp represent around 40–50% of the annual fishing export value, they represent only 5–7% of the total volume of national catches. The fishery also has remarkable social importance in several localities along the Mexican coastline, particularly in the northwest (the states of Sonora, Sinaloa), the southwest (Chiapas and Oaxaca), the northeast (Tamaulipas, in the northern Gulf of Mexico) and southeast (Campeche in the southern Gulf). The importance of the offshore industrial fleet is borne out by the export figures, but the artisanal fishery

in lagoons (whose effect is not reflected in export figures) provides the principal support for many local economies.

On the Pacific coast, there are around 1,200–1,300 industrial vessels and an unknown number of artisanal boats, assumed to be higher than 25,000. Catch oscillates around 27,000 tons/year and, after a period of decreasing catches, future trends are uncertain. In the Gulf of Mexico and on Caribbean coasts, there are fewer industrial vessels (~800–900) and about 15,000 artisanal boats, and the average catch is near 25,000 ton/year. A period of stabilization was followed by a slightly increasing trend in the northern Gulf. Here, too, the future trends are not apparent.

For 35 years on the Pacific coast and 3 years in the Gulf of Mexico, the present management scheme has followed the tradition of setting a closed season. More recently, other regulations have been adopted, like the establishment of areas closed to trawlers in waters shallower than 5 fm. Three years ago, a strip 15 nautical miles wide measured from MLLW was closed to industrial vessels in the southern Gulf of Mexico. Mesh size regulations and limits on the number of post-larvae and broodstock collected from the wild, destined for aquaculture activities, have been implemented. However, the closed season forms the backbone of the management of the shrimp fishery.

The management goals can be stated as follows: (1) Protect the reproduction of the parental stock that results in the recruitment of the main cohort, and (2) protect the growth of the main cohort until its individuals reach a marketable size. In the Gulf Of Mexico, the closed season has unintentionally become an allocation instrument: the date of the start and end of the season determine who among artisanal and industrial fishers will have access to the resource.

The main problems faced by the fishery are the ever increasing effort (lately more marked in the artisanal fishery), the decreasing catches (due to overexploitation and habitat loss), and the increasing pressure exerted by the industrial and artisanal sectors. On the technical side, a high uncertainty in estimations and projections, as well as on the nature of basic relationships (like stock–recruitment) is a constant. We also have to deal with the economic and social complexities involved in the fishery. Recently, fishers have been participating more in the management process, and this is expected to increase in the near future. We must account for large-scale trends in populations and habitat status. There is urgency to adopt alternative management strategies (quotas, effort-related regulations, etc.) and management approaches (including more flexibility). Technically, methods for dealing with high uncertainty must be adopted. Setting of biological reference points to explicitly set the management goals also is badly needed. These goals can be considered the landmarks that will guide the development efforts of the fishery in the near future.

Interpreting In Situ Target Strength Data

Tim Hammond, UW School of Fisheries

Knowledge of the target strength (TS) distribution of the fish being surveyed is necessary for accurate acoustic biomass estimates. Although dual-beam and split-beam transducers can measure TS in situ, these measurements are misleading because fish with higher TS are detected more readily, measurements are coming from several fish species, and measurements are made on the total echo from several unresolved targets. A Bayesian method of analysis was developed to extract information from TS data despite these problems. The first problem was addressed using a model of fish

detection that was calibrated with data from a survey of cod (Gadus morhua) on the Grand Banks. The second problem, species composition, was dealt with by incorporating information about the relative abundance of species groups. Prior information about the concentration profile of the species assemblage was used to take into account the third problem, multiple detection. Results suggested that the difficulties mentioned above are serious sources of bias that should not be ignored. The method also indicated how research effort can be directed to improve acoustic surveys.

How Much Can We Reduce Genetic Risk of Artificial Propagation? A Mathematical Analysis

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Mathematical models of gene frequency dynamics in a population under artificial enhancement by stocking is constructed to evaluate the effectiveness of tactics considered to reduce genetic risk of domesticating selection. The effectiveness is evaluated by comparing the conditions for the propagation of a domesticated trait with and without tactics. A tactic is considered effective if it reduces the propagation of the domesticated traits that increase fitness in the hatchery and reduce fitness in the natural environment.

Tactics considered are as follows: (1) Discriminate hatchery individuals in the population and prevent them from being introduced into broodstock in order to increase the fraction of natural-born individuals in the broodstock; and (2) introduce males from natural populations for broodstock if introduction of females from wild populations is difficult.

Parameters of the models include percentage of artificially produced individuals in the population (r, which will reflect the intensity of artificial stocking), discrimination accuracy of the hatchery fish (d, which will reflect the ratio of artificially released individuals with marks), ratio of the individuals born and grown in the hatchery in the broodstock (f and m for female and male, respectively), and the natural and the domesticating selection. Non-sex-specific selection that works on both sexes and sex-specific selection that works on females alone are separately considered. Discrete generation is assumed and two-allele diploid formulation is employed.

The models and the evaluation criterion are simple and they are analytically tractable. It is tentatively concluded that the complete discrimination of hatchery-raised animals is highly desirable if the stocking intensity is high (i.e., r >80%); if the percentage of artificially reared individuals is medium or low (i.e., r <50%), even incomplete discrimination (80–90% discrimination accuracy) works and is worth the try. It is also concluded that the introduction of males alone is not effective, and that the sex-specific domesticated trait is more difficult to verify than the non-sex-specific trait.

The Hanford Reach Tagging Project for Naturally Spawning Upriver Bright Fall Chinook

Marianne Johnson, UW School of Fisheries

Management concern is often focused on the conservation and allocation of naturally spawning salmon (Oncorhynchus spp.) stocks. Stock distribution information is used to shape appropriate

fishery regimes and consider stock-specific impacts. Logistically, though, it is often very difficult and expensive to collect naturally spawned salmon smolts for tagging. Collection efforts only become more difficult if the stock declines, while at the same time the information on stock distribution becomes more critical. It is usually assumed that naturally spawned salmon exhibit the same distribution as hatchery propagated salmon from the same area, provided they share stock origins and life history traits. The Hanford Reach tagging project has involved coded wire tagging naturally spawned chinook (*O. tshawytscha*) smolts since 1987, and offers a rare opportunity to test the assumption of common distributions for naturally spawned and associated hatchery-propagated smolts.

Quantifying Uncertainty About Depensation

Martin Liermann, UW Center for Quantitative Science

We quantify uncertainty about depensation using a simple stock–recruit model and over 100 spawner–recruit data sets. First, a biologically meaningful parameter, q, is derived to measure the degree of depensation. We then calculate the likelihood profile of q for each stock and combine the profiles by taxonomic group to create an informative prior of q for each taxa. The individual profiles are combined using a Bayesian approach called hierarchical modeling, which incorporates within- and between-stock variability in q.

Once these priors are constructed they can be used along with Bayes' theorem to calculate a posterior distribution of q for a new stock from that taxa. The resulting priors for the four taxonomic groups (salmoniforms, gadiforms, clupeiforms, pleuronectiforms) were relatively broad with tails extending well into the range of depensation. This suggests that depensation should not be ignored when dealing with a fishery about which little is known.

Investigation of Density Dependence in Salmon Spawner–Egg Relationships Using Queueing Theory

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A model based on queueing theory is presented to explain salmonid (*Oncorhynchus* spp.) spawner–egg relationships caused by redd superimposition. The model incorporates carrying capacity, spawner arrival times, egg protection, preference of redd sights, and accumulation of waiting spawners. Both analytical and simulation models are used to implement different levels of complexity. Results show that the relationship described by the Beverton and Holt stock–recruitment model produces more density dependence than just redd superimposition, and it should not be used to describe a salmonid spawner–egg relationship unless there is additional supporting information. The results show that the relationship described by the Ricker stock–recruitment model produces similar density dependence to the queueing model at both high and low spawner levels. The model presented here is a good initial building block for a full life history model for salmonids, and aspects of it could be used for other life history stages.

Physiological Stress Parameters as Predictors of Survival: A Predictive Survival Model of Pacific Halibut Trawl Bycatch

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One of the most important problems in the management of Pacific halibut (*Hippoglossus stenolepis*) in the north Pacific is the estimation of discard survival. To evaluate the effectiveness of quantitative stress parameters as explanatory variables, a stepwise generalized linear model (GLM) approach was employed. A cross-validation GLM survival estimation model was then constructed using the significant variables from the stepwise model. Besides blood stress indicator values, towing, handling, and recovery variables were used as explanatory variables. The survival rates obtained from this model were compared with observed survival rates of halibut of known fate after being discarded. Four models correctly predicted the fate of individual halibut more than 70% of the time. Towing time (t_{tow}) + sorting time (t_{blood}) and cortisol + t_{tow} + t_{blood} models predicted correctly 76% of the time, and potassium (K) and K + t_{tow} models predicted correctly 71% of the time. For management purposes, potassium as a single predictor in a survival prediction model might be the most applicable variable. Potassium also has the advantage of being easy to sample and analyze.

Structural and Market Consequences of Harvest Quotas in Canada's Pacific Halibut Fishery

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Changing a limited-entry common-pool fishery to a scheme of tradable individual quotas not only permits the capture of rents through allocative, technical, and scale efficiencies, but also permits additional surpluses to be captured through positive changes in the value of landed product and a redistribution of bargaining power in the ex vessel market. Individual catch quotas also have implications for the conservation, management, monitoring, and marketing of commercial bycatch species. Rent sharing by fishery participants is also affected by changes in crew composition and revenue shares as vessel owners and license holders adjust to longer seasons. The effective transition to a fishery managed through vessel quotas also requires the development of new institutions to coordinate effort and product flow among quota holders, monitoring agencies, processors, and wholesalers. Recovery of fisheries management costs is enhanced and made more efficient by a vessel quota scheme because the market information generated allows for effective institutional adjustment. However, multiple license holding by vessel owners in both quota and non-quota fisheries provides the potential for continued rent dissipation through cross-subsidization of available limited-entry, common-pool stocks and other open-access stocks.

The Bioeconomics of a Predator–Prey System in the Barents Sea

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This note reports the findings of a study (Sumaila 1996) that investigated the bioeconomically optimal way to exploit the cod–capelin (*Gadus morhua, Mallotus villosus*) predator–prey system in

the Barents Sea. Cod is a relatively expensive, long-lived demersal species while capelin is a relatively inexpensive, short-lived pelagic species.

The economic effects of the biological interrelationship between the two species under different management arrangements is examined (U.R. Sumaila, unpubl. ms.). First, Nash non-cooperative equilibrium solutions are determined when the two stocks are managed separately by their respective owners. Second, joint management equilibrium solutions are identified by assuming that exploitation and management of cod and capelin are carried out by a sole owner. The latter solution is best in the sense that the sole owner is expected to internalize the externalities that will originate from the natural interactions between the two species. Third, a cod-only scenario is implemented to investigate the economic merits of allowing cod to feed on capelin while only cod is harvested for human consumption.

Key questions addressed in the study include the following:

- What is the maximum discounted economic rent that can be derived from the resource under joint and separate management?
- How significant is the difference between these two solutions?
- What is the effect of exploitation on stock levels under these management regimes?
- Is it economically optimal to exploit both species at current market conditions?
- Under what market conditions would it be optimal to exploit only cod?

The results of the study indicate, among other things, the following:

- Maximum discounted economic rent of NOK67.19 billion (capelin contribution of 4%) is achieved when both species are harvested under joint management. Alternatively, an economic rent of NOK54.44 billion (capelin contribution of 11%) is obtained when the species are harvested under separate management. Under a cod only scenario, an economic result of NOK 65.58 billion is achieved.
- From the preceding numbers, we see that the economic loss stemming from the externalities that arise from the natural interactions between the two species is significant, reaching up to NOK12.75 billion, or about 23% of what is achievable under separate management. The higher benefits accruable under joint management are due to a sensible allocation of the prey stock between predation and harvesting.
- Joint management leads to a lower average annual catch of capelin (0.38 million metric tons [mt]) and a higher average annual catch of cod (1.24 million mt) compared with the separate management case (0.8 and 0.94 million mt, respectively). Also, the average annual standing biomass of 3- and 4-year-old capelin is higher under joint management (1.55 million mt) than under separate management (0.9 million mt) while the average annual standing biomass of cod is lower under joint management (2.23 million mt) than under separate management (2.62 million mt).

In summary, the study shows the following: (1) At prevailing market conditions, the Barents Sea capelin fishery should be restrained, allowing capelin to be "fished" indirectly by cod. Indeed, a reduction of over 50% of this fishery is called for under optimal (joint) management as compared with separate management. (2) There is an economic loss if cod and capelin are exploited assuming no biological interaction between them; allowing for the fact that modeling and computations are exercises in successive approximations, this loss is computed to be nearly 25% of what is achievable if this interaction is not neglected. Readers interested in a discussion of how the benefits of joint management should be distributed between the cod and capelin owners may refer to Munro (1979).

References

Munro, G. R. 1979. The optimal management of transboundary renewable resources. Canadian Journal of Economics 12(8):355-376.

The North Pacific Fishery Observer Program: The Politics of In-Season Management

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The North Pacific observer program has supplied fisheries managers with commercial harvest information since 1978 under the authority of the Magnuson Act. Fisheries observers compile a variety of commercial catch information, including catch composition and length frequencies of target species. They also collect trophic and age structure specimens, and monitor for marine mammal interactions and compliance with fisheries, US Coast Guard and MARPOL regulations.

From 1978–89, fisheries observers were placed only on foreign vessels operating inside the United States Exclusive Economic Zone (EEZ). Starting in 1990, observers also collected information on domestic vessels. The amount of observer coverage was specified by fishery, area, and length of vessel. During the transition from foreign to domestic observing, the fundamental management structure of the program changed. Many companies who contracted with National Marine Fisheries Service (NMFS) to provide observers became certified contractors. Competitive bidding for vessels between contractors drove the pay scale and other benefits for observers to very low levels. A large observer turnover rate, low morale, and a suspected increase in dry labbing (i.e., falsification of data) occurred.

In response to these factors and in an attempt to have more control over the management of the program, NMFS submitted a research plan (RP). The RP required vessel owners to pay an observer fee based on 2% of the ex vessel value of each vessel's retained catch instead of paying for their own observers through a contractor. The plan allowed NMFS to place observers where biological information was lacking or more intense monitoring was needed instead of assigning levels of observer coverage strictly by vessel category. The RP also developed an "arms length" relationship between the vessel owner and observer contractors. The fishing industry lobbied the North Pacific Fishery Management Council (NPFMC) heavily to kill this plan for cost reasons. The primary opponents were factory trawlers, which would be paying up to 2,000% more than they currently pay. However, the RP was designed to address the cost inequities of the current pay-as-you-go system where small trawlers may pay over 8% of their gross income for observer services. Nonetheless, this plan was effectively shelved and a new plan put forth, called the Third Party Plan. The Third Party Plan has not yet been approved by the NPFMC, but it has some serious conflict of interest and structural problems.

Why should scientists care about the observer program? Observers are the primary data gathering device used by scientists at NMFS, the Alaska Department of Fish & Game, universities throughout the country, and other institutions conducting a wide variety of research. Scientists should monitor and lobby the NPFMC for a strong program that promotes data integrity and good science. A healthy observer program compensates observers fairly based on their education, training, and performance, and retains experience within the program. Furthermore, observers should be insulated from industry harassment and bias in the data-gathering procedures. Adequate insurance should be provided to cover observers in this hazardous environment. The future of information from observer programs throughout the country is in jeopardy unless good program management and science are implemented.

SUMMARY OF DISCUSSION SESSION

The first question discussed was, "Is there a future in fisheries management?" Some students felt that fisheries biology is already sufficiently well known but the social and economic aspects of fisheries are not well studied. Several students suggested that bioeconomic analysis is the wave of the future.

Several students brought up an idea that has been proposed (C. Walters, Univ. British Columbia Fisheries Centre, Vancouver, pers. comm.) that the world should be closed to fishing but certain areas should be open if they can be fished without destroying any stocks (the "red light/green light" idea). This idea is a possible solution to the stock collapse problem, but it ignores socioeconomic factors, unless stock collapse is considered as a socioeconomic problem to be avoided. The idea is to be risk-averse. However, closing some areas may be risky; for example, the area might be a migration sink. Research would determine which areas would be reasonable for closure, but such research is time-consuming. Current policies are "head in the sand" with regard to the possibility of stock collapse, so we should discuss how to stop stock collapses. However, it is so difficult to predict fisheries systems that a risk-averse policy may not save the fish. For example, while Namibia instituted a risk-averse policy in the early 1990s, its fisheries collapsed anyway. Also, in complex cases like the North and Mediterranean seas, what is the risk-averse approach? This leads back to the problem of social and economic aspects of management. The fisheries would be better managed with cooperation, but there must be incentives to cooperate, and the participants need to know that it is in their best interests.

The second point of discussion was, "What is the role of fisheries biologists in management?" Some participants said that fisheries biologists should not have social and economic goals. Their job is to provide options to the managers based on objective science. However, some attendees? claimed that objectivity is not possible; the choice of modeling approach and data collection methods influences the results that biologists present. For example, a switch from single-species models to ecosystem-based models would change the range of advice that biologists give. Some students said that biologists should work for all sides in the politics; others said we should avoid politics. Objectivity and lack of bias is necessary but may be unattainable. Science is a debate, which is good, but it is unfortunate that interest groups take scientists out of the debate to further their own goals.

We ended with a discussion of interdisciplinary and multi-institution research in general, and research involving graduate students specifically. Some students said that, like fishers, members of academia need incentives to cooperate. The problem is institutional, and graduate students do not have time to do projects outside their own lab. We all agreed that more interaction between disciplines would be valuable.