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Graduate Student Symposium on Fish Population Dynamics and Management

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Marcello Vasconcellos and David Preikshot

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Preface

The Graduate Student Symposium on Fish Population Dynamics and Management was established in 1995 by the initiative of Alida Bundy, graduate student at UBC, and Elizabeth Babcock, School of Fisheries - University of Washington. Since then the graduate student symposium has been providing a unique venue for fisheries students to meet and discuss their work, and to foster communication links between graduate students in different west coast universities and departments.

This report is an attempt to disseminate the information on current research and ideas been developed by students in the different universities, and as so, contains abstracts and summaries presented by each speaker at the third annual conference. Readers interested in further details on the research work presented in this report should contact the respective authors at the addresses provided in the list of participants.

We thank everyone who made the event possible, specially all the students for the pleasant atmosphere during the meeting. Thanks also to the Faculty of Graduate Students, UBC, and specially for Tony Pitcher, Director of the Fisheries Centre, for providing funds and support for the conference.

Marcelo Vasconcellos
Dave Preikshot
Fisheries Centre, University of British Columbia

Summary of the Symposium

The third Fisheries Graduate student symposium was held at the Ralf Yorque room of the UBC Fisheries Centre, from March 21 to March 23, 1997. Attendees included 16 students from the UBC Fisheries Centre, 5 students from the School of Fisheries and School of Marine Affairs, University of Washington, 6 students from the School of Resource Management, Simon Fraser University and 1 student from the Department of Biology, University of Victoria.

The symposium was organized in four general subjects: ecosystems and fisheries; fish population dynamics and behaviour; climate and fisheries; and fisheries management. There was much discussion and an open exchange of views as the participants took advantage of an opportunity to discuss their research without the perception of pressure from advisors, faculty, or established researches. The conference was a success, illustrative of the high quality of fisheries research that is being conducted in the Pacific Northwest. Next years symposium will be held at the School of Fisheries, University of Washington.

Schedule

Friday, March 21

Ecosystem and fisheries

14:30 Lisa Thompson, UBC. Response of kokanee salmon (*Oncorhynchus nerka*) to large-scale nutrient additions: diet, density and distribution.

14:50 Eny Buchary, UBC. Ecosystem Dynamics of the Java Sea.

15:10 Coffee Break

15:30 Johanne Dalsgard, UBC. The fate of radionuclides in a marine ecosystem.

15:50 Maria Morlin, UBC. Fisheries-Forestry interactions

16:10 Judson Venier, UBC. Seasonal trophic models of the Looe Key National Marine Sanctuary

Saturday, March 22

Fish population dynamics and behavior

9:30 Jeff Grout, SFU. An evaluation of the management implications of depensatory predation mortality in Pacific Salmon using Bayesian decision analysis

9:50 Narima Jiddawi, UBC. Estimation of growth, mortality, recruitment and exploitation rate of *Rastrelliger kanagurta* (Scombridae) in the coastal waters of Zanzibar Island, East Africa.

10:10 Steven Mackinson, UBC. Bioeconomics and catchability: Fish and fishers behavior during stock collapse.

10:30 Coffee Break

11:00 Anthony Courtney, UBC. Population dynamics, uncertainty and utility per recruit in Scyllarid lobsters (*Thenus* spp.) on Australia's east coast.

11:20 Taja Lee, UBC. An individual based model of fish shoaling dynamics.

11:40 Sylvie Guénette, UBC. The role of marine reserves for migrating and schooling fish.

12:00 Lunch Break

Climate Variations and Fisheries

14:00 Jacqueline O'Connell, UVic. Inter-decadal assessment of fish remains from Saanich Inlet, B.C.

14:20 Bill Pinnix, UW. Incorporating climate signals into Puget Sound salmon run forecasts.

14:40 Coffee Break

15:20 John Field, UW. The implication of long term variability in the California Current's coastal pelagic fisheries.

15:40 Marcelo Vasconcellos, UBC. Stock collapse of *Sardinella brasiliensis*. Hypotheses and management considerations.

16:00 Discussions

19:00 Dinner

Sunday, March 23

Fisheries Management

10:00 Dave Preikshot, UBC. Using multivariate statistics to assess tropical artisanal fisheries

10:20 Hreidar Valtyson, UBC. Fisheries in Iceland from 1950 to the present with a focus on Redfish (*Sebastes* spp.) species.

10:40 Coffee Break

11:00 Ricardo Torres, UBC. Small-scale fisheries in Yucatan. Implications for their management.

11:20 Silvia Salas, UBC. Are fishers homogeneous in behavior in small-scale fisheries ?

11:40 Beth Babcock, UW. Using depth as a proxy for target species choice in the deepwater trawl fishery off the Oregon coast.

12:00 Lunch

Responses of kokanee salmon (*Oncorhynchus nerka*) in Kootenay Lake, B.C. to large-scale nutrient additions

Lisa C. Thompson
Fisheries Centre, UBC

Nutrients were added to the North Arm of Kootenay Lake, B.C., from 1992 to 1994, in an effort to restore the lake community to its status prior to the building of hydroelectric dams upstream. Kootenay Lake is 107 km long, about 4 km wide, 140 m deep, and is part of the Columbia River drainage. The lake provides popular sport fisheries for kokanee salmon (*Oncorhynchus nerka*), and a unique stock of rainbow trout (*Oncorhynchus mykiss*) which grows to trophy size by feeding on kokanee. The Duncan Dam formed the Duncan Reservoir (previously Duncan Lake) northeast of Kootenay Lake in 1967 (Northcote 1973) and in 1973 the Libby Dam, on the Kootenai River in Montana, formed the Koocanusa Reservoir, which stretches back into Canada near Cranbrook (Daley et al. 1981). The dams cause the phosphorus load to be only one-third of historical levels. Phosphorus concentrations in the lake declined during the 1970's. Kokanee abundance was erratic from 1978 to 1984, then began a steady decline in 1985, which prompted the B.C. Ministry of Environment, Lands and Parks to start the fertilization program to replace the missing nutrients. Intensive monitoring has been done because of uncertainties regarding the fate of the added nutrients. *Mysis relicta*, an exotic freshwater shrimp, competes with kokanee for zooplankton, and a detailed simulation model indicated that fertilization could benefit *M. relicta*, and actually hasten the decline of kokanee (Walters et al. 1991).

Nitrogen and phosphorus, in the form of liquid agricultural fertilizer, were added to the lake from a tugboat-barge unit, in a 10 km long area at the north end of the lake, weekly from April to September. It was expected that this would induce a nutrient gradient from north to south along the lake. Water chemistry and biological responses (phytoplankton, zooplankton, *M. relicta*, kokanee) were measured along the lake at 7 sampling stations. Since there were no feasible control or replicate lakes, the effects of nutrient additions were determined by testing for differences along the north-south gradient.

Time series data indicate that the fertilizer may be having beneficial effects. Macrozooplankton densities have increased during the fertilization period (Fig. 1), and are now similar to densities seen in the mid-1980's. Also, the proportion of cladoceran zooplankton, the preferred food of kokanee, is higher now than at any time previously measured. Kokanee spawner numbers have increased, although not to levels observed prior to the construction of the dams upstream (Fig. 2).

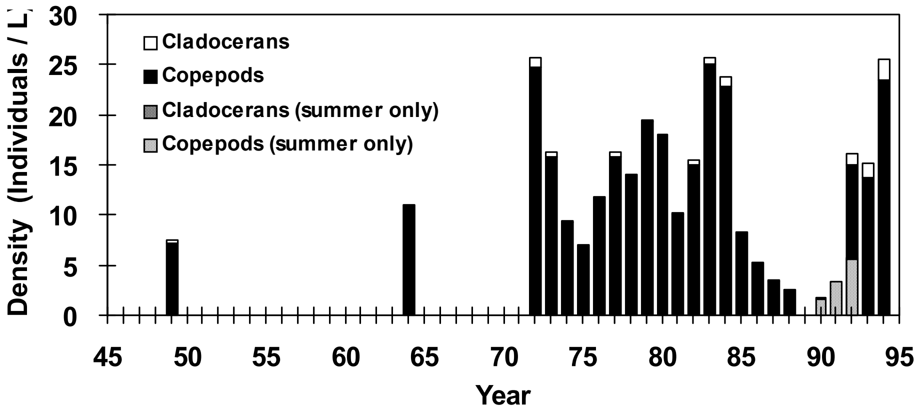

Fig. 1. Growing season average zooplankton density in Kootenay Lake for 1949, 1964, 1972 to 1988, and 1990 to 1994. Data indicated by hatch-marks (1990 to 1992) were collected only in mid-summer, and probably over-estimate densities.

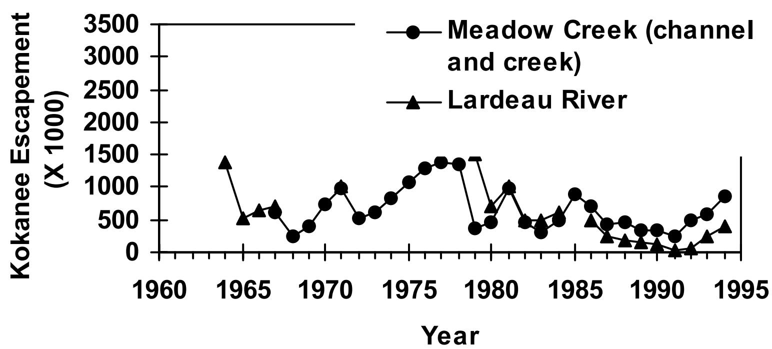

Fig. 2. Kokanee spawner escapement to Meadow Creek and the Lardeau River from 1964 to 1994.

Along the length of the lake, phytoplankton biomass, measured as chlorophyll *a*, appears to have responded positively to the nutrient additions (Fig. 3). Stations 1 and 2, nearest to where the fertilizer is added, had higher chlorophyll concentrations than other stations during the spring and summer bloom periods (1994 data shown). Zooplankton densities peaked in June and September (Fig. 4). The first cladocerans appeared in early May (May 3 sample at Station 2), but the first *Daphnia* were observed in mid-June (June 15 sample at Station 7). Cladoceran densities peaked in August, with the highest density observed at Station 6. Few cladocerans were observed in November. Zooplankton densities did not follow the nutrient gradient (i.e., higher at the north end of the lake, and lower in the south). This may indicate that kokanee and/or *M. relicta* responded to increased zooplankton productivity in the fertilized part of the lake by moving to that area to feed, thus cropping down the zooplankton. The hydroacoustic data on kokanee horizontal distribution support this hypothesis. Kokanee densities are higher in the north (fertilized) end of the lake in spring and summer, when zooplankton densities are low there (Fig. 5). However, kokanee move south over the summer, and by October their densities are even across the lake, as are zooplankton densities.

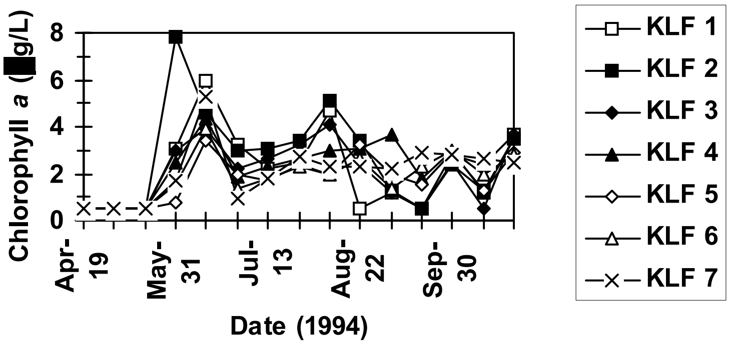

Fig. 3. Chlorophyll a concentrations along the length of Kootenay Lake in 1994 (bi-weekly sampling). (Adapted from Ashley et al. 1996).

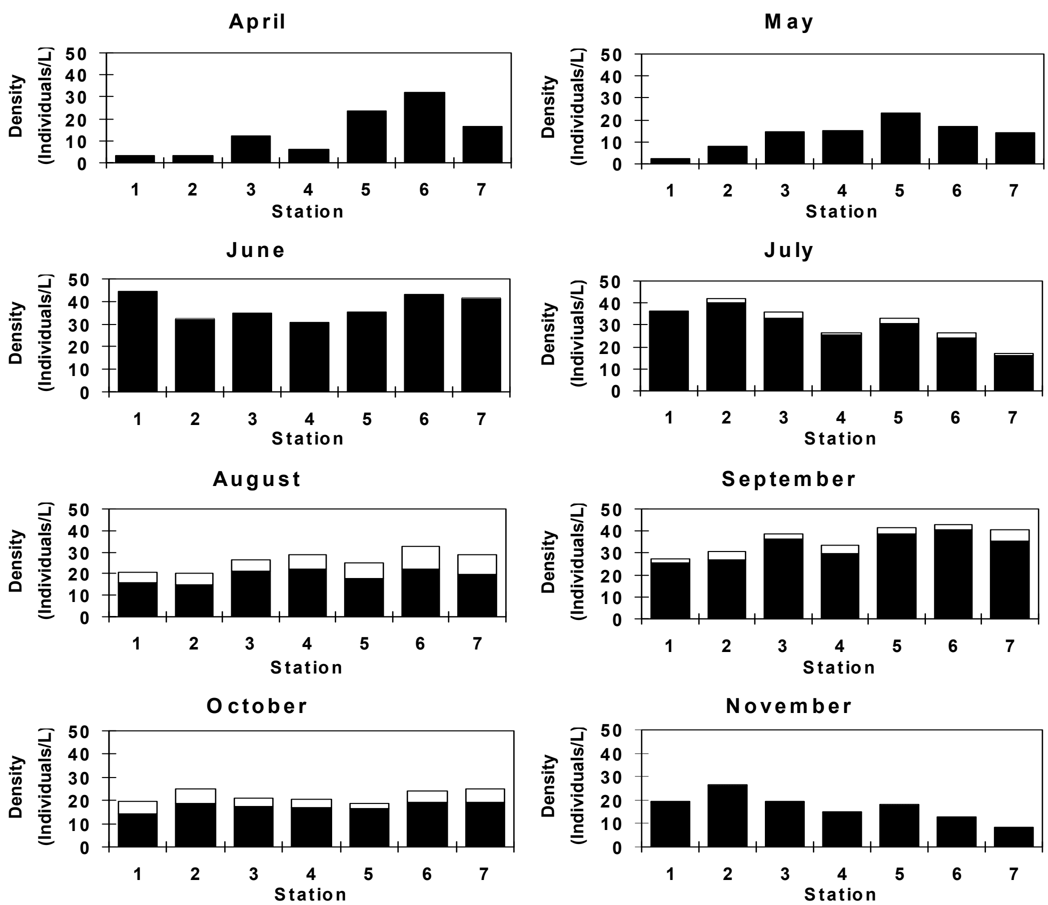

Fig. 4. Zooplankton density along the length of Kootenay Lake in 1994, plotted by month. Black bars indicate copepods, white bars indicate cladocerans.

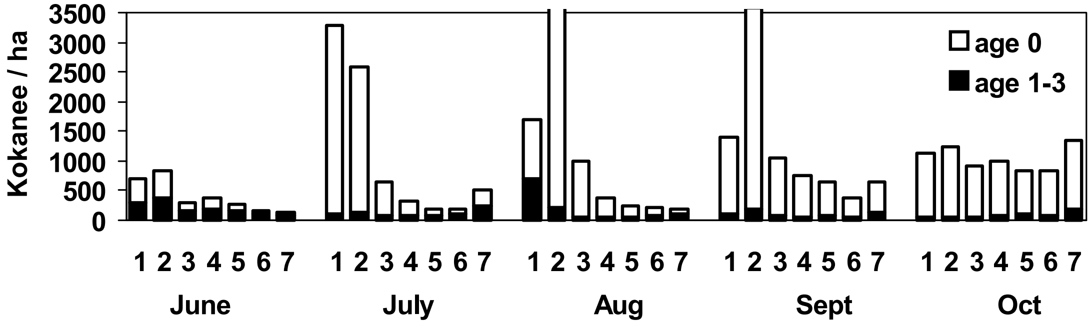

Fig. 5. Kokanee salmon densities along the length of Kootenay Lake in 1994, as determined from monthly hydroacoustic surveys. (Adapted from Ashley et al. 1996).

Additional years of fertilization and data collection are necessary to determine whether these observations are related to the nutrient additions. Since most main lake kokanee spawn at age 4, the fish in the first cohort to have experienced fertilization throughout their life-span should return to spawn in 1995.

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Ecosystem Dynamic of the Java Sea: A Trophic Model Analysis of the Impact of the 1980 Trawl Ban in Indonesia

Eny A. Buchary
Fisheries Centre, UBC

Fisheries development in Indonesia, in particular in western Indonesia, is very much shaped by historical background; including the trawl fisheries. Since its introduction in 1966, trawl started to dominate the fishery activities, and it was the main gear in Indonesian fisheries until the late 1970s.

The domination of trawl had caused social conflicts (resource competition and gear conflicts) between small scale inshore traditional fishers (particularly those operating fixed gears) and trawlers, resulting in open violence. Consequently, these conflicts became a major political issue which forced the government to take strong action.

Hence, by virtue of Presidential Decree No.39 of 1980, trawl operations was banned in western part of Indonesia, and then extended throughout Indonesian waters (except the Arafura Sea, adjacent to Northwestern Australia) in 1982.

Just recently, even though the current government is not interested in revoking the ban, there have been quite a debate and speculation among fisheries scientists and managers in Indonesia to review the ban decree (and possibly to revoke it) in order to eradicate poverty among fisher communities and to enhance fisheries development in the country. One of their arguments is that biologically, the system has recovered. This research aims to explore whether or not it is really biologically safe to revoke the ban now.

In this research, using a mass-balance and a simulation models, I simulated three scenarios in order to forecast the ecosystem dynamics of the Java Sea:

(1) what would have happened to the ecosystem if the trawl ban had never been put in place?,
(2) what would happen to the ecosystem if the trawl ban is revoked after 1980 ?, and
(3) what would happen to the ecosystem if the status quo is maintained ?

By the end of this research, I would like to be able to provide a solid ground for fisheries management purposes in the Java Sea, and a good reference point for further socio-economic explorations on fisheries in the area.

The fate of radionuclides in a marine ecosystem

Johanne Dalsgaard
Fisheries Centre, UBC

From 1948 to 1958 the US Government detonated 43 nuclear bombs (mainly atmospheric) on Enewetak Atoll, a small coral reef atoll in the Northwest Pacific. A number of radioisotopes were formed at the time of the detonations, and the fallout was distributed at or in the vicinity of the atoll. During and after the testing, studies were carried out measuring the level of radioactivity in various organisms. Furthermore, from the Mid-Pacific Marine Laboratory (a field station located on the atoll) marine scientist contributed by conducting a continuing assessment of the environmental impact.

By combining the existing information on this thoroughly studied atoll, the objective of my thesis is to: i) Construct a model of the aquatic ecosystem of Enewetak Atoll. ii) Map the distribution of radioactivity within the system, and evaluate if, how, and where in the food webs they accumulate. iii) Examine if the pattern of distribution can be predicted by the model.

Quantifying the decline in spatial diversity of salmonid stocks due to fish habitat damage caused by land use practices in British Columbia

Maria Morlin
Fisheries Centre, UBC

Since the 1950's fish escapement records in B.C. show a progressive concentration of production into fewer, larger populations. Small stocks from small watersheds are susceptible to extinction because they are vulnerable to unpredictable environmental variations, and habitat damage from development, logging, and other land use practices. The loss of spatial diversity of salmonid stocks, therefore, is blamed partially on habitat degradation; however, estimates of small population losses directly due to habitat damage are estimated at only 20-30%. Loss in diversity is also due to targeting by fisheries at large populations, likely enhanced by hatcheries or spawning channel creation, in mixed-stock fisheries, where small populations are fished out with the large ones. More accurate quantification of losses due to these causes must be made to solve blame-placing conflicts and to direct management of fisheries and forestry to critical areas.

This study will attempt to quantify stock loss due to land-use-inflicted habitat damage which has occurred since the 1950's in selected watersheds of the Fraser

Valley, as well as recovery of stocks. Timing of land use such as urban development, agriculture and logging is especially important to match habitat loss/damage with associated decline in fish populations. For example, losses due to logging may occur between 5-10 years later, as tree roots rot and slope stability declines until mass wasting occurs, whereas barriers such as landslides or dams may have immediate effects.

Seasonal Trophic Models of the Looe Key National Marine Sanctuary

Judson Venier
Fisheries Centre, UBC

The Looe Key National Marine Sanctuary is an 18km2 area in the Florida Reef Tract which was established in 1981 to protect the well developed Looe Key Reef, a popular dive site. The Sanctuary lies approximately 13km off of Big Pine Key in the Lower Florida Keys and in addition to the reef, includes the surrounding coral, sand and seagrass habitats. Although many previous studies have been conducted on the various components of Florida reef ecosystems, no comprehensive ecosystem models have been constructed. Looe Key was chosen as a representative Florida reef and the Ecopath approach and software was used to construct mass-balance ecosystem models of the Sanctuary using data acquired from the published literature on Florida reefs and other areas of the Caribbean and elsewhere. The structure used to build the model was adapted from an earlier ECOPATH II model of a Virgin Islands coral reef. These Ecopath models describe the flows of energy and other relationships between 20 functional groups by season (3 month periods). Through the construction of seasonal ecosystem models, changes which occur at Looe Key throughout the year can be presented. This process will eliminate, or greatly curtail, biases which exist for rates expressed as annual averages which, in reality, were collected during one season. I will also provide the first seasonal description of a coral reef ecosystem. Ecosystem models describe the population dynamics of the organisms they contain in a rigorous fashion in a total system context. Thus itenables the fisheries manager to identify options for, and impacts of, decisions regarding the management of exploited populations within the described system. Studies of non-fished ecosystems could therefore provide reference points for the establishment of marine reserves, a popular and growing fisheries management tool.

An evaluation of the management implications of depensatory predation mortality in Pacific Salmon using Bayesian decision analysis

Jeff Grout
Simon Fraser University

Management of Pacific salmon is often based on the Ricker stock-recruitment model. However, estimates of the parameters of the Ricker model are usually imprecise and such uncertainties are frequently ignored when harvests are based solely on the best point estimates of model parameters. In addition, it is uncertain whether the Ricker model is the appropriate form for describing the shape of the stock-recruitment curve. In some stocks of Pacific salmon, there is considerable anecdotal and empirical evidence to support including depensatory mortality (high proportion dying at low abundance) in the stock-recruitment relationship. Given these uncertainties, several fisheries scientists have advocated adjusting the harvest level downward to account for uncertainty, but the appropriate size of these "uncertainty adjustments" is unclear. For several stocks of Fraser River sockeye salmon (*Oncorhynchus nerka*), I used Bayesian decision analysis to compare the benefits of harvest strategies based on the commonly used Ricker model to those based on a stock-recruitment model that accounted for the possibility of depensatory predation mortality. This approach explicitly incorporated uncertainties in the model parameters and quantified the management implications (e.g. expected yield) of using a Ricker or depensatory stock-recruitment model over a range of management policies. For a constant escapement policy, the optimal escapement target was generally unaffected by the possibility of depensation. However, large "uncertainty adjustments" (i.e. increases to the escapement target) may be beneficial for stocks with a high degree of uncertainty about the fit of the stock-recruitment curve at high abundance of spawners. In contrast, under a constant harvest rate policy, the optimal harvest rate depends on the initial abundance of spawners. For a small abundance of spawners (e.g. 2,000) the possibility of depensatory predation mortality required low harvest rates initially to maximize the expected yield over the long term. Preliminary analyses also indicated that a rebuilding strategy (where harvest rates were reduced from 80% to 50% for four generations to allow rebuilding) for cycle lines with small numbers of spawners should increase the expected yield compared with a constant 80% harvest rate given uncertainty in the shape of the stock-recruitment curves for both the Ricker and depensatory models. Dramatic increases in yield may be possible if depensatory mortality actually does exist in these stocks.

Estimation of Growth, Mortality, Recruitment and Exploitation rate of *Rastrelliger kanagurta* (Scombridae) in the coastal waters of Zanzibar Island, East Africa

Narrima Jiddawi
Fisheries Centre, UBC

Rastrelliger kanagurta is among one of the important fish species caught in the purse seine fisheries of Zanzibar. Monthly length-frequency data sampled during 1989-1992 from the purse seine fisheries were used to estimate growth parameters K and L_{inf} using the ELEFAN 1 subroutine of the FISAT program. L_{inf} was estimated to be around 36 cm , while K was found to be 0.63 per year. Pauly's empirical equation was used to estimate the natural mortality M and subsequently the fishing mortality and the exploitation rate were derived. The recruitment pattern suggests that annual recruitment of the stock occurs in the form of two pulses of unequal strength.

Spatial Information for Harvest Control: Maximising Information Through Shifting Mind Sets

Steven Mackinson
Fisheries Centre, UBC

Why control harvest?

Fisheries on small pelagic fish are characterised by a catalogue of stock collapses. A few well known examples include; the Peruvian anchovy, Californian sardine, Norwegian spring spawning herring, North sea herring, and Pacific Herring in British Columbia. The efficient searching and catching ability of modern fishing vessels together with the schooling behaviour of small pelagics ensures that they are highly vulnerable to capture, even during periods of low abundance. The rapid economic gain that is possible from such fisheries may result in a pathological situation driving the stocks to collapse (Mackinson et al., in press).

Harvest regimes that take a fixed proportion of the available stock have been shown to offer the most suitable management strategy for species that typically exhibit wide natural fluctuations in abundance (Walters and Parma 1996). The central challenge for fishery managers directly involved in 'on grounds' management is determining how to implement these strategies. Without successful control, the strategy counts for nothing. There are three broad categories of tactical tools available to the fisheries manager; (i) catch limitation, (ii) effort limitation, (iii) access limitation.

What information is required?

Catch and effort limitations, do not require detailed information on the target species. They largely rely upon controlling fishers and their gear and are comprehensively used in most fisheries. Seasonal and area closures are common methods of limiting access. Too often however, they are selected for management convenience rather than designed with more appropriate biological rationale. There is significant room for improvement in the use of access limitation for harvest control. One particular growing area of research is the use of 'exposure limitation' tactics. Decisions whether to harvest or not are made in-season, based on an understanding of fish distribution. This is distinct from access limitations such as seasonal and area closures in which tactical decisions are made prior to the fishing season. The principle of exposure limitation is to ensure that only the desired proportion of fish are made vulnerable (exposed) to capture by virtue of restrictions based on space and time. Clearly, this approach requires considerable understanding of the spatial and temporal dynamics of the target species, i.e. fish behaviour.

The resolution of the required information depends on the desired fishing activity. For example, herring fisheries typically occur during three different life stages; (i) during summer feeding phase in the ocean, (ii) over-wintering, (iii) spawning. To develop space-time restrictions for harvest control it is necessary to gather detailed information in the critical periods during which fisheries are likely to occur.

Studying the behaviour of fishermen to gain an understanding of how they respond to changes in the distribution and abundance of their target species is equally important. This is a more tractable problem than studying fish behaviour for two simple reasons. Boats are easily visible and fishermen can talk.

Where can we find the information?

To develop our understanding, we must be able to gather the essential information on movement and distribution. An immediate hurdle that most scientists face is finding the necessary resources with which to collect such information. However, in my opinion there is a significantly greater barrier to overcome; the reluctance of science to utilise the potential sources of information. I say 'reluctance' for lack of a better word, in fact it is rather the case that certain sources of information are either overlooked or dismissed immediately without consideration. This is somewhat understandable since as most scientists[1] intrinsically know, only data collected in a scientific fashion can stand up to the rigors of statistical analysis and the strict rules we have set ourselves to make data acceptable.

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[1] Those trained in scientific disciplines such biology, zoology that have a strong emphasis on hypothesis testing with proof by statistics

To be honest, if not a little sarcastic, fisheries scientists have come a long way. We are very inventive at finding new ways of using the same data, and we can now admit uncertainty left, right and centre! The sad thing is, we are still discounting a huge wealth of potential information. We should not just be looking for new ways of handling old data, but rather for ways of accessing new[2] data. I suspect that with the exception of those working on fisheries in developing countries, few people reading this have ever used information other than that published in primary scientific journals or collected by fieldwork. One of the richest, but often overlooked sources of information is 'gray matter'. I am guilty too. As a 'scientist', non-scientists knowledge does not conform to the standard of information I know how to deal with. It's difficult to access and somewhat awkward to put into a spreadsheet.

Without this information, not only are we missing half the picture, but also we are in danger of 're-inventing the wheel'. During recent fieldwork, the skipper of a seine vessel revealed detailed knowledge of herring distribution and behaviour that to my knowledge has never been published in a scientific journal. Since fisheries science freely admits uncertainty, we should now be in a position to be able to expand our data sources to those that perhaps previously did not meet the desired specifications. It is imperative that we have diverse data sources and maximise their potential.

Who is qualified to give information?

Fishers must be considered a primary source of information. By virtue of their life style, most fishermen know lots about fish since their livelihood depends upon it. The good thing about this information is that when you get it, it comes compiled. Many fishers knowledge is based not only their experience, but their fathers, grandfathers and others they have fished with. Imagine how long it would take you to read three generations worth of knowledge? The other most obvious source, is fishery mangers who work on the grounds. They have practical, applied knowledge gained through experience and their own interactions with fishers. Thirdly, but not of least importance, is the requirement for detailed information collected on behaviour and distribution by scientific surveys. Hard data, collected by scientists in the desired format. Thus we have two types of information; hard data (scientific format) and practical data (applied knowledge). It is paramount that we close the gap between these data sources, combining them to build a more complete understanding (Figure 1).

One of the obvious benefits of this approach is greater acceptability of fisheries science and the recommendations that it offers. Those who may directly be influenced by management actions have contributed to their formulation.

[2] Data that may have been available but never used simply because we don't know how or did not give it credibility

Intuitively, this involvement provides a sense of worth and may be instrumental in fostering greater responsibility of fishers to the resource. If this were the case, we would likely avoid some errors in management that have resulted in conflict in the past.

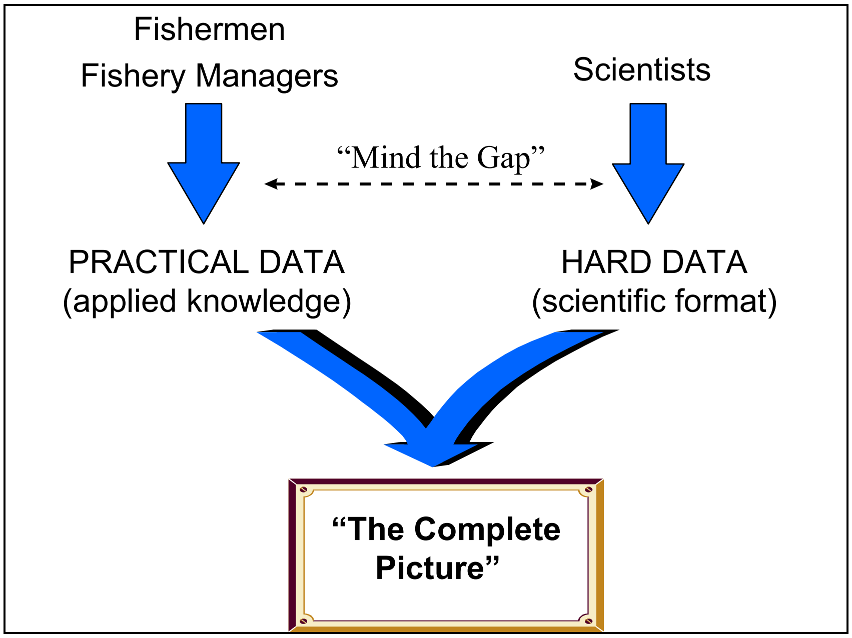

Figure 1. Combining sources of data

How do we record and present this information?
Constrained by our need for rigorous, testable, credible, accountable methodologies, we must find a way to record and present the information. A format that can be presented and scrutinised at various levels. It should be accessible and understandable to all.

An approach that I intend to pursue for my own research is developing an expert system. Expert systems (a branch of artificial intelligence) appears to offer a tool that can be used to represent the two types of data mentioned above. Information can be input in the form of heuristic rules[3] (practical data) and quantitative information in the form of algorithms (hard data). Combined, these sources of information form the knowledge base of an expert system.

In summary, to successfully implement space-time restrictions for harvest control, it is fundamental that we gain a better understanding of fish behaviour. A huge source of this information is already locked in the heads of fishermen and fishery managers. Science does not have the time or money to go and find the

[3] Rules of thumb, e.g. red sky in the morning, sailors warning. In an expert system these are rules that can be stated in an IF…THEN format.

answers for itself in the desired scientific format. To diversify our data sources and maximise their potential, we must give acceptance and credibility to 'new' forms of data. More time spent communicating would reduce the present knowledge gap.

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Population dynamics, uncertainty and utility per recruit in Scyllarid lobsters (*Thenus* spp.) on Australia's east coast

Anthony Courtney
Fisheries Centre, UBC

The population dynamics and exploitation of lobsters of the family Scyllaridae (squat or slipper lobsters) have received scant attention compared with that of the Palinuridae (spiny rock lobsters) and the Nephropidae (clawed lobsters). Of the seven genera constituting the Scyllaridae, Thenus is the most economically significant, contributing to many demersal trawl fisheries operating in tropical coastal waters of the Indian Ocean and Western Pacific. This presentation conveys results obtained from a 2.5 year study on two species in this genus, *Thenus orientalis* and *T. indicus,* which form a valuable by-product ($5-10 million annually) of prawn and scallop trawl fisheries on the east coast of Australia. During the course of the study we tagged and released over 12,000 lobsters to estimate growth rates, natural and fishing mortality rates, and movements. Because of the lack of previous tagging studies on this family, several hypotheses were tested to determine the effects of tags on recapture rate, moulting and survival. General linear modelling (GLM) was deployed to identify the most influential factors. The results can be used to improve future tagging studies for this group. Fabens (1965) method of analysing tag-recapture data was used to estimate K and L_∞, and their joint confidence intervals. A sequential tagging method, first described by Ricker (1975), was used to obtain an estimate of the instantaneous rate of natural mortality, M. Two estimates of the instantaneous rate of fishing mortality were derived, one based on subtracting M from total mortality (Z), the other based on the log-likelihood method of analysing tag-recapture data (Hilborn and Walters 1992). These population parameter estimates were used in value- and egg- per recruit simulations in order to identify and recommend an optimum minimum legal size.

An individual based model of fish shoaling dynamics

Taja Lee
Fisheries Centre, UBC

Insight into fish shoaling and schooling behaviour has come from a perspective that examines the costs and benefits to individuals. Extensive laboratory evidence shows that fish shoaling behaviour is driven by individual decisions of fish to *join, leave or stay (JLS)* with a group. These *JLS* decisions are largely determined by trade-offs between the availability of food and the perceived risk of predation. An individual-based simulation model of fish shoaling dynamics using algorithms based on the behaviour of individual fish presented. The aim of the model is to simulate fish shoal sizes based on *JLS* rules.

The role of marine reserves for migrating and schooling fish.

Sylvie Guénette
Fisheries Centre, UBC

The collapse of numerous pelagic and demersal fisheries worldwide have triggered renewed interest for marine reserves. Used in combination with other management strategies, marine reserves could make exact knowledge of catch and population abundance less critical. Simple simulations using dynamic pool model show that a reserve would increase the spawning biomass and decrease the number of years of weak recruitment. The setting of a reserve where the population is slightly exploited would decrease the yield. Exploited at higher levels, the population protected by a reserve would give better yields than a population for which only traditional regulations are used. Moreover the risk of collapse is diminished. Protecting one segment of the population, juveniles or older spawners, also have a beneficial effect on the population. High transfer rate of fish from the reserve to the fishing zone will decrease the positive impact of the reserve. This has been seen as a major objection to use marine reserve for fast moving fish. However possible solutions for migrating and schooling fish are given. Future models should take into account the spatial structure of the population: their movements, the schooling behaviour and the range dynamics.

Inter-decadal Assessment of Fish Remains from Saanich Inlet, B.C.

Jacqueline O'Connell
University of Victoria
Department of Biology

The remains of fossil fishes, such as scales, can provide key information about the former distribution of fishes, the seasonality and growth of these fishes, as well as otherwise unavailable paleoenvironmental information (Clason 1986). Knowing past fish population dynamics is fundamental to understanding current natural and anthropogenically induced fluctuations in fish communities, and this information will contribute to the effective establishment of management protocols to help sustain the world's fisheries.

This project is a part of a multidisciplinary study to develop a regional paleoenvironmental and climate reconstruction for the south-eastern tip of Vancouver Island. The anoxic, undisturbed sediments and absence of mechanical disruption in Saanich Inlet has allowed the preservation of delicate organic remains such as fish scales. The sediments in the inlet also show very clear annual laminations that will allow high-resolution paleoresearch to be undertaken. Several studies demonstrate successful application of fish scales to interpretation of past populations and dynamics factors (Baumgartner *et al*. 1992, Shackleton 1987, DeVries & Pearcy 1982). Further, fish populations and abundance reflect environmental conditions therefore, fish remains in the sediments can act as proxies for environmental change. In this study, fossil fish scales found in sediment cores taken from Saanich Inlet will be analysed to determine their potential in providing paleoecological and paleoenvironmental information.

Incorporating Climate Signals Into Puget Sound Salmon Run Forecasts

William Pinnix
School of Fisheries, UW

The Washington Department of Fish and Wildlife (WDFW) and the Northwest Indian Fisheries Commission (NWIFC) make yearly run forecasts for Puget Sound coho salmon (*Oncorhynchus kisutch*), and allocate allowable catches based on this forecast. The track record of these forecasts has been fair to poor due to inaccurate forecasts of ocean survival. Recent research has linked North Pacific salmonid (*Oncorhynchus spp*.) productivity with climate regimes of the North Pacific Ocean. Ocean survival rates of coho salmon were calculated from Coded Wire Tag (CWT) data. For comparative purposes 4 areas were examined, 2 inside

(Puget Sound, and Georgia Strait) and 2 coastal (Washington State coast, and the West coast of Vancouver Island). These rates and climatological data were compared to glean information about the link between climatic effects, both long term (interdecadal) and short term (interannual), and ocean survival of coho salmon. The insights gained will be incorporated into the WDFW and NWIFC coho salmon run forecast.

The Implications of Long Term Variability in the California Current's Coastal Pelagic Fisheries

John Field
School of Marine Affairs, UW

Abundance of coastal pelagic fishes have demonstrated an enormous degree of variability stretching back well before the advent of modern industrial fisheries. In the California Current Ecosystem, these species would include Pacific sardine (*Sardinops sagax*), Northern anchovy (*Engraulis mordax*) and market squid (*Loligo opalescens*). Holling's (1995) model of ecosystem functions compares favorably with current knowledge of life history characteristics of these species and the nature of long-term dynamic processes in the California Current. Using this as a model, the effects of historical and current commercial fishing pressure upon these populations will be explored, especially in regard to the status and nature of the current regulatory regime.

Stock collapse of *Sardinella brasiliensis*. Hypothesis and management considerations

Marcelo C. Vasconcellos
Fisheries Centre, UBC

Sardinella brasiliensis is the major pelagic fishery resource in Brazil, responding for over 25% of the total national marine catches from 1983 to 1987. Sardine landings peaked in 1973 with 228 thousand tons and remained around 124 thousand tons until 1987. The stock collapsed in 1990 after a period of rapid decline in catches. Failures in spawning and recruitment in the period of stock decline were attributed to a relaxing of enrichment mechanisms in the coastal region. Concurrently, a rapid increase in fishing effort, fleet capacity and range collapse seems to be responsible for an increase in stock catchability and fishing mortality. Regimes in stock productivity and changes in stock catchability cause substantial uncertainties on the efficiency of current regulations in controlling harvest rates. The lack of appropriate methods for scientific advice has been precluding the use of those uncertainties in the choice for management decisions. This work examine the use of a Bayesian decision analysis framework to combine available information on sardine population dynamics, management decisions and the diverse goals of fishery stakeholders.

A multivariate, interdisciplinary assessment of the "Health" of tropical artisanal fisheries

Dave Preikshot
Fisheries Centre, UBC

There is a consensus among practitioners that fisheries stock assessment would benefit from the incorporation of economics and other social science perspectives. This investigation, which aims at deriving and comparing multi-attribute descriptions of fisheries, examined what information could be extracted from economics, and other social sciences, and how it compares to information from biology and ecology. If successful, such an approach would facilitate the quantification of fisheries "health" in both a narrow sense of individual disciplines and a larger interdisciplinary sense. Multivariate statistics were used to form and test hypotheses regarding trends and relationships among simulated (n=40) to track qualitative changes of their "health" through time as pressure from human populations increased and the resource base declined. Techniques such as multi-dimensional scaling and cluster analysis provided a means of grouping the fisheries to display their qualitative and temporal relatedness. Such methods also allow the investigation of the correlations of the different variables being measured. Information obtained from these methods permitted the systematic assessment and comparison of these fisheries and the demonstration of a gradual decline of their health. The potential use of this approach for integrating multi-source data for other types of fisheries is discussed.

Fisheries in Icelandic waters from 1950 to the present with focus on Redfish (*Sebastes sp.*) species

Hreidar Por Valtýsson
Fisheries Centre, UBC

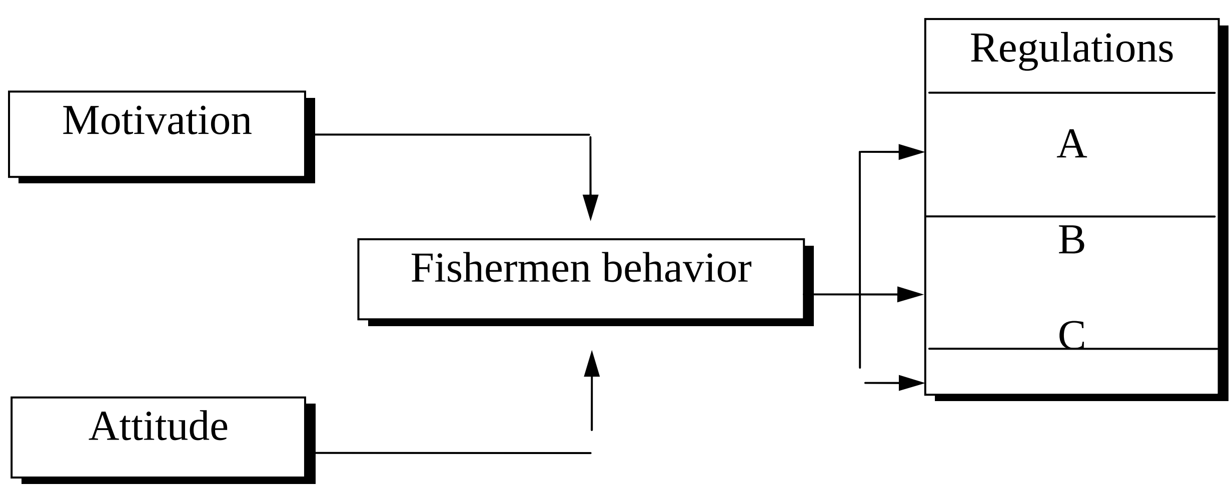
Since 1950 fisheries in Iceland have gone through dramatic changes. Two things have been the main reason for these changes: the extension of the exclusive economic zone (EEZ) and the introduction of individually transferable quota system (ITQ). Although this system probably saved many stocks from depletion, they did not save some stock from being overfished. The redfish is a good example of that. It has however also proved difficult to assess the redfish stocks. This paper present some of the difficulties encountered in redfish stock assessment.

Institutional arrangements in coastal fisheries: implications for their management

Ricardo Torres
Institute for Resources and Environment, UBC

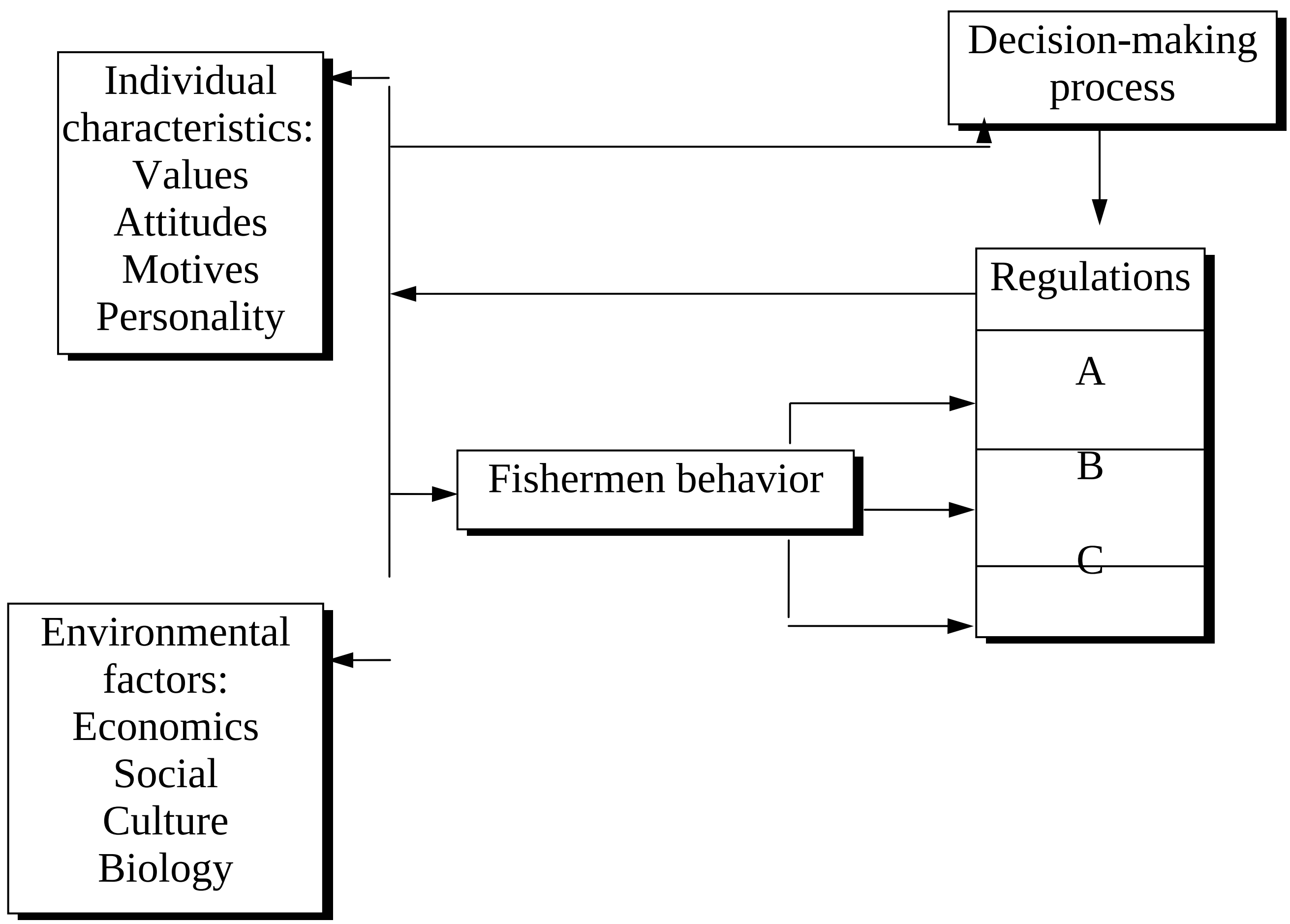
Fisheries are natural resources that are shared by a community of users. A key problem due to this characteristic is how to coordinate use by numerous individuals in order to obtain an optimal rate of overall production. Without coordination, users may, by accumulation, rapidly take excess of "resource units", causing the natural rate of production to decline.

In very extreme cases, the collapse of a resource as an economic activity is called "the tragedy of the commons". Advocate economists of this dilemma have applied it into fishery exploitation models, such as the bionomic model, where fishermen are seemed to behave in a myopic fashion. The basic assumption is that there is only one attitude: fishermen are indifferent to the aggregate effect of their activity over the fishing resources. Also, the only motivation they have is to maximize short-term profits. Consequently, the exhibited behavior is to catch now as much as possible, no matter how much future yields are disrupted, and in despite of alternative fishery regulations. This scenario is depicted in the following diagram:



Current fisheries systems refrain from considering a major complex set of interconnected factors, influencing each other and determining outcomes from these systems. Fishermen behavior is a function of individual's characteristics and the environment. Thus, attitudes interact with values, motivations or even with other attitudes, and with environmental factors (social, cultural, economical and biological ones), to determine fishermen's behavior. This behavior, in turn, may be different in response to alternative fishery's regulations, adapting the outcomes to satisfy fishermen's interests.

If individual characteristics and environmental factors are considered in the decision-making process, regulations may influence positively environmental factors, such as economic incentives or resource protection guidelines, and individual characteristics, such as attitudes or motivations. In this way, fishermen's behavior would more likely be based in respecting regulations, leading to a more efficient resource use since the objectives of those regulations are achieved.



Taken into account all of these factors is one of the relevant characteristics of institutional approach to analyze fisheries. This study is intended to compare outcomes fishermen achieve under different institutional arrangements in order to understand the operation of such arrangements and to disclose how they structure outcomes in alternative ways.

This information will provide useful guidelines for individuals and groups in devising, adapting and evaluating existing arrangements. Also, decision-makers will use this information in order to avoid conflicting incentives when they are designing fishery management schemes.

Fishing strategies of small-scale fishers. Are fishers homogeneous in behavior?

Silvia Salas
Fisheries Centre, UBC

Fisheries management involve allocating scarce resources among competing user groups. Each group of fishers has a set of preferences concerning the best use of the resources and different strategies for coping with natural and market variability. Thus, it is necessary to be aware of and to understand the impact of potential management decisions on one of the dynamic components of the system, the users. Hilborn (1985) stated that the collapse of some fisheries can be explained by the poor understanding of fishers' dynamics, more than by ignorance of biological processes

Fisheries experience both, short-term fluctuations in stock abundance and long-term trends, which are likely to vary if the environment changes. The special problem is to detect when such trends might additionally be induced by the effects of fishing. Clearly the problem of individual catching rates and their relation to catch abundance and productivity are of practical importance. Walters (1993), stated that models for long term dynamics seldom attempt to capture the rapid dynamic changes in effort associated with daily decisions of when, where and what to fish. This is particularly relevant in regions, where the adaptability of the boats allows fishers to target a variety of species. Predictions of these changes are critical to the design of regulatory systems for fisheries.

A conceptual model of the decisions that small-scale fishers have to face in a tropical fishery is presented, as well as some results of a study aiming to the identification of the factors driving the fishers’ decisions and fishers’ strategies in three ports in Yucatan, Mexico.

Decision-making process.
A fishing strategy is an internal decision-making process by which the fisher achieve his objectives accordingly with his constraint(s). In the case study , the conceptual model of the decision-making process (Figure 1), shows the choices fishers have to face: Go fishing or do something else (1); what species to target (associated to gear selection) (2,4) and for how long to keep the same target (3).

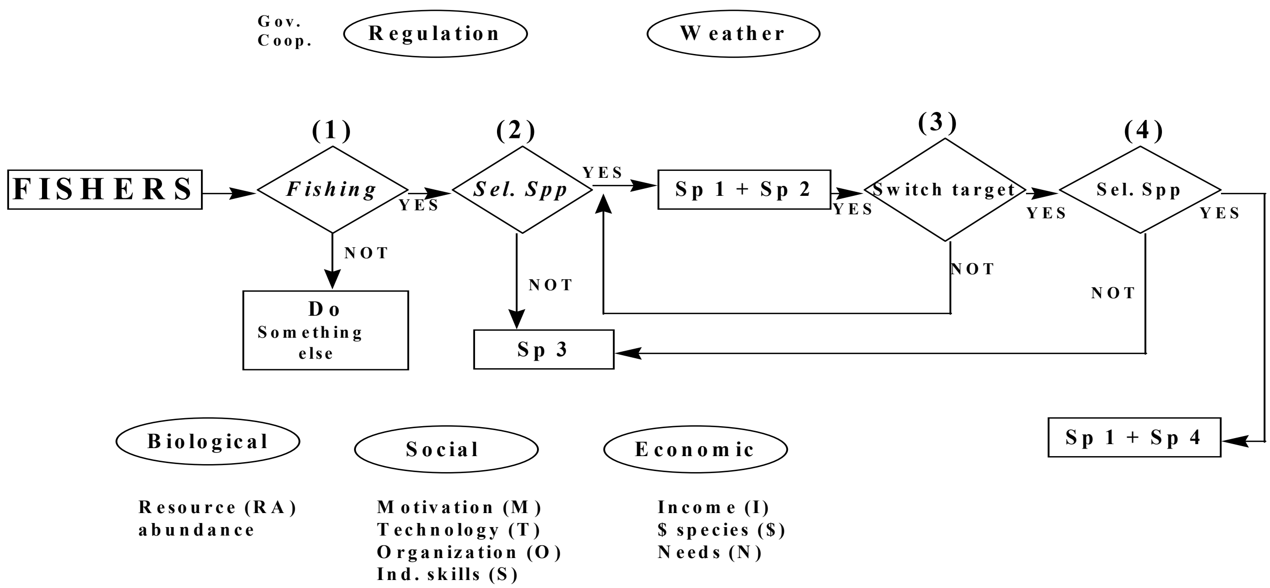


Figure 1. Conceptual model of fishers' decisions in small-scale fisheries in Yucatan, Mexico .

Among the motivations that drive the fishers' decision making process, economic is consider as the principal in the three ports, but not the only one. The goal of an "individual target " (that would not necessary be to maximize revenues, but achieve an specific aim given the alternative activities available as well as the willingness to do something different to fish) is also considered as an alternative in this particular case.

If fishers decided to go fishing, the criteria to select gear and target species is consider to be dependent on different constraints as : weather, availability of the resources, prices, regulatory system and technology . Socio-economic factors are considered as variables that drive also part of the decisions .

Fishers' strategies in a small-scale fishery
Differences among ports and within ports in the composition of the catch, catch value, as well as in fishing effort along the year were observed in the case study. Total catch patterns might look similar in trends in the three ports at first sight, but

when individual contribution is taken into account, it is evident the differences among them.

Two main strategies were identified: a particular strategy of cooperation teams in one of the ports, that seems to be used to compensate the possibility of low catch during "bad" days. The other one, observed in all the ports , involve switching among alternative species or combination of them along the year as an adaptation to a fluctuating environment, and the restrictions imposed by regulations.

Even some fishers claim they always target only one species. Not specialization was observed in any of the ports. Fishers could be considered as generalist people switching to the best opportunities available. They seem to concentrate in the most profitable species when available and pulling a mix of species that generate similar benefits when they do not have access to the others. The time assigned to a particular target or combination of species is assumed to be dependent on changes in the weather and availability of the resources , as well as socio-economic factors . However the weight of each variables in the decision-making process may vary from port to port.

General Considerations

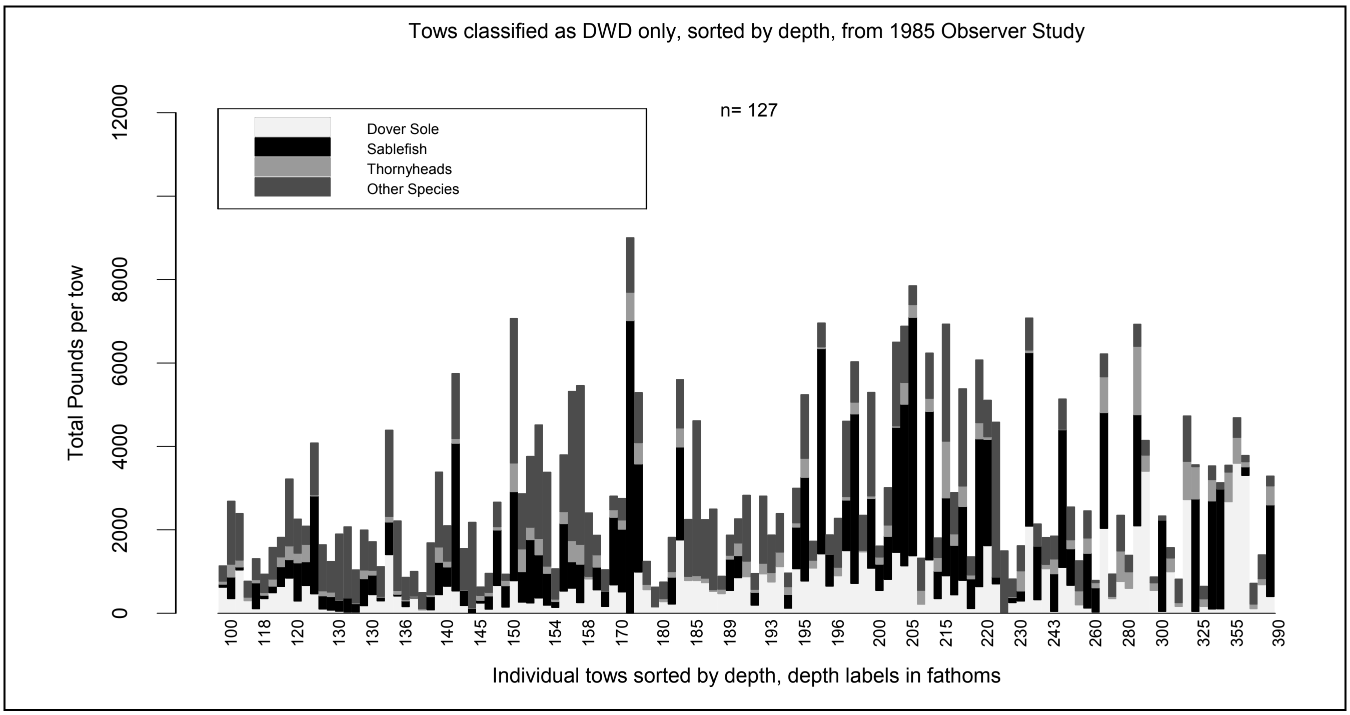
Differences in fishing patterns among an within ports is evident. Some of these differences are clear given the strategies developed by fishers in each port, as the cooperation teams in Dzilam Bravo, but are more uncertainty in others. The cooperation team strategy seems to pay-off in this port, even only a small group of fishers used it. Variation in fishing effort and competitive ability were also observed. However, the factors that define the strategies of fishers are not clear at this stage. It is important to evaluate the contribution of the variables involved in each port. This can lead to evaluate the impact that different management schemes may have in the strategies of small-scale fishers.

Bottom depth as a proxy for target species choice in the deepwater trawl fishery of the Oregon coast: A dynamic programming model

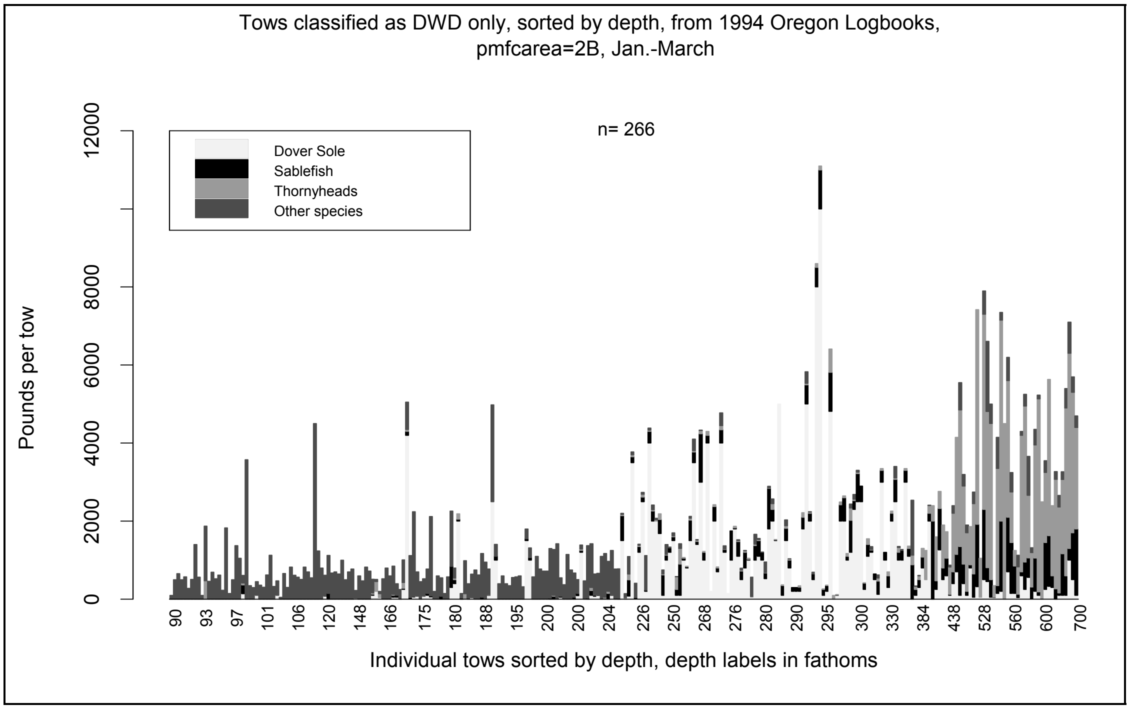
Elizabeth A. Babcock
School of Fisheries, UW

The deepwater trawl fishery off Oregon targets Dover sole (*Microstomus pacificus*), sablefish (*Anopoploma fimbria*), and thornyheads (*Sebastolobus* spp.) In order to maintain a year round fishery, the Pacific Fishery Management Council, which manages the U.S. west coast groundfish fisheries, has set limits on the landings by individual vessels, on the entire deepwater complex and on the individual species. The objective of this project is to determine whether fishers can target within the deepwater complex, and if so, to model fisher's choice of target species under various management regimes.

This species complex was first described by Pikitch et al. who interviewed fishers to determine which targeting "strategies" were used, as part of an observer study of discarding rates. One of the strategies described was the deepwater Dover (DWD) strategy, defined as, "generally catching Dover sole, sablefish, and thornyheads". Using the data from the 1985-1987 observer study, Rogers and Piktich (1992) used clustering and discrimination statistics to determine the species assemblages in the catch. They found that there was a DWD complex, composed of Dover sole and sablefish, with some association with shortspine thornyhead (*Sebastelobus alascanus*). The following shows the species composition of tows classified as DWD from the observer study from 1985, sorted by depth.



In 1985-1987, thornyheads and Dover sole were worth about $0.30 U.S. per pound, while sablefish was worth up to $1.00 per pound for the larger fish. In the last decade, the value of thornyheads has increased to more than $1.00 per pound for the larger fish; sablefish is slightly more valuable than thornyheads and Dover sole is still worth about $0.30 per pound. Unfortunately there is no observer data from this fishery between 1991 and 1996. Therefore, we are using logbook data to determine how well fishermen can target individual species by changing depth. For example, the following data is from Oregon logbooks from 1994, from the area off Newport, Oregon, during January through April.



Not all areas and seasons show so clear a relationship between depth and species composition. However, the logbook data clearly show that the fishery has moved to deeper water, and that thornyheads dominate the catch below about 500 fathoms.

The data from the Oregon logbooks will be used to paramaterize a dynamic programming model of fisher target species choice. The optimization criterion the maximization of the net profit from one month of fishing, for an individual vessel . The constraints are the current monthly cumulative landing limits and weekly trip limits on the deepwater species, and the decision variable is depth.

Reference: Rogers, J. B. & E. K. Pikitch. 1992. Numerical definition of groundfish assemblages caught off the coasts of Oregon and Washinton using commercial fishing strategies. *Can J. Fish. Aquat. Sci.* 49(12): 2648-2656

List of Participants

Anthony Courtney
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: tonyc@fisheries.com

Elizabeth Babcock
School of Fisheries
University of Washington
Box 357980
Seattle, WA 98195 USA
E-mail: bbacock@fish.washington.edu

Clint Alexander
School of Resource Management
Simon Fraser University

Dave Preikshot
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: preikshot@fisheries.com

Eny A. Buchary
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: eni@fisheries.com

Hreiðar P'or Valtýsson
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: hreider@fisheries.com

Ian Parnell
School of Resource Management
Simon Fraser University

Jacqueline O'Connell
Department of Biology
University of Victoria
E-mail: joconnel@uvic.ca

Jason Smith
School of Resource Management
Simon Fraser University

Jeff Grout
School of Resource Management
Simon Fraser University
E-Mail: jgrout@sfu.ca

Johanne Daslgard
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: johanne@fisheries.com

John Field
School of Marine Affairs
University of Washington.
E-mail: jcfield@u.washington.edu

Josie Osborne
School of Resource Management
Simon Fraser University

Judson Venier
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: judson@fisheries.com

Laura Vidal
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: lvidal@fisheries.com

Lisa C. Thompson

Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: thompson@ fisheries.com

Marcelo Vasconcellos
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: marcelo@fisheries.com

Maria Morlin
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: morlin@fisheries.com

Marla Maxwell
School of Resource Management
Simon Fraser University

Martin Liermam
School of Fisheries
University of Washington
Box 357980
Seattle, WA 98195 USA
E-mail: martin@oak.cqs.washington.edu

Narrima S Jiddawi
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: narrima@ fisheries.com

Ricardo Torres
Resource Management and Environmental Studies
University of British Columbia
E-mail: rtorres@unixg.ubc.ca

Rishi Sharma
School of Fisheries
University of Washington
Box 357980
Seattle, WA 98195 USA
E-mail: sharma@oak.cqs.washington.edu

Silvia Salas
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: salas@ fisheries.com

Steven Mackinson
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: smackin@ fisheries.com

Sylvie Guénette
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: sylvie@ fisheries.com

Taja Lee
Fisheries Centre
University of British Columbia
2204 Main Mall, Vancouver B.C. V6T 1Z4
E-mail: tlee@fisheries.com

William Pinnix
School of Fisheries
University of Washington
Box 357980
Seattle, WA 98195 USA
E-mail: pinnix@ fish.washington.edu