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Your ref. 90/13
Our ref. DF 12/22, 19/78

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15 December 1992

Executive Director
Fisheries Research and Development Corporation
PO Box 9025
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Dear Sir

RE: FINAL REPORT - PROJECT 90/13

Please find attached the final report to the Fisheries Research and Development Corporation of the FIRDC Project 90/13 titled "FISHERIES GRAPHICS SIMULATOR FOR SHARK, TUNA AND GEMFISH".

(i) Objectives

The objectives of the project were:

- To provide computer graphics, interactive models to industry members, scientists and managers of the southern shark, southern bluefin tuna and south east trawl fisheries.
- To improve management of these fisheries by increasing understanding of the implications of research results and of alternative management actions.
- To develop decision support tools for fisheries managers which provide new insights, improve communication betweeen scientists, industry and managers and can be used for educational purposes.

Two versions were produced of a software package called **SharkSim**, which was used in public and other meetings to communicate scientists' best understanding of Australia's southern shark fishery to industry and others. It had a significant effect in speeding up the process of education, understanding and consensus-building between various stakeholders in the fishery. It remains a useful decision support tool for analysing the fishery under certain assumptions.

Funds provided by FIRDC and other bodies were insufficient to attempt producing models for tuna or gemfish.

(ii) Funding and contributions

The SharkSim software package was created from

- Commercially available software purchased for the project;
- General purpose source code modules owned by Software Insight Pty. Ltd;
- Software specifically written for this application.

Software Insight Pty. Ltd. (SI) is a South Australian software company that has agreements with SADF relating to software development. In exchange for providing services for product development at cost or below, it retains rights to use software for non-fisheries applications.

During the past fourteen years, the South Australian Department of Fisheries has supported a population dynamics modelling project, staffed by Philip Sluczanowski and another mathematician. It has provided funding for salaries, operating funds, capital and paid for eight software development consultancies. The department developed two successful products using its own funding, YPR123 and PRAna.

Commonwealth Government funding bodies, FIRDC and FDTA, have helped fund three software development projects as follows:

	FIRDC		FDTA		
AbaSim	47,193				
SharkSim1	25,000		40,157		
SharkSim2E	20,000		65,000		
Total	92,193	+	105,157	=	197,350

The Research Organisation has a three year agreement with FRDC regarding AbaSim whereby FRDC receives a royalty of 10% of sales revenue.

Draft agreements are being prepared to reconcile the interests of potential users and the various parties involved in the development of the software to date. The Research Organisation will write to the FRDC shortly with proposals.

An agreement similar to that for AbaSim, but involving also FDTA, is envisaged.

(iii) Impact

SharkSim was commissioned by the Australian Fisheries Service (AFS) as "an agent for change" to convince industry and managers of the need for urgent and significant change in management of the fishery. It achieved this through a series of public meetings at fishing ports, followed by demonstrations and use by managers, politicians and other interested parties. The most significant result of these activities was the focussing of attention of stakeholders towards a common goal of understanding and interpreting complex scientific stock assessments. It hastened the advent of a new era of collaboration between industry and scientists.

Perhaps the most lasting effect of SharkSim on people who have seen and used it is that their conceptual understanding of fisheries population dynamics has risen significantly, leading to better decision making in future.

SharkSim won the 1991 Taronga Zoo Conservation Award and was highly commended in the 1991 IBM Conservation Awards. Dr Philip Sluczanowski presented the user interface technology at the 1991 American Fisheries Society Conference, the 1991 UK Marine Conservation Society Conference and the First World Fisheries Congress (WFC), where it was highly acclaimed. The final report of the WFC theme on Assessment Methodologies and Fisheries Management concluded that

> "Interactive procedures for fishery management decision making need to be used. Interactions among scientists, fishery managers, and clients can be facilitated with the use of software interfaces to build consensus in decision making . . from setting priorities for assessment research, to evaluating risks of alternative management schemes and developing criteria for success."

The methodology of building interactive graphics interfaces to models is being taken up by others. For example, James Scandol of James Cook University has developed a formidable program called COTSim to simulate Crown of Thorns Starfish on the Great Barrier Reef. The User Manual states that "It was inspired by . . . SharkSim, from the South Australian Department of Fisheries."

(iv) Recommendations

It is recommended that the new Fisheries Research and Development Corporation continue to support Fish Insight, the division of the Research Organisation responsible for computer graphics models, in further development and commercialisation of the technology. It can do so by:

- Funding projects that utilise and further develop Fish Insight technology and capabilities.
- Referring to Fish Insight projects that FRDC believes would benefit from application of the technology.
- Supporting Fish Insight as a "Centre of Excellence" in this area by encouraging potential "re-inventors of the wheel" in Australia to collaborate with Fish Insight rather than to compete.

I shall write to you soon regarding proposed arrangements for managing intellectual property arising from the project.

I thank you for your support and assistance.

Yours sincerely,

(R.K. Lewis)
DIRECTOR OF FISHERIES

FINAL REPORT

1 FRDC PROJECT NUMBER

90/13

2 PROJECT TITLE

FISHERY GRAPHICS SIMULATOR FOR SHARK, TUNA AND GEMFISH

3 ORGANISATION

Name:	SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE (SARDI)		
Department:	Department of Primary Industries		
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4 PRINCIPAL INVESTIGATOR

Name:	Dr. Philip Sluczanowski		
Postal Address:	as above	Location:	as above
Phone:	(08) 226 0633	Facsimile:	(08) 226 0693

5 FUNDING ORGANISATION

FISHING INDUSTRY RESEARCH AND DEVELOPMENT COUNCIL (FIRDC)

6 SUMMARY

SharkSim is a computer-based interactive graphics model of Australia's southern shark fishery.

SharkSim 1 was commissioned by members of the Southern Shark Fishery Structural Adjustment Task Force (SSFSATF) of the Australian Fisheries Service (AFS) as "an agent for change" to convince industry and managers of the need for urgent and significant change in management of the fishery.

Based on the best available data and population dynamics models, it simulates the effects of fishing effort by various gears on population structure, pups, catches and catch rates. The user can easily change control variables or model parameters and immediately see the effects as coloured dynamic graphics.

A working version of SharkSim 1 was completed in February 1991 and was demonstrated at industry meetings in ports in South Australia, Victoria and Tasmania. It was very effective in communicating scientists' best understanding of the fishery to date. Fishermen and their representatives were initially taken aback by the stark message of overfishing communicated by the model. The Minister of Primary Industries understood the rationale for the advice being presented by managers and instituted tough measures to contain fishing effort, at the same time as releasing funding to check the accuracy of the models underlying this advice.

During the months that followed, understanding of the stock, population dynamics and management issues grew substantially. Fishermen questioned why the outcomes predicted by SharkSim failed during certain years and also pointed out that their personal observations contradicted some of the key features of the presented scientific models.

Whilst industry did not accept the model's findings, it publicly praised the use of computer graphics in

> "providing an open mechanism for meaningful comment and criticism. This work has put the scientist's cards on the table, and taken the issues out of the ivory tower environment. This examples is one of the very few efforts to reasonably address the communications gap."

The SharkSim exercise helped force stakeholders in the fishery to confront stock assessment issues. Scientists were forced to take greater note of what fishermen reported and industry appeciated more the difficulties of stock assessment. A joint industry/scientist/management body called SIRLC (Shark Industry Research Liaison Committee) was formed and has resulted in new levels of cooperation and a coordinated approach to the management

problem by all parties. A number of these participants have stated their belief that SharkSim was the catalyst that speeded the evolution of events, thereby significantly contributing to the future benefits that will be gained from the fishery.

Under the guidance of the Bureau of Rural Sciences (BRS), SharkSim 1 has been consolidated into a more comprehensive software package (SharkSim 2E) that models the southern shark fishery based on the assumption of homogeneous populations. The Australian Bureau of Agricultural and Rural Economics (ABARE) provided economic models that have also been included in the package.

Funding from the Fishing Industry Research and Development Trust Fund ($45,000) was used to supplement the primary funding for the project, which was provided by the Fisheries Development Trust Account (FDTA) and the developers (South Australian Department of Fisheries, Software Insight Pty. Ltd.).

7 BACKGROUND - THE NEED

Scientists have often remarked that "fisheries management decisions involving industry and managers often don't take account of what we know about the fish stock." On the other hand, fishers often complain that scientists don't take account of their extensive observations and knowledge when they try to gain an understanding of stocks.

The problem is one of communication.

Scientific models and interpretations of data require complex analysis and a grasp of difficult statistical concepts. Stock assessments traditionally feature equations, tables and graphs that cannot be understood by non-specialists.

Recent advances in computer technology have opened the possibility of new methods of communication.

The "computer graphics simulator" project arose out the belief of the Principal Investigator that interactive graphics models of fisheries that employed the latest techniques of visualisation and game design could be used to communicate key issues in some of Australia's major fisheries. In particular, a lack of appreciation of the key population dynamics issues appeared to be holding back progress in management of the southern shark, southern bluefin tuna and gemfish fisheries.

8 OBJECTIVES

The objectives of the project were:

- To provide computer graphics, interactive models to industry members, scientists and managers of the southern shark, southern bluefin tuna and south east trawl fisheries.

- To improve management of these fisheries by increasing understanding of the implications of research results and of alternative management actions.

- To develop decision support tools for fisheries managers which provide new insights, imporve communication betweeen scientists, industry and managers and can be used for educational purposes.

9 METHODOLOGY

Data and preliminary modelling were provided by Dr. Terry Walker of the Victorian Marine Science Laboratory. Dr. Jeremy Prince was engaged as the modeller who calibrated the original mathematical model to the latest data. He later engaged in intensive industry liaison to further check the model's accuracy.

Software Insight Pty. Ltd. carried out the systems design and programming work. They also provided extensive database tools. The principal investigator designed the architecture of the user interface and sketched the representations that would appear on the computer screen. John Tonkin, a computer artist, programmed the actual screens.

The project involved the coordination of a number of diverse skills and capabilities within a formal project management framework for software development.

Although the developers had successully completed the AbaSim software package, SharkSim presented significantly greater technical challenges. Since (to our knowledge) no-one had ever built a similar software package before, the project had high technical risks. Most of the development of SharkSim 1 occurred in an intense three month "hothouse" atmosphere created by a deadline of scheduled industry meetings. Less than half the design and programming effort were paid for.

The addition of economics modules to create SharkSim 2E resulted in even greater technical problems. The commercial software tools being used for development (DOS, Paradox, C++) could no longer handle the complexity of the task and the developers had to collaborate with suppliers overseas to enable the package to be completed. DOS had to be substantially modeified. In the end, less than a quarter of the necessary design and programming time was paid for. However the project was completed and the software stands alone in comparison to similar existing products.

10 DETAILED RESULTS

The summary above describes the application of the model and its effects. Press cuttings relating to SharkSim and its use are appended (A).

11 DISCUSSION

As described above, the project achieved the objectives of the project for the southern shark fishery. Insufficient support for a computer graphics model for southern bluefin tuna or gemfish prevented these models from being attempted.

Feedback from participants at the 1st World Fisheries Congress in May 1992 indicated that a number of world leading fisheries scientists and managers (Beverton, Pauly, McGlade, Saila, Garcia) believe the technology is revolutionary and an important future direction in fisheries management. The final report of the theme on Assessment Methodologies and Fisheries Management concluded that

> "Interactive procedures for fishery management decision making need to be used. Interactions among scientists, fishery managers, and clients can be facilitated with the use of software interfaces to build consensus in decision making . . from setting priorities for assessment research, to evaluating risks of alternative management schemes and developing criteria for success."

The Australian Research Organisation that carried out the project now has the capability to develop further such models more cheaply and with less risk.

The project originally was aimed at improving communication between scientists and non-specialists. However, as the new technology was developed and used, new benefits became apparent.

Firstly, interactive graphics models can be used in the form of "managament games" that gave the users new insights into the dynamics of fisheries systems they have to manage. Just as the designer of an aeroplane understands the equations and dynamics of an aeroplane, he (she) still does not necessarily know how to fly. A flight simulator offers such a person new insights. They gain a "feel" for the dynamics, which represent insight and understanding well beyond what most people can gain from studying equations, tables of figures or static graphs.

Perhaps more importantly, interactive graphics models of fisheries provide access to models by non-specialists. The developers believe that in time, easy-to-use interfaces will enable fishers themselves, if they wish to, to enter data, analyse it and plan fishing management strategies in conjunction with other stakeholders. In the meantime, SharkSim and similar models, will play an important role educating people about fisheries management and about the need for good modelling.

12 IMPLICATIONS & RECOMMENDATIONS

"How do we enlighten and move decision-makers " and "make it possible for them to take tough decisions ?". This project has been based on the premise that the best way to achieve this is to make the understood consequences of alternative decisions so obvious to everyone that managers will make rational decisions.

SharkSim's greatest benefit was that it speeded up the processes of educating industry and managers about what scientists understood and of bringing stakeholders together constructively. A two year delay in taking tough action in the southern shark fishery could delay its recovery by 15 years[1]. Therefore the use of a computer graphics tool that "speeds up the process" of consensus-building could easily be valued at over $100 million.

The main thrust of this project has been to invent and develop a new technology (interactive graphics) for making models accessible to non-specialists. When judging its effectiveness, it is important to separate in one's mind the population dynamics models that underlie SharkSim from the graphic user interface.

The developers believe that SharkSim demonstrates a communications technology that will become increasingly important in the future. This view is reinforced by the reception the software received overseas and by the general reaction of the Australian fishing industry, many of whom have asked for similar interfaces for models used in their fisheries (e.g. SA rock lobster).

[1] This can be easily simulated using SharkSim.

However such software is not cheap to produce and because it is new, not all stakeholders are convinced that its production is cost justified. For example, some scientists argue that gaining improved knowledge about fish stocks is more important than spending scarce funds on extending to others what the scientists already understand. Some believe that communication of results should be marginal to the costs of research.

Whilst many scientists originally regarded interactive graphics models with scepticism (e.g. "pretty pictures and games"), their value is being increasingly recognised. The rate at which the technology will be adopted depends on its costs, perceived benefits and, to some extent, on the factional interests of stakeholders in the fisheries management process.

The developers plan to strengthen their capabilities in delivering user interfaces to data and models in fisheries and other areas, stressing quality and value for money.

The Fishing Industry Research and Development Council provided some funding in support of the new technology. It is recommended that the new Fisheries Research and Development Corporation continue to support the Research Organisation (Fish Insight) in its further development and commercialisation. It can do so by:

- Funding projects that utilise and further develop Fish Insight technology and capabilities.
- Referring to Fish Insight projects that FRDC believes would benefit from application of the technology.
- Support Fish Insight as a "Centre of Excellence" in this area by not encouraging Australian potential "re-inventors of the wheel" to collaborate with Fish Insight rather than compete.

13 INTELLECTUAL PROPERTY

The intellectual property arising from the project is source computer software used to programme the underlying simulation models and the user interface and the resulting software packages.

Draft agreements are being prepared to reconcile the interests of potential users and the various parties involved in the development of the software to date. The Research Organisation will write to the FRDC shortly with proposals.

14 TECHNICAL SUMMARY

A copy of the SharkSim 1 User manual is appended (B). The software can be viewed at user sites as agreed with the sponsors of the development under FDTA funding (AFMA, BRS, ABARE, CSIRO + various state departments).

A working version of SharkSim 2E has been delivered to BRS for testing. A specification of the underlying population dynamics models is appended (C).

APPENDICES

A Press cuttings about SharkSim

B SharkSim 1 User Manual

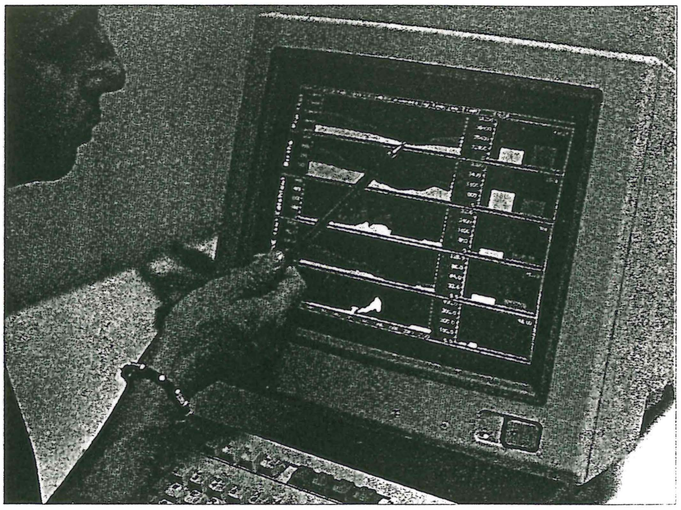
C SharkSim 2E population dynamics models

A Press cuttings about SharkSim

2: Fishing for sympathy with computer simulations

IN THE battle to convince politicians of the need to protect sharks, researchers are turning to computer simulations. Philip Sluczanowski of the South Australian Department of Fisheries heads a group of biologists, computer experts and graphic artists who have developed a mathematical model known as SharkSim.

SharkSim is an interactive computer model of the southern Australian fishery for gummy shark and school shark. It simulates the effects of fishing on sharks and presents the results in full-colour graphics. The user can easily change variables—such as how many boats, fishermen and nets are involved, for how long, and the type of gear used—to see immediately the impact on the population structure, pups, catches and catch rates.



Philip Sluczanowski/South Australian Dept of Fisheries

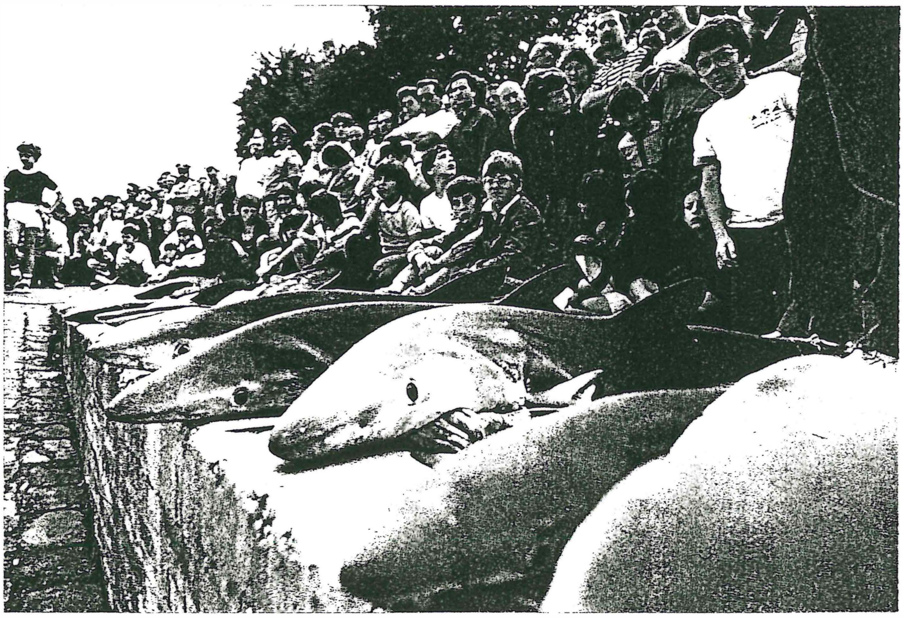
Persuasive model: Sluczanowski predicting the effects of fishing on shark populations

Early this year fisheries scientists began using the model as an educational tool. They have visited politicians, policy makers and fishermen, using SharkSim to explain why they believe that drastic action is necessary to prevent the collapse of the local shark population. Previous attempts to convince key participants of the need for change have had little success, but SharkSim has already had positive results. In March, Australia's Commonwealth minister responsible for fisheries, John Kerin, announced an immediate reduction in shark fishing as an important step towards a long-term management regime.

SharkSim has been successful because it gives nonscientists "insights not numbers", says Sluczanowski. "People see, feel and experience the evolution of the fishery in time. It moves on the screen," he says. It is also fun and simple to use. "I'm using my eight-year-old as a test."

probability of being killed by a shark is infinitesimal compared with the chances of drowning or dying from a bee sting.

So why the bad image? Films such as *Jaws* undoubtedly have a lot to answer for. But there is another reason: until recently, even biologists knew surprisingly little about most species, and knowledge is still "fragmentary", says Stevens.



Planet Earth

Animals we love to hate: shark conservationists see educating the public as a top priority

Shark life histories are a particular mystery. There are vast gaps in our understanding of the development and reproductive cycles of most species.

Much of the information that is available about shark biology and behaviour has come from fish caught in beach nets. To remove sharks from areas near public beaches, countries such as Australia and South Africa maintain extensive netting programmes. But researchers can glean only sparse biological information from these programmes, as the relatively few fish that are caught are often not representative of the population at large. And ocean-going studies are inherently difficult.

John Paxton, a shark researcher at the Australian Museum in Sydney, sums up the problem: "We can't get down there [into the ocean] and be with them all the time. You can't put a tag on individuals and follow them through life." Similarly, obtaining representative samples of sharks for study in the laboratory can be laborious, and therefore expensive.

To halt the decline in shark populations, researchers are calling for controlled fisheries, protected nursery areas for young sharks, shark reserves and an international ban on finning. They also want more research to enable experts to develop detailed conservation and management strategies. But the researchers stress that they cannot act alone: they need financial, legal and political help, as well as cooperation from the public. Otherwise, they fear, future conservation programmes—perhaps even the forthcoming US controls—will fail as badly as Australia's attempt to protect the grey nurse shark.

Meanwhile, Australians and South Africans continue to demand extensive beach netting of sharks. Australians net between 1000 and 1500 sharks each year and, according to Geremy Cliff, a biologist on the Natal Shark Board, South Africans net an average of 1400 sharks annually. Convincing people of the need to curb such activities may prove a tall order for shark researchers, some of whom worry that even if the public's attitude does shift, the change may prove too little, too late. Robert Heuter summed up their concern at the Sydney meeting. He showed a slide of an American roadside billboard. The sign was intended for a sports club, but the sentiment was applauded by the gathered scientists. The message: "Good luck, sharks!"

Scientific responsibility in communication

FROM: Peter Peterson
Executive Director
South Australian Fishing Industry
Council Inforporated
Unit 7/70 Walkerville Tce
Walkerville SA 5081

SIR:

I read with some interest the dialogue between Dr Kesteven and Dr Penn.

The sarcasm evident in both letters belies the professionalism of both parties. There is no doubt in my mind that Dr Penn should have addressed the purported errors of fact and not attacked the messenger. Further, I find it surprising that Dr Kesteven should be replying in a similar vein.

Recent events in the southern shark fishery have highlighted the need for scientists to be both open and accurate in terms of their scientific work. Industry involvement in all facets of fisheries is something to be sought, and has not occurred in a reasonable manner until very recent times. Dr Sluzenauski, in establishing his shark model, had a primary goal of facilitating effective communication with industry. Such an approach is to be commended.

Even if industry does not accept the model's findings it provides an open mechanism for meaningful comment and criticism. This work has put the scientist's cards for the shark fishery on the table, and taken the issues out of the ivory tower environment. This example is one of very few efforts by fisheries scientists to reasonably address the communication gap.

The point scientists must note is that fishermen do read "Professional Fisherman" and like publications, but rarely read the excellent but non communication orientated academic journal. Fisheries scientists do determine many people's livelihoods and in my view are duty bound to expose their work in an understandable format, in an accessible form, as often as possible.

How useful is the SharkSim model?

Russell Reichelt, chairman of the Southern Shark Research Group and director of the Fisheries Resources Branch of the Bureau of Rural Resources, gives his assessment of SharkSim.

Scientists published their first warning about the risks of over-exploitation in the southern shark fishery in 1959. Our current advice is that a cut in current catch levels of between 70 and 80 per cent is required to halt the decline of the school and gummy shark stocks.

The difficulty in communicating this message to fishermen lies in the perennial problem that fishermen can still take substantial catches at what they view as 'reasonable' (that is, economically viable) catch rates from what scientists have assessed to be a very depleted population.

A similar situation existed in gemfish and southern bluefin tuna. In the case of gemfish, also a schooling species, scientists have been shown to be very *optimistic* in their assessments in the past.

To the individual fisherman, the fishery appears to be in a long-term stable state or, at worst, only slowly declining. To the scientist, taking a view spanning more than 60 years and incorporating the biology of the species, the high catches since the 1960s (a period representing only half the natural life span of a school shark) coupled with the fact that they have been taken with steadily rising effort, signal a stock that is headed for collapse.

In spite of these differing views, there appears to be broad agreement among all parties that the stock is in decline and that strong management action is needed. The disagreement seems to lie mainly in the degree of catch restriction and in the speed with which this action is taken.

We know the SharkSim model is not perfect — no model ever will be — but it is our best available representation of the fishery. It incorporates most of our present knowledge of the stocks and has been useful in illustrating some of the long-term aspects of the fishery to fishermen and managers alike.

One of the aims in developing the model was to help scientists explain the implications of their findings to others. I think we are all agreed that communication between scientists, managers and industry has long stood in need of improvement. To this extent, the model has been successful. Undoubtedly it has been instrumental in prompting radical management action in the restructuring of the southern shark fishery.

Although SharkSim is a mathematical model, it does incorporate a large amount of biological information about school and gummy shark. Because it is non-spatial it cannot illustrate very well the regional variation in the fishery. For example, the South Australian fishery has expanded to the west and recent catches from this sector are not simulated well because the model uses catch data from the stock further east.

These regional effects are being looked at now to assess whether allowance for them will significantly change the results from the model. Scientists are also acutely aware of the need to discuss fishermen's observations to a much greater extent, and to incorporate these into the assessment process where possible.

In spite of these weaknesses, Sharksim has enhanced our understanding of the present state of the fishery and, used cautiously in conjunction with other fishery models, allows us to make useful predictions about the likely future of the stock under different levels of fishing pressure

Considerable attention has been focused on SharkSim, but often in a selective way. For example, one of the results publicised from the February 1991 assessment was that the stock biomass may be as low as 9000 tonnes. In the same report we said this estimate could be wrong by a factor of two, that is, there may be 18 000 to 20 000 tonnes standing stock. This qualifier tends to be ignored by SharkSim critics, or worse, it is taken to mean that the yield estimate we have given (500 to 800 tonnes) may be in error by the same margin. That doesn't follow. Even if the standing stock level is higher than we have so far judged, the yield estimate may not be significantly higher.

This misunderstanding highlights the need for us to communicate the areas of uncertainty in our assessment more effectively.

Scientists have acknowledged the assumptions inherent in SharkSim and we are continuing to rigorously test the model. Work is also continuing on other models of the shark populations. During the three months in which we will be refining our preliminary assessment of the fishery, we will be addressing both fishermen's and scientists' concerns about SharkSim in order to provide a firmer basis for management actions.

'We know the SharkSim model is not perfect — no model ever will be — but it is our best available representation of the fishery.'

SHARK IN CRISIS

Gillnet operators in the southern shark fishery have recently been hit by drastic gear restrictions. Hook fishermen are also feeling the pinch as the Government attempts to reduce annual catch from over 3500 tonnes to around 650 tonnes.

'Australian Fisheries' invited industry leaders to let off steam, and their opinions are featured in 'Talkback' (page 13). But first we present the background to these recent management developments.

Since the early 1980s scientists have advised that an annual catch level of 2700 tonnes is an appropriate target level if the southern shark fishery is to be commercially viable in the long-term. That figure has been exceeded every year since 1982, in spite of the management plan introduced in 1988 which was specifically aimed at reducing the level of catch from around 3500 tonnes to meet the target.

In February this year, after a concentrated program of research, scientists advised that their earlier estimate was optimistic and that catch levels must be reduced substantially and immediately if the decline of the fishery was to be brought to a halt.

Scientists now consider that the biomass of both the school and gummy shark stocks — which are the main species of the fishery — have been reduced to less than 30 per cent of their original levels. Moreover, the age structures of the current stocks show a worrying imbalance. The older part of each stock has been virtually removed, which will have a drastic effect on recruitment, as the fecundity of these species increases with age.

Allied with the recent increase in research activity in the fishery has been the development of a computer-based model of the fishery called 'SharkSim'. SharkSim is an interactive graphics software tool which can be used to determine and illustrate how school and gummy shark populations and yields vary with quantity and type of fishing effort.

The computer graphics program of the model is based on two highly successful models developed by the South Australian Department of Fisheries — 'AbaSim', which simulates part of the Tasmanian abalone fishery, and 'PRAna' (Per Recruit Analysis), a software package which scientists can use for analysing how changes in age at first capture and fishing effort affect eggs, catch and catch rate per recruit. The shark population dynamics program is derived from the work of scientists Terry Walker and Mick Olsen, representing 40 years of research experience.

SharkSim encompasses data on the fishery recorded since 1927. It takes account of all available information on equipment selectivity, the biology of the two species and catch histories, including anecdotal evidence from fishermen. It has been critically tested for internal consistency and has also been assessed by independent scientists using alternate models.

This assessment is continuing as scientists attempt to refine the fishery models and test whether biases in the catch and effort data will influence the conclusions drawn from the model.

The SharkSim model has been used to predict a number of options for the level and timing of future catch reductions in the southern shark fishery to meet the latest target levels advised by scientists.

The outcomes of this model, coupled with scientific advice that catches of school and gummy sharks should be reduced to less than 1000 tonnes, were put before the Southern Shark Fishery Restructuring Task Force, which encompasses Government and industry representatives from all southern States, in February. Meetings were also held with fishermen in Melbourne, Adelaide, Hobart, Port Lincoln, San Remo and Lakes Entrance to allow them to view SharkSim's predictions and discuss management options. These followed on from the intense round of Government/industry consultations which took place in 1990, including a series of port meetings last August.

The initial response of the Task Force to the scientific advice and outcomes of the model was to recommend a closure of the fishery for a three-month period while longer term management options were developed.

This response took into account the preliminary nature of the scientific assessment as well as the known uncertainties of the SharkSim model. It was considered that these uncertainties, even if resolved, were not significant enough to warrant a major change because of scientists' advice.

Alternative measures to total closure were proposed by Task Force members to accommodate a number of practical concerns:

- ☐ Mr Rob Lewis, Director of the South Australian Department of Fisheries, proposed an annual TAC of 500 tonnes to be taken by a limited number of fishermen to provide an ongoing source of data to assist further scientific research.
- ☐ Mr Dale Bryan, Executive Officer of the Tasmanian Fishing Industry Council, proposed an initial ban on gillnets with the qualification that some net fishing for gummy sharks could be permitted in the future if circumstances warranted.
- ☐ Industry representatives from South Australia (Mr Peter Peterson) and Victoria (Mrs Melita Proebstl) questioned the validity of the model, but acknowledged that if the scientific advice was correct, drastic action was required. Their final position was to support a 36 per cent reduction in nets to be used pending confirmation of the state of the stocks.

The Task Force recommended to the then Minister of Primary Industries and Energy, Mr John Kerin, a 50 per cent cut in all gillnet holdings.

Interim management

Taking into account the wide range of views from various sectors of the fishery, and bearing in mind that any measures would be temporary, the Minister endorsed the introduction of interim arrangements which have resulted in a reduction of around 33 per cent in gillnets and controls on shark catches by hook and trawl fishermen (see April issue of *Australian Fisheries* for details). These net reductions, effective from 15 April, are to be reviewed when the preliminary scientific advice has been refined after a three-month period of additional research. Results could be available by August 1991.

The Task Force is currently deliberating several options for adjustment in the fishery, which is now considered a matter of urgency.

For further information about the southern shark fishery contact Mr Campbell McGregor, AFS manager, Shark, Scallop and South East Trawl Fisheries, telephone (06) 272 5184.

SOUTH AUSTRALIAN DEPT. OF FISHERIES WINS INTERNATIONAL SHARK CONSERVATION AWARD

By BECCA SAUNDERS

Scientists from the South Australian Department of Fisheries won the inaugural $2000 Conservation Prize awarded at the Taronga Zoo's Sharks Down Under Conference.

SCIENTISTS from the South Australian Department of Fisheries have been awarded the inaugural Taronga Zoo Conservation Award for a computer software package set to revolutionise the way in which scientific advice influences management decisions about fish resources.

The local team, headed by Dr Philip Sluczanowski was contracted by the Australian Fisheries Service to develop the software in order to visually communicate scientific understanding of the southern shark fishery to managers and to the public.

The computer model simulates the effects of fishing on Australia's southern shark populations from infants to fully mature adults and calculates the resulting catches and catch rates. It then uses coloured graphics displays to illustrate the evolution of the fishery and how its future is likely to be affected by alternative management strategies.

Prior to attending the conference, the developers of the package visited fishing ports where they used the model to explain to fishers why they believe that drastic action is necessary to halt the decline in the fishery and then how to rehabilitate it under alternative management arrangements.

Computer graphics models allow fisheries scientists to make plain their advice. They believe that by making scientific interpretations much easier to understand, this new technology will play an important role in the future, ensuring that harvests are kept to sustainable levels.

Adelaide based company, Software Insight Pty Ltd provided the computer systems development services for the project, which was funded by the south Australian Department of Fisheries, the Fishing Industry Research and Development Trust Fund and the Fisheries Development Trust Account.

Director of Fisheries, Rob Lewis, said that the model used a combination of over forty year's of research into the shark fishery by Australian scientists including Mr A.M. Olsen and Mr Terry Walker from the Marine Science Laboratory at Queenscliff in Victoria.

The aim of the Conservation Prize was to recognise the paper presented at the Taronga Zoo's Sharks Down Under conference which made the most valuable contribution to elasmobranch conservation. Chosen from 64 possible presentations made by scientists from all over the world, this Australian paper was considered the best.

RAIL LINK PLAN FOR AIRPORT

THE NSW government has called for expressions of interest from the private sector to develop a rail link from Sydney city to the airport. At present airport users travel by road, by car, taxi or express government bus service.

The expressions of interest are to canvass all options for a rail link from Central railway station to the airport, including expansion of an existing goods line on which containers are carried to Port Botany. The cost of the new link could be in the vicinity of $200m.

The NSW Minister for Transport, Bruce Baird, says a recent environmental impact statement that favoured construction of a third runway at Sydney airport, forecast that the number of passengers using the airport would rise from the present 14m a year to about 24m in 10 years.

An increase of this size would worsen the already bad road congestion between the city and the airport. Travelling times have been lengthening in recent years, but a rail link could cut the time to 15 minutes.

A private consortium comprising Qantas, CRI Ltd and Westpac, has recently prepared its own proposals for a rail link between the city and the airport. Bruce Baird says this proposal is exciting, but government policy requires expressions of interest to be called. The time for lodging expressions of interest close early in November.

NEW TAXATION OFFICES

NEW OFFICES are to be built for the Australian Taxation Office (ATO) in Bankstown, in Sydney, and Chermside, in Brisbane, as part of ATO's program of modernisation and decentralisation.

The Bankstown office will have 650 Taxation staff, and there will be up to 700 in the Chermside office.

Two NSW government departments, Local Government and the State Pollution Control Commission, are relocating to Bankstown.

Both the new ATO offices will be of six levels. The Bankstown building will be constructed by Meredith Projects and leased back to the Commonwealth. It is expected to be finished in May 1992. The Chermside project will be built by Silverton Ltd, and work is due to start in February 1991.

COMPUTER GRAPHICS IN THE SHARK INDUSTRY

A COMPUTER-BASED model is to be developed of the southern shark fishery using interactive graphics.

The project is being undertaken by the South Australian Department of Fisheries in collaboration with the Victorian Departments of Conservation and Environment, and a firm of consultants.

The Commonwealth is putting in $40,000 and the Fishing Industry Research and Development Council another $25,000 towards the cost.

The Minister for Primary Industries and Energy, John Kerin, announcing the grants, says using computer interactive graphics will being a new level of sophistication to fisheries research, management and communication with industry.

It will enable improved management decisions through easier analysis of known fishery dynamics, assumptions, alternative strategies, risks and benefits.

Using the model, it will be possible to identify combinations of fishing effort, catch and size limits that produce sustainable stocks, in contrast to those that lead to stock extinction. John Kerin believes the value of the technique will be accepted quickly here, and will be applied in other fisheries in Australia and overseas.

The project is to be finished by February 1991.

NON DECISION MAKING

The catastrophic situation that purportedly faces the shark fishing industry in Australia is largely the result of indecision and poor communication.

Clearly, effort has increased more than significantly in that fishery. Warnings commenced with Mr Olsen as early as the 1950s and warnings have been continued by scientists since that time. However, all such advice has been accompanied with qualifications that the scientific community might be wrong. Such qualifications gives the fisheries manager an excuse not to address the problem directly, if at all.

Accordingly, scientific evidence must be accompanied by strength of commitment and clarity of argument. The argument must be clearly unambiguous and provide a clear layman's explanation of work being undertaken. Otherwise, the strongest argument will fail for lack of support.

As a person who has been involved in the scientific community it is clear to me that many scientists have a passionate fear of being seen to be wrong. There is reflection of an ivory tower mentality, in that often views are qualified or withheld for fear of peer group criticism or even ostracism.

Such consideration inhibits open discussion and the clear statement of objectives and proceedings in an intelligible manner. Consequently, commitment to analytical results is qualified by the expectations of the academic community.

Most fisheries are fully exploited or over exploited, for instance, the shark fishery, the gemfish fishery, various marine scale fisheries, scallop, etc., and the maintenance of resource in such a state requires a ready response mode facilitated by direct communication with both industry and management.

In the shark fishery we have had 40 years of worrying. What do we have now extreme overcapitalisation, an apparently worsening problem, government inaction and,worst of all, no industry confidence. Moderate decision making even 10 years ago would have saved industry from the extreme management decisions that are now being suggested as necessary.

COMMUNICATION ENHANCEMENT

The two leading examples of effective industry and government commitment are the Western Australian Rock Lobster Roadshow and the Annual Queensland prawn workshop. Both these approaches facilitate direct industry input into decision making and expedite the explanation of technical approaches to fishermen.

South Australia has had two outstanding examples of effective communication by scientists which have engendered industry confidence that scientists can communicate in an open and meaningful manner.

The Sharksim model developed by Dr P Sluczanowski and Dr J Prince has proved to be invaluable.

Industry perceives this model as being 'user friendly' and facilitates a 'laying the cards on the table' approach. This recent development is applauded by industry as the most complete communication devised as yet. This is not to suggest that the model is endorsed, rather that it has facilitated criticism and input by industry. That is, the problem is now being addressed in a manner that is meaningful to all concerned. The problems, in this case, are the gravity of the situation in the Southern Shark Fishery which requires immediate decision making, and that the opportunity for industry input is still perceived to be insufficient.

The other outstanding example of effective communication has occurred through the biologists servicing the Spencer Gulf prawn fishery — reportedly one of the best managed fisheries in Australia.

In this fishery the commitment of an ongoing interface of research and industry has allowed the recognition by all parties that the annual catch depends on the levels of recruitment, growth, and mortality in specific areas of the gulf. The profitability generated by the fishery is largely influenced by the level of recruitment, biovalue, and costs associated with harvesting through confidence in consultation and scientific advice. The biological advisers have been forthright in their advice and have recognised that one of the most important components in the management of a fishery is the industry itself. Mutual cooperation between fishermen, biologists, and managers is of paramount importance. The fishermen provide valuable data and have the potential to take an active role in both research and management. This has been exemplified by the Spencer Gulf prawn fishermen who over the last eight years have provided vessels and funds for research, as well as playing an active role in the conduct of research management, and allowing a detailed management program strategy to be established.

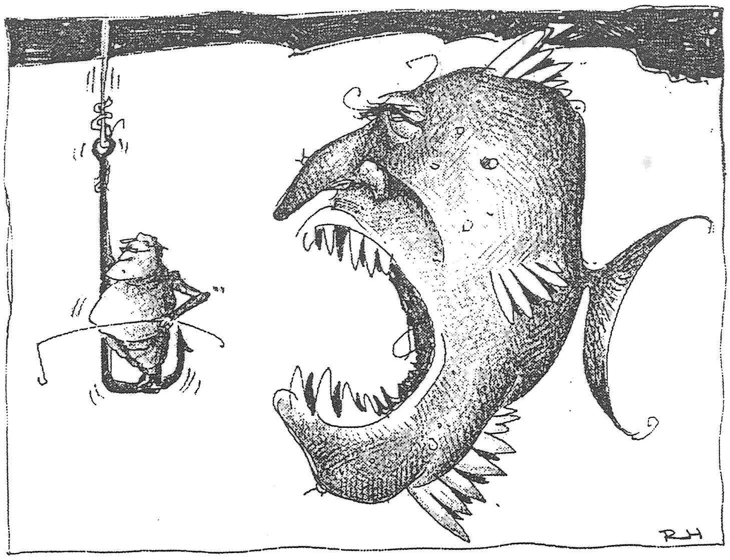
Such a detailed and effective program is not possible without detailed and effective communication.

Regrettably this open communication has been facilitated by the work of individuals and cannot be considered a general perspective of the scientific community. Non directional research has and will continue to be condemned by industry.

cont.

Fishing's future on the line

Government is taking tough steps to tackle the fishing industry's development-versus-sustainability dilemma. ROBERT GARRAN reports.



LIKE other Australian primary industries, Australia's fishing industry is in crisis.

But where wool and wheat are in dire straits because of slumps in their markets, Australia's fisheries are fighting a losing battle with the environment.

Some of Australia's biggest fisheries, like many others around the world, are close to extinction.

Although the issue does not raise the hackles of the green movement like forestry or mining, the environmental implications of the Government's fisheries management are just as far-reaching.

Once again, the Minister for Primary Industries, John Kerin, has found himself struggling to strike a balance between development and sustainability.

This time, he is leaning very much towards the advice of scientists who have urged severe reductions in the catch from most Australian fisheries. The latest to come under his scrutiny is the southern shark fishery, which extends from eastern Victoria to the western boundary of South Australia, including waters off Tasmania.

Mr Kerin wants to reduce the annual catch by more than three quarters.

In one respect, this battle is easier than some of the others he has fought: the fishing industry is made up of a large number of boat-owners, most with just one boat, some with two or three. Individually, they lack political clout; strong individualists, they are not strong members of industry groups.

Although not contesting the general arguments made by the scientists, the industry strongly contests the detailed predictions, which they say have not been adequately researched.

One grim forecast is that if the southern shark fishery were shut down today, it would take 15 years to return to a sustainable level.

Faced with such figures, Mr Kerin's department undertook a review of fisheries policy, contained in a paper released in December 1989, *New Directions for Commonwealth Fisheries Management in the 1990s*.

In it, Mr Kerin painted a stark picture: "World-wide experience has shown that unregulated fisheries generally suffer from over-capitalisation and falling productivity and, with increasing frequency, face the threat of biological collapse."

His announcement in March of severe restrictions on shark fishing is the latest decision flowing from this new approach.

Fishermen are furious at the move, which they say is based on inconclusive scientific evidence and will devastate the industry.

For Mr Kerin, however, it is the kind of desperate measure needed in an industry he believes will otherwise face extinction.

It is an example of the need for principles of ecologically sustainable development — and also of the problems in applying them.

In the southern shark fishery, the annual catch needs to fall to between 500 and 800 tonnes, down from its recent annual level of 3,500 tonnes, Mr Kerin says.

His first step is much more modest — a reduction of almost a third in the number of nets fishermen are allowed to use.

Even this would be a severe cut in any industry, and the fishermen insist it will be enough to bring the shark catch down to sustainable levels.

Mr Kerin's advisers disagree. He has tried to meet some industry concerns by looking further at the scientific evidence on the fishery, but officials claim the 30 per cent cut is not likely to reduce the catch at all, as fishermen will simply increase their fishing effort to maintain their incomes.

There is little doubt Mr Kerin will introduce much harsher measures by the end of the year.

The fish shops of Melbourne, which use the bulk of the shark produced from the fishery, will be forced to find alternative sources of shark meat (known as flake) or use other species; prices will rise.

But for the 250 fishermen and their families, the restrictions will bring much more drastic change. Many face financial ruin; many will be driven from the industry.

The president of the Victorian Fishing Industry Federation, Mrs Melita Proebstl, says there is no doubt the industry faces bad times.

"What we're asking for is at least to be making sure that we're making these decisions on sound advice," she said.

"We're not disputing the fact that there needs to be a reduction in fishing, but we are concerned about the level of the reduction."

The problem, says Dr Philip Sluczanowski of the South Australian Department of Fisheries, is that fish are often harvested on a large scale, using poorly controlled hunting operations.

The issues facing the southern shark fishery differ only in the details from those facing nearly all fisheries in Australia and the world.

Very often, there is only a poor understanding of the biology of the fish, their relationship with the environment, the impact of fishing on the fish population, and the effects of different type of fishing gear.

The problem is one that has been repeated all around the world: fishermen are catching fish faster than they can reproduce.

The scientists have worked out what they believe is the optimum level of fishing effort to give the maximum possible catch while keeping the population of fish at a sustainable rate: it is generally around half the population (or biomass) of the fishery before fishing began.

The go-for-broke approach to fishing was fine as long as the fishing effort was not so great as to reduce fish populations beyond the threshold where an ever-increasing fishing effort was needed to maintain a catch of a given size.

In recent years, in many fisheries, this threshold of "maximum sustainable yield" has been breached.

In some fisheries, there is a real risk that the fish population will fall below the level needed to reproduce, and become extinct.

In the case of the southern shark fishery, scientists believe the population is down to about a seventh. If fishing continues at present rates, Dr Sluczanowski calculates, the fishery will collapse altogether after about eight years.

The fishermen fiercely contest this calculation, pointing to errors in the scientists' models, past errors in fishery management, and their lack of control over the proposed new management regimes.

The shark fishery developed during World War II, when shark oil was used as a substitute for cod-liver oil which had become scarce.

Shark meat was sold in the Melbourne fish markets as flake, and quickly became the staple of the local fish shops.

By the late 1970s, fishermen noticed their catch rate for a given amount of effort was declining, although the total catch continued to increase as a result of new techniques and increases in the total fishing effort.

At that stage, already, there had been warnings from scientists that the shark were becoming overfished, but little was done to tackle the supposed problem. As far as the fishermen were concerned, even though it took more effort and improvements in technology, they were able to continue making a living.

The latest step has been Mr Kerin's announcement of reductions in net allowances. Now his officials are negotiating with the industry over the next measure — the introduction of quotas.

Mr David Townsend, the executive officer of the National Fishing Industry Council, says the industry has received conflicting signals from different State and federal governments, all of which may have responsibility for some aspects of fisheries management.

"This division of responsibility has been part of the problem," he said.

"Fish could be in Commonwealth waters or State waters, with two different kinds of management. The fish haven't known about this."

While he agrees the shark fishery is "going down a hole fast", part of the problem is because of encouragement in the past from government to increase the fishing effort — particularly in the trawl fisheries, where foreign fishermen had been trying to boost their efforts in Australian waters.

The industry's response to the crisis — not just in the shark fishery, but in most fisheries around Australia — has been to call for self-regulation, within annual plans approved by government.

"The industry has said that if they had been in control, fewer people would have been after fish to begin with; the peer group would have exercised tougher restraint," Mr Townsend said.

"In the shark fishery, the best judge is the industry. The Government has gone from one adviser to another adviser. There is confusion of advice at the scientific level. They're trying to apply rules, and trying to use the States to police them, but it hasn't worked.

"You should be making decisions on the basis of the majority view. But there's argument in the scientific community as to what's the best scientific view."

ATTACKS on the veracity of the calculations used by the scientists advising the Government have been the industry's other main line of defence. "Like a lot of scientific advice, you have to have more accurate data. In the case of shark fishery, the data is questionable," Mr Townsend said.

Dr Sluczanowski rejects the attacks on his forecasts, which have formed the basis of the Federal Government's latest decisions on the shark fishery.

His job, he says, is something like that of a weather forecaster. "People have to make decisions based on the best information they have to date. There will always be uncertainty. But you have to weigh up the probability of being wrong compared to the consequences of not taking action.

"We can say we are pretty certain where the fishery is at, but I can't predict the exact level of next year's catch very well."

Nevertheless Dr Sluczanowski's forecasts, based on complex computer models that take account of the reproduction rate, age structure and historical catches, are chilling.

If the southern shark fishery were shut down now, it would take 15 years to return to half its original biomass — taken to be the level of maximum sustainability, at which the greatest possible catch could continue indefinitely.

With a quota limiting the catch to 800 tonnes starting now, the fishery could manage for 25 years, but would then collapse.

Even one year's closure of the fishery can make a big difference. Using the same 800-tonne quota, but with a year's closure, the fishery would reach a sustainable level after 25 years, Dr Sluczanowski has found.

Every year of delay now, however, will add three years to the time needed to get potential benefits from quotas or from a temporary closure.

Until the 1950s, regulation of the fishing industry in Australia was minimal. In those days, it seemed there was no limit to the fish in the sea, and anyone who asked would be granted a licence.

The second phase in fishery management has been called an era of "regulated inefficiency". It began with the realisation that fish stocks would be depleted unless some controls were established. So to try to limit the catch, various restrictions were placed on the gear fishermen could use. There were limits on the engine size of fishing boats and on the numbers of nets.

Not surprisingly, fishermen were keen to maintain or increase their catches and their incomes, and so various ways were found to circumvent the restrictions. The most obvious was simply to work harder. Also, technological improvements boosted their catch, despite the regulated restrictions on productivity.

Under the latest management phase, dominant since the mid-1980s, the problem is tackled by setting quotas on the amount of each species of fish that can be caught.

This approach, too, has a drawback: it is more difficult to implement, requiring greater understanding and knowledge of fish populations, and is more difficult to enforce. Instead of simply checking the size of a fisherman's boat engine or the number of his nets, the authorities have to ensure they have an accurate measure of each fisherman's catch.

Mr Kerin's 1989 policy statement explains that there is one issue that makes managing fisheries much more difficult than other industries.

Unlike forests or fields, it is difficult to define who owns fish. With no clear ownership rights, there is no one with a direct and immediate interest in ensuring the long-term viability of the industry.

It is in each fisherman's short-term interests to harvest as many fish as possible, regardless of the long-term impact on the fishery. There is no incentive for fishermen to reduce their fishing effort when they know other fishermen will move in to try to catch the fish they leave behind.

"When resources belong to nobody, nobody will look after them; when resources belong to everybody, everybody must look after them," the paper argues.

A key recommendation is that, where possible, "individual transferable quotas" should be introduced to establish something close to ownership rights over fisheries.

These ITQs have been introduced in several fisheries, along with plans to reduce the number of fishermen by subsidising their exit from the industry.

The paper also advocates the use of a resource rent tax for fisheries, "to collect an appropriate charge from individual fishermen exploiting a community resource for private gain".

The industry contests the virtue of this proposal, which it says ignores the huge investments fishermen have made in the industry with no continuing rights of access to fisheries.

On July 1, negotiations for the RRT will become the responsibility of a new Australian Fisheries Management Authority, which has been set up to counter the industry's complaints of bureaucratic inefficiency within the present Australian Fisheries Service, a division of the Department of Primary Industries and Energy.

The new authority may well improve the administrative efficiency and management of the industry. The fundamental problem of fisheries remains, however: it is an over-exploited resource which requires strict and unpopular management decisions if it is to return to sustainability.

A bioeconomic model of the southern shark fishery

The bioeconomic model of the southern shark fishery developed in ABARE draws on the biological relationships developed by Olsen (1984), Walker (1991b) and the South Australian Department of Fisheries (1991). Onto these biological relationships are imposed the economic and physical features that affect and are affected by fishery management decisions. The model can be used to examine the impact of various management options on both the profitability of the fishery and the biological state of the fishery.

Previous biological models of the fishery have been very useful in highlighting the need for urgent action to protect the resource. In particular, the 'SharkSim' model, developed by the South Australian Department of Fisheries (1991), has captured the attention of both industry and managers. The model simulates the dynamics of the school and gummy shark stocks in the southern shark fishery. The major strength of SharkSim is that it incorporates interactive graphics software that gives a picture of the complex interactions and dynamics of the fishery. The model can be used to demonstrate how the stock structure alters in response to different types and levels of fishing effort.

The ABARE model

While it is an effective tool, SharkSim can only be used to estimate the consequences of applying given amounts of fishing effort in a fixed sequence. It cannot be used to estimate the best sequence to achieve certain objectives, except through trial and error. Further, it excludes the effects of management decisions on the economic performance of the commercial operators in the fishery. The ABARE model, in contrast, is an optimisation model, which means that it can be used to maximise a given variable, such as profit, subject to a set of constraints imposed in the model. In this case, the model is used to estimate the number and type of boats, the type of gear used and the timing of fishing (that is, which years the boats fish) that maximise the net present value of either profits, gross margins or revenue over time under the constraints imposed by the stock and management action.

Table G.13 presents the AFS budget for the fishery, for the period 1988 to 1991. The management levy charge applied per unit is calculated by dividing the estimated management levy by the estimated number of units that will pay the levy. The levy charge is then rounded to the nearest $10. Because the levy is based on estimates, of both cost and number of units, it is acquitted at the end of the financial year. This results in a deficit or surplus carry-over into the following financial year.

Total AFS reimbursements to the States for surveillance for 1990-91 amounted to $280 702. Of this, South Australia received $103 000, Victoria $73 000 and Tasmania $104 404.

Research and logbooks

Scientific research is undertaken mainly by State fisheries agencies in Tasmania, South Australia and Victoria. The Southern Shark Assessment Group based at the Marine Sciences Laboratories (MSL) in Victoria undertakes the collation and analysis of logbook data for the fishery. CSIRO Division of Fisheries also undertakes some shark research. The Southern Shark Research Group (SSRG) is an umbrella organisation which brings together research agencies undertaking shark research and provides scientific advice to Governments and the southern shark fishery MAC (SSFMAC).

Research into the southern shark fishery has led to the development of SHARKSIM, a computer model of the fishery, incorporating catch data since 1927, and biological information of school and gummy shark. It also takes into account available information on fishing gear selectivity. The model was developed by Software Insight Pty Ltd for the South Australian Department of Fisheries (SADF) under the coordination of SADF in conjunction with the MSL and supported by FIRDC and FDTA grants. SHARKSIM has been used to estimate sustainable yields and biomass estimates for the fishery (refer to section 'Status of the fishery'). While SHARKSIM is the best available model of the fishery, it has limitations. Reichelt and Tilzey (1991, p.1) note:

> SHARKSIM is a useful tool for predicting the effects of changes in catch levels, recruitment, and so on, but does not allow a full assessment of uncertainty in such estimates.

The South Australian Shark Fishermen's Association (SASFA), believes that shark stocks are higher than SHARKSIM estimates indicate. The SASFA submitted that the database on which the computer model is based does not include data from west of Kangaroo Island and that catches from this area represent 80 per cent of the total South Australian catch. Reichelt (personal communication 1991) concedes that the model does not incorporate the fishing of new grounds towards the west, but indicated that preliminary evidence of declining shark size and catch per unit effort in the western area indicates that the addition of data from this area will not greatly alter the SHARKSIM biomass estimates. However, he claimed that the addition of these data is a high research priority, which will improve the model's predictive capability.

Some shark fishermen provided anecdotal evidence from their own catch history to support their case that SHARKSIM biomass estimates are too low. However, Reichelt and Tilzey (1991, p. 3) warn that:

> Short-term changes in catch rates are misleading. In this fishery only the long term catch data set should be used to assess fishery trends and then used with caution. For example, any schooling behaviour (or other form of aggregation) by the sharks, or any increase in efficiency by the fishermen in terms of locating sharks, will result in catch rates being an optimistic indicator of stock abundance.

Financial performance

ABARE undertook a financial survey of the southern shark fishery for the 1988-89 financial year (Campbell et al 1991), and the findings are presented in Table G.14. ABARE will use the results of the survey to assess the possible economic impact of various management proposals. The return to full equity is calculated on the basis of total receipts from the diversified fishery. A majority of the fishermen with A6 and B endorsements are not fully dependent on the shark catch. These fishermen made a return to full equity which was far less than the inflation rate. One implication may be that the below average returns of these fishermen may be due to the poor performance of the other fisheries on which they depend.

Campbell et al (1991, p.5) conclude that:

> ...fishermen in 1988-89, on average, made a return (rate of return to full equity which excludes interest payments made in servicing debt) which was less than the inflation

Comment

Australian 7/2/92 p11

Model approach to conservation

SHARKS are less dangerous to people than people are to sharks. During the silly season shark scares are good copy. Everybody is scared of them, and despite the fact that injury or death from attack is far less likely than from jogging, even normally responsible police seeing one from a helicopter will blaze away like airborne cowboys.

It is often pointed out that people eat more sharks than sharks eat people. But the very survival of some species of sharks is threatened by people eating them. Specifically, the shark population in Australia's southern shark fishery has dwindled to dangerously low levels owing to overfishing, and could disappear unless urgent action is taken. In short, Victorians and South Australians are going to have to moderate their appetite for fish and chips.

That very useful government research body, the Australian Bureau of Agricultural and Resource Economics (ABARE) which is at present conducting its annual Outlook conference in Canberra, has devoted considerable attention in recent times to the fishing industry and its economics. Now it is common to talk about "aquaculture", and even "aquacultural economics". Fishing is big business, and could in the future become an even more important resource for Australia. But there are very important issues of the environment and conservation to take into account.

Every time I visit one of the restaurants in Robert Campbell's beautifully restored old warehouse in Sydney's Rocks I reflect on this. For this is a monument to unwise marine exploitation. Many people are not aware that Campbell built his wealth on Australia's first important export industry – seal furs and oil. Within a few years the once abundant seals which ranged the coast north and south of Sydney, and basked on the harbour foreshores, were virtually totally wiped out.

Nobody coos and sentimentalises about baby sharks – but, these days, they are in much more danger than baby seals.

ABARE's latest study is entitled A Bioeconomic Model of the Southern Shark Fishery, and it is a fascinating example of how biological and economic knowledge and analysis can be combined (ABARE research report 92.1, by Sean Pascoe, Tony Battaglene and David Campbell).

The southern shark fishery includes the waters to the south of South Australia, Victoria and Tasmania. Two main species of sharks are caught, chiefly by gill-net or hook: school and gummy sharks, though 15 per cent of the 3000 tonnes carcass weight caught in 1990 consisted of other species, such as the common saw shark, southern saw shark, elephant fish and angel shark. That catch was valued at over $15 million. Thus it is not a very big industry.

McGUINNESS

Earlier economic work by ABARE has shown that profitability in the industry was low and much of the fleet involved was making losses. Evidence on the dwindling shark population made it clear that unless the catch was drastically reduced the industry would face collapse.

It is not easy to obtain firm information on the shark population. But birth rates of sharks, their time to maturity of both sexes, their lifespan all feed into the model. The "SharkSim" biological model of the South Australian Department of Fisheries estimates the numbers of sharks in each age cohort, up to 16 years and over. Growth rates and ultimate sizes are factored in. Thus male gummy sharks tend to a maximum length of 1387mm and females 2019mm. (School sharks, with similar sizes of males and females, tend to a length of 1600mm.) Age of sexual maturity is also taken into account, with only a small proportion of gummy females being mature before the age of nine years, and of school sharks before the age of 12 years.

'Economics and biology can mesh'

The physical elements of the bioeconomic model are the equipment constraints of the fishing fleet – numbers of boats, gear used, size of net mesh, etc.

The economic elements are chiefly derived from information on the Melbourne market. I was surprised to learn how high the price of shark is – about $6 a kilo wholesale – and that this is not much affected by variations in the supplies available. But as the report observes, a very great reduction in available supplies might affect the price substantially. However, blue grenadier appears to be an acceptable substitute for shark.

Essentially, the report puts together what is known, as well as a certain amount of what is uncertain, about the size and rate of replacement of shark populations, to conclude that drastic action (some of which was initiated at the end of 1990) is necessary if Melburnians are not to be permanently deprived of their favourite flake.

The best option would be simply to close down the fishery for a period of from eight to 12 years – long enough to allow a replenishment of sexually mature females. But there is doubt about the "recruitment" rate into the shark population. In purely biological terms, the lowest risk strategy would be to close down the industry. But if the possibility exists that the shark population has substantial regional variations, and that breeding stock is recruited from non-fished areas into fished areas, then such drastic action might not be necessary.

However, the "constant recruitment" option would still require a drastic reduction in the amount of shark taken – to about half the 1990 catch. This, combined with careful monitoring to test the validity of the assumptions about recruitment into the shark fishery, would be much more sensible economically than the absolute biological no-risk option.

"It can be seen," the paper says, "that the benefits of closing the school shark fishery for a period of eight to 12 years outweigh the other alternatives. If the constant recruitment assumption for gummy sharks is correct, the optimal management option may involve reducing the number of boats to about 20, with a total allowable catch of about 1500 tonnes.

"Given that the cost of closing the gummy shark fishery if the constant recruitment assumption is correct far outweighs the cost of keeping the fishery open if the baseline biological assumptions are correct, an optimal short run policy may involve keeping the fishery open (with a substantial reduction in boat numbers) until the question of recruitment is resolved."

This report (and other related material) constitutes an excellent example of how to reconcile environmental and economic considerations. It takes into account not only risks but costs and profitability of the industry, and assesses not just the worst case situation but the best approach to ensure that if the worst case situation should prove correct, the population will not have deteriorated beyond rescue. At the same time it avoids the popular environmentalist trap of maximising the cost of environmental and species protection.

It shows how well the various disciplines of the economist and the biologist can mesh to produce useful advice on the viability of a primary industry. Clearly, for example, the same kind of research and modelling procedure could be adapted to land animals – as when we finally get around to running a proper kangaroo meat industry – or other kinds of fish and marine resources.

This is what sustainable economic development is about. It might be argued that perhaps the fishery should be closed for longer in order to allow shark populations to regenerate to earlier levels. But we don't need more sharks, we need enough.

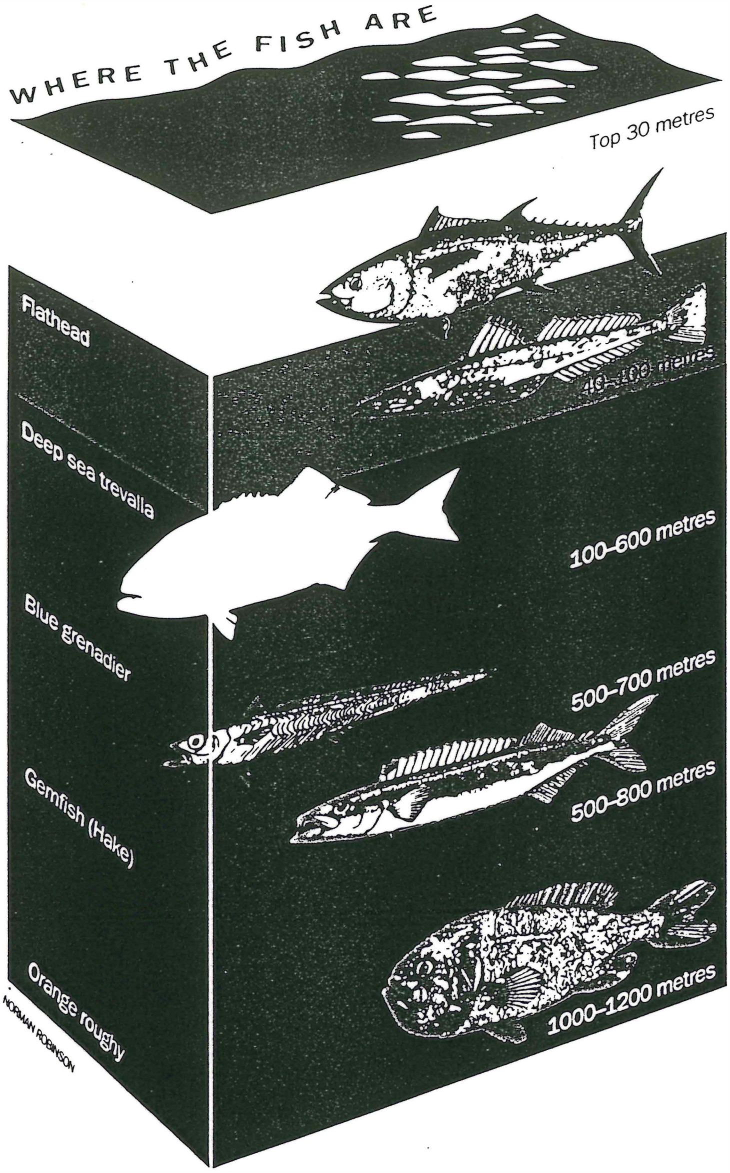
–Padraic P. McGuinness

But the bumper harvests of the mid to late '80s cannot last. CSIRO research on the fishery has shown orange roughy to be extremely long-lived. Their life span is comparable to that of human beings – about 70 to 80 years (the oldest known specimen is 149 years old). They breed later than humans, at about 32 years of age.

Obviously, a fish that takes so long to grow and reproduce will not sustain intensive commercial fishery. CSIRO scientists have warned the industry that it has to reduce its total allowable catch from 12000 tonnes to 2700 tonnes for this valuable fishery to last.

WORKING SMARTER NOT HARDER

The problems faced by the orange roughy and southern shark fisheries – overexploitation of stocks, improvements in efficiency resulting from new techniques and technologies, and excessive exploitation of newly-identified resources – are repeated elsewhere in Australia. The prognosis for the southern blue-fin tuna fishery, for example, is even worse than that of the shark fishery.



Apart from better management of the fisheries, there are other ways to reduce our "predation pressure" on wild fish stocks. Aquaculture – the intensive farming of shellfish and fish – is one means. Australia's past efforts here have concentrated on oysters and salmon trout. Researchers are now looking at other aquaculture prospects such as prawns, shellfish other than oysters, and fin fish.

But the most promising avenue for making more productive use of our catch at the moment is in value-adding, through better post-harvest processing and marketing. Tuna is a good example. As mentioned earlier, one of our tuna fisheries has already suffered excessive levels of fishing.

Much of the Australian tuna catch ended up in tins. The irony is that Australian cats were eating fish that could fetch $75 per kilo in the Japanese raw fish or sashimi market. Now, in Queensland, researchers and marketers are looking at ways of adding value to fisheries products like tuna to cash in on lucrative export markets.

At the International Food Institute of Queensland, a team of seafood technologists, microbiologists and marketing consultants has found a way of processing and presenting longtail tuna, traditionally

Another success story is the Japanese king prawn project. The Institute set up a joint venture with a private prawn farm to produce live prawns for the Japanese market. The research component involved finding optimal temperatures for transporting the prawns, and identifying a suitable support medium – sawdust – in which to pack them. The first commercial shipments of the live prawns have proved a success, fetching up to $80 a kilo in Japan with a 95-100 percent survival rate for the prawns.

Work is continuing on a number of other projects, including spanner crabs and brown tiger prawns. Institute researchers plan to apply their expertise in the transport of live crustaceans to both these species. The point is that we don't have to take more fish out of our waters to increase or maintain the value of our fisheries. As with every other industry today, the choice does not have to be working harder, but working smarter.

AT THE END OF THE DRAIN

Through its sustainable development initiatives, the Government is taking a broader approach to the preservation of our fisheries. Sustainable development is not just about commercial fishing, says Dr Murray Johns, Executive Officer of the Commonwealth Government's Sustainable Working Group on Fisheries. The management of our fisheries resources has to take into account tourism, recreational fishing, conservation of species and protection of the environment. With a renewable natural resource, you can only live off the interest; if you start living off the capital, you run the resource down, leaving nothing for future generations.

Recreational fishing can have a significant impact on commercial fisheries. Surveys of some fishing spots have shown that the recreational catch can be up to 20 times the commercial catch. "As Australians, we all believe we have a right to catch a fish whenever we want", continues Dr Johns. "Yet we can't just go out and cut down a tree in a state forest".

Pollution and habitat degradation also have an impact. Industrial waste is one well-known source, but another important problem is resort and marina development, particularly along the coast adjacent to Queensland's Great Barrier Reef where mud flats (a favourite nursery for many fish and crustaceans) have been destroyed for recreational or urban development.

Mary-Lou Considine, a science graduate with experience in marine biology, is a freelance journalist based in Melbourne.

OFF THE MENU

Is there cause for concern? The plight of a couple of our most popular seafood items, flake and orange roughy, highlights some of the issues. Flake is the meat from two species of sharks – the gummy shark and the school shark. These sharks sustain a fishery that extends from eastern Victoria, south to the waters off Tasmania, then west to the western boundary of South Australia.

Like most other Australian fisheries, the southern shark fishery enjoyed an initial boom phase that, decades later, has slowed down. In recent years, shark fishermen have been able to use new techniques for increasing their total catch, but the catch yielded per unit effort on the part of fishermen has been declining. In other words, they are having to pedal faster just to keep up.

Scientists have long been concerned about overfishing. Research on the biology of the sharks has shown that both species are relatively long-lived and produce few offspring, leading scientists to conclude that stocks are not as rapidly replenished as shorter-lived marine species such as prawns.

Consequently, the Federal Government's Department of Primary Industries is trying to encourage the southern shark fishery to reduce its catch, placing restrictions on the number of nets that fishermen can use. The aim is to reduce the annual catch from 3500 tonnes to somewhere between 500 and 800 tonnes.

Shark fishermen are not happy about conforming to restrictions based on research results that they believe to be imprecise and inaccurate. Imprecision is a universal problem for marine biologists. Unlike land animals, fish can't be easily observed, counted and followed. The methods that scientists use to estimate a marine species' abundance, growth rate, life span and breeding rate involve indirect measurements and some "guesstimates".

> **Unlike land animals, fish can't be easily observed, counted and followed**

But as Dr Phil Sluczanowski of the South Australian Department of Fisheries points out, scientists' predictions, even though they may not be completely accurate, are better than nothing. We can only base our predictions on the best available information, says Dr Sluczanowski. Uncertainty will always be there. But fisheries managers and fishermen have to weigh up the consequences of taking action and being wrong, against the consequences of taking no action.

Dr Sluczanowski and his colleagues have developed a sophisticated computer model, SharkSim, which simulates the effects of different fishing techniques on the age structure and reproduction rate of the fish population and on the catches and catch rates of the fishery.

The model combines the results of more than 40 years of research into growth, density, mortality, reproduction, catchability, selectivity and fishing statistics. It offers scientists and managers a window onto the future, mapping out the consequences of various policies and regulations in terms of their impact on the catch.

The pictures that the model paints are not comforting. Taking the case of the most severe remedial action, immediate closure of the fishery. It would take 15 years for stocks to return to a level at which they could be fished indefinitely. If the annual catch was limited to 800 tonnes, the fishery could survive for 15 years and then collapse. Total collapse could be avoided if the fishery was to be immediately closed for one year to allow stocks to recover.

Delayed action, while fishermen demand more accurate data or while management bodies avoid making tough decisions about

Effective communication between scientists and the fishing industry is a major barrier to getting agreement on appropriate action from the different interest groups, according to Dr Sluczanowski. Scientists have to wear some of the blame; their research results tend to be buried in academic journals, and the limitations of their data are often not adequately explained to non-scientists.

SharkSim provides a ray of hope, allowing users to view the effect of different management strategies such as the use of fewer nets. With its arresting colour displays, SharkSim can graphically convey the consequences of inaction to fishermen and fisheries managers. In fact, SharkSim and its relatives – AbaSim, an abalone fishery simulation package and PRAna, a tool for estimating recruitment to fish stocks – may eventually be applied to other fisheries as a way of communicating research findings to managers and operators.

If the shark fishery eventually fails, we may have to look at alternatives for ever-popular flake. One suggestion has been to import hake from overseas, but as Dr Sluczanowski points out, fisheries overseas are facing the same crisis as those in Australia. There is no doubt though that, for the consumer, the loss of local fisheries like the southern shark would mean an increase in the retail price of fish.

DIGGING DEEP

Demonstrating the outcomes of present management strategies may not be enough to convince fishermen. As small business managers, their major concern is the present, not the problems that might arise in 15 years.

Like most fisheries in Australia, the shark fishery mainly involves individual operators, each having a considerable investment tied up in their boat and associated navigational and fishing equipment. With this investment at stake, they have little incentive to become less productive and lose revenue. So they will continue to do what they have done for years – work their gear as hard as they can.

The Commonwealth Government is aware that we have too many players in all our commercial fisheries, but rationalisation is a process that involves putting people out of work, not an easy decision to make.

One fishery undergoing a major restructure is the northern prawn fishery. The restructure will cut the number of fishing vessels operating in the fishery by half. Many boats have already been removed, and the owners compensated for their loss.

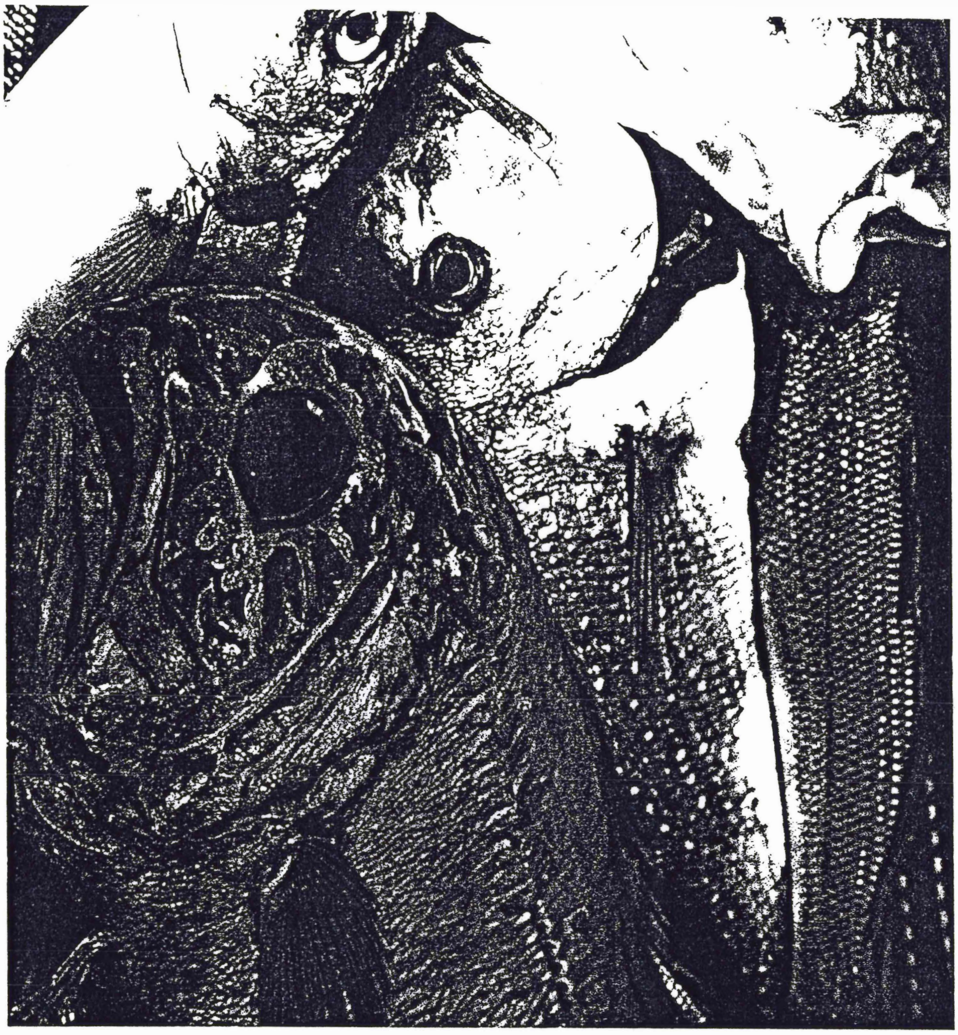
The Government sees subsidised withdrawl, with a system called "individual transferable quotas" (ITQs), as the most effective means of protecting our dwindling fisheries resources. ITQs may provide a means of establishing ownership rights over fisheries because, as they stand, fisheries belong to nobody, so nobody is responsible.

But will managers get the right strategies in place in time to save valuable species like the orange roughy? Orange roughy was a bit of a stranger to Australian palates 10 years ago. In recent years, our appetite for the fish, and the price it commands in export markets, has had fishermen rushing to "hot spots" off the Tasmanian coast to take part in a fishery worth about $50 million a year.

After 1985, when the first catches were made, the fishing industry moved fast to exploit the resource, with new entrants investing in special acoustic sounding and trawling equipment to work the deep sea floor on which the fish lives, more than 1000 metres down. Naviga-

T[illegible] Magazine of the Commission for [illegible]

21•C WINTER•SPRING 1991



LORRIE GRAHAM

The chips are down

It may not be long before the trendy, tender types of fish so popular with diners today are rubbed off restaurant blackboards for good

BY MARY-LOU CONSIDINE

Can eating a humble piece of flake be compared to eating a venison steak or a haunch of wild boar? Some conservationists argue that our generation may be the last to have the privilege of eating cheap game meat from animals that live and reproduce as they have done for millenia – the wild animals of the sea.

Modern fishing technologies have made man a deadly predator, not just of individuals, but of whole species. Unlike game animals which are hunted and killed with simple weapons like rifles, fish are hunted and killed on a large scale, using technologies that are so accurate and efficient that fish are being tracked down and taken faster than they can replace themselves.

Fish do not have the endearing qualities of a panda and their habitats don't offer the mist shrouded beauty of a rainforest. They are slimy and decidedly uncuddly and the wilderness they inhabit is wet, cold and uninviting. So when it comes to the issues of conservation and sutainable development, they tend to miss out on public concern. But Australians cannot afford to ignore their fisheries resources for much longer. Right now, scientists around the country are calling for much tighter restrictions on commercial fishing. Their research indicates we may have overstepped the limits of sustainable harvesting.

The fishing industry, on the other hand, is not convinced. It claims that many of its problems have been caused by fragmented and contradictory management of the resource divided as it is between State and Commonwealth Governments – and that scientists' predictions are unreliable.

B SharkSim 1 User Manual

SharkSim 1

A computer graphics model of
Australia's southern shark fishery

USER MANUAL

Department of Fisheries
South Australia

Software product:	SharkSim v1.0
This publication:	USER MANUAL
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CONDITIONS OF USE

There are restrictions on copying, transfer and types of uses of the *SharkSim 1* software.

An agreement between the South Australian Department of Fisheries and each legitimate user deals with these. Please refer to it before using the software.

Whilst every effort has been made to check the accuracy of the calculations, serious users should use independent models to check the model outputs. Neither the South Australian Department of Fisheries nor anybody associated with the production of *SharkSim 1* shall be liable for damages resulting from the use or misuse of these programs.

WARNING

USE *SharkSim 1* FOR FISHERIES MANAGEMENT ONLY WITH APPROPRIATE SCIENTIFIC ADVICE.

USER MANUAL - CONTENTS

PREFACE

About this manual

This manual describes how to operate the *SharkSim v1.0* software package. It assumes you are familiar with the basics of using a DOS personal computer and that you understand terms such as keys, files, windows and **[esc]**. Contact the developers if you need help (Appendix A: Service and support).

If *SharkSim v1.0* is installed on your computer, the quickest way to learn to use it is to step through the EXAMPLE described on page 29.

The installation procedure is described on page 7.

The manual does not teach the user fish population dynamics.

About the model

The software implements mathematical models specified by scientists who studied the fishery. Some aspects of these models were checked by independent experts at a five day workshop. The models are continually being rechecked, refined and modified.

The population dynamics models underlying *SharkSim* are complex and depend on assumptions and parameter estimates which need qualification. Fisheries scientists should be involved in analysis and interpretation using the package.

WARNING

USE *SharkSim 1* FOR FISHERIES MANAGEMENT ONLY WITH APPROPRIATE SCIENTIFIC ADVICE.

Ackowledgements

We thank the following organisations and individuals for their <u>assistance and support</u>:

- Fishers, their families and representatives

- Bureau of Rural Resources (Canberra)
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- Victorian Department of Conservation and Environment (Queenscliff)
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- South Australian Department of Fisheries
- Fisheries Development Trust Account (FDTA)
- Fishing Industry Research and Development Trust Fund (FIRDTF)
- Software Insight Pty Ltd and other developers

1 DESCRIPTION

1.1 Description of model

SharkSim models the southern Australian fishery for gummy shark *Mustelus antarcticus* and school shark *Galeorhinus galeus*. Based on the best available data and population dynamics models, it simulates (Walters 1969) the effects of fishing effort by various gears on population structure, pups, catches and catch rates. The user can easily change control variables or model parameters and immediately see the effects as coloured dynamic graphics that clearly illustrate the evolution of the fishery and the consequences of alternative management strategies or of parameter uncertainty.

The model combines the results of over forty years of research into growth, density dependent natural mortality, reproduction, catchability, selectivity, fishing effort allocation and catch and effort statistics. (Olsen 1984, Walker 1991)

It was developed for use by scientists, managers, fishers and related industries, conservationists, educators and the community. It can be used to fit models, analyse and understand them, communicate, educate, manage fisheries, develop policies, focus effort, capitalise expertise, cost research, clarify issues and entertain.

1.2 Hardware requirements

Running *SharkSim v1.0* requires

- IBM PC compatible computer
- DOS v3.3 (or later version)
- 286 CPU (or later version)
- Standard VGA colour graphics adapter and screen
- 2Mb RAM minimum with EMS (expanded memory specification) driver, at least 530 Kb conventional memory
- 2Mb space on hard disk (initially, but the database can grow)
- 3.5" high density (1.4Mb) diskette drive for installation
- 287 math co-processor (or compatible later version) highly recommended
- the CONFIG.SYS file must have minimum:
  FILES=10, BUFFERS=20
- no conflicting packages (e.g. Terminate Stay Resident TSR programs such as SIDEKICK(c))

2 INSTALLATION

SharkSim v1.0 is supplied on a 1.4Mb 3.5" diskette.

The following procedure creates a sub-directory called **SHARKSIM** (or whatever you wish) on the hard disk and copies *SharkSim v1.0* to it.

Installation procedure

1 Insert the supplied *SharkSim v1.0* diskette into a diskette drive and type **A:INSTALL [Enter]**.

2 An installation programme will run. When it asks, type in the name of the directory into which the *SharkSim v1.0* files will be loaded.

3 Remove the supplied *SharkSim v1.0* diskette and store it securely.

The installation program automatically checks whether your computer has a maths coprocessor and loads the appropriate files.

WARNING

When you install *SharkSim v1.0* into a sub-directory, it will overwrite any files that were previously stored there. If these contained *SharkSim* files (e.g. Simulations) you had created in addition to those supplied with the software, you will lose them.

3 OPERATION

3.1 Starting the programme

1 Enter the *SharkSim* subdirectory.

(e.g. C:> **CD SHARKSIM [Enter]**)

2 Type: **SS [Enter]**

After displaying the opening screen, *SharkSim* loads into the computer's working area with a default Start Parameter Set (see 3.5.1 below).

3.2 Leaving the programme

You can leave *SharkSim* by typing **[Alt-X]** (or **/X**) if no windows are displayed. Eliminate these using **[Esc]**.

3.3 Understanding the main screen

3.3.1 Status line

A status line at the top of the main screen shows

- The version of *SharkSim* being used
  (e.g. **"SharkSim v1.0"**)
- What is being displayed
  (e.g. **"FISHERY Biomass by Species"** or
  "GUMMY FEMALE Number by Length-class")
- The year at which PIT is positioned (see 3.3.2).
  (e.g. **"1990"**)

3.3.2 Colourbands

The main screen has five rows of information shown as stacked coloured graphs called "colourbands":

Screen name	Variable displayed	Units (Biomass or Numbers)
Pop (cw)	Population	tonnes carc.wt. or 1000 sharks
Births	Births	tonnes or 1000 sharks
Catch (cw)	Catch	tonnes carc.wt. or 1000 sharks
CPUE (cw)	Catch per unit effort	(summed)
Effort	Fishing effort by gear	1000km-lft or hook equiv.

3.3.3 PIT - "Point-In-time"

A vertical white cursor called PIT ("point in time") can be moved left and right using the arrow keys. The histograms on the right of the screen show the values of the stacked colourbands at PIT. The values can be displayed as figures by pressing **F**, allowing you to measure them.

The histograms show the values to the immediate <u>left</u> of PIT for the top four rows, and the values to the <u>right</u> of PIT for the bottom row (Fishing Effort).

3.3.4 Colour code

Depending on what is displayed on the screen, different colours present different information. For example, if you display **"GUMMY FEMALE Biomass by Length-class"**, each length-class category will have a different colour.

APPENDIX B details the colour codes.

3.4 Keyboard control in the Main Screen

You can alter the image on the screen using keyboard commands. (You can first eliminate any visible windows using **[esc]**.)

3.4.1 Moving PIT

[Right]	Move PIT forward one year
[Left]	Move PIT back one year
[Home]	Move PIT to Initial Year
[End]	Move PIT to last simulated year
[Shft][Right]	Move PIT forward ten years
[Shft][Left]	Move PIT back ten years

3.4.2 Adjusting fishing effort

[Up]	Increase PIT fishing effort of selected gear type (indicated by colour underline in the bottom right histogram)
[Down]	Reduce fishing effort of selected gear
[Ctrl][Right]	Select next gear type for adjustment
[Ctrl][Left]	Select previous gear type " "
[Ctrl][Up]	Increase fishing effort - fine tuning
[Ctrl][Down]	Decrease fishing effort - fine tuning

3.4.3 Other controls

F	Displays figures giving values of histograms. Press **F** again to display totals, and again to switch them off.
/	Calls up the menu of Commands
[Esc]	Eliminate Command windows
[Enter]	Carries out a simulation for the year following PIT using the fishing effort shown in the bottom right histogram.
[Alt-X]	Leave *SharkSim*.

3.5 Entering and Editing Data

When using *SharkSim*, there are occasions when you need to enter or edit text or numerical values in fields (e.g. Naming files or altering parameters). The *SharkSim* editor is simple.

Moving between fields

Each field is surrounded by a box. When you are working with data on screen-based forms which contain more than a single field, you can move between fields using **[Tab]**, **[Shft-Tab]**, **[Up]**, **[Down]**, **[Left]** and **[Right]**.

Entering/editing a field

To edit an existing field, position the cursor there and type **[F2]**.

When editing within a field, the cursor highlights the active position where entering/editing takes place. You can move it using **[Left]**, **[Right]**, **[Home]** and **[End]**.

You can use the **[Backspace]** and **[Delete]** keys to delete characters and toggle between insert and overwrite modes using the **[Insert]** key.

When entering numerical values, you can type them in as integers, decimals or in scientific notation.

When you are satisfied with what is in a field, press **[Enter]** to accept it. If you want to leave the contents of a field unaltered from when you started, press **[Esc]**.

> **WARNING**
>
> Pressing **[Ctrl-Alt-Del]** or switching off the computer while *SharkSim* is accessing a disk or its database may cause problems.

4 COMMANDS

4.1 Using commands

Calling up the Command Menu

Press **/** while in the Main Screen to call up the Command menu.

Selecting a Command

Select a command by pressing the letter highlighted on the screen (e.g. **F** for **F**ile) or by selecting a command using **[Left]** and **[Right]** and pressing **[Enter]**.

Command notation

Commands which lead to further menus have three dots displayed after them (e.g. **View...**). Ones which execute and return to the main screen are followed by a single dot.

4.2 The command structure

SharkSim v1.0 Command Structure

```
File...
        Load...
        Save...
                Simulation
                Start Parameter Set
Stock/substock...
        Fishery...
                by Sex & Species.
                by Species.
        Gummy...
        School...
                Female...
                Male...
                        by Age-class.
                        by Length-class.
                        Total.
Models...
        Initial Year
        Initial Age Structure...
                Gummy
                School
                Grab age structure.
        Mortality
        Growth...
                Gummy
                School
        Catchability
        Reproduction
        Effort Allocation
        Selectivity...
                Nets
                Non-net...
                        Gummy
                        School
View...
        Biomass.
        Numbers.
        Rescale.
        Zoom...
                30 yrs.
                50 yrs.
               100 yrs.
               150 yrs.
About.
Exit.
```

4.3 File command

SharkSim v1.0 has an inbuilt database. The **F**ile command allows you to load and save two types of files: Start **P**arameter Sets and **S**imulations.

Before you carry out a simulation, you must specify:

- the parameters that remain constant throughout the simulation (e.g. **G**rowth parameters)
- the initial age structure

These data are called the Start **P**arameter Set. You can change them using the **M**odels command (Section 4.6)

A **S**imulation is based on a particular Start **P**arameter Set and consists of an Initial **Y**ear, a fishing effort control sequence created interactively by the user and the effects of these over time on various variables such as population, births, catch and catch per unit effort (CPUE).

A **S**imulation is **L**oaded with the same screen configuration as when it was **S**aved.

/FL... /**F**ile **L**oad When you **L**oad a file, it replaces the simulation shown on the screen. Unless you have saved them beforehand, you will lose the existing Start **P**arameter Set and **S**imulation. You must know the name of the file you wish to load before you do so. Enter it exactly and press **[enter]**.

/FLS /**F**ile **L**oad **S**imulation Type file-name, **[Enter]**

/FLP /**F**ile **L**oad Start **P**arameter Set " " " , **[Enter]**

/FS... /**F**ile **S**ave When you **S**ave a file, you must name it. Use standard keys. Capitals are regarded as different from small letters (e.g. "best" and "Best" are different). The database grows each time you save a file.

/FSS /**F**ile **S**ave **S**imulation Type file-name, **[Enter]**

/FSP /**F**ile **S**ave Start **P**arameter Set " " " , **[Enter]**

When you carry out the <u>installation</u> procedure, the database is initialised to contain only those files supplied with the software and described in this manual (APPENDIX C). You can have separate databases in separate sub-directories.

4.4 Stock/Substock command

The **S**tock/Substock command allows you to select which portion of the fishery stock should be shown on the screen.

Stock

/SF... /**S**tock **F**ishery - The entire fishery stock (2 species, 2 sexes) is shown.

/SFX /**S**tock **F**ishery by Se**x** and Species - 4 colourbands represent Gummy Females, Gummy Males, School Females, School Males respectively.

/SFS /**S**tock **F**ishery by **S**pecies - 2 colourbands represent Gummy and School sharks respectively.

/SFT /**S**tock **F**ishery **T**otal - a single colourband represents the whole stock.

Substocks

/SG... /**S**ubstock **G**ummy

/SGFA /**S**ubstock **G**ummy **F**emales by **A**ge-class

/SGFL / " " " by **L**ength-class

/SGFT / " " " **T**otal

Similarly for

- School (e.g. /**SSFL** instead of /**SGFL**)
- Males (e.g. /**SGML** instead of /**SGFL**)

4.5 View command

The **V**iew command changes how you view the information shown on the screen.

/VB (/**V**iew **B**iomass) - the heights of the colourbars representing the population, catches or catch rates (CPUEs) reflect stock biomass as carcass weight. (The Status Line at the top of the screen shows whether "Biomass" or "Numbers" are shown.)

/VN (/**V**iew **N**umbers) - the heights represent numbers of fish. (see /VB above)

/VZ... (/**V**iew **Z**oom) - the time scale can be 30, 50, 100 or 150 years.

/VZ3 (/**V**iew **Z**oom **3**0yr) - the screen time scale = 30yr

/VZ5 (/**V**iew **Z**oom **5**0yr) - " " " " = 50yr

/VZ1 (/**V**iew **Z**oom **1**00yr) - " " " " = 100yr

/VZ0 (/**V**iew **Z**oom 15**0**yr) - " " " " = 150yr

4.6 Models command

The **M**odels command allows you to change the parameter values of the underlying population dynamics models. Use it to change Initial **Y**ear and data which forms the Start **P**arameter Set (e.g. **M**ortality).

Press **/M** for a menu of sub-models which combine (according to the algorithm described in Appendix D) to generate all the dynamic variables shown on the screen. The parameter values of these submodels remain constant throughout any simulation.

Changing parameter values

To change the parameter values in a particular sub-model (e.g. **G**rowth), press the letter (e.g. **G**) to select the form for that model. It appears as a window. Section 3.5 describes how to enter and edit the parameter values in the various fields, which appear in boxes on the screen.

When you are satisfied with the parameter values displayed on the form, press **[Alt-K]** to accept them. Remember to press **[Enter]** to complete entering a field. Press **[Esc]** or **[Alt-C]** if you want to leave the original values intact.

Keep changing parameter values of various sub-models until you are satisfied with them. Then you must **S**ave them as a Start **P**arameter Set. The new values will be loaded into the *SharkSim* database, the model will recalculate its dynamics using the new parameters and set PIT at the Initial Year.

The Start **P**arameter Set is the set that will be used each time the model is started.

Initial Year - A special case

Because Initial **Y**ear is a parameter stored as part of a **S**imulation file rather than as part of a Start **P**arameter Set file, special rules apply when changing the Initial **Y**ear. See 4.6.1 below.

4.6.1 Initial Year command

The Initial **Y**ear is the first year of the simulation. Its population structure is that given by the **I**nitial Age Structure sub-model (see 4.6.2 below).

To change the Initial **Y**ear:

- enter the main screen
- press **/MY** to display the form on the right
- Enter/edit the year
- Press **[alt-K]** to accept the value
- Press **[esc]** to return to the main screen

You must immediately **S**ave the existing simulation as a **S**imulation file using any name (e.g. **default**).

SharkSim will recalculate the model using the existing Start Parameter Set and set PIT at the newly entered Initial Year.

4.6.2 Initial Age Structure command

The Initial Age Structure (for a given species and sex) is the number of fish assumed to be in each age class from 0+ to 32+ at the Initial **Year**.

/MIG or **/MIS** calls up the Initial Age Structure form for gummy or school respectively (see figure at right).

You can enter the numbers manually, one species at a time.

Alternatively, you can "g**R**ab" the PIT age structure in any simulation and make it the Initial Age Structure. Both species are treated at once.

Initial Age Structure

	Female	Male
0	2796	2796
1	1159	1159
2	481	481
3	199	199
4	164	164
5	134	134
6	110	110
7	90	90
8	74	74
9	61	61
10	50	50
11	41	41
12	34	34
13	28	28
14	23	23
15	18.7	18.7
16	15.4	15.4
17	12.6	12.6
18	10.4	10.4
19	8.5	8.5
20	7	7
21	5.8	5.8
22	4.7	4.7
23	3.9	3.9
24	3.9	3.9
25	2.6	2.6
26	2.1	2.1
27	1.8	1.8
28	1.4	1.4
29	1.2	1.2
30	1	1
31	0.8	0.8
32	3.68	3.68

OK Cancel

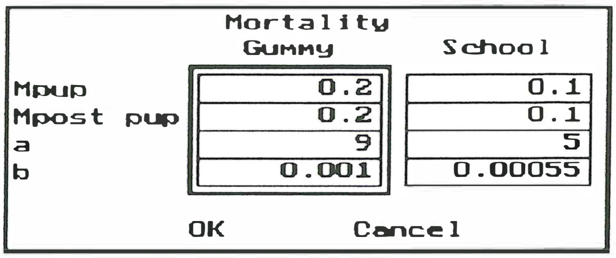
The latter option is particularly useful for creating a stable initial age structure which is determined by the density-dependent pup mortality parameters $\mathbf{a}_{Sp}$ and $\mathbf{b}_{Sp}$ (see 4.6.3 below). You can select a set of parameter, set zero fishing effort, and simulate the population until it stabilises. Then g**r**ab the age structure and make it the initial one.

Definition

$N_{a,0,Sp,Sx}$ is the number of fish of age **a+** in the Initial Year (**0**) for species **Sp** and Sex **Sx**.

4.6.3 Mortality command

You can alter the natural **M**ortality parameters for each species separately. Males and females of the same species are assumed to have the same natural mortality.



/MM calls up the **M**ortlaity form above.

Definition

$M_{a,y,Sp}$ is the instantaneous natural mortality of **a+** age-class fish of species **Sp** in year **y**.

Equations

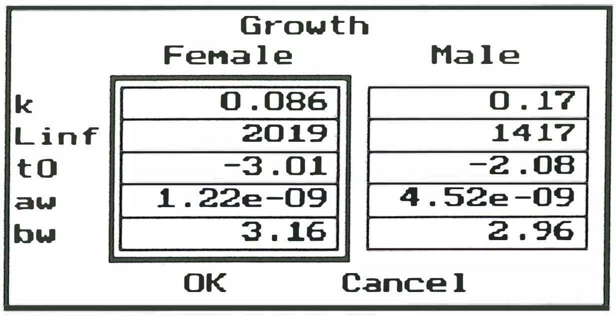
For pups (Gummy ages 0+ to 4+, School ages 0+ to 8+):

$$M_{a,y,Sp} = M_{pup,Sp} + (b_{Sp} . sum_{(both\ Sx)} sum_{(a+\ to\ 32)} [N_{a,y,Sp,Sx}])$$

For post-pups (Gummy ages 5+ to 32+, School ages 9+ to 32+):

$$M_{a,y,Sp} = M_{post-pup,Sp}$$

6.4.4 Growth command



The **G**rowth command lets you set von Bertalanffy and allometric growth parameters for each species and sex separately. The model dynamics are based on the whole weight of individual fish. The catches, however, are displayed as carcass weight only (see Appendix D).

/MG calls up the **G**rowth form at right.

Definition

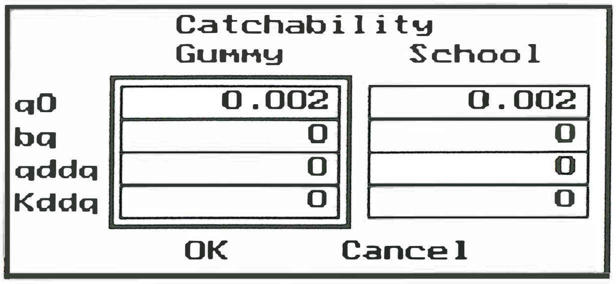
$L_{a,Sp,Sx}$ is the length of a fish of age **a+**, species **Sp** and Sex **Sx**. $W_{a,Sp,Sx}$ is its weight.

Equations

$$L_{a,Sp,Sx} = \mathbf{Linf}_{Sp,Sx} \cdot [1 - \exp\{-\mathbf{k}_{Sp,Sx} \cdot (a - \mathbf{t0}_{Sp,Sx} + 0.5)\}]$$

$$W_{a,Sp,Sx} = \mathbf{aw}_{Sp,Sx} \cdot L_{a,Sp,Sx} {**} \mathbf{bw}_{Sp,Sx}$$

4.6.5 Catchability command



Catchability $q_{y,Sp}$ is the parameter relating the proportion of the stock of species Sp caught by a unit of fishing effort. Combined with selectivity, it converts fishing effort by a particular gear type to fishing mortality (see Appendix D).

/MC calls up the **C**atchability form above.

Definition

$q_{y,Sp}$ is the catchability of species **Sp** to standardised net gear in year **y**.

Equation

The formulation of this sub-model allows you to simulate increases in unit efficiency over years using parameter **bq** and the effects of schooling behaviour using parameters **qddq** and **Kddq**.

$$q_{y,Sp} = \mathbf{q0}_{Sp} + (\mathbf{bq}_{Sp}.y) + \mathbf{qddq}_{Sp}.\exp(-\mathbf{Kddq}_{Sp}.\mathrm{sum}_{postpup}\mathrm{sum}_{Sx}[N_{a,y,Sp,Sx}])$$

4.6.6 Reproduction command

The **R**eproduction model determines how the number of births each year are computed from the age structure of adults remaining at the end of the previous year.

/MR calls up the **R**eproduction form.

Each female of parental age (pa) produces a number of births related to her weight (gummy) or age (school). The **ar** and **br** parameters affect this.

The number of births produced by a parental age-class $BI_{ap,y,Sp}$ is the product of the above number, the number of pa-aged females and the proportion of the females that are mature $f_{ap,Sp}$ (e.g. In the figure: 75% of 19+ year old school females are mature).

Reproduction

	Gummy	School
ar	-3.1	29.7
br	1.43	0
0	0	0
1	0	0
2	0	0
3	0	0
4	0.01	0
5	0.02	0
6	0.03	0
7	0.05	0
8	0.07	0
9	0.5	0
10	0.84	0.02
11	0.92	0.05
12	0.98	0.18
13	1	0.25
14	1	0.32
15	1	0.4
16	1	0.5
17	1	0.6
18	1	0.65
19	1	0.75
20	1	0.83
21	1	0.85
22	1	0.86
23	1	0.88
24	1	0.9
25	1	0.92
26	1	0.94
27	1	0.96
28	1	0.98
29	1	1
30	1	1
31	1	1
32	1	1

OK Cancel

Definition

The total number of births at the beginning of a simulation year $N_{0,y,Sp,Sx}$ is the sum of births from all parental age-classes. The model assumes that fish are all borne at the start of a year and that half are female.

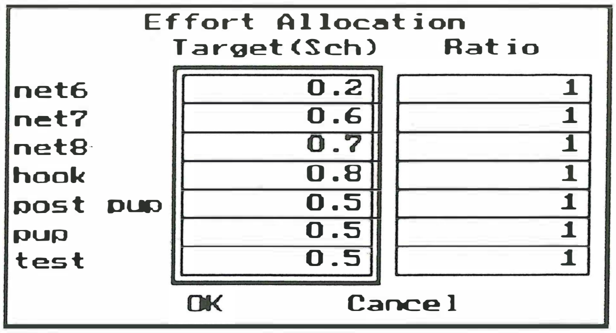
Equations

$$BI_{ap,y,Sp} = \max[0.0, \mathbf{ar}_{Sp} + \mathbf{br}_{Sp} . W_{a,Sp,female}] . N_{ap,y,Sp,female} . f_{ap,Sp}$$

$$N_{0,y,Sp,Sx} = \text{sum}_{ap}[BI_{ap,y,Sp}]/2$$

4.6.7 Effort Allocation command

The user can set fishing effort by gear types using interactive controls (see 3.4.2). The **Effort** Allocation model splits these between gummy and school sharks.



/ME call up the form above. Two parameters are entered for each gear type **g**.

If the parameter **Ratio** = 1.0, then effort is split into the simple proportions specified by the first parameter **Target(Sch)** (e.g. In the figure above, 0.7 of 8" net effort targets school shark). If you set **Target(Sch)** = 0.5, equal amounts of effort of that particular gear type are allocated to both species. (Note: **Sch** stands for "school".)

If **Ratio** = 0.0, then fishing effort in year **y** by gear **g** is allocated between the species in the same proportion as their catches by that gear in the previous year (y-1). In this case, the **Target(Sch)** parameter is not used.

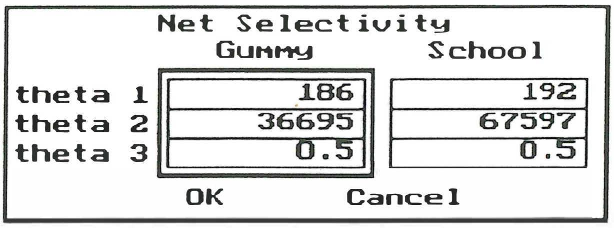
Values of **Ratio** (**R**) between 0.0 and 1.0 determine the relative weighting given to the two alternative effort allocation mechanisms described above. (e.g. If **Ratio** = 0.5, half the effort is allocated according to the **Target(Sch)** (**T**) parameter and half in proportion to the previous year's catch.)

For a particular gear **g** and species **Sp**, the total fishing effort set by the user $TEU_{y,g}$ is split between species as:

$$E_{y,g,Sch} = TEU_{y,g} \cdot [\mathbf{R} \cdot \mathbf{T} + (1-\mathbf{R}) \cdot C_{y-1,g,Sch} / sum_{Sp}\{C_{y-1,g,Sch}\}]$$

$$E_{y,g,Gummy} = TEU_{y,g} - E_{y,g,Sch}$$

4.6.8a Selectivity (nets) command



The **S**electivity sub-model determines the relative effectiveness of a particular gear type **g** in catching fish of different age-classes **a+**. The **S**electivity (nets) model deals with gill nets.

The selectivity of 6", 7" and 8" mesh nets is based on the two parameter (**theta1, theta2**) model of Kirkwood and Walker 1986. An additional parameter has been added (**theta3**) to deal with different possible levels of "ghost fishing".

/MSN calls up the **S**electivity (nets) form above.

Definition

For species **Sp**, the selectivity $s_{a,g,Sp,Sx}$ of (net) gear of mesh m_g depends on the lengths of fish in the various age classes.

Equations

Given **theta1**, **theta2**, **theta3**, $\mathbf{m_g}$ and $L_{a,Sp,Sx}$:

$$beta_{g,Sp} = -0.5[\mathbf{theta1_{Sp}.m_g} - (\mathbf{theta1_{Sp}}**2.\mathbf{m_g}**2 + 4.\mathbf{theta2_{Sp}})**0.5]$$

$$alpha_{g,Sp}.beta_{g,Sp} = \mathbf{theta1_{Sp}.m_g}$$

The Kirkwood & Walker selctivity is given by:

$$sKW_{a,g,Sp,Sx} = (L_{a,Sp,Sx}/\{alpha_{g,Sp}.beta_{g,Sp}) ** alpha_{g,Sp} . \exp(alpha_{g,Sp} - L_{a,Sp,Sx}/beta_{g,Sp})$$

The **theta3** parameter can be used to examine the effects of "bounce-off", whereby even though larger sharks are not actually caught by the net, they are killed by it and this contributes to mortality.

If **theta3** = 0.0, then the Kirkwood & Walker selectivity model is used. i.e.

$$s_{a,g,Sp,Sx} = sKW_{a,g,Sp,Sx}.$$

This simulates larger sharks not being as vulnerable to small mesh gear as are smaller ones.

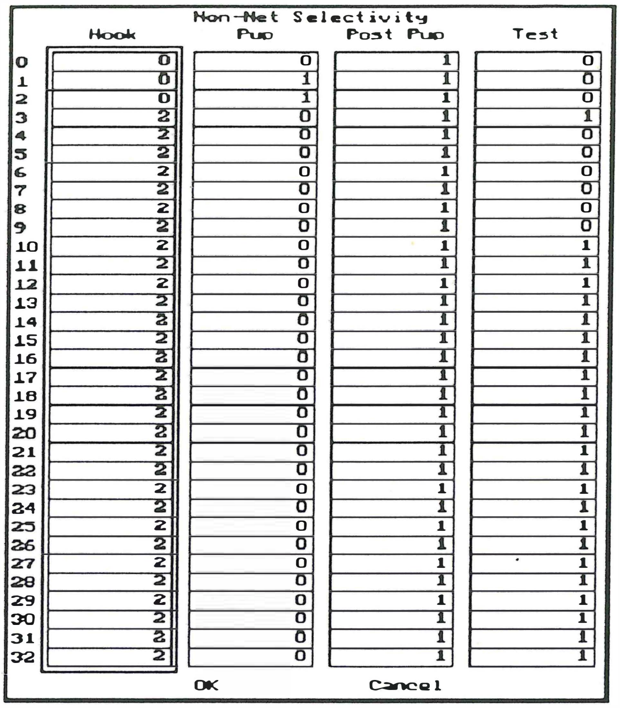
If **theta3** = 1.0, then $s_{a,g,Sp,Sx}$ = 1.0 for all ages above the age at which $sKW_{a,g,Sp,Sx}$ reaches its maximum value. This simulates all sharks above a certain age being equally susceptible to the gear.

Values of **theta3** between 0.0 and 1.0 enable the user to alter smoothly and linearly the proportional weighting of these two models.

4.6.8b Selectivity (non-net) command

The selectivity of gears other than nets is entered directly by gear and age for a particular species.

/MOG or **/MOS** calls up the **S**electivity (non-net) form on the right for gummy and school sharks respectively.



Non-Net Selectivity

	Hook	Pup	Post Pup	Test
0	0	0	1	0
1	0	1	1	0
2	0	1	1	0
3	2	0	1	1
4	2	0	1	0
5	2	0	1	0
6	2	0	1	0
7	2	0	1	0
8	2	0	1	0
9	2	0	1	0
10	2	0	1	1
11	2	0	1	1
12	2	0	1	1
13	2	0	1	1
14	2	0	1	1
15	2	0	1	1
16	2	0	1	1
17	2	0	1	1
18	2	0	1	1
19	2	0	1	1
20	2	0	1	1
21	2	0	1	1
22	2	0	1	1
23	2	0	1	1
24	2	0	1	1
25	2	0	1	1
26	2	0	1	1
27	2	0	1	1
28	2	0	1	1
29	2	0	1	1
30	2	0	1	1
31	2	0	1	1
32	2	0	1	1

OK Cancel

3.5.5 About command

/A displays a screen of information about *SharkSim v1.0*.

3.5.6 Exit command

/XY (/Exit Yes) - Finish using *SharkSim*. This is equivalent to entering **[alt-X]**.

You will lose the current simulation unless it has been **S**aved previously.

/XN No, don't exit *SharkSim*.

4 EXAMPLE

The following sequence of commands enable the user to learn the essentials of using **SharkSim** in about 30 minutes (using the recommended hardware).

1	Start *SharkSim*.	(see Section 3.1)
2	**/FLSshow[enter]**	This **L**oads the **S**imulation called **"show"** onto the screen. It illustrates scientists' best understanding of the fishery in February 1991.
3	**FF**	Note the values and totals of the colourbands and histograms at PIT.
4	**[end]**	Move PIT to the end of the simulation.
5	**[home]**	Move PIT to the Initial Year.
6	**/VZ1**	Zoom the view so that the entire simulation is visible at once.
7	**[end][enter]**	Simulate fishing in 1991 with the same fishing effort as in 1990.
8	Use **[down]**, **[ctrl-right]** repeatedly to set fishing effort equal to zero in 1992. Press **[enter]** 15 times to simulate closing the fishery from 1992 to 2007. Note the rate of recovery.	
9	Press **FF** and then use the keyboard commands listed in Section 3.3.2 to set 6" and 7" effort to 30 each. Press **[enter]** ten times to show a sustainable policy yielding at least 1000 tonnes annually.	
10	Use the keyboard commands listed in Section 3.3.1 to measure values in different years.	
11	**/SSFA**	View the school females part of the stock by age-class (see Appendix B for colour code).
12	Experiment on your own.	
13	**[alt-X]**	Exit

APPENDIX A Service and support

If you experience any difficulty using **SharkSim** please contact the developers as soon as possible.

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SENIOR SCIENTIST (MODELS)
CONSULTANT

Hoselito Stankovic
SYSTEMS DESIGN

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GPO Box 1625
Adelaide SA 5001

Tel: (08) 226 0633
Fax: (08) 226 0664

Your suggestions for improvement of the software, manual or data sets are welcome.

APPENDIX B Colour codes

Depending on what is displayed on the main screen, different colours represent different information as follows:

i) by Species

Pop (cw), Births, Catch(cw) and CPUE (cw) can be displayed by Species. ('cw' indicates carcass weight)

Colour	Species
Light green	Gummy shark
Light blue	School shark

ii) by Sex and Species

Pop (cw), Births, Catch(cw) and CPUE (cw) can be displayed by Sex and Species.

Colour	Sex and Species
Green	Male gummy shark
Light green	Female gummy shark
Blue	Male school shark
Light blue	Female school shark

iii) by gear

The Effort row is always by gear. When you display a Species Sex by age-class or length-class, Births, Catch(cw) and CPUE (cw) will also be displayed by gear.

Colour	Gear
Red	6-inch gill net
Yellow	7-inch " "
Brown	8-inch " "
Light magenta	Longline hooks
Light green	Gear targeted at post-pups
Light cyan	Other gear targeted at pups
Magenta	A test gear type for advanced analysis

iv) by age-class

Pop (cw) and Births can be displayed by age-class. The Births row shows births *by age-class of parent females.*

The colour code is different for School and Gummy sharks.

Code	Colour	School age-class	Gummy age-class
Births	Blue	0+	0+
Immat_y	Light blue	1+ to 4+	1+ to 2+
Immat_o	Cyan	5+ to 8+	3+ to 4+
Mat<50y	Light cyan	9+ to 11+	5+ to 6+
Mat<50o	Green	12+ to 14+	7+ to 8+
Mat>50y	Light green	15+ to 21+	9+ to 10+
Mat>50o	Yellow	22+ to 28+	11+ to 12+
Mat100	Pink	29+ to 31+	13+ to 16+
Survivor	Red	32+ and over	17+ and over

v) by length-class

Pop (cw) and Births can be displayed by length-class. The Births row shows births *by length-class of parent females.*

The colour code is the same for School and Gummy sharks.

Colour	Length-class (mm)
Blue	less than 800
Light blue	800 - 899
Cyan	900 - 999
Light cyan	1000 - 1099
Green	1100 - 1199
Light green	1200 - 1299
Yellow	1300 - 1399
Pink	1400 - 1499
Red	1500 and more

APPENDIX C Scenarios

The database supplied with *SharkSim v1.0* contains some data sets. These represent scientists' best understanding as at February 1991 of the situation of the fishery at this model resolution. Most of the simulations relate to predictions of the consequences of alternative management policies starting in 1991. Contact Dr Jeremy Prince, consultant, for more details.

Read the PREFACE of this manual and use these scenarios with caution.

Note that capital and small letters used in file names are treated differently.

File	Scenario	Result
history	History of fishery	B-1925/B-1990 = 15%
ITQ800	800t quota	Characteristic final escalation of effort, 25y
C1ITQ800	800t quota, 1yr closure	Final recovery, 30y
ITQ600	600t "	Recovery, 25y
	Effects of management delay	
D1ITQ600	600t quota, 1yr delay	Slower recovery, 35y
D2ITQ600	600t " , 2yr "	Eventual collapse, 30y
	Gear types	
six"future	Current effort, just 6" net	Total collapse
seven"future	" " , " 7" "	" "
eight"future	" " , " 8" "	School collapse, low gummy equilibrium
hookfuture	" " , " hook	Total collapse (ref:JP)
	Effort restrictions	
effred50	50% " " "	Stabilises 650t
eff6red50	50% " " (6")	550t, declining
eff7red50	50% " " (7")	730t, gummy recovers, school low
eff8red50	50% " " (8")	1000t, slow recovery
effred66	66% " " (6&7")	1600t, recovery

APPENDIX D Mathematical algorithm

SharkSim v1.0 simulates a complex fishery. The overall model is a combination of a number of smaller "sub-models". These are described in section 4.6. This appendix describes the method and sequence in which these submodels are combined to generate the variables described on the screen.

For age-class **a+**, year **y**, gear type **g**, species **Sp** and sex **Sx**:

1 $N_{a,0,Sp,Sx}$ is given by the **I**nitial Age Structure model. Set y=0.

2 The user sets a total effort $TEU_{y,g}$. The **E**ffort Allocation model splits this into $E_{y,g,Sp}$.

3 Fishing mortality:

$$F_{a,y,g,Sp,Sx} = q_{y,Sp} \cdot s_{a,g,Sp,Sx} \cdot E_{y,g,Sp},$$

where q and s are supplied by the **C**atchability and **S**electivity models.

4 Total mortality:

$$Z_{a,y,Sp,Sx} = M_{a,y,Sp} + sum_g sum_{Sx}[F_{a,y,g,Sp,Sx}],$$

where M is supplied by the **M**ortality model.

5 Next year's starting population of fish aged 1+ and above:

$$N_{a+1,y+1,Sp,Sx} = N_{a,y,Sp,Sx} \cdot exp[-Z_{a,y,Sp,Sx}]$$

6 The catch in numbers in year **y**:

$$CN_{a,y,g,Sp,Sx} = (N_{a,y,Sp,Sx} - N_{a+1,y+1,Sp,Sx}) \cdot F_{a,y,g,Sp,Sx}/Z_{a,y,Sp,Sx}$$

7 The catch in weight (carcass weight):

$$CW_{a,y,g,Sp,Sx} = \mathbf{0.67} \cdot CN_{a,y,g,Sp,Sx} \cdot W_{a,Sp,Sx},$$

where W is supplied by the **G**rowth model.

8 The new-bornes $N_{0,y+1,Sp,Sx}$ entering age-class 0+ in year **y+1** are supplied by the **R**eproduction model.

9 Aggregates (e.g. Catch by age-class) and ratios (e.g. CPUE) are calculated, the year is incremented by 1, and the algorthm then proceeds to step 2 above with a new age structure $N_{a,y+1,Sp,Sx}$.

APPENDIX E References

Francis, R.C. (1990). Fisheries science and modelling: A look to the future. *Natural Resource Modeling* **4**, 1-9.

Lewis, R.K. (1991). Personal communication.

Olsen, A.M. (1984). 'Species synopsis of school shark, *Galeorhinus australis* (Macleay 1981)'. *FAO Species Synopsis No. 139*. (Food and Agriculture Organisation of the United Nations: Rome). 44p.

Walker, T.I. (1991). A fishery simulation model applied to the gummy shark component of the southern Australian Shark Fishery. *Sharks Down Under Conference Proceedings*.

Walters, C.J. (1969). A generalized computer simulation model for fish population studies. *Transactions of the American Fisheries Society* 98, 505-512.

APPENDIX F RATIONALE FOR AND USE OF MODEL: 1990-91

In the past, our economic system encouraged the exploitation of fish stocks at levels which depleted even those fisheries which once laid claim to being 'the largest in the world'. Fishing pressure continues to increase and stocks that are still economically productive have never been under greater threat. Long-lived species which produce few offspring, such as shark, are particularly at risk.

How do we 'enlighten and move decision-makers' (Francis 1990) and make it possible for them to take tough political decisions (Lewis 1991) ?

The *SharkSim* project is based on the belief that the most effective way is to make the situation of remaining stocks and the consequences of alternative management actions so obvious to everyone, including fishers and the public, that difficult management decisions, which may have severe financial repercussions for those in the industry, are nevertheless taken.

SharkSim is a computer package built for this purpose. It was sought by a specialist task force in the Australian Fisheries Service as "an agent for change" to be used to convince industry and the public of the need for urgent and significant management changes in the southern shark fishery.

In 1991, the model played a key role in convincing those involved with the fishery of the need for significant change in its management. The specialist task force together with fisheries scientists visited fishing ports where they used the computer graphics package to explain to the fishing industry why they believed that drastic action was necessary to halt the decline in the fishery and how various management policies could rehabilitate it.

The exercise highlighted the value of biological research and of long term catch and effort data sets. *SharkSim* was also used to identify those areas of research which offer the greatest benefits for future management of the fishery.

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C SharkSim 2E population dynamics models

SHARKSIM 2E

These five pages describe the population dynamics models underlying SharkSim 2E

TIME DEPENDENT VARIABLES DISPLAYED ON SCREEN (POPULATION MODE)

Variable name on screen		Name	Units	Symbol or Equation
Populatn	✓	Population	tonnes cw	$N_{a,y,Sp,Sx} \cdot W_{a,Sp,Sx}$
Births	✓	Births	tonnes cw	$BI_{ap,y,Sp,Sx}$
Catch,g	✓	Catch by gear	tonnes cw	$sum_a\ sum_{Sx} CW_{a,y,g,Sp,Sx}$
CPUE,g	✓	Catch per unit effort by gear	tonnes cw/1000km-lift	$CPUE_{y,g,Sp,Sx}$
Catch,a		Catch by age	tonnes cw	$sum_g\ sum_{Sx} CW_{a,y,g,Sp,Sx}$
CPUE,a		Catch per unit effort by age	tonnes cw/1000km-lift	$CPUE_{a,y,Sp,Sx}$
Av.Ln	✓	Average length of catch by gear	mm	$sum_a CW_{a,y,g,Sp,Sx} \cdot L_{a,Sp,Sx} / sum_a CW_{a,y,g,Sp,Sx}$
Av.Wt		Average weight of catch by gear	kg	$sum_a CW_{a,y,g,Sp,Sx} \cdot W_{a,Sp,Sx} / sum_a CW_{a,y,g,Sp,Sx}$
AvLn.All		Average length total	mm	$sum_g sum_a CW_{a,y,g,Sp,Sx} \cdot L_{a,Sp,Sx} / sum_g sum_a CW_{a,y,g,Sp,Sx}$
SpEffrt		Effort by species	1000km-lift	$sum_g E_{y,g,Sp}$
Effort	✓	Fishing effort by gear	1000km-lift	$E_{y,g,both\text{-}Sp}$

Variable with ✓ means it is on screen by default on start-up

SHARKSIM 2E

START PARAMETER SET (POPULATION MODE)

Model	Explanation	Parameters		Default (start-up) value			
Initial Year	Calender year at start of simulation	Displayed calender year (y=0)		1923			
Initial Age Structure		$N_{a,0,Sp,Sx}$		Table (see figure...)			
Mortality	To compute			Gummy		School	
	$M_{a,y,Sp}$ from	$M_{pup,Sp}$		0.20		0.10	
	$N_{a,y,Sp,Sx}$	$M_{post\text{-}pup,Sp}$		0.20		0.10	
		aM_{Sp}		2.00		4.00	
		bM_{Sp}		9.00		5.00	
		cM_{Sp}		0.00		0.00	
Growth	To compute			Gumm	Gummy	School	School
	$L_{a,Sp,Sx}$			y	Male	Female	Male
	and $W_{a,Sp,Sx}$	$L_{inf,Sp,Sx}$		Female	1417.00	1618.00	1583.00
		$k_{Sp,Sx}$		2019.00	0.17	0.16	0.17
		$t0_{Sp,Sx}$		0.09	-2.08	-1.28	-1.25
		$aW_{Sp,Sx}$		-3.01	0.00	0.00	0.00
		$bW_{Sp,Sx}$		0.00	2.96	3.18	3.17
				3.16			
Reproduction	To compute			Gummy		School	
	$N_{0,y+1,Sp,Sx}$ from	ar_{Sp}		-3.10		29.70	
	$N_{a,y,Sp,female}$	br_{Sp}		1.43		0.00	
		$f_{ap,Sp}$		Table (see figure...)			
Effort Allocation	To compute $E_{y,g,Sp}$ from $E_{y,g,both\text{-}Sp}$	(for PIT year = 1923)					
				Targ-S		Rat	
		$Targ\text{-}S_{n6}$	Rat_{n6}	1.00		0.20	
		$Targ\text{-}S_{n7}$	Rat_{n7}	1.00		0.60	
		$Targ\text{-}S_{n8}$	Rat_{n8}	1.00		0.70	
		$Targ\text{-}S_{ho}$	Rat_{ho}	1.00		0.80	
		$Targ\text{-}S_{pp}$	Rat_{pp}	1.00		0.50	
		$Targ\text{-}S_{pu}$	Rat_{pu}	1.00		0.50	
		$Targ\text{-}S_{te}$	Rat_{te}	1.00		0.50	
		(There is a different parameter set for each PIT year)					
Catchability / Power	To set $p_{g,Sp}$ and compute $q_{y,g,Sp}$ from y and $N_{a,y,Sp,Sx}$	$q0_{g,Sp}$ $bq_{g,Sp}$ $qddq_{g,Sp}$ $kddq_{g,Sp}$ $p_{g,Sp}$		Table (see figure...)			
Selectivity$_{(Net)}$	To compute			Gummy		School	
	$s_{a,g,Sp,Sx}$ for nets	$theta1_{gummy}$	$theta1_{school}$	186.00		192.00	
	using method of	$theta2_{gummy}$	$theta2_{school}$	36695.00		67597.00	
	Kirkwood and Walker 1986	$theta3_{gummy}$	$theta3_{school}$	0.50		0.50	
Selectivity$_{(Non\text{-}Net)}$	To set $s_{a,g,Sp,Sx}$ for non-net gears (gummy and school separately)	$s_{a,g,Sp,Sx}$ for non-net gears		Tables (see figures ... & ...)			

SHARKSIM 2E

SIMULATION ALGORITHM (POPULATION MODE)

1. Enter Start Parameter Set (see page ?)

2. Calculate preliminary parameters and variables

Length: $L_{a,Sp,Sx} = L_{inf,Sp,Sx}.[1 - \exp\{-k_{Sp,Sx}.(a_{Sp,Sx} - t0_{Sp,Sx} + 0.5)\}]$

Whole weight: $W_{a,Sp,Sx} = aW_{Sp,Sx}.L_{a,Sp,Sx} ** bW_{Sp,Sx}$

Selectivity of nets using method of Kirkwood and Walters (1986). For m_g = 6", 7", 8":

$$beta_{g,Sp} = -0.5[theta1_{Sp}.m_g - (theta1_{Sp}**2.m_g**2 + 4.theta2_{Sp})**0.5]$$

$$alpha_{g,Sp}.beta_{g,Sp} = theta1_{Sp}.m_g$$

$$s_{a,g,Sp,Sx} = (L_{a,Sp,Sx}/\{alpha_{g,Sp}.beta_{g,Sp})**alpha_{g,Sp}.\exp(alpha_{g,Sp} - L_{a,Sp,Sx}/beta_{g,Sp})$$

3. $N_{a,0,Sp,Sx}$ is given by the Initial Age Structure model from Step 1 above. Set y=0.

4. The user sets a total effort $E_{y,g,both\text{-}Sp}$. The Effort Allocation model splits this by species:

$$E_{y,g,school} = E_{y,g,both\text{-}Sp}.[Rat_g.Targ\text{-}S_g + (1-Rat_g).C_{y-1,g,school} / sum_{Sp}\{C_{y-1,g,school}\}]$$

$$E_{y,g,gummy} = E_{y,g,both\text{-}Sp} - E_{y,g,school}$$

5. Natural mortality: $M_{a,y,Sp} = M_{pup,Sp} + cM_{Sp}.sum_{(both\text{-}Sx)}sum_{(a=bMs,\ to\ 32)}[N_{a,y,Sp,Sx}])$ for pup ages (a=0 to aM_{Sp})

$M_{a,y,Sp} = M_{post\text{-}pup,Sp}$ for post-pup ages (a=aM_{Sp}+1 to 32)

6. Fishing mortality:

Catchability $q_{y,g,Sp} = q0_{g,Sp} + (bq_{g,Sp}.y) + qddq_{g,Sp}.\exp(-kddq_{g,Sp}.sum_{post\text{-}pup}sum_{Sx}[N_{a,y,Sp,Sx}])$

$$F_{a,y,g,Sp,Sx} = q_{y,Sp}.p_{g,Sp}.s_{a,g,Sp,Sx}.E_{y,g,Sp}$$

7. Total mortality: $Z_{a,y,Sp,Sx} = M_{a,y,Sp} + sum_g[F_{a,y,g,Sp,Sx}]$

8. Next year's starting population of fish aged 1+ and above:

$$N_{a+1,y+1,Sp,Sx} = N_{a,y,Sp,Sx}.\exp[-Z_{a,y,Sp,Sx}]$$

9. The catch in numbers in year y:

$$CN_{a,y,g,Sp,Sx} = (N_{a,y,Sp,Sx} - N_{a+1,y+1,Sp,Sx}).F_{a,y,g,Sp,Sx} / Z_{a,y,Sp,Sx}$$

10. The catch in weight (carcass weight):

$$CW_{a,y,g,Sp,Sx} = 0.67.CN_{a,y,g,Sp,Sx}.W_{a,Sp,Sx}$$

11. The new-borns $N_{0,y+1,Sp,Sx}$ entering age-class 0+ in year y+1 are supplied by the Reproduction model

$$BI_{ap,y,Sp} = \max[0.0, ar_{Sp} + br_{Sp}.W_{a,Sp,female}].\ N_{ap,y,Sp,female}.f_{ap,Sp}$$

$$N_{0,y+1,Sp,Sx} = sum_{ap}[BI_{ap,y,Sp}]/2$$

12. Aggregates (e.g. Catch by age-class) and ratios (e.g. CPUE) are calculated, the year is incremented by 1, and the algorithm then proceeds to step 4 above with a new age structure $N_{a,y+1,Sp,Sx}$.

SHARKSIM 2E

DEFINITION OF SYMBOLS, INDICES, AND NOTATION USED (POPULATION MODE)

Symbol	Definition
Indices	
a	Age
ap	Parental age of female
both-Sp	Both species
female	Female
g	Gear type
gummy	Gummy shark
GF	Gummy female
GM	Gummy male
ho	Gear type, hook
male	Male
n6	Gear type, 6-inch gill-net
n7	Gear type, 7-inch gill-net
n8	Gear type, 8-inch gill-net
post-pup	Sharks aged aM_{Sp}+1 and over
pp	Gear type, gear that kills post-pups
pu	Gear type, gear that kills pups
pup	Sharks aged 0 to aM_{Sp}
school	School shark
Sp	Species (gummy, school)
Sx	Sex
SF	School female
SM	School male
te	Gear type, test gear
y	Year
Parameters, Observations, and Symbols	
$alpha_{g,Sp}$	Net selectivity parameter related to gear mesh size m_g and length of sharks for species *Sp* (see Kirkwood and Walker 1986)
ar_{Sp}	Parameter affecting number of births for female of parental age for species *Sp*
aM_{Sp}	Parameter used in mortality model: "Last age at which shark called a pup"
$aW_{Sp,Sx}$	Allometric growth parameter in the von Bertalanffy growth equation for species *Sp* and sex *Sx*
Av.Ln	Time dependent variable name shown on screen (see page 1)
AvLn.All	Time dependent variable name shown on screen (see page 1)
Av.Wt	Time dependent variable name shown on screen (see page 1)
$beta_{g,Sp}$	Net selectivity parameter related to gear mesh size m_g and length of sharks for species *Sp* (see Kirkwood and Walker 1986)
$bq_{g,Sp}$	Parameter used to compute $q_{y,g,Sp}$ representing increased efficiency over years
br_{Sp}	Parameter affecting number of births for female of parental age for species *Sp*
bM_{Sp}	Parameter used in mortality model (density dependence)
$bW_{Sp,Sx}$	Allometric growth parameter in the von Bertalanffy growth equation for species *Sp* and sex *Sx*
Births	Time dependent variable name shown on screen (see page 1)
$BI_{ap,y,Sp}$	Number of births produced by a parental age-class in year *y* for species *Sp*
cM_{Sp}	Parameter used in mortality model (density dependence)
$C_{y,g,Sp}$	Catch in year *y* by gear *g* for species *Sp*
Catch,a	Time dependent variable name shown on screen (see page 1)
Catch,g	Time dependent variable name shown on screen (see page 1)
$CN_{a,y,g,Sp,Sx}$	Catch in numbers of fish of age *a*+ in year *y* for a particular gear *g* for species *Sp* and sex *Sx*

CPUE	Catch per unit effort
CPUE,a	Time dependent variable name shown on screen (see page 1)
CPUE,g	Time dependent variable name shown on screen (see page 1)
$CW_{a,y,g,Sp,Sx}$	Catch in weight (carcass weight) of fish of age *a+* in year *y* for a particular gear *g* for species *Sp* and sex *Sx*
E	Fishing effort
$E_{y,g,both\text{-}Sp}$	Fishing effort in year *y* for gear *g* and both species (gummy and school)
$E_{y,g,Sp}$	Fishing effort in year *y* for gear *g* and species *Sp*
Effort	Time dependent variable name shown on screen (see page 1)
$f_{ap,Sp}$	Proportion of females by parental age that are mature for species *Sp*
F	Fishing mortality
$F_{a,y,g,Sp,Sx}$	Fishing mortality for fish of age *a+* in year *y* from gear *g* for species *Sp* and sex *Sx*
$k_{Sp,Sx}$	Allometric growth parameter in the von Bertalanffy growth equation for species *Sp* and sex *Sx*
$kddq_{g,Sp}$	Parameter used to compute $q_{y,g,Sp}$ (density dependence)
$L_{a,Sp,Sx}$	Length of a fish (mm) of age *a+* for species *Sp* and sex *Sx*
$L_{inf,Sp,Sx}$	Asymptotic length parameter in the von Bertalanffy growth equation for species *Sp* and sex *Sx*
m_g	Mesh size of gill-net, i.e. *g* inches
M	Natural mortality
$M_{a,y,Sp}$	Instantaneous natural mortality of *a+* age-class fish in year *y* for species *Sp*
$M_{pup,Sp}$	Instantaneous natural mortality of pups for species *Sp*
$M_{post\text{-}pup,Sp}$	Instantaneous natural mortality of post-pups for species *Sp*
N	Number of fish
$N_{0,y,Sp,Sx}$	Total number of births at the beginning of a simulation year *y* for species *Sp* and sex *Sx*
$N_{a,0,Sp,Sx}$	Initial age structure: Number of fish of age *a+* in the Initial Year (*0*) for species *Sp* and sex *Sx*
$N_{a,y,Sp,Sx}$	Number of fish of age *a+* in year *y* for species *Sp* and sex *Sx*
$N_{ap,y,Sp,female}$	Number of female fish of parental age in year *y* for species *Sp*
$p_{g,Sp}$	Power by gear *g* and species *Sp*
Populatn	Time dependent variable name shown on screen (see page 1)
q	Catchability
$q_{y,g,Sp}$	Catchability of species *Sp* to gear *g* in year *y*
$q0_{g,Sp}$	Parameter used to compute $q_{y,g,Sp}$ (base value)
$qddq_{g,Sp}$	Parameter used to compute $q_{y,g,Sp}$ (density dependence)
Rat_g	Ratio: Parameter allocating the amount of fishing effort in year *y* of a particular gear type *g* to each species in proportion to catches in the previous year (*y-1*); values range from 0.0 (effort in same proportion as their catches in the previous year) to 1.0 (effort split into simple proportions specified by Target(School)), e.g. if Ratio = 0.5, half the effort is allocated according to the Target(School) parameter in year *y* and half in proportion to the previous year's catch
s	Gear selectivity
$s_{a,g,Sp,Sx}$	Selectivity of gear *g* for fish of age *a+*, species *Sp* and sex *Sx*
SpEffrt	Time dependent variable name shown on screen (see page 1)
$t0_{Sp,Sx}$	Parameter in the von Bertalanffy growth equation for species *Sp* and sex *Sx*
$theta1_{Sp}$	Net selectivity parameter based on model of Kirkwood and Walker 1986, for species *Sp*
$theta2_{Sp}$	Net selectivity parameter based on model of Kirkwood and Walker 1986, for species *Sp* (Variance of length of fish captured by gill-nets (constant for all mesh sizes), for species *Sp*)
$theta3_{Sp}$	Additional net selectivity parameter dealing with different possible levels of "ghost fishing", (e.g. the effects of "bounce-off", whereby larger sharks not actually caught by the net, are nevertheless killed by it thus contributing to mortality). Values of *theta3* between 0.0 and 1.0 enable user to alter smoothly and linearly the proportional weighting between the model of larger sharks not being as vulnerable to small mesh gear as the smaller ones, and the model of all sharks above a certain age being equally susceptible to the gear
$Targ\text{-}S_g$	Target (School): Parameter allocating the amount of fishing effort of a particular gear type *g* to each species; values range from 0.0 to 1.0, e.g. if Target(School*) = 0.5, equal amounts of effort of that particular gear type are allocated to both species
$W_{a,Sp,Sx}$	Whole weight of a fish (kg) of age *a+* for species *Sp* and sex *Sx*
$Z_{a,y,Sp,Sx}$	Total mortality of fish of age *a+* in year *y* for species *Sp* and sex *Sx*