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Australian Society for Fish Biology Workshop

LEGAL SIZES and their use in FISHERIES MANAGEMENT

Lorne • 24 August 1990

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D. A. Hancock

Department of Primary Industries and Energy
Bureau of Rural Resources

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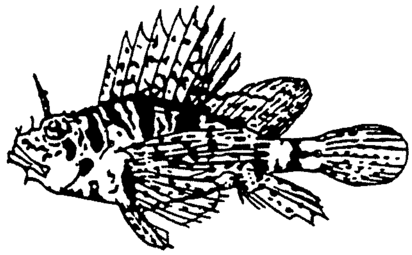

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The Bureau of Rural Resources within the Department of Primary Industries and Energy was established in October 1986. It provides scientifically objective advice to the Commonwealth Government in the rural sector. The Bureau's mission statement is "to promote efficient and sustainable use of Australia's agriculture, forestry and fisheries resources by providing scientific and technical advice to goverment".

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Foreword

J.P. Glaister

President, Australian Society for Fish Biology

The Workshop on "Legal Sizes and Their Use in Fisheries Management" was held on August 24, 1990 at Erskine House, Lorne, courtesy of the Victorian Department of Conservation and Environment. Its purpose was to examine the usefulness of legal sizes as management tools. It was preceded by a two day workshop entitled "The Measurement of Age and Growth in Fish and Shellfish" and both were part of the annual conference of the Australian Society for Fish Biology (ASFB). Funding for the workshops and administrative resources was provided by the Fishing Industry Research and Development Council (FIRDC), the workshops were coordinated by Dr Don Hancock (ex W.A. Fisheries), and publication of the proceedings made possible by the Bureau of Rural Resources.

A great deal of interest had been generated on this topic around Australia, particularly as to the question: Why have a legal size? The common consensus was the age-old response of enabling all species "to spawn at least once", a premise which seems to have become less fashionable with time. The rationale for many existing legal sizes has become lost in files or because the original recommendation was based on "what is a reasonable size".

As pressure on our fisheries resources increases, the demand for legal size regulation and other management measures will increase and managers will need to consider carefully both the past history and current thinking on the scientific and practical justification for applying legal sizes, and their place in fisheries management. The workshop benefited greatly from the two previous days of deliberations on Age and Growth which provided an important springboard for the topic of Legal Sizes.

Dr Burke Hill, Officer-in-Charge of the CSIRO Cleveland Laboratory, commenced with a comprehensive outline as part of his keynote address. Burke's address was particularly interesting as he had painstakingly researched many of the underlying reasons and assumptions regarding legal size regulations. Dr Don Hancock followed with a detailed compilation of current usage on a state-by-state basis. These two speakers set the scene for subsequent panel discussions.

As with the preceding workshop on Age and Growth, the programme was designed around several key themes, with panels of experienced speakers examining each area, followed by a general discussion by all participants. Sessions were chaired by Rob Lewis, John Glaister and Ross Winstanley. Dr Bob Kearney presented a comprehensive overview of discussions and outcomes.

The Society is extremely grateful to FIRDC and the Bureau of Rural Resources for their support, and to the host State, Victoria, for the excellent arrangements for the meetings. It is envisaged that similar workshops of national interest to fish and fisheries will be a feature of the ASFB's Annual Conference in future years.

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Opening Address: Should There Be a Contemporary Role for Societies Such as ASFB?

W.A. Chamley

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I would like to thank the organisers for the opportunity to speak at the opening of this workshop. As you all know this is one of two workshops which will run in conjunction with the 17th Annual Meeting of the Australian Society for Fish Biology.

Before formally opening the workshop I would like to make just a few brief comments about the role of societies such as this one. I hope that after you have considered my opening address, members might give due consideration to this question.

If a questionnaire were to be circulated amongst current members, about the role of the ASFB, I would suggest that the bulk of responses would probably describe the ASFB, as a body which brings together persons with a common interest in fish biology, and which essentially organises information exchange. Some responses might recognise a training role for the more junior members and might in fact see a workshop such as the one which will begin in a moment, as a demonstration of that training role.

I would hope that a few of the responses might see a role of the ASFB as one which also focused upon community education and active participation in public debate about issues which do, or might at some future date, impact upon fish biology, dynamics, distribution etc.

I wish to suggest that the small number of professional/technical societies whose members' interests are with aquatic resources, habitat etc, ought to give more consideration to assuming such a role and working through a longer term strategy to develop and achieve this.

Currently there are a range of inquiries and debates going on in this country and indeed even tactical responses being worked out by governments.

My list is not exhaustive but included in such a list would be:

- the House of Representatives inquiry into protection of the coastal environment;
- a proposed inquiry by the Resource Assessment Commission into coastal planning;
- the Southern Bluefin Tuna debate;
- the Greenhouse Effect and responses by governments both state (territories) and federal to this issue;
- in Victoria, a Parliamentary inquiry into commercial and recreational fishing in bays and inlets;
- the Commonwealth Sustainable Development Paper;
- proposed large scale pulp and paper manufacture in this country;
- the Commonwealth Policy Paper on Commercial Fisheries Management and the proposal to establish a Statutory Authority to manage commercial harvesting of a common property resource;
- a proposed reduction in Commonwealth research funds for fisheries research by at least 50%.

From where I sit, the input by the various aquatic societies to these inquiries and their contributions towards these debates has to date been a deafening silence. I wish to suggest that societies such as this one must begin to become active in these debates and inquiries and this should become one important contemporary role.

The members of course have every right to decide that this should not be a major role of such a society. If they come to that conclusion then I think there is a real risk and, collectively they ought to be aware of that real risk. The real risk, I suggest, is that the discipline ceases to be seen as one which is important and relevant to contemporary society and the institutions which govern it.

While such a situation may not pose a threat to the more established members who will attend the next few days of meetings, there is a possibility that the more junior members will find themselves on the same endangered species list as some of the fish species which will be discussed at these very meetings.

Let me finish with a few brief remarks about a contemporary role for societies such as this as a community educatory. I don't believe that anyone would deny the fact that the general public are fascinated by aquatic biology. Television has exposed them to aquatic biology through a range of programs put together by pioneers such as Jacques Cousteau and later by David Attenborough and David Suzuki as well as organisations such as the National Geographic Society and others. These have usually depicted marine species in their habitats and raised issues about the impact of mankind. The same degree of focus on freshwater species and habitats has yet to be achieved.

The more recent development of highly sophisticated public aquaria and the clear demonstration that thousands of people are prepared to pay to enter and experience these facilities, suggests to me that this public interest is not declining. Despite this the very professional and technical people who investigate, monitor and analyse so as to produce the data and descriptive information about what is exhibited to the public are currently in what I call "bunker mode". The symptoms of "bunker mode" are:

- a steady decline in financial support which has now been evident across Australia for several years;
- a serious and widespread de-skilling problem the end of which is not yet in sight;
- ageing infrastructure in many of the institutions where work is being carried out;
- an inability now of the discipline to capture many of the nation's top-scoring students be they school leavers or graduates.

The various societies must collectively address the following question. Despite clear public interest and a wide range of public concerns (look at the number of government inquiries) why is financial support of the aquatic disciplines so far down on the priority list? I suggest furthermore that the time has arrived when collectively, the societies must do something about it.

Ten or so years ago I was working in medical research. At that time in Australia, medical research was in exactly the same situation as I am suggesting the broad aquatic discipline is in now. The various specialist groups such as cardiology, diabetes, etc, pooled their efforts and over ten years they have essentially reversed that situation. Last week was medical research week in Melbourne and the various societies no doubt held their individual meetings. However, running in parallel with these was a series of popular talks about medical science, public health, etc. These took place in Melbourne's Concert Hall and they drew in city commuters who had just finished a working day. The chairperson at each session was not an eminent scientist. Indeed media personalities like John Jost took up the challenge.

The importance of this community education process and its ability to generate public support should not be overlooked.

Finally I am delighted that the ASFB is running these workshops and I wish you all the best over the next few days of conference.

Introduction

J.P. Glaister

President, ASFB
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Ladies and gentlemen, welcome to the workshop on "Legal Sizes and Their Use in Fisheries Management". The previous two days have been concerned with the "Measurement of Age and Growth in Fish and Shellfish" and it is now appropriate to see to what use such information can be put by managers.

Our Society has developed since its inception in 1971 and our aim of the interchange of science in a relaxed but effective forum. We progressed from joint meetings with the Australian Marine Sciences Association to our first conference in our own right in 1975 at Port Stephens. Who could forget that Annual Dinner when Barry Goldman took us to new heights by scaling the coconut trees? Today we are a Society of over five hundred members but we are an ageing Society, and we need new strong year classes coming through our population. Looking around it is encouraging to see a good mix of younger scientists present.

The concept of pre- and post-conference workshops was fittingly initiated last time we were here in Victoria in 1985 at the Arthur Rylah Institute when John Harris and Fred "Callop" Reynolds held the "Australia's Threatened Fishes" workshop. The following year in Darwin we saw the "Advances in Aquaculture" workshop, convened by Rex Pyne, and "The Use of By-Catch Resources" workshop convened by Barry Russell. That year also saw the inaugural presentation of the Donald D. Francois award for an outstanding contribution to fish biology, an award that is still keenly contested each year.

In 1987 we put frivolity behind us with the "Scientific Advice for Fisheries Management - Getting the Message Across" workshop in Canberra and for the first time with the assistance of the Bureau of Rural Resources, the Proceedings were published. The following year in Sydney saw the "National Fish Tagging Workshop" convened by John Beumer and Albert Caton. Coincidentally, the Standing Committee on Fisheries had also recommended such a workshop. Bureau staff Albert Caton, Phil Stewart, Jim Stoddart and Richard Tilzey together with Don Hancock, turned the results of the workshop into an impressive publication with the assistance of Gregg Berry. Last year at Magnetic Island, the workshop dealt with "Translocation of Fish". The pilot's strike of course meant that some people had considerable difficulty in getting home again, with a few needing to travel via strange and exotic locations. However, it too was a successful workshop with Dave Pollard and again Gregg Berry producing an impressive "Proceedings".

So we come to today to discuss "Legal Sizes". This topic has been of particular interest to fisheries managers and scientists alike. Why have them? The hope of the workshop is that the assembled expertise may arrive at an agreed response to that question as well as outlining the science necessary to develop legal-size recommendations. This year we were fortunate in obtaining Fishing Industry Research and Development Council (FIRDC) financial support to hold this workshop and we are fortunate in having a FIRDC councillor, Dr Bob Kearney, as a participant at this workshop. In applying for FIRDC support, the objectives we outlined were:

- to promote the opportunity during the Australian Society for Fish Biology annual conference for the national fisheries research expertise to focus on a technical area or subject of current or perceived national or regional fisheries significance. Such area or subject to be identified by the membership of the Society *or by the Council* as appropriate;

- to support *where appropriate* visiting fisheries scientists of acknowledged expertise in the workshop subject area to offer a national or international perspective;
- to assist in the publication of workshop proceedings as a benchmark document of current knowledge in the workshop subject area;
- as a result, to identify and define research questions of national fisheries significance.

I am sure you would agree that "Legal Sizes and Their Use in Fisheries Management" is such a topic.

Again, we will be publishing the results of this workshop with the assistance of the Bureau of Rural Resources and Gregg Berry after scientific editing by Don Hancock. The Society deeply appreciates the cooperation and support of the Bureau with its Workshops now over four consecutive years.

Today's workshop will consist of three major sessions: the basis for setting lengths, chaired by Rob Lewis; a series of case studies to look at problems encountered, chaired by John Glaister; and a general discussion session, chaired by Ross Winstanley. Summing up will be undertaken by Bob Kearney. We do urge all participants to assist us in arriving at consensus on why and how we need legal sizes. To assist rapporteurs in recording proceedings, please identify yourselves clearly.

Introduction of Keynote Speaker

J.P. Glaister

President, ASFB
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PO Box 46
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Our workshop on "Legal Lengths and Their Use in Fisheries Management" is to commence with a keynote address, and it is my pleasure to introduce Dr Burke Hill, Senior Principal Research Scientist at the CSIRO Laboratory, Cleveland.

Burke undertook his Ph.D. research work at Rhodes University in South Africa on portunid crabs, particularly the mud crab, *Scylla serrata*. In 1974 he spent a year doing comparative research on Queensland mud crabs. Australia had a lasting impact and in 1978 Burke returned to Queensland as Research Director at the Queensland Department of Primary Industries. Burke's enthusiasm and quiet determination had a significant effect on the research direction at QDPI and the success of that organisation can largely be attributed to his efforts. In 1982 Burke was "press-ganged" by CSIRO, made a Principal Research Scientist and headed up a Behavioral Unit at the Cleveland laboratory. His current work includes penaeid behavioral studies and the fate of discarded by-catch. He is to take over from Bill Dall as Officer-in-Charge of the Cleveland laboratory in September.

When I first approached Burke to consider presenting the keynote address, he was very enthusiastic about the topic. Burke is presently completing a book on the "Marine Fisheries of Australia" which has a section on management and he thought that the background work would thus be put to good use. Well, the book is due for publication in early 1991 and he has confided in me that, at times, he felt that the book would be ready before the keynote!

However, those of us who know Burke have anticipated that he will give the same thorough and comprehensive treatment to this topic that he does to all his scientific endeavour.

Ladies and gentlemen, please welcome our keynote speaker, Dr Burke Hill.

Keynote Address: Minimum Legal Sizes and Their Use in Management of Australian Fisheries

B.J. Hill

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Introduction

Minimum legal sizes set the smallest size at which a particular species can be legally retained if caught. By increasing the size at which animals are caught, and by increasing or maintaining the size of the spawning stock, minimum sizes can be used to assist in the control of two major problems in fisheries management, growth overfishing and recruitment overfishing. Minimum sizes are used in commercial and recreational fisheries and, in practice, are one of the few methods of controlling recreational fisheries. They have the advantage of being a logical, readily understandable and acceptable management measure that affects all users equally and so are seen to be fair. They are also not seen to be harmful. It is generally agreed, however, that minimum sizes alone are inadequate for stock management and additional control measures are needed (Harrison 1986).

Minimum sizes have a long history as a management tool in fisheries in Australia. For example, restrictions on the size of fish taken were introduced in Victoria in 1873 and in Queensland in 1877, apparently to produce marketable sizes. In the twentieth century, a growing perception that the sea's harvest is not infinite introduced the principle of allowing the animals to spawn at least once. The use of minimum sizes is still based on enhancing the value of the retained catch and protecting the stock.

The apparent simplicity of imposing minimum sizes should not, however, lead to their introduction without considering the consequences. Imposition of a minimum size designed to protect the spawning stock in the case of a lightly fished species is counter-productive because it reduces the proportion of the catch that can be retained and may be expensive to enforce. There is also no gain, if undersized animals that are returned to the water, subsequently die. Managers must be clear as to their objectives when setting minimum legal sizes.

Objectives of Legal Sizes

Prevention of growth overfishing

The value of fisheries can be increased by varying the size at which the animals are caught. Although this is an extremely important aspect of fisheries management, managers of commercial and recreational fisheries can have a quite different perception of 'value'. The commercial sector favours legal sizes that maximise value per recruit or value per unit of effort. In the recreational fishery, by contrast, some anglers may wish to maximise the numbers or total weight of fish they catch, others may be more interested in trophy fish and so want to catch large animals and are prepared to trade off numbers for this. It is clearly unlikely that any one management measure will suit the whole community.

Prevention of recruitment overfishing

The fishing mortality in heavily fished stocks may be so high that the size of the spawning stock is reduced to the level where it cannot maintain the population. One solution is to protect prespawning or immature animals by means of a minimum size limit. Biologically the result is similar to a closed season that operates until the animals reach a particular size. Closures of this type do not have to include the spawning season, for the most effective closure is one that protects the smaller stages. Thus a prespawning closure is more effective than a spawning closure. Thus any minimum size - even one that is set below the minimum spawning size - will increase the proportion of animals surviving to spawning size provided that the size protected would otherwise have formed part of the retained catch. Thus the minimum size does not necessarily have to be the size at which animals spawn, although the closer it is to this size the more effective it becomes.

Methods of Determining Legal Sizes

Enhancing the value of the catch

In many commercial fisheries, markets drive the sizes that are targeted by setting a scale of prices that are size-related. This system does not, however, maximise the economic yield from the fishery because some sizes might be marketed below the optimum that could be realised if catching them were deferred until they were larger and more valuable.

Yield models by contrast, use information about the rate of growth and mortality and the value at different sizes to estimate the optimum size at which the animals should be captured (Somers 1985). These mathematical models take into account that although animals may increase in value as they grow, their numbers are decreasing through natural mortality. Yield models can also be applied to recreational fisheries (Jones *et al.* 1990).

Increasing reproductive output

The most common method of increasing reproductive output through the use of size limits is to set the minimum size equivalent to the size at which the females become sexually mature. As members of a species do not achieve sexual maturity at the same size, there is some flexibility in choice of sizes: it could be the smallest size at which any of the animals mature or it could be a size at which a higher proportion are mature. The greater the minimum size, the more protection it offers the spawning stock and so the greater the reproductive output.

In nearly all species, the number of eggs produced by a female is related to the size of the female - larger individuals produce more eggs. Where it is judged that egg production should be increased, it is advantageous to set the minimum size above that of first spawning. This has the double advantage of allowing females to spawn more than once and increasing the numbers of eggs per spawning. The positive effects are likely to include a higher yield per recruit and a higher yield (weight) per unit of effort.

However, the higher the size limit, the fewer the animals outside it and so the smaller the proportion of the catch that can be retained. Thus raising the size limit decreases the number of legal-sized animals caught per unit of effort. In cases of recruitment overfishing, this disadvantage may be offset in the longer term by a larger overall population leading to higher catches.

Compatibility of the two objectives

In some species, the size at which yield per recruit is maximised is smaller than the size at first spawning. This is the case for saucer scallops (*Amusium balloti*) in Queensland (Dredge 1988), and King George whiting (*Sillaginodes punctata*) in South Australia (Jones *et al.* 1990). These complications are usually resolved by giving greater priority to one of the factors.

Types of Minimum Sizes

Some of the early minimum sizes were based on length; for example in 1882 a 10 inch size limit was introduced for rock lobsters in Tasmania (Wilson 1987). Most limits however, were based on weight. By the early 1920s limits were based on length. Weights are more difficult to measure precisely, especially at sea; animals dry out and lose weight after capture and fish are often cleaned and gutted shortly after capture. Linear measurements require the simplest of equipment and are unaffected by most handling techniques.

Processing may make it difficult to determine the original size. This can be dealt with in one of two ways: banning processing at sea so that the animals are landed intact (as in most scallop and abalone fisheries) or by having one size for the intact animal and another for the partially processed animal. In Victorian shark fisheries for example, one size is the total length and one the length after its head is cut off (the distance from behind the last gill slit to the tip of the tail (Figure 1) (Victorian Department of Fisheries and Wildlife). Partial measurement is also used in some invertebrates. The size limit on tropical rock lobster (*Panulirus ornatus*) in Torres Strait is the length of the tail, since this is the only part of the animal that is landed (information from the Queensland Fish Management Authority). The essential requirement in these cases is that the processed animal should have some structure that can be measured easily and whose length is correlated with the measurement used on the intact animal. This is obviously not applicable to processed scallops or abalone.

Size limits are not restricted to minimum sizes. There is an upper size limit as well as a lower one for some species. The minimum size for the Queensland groper (*Epinephelus lanceolatus*) is 35 cm and the maximum is 120 cm (Hancock 1992). The upper size limit was introduced after complaints about large groper being killed; it reflects a community emotional response to these extremely large fish. There was, until 1985, an upper size limit of 112 cm overall length on school shark landed in Victoria, because the older - and hence larger - animals might have accumulated unacceptably high mercury levels (Victorian Department of Fisheries and Wildlife). In Western Australia, sharks with a dressed weight greater than 18 kg may not be sold. Trochus (*Trochus niloticus*) in Queensland have a lower limit of 80 mm based on the size at spawning, and an upper of 125 mm to protect the large individuals that provide most of the egg production. The sizes between are the ones preferred by button manufacturers. The large old animals were formerly not fished because their shells tended to be eroded, but when a trade in trochus meat and a market for crushed shell led to exploitation of these large animals, an upper size limit was introduced (Queensland Fish Management Authority).

The size limit may be varied seasonally. The limit on the Queensland saucer scallop (*Amusium balloti*) is 90 mm from 1 November to 1 May and 95 mm for the rest of the year. That is because the scallops reach maturity around 90 mm, so the 95 mm minimum size protects them during the winter and spring spawning season. For the rest of the year the size is based on a yield per recruit analysis that indicates that yield is maximised if the size at first capture is between 85 and 90 mm (Dredge 1988).

The minimum sizes for commercial fishing can also be different to those for recreational fishing, which gives amateurs preferential access to part of the stock. In the Northern Territory, the minimum size of barramundi (*Lates calcarifer*) in the recreational fishery is 50 cm, while for the commercial sector it is 57.5 cm (Hancock 1992)[+]. In Western Australia, the minimum size for Roe's abalone (*Haliotis roei*) is 60 mm for the recreational fishery. It is also 60mm for the commercial fishery except in the Perth metropolitan area where it is 70mm (Hancock 1991). In South Australia, the minimum size for blacklip abalone (*H. rubra*) is 12.5 cm for the commercial fishery in the southern zone only; elsewhere it is 13 cm for the commercial fishery, and 13 cm thoughout the recreational fishery.

Differences in size limits are also found in Victoria (Hancock 1992). The minimum size

[+] Standardised at 55 cm from 1 March 1991.

limit for black bream (Acanthopagrus *butcheri*) is 25.5 cm in the commercial fishery but only 24 cm in the recreational fishery. In the case of yelloweye mullet (*Aldrichetta forsteri*), there is a 24 cm limit in the commercial fishery but no limit in the recreational fishery.

Biological Difficulties Associated with Minimum Sizes

Some of the problems with minimum sizes relate to biology, others to administration.

Inappropriate sizes

There are numerous cases where the minimum size being set is below the size at sexual maturity. Rock lobsters are a prominent example (Table 1), but many scale fish also have apparently inappropriate size limits. Male Australian bass (*Macquaria australasica*) seldom grow to a length in excess of 25cm whereas females grow to approximately twice this length. The minimum legal size for this species in Queensland is 30cm; the fishery is therefore concentrated almost entirely on females. In Queensland, narrow-barred Spanish mackerel mature at 80 cm but the minimum legal length is 45 cm. Some of these apparent discrepancies have a valid reason as shown below, but others appear to reflect managerial inertia in the face of new biological information.

Migratory species

Species that migrate over long distances are caught at different sizes along the coast. The western species of Australian salmon (*Arripis esper*) leaves its nursery areas in Victoria and Tasmania when the fish are around 2 years old, migrate westwards across the Great Australian Bight and spawn off the coast of Western Australia at 3 to 6 years of age when 55 to 60cm long (Anon 1968). Australian salmon in South Australia are 2 to 3 years old (Malcolm 1960). In Victoria and South Australia the minimum legal size for Australian salmon is 21 cm, well below the size at sexual maturity. They form an important fishery in South Australia, where about 500 t are caught each year. If the minimum length in South Australian waters were the size at sexual maturity then there would be no fishery for this species in these waters.

Migration can lead to problems with the use of minimum sizes even over relatively short distances. Tailor (*Pomatomus saltator*) in the Swan River estuary in Western Australia are mostly juveniles under the size at which they become sexually mature (30 cm). They migrate out of the estuary into the sea as they grow to maturity. If the minimum size were raised to 30 cm from the present 25 cm, the estuarine fishery for this species would virtually disappear.

Age-size differences

In most species, sexual maturity is attained at a particular age rather than a particular size as do humans. Blacklip abalone (*Haliotis rubra*) in Tasmania become sexually mature at 8.5 to 9.5 years but their length at this age varies regionally from 60 mm to 115 mm (Nash 1990). Even within a single area, the fastest growing animals are the ones that will reach the minimum size soonest, but because they are young, they are less likely to be mature. Thus size is not a good indicator of sexual maturity in this species. It is, however, obviously impractical to set an age rather than a size limit. The result has been a large number of different size limits for abalone (Table 2); which is not a problem in the commercial fishery, because the divers tend to operate in a limited area and are familiar with the local regulations.

Sex changes

Many species of fish undergo a sex change as they age. Barramundi (*Lates calcarifer*) mature as males when 3 to 4 years old at a length of 60 to 70 cm. They change into females at between 6 and 8 years of age when they are 85 to 100 cm long (Grey 1986). The size limits applied to barramundi in the commercial fishery are 57.5 cm in the Northern Territory (since changed to 55 cm) and 55 cm in Queensland. As a size limit around 85cm would be strongly opposed by both the commercial and recreational fishing lobby, alternative measures for protection of the stock are needed. The problem is not unique to fish. Goldlip pearl oysters (*Pinctada maxima*) mature as males at a shell diameter of 110 to 120 mm. Subsequently 30 to 40% change sex and by the time they reach 200 mm the sex ratio is about 1:1.

Discarding

Where size limits are applied, some of the catch is commonly discarded because it is undersized, and a significant proportion of the discarded animals will be injured or dead. This was one of the criticisms of minimum size limits in the southern bluefin tuna (*Thunnus maccoyii*) fishery as tuna have to be landed on deck before they can be measured. It was unlikely that if many were caught at one time, each would receive the necessary attention to ensure it was returned to the water alive.

Research in Western Australia showed that keeping lobsters out of water for even short periods can result in mortality or in depression of growth in the survivors (Brown 1981). In some animals, such as prawns, virtually all the discarded animals would be dead. No commercial prawn fishery uses size limits, although they are used in an amateur prawn fishery in Western Australia. Spanner crabs (*Ranina ranina*) that suffer even relatively minor damage when being removed from tangle nets, have a high probability of dying (Kennelly *et al.* 1990).

In 1988, a minimum tail length of 100 mm (equivalent to a tail width of 52 mm) was introduced into the tropical rock lobster (*Panulirus ornatus*) fishery in Torres Strait (Queensland Fish Management Authority). A comparison of the size frequency of the commercial catch in June 1988 (before the size limit was introduced) and in July (the first month with the size limit) shows a clear difference (Figure 2). The size limit in this case appears to have been successful. However, these lobsters live in holes and crevices in coral and are captured by being speared. Thus they can be measured only after capture and, if released because they are undersized, are most unlikely to survive. Divers had to learn to estimate the size of lobsters before spearing them. Divers who did not do so would be killing undersized animals.

Clearly damage due to the catching method may undermine the value of minimum sizes. The amount of mortality suffered by under-sized individuals from capture, measurement and release needs to be assessed wherever size limits are a major part of the management strategy. All mortality of animals that are just below the legal size is particularly deleterious because these animals would have a high probability of surviving to legal size.

Problems with identification

Species of Sciaenidae (mulloway) are difficult to distinguish and the taxonomy relies heavily on the structure of the swimbladder. Several species in Queensland, all of which are known as mulloway, mature around 30 cm. The minimum legal size for mulloway is 30 cm. However, in southern Queensland, one species - (*Argyrosomus hololepidotus*) - grows to a very large size and only becomes sexually mature at around 70 to 75 cm. Many fishermen are convinced that the small species are the juveniles of this large one and so they want the size limit increased. But such an increase would prevent the catching of the numerically more abundant small species. In this case management has to decide whether to protect the large species or allow capture of the smaller species.

Numbers and complexity of limits

Size restrictions on a great many species are in force. In the case of marine fishes (Table 3) alone, 38 species are listed in Western Australia, 28 in Queensland, and 24 in Victoria (Hancock 1992). This makes it difficult, especially for amateurs and interstate visitors, to know the size limits. The problem is especially acute where several similar species have different size limits. In Western Australia for example there are three whiting with two different sizes and two mullet also with different sizes (Table 4). In New South Wales the minimum size for eastern rock lobster (*Jasus edwardsii*) is 104 mm, while for female southern rock lobsters (*Jasus verreauxi*) it is 105 mm, and for males it is 110 mm. Since the sizes for eastern rock lobsters bear no relation at all to spawning - the smallest ovigerous female recorded was 140 mm - it is not clear why there should be three different limits instead of one for all rock lobsters of either sex.

The Queensland approach of grouping similar species has led to considerable simplification. Three flathead species are grouped together with a minimum size of 30 cm, the limit for two species of whiting is 23 cm, and for three species of mackerel, 45 cm. Grouping leads to significant differences between states in the number of different sizes used (Table 3).

Differences between States in minimum sizes for the same species can cause difficulties. This has been a major problem with interstate trade in mud crabs (*Scylla serrata*) and in rock lobsters. Mud crabs caught in the Northern Territory (minimum size 130 mm) have been seized in Queensland (minimum size 150 mm) when being shipped to New South Wales (minimum size equivalent to 127 mm). In the case of rock lobsters, such differences have caused financial loss and even resulted in export establishments moving interstate.

How Effectively do Minimum Sizes Meet their Objectives?

There is strong evidence that many amateur fishermen do not observe minimum sizes. The size composition of amateur catches of flathead (*Platycephalus* sp.) and snapper (*Chrysophrys auratus*) in South Australia, were reported to be respectively, 12% and 8% undersized (Jones *et al.* 1990). The authors pointed out that these observed proportions of undersized fish retained were probably underestimates because some anglers were reluctant to fully disclose their retained catch. The size compositions of flathead and snapper in these catches show no sharp cutoff at the minimum size, which suggests the minimum sizes are seldom observed. Similar results have been reported in recreational fisheries in New South Wales and Queensland. For example, half of the whiting (*Sillago* sp.) retained by recreational anglers in Hervey Bay, Queensland were undersized (Moore 1986).

A review committee in Western Australia found that size limits for many small abundant fish such as herring, whiting, garfish and mullet were generally ignored and there was little evidence to suggest that size limits had curtailed their exploitation (Recreational Fishing Advisory Committee 1990). The committee recommended that minimum legal lengths be eliminated for these species and suggested that realistic and uniform bag limits would be a more effective conservation method.

Although there are few published data, observance of minimum sizes appears to be better in commercial fisheries than in recreational fisheries. This is probably because the sizes are usually related to price and so there is a clear benefit in landing animals of a size preferred by the market. In commercial fisheries such as fishing for rock lobsters, crabs and abalone where the target species has a minimum size, a simple measuring gauge is part of the equipment carried on the boat. In abalone fisheries, many divers measure their catch underwater.

The effectiveness of minimum legal sizes is difficult to determine directly. One method that is used is to examine the effect of a change in size by means of a theoretical model. Jones *et al.* (1990) did this for King George whiting in South Australia and showed that it would lead to a drop in the numbers of fish caught per unit effort, but increases in yield per recruit, yield per effort and the number of eggs produced by the population (Table 5). This example shows how even small changes in minimum legal size can have complex and far reaching effects. In the case of the western rock lobster, a simulation was made of the effects of raising the minimum legal length from 76 mm to 77 mm (Hall 1989). This showed an increase of about 2% in the long term catch. This amount is unlikely to have a significant effect on yield. The catch of the largest and most valuable lobsters would drop by 40% and the weight of the next most valuable size class would increase by about 28%. After 2 years, there would be about 22% more breeding lobsters and this might lead to an increase in recruitment after 4 to 5 years.

Simulations offer a useful technique for assessing the effect of minimum legal sizes but they need considerable background information about the biology of the species as well as a thorough knowledge of the fishery and the extent to which the minimum size is observed.

Alternative Ways of Protecting Small Animals

The use of minimum sizes for management should be assessed relative to other ways of achieving the objectives. Some of the obvious alternative management methods are as follows.

Gear restrictions

Gear restrictions are the most commonly used method to control the minimum size at which fish are captured. In many recreational fisheries, this is only applicable to netting. Catching methods in many commercial fisheries tend to be size-selective and so gear restrictions such as mesh sizes can be used to achieve the objectives aimed at with minimum sizes. The principle extends to catching of invertebrates; there are minimum mesh sizes for prawn and scallop trawls and most states require that lobster pots have escape gaps to allow most of the undersized animals to leave the pot.

Closed seasons

These are only suitable for rapidly growing species with a fairly short recruitment period. A good example is the the Northern Prawn Fishery which prohibits trawling for prawns over the whole of northern Australia from Cape York to Western Australia each year until April. The opening date for this fishery is chosen to maximise the export revenue from the fishery (Somers 1985).

Closed areas

These are commonly used where the juveniles and adults live in different areas. Examples include some bays and estuaries in Tasmania that are closed to protect juvenile sharks, and seagrass beds and estuaries in the Gulf of Carpentaria that are closed to trawling to protect juvenile prawns.

Quotas and bag limits

Overall quotas can have a negative effect since they introduce a competitive element into the fishery that encourages operators to increase their share regardless of the size of the animals caught. Individual transferable quotas (ITQs) on the other hand, encourage fishers to maximise the value of their landings. This was seen for example in the fishery for southern bluefin tuna where, following the introduction of ITQs, operators concentrated on catching the larger, more valuable fish (Geen and Nayar 1989). This process could have been further encouraged by setting the quota on numbers of fish with no restriction on weight.

Bag limits encourage anglers to concentrate on catching larger fish. The real effect is difficult to assess, however, since they may also encourage anglers to discard the smaller individuals, leading to significant waste.

Long-Term Effects of Size Selection

As pointed out earlier, many species reach sexual maturity at particular ages, not sizes. Also, minimum sizes tend to be set at the smallest size at which sexually mature animals are found. Thus the fastest-growing individuals in a population may reach the minimum size before reaching sexual maturity. Size selective fishing has the effect of removing these individuals from the population before they reproduce. If fishing pressure is very heavy and few individuals survive beyond the minimum size then there will be selection pressure against fast growth because the fastest growing members of the population will be killed before they can reproduce. The long-term consequence would be a shift towards slower growth and smaller size at sexual maturity, as well as a drop in production (Sutherland 1990). The speed of response would depend on the generation time: short-lived animals would respond more rapidly than long-lived ones.

How serious is this matter? In most animals growth is a product of genetic and environmental factors, and thus not all of the sometimes large difference in size at sexual maturity has a genetic basis. In abalone in Tasmania, for example, there are large differences in size at sexual maturity - ranging from a shell length of 60 to 120 mm. The mean age at reproduction for the same populations has, however, a far smaller range, from 7.5 to 9.5 years. Even this may have a large environmental component, so there may be little genetic variation on which selection can operate.

There is one case in Australian fisheries that suggests that size-selection has already occurred. The size at first maturity of King George whiting (*Sillaginodes punctata*) in South Australia in 1953 was 32 cm for males and 36 cm for females. By the 1980s it had decreased to 27 cm for males and 32 cm for females. This species is intensively fished and the minimum legal size (28 cm) is below the size at sexual maturity (Jones *et al.* 1990). It is not known whether the decrease in size at sexual maturity is a consequence of the fishing of immature fish or has resulted from another cause. But the example is a reminder that managers need to keep the possible long-term consequences of size-selection in mind, particularly when dealing with short-lived species.

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Table 1. Minimum sizes and maturity size for rock lobsters

Minimum size (carapace length) data from Hancock (1992). Size at maturity for eastern rock lobster (*Jasus verreauxi*) personal communications from S. Montgomery (NSW Fisheries), western rock lobster (*Panulirus cygnus*) from B. Phillips (CSIRO) and tropical rock lobster (*Panulirus ornatus*) from R. Pitcher (CSIRO)

Species (mm)	Minimum size (mm)	Size at maturity
Eastern rock lobster	104	140
Western rock lobster	76	80-95
Tropical rock lobster	74*	80

* The carapace length for tropical rock lobsters is equivalent to the minimum legal tail length of 100 mm.

Table 2. Size limits for blacklip abalone (Haliotis rubra) by State

Data from Hancock (1992)

State	Area	Minimum size (mm)
New South Wales	Entire State	115
Victoria	Port Phillip Bay	100
	West of Lorne	120
	Lorne to Lakes Entrance	110
	East of Lakes Entrance	120
Tasmania	South and West Coasts	140
	North Coast	132
South Australia	Recreational	130
	Commercial - southern zone	125
	Commercial - elsewhere	130

Table 3. Numbers of species of marine fishes (including barramundi) for which there are size limits in each State and the number of different sizes used

Data from Hancock (1992)

State	Number of species	Number of size categories
Queensland	28	7
New South Wales	16	9
Victoria	24	13
Tasmania	13	7
South Australia	17	11
Western Australia	38	16
Northern Territory	1	1

Table 4. Size limits for whiting and mullet in Western Australia
Data from Hancock (1992)

Species	Size limit (cm)
King George whiting (*Sillaginodes punctata*)	25
Western sand whiting (*Sillago schomburgkii*)	22
School whiting (*Sillago bassensis*)	22
Sea mullet (*Mugil cephalus*)	24
Yelloweye mullet (*Aldrichetta forsteri*)	23

Table 5. The effect of changing size limits for King George whiting (*Sillaginodes punctata*) in South Australia
The percentage change in various parameters if the age at first capture is increased from 2 years to 3 years. Data from Jones *et al.* (1990)

Parameter	Percent change
Numbers per unit effort	-23 to -25
Yield per recruit	+18 to +42
Yield per effort	+35 to +81
Number of eggs	+73 to +330

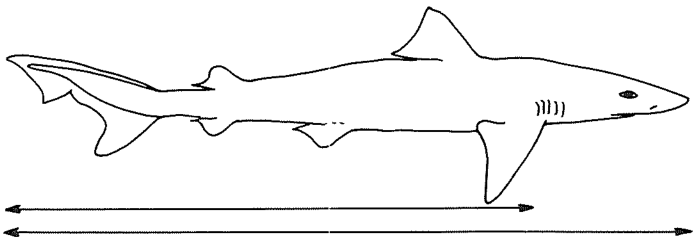

Figure 1. Legal lengths used for whole and processed sharks in Victoria.

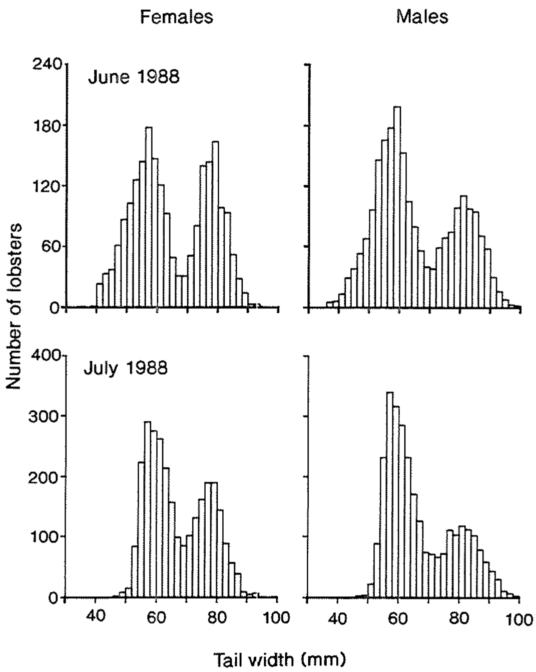

Figure 2. Size composition of lobsters (Panulirus ornatus) landed in Torres Strait. The sizes landed before (June 1988) and after (July 1988) the introduction of a size limit corresponding to a tail width of 52mm. Unpublished CSIRO data.

Current Use of Legal Size and Associated Regulations in Australian and Papua New Guinean Fisheries

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In 1989, the Workshops Planning Committee of the Australian Society for Fish Biology decided to solicit information on the use being made throughout Australia and by Papua New Guinea of size regulations for fish and shellfish. Questionnaires (Appendix 1) were sent to each of the Australian States, the Northern Territory, the Commonwealth (Department of Primary Industries and Energy) and to Papua New Guinea. Information was also subsequently provided by the Australian Capital Territory.

The questionnaire requested details of legal sizes currently in use, the purpose(s) for which they were introduced, and any associated or alternative means of control, such as escape gaps, nursery closures, closed seasons and mesh size. Supplementary questions included any prohibitions on the capture of spawning (berried) females, any bag limits or catch quotas, together with information on the basis for selecting the legal size i.e. whether by 'proper' scientific assessment (including any subsequent revisions), or by using only selected data, such as size at first maturity, spawning period, etc.

Sincere thanks are due to all those who responded to the questionnaire and assisted with the checking of entries into summary tables.

While every effort has been made to ensure correctness in every detail, specific enquiries should still be addressed to the relevant authorities and appropriate published regulations (Appendix 2), which usually also describe the precise measurement to which the legal size has been applied. Legal sizes listed almost always apply to both commercial and recreational fisheries - Hill (this meeting) mentions four fisheries where they are different i.e. barramundi in N.T. (subsequently made the same from 1 March 1991), Roe's abalone in W.A., blacklip abalone in S.A. and black bream in Victoria. For yelloweye mullet in Victoria, the legal minimum applies only to the commercial fishery. Other regulations, in particular bag limits, may apply only to the recreational fishery.

Use of Legal Sizes Overseas

Without researching the topic deeply, or attempting to summarise the situation overseas at the present time, two examples referred to by Dow (1980) are given here, in order to demonstrate how legal sizes have been subject to continuing review and adjustment.

The first is for the American lobster (*Homarus americanus*). In 1977, under U.S. Lobster regulations, one State had a maximum carapace length of 127 mm and a minimum of 81. Seven other States had a minimum of 81 mm and three had 79. In neighbouring Canada the minimum carapace length ranged from 63.5 mm (three districts), 70 (one district), 76 (five districts) to 81 mm (twelve districts). In 1980, it was proposed, on biological grounds, to change to a uniform 89 mm or larger throughout the United States. Canadian scientists, working cooperatively with the U.S., hoped to increase the size limit from 63.5 to 76 mm in some areas, with further changes in the pipeline.

The second example is for the Norway lobster (*Nephrops norvegicus*) in Europe. Because most *Nephrops* are taken by trawl nets, the principal management efforts have been directed towards mesh sizes - France 50 mm, Iceland 80 mm, U.K. 70 mm except for 50 mm in the Irish Sea. From 1936, the minimum *landing* size in Denmark was 160 mm total length. A Convention in 1952 resulted in a common minimum total length of 150 mm in Denmark, Norway and Sweden. This was amended in 1959 to 130 mm by Norway and Sweden. Denmark changed to 147 mm in 1965 but later joined the others at 130 mm. France had a 115 mm total length north of 48° N and 100 mm south. Thus at one time there was 130 mm for Norway, Sweden and Denmark, 100 mm and 115 mm for France, while Spain had a minimum *overall* length (eye socket to base of telson), Iceland a minimum abdominal *weight* of 10 g, and Greece a total weight of 100 g.

The various ways of expressing legal sizes have involved conversions between the different measurements so as to make meaningful comparisons. This applied equally to, for example, the scale fish *Pomatomus saltator* - 'tailor' in Australia, 'bluefish' in the U.S., and 'elf' in South Africa. Elf has a minimum fork length in Natal and a minimum total length at the Cape. Elsewhere a minimum standard length may be used.

Role of the Commonwealth

Management measures such as limited entry, seasonal closures, gear restrictions, quotas and controls on fishing capacity of vessels are the principal mechanisms used to regulate Australia's offshore fisheries (DPIE 1989). These measures are implemented through the application of management plans and notices, or a combination of the two.

Unlike the States and Territories, the Commonwealth rarely uses size regulations except where parallel legislation may be enacted to mirror an individual State/NT Fisheries Authority regulation. This is the case adjacent to NSW, where Fisheries Notice 44 (as amended) provides for minimum sizes of 23 species of fish within a specified area of proclaimed waters.

Australian Capital Territory

Two elements of fisheries management pertain to the A.C.T - (1) freshwater fisheries within the A.C.T., and (2) sea and freshwater fisheries within the Jervis Bay Territory. The latter are currently managed by the A.C.T. Parks and Conservation Service on behalf of the Commonwealth. A.C.T. fisheries legislation dates back to 1967 (Fishing Ordinance 1967, now Act of 1967) for which all measurements were under the Imperial system.

Following the attainment of self-government by the A.C.T in 1989 there is a need for a review of the fisheries regulations. Meanwhile there are included amongst the various regulations, minimum sizes (in inches) for 51 species of sea fish, two species of marine crayfish (rock lobster), and two species of freshwater fish (Australian bass and trout). In addition, under the A.C.T. Nature Conservation Act 1980, five species have been listed as 'Protected Fish' i.e. eastern freshwater cod, trout cod, Clarence and Swan galaxias, and blue groper. A.C.T. regulations have not been included in the accompanying Tables.

Legal Sizes in Australia and Papua New Guinea

Tables 1-10 summarise information provided by the various States, N.T. and Papua New Guinea. The situation in P.N.G. is uncomplicated and straightforward, with only one gazetted size limit (barramundi) and eleven species of invertebrate proposed for gazettal (Table 1).

Maximum Legal Sizes

Maximum legal sizes have been used only rarely in Australia (Table 5), with Queensland being the only State to do so - for Queensland groper, *Trochus* and pearl oysters. In N.S.W., a maximum was proposed for Murray crayfish but rejected; one is under consideration for Australian bass, while Montgomery (this meeting) has proposed a maximum size for the eastern rock lobster in N.S.W. P.N.G. has proposed gazettal of maximum sizes for *Trochus*, *Turbo* and *Pinctada maxima*, each of which will have a legal minimum. In W.A., sharks with a dressed weight exceeding 18 kg may not be sold, as a precaution against public consumption of excessive mercury. There was similarly, from 1982 to 1985, a maximum permitted size for school shark.

Minimum Legal Sizes

On the other hand, minimum legal sizes have been employed as a management measure for more than 100 years (Hill, this meeting), with the chosen sizes being reviewed, but not always changed, from time to time. Table 1 summarises the minimum legal sizes currently in use for marine fishes, invertebrates and freshwater fishes. Most of the sizes are expressed linearly, usually as total length, occasionally partial length (e.g. sharks, rock lobsters, cobbler), sometimes width (e.g. some crabs) and more rarely weight (*Turbo* in Queensland). Occasionally there are different ways of measuring the same animal e.g. shark, total length and partial length; crabs, length in N.S.W. and width elsewhere; green snail, weight in N.S.W. and length in P.N.G.; rock lobsters, carapace length in most States but tail length in Queensland.

The total current usage of minimum legal sizes involves 125 species (noting that a 'species' may occasionally represent a group including more than one species) on 227 separate occasions, not including the 55 species in the A.C.T. Of these W.A. has 53, Queensland 41, Victoria 37, N.S.W. 29, S.A. 29, Tasmania 24, N.T. 2, P.N.G. 12. By far the majority of these were for marine fishes, with a smaller number for invertebrates, and fewer still for freshwater fishes.

It is of interest to look at the six species for which minimum sizes exist in five or six States and Territories i.e. flathead (25, 33, 30, 30, 30 cm), sea mullet (25, 30, 21, 30, 20, 24) pink snapper (27, 28, 38, 25 with W.A. 28 and 41) brown and rainbow trout (25, 25, 28, 22, 30) and southern rock lobster. Inconsistencies and differences do occur, possibly representing differing approaches and pressures within individual States/Territories, but also sometimes regional differences in size and growth, e.g. the migratory Australian salmon which has 21 cm in Victoria and S.A. but 30 cm in W.A.

Nine species have minimum sizes in four of the States/Territories and demonstrate both consistency, e.g. flounder (four with 23 cm), and inconsistency, e.g. mulloway (38, 30. 33 and in S.A. 46 and 75); blue sand crab, 6 cm length in N.S.W., 11, 12.7 and 15 cm width in other States (see Table 1). Other species represented on four occasions are black bream, yellowfin bream, garfish, yelloweye mullet, and school shark. A further eleven species had minimum sizes in three States or Territories.

Species may have a minimum size in only one State or Territory due to their restricted distribution e.g. Queensland groper, Westralian jewfish etc. On the other hand the wide-ranging Australian herring has a minimum size only in W.A.

The few sizes based on interstate arrangements (Table 7) include shark (gummy and school) between Victoria, S.A., Tasmania and the Commonwealth, with N.S.W. cooperating with school shark to assist with enforcement. Five States cooperated to set the minimum size for rock lobster; Victoria and N.S.W. cooperated over trout; while N.S.W. set a legal size for spanner crabs to be consistent with Queensland.

For various reasons, a small number of species have two minimum sizes (Table 6). Sometimes these represent geographical differences e.g. mulloway between the Coorong Lagoon and other S.A. marine waters; abalone in Tasmania and Victoria; snapper between the west and south coasts of W.A.; abalone in S.A..

With barramundi in N.T. there was a different legal size for amateurs and professionals (standardised at 55 cm from 1 March 1991); Roe's abalone in W.A. (metropolitan area only) and black bream in Victoria have different sizes for amateurs and professionals. In South Australia, there is a minumum size of 12.5 cm for professionals in the southern zone, but elsewhere 13 cm for professionals, with 13cm for the recreational fishery everywhere. In Queensland, the minimum size changes from 9 to 9.5 cm between 1 May and 1 November to afford greater protection of spawning individuals, but also to prevent the sale of small meats - here the legal size acts like a closed season. N.S.W. and S.A. both have regulations, to protect mulloway and snapper respectively, involving a reduced bag limit for individuals larger than a certain size (Table 6).

Purposes for Setting Legal Size

Several States advised that records of the purposes for which legal sizes were established no longer exist. For example, N.S.W. reported that most of its size limits were well in place before 1960, since when relevant files have been destroyed (Table 9). Most of the legal lengths there appeared to have been based on empirical information from law enforcement staff, since there were few biologists doing population dynamics work before 1958. In 1960, many species were removed from the size limit schedule because there was no biological or marketing justification. Similarly, in Queensland, records no longer exist of the historic basis for establishing legal sizes, and present staff are unaware of their background. On the other hand, the annual reports of the Western Fisheries Research Committee have for a number of years included a section entitled 'List of Amendments to Fisheries Notices', which listed not only any changes to legal sizes but also their designated purpose. Such records, if adopted throughout Australia, would be of considerable assistance to biologists and administrators.

Information provided by contributors has been summarised in Table 2. The favoured purpose by far was protection of immatures i.e. 'to allow individuals to spawn at least once.' Control of fishing until optimum market size was cited next in importance, followed closely by the objective of controlling harvesting. Economic reasons were rarely cited, most of the examples being from S.A. The heading 'aesthetics' described the intent to make available larger individuals rated highly in the recreational fishery, e.g. trout, salmon, marron. In one State (S.A.), at least, the size of trout resulted from representations by amateur fishing interests. More than one purpose was frequently cited for an individual species.

Nomenclature

An attempt was made to allocate scientific names to species referred to by common name across Australia, but this could not be completed in the time available. Instead the serious reader should consult 'Recommended Marketing Names for Fish (DPIE, 1988)' together with relevant State and Commonwealth regulations e.g. W.A. Government Gazette, 20 May 1988. 'Recreational Fishing in South Australia, a guide to the regulations, December 1989' also includes scientific names, but this is not usual in the documents listed in Appendix 2, and they would be a worthwhile inclusion in future printings.

Associated Controls

Table 3 summarises associated control measures used, for the most part in conjunction with legal sizes listed in Table 1.

Escape gaps have relevance mostly to trap-caught crustaceans, but also kingfish in N.S.W. Nursery closures are used more in N.S.W. and Queensland than in other States. Mesh sizes have prominence in N.S.W., Queensland and Tasmania, but are seldom used in Victoria (shark), W.A. (prawns, scallops) or N.T. (barramundi).

Bag limits have become a widely used method of limiting catches either in association with, or as an alternative to, a legal size. In W.A., the Recreational Fishing Advisory Committee (1990) has recommended rescinding size limits for garfish, Australian herring, blue mackerel, sea mullet, yelloweye mullet and sole, in favour of bag limits. Four categories are proposed - 'prize fish' (5 of each species/person/day), 'reef fish' (a mixed bag of 10 fish/person/day), 'table fish' (20 fish of each species/person/day) and 'bread and butter fish' (50 fish of each species/person/day). Legal sizes will continue to apply with the exception of those to be rescinded. Combined daily bag limits are already in force in W.A., e.g. for abalone (greenlip and brownlip); crab (brown mud and green mud); mackerel species; 3 species of rock lobster; octopus, squid and cuttlefish. A group bag limit of 10 per day applies to any combination of coral trout, baldchin groper, red emperor, samson fish, pink snapper, north-west snapper and blue morwong. Tasmania has a bag limit of twelve fish consisting of salmon, trout, blackfish or freshwater crayfish. Queensland exercises a bag limit of 50 of any species of mollusc (excluding oysters).

In South Australia and New South Wales, certain bag limits are differentially related to size. For snapper in S.A., minimum legal size 38 cm, there is a recreational bag limit of 15 fish per person per day in the size range 38 - 60 cm, but with a limit of two fish larger than 60 cm. N.S.W. (Table 6) has a 'slot' limit for mulloway - 5 in total but only 2 greater than 60 cm; and for tuna, a restriction to 2 of any combination of tuna species greater than 15 kg whole or 12.5 kg gilled and gutted. A minimum size of 38 cm applies to mulloway in N.S.W. but there is no minimum length for tuna.

A form of associated control not listed is that of restrictive licences. Some species may not be taken from the wild by professionals e.g. trout and marron in W.A., while amateurs must have the appropriate recreational fishing licence. Others may be fished professionally with a licence, but amateurs may fish them without a special recreational licence e.g. abalone in W.A. In Tasmania, abalone may be fished by professionals and by holders of a non-commercial diving licence, but unlicensed persons may not collect abalone in any way 'even by wading or picking up from the rocks'.

Species Under Review or Recently Reviewed

Species which have recently been, or are being, reviewed are listed in Table 4. It is perhaps surprising that the list is not longer, considering that so many legal sizes were established so long ago, and that the origins of many of them are no longer known (see also Table 9).

Of the total of 227 minimum sizes listed, some 52 were classified as under review or recently reviewed - of these, 11 are P.N.G. invertebrates.

Of those listed as recently reviewed, there resulted no change for one (W.A. rock lobster) and four were rescinded i.e. Australian herring in S.A., and Murray cod (now totally protected) in S.A., pearl oysters for MOP purposes in W.A. and pearl oysters in N.T. (From 1 March 1991, the minimum size of barramundi has been made the same for the commercial and recreational fisheries).

Fisheries regulations in the A.C.T. are to be reviewed following self-Government.

Species with Total Protection

Species afforded total protection are listed in Table 8, which includes those for which fishing is totally prohibited, many of them in N.S.W., and those for which there is protection of one stage in the life cycle. The latter applies in particular to the egg-bearing females of marine and freshwater crustaceans, while in Queensland this protection is extended to all female sand (blue) crabs and mud crabs. In N.S.W. certain species are partially protected in that they may not be commercially harvested. This applies also to bream in Tasmania, where the capture of indigenous freshwater species (except grayling, crayfish, blackfish, eels and whitebait) is restricted to one method of fishing i.e. 'bushpoling'. In N.S.W., the protection of Murray cod, trout cod, and turban shells relates to specific areas. As mentioned earlier, there are five species of 'protected fish' in the A.C.T.

Minimum Sizes Based on Scientific Assessment

These are listed in Table 9. Clearly, and once again considering the long lists of minimum sizes in Table 1, very few have had their basis in the procedures for detailed scientific assessment offered, for example, by Beverton and Holt (1957), Ricker (1958), Gulland (1961) or Allen (1953).

The case of the western rock lobster is interesting because careful review (Hall 1989) concluded that the minimum legal size set as long ago as 1897 (Bowen 1980) appears to remain appropriate for the current fishery. Hancock (1965, 1975) had a similar experience with his examination of two fisheries for edible crabs on the east coast of the U.K., and this seems not to be an unusual event. This begs the question as to whether stocks become adjusted dynamically around this one parameter, or alternatively whether the data are inadequate to provide conviction, especially to fishery managers who might realistically prefer to 'leave well alone'.

It will be important to focus attention on any recent reviews or proposed changes to legal sizes. This should provide guidance on current thinking on any justification for introducing or changing them or leaving them unchanged.

While Table 2 shows a clear preference for protecting immatures as a justification for a legal size, there are surprisingly few claims of the relevant data on size at first maturity (Table 10).

Summary

- Legal sizes have been used in fisheries management for more than 100 years and are still widely employed.
- Minimum legal sizes have been the most frequently used, with maximum legal sizes only rarely.
- Of more than 200 minimum legal sizes currently on the record only a few per cent have their basis in a proper scientific assessment, and not many more on length at first maturity information.
- The original reasons for setting minimum sizes have often become obscured by history and there is a need for the basis of all management measures to be properly recorded.
- The favoured reason cited for a minimum size is the protection of immatures i.e. allowing to spawn at least once, followed by optimum market size and desire to control harvest.
- Among complementary management measures, bag limits are being increasingly applied to the recreational fishery. Area closures, closed seasons and gear restrictions are also used, together with prohibited capture of spawning females of marine and freshwater crustaceans.
- When subjected to proper scientific review, long-established minimum sizes often seem to be appropriate even though not originally scientifically based.
- Any sizes recently or currently under review should provide the workshop with the opportunity to take a closer look at current philosophy on the subject.
- Although maximum legal sizes have been rarely invoked, they remain of interest and modern technologies (e.g. Sluczanowski *et al.* this meeting) should enable a closer examination of their relevance and usefulness.

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Table 1. Minimum legal sizes (cm) for fish and shellfish in Australian and Papuan New Guinean fisheries

Totally protected species are listed in Table 8

MARINE FISHES

Common name	Vic	NSW	SA	Qld	Tas	WA	NT	PNG
Blackfish, rock (drummer)	-	25	-	-	-	-	-	-
Bream, black	24[b] 25.5[d]	25	28	-	-	25	-	-
Bream, pikey	-	-	-	23	-	-	-	-
Bream, yellowfin	24	25	-	23	-	25	-	-
Bream	-	-		-	23	-	-	-
Butterfish (dusky morwong)	23	-	-	-	-	-	-	-
Cobbler (*Cnidoglanis)*	-	-	-	-	-	23[a]	-	-
Cod, estuary rock	-	-	-	35	-	-	-	-
Cod, rock	22	-	-	-	-	-	-	-
Coral trout	-	-	-	35	-	45	-	-
Emperor - red	-	-	-	35	-	28	-	-
Emperor - red finned	-	-	-	30	-	[e]	-	-
Emperor - sweetlip	-	-	-	30	-	[e]	-	-
Flathead (all spp.)	25	33	-	30	30	30	-	-
Flounder (all spp.)	23	-	23	-	23	23	-	-
Garfish (river and sea)	20	-	21	-	23	23	-	-
Groper, baldchin	-	-	-	-	-	40	-	-
Groper, blue	-	-	60	-	-	40	-	-
Groper, Queensland	-	-	-	35	-	-	-	-
Herring, Australian	-	-	-	-	-	18	-	-
Javelin fish	-	-	-	30	-	-	-	-
Jew-fish, silver	-	-	-	30	-	-	-	-
Jew-fish, spotted	-	-	-	30	-	-	-	-
Jew-fish (Westralian)	-	-	-	-	-	50	-	-
Kingfish, yellowtail	-	60	40	-	-	-	-	-
Leatherjacket	-	-	-	-	-	25	-	-
Ling, rock	33	-	-	-	-	-	-	-
Luderick	22	25	-	23	-	-	-	-
Mackerel, broad-barred	-	-	-	45	-	76	-	-
Mackerel, narrow-barred	-	-	-	45	-	76	-	-
Mackerel, Queensland school	-	-	-	45	-	-	-	-
Mackerel, spotted Spanish	-	-	-	45	-	50	-	-
Mackerel, blue (common)	-	-	-	-	-	15	-	-
Mackerel, jack	-	-	-	-	29.5	-	-	-
Mackerel, wahoo	-	-	-	-	-	76	-	-
Morwong, blue (green snapper)	-	-	-	-	-	30	-	-
Morwong (jackass fish)	-	28	-	-	23	-	-	-
Morwong, red (sea carp)	-	25	-	-	-	-	-	-
Morwong, rubberlip	-	28	-	-	-	-	-	-
Mullet (flat tail and sand)	22	-	21	-	-	-	-	-
Mullet, sea	25	30	21	30	20	24	-	-
Mullet, yelloweye	24[d]	-	21	-	20	23	-	-
Mulloway	-	38	46[g]/75[c]	30	-	33	-	-
Nannygai	-	-	-	-	-	23	-	-
Pike (long-finned)	-	-	-	-	-	33	-	-
Salmon, Australian	21	-	21	-	-	30	-	-
Salmon, Burnett	-	-	-	40	-	-	-	-
Salmon, Cooktown	-	-	-	40	-	-	-	-
Samson fish	-	-	-	-	-	60	-	-
Shark, gummy	45[a]	-	45[a]	-	75(45[a])	-	-	-
Shark, school	40[a]	91	40[a]	-	71(40[a])	-	-	-
Snapper, North-west	-	-	-	-	-	28	-	-

Table 1 continued

Marine fishes continued

Common name	Vic	NSW	SA	Qld	Tas	WA	NT	PNG
Snapper, pink	27	28	38	25	-	41(west) 28(south)	-	-
Snapper, red	-	-	-	-	-	23	-	-
Snook (short-finned pike)	36	-	36	-	-	28	-	-
Sole (all spp.)	20	-	-	-	23	20	-	-
Stranger (grass whiting)	20	-	-	-	-	-	-	-
Sweep	23	-	21	-	-	23	-	-
Tailor	23	-	-	30	-	25	-	-
Tarwhine	-	20	-	23	-	23	-	-
Teraglin	-	38	-	30	-	-	-	-
Trevally, silver	20	-	-	-	-	-	-	-
Trevally, skipjack	-	-	-	-	-	20	-	-
Trumpeter, bastard	-	-	-	-	33	-	-	-
Trumpeter, real (stripy)	-	-	-	-	33	-	-	-
Tuna, southern bluefin	70	[f]	-	-	-	-	-	-
Whiting, golden-lined	-	-	-	23	-	-	-	-
Whiting, King George	27	-	28	-	-	25	-	-
Whiting, sand (silver)	-	27	-	23	-	-	-	-
Whiting, school	-	-	-	-	-	22	-	-
Whiting, western sand or yellowfin	-	-	24	-	-	22	-	-
Total marine fishes	24	16	17	27	13	38	0	0

[a] Partial Length
[b] Recreational
[c] Elsewhere
[d] Commercial
[e] Snapper, North-west
[f] See Table 6
[g] Coorong

Table 1 continued

INVERTEBRATES

Common Name	Vic	NSW	SA	Qld	Tas	WA	NT	PNG
Abalone, blacklip	10-12[g]	-	12.5/13[g]	-	-	-	-	-
Abalone, brownlip	-	-	-	-	-	14	-	-
Abalone, greenlip	13	-	13-14.5[g]	-	-	14	-	-
Abalone, Roe's	10-12[g]	-	-	-	-	6/7[g]	-	-
Abalone, other/unspecified	10-12[g]	11.5	13	-	13.2/14	-	-	-
Actinopyga, 2spp.	-	-	-	-	-	-	-	(5/7)
Cockle (*Donax*)	-	-	3.5	-	-	-	-	-
Cockle (*Katelysia)*	-	-	3	-	-	-	-	-
Crab, blue swimmer or sand	-	6[c]	11	15[f]	-	12.7	-	-
Crab, brown mud	-	-	-	-	-	12	-	-
Crab, green mud	-	-	-	-	-	15	-	-
Crab, mud, black or mangrove	-	8.5[c]	-	15[f]	-	-	13[f]	-
Crab, spanner	-	9.3[c]	-	10[f]	-	-	-	-
Crayfish, freshwater	-	8[e]	-	-	-	-	-	-
Crayfish, giant freshwater	-	-	-	-	13[e]	-	-	-
Holothuria, 4 spp.	-	-	-	-	-	-	-	(8-17)
Marron	-	-	-	-	-	7.6[e]	-	-
Pearl oyster (*P. maxima*)	-	-	-	13	-	12	-	(13)
Pearl oyster (*P. margaritifera*)	-	-	-	9	-	-	-	(9)
Prawn, western king	-	-	-	-	-	7.6	-	-
Prawn, school	-	-	-	-	-	5	-	-
Rock lobster, common[e]	-	10.4	-	-	-	-	-	-
Rock lobster, southern (m)[e]	11	11	9.85	-	11	9.85	-	-
Rock lobster, southern (f)[e]	10.5	10.5	9.85	-	10.5	9.85	-	-
Rock lobster, tropical	-	-	-	10[d]	-	-	-	-
Rock lobster, western[e]	-	-	-	-	-	7.6	-	-
Scallop, commercial	-	-	-	-	8	-	-	-
Scallop, doughboy	-	-	-	-	8	-	-	-
Scallop, queen	-	-	-	-	10	-	-	-
Scallop, saucer	-	-	-	9/9.5[b]	-	-	-	-
Snail, military turban	-	7.5[a]	-	-	-	-	-	-
Snail, Sydney turban	-	7.5[a]	-	-	-	-	-	-
Thelenota	-	-	-	-	-	-	-	(11)
Trochus	-	-	-	8	-	6.5	-	(8)
Turbo	-	-	-	280[g]	-	-	-	(15)
Total invertebrates	5	9	7	9	6	13	1	(11)

[a] Specified Areas
[b] Seasonal
[c] Length
[d] Tail length
[e] Partial length
[f] Width
[g] See Table 6
( ) Proposed

Table 1 continued

FRESHWATER FISHES

Common name	Vic	NSW	SA	Qld	Tas	WA	NT	PNG
Barramundi	-	-	-	55	-	-	57.5[c+]	38[b]
						-	50.0[d+]	-
Bass, Australian	25	-	-	30	-	-	-	-
Blackfish, river	22[b]	-	-	-	22	-	-	-
Catfish	-	-	33	-	-	-	-	-
Cod, Murray	40[b]	-	-	50	-	-	-	-
Eel	30	-	-	-	-	-	-	-
Perch, estuary	25	-	-	-	-	-	-	-
Perch, golden (callop)	-	-	33	-	-	-	-	-
Perch, Macquarie	25	-	-	-	-	-	-	-
Perch, silver	-	-	33	30	-	-	-	-
Salmon, Atlantic	-	25	-	-	22	-	-	-
Salmon, Dawson River (Saratoga)	-	-	-	35	-	-	-	-
Trout, American Brook	-	25	-	-	22	-	-	-
Trout, brown	25[b]	25	28	-	22	30	-	-
Trout, rainbow	25[b]	25	28	-	22	30	-	-
Total freshwater fishes	8	4	5	5	5	2	1	1

[b] Within specified areas
[c] Commercial
[d] Recreational
[+] Standardised at 55 cm from 1 March 1991

+

ALL SPECIES

Common name	Vic	NSW	SA	Qld	Tas	WA	NT	PNG
Marine	24	16	17	27	13	38	0	0
Invertebrates	5	9	7	9	6	13	1	(11)
Freshwater	8	4	5	5	5	2	1	1
Total	37	29	29	41	24	53	2	1(11)

Table 2. Purposes for which minimum legal sizes were established

VICTORIA		
Protect immatures*	-	all species listed in Table 1
Control harvest	-	shark (gummy and school)
Optimum market size	-	bream (black and yellowfin), stranger, tailor, eel.
Aesthetics	-	trout (rainbow and brown), snapper
NSW		
Protect immatures*	-	yellowtail kingfish, all estuarine breeding fish, freshwater crayfish, spanner crabs, abalone, turban snail
Control harvest	-	yellowtail kingfish
Optimum market size	-	mulloway, sand whiting, sea mullet, mud crab, blue crab, abalone
Aesthetics	-	(mud crab, blue crab)
SA		
Protect immatures*	-	black bream, flounder, blue groper, mulloway, shark (gummy and school), yellowfin whiting, silver perch, catfish, callop, rock lobster.
Control harvest	-	black bream, flounder, garfish, blue groper, mulloway, shark (gummy and school), snapper, King George whiting, yellowtail kingfish, catfish, abalone, cockle, blue crab, rock lobster.
Economic reasons	-	mullets, mulloway (Coorong), Aust. salmon, shark (gummy and school), yellowfin whiting, abalone, cockle, blue crab, rock lobster.
Optimum market size	-	callop, silver perch, cockles, blue crab, rock lobster.
Aesthetics	-	snapper, mulloway, trout (at request of Fly Fishermen's Assoc.)
QUEENSLAND		
Protect immatures*	-	all those listed in Table 1 *except* Murray cod, estuary rock cod.
Control harvest	-	all listed *except* sea mullet.
Economic reasons	-	saucer scallop.
Optimum market size	-	all listed *except* golder perch, silver perch.
Aesthetics	-	golden perch, silver perch, tailor.
TASMANIA		
Protect immatures*	-	all marine species listed, and giant freshwater crayfish.
Aesthetics	-	trout, blackfish, salmon.
WA		
Protect immatures*	-	cobbler, coral trout, groper, jewfish, Spanish wahoo, Samson fish, pink snapper, crab, rock lobster, abalone, trochus.
Control harvest	-	rock lobster (originally opt. market size)
Economic reasons	-	pearl oyster (also to allow sex change)
Optimum market size	-	bream, flathead, cobbler, flounder, garfish, Aust. herring, jewfish, leather jacket, blue mackerel, Spanish mackerel, mullet, mulloway, nannygai, long-finned pike, red emperor, Aust. salmon, skipjack trevally, snapper (exc. pink), snook, sole, sweep, tailor, tarwhine, whiting, abalone, prawns.
Aesthetics	-	trout, marron.
NT		
Protect immatures* (and 1st year spawners)	-	mud crab, barramundi, pearl shell (since removed)
Control harvest	-	barramundi, mud crab.
Economic reasons	-	pearl oyster (since removed)
Optimum market size	-	mud crab, pearl oyster (since removed)
PNG		
'Control growth overfishing'	-	barramundi (NB - proposals for 11 invertebrates - all to protect immatures).

* Questionnaire reads "Protect spawners".

Table 2 continued

SUMMARY

	Protect immatures	Control harvest	Economic reasons	Optimum market size	Aesthetics
Victoria	37	2	0	5	3
NSW	6	1	0	6	2
SA	10	15	10	5	3
Queensland	34	35	1	34	3
Tasmania	19	0	0	0	3
WA	11	1	1	26	2
NT	2	2	0	1	0
PNG	1(+11)	0	0	0	0
Total*	120 (+11)	56	12	77	16

* Approximate totals only; sometimes more than one species per listing.

Table 3. Associated controls

Those listed relate primarily to species listed by respondents as having a legal size, for which refer to Table 1

VICTORIA		
Escape gaps	-	rock lobster
Area closures	-	shark
Closed season	-	abalone, rock lobster, commercial scallop, river blackfish, bass, estuary perch, Macquarie perch
Mesh size	-	shark
Berried female	-	freshwater crayfish, southern rock lobster
Catch quota/bag limit	-	abalone, bream (Sydenham and Benson Rivers only), Chinook salmon, fresh crayfish, scallop, southern rock lobster, squid, trout, Macquarie perch
Gear limitation	-	longline for snapper in specified areas; prohibition on use of monofilament gill nets in specified areas; prohibition on multifilament gill nets of mesh size > 130mm during October - December; limit on length of shark nets and number of rock lobster pots.
NSW		
Escape gaps	-	kingfish, rock lobster
Nursery closures	-	Port Hacking, Brisbane waters, Wagonga inlet, acquatic reserves, estuarine net closures, juvenile king prawns
Closed season	-	commercial netting closures, freshwater fish, abalone (for marketing)
Mesh size	-	prescribed for *all* nets and traps, e.g. 50 mm for traps, 90 mm fish trawl, 40 mm prawn trawl, 80 mm mesh nets
Berried female	-	crayfish (freshwater and saltwater)
Catch quota/bag limit	-	*bream/tarwhine*, groper, *yellowtail kingfish*, mackerel, *red morwong*, *sea mullet* (live bait), *mulloway*, *snapper*, *teraglin*, tuna, *abalone*, cockle, mussels, pipi, *crabs*, gastropods, *rock lobster*, sea urchin, Australian bass/Estuarine perch, *Atlantic salmon/trout* (italicised have legal size)
SA		
Escape gaps	-	southern rock lobster (recreational fishery)
Nursery closures	-	mulloway (Coorong), King George whiting (aquatic reserves and netting closures in
Closed season	-	Gulf)
Mesh size	-	black bream, mulloway (Coorong), Goolwa cockle
Berried female	-	black bream, flounder, garfish, mulloway (Coorong), shark
Catch quota/bag limit	-	southern rock lobster, blue crab, yabbie
		A. salmon (commercial fishery only), mulloway, snapper, blue crab, southern rock
Closed areas	-	lobster, abalone
		blue groper, aquatic reserves
QUEENSLAND		
Nursery closures	-	Emperor (red, red-finned, sweetlip), flathead, javelin fish, jewfish, luderick, perch, saratoga, snapper, tarwhine, tailor, teraglin, coral trout, salmon, scallop, whiting, barramundi, Australian bass, crabs
Closed season	-	barramundi
	-	targeting for tailor, specific areas closed September for all species
Mesh size	-	mackerel, sea mullet, tailor, salmon, scallop, whiting, barramundi, sand crab, spanner
Berried female	-	crab
Catch quota/bag limit	-	spanner crab, Balmain bug, Moreton Bay bug, slipper lobster
		A. bass, barramundi, mud crab, spanner crab, molluscs (excluding oysters)
TASMANIA		
Escape gaps	-	rock lobster
Nursery closures	-	estuaries closed to commercial gill netting, coastal waters to one nautical mile to trawling
	-	shark nursery area
Closed season	-	rock lobster, scallops
	-	freshwater species: closed season for rod and line, but not'bush people'
Mesh size	-	all marine scalefishes and shark
	-	seine nets and gill nets prohibited in freshwater
Berried female	-	rock lobster
	-	giant freshwater crayfish
Catch quota/bag limit	-	jack mackerel, abalone, scallops, whitebait (6 species), all salmonids, blackfish, crayfish

Table 3 continued

WA		
Escape gaps	-	rock lobster
Nursery closures	-	prawns
Closed season	-	abalone, crab (Cockburn Sound), prawn, rock lobster, (scallop*)
Mesh size	-	prawn, (scallop*)
Berried female	-	rock lobster, marron
Catch quota/bag limit	-	abalone (brownlip, greenlip or Roe's), barramundi, black bream, blue groper, blue manna crab, cockles, dolphin fish, King George whiting, mackerel (Spanish spotted or shark), marron, mud crabs (brown or green), mussels, prawns, rock lobster, Australian salmon, southern bluefin tuna, trout (brown or rainbow), Westralian jewfish. There is a group bag limit of 10 for one day of baldchin groper, blue morwong, coral trout, North-west snapper, red emperor, Samson fish and snapper (of species listed, only barramundi, cockles, dolphin fish, mussels and southern bluefin tuna, have no minimum legal size)
NT		
Nursery closures	-	barramundi (commercial only)
Closed season	-	barramundi (commercial; recreational in Daly and Mary Rivers only)
Mesh size	-	barramundi
Catch quota/bag limit	-	barramundi, mud crab, pearl oyster
PNG		
None reported		

* As alternative to minimum size; corresponds to 90 cm shell.

Table 4. Species under review or recently reviewed

VICTORIA	-	trout cod (prohibition on capture), Macquarie perch (under review), spiny freshwater crayfish (to be 90 mm except in Glenelg River, 100 mm), yabbie (gear and bag limits), eel (abolishment of minimum size).
N.S.W.	-	proposal for mulloway, from 38 cm to 60 cm to control harvest
	-	snapper, probably to 30 cm, research continuing
	-	Australian bass, *maximum* size being considered
	-	freshwater native fish sizes and bag limits under review
	-	lobster, eastern rock, to protect immatures
	-	ban on taking of berried crabs has been proposed
S.A.	-	flounder, size to be reviewed on economic grounds, 23 to 25 cm
	-	King George whiting, under review to protect immatures and for economic reasons, 28 to 30
	-	black bream, 25 to 28; snapper, 28 to 38, now introduced
	-	A. herring, rescinded in recent years
	-	sweep and yellowtail to be rescinded
	-	Murray cod rescinded in favour of total protection (Table 8)
QUEENSLAND	-	under review - all commercial reef spp., snapper, mulloway, mackerel (4 spp.), pearl perch, venus tusk fish
TASMANIA	-	rock lobster and abalone under scientific review
	-	flounder regulations to be reviewed on basis of current scientific knowledge
W.A.	-	rock lobster given scientific review (Hall 1989) but size not changed - original purpose was optimum market size (see Table 9)
	-	red emperor and spangled emperor, 28 to 41 cm, to enable fish to breed before capture, and mulloway, 33 to 43 cm, for economic reasons, both changes proposed by Recreational Fishing Advisory Committee (1990). Also proposed are rescinding of size limits for garfish, A. herring, blue mackerel, sea mullet, yelloweye mullet and sole, to be accompanied by a much wider range of bag limits for recreational fishermen
	-	pearl oyster, minimum size for MOP rescinded (see Table 6).
N.T.	-	pearl oyster, previously 12 cm for culture shell and 20 for mother-of-pearl - rescinded October 1989, in favour of control by catch quota and economic factors
	-	barramundi, proposal to standardise on 55 cm, from 57.5 (commercial), 50 (recreational)$^{+}$
P.N.G.	-	proposal for minimum sizes for 11 species of invertebrate and maximum sizes for three of them (*Trochus*, *Turbo* and *P. maxima*).

$^{+}$Standardised at 55 cm from 1 March 1991.

Table 5. Maximum legal sizes

VICTORIA, S.A., TASMANIA, W.A., and N.T.	-	Nil
N.S.W.	- -	under consideration for Australian bass proposed for Murray crayfish but rejected
QUEENSLAND	-	groper, 120 cm (minimum size 35 cm), *Trochus* 12.5 cm (minimum 8 cm), pearl oyster 23 cm (13 cm minimum)
P.N.G.	-	proposed for *Trochus, Turbo*, and *Pinctada maxima*, each of which will have minimum size.

Table 6. Species with two minimum legal sizes

VICTORIA	- -	blacklip and Roe's abalone; 10 cm in Port Phillip Bay, 11 cm between Lorne and Lakes Entrance (except Port Phillip Bay), 12 cm east of Lakes Entrance black bream 24 cm recreational, 25.5 commercial
N.S.W.	- -	mulloway, 38 cm with restriction to 5 fish per day of which only two to be larger than 60cm tuna, no minimum length, but only 2 greater than 15 kg or 12 1/2 kg gilled and gutted
S.A.	- - - -	snapper, 38 - 60 cm restricted to 15 fish per day; greater than 60 cm 2 per day, for recreational fishing mulloway, 46 cm in Coorong, 70 cm in other marine waters greenlip abalone, western zone 14.5 cm; all other waters 13 cm blacklip abalone, 12.5 cm in southern zone commercial fishery, all other waters 13 cm; 13 cm throughout the recreational fishery
QUEENSLAND	-	saucer scallop has 9 cm but varied to 9.5 from 1 May to 1 November, to protect scallops during the spawning period and prevent small meats from being sold i.e. an alternative to a closed season
TASMANIA	-	abalone, 13.2 and 14 cm
W.A.	- - -	pink snapper, west coast 41 cm, south coast 28 cm pearl shell, the minimum size for culture shell remains at 12 cm but the minimum size for commercial shell (MOP) was abolished in 1983 when MOP was made part of the quota. MOP was phased out in 1986 Roe's abalone 6 cm throughout the recreational and professional fisheries, except for the metropolitan professional fishery where it is 7 cm.
N.T.	- -	pearl oyster, originally had one legal size for culture shell and one for MOP, but both were removed in 1989 because it was considered uneconomic to harvest shell of less than 12 cm. barramundi, currently 57.5 (commercial) and 50 (recreational); proposal to standardise at 55 cm.[+]
P.N.G.	-	minima and maxima proposed for *Trochus, Turbo* and *P. maxima*

[+] Standardised at 55 cm from 1 March 1991.

Table 7. Species for which legal sizes are based on interstate arrangements

Shark (gummy and school)	-	Victoria, South Australia, Tasmania and Commonwealth
Shark (school)	-	by N.S.W. to provide interstate consistency for enforcement
Southern rock lobster	- -	Victoria, New South Wales and Tasmania South Australia and Western Australia
Trout (rainbow and brown)	-	Victoria and N.S.W.
Spanner crabs	-	by N.S.W. to be consistent with Queensland

Table 8. Species with total protection

VICTORIA	-	egg bearing females of freshwater crayfish and southern rock lobster
N.S.W.	- - - - -	Queensland groper, estuary cod, black cod, blue devil fish, elegant wrasse, grey nurse shark, Herbst nurse shark, Australian grayling, eastern freshwater cod Murray cod and trout cod in 70 km of Murray River turban shells (north of Seal Rocks) partial protection (no commercial harvesting) - marlin, bass, estuary perch, groper (blue, brown, red), freshwater spiny crayfish egg bearing females of crayfish (freshwater and saltwater)
S.A.	- -	Murray cod, leafy sea dragon, all marine mammals, Murray River crayfish egg bearing females of rock lobster, blue crab and yabbie
QUEENSLAND	- - -	female sand crabs (blue crab) female mud crabs (*Scylla serrata*) egg bearing females of Balmain bug, Moreton Bay bug, spanner crab and slipper lobster
TASMANIA	- - - -	grayling egg bearing females of southern rock lobster indigenous freshwater species (except grayling, crayfish, blackfish, eels, whitebait) may only be taken with 'bushpole' bream (no commercial harvesting)
W.A.	-	egg bearing females of western rock lobster and marron

Table 9. Minimum legal sizes based on scientific assessment

VIC. -	Minimum sizes for southern rock lobster and abalone are based on a size above the size at first maturity. For gummy shark and school shark they are designed to complement a minimum mesh size and to minimise mercury levels in the commercial catch. (From 1982 to 1985, there was a maximum length for school shark for this purpose).
N.S.W. -	"Most of the size limits shown were in place well before 1960. Files containing information on the derivation or justification have been destroyed. The 1902 Act listed 30 marine fish, 7 freshwater fish and 3 crustaceans. The 1938 draft Act listed 49 marine fish, 17 freshwater fish and 6 crustaceans. In about 1960 many species including prawns were removed from the size limit schedule because there was no biological or marketing reason for the limits. Most of the minimum legal lengths appear to be based on empirical information from law enforcement staff since there were few biologists doing population dynamics work before 1958."
-	"The flathead and morwong size limits have resulted from the CSIRO work done by Blackburn. The abalone size limit was based on Beverton and Holt yield per recruit assessment, and related mainly to optimum market size. It also protected spawners (deduced from population fecundity curve modelling)."
S.A. -	"Five species of marine scale fish have been studied in relation to determining the minimum legal size." They are: Australian salmon (Cappo 1987), mulloway (Hall 1986), snapper (S.A. Department of Fisheries 1990), King George whiting (S.A. Department of Fisheries 1990), southern garfish (Jones 1990; S.A. Department of Fisheries 1990).
QLD -	"In relation to the historic basis for establishing the minimum sizes no records exist and present staff are unaware of the background. It is felt that the minimum sizes were applied with size at sexual maturity, sex change and market acceptability in mind. However, no firm evidence is at hand to confirm this." However, "a minimum legal length for tailor was introduced on the basis of tag return data" obtained from a project by Morton (1988).
TAS. -	No species for which sound scientific advice is currently available except flounder. - Rock lobster and abalone are under scientific review.
W.A. -	Western rock lobster. "The legal minimum length had its basis in the concept of the approximate size at first maturity, together with the size acceptable to the local market. In March 1897, a minimum weight of 8 oz was prescribed, but in September of the same year this was increased to 12 oz." (Bowen 1980). In 1940, when the Act was amended to allow a minimum carapace length, the equivalent of 2 1/2 inches was applied, then 3 inches but only by a new method of measurement, which converted to the 76 mm in force today. (Hall 1989), at the request of a section of the fishing industry, conducted a scientific review of the biological, practical, social and economic consequences of a proposed increase, as a result of which the minimum size, which has been in effect for more than 90 years, remains unchanged. - *Pink snapper.* As part of a scientific study of the snapper stocks of Shark Bay, Moran (1987) proposed an increase from 38 to 45 cm. The size was set at 41 cm (see also Moran, this meeting).
N.T. -	*Barramundi.* A minimum size of 23" was set in 1962, based on Dunstan's (1959) Queensland data, and information from Thailand. This converted to 57.5 cm (commercial), 50 cm (recreational).* The proposal is to standardise at 55 cm+. Barramundi has been the subject of several scientific workshops e.g. in 1988 (Glaister *et al.* 1988). - *Pearl oyster.* The minimum sizes (culture and MOP) are not currently enforced. An assessment was made of the N.T. pearl oyster fishery as part of new Commonwealth/Territory management arrangements.
P.N.G. -	"... a number of size limits for shells and beche de mer have been proposed as management tools. The proposed sizes are based on scientific study either in PNG or other south Pacific countries."

* Recreational limit of 50 cm based on protecting first two year classes.
$^{+}$Standardised at 55 cm from 1 March 1991.

Table 10. Legal sizes based on size at first maturity*

VICTORIA	-	Rock lobster and abalone
N.S.W.	-	"Most estuarine fish sizes were apparently set on this basis; marketing may also have been a factor."
	-	*Yellowtail kingfish*, size proposed by commercial and recreational fishermen to control the harvest and protect spawners. Information on fecundity at age from California was used to resist a proposal to set the size at 50 cm. "The Department's goal pending further research is to protect immature fish."
	-	*Turban snail*, size set on an interim basis at above the length at first maturity, i.e. 100% of snails this size had visible gonadal development.
	-	*Abalone*, size limit set on Beverton and Holt yield per recruit assessment also protects spawners (deduced from fecundity curve).
S.A.	-	Southern rock lobster
	-	Species for which full assessments have not been carried out, but for which there is first spawning information include: blue groper, yelloweye mullet, greenlip and blacklip abalone, flounder, catfish, callop, silver perch and yellowfin whiting.
QUEENSLAND	-	The intent was to base regulations on size at first maturity but, except for scallops, full scientific assessments have not been made, and most sizes are in need of review.
TASMANIA	-	Species for which size at first maturity have been the reference point include: abalone (size at first maturity + 3 years (loosely a YPR)), jack mackerel, scallops (size at first maturity + 1-2 spawnings), and flounder.
	-	giant freshwater crayfish.
W.A.	-	Thomson (1975) provided estimates of fecundity, size and age at first maturity of 13 W.A. species.
	-	*Western rock lobster*, minimum size reflects the approximate size at first maturity (Bowen 1980).
	-	*Snapper*, at 45 cm. 90% will have spawned at least once before capture, compared with few at 38 cm. The current size is 41 (Moran this meeting).
	-	*A. herring*, minimum size approximates to length at maturity (Hall and Lenanton unpubl.).
	-	Blue manna crab starts to reach the minimum legal size in the summer when approximately one year old (Potter *et al.* 1983).
N.T.	-	Mud crab(*Scylla serrata*), size chosen to protect juveniles and first year spawners, a compromise based on limited scientific evidence by Hill *et al.* (1982) and discussion with industry.
P.N.G.	-	See Table 9.

* This table to be read in conjunction with Table 2.

Appendix 1. Questionnaire

PURPOSE(S)								ASSOCIATED/ALTERNATIVE METHODS			
Species	Size	MIN = A MAX = B	Protect Spawners	Control Harvest	Economic	Optimum Market Size	Aesthetics	Escape Gaps	Nursery Closures	Closed Seasons	Mesh Size

Appendix 2. Some State and Territory fishery regulations

'Victorian Fishing Guide'. Department of Conservation Forests and Lands, F.D. Atkinson, Government Printer, Melbourne, Revised Edition, November 1989.

'1990 Saltwater Guide'. Division of Fisheries, N.S.W. Agriculture and Fisheries, Fourth Edition, 1990.

'1990 Freshwater Guide'. Division of Fisheries, N.S.W. Agriculture and Fisheries, Fourth Edition, 1990.

'Recreational Fishing in Southern Australia - A Guide to the Regulations'. S.A. Department of Fisheries, December 1989.

'Recreational Fishing in Queensland'. Queensland Fish Management Authority, 1990.

'Fishing Code for Anglers in Tasmania, Season '90-'91'. Inland Fisheries Commission, 127 Davey Street, Hobart.

'A Guide to Recreational Sea-Fishing Regulations. Finfish'. Department of Primary Industries, Tasmania, Fisheries Division, 1989.

'A Guide to Recreational Sea-Fishing Regulations. Crayfish, Abalone and Scallops'. Department of Primary Industries, Tasmania, Fisheries Division, 1989.

'Anglers and Divers. Fishing Guide to Western Australia'. Fisheries Department of W.A., November 1988.

Dr John Alan Gulland F.R.S.

16 September 1926 - 24 June 1990

At the conclusion of his presentation, Don Hancock made reference to the premature passing of Dr John Gulland only weeks previously.

John Gulland, whose work would be cited frequently throughout these Workshops, was held in high esteem throughout Australia, both as a person and for his outstanding contribution to fisheries science.

Referring to John's special qualities as a communicator with a gift for giving clarity to otherwise difficult topics, the speaker recalled an incident at the First International Course in Population Dynamics of Fish Populations held at Lowestoft in 1957. John was one of four lecturers and following one session one overseas participant commented to another "Who is this man Goolandt? He speaks very good the English!" He has been speaking "very good the English" ever since! John Gulland had become well known, and greatly appreciated, in Australia through his visits, lectures, courses and personal and collective advice on fisheries science.

ASFB President Dr John Glaister, in offering the Society's condolences to Mrs Audrey Gulland, wrote "His clarity of thought and beautifully constructed prose is a standard to which every fisheries scientist aspires. However, many Australians are privileged to have known John as a friend and in talking to them, an aggregate view is of a brilliant mind, a kind and thoughtful manner and unpretentiousness that laid bare any humbug." He will be sadly missed.

SESSION 2

Basis for Setting Legal Lengths

Chairperson:	R.K. Lewis
Panellists:	T.I. Walker
	R.H. Winstanley
	P.W.R. Sluczanowski
Rapporteur:	I.W. Brown

Chairperson's Introduction

R. K. Lewis

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I thank the Society for the opportunity to chair this session entitled "Basis for Setting Legal Lengths". The session will consist of three presentations. The speakers will be representatives of the various research and management areas involved in determining legal lengths. The first speaker will be Mr Terry Walker who will be speaking from the scientist's perspective. This will be followed by Mr Ross Winstanley with the Manager's perspective, and then Dr Philip Sluczanowski who will present some recent advances in modelling with particular reference to legal lengths.

Before proceeding I wish to present a sincere apology from Dr Rod Lenanton of the Western Australian Marine Research Laboratories. Rod was to speak on the biological parameter requirements for determining legal lengths but unfortunately was injured in a sporting accident and is unable to attend.

Legal length is a tool commonly used by fisheries managers when pursuing their main objectives of stock sustainability and optimum resource utilisation. These objectives, as well as biological, economic and other factors, must be considered when setting legal lengths.

I would like to comment on one of the matters raised in general discussion during the last session. In relation to comments on the relevance or not of legal lengths, particularly minimum lengths, I would like to highlight that to the general public, particularly the commercial and recreational fishers, it is one management measure that is universally accepted and quite frequently demanded. It is one measure the public perceives as of conservational value whether this is true or not.

The legal length affects stock reproductive potential (e.g. spawning biomass, eggs), catch and catch per effort (in numbers, biomass and value). Different outputs are of interest to different user groups. For example, conservationists are interested mainly in the reproductive potential, processors may want fish of certain market-determined size, whereas fishers usually want to maximise their individual catches and catch rates.

Population dynamics models enable managers to assess the trade-offs between competing issues. Such models are based on information obtained by field biologists who measure the underlying dynamic processes such as fecundity, growth and mortality. "Per-recruit" models are particularly useful when setting size limits.

The effectiveness of legal lengths depends also on how well they can be enforced and to what extent the community supports them.

A Fisheries Biologist's Application of Minimum Legal Lengths

T. I. Walker

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Abstract

Described is a scheme for classifying natural and harvested populations of marine animals on the basis of reproductive capacity and natural mortality of the species providing the stocks. The implications of such a classification for the population's stability and management are considered, along with the applicability of minimum legal lengths (MLL) for controlling age-at-first capture, and alternatives to MLLs, such as closed seasons for fisheries based on small fish too numerous for sorting, and regulated mesh sizes in gill net and trawl fisheries where the fish are landed dead or in poor condition.

The principle of having MLLs 'the bigger the better' is not necessarily valid when the mesh size of gill nets is regulated as a means of safeguarding the net reproductive rate.

The value and limitations of analyses such as yield-per-recruit, and eggs-per-recruit or, for viviparous and ovoviviparous animals, births-per-female born, are discussed with an emphasis on the dangers of ignoring reproductive capacity of the species and net reproductive rate of the stock.

Introduction

The size of a natural population depends on the population's rate of natural mortality and its net rate of reproduction. When these rates are similar and relatively constant from year to year the population size is stable but when these rates vary, population size fluctuates.

The size of a harvested population depends not only on net reproductive rate and natural mortality, but also on fishing mortality, which is a multiple of fishing effort, catchability of the species and size selectivity of the fishing gear deployed. Consequently if depletion, and possibly collapse, of a harvested population is to be avoided, the population must be capable of sustaining the fishing mortality. A reliable assessment of sustainable yields is therefore imperative. Maximising a short-term yield requires a compromise between allowing recruits to grow and risking their loss from natural mortality. Maximizing long-term yield requires maintenance of the net reproductive rate of the stock.

In this discussion I propose a scheme in which natural mortality and reproductive capacity of species are used as the criteria for classification of fisheries stocks. I then use the classification scheme as a basis for determining the appropriate method for determining yields from a fishery and for regulation of catches, with special emphasis on the appropriateness of MLLs.

Classification of Stocks

I envisage most species being classified as possessing an intermediate condition somewhere along the spectrum between two extreme classes: in one of these the species are of 'high natural mortality and high reproductive capacity'; in the other class the species are of 'low natural mortality and low reproductive capacity'. Here natural mortality applies to recruits and pre-recruits to the fishery and reproductive capacity is defined as the potential of a species to provide pre-recruits to the stock after mortality of gametes, fertilised eggs and larvae, or embryos of viviparous and ovoviviparous animals.

An individual of a species with a 'high reproductive capacity' has the potential to produce a large number of pre-recruits when the environmental conditions are suitable; conversely, an individual of a species with a 'low reproductive capacity' can only ever produce a relatively small number of pre-recruits.

An individual of a species of 'high natural mortality' has a much shorter life expectancy than an individual of a species of 'low natural mortality' and is generally short-lived. These short-lived species inevitably reach maturity at an early age, whereas long-lived species tend to take more time to reach maturity.

Populations of natural and harvested populations of 'short-lived species of high reproductive capacity' tend to fluctuate widely over time depending on environmental conditions whereas stocks of 'long-lived species of low reproductive capacity' tend to remain relatively stable. The level at which the population stabilises depends on the mortality rate (including natural and fishing mortality); the higher the mortality the lower the level at which the stock will stabilise. Above a critical mortality the stock will collapse.

Towards one extreme of the classification are stocks of short-lived species of high fecundity, such as prawns, squid and clupeoids, prone to large fluctuations which can be affected as much or more by environmental factors as by fishing. Recruitment to the fishery is greatly affected by environmental perturbations and the correlation between stock size and recruitment is poor. Recruitment failure in any one year is inevitably disastrous for the fishery.

Towards the other extreme of the classification are stocks of long-lived species of low fecundity, for example, whales, seals and sharks. Such species give birth to well-developed young and hence have relatively low post-natal and pre-recruit mortality, and tend to provide fisheries with the most constant catch rates from year to year. Such a stock is characterised by a strong stock-recruitment relationship but there is inevitably a time lag between the number of young animals recruited to the fishery and the size of the parent stock. The time lag is equivalent to the time it takes from birth to reach age-at-recruitment.

Subtle changes in rates of natural mortality, reproduction and allometric growth in response to changing population density are likely to be greater in long-lived species of low fecundity than in short-lived species of high fecundity.

The concept of a maximum sustainable yield is not valid for widely fluctuating stocks of short-lived highly fecund species, whereas the concept is applicable for longer-lived species.

If stocks of short-lived highly fecund species are overfished, the stocks have a better capacity to recover than do those of long-lived species of low fecundity.

The fecundity of blacklip abalone (*Haliotis ruber*), southern rock lobster (*Jasus novaehollandiae*), and scalefish such as snapper (*Chrysophrys auratus*), black bream (*Acanthropagrus butcheri*) and King George whiting (*Sillaginodes punctatus*), which provide important fisheries in southern Australia can be described as intermediate because each mature female can produce a large number of eggs, but which take several years to reach maturity. Consequently high fishing mortality can reduce the number of breeding animals in the stock to levels which lead to recruitment failure. For fisheries relying on these species the effects of natural failure of recruitment in any year are dampened because the catch includes several year classes.

The commercial scallop (*Pecten fumatus*), also from southern Australia, is more difficult to classify because of uncertainty over natural mortality rates. The species is highly fecund and matures at an early age, but some individuals have been found to be long-lived. Rapid stock recoveries and estimates of about 50% for annual natural mortality in Port Phillip Bay suggest the scallop should be classified as highly fecund and short-lived. However, as some fisheries scientists believe, part or perhaps most of the natural mortality measured is induced by scallop dredging, which implies, in the absence of fishing, the scallop is longer lived and therefore to be classified as intermediate.

Because the fecundity of a mature female usually increases with length, the fisheries manager can safeguard the stock's net reproductive rate by setting an appropriate MLL for individuals of each species being harvested.

But how are appropriate MLLs best determined and when is it practical to apply them?

Value and Determination of Minimum Legal Lengths

Because MLLs are a means of regulating the age-at-first capture of animals in a catch, the value of MLLs depends on the species and the fishing method.

MLLs are impractical for fisheries involving catches of large numbers of small animals such as those taken in prawn, squid, clupeoid and scallop fisheries, or for fisheries where the fish are landed dead or in such poor condition that if returned to the water their chances of survival are poor. In fisheries where the animals are small, particularly where the species are short-lived and the fishery is based mainly on one or two cohorts, age-at-first capture is better controlled by carefully regulated closed seasons designed to allow growth of the youngest animals and where possible protect the recruitment processes. In gill net and trawl fisheries where the fish are landed dead or damaged, age-at-first capture can be controlled by regulating mesh size.

Hence, MLLs are practical only in fisheries where the fish are landed in good condition, where the fishers handle each animal individually and, generally for fisheries where the fish are long-lived and take several years to mature. Scalefish and sharks taken by hook, rock lobsters taken by pots, and abalone taken by diving, are examples of appropriate application of MLLs.

Setting the MLL at a length above the length at first maturity for the southern rock lobster and blacklip abalone has ensured protection of part of the breeding stock despite the high fishing effort in these fisheries.

The breeding stock will be protected if the MLL is set higher than the species' length at first maturity. Therefore should the principle of 'the bigger the better' be adopted for MLLs?

That principle is not necessarily valid when attempts are also being made to improve the net reproductive rate by imposing mesh sizes calculated from age-at-first maturity.

In gill netting, as in the southern shark fishery for gummy shark (*Mustelus antarcticus*) and school shark (*Galeorhinus galeus*), fish of different size are not equally vulnerable to capture. Small fish swim through gill nets but become progressively more vulnerable to capture as they grow. After reaching the length of maximum vulnerability, fish then become progressively less vulnerable as they tend to bounce off the nets because their heads cannot so readily penetrate the meshes. Gill net selectivity means that fishing mortality has to be described as a function of size or age of the fish. Small fish are caught most effectively in gill nets with a small mesh size whereas large fish are caught most effectively in gill nets with a larger mesh.

Fish grow rapidly during early life and then more slowly during later life, generally following the pattern described by the von Bertalanffy model. It then follows that fish are vulnerable to capture by a small mesh size for a shorter period than by a large mesh size; consequently, for a specific fishing effort, overall fishing mortality for the stock is lower for the small mesh size than for the large mesh size.

But age-at-first capture and hence MLLs can be set too low because of problems associated with assessing how much fishing mortality and natural mortality each contribute to total mortality and because of an assumption that egg production is proportional to biomass.

Fishing mortality and natural mortality are interdependent in any method of estimation. For example determining mortality from tagging experiments is often based on several assumptions: (a) tagging causes no initial mortality amongst the tagged animals, (b) no tags are lost from tagged animals, (c) reporting of recaptured tagged animals is complete; and (d) fishing effort does not increase while the tagging experiment is in progress. In all tagging experiments most of these assumptions are violated and, more importantly, unless appropriate corrections are made, the results are biased to give overestimates of natural mortality and underestimates of fishing mortality. These biases are serious because they can lead a scientist using yield-per-recruit analyses to incorrectly advise managers that higher exploitation rates can sustain higher catches which can be achieved by higher fishing effort and smaller MLLs.

Analyses of yield-per-recruit are used to select combinations of fishing effort and size-at-first capture as a compromise between risking the loss of the recruited individual from natural mortality and allowing the individual to grow to provide optimum yield.

An important limitation of the yield-per-recruit analysis is that it takes no account of net reproductive rate. Maximising the yield-per-recruit might require lowering MLL to allow capture of smaller animals which might reduce the net reproductive rate and hence long-term yields.

A manager would be unwise to drop an MLL to take advantage of an increase in yield-per-recruit if such an increase resulted in a major decrease in eggs-per-recruit or, for viviparous and ovoviviparous animals, births-per-female born.

An analysis of eggs-per-recruit or births-per-female born is a valuable guide to the wisdom of changing the age at first capture, although the analysis does not indicate the maximum sustainable yield.

Ignoring recruitment processes in any fishery is poor management practice, but to allow recruitment-overfishing of long-lived species will usually have more serious long-term effects than will recruitment-overfishing of short-lived highly fecund species. The population size of a short-lived highly fecund species which reaches maturity within 1-2 years can build up much more quickly than will that of long-lived species.

The classification scheme I propose is based on longevity and fecundity of animals and will, when considered along with handling procedures and condition of the fish when landed, help determine the suitability of MLLs for protecting recruitment processes or maximising long-term yields from a fishery.

A Fisheries Manager's Application of Minimum Legal Lengths

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Introduction

Minimum legal lengths have been a major tool for fisheries managers in Australia since the need for some forms of control of fish catches and sales was first recognised more than a century ago. The foresight of the early managers[1] in their selection of sizes which have proved to be vital and effective in the conservation of fisheries resources has been noted frequently by managers in recent times. In most instances, despite the great advances which have been made in our knowledge and understanding of the resources and the fisheries, we have no grounds for varying those sizes which were chosen a century ago on the basis of intuition or very basic empirical information.

Why are Minimum Legal Lengths Used in Fisheries Management?

During last century in Australia, minimum legal lengths and weights were introduced to place a lower limit on the marketable size of fish and to conserve stocks based on the commonsense ideas firstly that there should be some restrictions on the numbers of fish taken and, secondly, that fish should have the opportunity to reproduce at least once before being liable to capture. Prescriptions of "appropriate" sizes for first capture were probably based on market perceptions of what constituted a saleable commodity, on enforcement officers' views on "acceptable" sizes and on the sizes at which maturity was first observed.

In Victoria, the first fisheries legislation prescribing such restrictions appeared in 1890 and set out minimum legal weights for virtually the same list of species as are currently the subject of minimum legal lengths.

Used in combination with gear restrictions, minimum legal lengths have continued to be the central elements of fisheries management strategies directed at both commercial and recreational fisheries.

To a greater or lesser degree, all States continue to use minimum legal lengths to assist in

- protection of immature fish;
- control of the numbers and sizes of fish landed;
- maximisation of marketing and economic benefits from commercial landings;
- promotion of aesthetic values of fish.

The maintenance of suitable sex ratios is also an objective in the case of southern rock lobsters in Victoria and Tasmania where the minimum legal length for females was lowered several years ago in order that the exploitation rate for females relative to males should be increased.

For a given species in a particular water or state, differential minimum legal lengths may be specified allowing anglers to take fish at a smaller size than commercial fishers so that:

- the resource is effectively conserved, and
- the fish taken for sale conform to the size preferred by consumers.

1. Note that these early "fisheries managers" were actually government officials primarily responsible for areas such as ports, public works, police, customs and agriculture acting in collaboration with fishing industry and marketing people.

In Victoria, black bream may be taken at a smaller size by anglers than by commercial fishers.

How are Minimum Legal Lengths Applied in Fisheries Management?

The most direct means of addressing the objective of preventing the catching, possession and sale of fish below a specified size is by the proclamation and enforcement of a minimum legal length.

This objective is often complemented directly by measures such as:

- escape gaps in rock lobster pots;
- minimum mesh sizes for gill, seine and trawl nets;

or less directly by measures such as closed "nursery areas" or closed seasons.

The broader objectives to which minimum legal lengths are directed are supported by measures such as bag limits or catch quotas and the protection of berried females, as well as the measures listed above.

In relation to the number of species for which minimum legal lengths are prescribed in Australia, there are very few examples of sizes which have been either specified or revised on the basis of thorough scientific assessments. South Australia's recent increases of minimum legal lengths for snapper, whiting and mulloway are notable exceptions which illustrate the necessity for comprehensive and credible data as the basis for the implementation of such measures.

Pre-requisites for Effective Minimum Legal Lengths

Today, minimum legal lengths remain as a central and effective element of the management strategies for those fisheries which are characterised by:

- low volume, medium to high value species which are marketed locally, e.g. snapper, whiting;
- the more traditional, low technology fisheries, e.g. estuary scale-fish netting and line-fishing;
- strong adherence by commercial and recreational fishers to the importance of allowing fish to reproduce at least once before being recruited.

Usually, if the rationale for minimum legal lengths is readily understood, adherence becomes part of the culture of the commercial and recreational fishing communities. Provided this rationale and the legal minimum length are seen to be:

- based on sound information;
- simple to understand and apply;
- promoted as part of the fisheries conservation message in schools and among commercial and recreational fishers;
- backed up by a significant level of overt enforcement effort;

then there is a strong probability that current and future generations of fishers will comply readily.

The astute fisheries manager recognises the power of the fishing culture and nurtures it so that peer pressure takes on a major role in promoting compliance with minimum legal lengths. In this regard, the emotive attachment of most fishers to "the protection of the spawning stock" is a valuable aspect of the fishing culture.

Even where illegal fishing for species such as snapper and whiting for sale is undertaken by anglers, most observe the minimum legal lengths for these species because:

- they - like many legitimate anglers - view the taking of undersized fish as a more serious or genuine offence than the sale of fish taken by legal means for illegal purposes;
- while some fish buyers may be keen to buy fish from anglers, few are prepared to take possession of undersized fish at any price.

Special applications

The situation where different minimum legal lengths are specified for a species within a State may be beneficial where:

- the growth rate varies significantly from locality to locality; and
- where there is sound information on the growth rates in the distinct localities where these sizes apply; and
- where the combination of fishers' agreement to the strategy plus effective enforcement make the arrangement workable.

For example, in Victoria, the minimum legal length for blacklip abalone has three values in different areas. In fact this situation is further complicated by the knowledge that, within the area where each size applies, there are fast-growing stocks in exposed waters off open headlands and slower growing stocks in more sheltered waters. In one management zone, the minimum legal length protects the highly productive fast growers, while the slow growers are able to be effectively utilised by the use of special days, selected by mutual agreement between enforcement officers and commercial divers, when abalone below the specified size may be caught and landed under close supervision.

A second special application of the legal length is the maximum legal length. For many years in the Victorian shark fishery, a maximum legal length was specified for school shark as part of a strategy intended to regulate the mean mercury concentration of shark flesh sold to Victorian consumers. This objective is now addressed by a different regulatory strategy. Maximum legal lengths are sometimes used to protect the large mature fish in stocks as an aid to recruitment, e.g. Queensland's protection of groper larger than 120 cm.

A variation away from the formal legislative prescription of fish below a specified size is being tried in the Victorian ocean scallop fishery where the Government and the industry have agreed to close the fishery if the proportion of scallops measuring less than 70 mm shell height taken in dredges rises to 20 % of the total. In this instance, the aim is to protect beds of small scallops so that they may have two major spawnings before capture - without closing the whole fishery to achieve this.

Problems Encountered in Use of Minimum Legal Lengths

Uniformity between States

One of the chronic problems associated with the use of minimum legal lengths is uniformity - or the lack of it - between the minimum legal lengths prescribed in different States. This problem is particularly troublesome for contiguous States which have different minimum legal lengths for a species for which effective conservation and inter-state marketing are of particular concern.

One notable example involves the mud crab with a 15 cm minimum legal length in Queensland where the major resource and fishery occur, and a much smaller minimum legal length in New South Wales where a major commercial market exists. The result is a flourishing illegal trade in undersized mud crabs in Sydney.

A second example which has the added dimension of export marketing issues arises from the difference between the minimum legal lengths for southern rock lobsters in South Australia (98.5 mm for males and females) and in Victoria and Tasmania (110 mm for males and 105mm for females in both states). The existence of the largest commercial fishery and the smallest minimum legal length in South Australia and the largest domestic market, the smallest domestic fishery and the closest international airport for live exports in Victoria has produced one set of issues surrounding resource conservation and interstate trade. The existence of a fleet of boats at Port MacDonnell, many of which fish for rock lobsters in both Victorian and South Australian waters, produces boundary enforcement and localised resource conservation issues.

Of lesser, but genuine concern is the situation where a species for which there is significant fishing pressure and a management strategy including a minimum legal length in one State is not considered to warrant such a measure in an adjacent State - particularly when anglers may pass by water from one State's waters to the other in the course of a fishing trip. An example is the group of sub-tropical mackerel species which are caught either side of the Queensland/New South Wales border - the former State has prescribed a minimum legal length, while the latter does not. On a more localised scale, fishing for mulloway is subject to a minimum legal length in the short section of the Glenelg River which passes through South Australia but faces no such restriction in the upstream and downstream stretches in Victoria.

In some such instances, one State has implemented a minimum legal length for a species for which it has no particular concern, essentially to support the management regime in an adjoining State, e.g. New South Wales' minimum legal length for spanner crabs.

Highly profitable illegal fisheries

The continued effectiveness of minimum legal lengths is diminished where there is large-scale illegal fishing for low volume, high value species, such as abalone, which are readily marketed at all sizes. This combination of factors produces large profits and low risks of prosecution, with the result that there is an overwhelming incentive for the illegal fisher to maximise short-term gains by breaking several regulations in the conduct of the illegal operation.

The mud crab example given previously also illustrates this point.

Scallops

During the 1960s and 1970s, minimum legal lengths were central to the management strategies for scallops in the Victorian Port Phillip Bay and ocean fisheries. However, in times of low scallop abundance, the damage caused to undersized scallops as boats worked all day to make up their bag limits, and the resultant fishing-induced mortality, convinced fishers and fishery managers that the reliance on a minimum legal length was not in the best interests of resource conservation, profitability and effective enforcement.

Consequently, the Victorian scallop fisheries have been managed primarily by the combination of bag limits and closed seasons. The current alternative approach to protecting scallops below 70mm shell height in ocean waters(mentioned above) is a further attempt to move away from these problems.

Compliance vs probability of capture of legal sized fish

Compliance with minimum legal lengths diminishes where, while fish are readily caught by anglers, almost all of the fish are below the specified minimum legal lengths. For instance in Melbourne, many inner urban fishers - including children, low-income, aged and handicapped anglers whose fishing opportunities are very limited - fish from wharves, jetties and retaining walls in the northern waters of Port Phillip Bay. Their chances of catching black bream, mullet, garfish and Australian salmon are very good, but only a very small proportion of the catch will satisfy the minimum legal lengths for these species. Similarly, juvenile snapper are often extremely abundant and readily caught in eastern Australian estuaries targeted by tourist anglers, but most snapper leave the estuaries before they reach the minimum legal length.

In these circumstances, the level of non-compliance is high.

A pragmatic approach to a similar situation has been adopted by South Australia which has chosen to accommodate continued fishing for mulloway down to 46cm in the multi-species net fishery in the Coorong because these fish will inevitably be caught there, while elsewhere in the State, the minimum legal length has been raised to 75 cm on the basis of recent research.

Species for Which Minimum Legal Lengths are Inappropriate

Minimum legal lengths, as such, have been found to have no place in the effective conservation of:

- deepwater species which are either dead at capture or incapable of return to the depths alive because of inflated swim bladders, scale-loss, etc.;
- high volume (low or high value) species where the sheer numbers of fish taken per catch make the application of a minimum legal length impractical;
- short-lived species with high natural mortality, such as squid, scallops and prawns.

In such cases, effective management strategies may be based on other input controls, such as minimum mesh sizes and other gear restrictions, or by output controls.

The effective reliance on minimum legal lengths primarily for resource conservation is also diminished where:

- the act of capture usually kills the fish, e.g. shark meshnetting, spearfishing;
- high value, low probability of capture and/or low punitive value of penalties, ready accessibility and markets, result in significant illicit fishing in which the benefits of selling undersize fish are also great, e.g. abalone.

The Importance of Adequate Data

As the levels of exploitation of most species increase, so does the pressure for management strategies to be revised to ensure the best use of the resources. In spite of this, as mentioned earlier, very few minimum legal lengths have been either introduced or revised as the result of thorough scientific assessments which provide credible evidence of the benefits of the measures proposed or of the costs of failure to act. The recent increases of the minimum legal lengths for snapper, whiting and mulloway in South Australia have been given as an example of such revisions.

Another consequence of increased fishing intensity is the increased pressure for management strategies to resolve conflicts. Fisheries managers must be wary of pressures to change minimum legal lengths as a "quick fix" attempt to solve one management problem at the possible expense of creating or aggravating others.

For example, the southern rock lobster's marketing and associated enforcement problems, mentioned above, have prompted some suggested solutions, several of which hinge on changes to the minimum legal lengths in Victoria, Tasmania and South Australia. Given the pivotal roles of the minimum legal lengths in the resource conservation strategies and the circumstances in each fishery, clearly no State is likely to vary its minimum legal sizes except on the basis of compelling evidence arising from thorough assessments of their stocks and fisheries.

Fisheries management is, inevitably, a matter of compromises, for instance:

- information needs versus costs;
- whether to set legal sizes to protect fast or slow growing populations;
- the differing interests of competing groups of fishers or adjacent States;
- resource conservation versus immediate economic considerations.

Just as fisheries biologists have the obligation to provide the best possible advice and information to managers, so managers (and the community) have an obligation to refrain from

Examining the "per Recruit" Effects of Size Limits Using the PRAna Software Package

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Introduction

The paper discusses minimum legal lengths (MLLs) in relation to per-recruit analysis. Such analysis provides the most direct method of examining how a fishing regime affects "the average fish" in a fishery. Another advantage of the method is its low data requirement. Even a simply obtained growth curve can be used to provide useful management information. Per-recruit analysis also can show how MLL and fishing effort (f) affect the interests of "competing" groups such as conservationists, fisheries biologists, commercial and recreational fishers. Per-recruit analysis takes no account of density dependent effects. It is unsuitable for analysing the short-term effects of fishery management controls on long-lived species.

Yield-per-recruit analysis was invented by Beverton and Holt (1957). They derived a formula based on measurable fishery parameters which calculates how yield Y (or catch biomass) is affected by fishing mortality F and MLL.

More recently, a number of per-recruit analyses have dealt with eggs (or "spawning potential") as well as yield (see References marked *). Generally, changes in MLL which increase one of these outcomes reduce the other. Since survival of the stock is related to eggs, managers have the difficult task of balancing production (Y) against sustainability (or "risks associated with different levels of eggs").

Eggs-per-recruit analysis was made possible by computers because intensive numerical techniques could be applied. Computers are also a powerful medium for communication. One can convey much more information than was previously possible by using techniques of visualisation and user interaction. For example, it is possible to immediately see how various fishery outcomes respond to changes in MLL and f (fishing effort).

As demonstrated in this paper, it is now possible to include in per-recruit analysis not only yield and eggs, but also biovalue (BV), catch numbers (No) and catch rates (Y/f, BV/f and No/f). Utility-per-recruit analysis offers further directions for improvement (Die *et al.* 1988).

The purpose of the paper is to improve understanding of fishery size limits (MLLs) by applying PRAna, a computer graphics tool for carrying out per-recruit analysis, to South Australian (SA) King George whiting.

The Fishery

King George whiting *Sillaginodes punctata* is the most valuable of South Australia's marine scalefish species. The landed value of the 1989-90 commercial catch was A$4.17 mil (634 t) and the catch taken by an estimated 300,000 recreational fishers is believed to at least match this.

Despite measures aimed at reducing fishing effort, fishing mortality has increased during the last decade, as has conflict over resource allocation. A Green Paper (Jones *et al.* 1990) summarised the status of the fishery.

Minimum legal length is one of the more easily implementable management tools. An internal 1988 analysis recommended an increase in King George whiting MLL, from its present level of 28cm, to 30cm. The paper advises managers on the likely effects of such changes.

Method

Per-recruit (/R) analysis examines how management controls affect fishery outcomes, as follows.

Management controls:	Fishery outcomes:
f (fishing effort)	Y (yield /R)
MLL (minimum legal length)/(age)	BV (biovalue /R)
	No (catch number /R)
	Eggs /R
	Y/R/f (relative kg/R/hr)
	BV/R/f (relative $/R/hr)
	No/R/f (relative No/R/hr)

The data types listed in Table 1 can be used in per-recruit analysis.

Dr G K Jones has led a research programme on the SA Marine Scalefish Fishery since 1977. Jones *et al.* (in prep) describe in detail the data and assumptions on which this analysis is based. It shows how catchability (q), selectivity (s_a), vulnerability (v_a) and existing fishing effort (f) were estimated and combined into a measure of age-specific fishing mortality F_a as follows:

$$F_a = q.s_a.v_a.f$$

The data used for the analysis of (medium growth rate) King George whiting are listed in Figure 1. The usefulness of information generated by such an analysis depends on how many of these factors have been estimated and the quality of these data.

Analysis was carried out using the PRAna (Per-Recruit Analysis) software package developed by the S.A. Department of Fisheries. The product is in prototype stage.

The analysis was based on "Legal age at first capture" (a_c) rather than on MLL. This obscures the following significant assumption, whose effects should be considered on a case by case basis.

Assumption 1:
Fish in a stock grow at the same rate

King George whiting in different regions in South Australia are known to grow at different rates. The analysis is based on "medium growth rate" fish, which were judged to be most representative of the overall situation.

Results

The existing situation of medium growth rate SA King George whiting is examined first.

The present MLL is 28 cm and is represented here as age 2.0. f = 1.1 corresponds most closely to the fishing and total mortality rates estimated by Jones *et al.* (in prep). Figure 2a shows the biomass age structure, what proportion is taken as catch, and the relationship to the unfished stock. Note that the stock biomass of the fished population is about a third of that of the unfished population.

Figure 2b shows the effect of changing the MLL to 35 cm, which corresponds to an age at first capture (a_c) = 3.0. PRAna allows the user to "step through" such changes interactively and immediately see the effects of changes in a_c and f on the age structure of No, Y, BV and eggs.

Figure 3 deals with eggs. It shows that eggs-per-recruit under the existing fishing regime (Figure 3a) are only 4% of those produced by an unfished population. Increasing MLL to 35 cm would increase this number to 10% (Figure 3b). At present, scientists are uncertain about how important such an amount is. If such information was available, it would significantly improve fisheries management by allowing risk of recruitment collapse to be included in the formulation of management policies. It may be possible to obtain a general understanding of acceptable levels of eggs-per-recruit for stocks under particular conditions through a collaborative research programme which compares the eggs-per-recruit situations of fisheries which have "collapsed" with similar ones which did not. Computer tools such as PRAna make such data analysis feasible financially.

Figure 4 shows the trade-off between the various fishery outcomes which depend on the management controls. They are expressed as percentages of the maximum possible. The significance of the absolute values can be debated, as in the case of eggs (see above). However the analysis is most useful for examining the effects of management changes. For example, it is possible to offer the following direct and relevant management advice:

"Assuming that fishing effort rises from f = 1.1 to 1.4, then changing MLL from 28 cm to 35 cm will significantly improve Y/R, BV/R and f/R, will have little effect on kg/hr and $/hr but will halve catch rates in terms of No/hr".

The results given above are based on the following assumption.

Assumption 2 : Changes in MLL do not affect the fishing mortality (F_a) of the age classes which remain in the fishery

This is probably untrue. If MLL is increased, fishers who used to catch smaller fish are likely to adjust their operations to target larger legal ones, leading to a corresponding increase in fishing mortality. Theory and data are lacking in this area, leading to uncertainty in recommendations that can be made.

Figure 5 summarises the advice to managers. It shows how four fishery outcomes are related to changes in MLL and fishing effort (f). Yield and eggs-per-recruit show familiar behaviour. However No/hr and $/hr give additional insights which were not available using previous analytical tools. Individual fishers may be more concerned with these than with Y and eggs. Commercial fishers usually want to maximise $/hr. Recreational fishers vary, some seeking maximum No/hr (sport, or aiming to catch bag limits) while others want kg/hr (regular supply of fish for consumption). A survey is underway to assess their attitudes on this issue.

Some important parameters are difficult to estimate. For example, M for SA King George whiting is believed to lie somewhere between 0.33 and 0.56, but this is based on scant evidence. How are the results of the above analysis affected by M? Figure 6 shows the same diagrams as Figure 5, but for extreme values of M. Their "shapes" are very similar, indicating that the management advice based on them is relatively insensitive to natural mortality M (on its own) within these ranges of M. This is important to know when deciding how to allocate Research & Development funds. Ideally, such analysis should be used at each milestone in a research programme to compare the cost/benefit of alternative future research activities (see Sluczanowski 1989).

PRAna has the ability to compare the effects of the same management regime (combination of a_c and f) being applied to substocks with different population characteristics. Work is being carried out at present investigating how the existing fishing controls on King George whiting in South Australia affect "fast-growers" compared with "medium-growers" and "slow-growers". Compromise at these levels is important and has many applications. For example, enforcement in the southern rock lobster fisheries in South Eastern Australia would be more cost-effective if there were a single MLL across States. It is also an important issue in abalone fisheries, where geographically separated and independent substocks are subject to a common MLL. The "best" size limits for some substocks may be catastrophic for others.

Discussion

The results show that fishers of SA (medium growth rate) King George whiting are likely to suffer continuing reduction in catch numbers per hour unless fishing effort can be contained. Figure 5 shows that if f continues to increase, as it has over the past decade, all outcome indicators (except total No/R caught) decline, with eggs-per-recruit becoming even lower. A response to this situation could be to increase the MLL.

Table 2 analyses the situation corresponding to an increase in MLL from 28 cm to 30 cm, as presently proposed. The second row shows the effects of a 25% increase in fishing effort (f) with the existing size limit. The third row shows how the figures change if MLL increases to 30 cm based on the assumption (2) that the fishing mortality does not change. If effort increases by 25% as a result of the change, as well as because of "natural" increases, the situation illustrated by the last row will arise. Not many gains would be achieved, and the numbers caught per hour will have fallen significantly.

Eggs-per-recruit analysis reveals that the present SA King George whiting population produces about 4% of the eggs in an unfished population. Some fisheries biologists believe that safe levels lie between 30% and 50% and therefore feel that this gives cause for concern. Others argue that too little is known about the subject to give advice. Most agree that the topic deserves more work.

A more effective management policy than changing MLL in response to rising fishing effort (f) is to restrain and reduce (f). Combined with increases in MLL, this option can be even more effective.

The advice to managers given in this paper can be improved through more analysis and further scientific measurement and experimentation.

Managers of the King George whiting fishery should use the information presented above, suitably qualified by biologists and modellers, to decide on MLL and other management actions.

They should support work to carry out analyses at higher resolution (quarterly), sensitivity analyses of outcomes to parameter uncertainties and to alternative management outcomes, and field experiments to obtain better estimates of fecundity relationships. (In particular, does fecundity depend on fish size or age ?)

The paper has identified the need for the following work:

- Is recruitment failure related to low eggs-per-recruit ?
- How do changes in MLL affect fishing mortality ?
- PRAna should be developed further and distributed to make it accessible to more fisheries biologists.

The authors may be contacted for more information about the PRAna software package.

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(References marked * have not been referred to in the text).

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Table 1. Data usable in Per-recruit analysis
Types of data used by PRAna for fishery per-recruit analysis. # indicates that it may be age specific

Maximum age	% mature (#)
Length (#)	% female (#)
Weight (#)	Vulnerability (#)
Natural mortality M (#)	Selectivity (#)
Catchability q	Value per unit weight (#)
Eggs/fish/year (#)	

Table 2. Effects of changes in minimum legal length and fishing effort on SA King George whiting
Effects on five outcome indicators of the SA (medium growth rate) King George whiting fishery of a 25% increase in effort (f) and change in minimum legal length (MLL) from 28 cm to 30 cm. Values are percentages of the maximum possible

Outcome indicator	Eggs	Yield	$/hr	No/hr	kg/hr
Interest group	Cons-ervat-ionist	Biolog-ist	Com-mer. fisher	Recreational fishers	
Existing situation	4	64	23	45	27
25% effort increase	2	63	17	39	21
MLL increase 28-30 cm	7	74	31	38	31
Both increase together	5	75	24	33	25

MODEL IDENTITY DATA		MODEL GLOBAL DATA	
File Name Stock Name Date	mkg.dat King George whiting 16/08/90	Number of Time Units Maximum Fishing Effort	16y 2.75
STOCK DATA			

M	L∞	k	t_o	aw	bw	ae	be	q
0.45				0.00075	3.49	0.00	0.00	1.00

Age	Mort.	Length	Weight	Egg/Fish/t	%Matu	%Fema	Vlnblty	Select'y	Valu/Unit Wt
0	0.45	3.00	0.00	0.00	0	50	0.000	0.000	0.000
1	0.45	15.10	0.97	0.00	0	50	0.650	0.500	0.000
2	0.45	26.50	6.93	0.00	0	50	1.000	0.920	3.370
3	0.45	35.00	18.31	10.00	50	55	0.850	1.000	6.000
4	0.45	41.60	33.46	25.00	100	72	0.770	1.000	6.000
5	0.45	46.40	48.98	57.50	100	85	0.390	1.000	6.000
6	0.45	49.80	62.69	90.00	100	93	0.390	1.000	6.000
7	0.45	52.10	73.39	115.00	100	96	0.390	1.000	6.000
8	0.45	54.00	83.17	145.00	100	98	0.040	1.000	6.000
9	0.45	55.30	90.37	162.00	100	100	0.040	1.000	6.000
10	0.45	56.20	95.61	185.00	100	100	0.040	1.000	6.000
11	0.45	57.00	100.44	193.00	100	100	0.040	1.000	6.000
12	0.45	57.50	103.55	200.00	100	100	0.040	1.000	6.000
13	0.45	57.90	106.08	218.00	100	100	0.040	1.000	6.000
14	0.45	58.20	108.01	225.00	100	100	0.040	1.000	6.000
15	0.45	58.40	109.32	250.00	100	100	0.040	1.000	6.000

Figure 1. Input data for a per-recruit analysis of SA (medium growth rate) King George whiting shown as the PRAna "DATA" input screen.

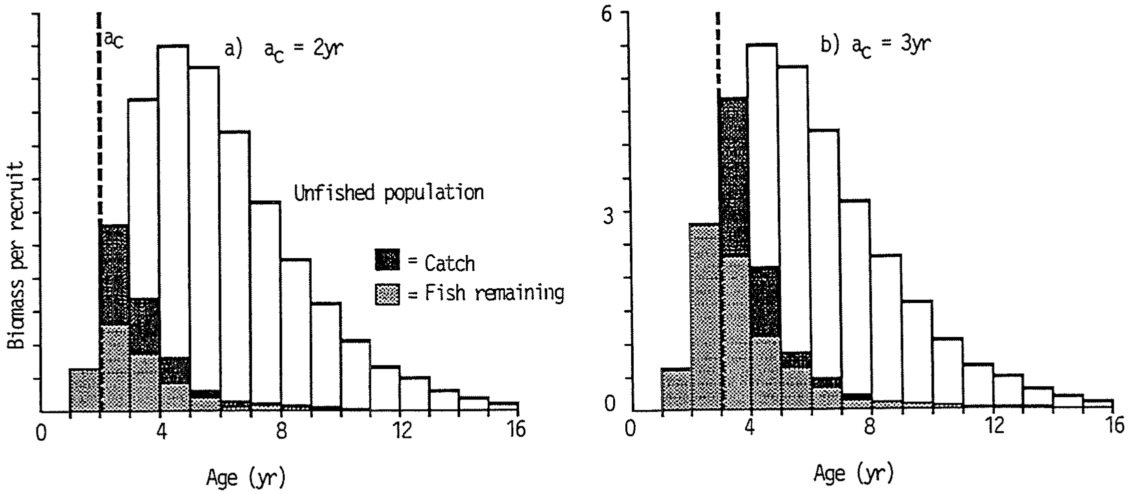


Figure 2. Effects on the biomass age structure of SA (medium growth rate) King George whiting of changing age at first capture (via MLL) from (a) a_c =2 yr to (b) a_c =3 yr assuming constant recruitment and fishing effort f = 1.1.

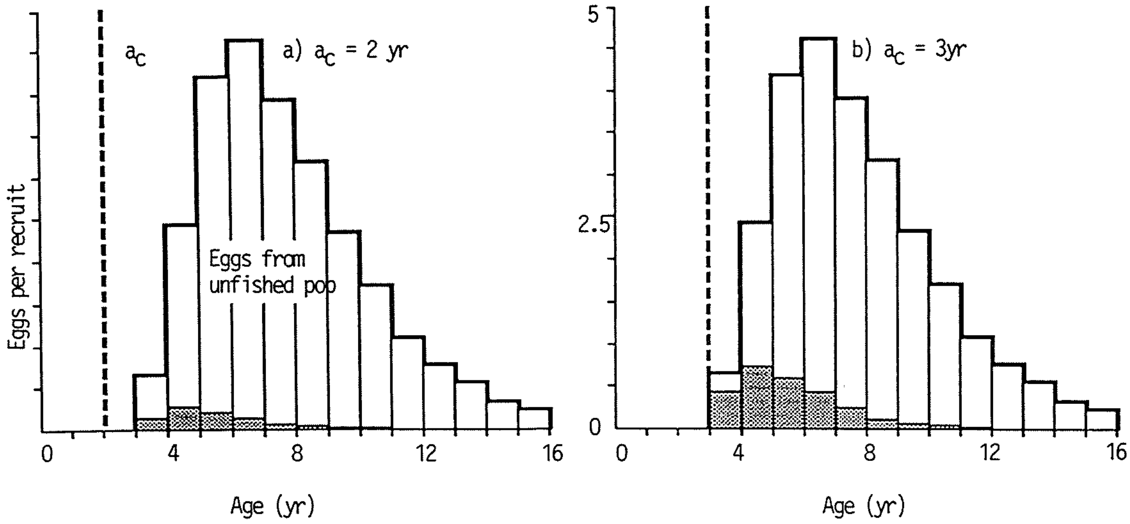


Figure 3. Effects on egg production by age (shaded) of SA (medium growth rate) King George whiting of changing age at first capture (via MLL) from a_c =2 yr to 3 yr assuming constant recruitment and fishing effort f = 1.1.

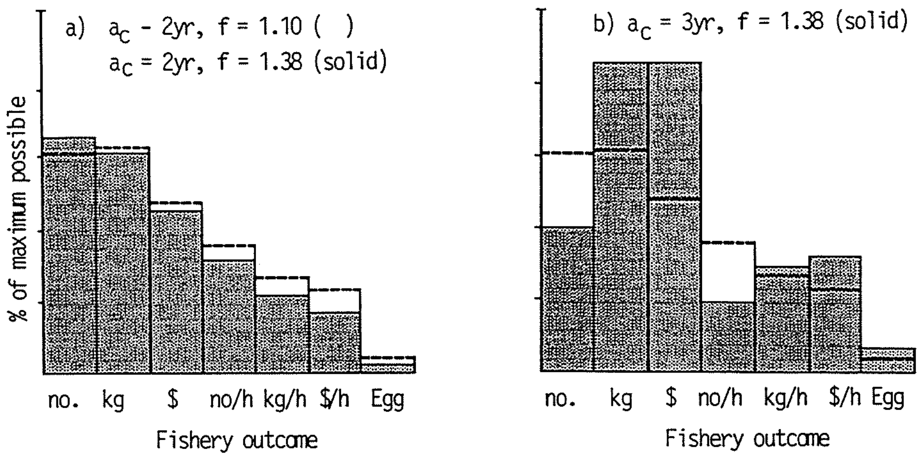


Figure 4. Effects on seven whiting fishery per-recruit outcomes of: (a) an increase in fishing effort from f = 1.10 (dashes) to 1.38 (solid) for minimum legal length MLL = 28cm and; (b) an increase in MLL to 35cm (solid) in response to the increased f shown in (a).

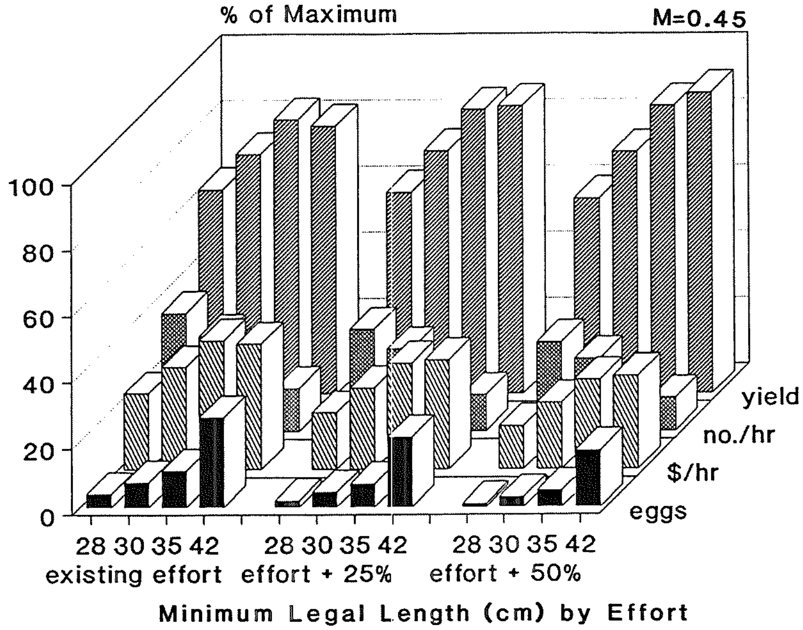
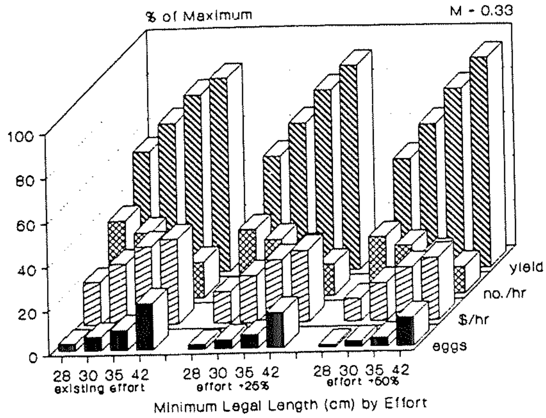


Figure 5. Effects of changes in minimum legal length and fishing effort on eggs-per-recruit, relative $/hr, relative No/hr and yield-per-recruit for SA (medium growth rate) King George whiting.



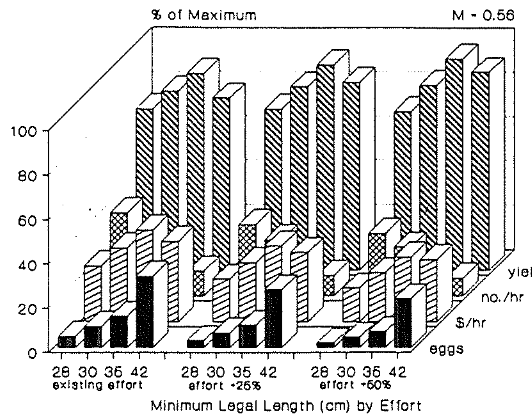


Figure 6. Effects of extreme values of natural mortality M (0.33, 0.56) on advice to management presented in a similar fashion to that given in Figure 5 for nominal M (=0.45)

Discussion of Basis for Setting Legal Lengths

Recorded by I. W. Brown

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Questions were addressed to individual speakers and followed by more general discussion

Peter Young challenged *Terry Walker's* assumption of yield-per-recruit being the appropriate way to approach the management of highly fecund animals. It doesn't work with scallops, which are sedentary self-recruiting animals. There is evidence of large populations having been fished down over a period of 3 years or so and never recruiting back. These highly fecund animals may only recruit successfully once in 10 years; if they're cleaned out in the couple of years before they spawn there may be no reproduction because the remaining spawners are so widely dispersed. It may be that the only effective spawning occurs in very dense beds.

Terry Walker agreed that it is difficult to generalise, but the scallop is a classic case because growth rates and natural mortality are known and can be modelled to determine how best to organise the open season to maximise yield. On the question of fecundity, he pointed out that the Port Phillip Bay population has collapsed three times, but has come back again each time.

Peter Young's response was that the Port Phillip Bay fishery is closed to fishing when catch rates fall to a certain level, so that it is never fished to extinction.

In asking about the minimum legal size effect, Murray Macdonald asked whether the longer-lived, lower fecundity animals are more appropriate to management by size limits.

Terry Walker responded by saying that the size limit concept is useful as a way of maximising reproductive potential in long-lived species.

Following the presentation by *Ross Winstanley*, Rob Lewis pointed out that from this workshop it is hoped to produce a document for direction and advice. We should be suggesting that the management authorities use the correct scientific rationale for using minimum legal lengths as a management tool, and we need to identify the costs and benefits associated with the necessary research.

Alex Schaap reopened the discussion on scallops by saying that this fishery should be managed on the basis of maximising yield. Tasmania does have minimum legal sizes for scallops, and intends to retain them, not so much for management on the basis of size, but as a useful enforcement aid. With bed-by-bed management of the scallop fishery, minimum sizes can help ensure that beds not suitable for harvesting are left alone. Thus the minimum size, which does not have much biological significance, is being used as an enforcement tool to support a quite distinct management strategy. In Port Phillip Bay this is obviously not appropriate, because the Bay is either totally open or totally closed to fishing.

Ross Winstanley was of the view that the experience in Victoria is that the minimum legal size is a useful concept. However there may be problems with damage to the bottom and to the younger scallops by boats continuously scouring the bottom to get their quota of legal-sized scallops. With the ocean scallop fishery, it was intended to use a variation of the minimum size concept. This requires agreement with industry on an arbitrary size corresponding to an age of 1+ or perhaps 2 years. When more than 20% of the catch comprises scallops below this size, the fishery is closed. This avoids the need for fishermen to sort the catch, and reduces the mortality on small shell from repeated dredging of the same ground.

Rob Lewis concluded that the various comments highlighted the increasing need for real-time management decisions: decisions that have to be made on the basis of what is actually happening at sea at the time.

After *Philip Sluczanowski's* presentation Rob Lewis emphasised how important such visual modelling will be in selling particular management options to managers and industry. There is a need, however, for a degree of biological conservatism regarding minimum size options when dealing with stocks comprising more than a single species or involving the use of several different fishing methods. It might mean that one of the target species in a suite may not be able to be captured at all.

John Glaister referred to the morning's contribution by Burke Hill when he elegantly listed the main reasons for looking at legal sizes, that is:

- increasing reproductive output;
- enhancing the catch;
- decreasing exploitation.

Burke Hill had argued that legal size legislation is not an effective way of achieving decreased exploitation. John Glaister wondered if anyone had strong views as to whether minimum legal sizes do in fact increase reproductive output, and disputed Terry Walker's idea that "bigger is better" on the grounds that there has been some suggestion that the viability of progeny declines as animals get older. Perhaps it is better to have more small spawners than a few super-fecund old ones.

Dave Pollard, in a provocative mood, suggested that the concept of maximum legal sizes should be subject to more serious consideration. The argument has been heard that although larger animals may be more fecund than smaller ones it is possible that survival of progeny may decline. The Queensland groper maximum size limit was applied, it is understood, more for aesthetic reasons than the biological reason of the species' protogynous hermaphroditism, and the same applies to the reasons for protecting male serranids in NSW. He was not sure why the proposed maximum size limit for Murray River freshwater crayfish was rejected, and presumed John Harris would comment on the situation with Australian bass. The barramundi, which is a protandrous hermaphrodite, may also need an upper legal size limit. Is it possible to model this, and if so, have we the option to do it with the whiting model?

Philip Sluczanowski responded that there is no maximum legal length option in the model. He was involved in some of the southern shark work, and maximum legal sizes can certainly have a significant effect. It may be that the animals contributing to all our future stocks are ones that have escaped the "gauntlet". This emphasises the importance of fishing mortality in the "gauntlet", and you can't start thinking about maximum sizes unless you have some idea of the number of animals surviving. By the time they've got through, they are also subject to natural mortality and there's not much biomass left. It can be analysed, but he emphasised the importance of measuring fishing effort and fishing mortality.

John Harris referred to the mention made of the Australian bass as a species which might benefit from a maximum size limit. The situation is a little different from that of the barramundi which changes sex; in bass (and several other species) there's a sexual dimorphism in size. The *L*-infinity of male bass is about 27 cm, and many years ago the NSW minimum size was set very near this value, with the result that almost all the fishing pressure was applied to one sex. There is no longer a legal limit on bass, but there is strong philosophical pressure for a limit, particularly among recreational fishers who do perceive some sort of minimum size as being biologically reasonable. Consideration also needs to be given to the question of heritability of growth characteristics where, in heavily exploited populations, size limits place disproportionately more of the fishing pressure on the larger faster-growing individuals. He believed that especially in heavily exploited freshwater fish stocks much more emphasis needs to be given to considering either maximum sizes or "slot" widths, which balance the various opposing management objectives.

Patrick Coutin mentioned a point made earlier about the size of fish at spawning, and wondered if all fish are spawned equal - i.e. do the smaller and larger fish contribute equally to the spawning stock? In some tropical species which spawn over a long season, perhaps it's the larger individuals whose reproductive output is most likely to coincide with the most environmentally favourable period for egg and larval survival, and thus contribute most to strong year classes.

John Glaister replied that the point he had made was from discussions with Rod Garrett at the Northern Fisheries Centre concerning barramundi aquaculture. They tried getting eggs from very large females, but experienced difficulties in handling the big animals and found that the viability of eggs from smaller individuals was better. So now they concentrate on smaller females.

Don Hancock pursued the argument a stage further by asking how many of the animals actually reach maximum legal size because of natural mortality? He noticed that in Philip Sluczanowski's model, the value of M is quite high, about 0.45, which is about 1/3 of the stock every year, and wondered how sensitive the model is to changes in natural mortality. If it is very sensitive, is the estimation of M likely to be a stumbling-block to the formulation of policy options?

Philip Sluczanowski referred to his screen display which gave management advice on the basis of M=0.33 and M=0.56. He is very interested in graphics and visualisation, and the management advice is contained in the shape of these curves and their relative positions. For relatively low and quite high values of M the management advice doesn't change very much. However the qualifications the biologists have to make regarding eggs-per-recruit will change significantly. Biologists need to be doing the sort of things Scoresby Shepherd suggested - looking at fisheries that have collapsed and determining the pre-conditions of eggs-per-recruit, and comparing those with fisheries which have survived. Perhaps from this can be produced a guide to managers about what sort of level of eggs-per-recruit we should be aiming for.

Laurie Lawrenson asked a question on the effort measure used in the particular model. When effort is altered by adjustments to the minimum legal size, what the fishermen will do can't be predicted - they may shift their effort to a different area, and the whole system may fall over.

Philip Sluczanowski agreed, saying that what will actually happen is that effort will redistribute itself. One way of dealing with this is to assume that the effort that used to be on this biomass redistributes itself over the remaining age classes in proportion to the biomass that's there. That is one model which could be built, and it theoretically should be included in the models. Experiments are also needed to check what actually happens.

Terry Walker asked whether when the value for natural mortality was adjusted, was q also changed? When estimating M from some sampling or tagging experiment you can probably get a reliable estimate of total mortality, but if F has been overestimated, M will be too low.

Philip Sluczanowski agreed that because M and q are related, as one goes up the other goes down.

Rick Fletcher wanted to know how soon after changing the management strategy (e.g. by adjusting effort or minimum legal length) will the actual effects in catches become apparent to the managers? It won't be instantaneous, will it?

Philip Sluczanowski said that he could show that in a simulation; the amount of time would depend on whether it's one of Terry Walker's slow growing or fast growing fish. It will take some time for the effects to appear, and of course they will be modified by random and environmental effects.

Rob Lewis commented that the danger with this type of technology is that one can forget the basic underlying assumptions and qualification behind the parameters and their estimation. When the manuals for these computer models are written, the assumptions and qualifications will have to be explicitly spelled out.

Scoresby Shepherd wanted to reinforce the plea for examining maximum legal sizes, especially in abalone, because fecundity is a power function of weight, and there are differences between sexes in growth rates, with females growing faster than males. In the Omani abalone fishery a maximum size limit had been recommended.

David Hall proposed the idea that the real objectives of minimum legal lengths are (a) to increase the quality of recreational angling in the case of an angling species, and (b) to maximise the economic benefits if it's a commercial species, or both if it's a combination of the two. One thing he felt had been overlooked by the biological models is the reactions of the fishermen. This should if possible be built into the model. In Philip Sluczanowski's model the effort that would be applied at different lengths will be different. For example, a yield-per-recruit analysis on mulloway pointed to an optimum minimum legal length of 1 metre. If this minimum length were applied, there would be virtually no fishery, because most of the fish are taken in the nursery area, outside of which they are largely inaccessible. This is an area where fisheries managers are often put in a difficult situation, and it may well help if the fishermen's reactions were incorporated into the model.

SESSION 3

Case Studies: Problems Encountered

Chairperson:	J.P. Glaister
Panellists:	M.C.L. Dredge
	D.J. Die
	S.S. Montgomery
	M.J. Moran
Rapporteur:	A.J. Fowler

Chairperson's Introduction

J. P. Glaister

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In deciding on the format for this Workshop we thought that, as in all good psychology courses, a session on case studies would be worthwhile. You know, where staid, thoughtful souls stand up and reveal their real personae. So it is with the problems encountered with legal sizes. We are fortunate in not only spanning the animal kingdom (barramundi, scallops, rock lobsters, snapper and prawns) but in also having the said staid, thoughtful, aforementioned. Now, sit back and enjoy the *real* story - what *really* happens with legal sizes ...

Barramundi

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Abstract

Barramundi (*Lates calcarifer*) is a large centropomid perch which grows to at least 150 cm TL and 50 kg. It is widely distributed throughout the coastal waters of the Indo West Pacific, has a protandrous hermaphroditic reproductive development and a generally catadromous life history strategy. The species supports significant commercial gill-net and recreational angling fisheries in Queensland, Northern Territory and Western Australia. The commercial fishery is multi-species.

Legal size regulations were introduced in Queensland in 1877 (16 oz) and subsequently increased in 1989 to 55 cm TL. Initial regulations were aimed at ensuring 'reasonable size' fish (market, aesthetics), though later, in 1954, the minimum size was increased to 'allow fish to spawn at least once' (existing biological understanding was that barramundi were gonochoristic, that is, sexes separate). Subsequent studies identified sex inversion, and legislation was changed to protect fish (males) less than the earliest maturity seen (55 cm). A minimum legal length of 23 inches (58 cm) was established in July 1966 in the Northern Territory and it is thought that this was a direct result of Queensland legislation (spawn at least once).

There are three groups of problems that are encountered when considering the use of legal size in the management of barramundi: reproduction, yield and the multi-species nature of the fishery. This paper presents a description of these problems.

Introduction

Barramundi *Lates calcarifer* (Bloch) is a large centropomid perch which grows to at least 150 cm TL and 50 kg. It is widely distributed throughout the Indo West Pacific and exhibits protandrous hermaphroditism (changes sex from male to female). It is also reported to exhibit a catadromous life history (spawns in inshore coastal waters and undertakes juvenile history in freshwater). The species supports commercial gill-net fisheries in tidal coastal waters and river mouths in W.A., N.T. and Queensland which target generally larger and mature fish (male and female). Barramundi are also keenly sought by recreational fishermen who target fish of any size, generally with lures or bait. The N.T. and Queensland commercial fisheries also take threadfin or king salmon (*Polynemus sheridani*) in great numbers whilst the Queensland fishery also includes blue or Cooktown salmon (*Eleutheronema tetradactylum*) and banded or golden gunter (*Pomadasys kaakan*) (Moore 1979 and Griffin 1987).

Legal Sizes

There is uncertainty surrounding the original scientific basis for a legal size for barramundi. The Queensland Fish Act (Fisheries) of 1877 included minimum size regulations for a number of species which were specified in weight. Barramundi were required to be greater than 16 oz though it was not made clear how fishermen were to measure their catch. The Fish and Oyster Act (1914) and its subsequent amendment in 1932, set minimum legal lengths of 14 inches and 15 inches respectively. The author was unable to uncover the basis for this size and it is suspected uncover the basis for this size and it is suspected that it was a length transformation of the previous legal weight.

The Act was amended in 1954 and the minimum legal length increased to 20 inches. The reasons for this are not clear, but the common perception was that 20 inches was 'about the right minimum size' for a species known to reach 60 inches (V. Curtis, pers. comm.). However, at about the same time, the Queensland Government had requested Mr D. Dunstan of CSIRO to undertake a study on barramundi, following numerous complaints that the species was being overfished. At the time Dunstan assumed that barramundi were gonochoristic since it was not known that they changed sex (though he recognised the larger fish were female). It is also significant that most of Dunstan's biological studies were conducted in the Fitzroy River, near the southernmost limit of its range.

Dunstan (1959) reported that 'In Queensland waters, the smallest female barramundi with well-developed gonads was 76 cm in length, 11 lb in weight and 2 years of age'. Thus Dunstan's work was the basis of early management in Queensland and Western Australia. Certainly his results showed the recorded catch of barramundi from east coast waters had declined since 1947. He concluded that the 'very great increase' in the number of licensed fishermen (258%) and licensed traps (116%) between 1949 and 1954 'may have contributed to the decline in abundance of the species'.

Reynolds and Moore (1982) reported sex inversion in Papua New Guinea barramundi, and this phenomenon was verified independently by Davis (1982) in the Northern Territory, and Garrett and Russell (1982) in Queensland. The discovery of protandrous hermaphroditism caused some confusion within management circles as it cast doubt on the efficacy of a legal size based on an objective of letting male fish breed at least once during their lifetime. A further complication for management was the suggestion that barramundi comprise discrete genetic stocks with differing size at maturity, reproductive potential, breeding season and other attributes.

Morrissy (1969) investigated the impact of river impoundments on barramundi and the emerging recreational-commercial conflict in Western Australia. However much of the regulatory basis for barramundi (including minimum legal size) in that State, derived from Dunstan's (1959) work in Queensland.

As part of a Fishing Industry Research Committee grant, John Russell undertook a comprehensive investigation of the east coast Queensland inshore commercial gill-net fishery for barramundi (Russell 1987). Russell made several major recommendations including that of increasing the minimum legal size of barramundi (based on an analysis of size at first male maturity) and a maximum legal size (based on the assumption that exponential increases in fecundity with size proportionately increase successful recruitment). However Russell argued against 'imposing a politically unpopular and virtually unenforceable maximum legal size' and instead suggested mesh size restrictions and effort controls to ensure an adequate spawning biomass.

Biological Constraints

Management plans for barramundi stocks in Australia generally have had unstated objectives, but they are usually economic or more rarely social objectives, with biological constraints. One regulatory tool applied to barramundi to achieve the economic objective is legal size, but the main difficulty is the uncertainty as to the effect on the biology of barramundi and its populations. Three main problems are apparent:

- *The reproductive problem*. The contribution of many smaller females greater than that of fewer, larger females (given relative fecundities and survivorship)? In other words should the legal size be a minimum, a maximum or both?

- *The yield problem.* If recruitment is not limiting (no demonstrable spawner-recruitment relationship), is yield optimised with a larger minimum size, given that recreational and commercial fishermen target different life history stages? The combined fishing pressure tends to focus on mature male fish, the more abundant age classes.
- *The multi-species problem.* The principal commercial fishing method is gill-netting and the mechanism of achieving size limits is through the regulation of selectivity through mesh sizes. Given that the fishery has become multi-species, is it better to regulate mesh size for barramundi solely, or for all the total species targeted?

The reproductive problem

The effect of sex reversal in barramundi suggests that any minimum legal size regulations around those currently in force or proposed are likely to largely protect males and relatively few mature females except for those precocious stocks. In an investigation of the protogynous (female changing to male) hermaphroditic reproductive strategy of some exploited serranids (groupers), Bannerot (1984) suggested that there could be potential reduction in the reproductive capacity of protogynous or protandrous hermaphroditic populations during intense exploitation of spawning aggregations. He considered that such populations could respond differently than do gonochoristic populations (sexes separate and unchanging). Responses he suggested included changes in the time required for individuals to change sex, changes in the range of sizes capable of changing sex and changes in the population sex ratio resulting from effects of exploitation. Thus for barramundi populations, if the timing and size of transition from male to female were so affected by exploitation it could account for the sexually precocious barramundi reported from Thailand populations that have experienced heavy exploitation (Barlow 1981). Interestingly, many years of intense fishing in the Gulf of Carpentaria has not caused a reduction in the age at maturity.

However, sex changes aside, the exponential relationship between female size and fecundity suggests that the vast reproductive potential of large females would warrant protection by a maximum legal size unless viability of progeny decreases with the age of the mother. The simple objective of allowing females to spawn once before being available to exploitation would seem inappropriate in the case of barramundi.

The yield problem

Computer simulations with a theoretical barramundi population with population parameter estimates derived from Northern Territory stocks, were run at a barramundi workshop held in Darwin in 1987. The simulator applied was the generalised population simulator GXPOPS (Fox 1973) configured for the protandrous hermaphroditic life history strategy, a fecundity modelled on Davis' (1982) data, growth modelled on data of Davis and Kirkwood (1984) and Griffin (unpublished data), and an availability schedule (vulnerability) for recreational anglers and commercial gill-netters estimated from respective catch curves and selectivity data. The number of year classes, natural mortality coefficient, breeding regime and age at recruitment were all held constant as were age-maturity fractions and sex ratios.

The simulator allowed the effects of management manipulations to be followed through the theoretical population and dependent upon the desired objective (maximise yield, maximise eggs per recruit or maintenance of a proportional spawning biomass) evaluated.

Preliminary runs suggested an increase in size at first capture would contribute to most management objectives. In the Northern Territory and throughout most of the rest of its distributional range, recreational anglers target fish in upstream fresh and brackish waters which are predominantly male and transitional females (ages 2 to 7) whilst commercial gill-netters target older, mature males and females in downstream river mouth salt water (ages 4 to 10). Any substantial increase in size at first capture through, say, area closures or minimum size regulation would disproportionately impact recreational anglers.

Management authorities in the Northern Territory have taken the decision to reduce the commercial gill-netting activity in several major river systems and promote the recreational angling activity on economic grounds, based on the assumption that economic multipliers associated with the recreational fishery mean that this sector contributes more to the Northern Territory economy than the commercial sector. In addition, since recreational and commercial fishermen target different sizes in different regions of the river system, Northern Territory managers introduced separate legal sizes for recreational (50 cm) and commercial (57.5 cm) fishermen (standardised at 55 cm from 1 February 1991). In Queensland, as a consequence of river morphology, recreational and commercial fishermen are not spatially separated and catch-sharing arrangements are by negotiation.

When considering the management of a recreational fishery, the question is often asked: Should management be aimed at producing few, large, trophy fish or many small plate fish? Most Northern Territorians consider any size of barramundi is acceptable since 'a barra is a barra'. In terms of yield maximisation only, a fishery based on the older age classes (large legal size) would seem desirable. In other words, favouring a commercial fishery.

The multi-species problem

The commercial gill-net fishery for barramundi is a multi-species fishery with king salmon (*Polynemus sheridani*) and Cooktown or blue salmon (*Eleutheronema tetradactylum*) the principal additional species also taken, with smaller quantities of banded grunter (*Pomadasys kaakan*), mud flathead (*Platycephalus fuscus*) and queenfish (*Chorinemus lysan*) also captured. However barramundi is the 'target' species and mesh regulations have evolved to manage that species. In recent years the incidentally taken species have become more economically significant to fishermen and, in most quarters, are not regarded as by-catch but as (seasonally) significant components of a multi-species fishery. Catches for different areas of the fishery, from the Northern Territory to the Queensland east coast, vary in species composition of the catch with differing species being locally significant.

Fish are retained in mesh nets by wedging in a mesh, by tangling in meshes on bony parts and by looping over maxillaries or other mouthparts (known respectively as 'gilling', 'tangling' and 'lipping' or 'bridling'). Different species have varying (with size) susceptibility to the latter two, though barramundi (*L. calcarifer*, 'calcarifer = thorn carrier') is very susceptible to all three. Research by Griffin in the Northern Territory and Garrett and Russell in Queensland have shown that the proportion of undersized (illegal) barramundi present in the size frequency distributions of the commercial catches of barramundi and other major species varies between mesh size, species targetted by sex and by season.

For example in Queensland, commercial gill-nets have a minimum legal mesh size of 15 cm in coastal waters and 11.5 in some rivers on the east coast. Russell (1987) collated commercial catch data for the major species for a range of mesh sizes commonly used in the commercial fishery. He found 75% of barramundi captured in the 11.5 cm river nets were below the statutory legal size of 50 cm, whilst approximately 2% were less than legal size in the 15 cm coastal net. Conversely, large numbers of legal king and blue salmon were absent from the size distributions of catches from those nets with meshes greater than 11.5 cm, suggesting changes in vulnerability.

As with any multi-species fishery then, the question is what is the overriding management goal? That of regulating for some management objective (economic or/and social) for barramundi alone? Or that of regulating for management objectives for all species (some of which may be common to all species)?

Conclusions

It is apparent that in the case of barramundi, legal size and its regulation have evolved as the fishery has developed. Early regulations were aimed at allowing individuals to breed once before becoming accessible to the commercial fishery, though the discovery of protandrous hermaphroditism caused some confusion in this regard. More recently it appears pragmatism and politics have largely replaced any defined management objective. The complex life history of the barramundi, the recreational/commercial exploitation of its different life history stages, and the increasingly multi-species nature of the commercial fishery towards the extremes of the barramundi geographical distribution, make it a fascinating case for the student of fishery management science, but the question does remain: What precisely is the purpose of legal size regulations for barramundi?

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Using Size Limits to Maintain Scallop Stocks in Queensland

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(paper presented in summary to Workshop by P.C. Young)

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Abstract

The fishery for saucer scallops (*Amusium japonicum balloti*) in Queensland waters has been characterised by long term changes in total catch and catch rates. Declines in catch rates between 1978 and 1988 and landings between 1982 and 1987 were interpreted as being indicative of recruitment overfishing. Saucer scallops have growth characteristics such that they were subjected to heavy fishing pressure prior to attaining sexual maturity. This was seen as a contributing factor to recruitment overfishing. A size limit, first introduced in 1984 as a means of optimising yield in the fishery, was subsequently increased and manipulated to increase spawning biomass of the scallop stock. At the same time, area closures were established as spawning stock refuges.

Ongoing modelling processes are being used to establish which of these management techniques is of most value in restoring the stock to an optimum level of production.

Introduction

The saucer scallop, *Amusium japonicum balloti*, supports a trawl fishery in central Queensland waters from which annual landings have varied between approximately 500 and 1400 tonnes between 1980 and 1990. Effort directed at the stock has increased considerably in this period, from an estimated 40,000-50,000 boat hours trawled per year in the early 1980s to a present level in excess of 200,000 boat hours per year (Dredge 1988, Trainor 1990). A range of management measures aimed to meet both biological and economic criteria have been applied to the fishery. Variable size limits are an important constituent of the management package. In this paper, the rationale behind the use of variable size limits is explained, and a model designed to evaluate their effectiveness is introduced.

Biology of A. j. balloti

The biology of *A. j. balloti* is reasonably well known, and comparatively simple. The species occurs between 15°S and 35°S, typically in water depths of 30-50 m. *A. j. balloti* is gonochoristic and spawns between May and September/ October (Dredge 1981). There is some evidence that there may be two or more peaks of settlement following the spawning season (Dredge 1985a). The larval phase extends for about 14-18 days (Rose *et al.* 1988), and byssal attachment, if present in wild populations, has a limited duration. Growth in the species is characterised by both speed and variability. Williams and Dredge (1981) give growth parameters which indicate that *A. j. balloti* may attain a shell height of approximately 85 mm in 28-35 weeks, and 90 mm in 33-42 weeks, depending on location of settlement. Adductor condition varies considerably with time of year. Best meat recoveries occur during summer, when gonads are least developed. This has considerable implications for the fishery's management, as saucer scallops are processed as roe-off meat and there is currently a considerable differential between small and large meats.

Like most scallops, *A. j. balloti* are effectively sedentary after settlement. Their natural mortality rate is high (M is about 0.020-0.025 per week) (Dredge 1985b) and few animals appear to survive more than 3 years (Heald and Caputi 1981). An elementary yield per recruit model indicated that meat yield would be maximised with a size at first capture of approximately 85-90 mm (Dredge 1985b).

The Fishery

The saucer scallop fishery is a component of Queensland's multi-species east coast trawl fishery. Vessels which are licensed to participate in the fishery with few exceptions have access to all species and components of the fishery.

Scallops were initially fished in Hervey Bay during the 1950s. They were recognised as a major resource in the late 1960s, when export of scallop meat to the U.S.A. and Europe began. Annual landings varied considerably in the 1970s (Table 1). As much of the ground now known to support scallop beds was not fished at the time (Dredge 1988), there is some basis for believing that variations in landings may have been a consequence of fishermen directing effort towards alternate target species (penaeid prawns) in the fishery, rather than non-availability of scallops.

Owners of trawlers fishing for scallops in the late 1970s made super-normal profits. Investors, recognising that these profits were available, directed additional effort towards the stock, in some instances by building and operating purpose-designed scallop trawlers. Until 1988, the fishery was characterised by 24 hour/day fishing operations. While economically efficient, the practice allowed fishermen to operate at low catch rates and facilitated high effort levels. Effort directed at the scallop fishery increased from about 11,000-25,000 boat hours in the late 1970s to approximately 200,000 boat hours in 1990 (Table 1). Catch rates declined from 1978 onwards with scallops being harvested from beds with a density as low as 1 per 150 m^2 by 1984 (Dredge 1988). Total catch declined between 1982 and 1987. The need for management intervention in the fishery was predicted in 1984.

Management of the Scallop Fishery

The declining catch rates observed in the early 1980s were indicative that the scallop stock was being exploited heavily and needed controls on exploitation. There were two independent concerns viz. the need to obtain maximum value from the stock (yield per recruit maximisation) and the need to maintain or increase brood stock levels.

Management in the fishery was addressed through an extended consultative process with industry. Numerous public and committee meetings were required before the majority of fishermen and processors a) accepted that the fishery faced real problems which needed a specific management package and b) reached any degree of consensus on management measures used in the fishery. Consequently, in the period between 1984 and 1990, management measures evolved and changed considerably.

Management practices initially focused on size limits (Table 2) despite the practical difficulties associated with tolerance requirements needed by fishermen catching several thousand animals per day and sorting/grading them mechanically. Initially, size limits were set at a size well below that which scallops were normally rejected by fishermen. They were gradually increased (80 mm to 85 mm to 90 mm) as effort directed at the stock increased and fears about future recruitment failure became more prevalent. Increased size limits were also viewed as a means of increasing value from the resource by taking larger (and relatively more valuable) meats. Size limits were further manipulated in 1989 by the introduction of a variable size limit of 90 mm from November 1 to April 1, and 95 mm for the remainder of the year. This measure was introduced: as a means of reducing effort directed at the stock during the spawning season, thereby increasing broodstock levels; and increasing the proportion of larger, more valuable meat coming on to the market. Fishermen appear to have had some difficulty in coping with the increased size during winter, as their sorting equipment was geared solely for handling a 90 mm size limit.

The problems of tolerance have been addressed by allowing fishermen a prescribed tolerance of undersized scallops in their load. Current guidelines in use call for forfeiture of a load if the proportion of scallops in the catch is greater than 3%, and prosecution if this proportion is greater than 5%. Despite legal problems associated with sampling errors, size limits have generally been accepted and adhered to.

In 1989 effort directed at the scallop stock was effectively reduced by at least 40% through the prohibition of trawling in daylight hours. There was initial resistance to this management measure, but its effectiveness has been generally accepted in the fishery. A more controversial management measure introduced in 1989 called for the prevention of trawling in three 10-minute by 10-minute areas which were to act as broodstock reserves. Two of the three closed areas held substantial populations of undersized scallops at the time of their closure. Spatial modelling indicated that such closures could increase subsequent spatfall significantly. Policing these areas proved to be a practicable impossibility, and the closures were repealed after a 15-month trial.

Evaluation of Management Measures

Evaluation of the management measures, both as a means of maximising yield and of increasing spatfall, has practical difficulties. Management measures were introduced without serious consideration for their consequent evaluation. The range and short duration of these management measurements has meant that *a posteri* evaluation was difficult. Limited data from processors (Table 3) suggest that management measures taken after 1988 were responsible for an appreciable decline in the proportion of small meats but there is no way of evaluating the effectiveness of management measures in increasing spatfall other than to observe that total landings from the fishery have increased appreciably between 1988 and 1990, albeit from increased effort directed at the stock.

Modelling Management Measures

Management measures can be evaluated through the use of modelling techniques. Such a model is being developed for saucer scallops.

The initial framework of the model consisted of a series of two dimensional matrices. In the initial matrix, one axis was used to specify a series of recruitment cohorts and the other, time. Recruits were "fed into" the first cohort at time step 1, and subsequent cohorts were fed at times 2-n in such a way as to simulate a recruitment process. In the initial stage of development sixteen cohorts were fed into the model over a sixteen week period, in two identical, normally distributed pulses. This sequence simulates current understanding of spawning and spatfall in *A. j. balloti* (Dredge 1981; 1985a). As time in the model progressed, numbers of survivors from cohorts 1-n were diminished through the application of mortality, i.e. $N_{t+1} = N_t . e^{-z}$.

A second matrix was developed to give size of scallops in each cell of the model. A deterministic growth model, using von Bertalanffy parameters given in Williams and Dredge (1981), was used for growth parameterisation. A third matrix was used to convert size of scallops to adductor meat weight, using monthly meat weight-shell height algorithms given in Williams and Dredge (1981). A fourth matrix was used to give value to each cohort, by multiplying numbers of survivors by average meat weight at age by unit value of meat weight, as determined from the differential price structure applied to meat weights of varying size.

Fishing pressure was applied to the model by increasing mortality from a rate based solely on a natural mortality rate ($M= 0.020$ week $^{-1}$) to a rate which allows for anything from light ($F= 0.005$ week $^{-1}$) to heavy ($F= 0.020$ week $^{-1}$) exploitation, after scallops had reached a given size. The catch, in both weight and dollar terms, was then cumulatively added as the model progressed through time.

A limited range of management scenarios have been trialed. The model has been manipulated to allow exploitation only after scallops attain a given size (90 mm), or to have a variable size limit (90 mm in summer months, 95 mm in winter), or to have a seasonal (winter) closure of the scallop fishery. These options have been used or considered as management measures in the scallop fishery.

Initial simulations suggested that there was little loss to the fishery, in dollar terms, when a variable size limit (90 mm in summer, 95 mm in winter) was compared with a constant 90 mm size limit (Table 4). On the other hand, closure of the fishery during winter induced appreciable losses (Table 4), presumably allowing a greater survival of spawners. Varying recruitment patterns between unimodal, even bimodal and asymmetric pulses induced less than 10% variation in the value of landings.

There is considerable scope for further development of the model. At this stage, it is deterministic. Introducing variability in growth parameter and mortality estimates will offer a little more scope for reviewing expected variability in value of landings as a consequence of variation in these parameters. Managers must also be made aware of potential changes in spawner survivorship as a consequence of varying size limits or other management strategies. Further variation of recruitment processes has scope for more detailed examination.

One of the most valuable features of this type of model is its ability to highlight information deficiencies. For example, when this model was developed, the lack of understanding as to when young-of-the-year scallops were spawned became glaringly apparent. Variability in growth parameters, although acknowledged, is little understood at this time, and requires further study. Relative value of scallop meats, a key determinant for model output, has changed considerably in the past three years and needs constant updating if the model is to have meaning.

Despite these deficiencies, a model of this nature can have real value to managers as a preliminary evaluation tool. In this instance, the model indicates that the current management regime appears to be a worthwhile compromise between maximising income from the resource, maintaining broodstock levels and maintaining continuity of fishing operations.

Acknowledgements

Much of this paper is based on unpublished data supplied by Phil Pond, Neil Trainor and Joe Ksiazek. My indebtedness to these gentlemen is acknowledged, as it is to Tony Courtney, David Die and John Glaister, all of whom read the manuscript and made constructive comments.

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Table 1. Estimates for annual catch, average catch rates and effort directed at the Queensland scallop fishery

Year	Annual catch (tonnes of adductor meat)	Standard catch rate (kg/boat hour trawled)	Annual effort (boat hours) directed at stock
1976	70	21.2	3000
1977	380	36.0	11000
1978	950	38.4	25000
1979	250	18.6	14000
1980	530	12.2	43000
1981	660	11.9	53000
1982	1220	13.7	86000
1983	880	23.8	38000
1984	900	10.8	81000
1985	660	6.0	107000
1986	700	6.6	116000
1987	450	5.6	77000
1988	720	7.8	92000
1989	640	6.8	95000
1990	1350	6.2	202000

Table 2. Summary of management procedures in the scallop fishery

Source: P. Pond, pers. comm.

Date	Shell size	Gear size	Maximum mesh size	Trawl closures	Designated shucking areas	Preservation zones
11/84	80 mm	Combined headrope and footrope no more than 109 m	82 mm			
7/84	85 mm		75 mm			
10/87	90 mm			Daylight trawl ban 1/10-31/1 each year		
12/87				Daylight trawl ban lifted		
11/88					Three areas - Urangan, Gladstone & Rosslyn Bay	
2/89				Daylight trawl ban		Three 10-minute by 10-minute areas closed to fishing
3/89	95 mm April 1989 - October 1989, ... 90 mm November 1990 - March 1991					
5/90	95 mm May 1990 - October 1990 .... 90 mm November 1990 - April 1991					Closures deleted

Table 3. Changes in the proportion (%) of meat grades landed each month between 1988 and 1990
Source: J. Ksiazek, pers. comm.

	1988 Meat grade (count/kg)			1989 Meat grade (count/kg)			1990 Meat grade (count/kg)		
Month	<88	88-132	>132	<88	88-132	>132	<88	88-132	>132
Jan	79	17	4	86	12	2	75	18	7
Feb	75	20	5	80	17	3	82	15	3
Mar	57	36	7	75	22	3	85	12	3
Apr	41	47	12	82	26	2	70	28	2
May	19	66	15	65	34	1	72	25	3
Jun	24	63	13	67	30	3	89	9	2
Jul	42	55	3	58	40	2	67	28	5
Aug	16	81	3	56	41	3	52	47	1
Sep	24	71	5	75	22	3	63	30	7
Oct	44	53	3	75	22	3	78	17	5
Nov	55	44	11	77	20	3	80	17	3
Dec	57	39	4	83	14	3	89	9	2

Table 4. Standardised yield ($ value) from fixed recruit numbers under varying recruitment patterns, size limits, management regimes, and exploitation levels, and % ( ) loss as a consequence of management regimes
Exploitation levels: low, F=0.05; medium, F=0.10; high, F=0.20

Recruitment process	Exploitation level	Management regime		
		90-summer 90-winter	90-summer 95-winter	90-summer no winter fishery
1 pulse of recruits - in weeks 1-8	low	545	545(0)	402(26.2)
	medium	792	792(0)	613(22.6)
	high	922	922(0)	778(18.5)
2 recruit pulses - pulse 1 (weeks 1-8) double pulse 2 (weeks 9-16)	low	697	676(3.0)	506(27.4)
	medium	822	802(2.4)	627(23.6)
	high	980	967(1.3)	821(16.3)
2 recruit pulses - pulse 1 (weeks 1-8) equal to pulse 2 (weeks 9-16)	low	692	686(0.8)	504(27.1)
	medium	812	807(0.6)	623(23.3)
	high	961	959(0.2)	807(16.3)
2 recruit pulses - pulse 1 (weeks 1-8) half to pulse 2 (weeks 9-16)	low	549	544(0.9)	403(26.7)
	medium	802	795(0.9)	618(22.9)
	high	942	937(0.5)	793(15.8)
1 pulse of recruits - in weeks 9-16	low	562	539(4.1)	405(27.9)
	medium	832	805(3.2)	632(24.0)
	high	1000	982(1.8)	836(16.4)

Is there a Case for a Maximum Legal Length on the Eastern Rock Lobster, *Jasus verreauxi* ?

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Rock lobsters have been exploited commercially in waters off New South Wales since 1873. Catches are composed almost entirely of the eastern rock lobster, *Jasus verreauxi*. The only restrictions in this fishery are a minimum legal length of 104 mm carapace length (C.L), introduced in 1902, and a freeze on the total number of fishing vessels licensed to fish off New South Wales.

In 1986 NSW Agriculture and Fisheries received funds from the Fishing Industry Research and Development Council for a two year preliminary study of the rock lobster fishery off New South Wales. The results showed that catch rates in the fishery had fallen over the period for which information on the level of catch and fishing effort were available (1969-70 to 1987-88). The shortest length at which 50% of female eastern rock lobsters carried eggs is 167 mm C.L., far longer than the present minimum legal length. Further, approximately 64% of the average total landings of rock lobsters in New South Wales came from areas where *all* eastern rock lobsters sampled were immature.

The rock lobster resource should be conserved at its present density until the information necessary for assessing conditions of optimum yield are available. Considering that a large proportion of this fishery catches only immature rock lobsters, and that markets prefer rock lobsters far shorter than the size at onset of breeding, one management strategy may be to set a maximum, as well as a minimum, legal length. The maximum length would help to protect the breeding stock, while permitting a limited amount of fishing pressure on immature lobsters. Meanwhile, research needs to be continued to collect the data necessary for modelling the consequences of various management options, including the important relationship between stock and recruitment.

Yield and Egg-per-recruit Models of Shark Bay Snapper: a Case Study in Justification and Implementation of an Increase in Minimum Legal Length

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Abstract

Yield-per-recruit models indicated that, over a wide range of values of fishing mortality and for assumed natural mortality rates of 0.2 and 0.3, yield-per-recruit of snapper would either be increased or not affected by increases in minimum legal length from 38 to 41, 45 or 50 cm. Egg-per-recruit models indicated that the reproductive potential of the population was substantially improved by increases in minimum length, especially when fishing mortality was high. Based on these results, an increase in minimum legal length from 38 to 45 cm was recommended. Consultation with recreational and commercial fishermen revealed that while most supported the change, it would adversely affect a developing export market for snapper. A compromise decision was made to increase the minimum length to 41 cm.

Introduction

The Shark Bay snapper fishery

Pink snapper, *Chrysophrys auratus* Bloch & Schneider, is the major exploited species of finfish in the Shark Bay region of Western Australia. A commercial fishery operates mainly on stocks around the mouths of the Bay and in the adjacent ocean waters. By means of traps, handlines and droplines, the fishery has taken annual catches of 400 to 1300 tonnes during the 1980s. There is also a recreational fishery, important to local tourism, which operates chiefly in the inner gulfs of Shark Bay, taking approximately 50 tonnes per year. The commercial fishery in particular concentrates on dense aggregations which form close to the mouths of the Bay in winter, when the snapper in this region are spawning.

Need to protect the breeding potential of the stock

The catch and fishing effort of the commercial fishery increased dramatically between 1983 (586 tonnes) and 1985 (1302 tonnes). There was a concurrent spatial shift in fishing effort away from the traditional main grounds to areas more distant from port and anchorages. The mean length to caudal fork of the snapper also fell from 48 cm to 45 cm over the two years, and fishermen complained that fish were hard to find on the old grounds.

An industry-government snapper working group was convened in 1985 to discuss problems in the snapper fishery. It concluded that the catch was probably too great to be sustainable. The working group recommended the introduction of limited-entry management and a total closure during July as means of reducing pressure on the stock. The target of the management plan was to keep annual catches below 500 tonnes.

Despite these attempts to reduce fishing effort, the catch in 1986 was 560 tonnes. The industry had increased its efficiency in several ways: employing more crew per vessel; landing whole fish so that no fishing time was taken up in processing; using shore staff to unload the boats to reduce turnaround time in port; using pre-baited hooks, more hooks per line and more efficient traps. Also, historically there had always been a high annual turnover of vessels, so that each year there was a proportion of inexperienced snapper fishers whose catch-rates lowered the average. With limited-entry management, these vessels were excluded, contributing further to the increased efficiency of the fleet. To try to counteract these trends, the July closure was extended in 1987 to include a week of June also but the catch still remained high at 712 tonnes.

It appeared that the industry was able to circumvent any but the most stringent controls applied to fishing effort. An increase in minimum legal size was therefore investigated as a means of safeguarding a proportion of the spawning stock to prevent serious recruitment overfishing. The minimum legal length at that time was 38 cm total length, which corresponds closely to the length at first maturity of snapper in the stock off Shark Bay.

The egg-per-recruit approach

To evaluate the effects on yield which are likely to result from a change in length at first capture, yield-per-recruit models have been used for many years (Beverton and Holt 1957). More recently, egg-per-recruit models have been used to evaluate such effects on the reproductive output of exploited fish populations (Campbell 1985). Both types of model require estimates of growth parameters and the natural mortality rate. Yield and reproductive output per recruit to the stock are then calculated for various combinations of values for length at first capture and rate of fishing mortality. An additional requirement for the egg-per-recruit models is a knowledge of the relationship between mean fecundity and the length or age of fish.

Appropriateness of minimum size in this fishery

In some fisheries, minimum size is not appropriate as a tool for managing the stock. This can be because the fishers have little control over the size of fish they catch and because undersize fish returned to the water have little chance of survival, e.g. a deep-water fishery where all sizes of fish are caught together. In the commercial snapper fishery off Shark Bay, different aggregation grounds consistently have different sizes of snapper so that fishers can avoid locations which have smaller fish (Figure 1). In the recreational snapper fishery, fishing is usually in shallow water where fish are likely to survive if returned quickly to the water. In this region, therefore, and with these fishing techniques, minimum size is an appropriate tool for managing the snapper stock.

Methods

Growth curve: mean weight at age

Snapper sampled from the commercial fishery or as part of research fishing operations were used to generate tables of means and standard deviations of length and weight at age.

All research data use length to caudal fork, but regulations of minimum legal lengths use total length. The relationship between the two measurements is:

Total length =

$0.1 + 1.18 \times$ length to caudal fork (cm).

Ages were estimated from rings on scales which had been validated using the annual cycle in width of the marginal increment between the outermost ring and the edge of the scale. A von Bertalanffy growth curve was fitted, using nonlinear regression, to the lengths at age of a large sample of snapper aged 4-11, taken in the peak season commercial fishery.

Fecundity index at age

Counts of eggs retained by a 100-μm sieve were made on sub-samples of ovary suspension following digestion of the ovarian tissue in Gilson's fluid. This is similar to the technique used by Crossland(1977) to estimate fecundity of this species in New Zealand. These counts were adjusted to give the total number of such eggs per fish. Samples of snapper were taken throughout the spawning period and the reduction in numbers of eggs as the season progressed indicated that the number of eggs per female at the beginning of June is a reasonable index of fecundity. The fecundity index was linearly related to fish weight and from this, the mean fecundity index at each age was calculated.

Yield-per-recruit and egg-per-recruit model

A population model was constructed which took account of the variation in length at age. The standard deviation of length did not show any trend with age, so a constant mean standard deviation was applied to all age groups.

The mean length at each age used in the model was that predicted from the von Bertalanffy growth curve. Using these figures, the proportion of each age-class that exceeded the minimum legal length was calculated. All fish smaller than this length were assumed to be affected only by natural mortality, while all fish larger than the length were assumed to be fully vulnerable to fishing as well as natural mortality. The number of fish taken by the fishery and the number of fish surviving in each age-class were calculated. Mean weight and fecundity at each age were used to convert these to total yield and population fecundity index for each combination of natural mortality, fishing mortality and minimum length.

Two values of the exponential rate of natural mortality, M, were used, 0.2 and 0.3. The higher value was that predicted from the regression on growth parameters and sea temperature (Pauly 1980). Other workers on *Chrysophrys auratus* have estimated lower values for M; also a lower value gives results that are more conservative for fisheries management.

A range of values of the exponential rate of fishing mortality, F, was used, from 0 to 1.8. The upper value would normally be considered to be extreme for a fish like snapper. Minimum legal lengths of 38, 41, 45 and 50 cm total length were considered. These were converted to lengths to caudal fork before being used in the model.

Results

Length at age

The equation derived to fit the length at age of the 4-11 year old snapper taken in the main winter season was:

$$\text{Mean length at age t years} = 83 \times [1-e^{-0.105 \times (t+1.1)}] \text{ cm}$$

and the average standard deviation around this mean was 2.9 cm (Figure 2).

Yield-per-recruit

The values of yield per recruit generated by the model are shown across the range of fishing mortality in Figure 3. For each assumed value of natural mortality, M, the effects of minimum length on yield can be compared. For M=0.2, there is little effect of minimum length while fishing mortality is low; at higher levels of fishing mortality, yield-per-recruit becomes greater as minimum length increases. For M=0.3, the yield-per-recruit is not very sensitive to changes in minimum length at any level of fishing mortality.

Eggs-per-recruit

For both the models with M=0.2 and M=0.3, the effect of increasing minimum length is to increase the eggs produced per recruit (Figure 4). As expected, this effect is most pronounced at the higher levels of fishing mortality. This is because when the survivorship of the fish larger than the minimum length becomes very low, the reproductive output of the population becomes a function of the number of mature fish smaller than the minimum length.

Discussion

Recommendation of a new minimum length

The yield-per-recruit model indicated that, if natural mortality M was really in the vicinity of 0.2 or 0.3, the effects on yield of increasing the minimum legal length from 38 cm to any of the higher values considered would be either negligible or beneficial. The egg-per-recruit model, however, indicated that the effect of increasing the minimum length would always benefit the reproductive potential of the population, particularly at high levels of fishing mortality. The minimum length of 38 cm total length corresponds closely to the size at which snapper reach sexual maturity. Under very heavy fishing, therefore, the population of mature fish could be almost eliminated. If the minimum length were 45 cm, however, mature fish would have a year of immunity from fishing in which to breed before becoming vulnerable to capture. A 50 cm minimum length would have an even greater effect but would result in many fish being returned to deep water with little chance of survival.

In 1987, the possibility of fishing mortality reaching very high levels appeared very real. Because the main fishery is on schooling fish, viable catch rates could be maintained until the stock reached a very low abundance. The fleet would continue to take a similar catch out of a population that became smaller every year, generating higher levels of fishing mortality. Attempts to constrain fishing mortality by limiting fishing effort seemed to be failing. The issue of maintaining an adequate breeding stock became urgent and the W.A. Fisheries Department canvassed a proposal to increase the minimum total length to 45 cm.

Consultation with the fishing community

Recreational fishing representatives and professional fishing associations from all ports with an interest in snapper were asked for their response to the proposal. All the groups understood the reason for the proposed increase in minimum length and all supported it except for two professional fishing associations. One of these groups represented fishers who targetted the small snapper around the Abrolhos Islands and claimed that their income would be very adversely affected. The other group was pioneering the export of high-quality chilled snapper from Western Australia to Japan, and argued that the Japanese market did not want large snapper.

The compromise decision and its effectiveness

The potential benefits of a viable Japanese market to the snapper fishing industry were considered important. Consequently the minimum total length of snapper was increased from 38 to 41 cm instead of to 45 cm. Attempts to control fishing effort were renewed, resulting eventually in a quota system which has stabilised the commercial catch at around 500 tonnes annually. The recreational fishing effort is increasing and presumably will continue to do so.

The export market for snapper, which was an important factor in the decision not to fully implement the recommendation to increase the minimum length from 38 to 45 cm, has also made possible the control on catches and thence fishing mortality. This is because higher prices were paid to the fishermen for snapper following the beginning of exporting. Fishermen took much greater care of the product and this resulted in higher prices on the Australian market also. The fishermen were prepared to accept a reduction in catches because the unit price was higher.

While the management of the commercial fishery off Shark Bay is now in a satisfactory state, stocks of snapper in more southern ocean waters and in the inner gulfs of Shark Bay have received little protection from the small change in minimum length. Exploitation of those stocks is not constrained by quotas or any other measure. Also, while there have not been such detailed studies of the growth of snapper other than the ocean stock off Shark Bay, it is almost certainly true that both the inner Shark Bay snapper and the more southern oceanic snapper grow to much larger sizes than the stock off Shark Bay. This makes it probable that a minimum size which would protect the reproductive capacity of all Western Australian snapper stocks would be greater than 45 cm.

This case study illustrates that calculation of an appropriate minimum length based solely on the biology of a fish stock may not be sufficient to cause introduction of that minimum length in the regulations. Other important factors to be considered are:

- mortality of undersize fish returned to the water, which was thought not to be a problem with these snapper;
- effects of changes in minimum length on the viability of the commercial fishery;
- other management measures which may be more appropriate to conserve the stock; and
- variation in biological parameters among populations may mean that a single minimum length may not be appropriate for all parts of the region administered by the fisheries management agency.

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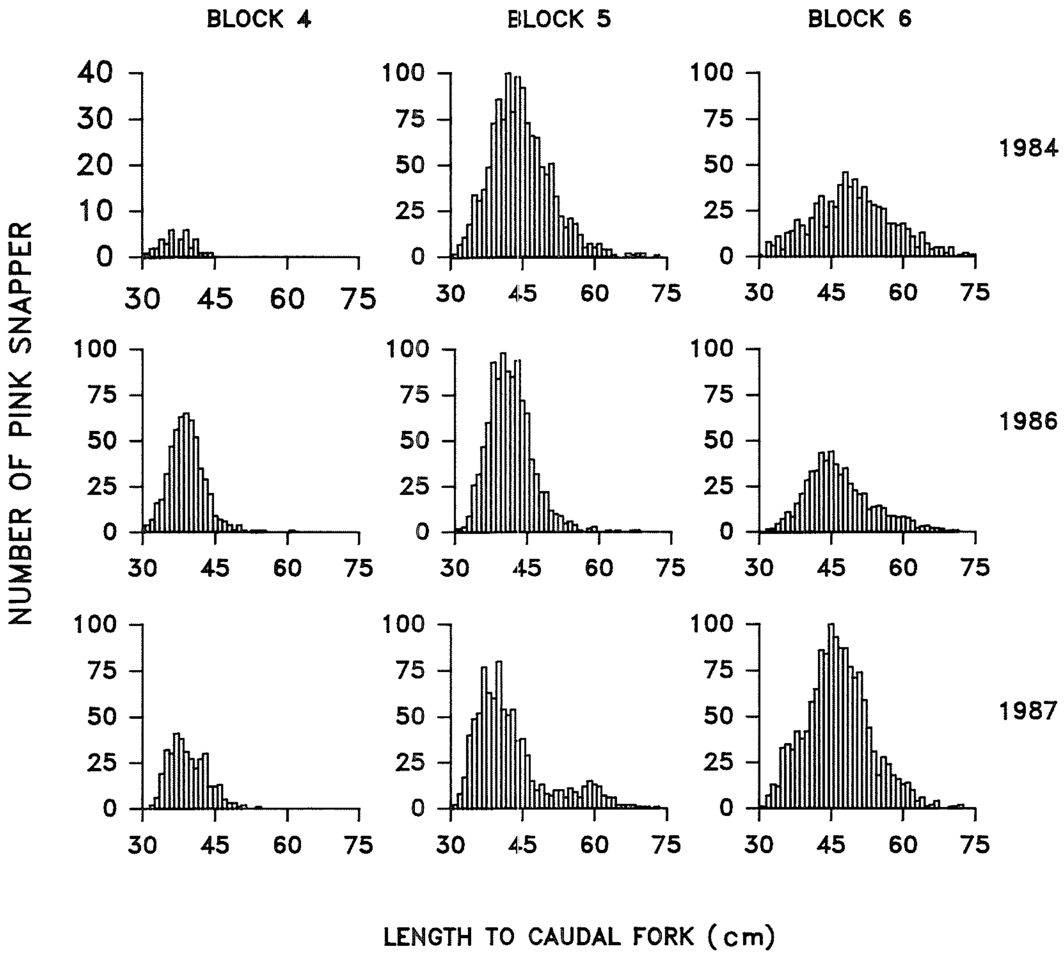

Figure 1. Length-frequency distributions from three 10 minute square blocks on the main fishing grounds outside Shark Bay, in 1984, 1986 and 1987.

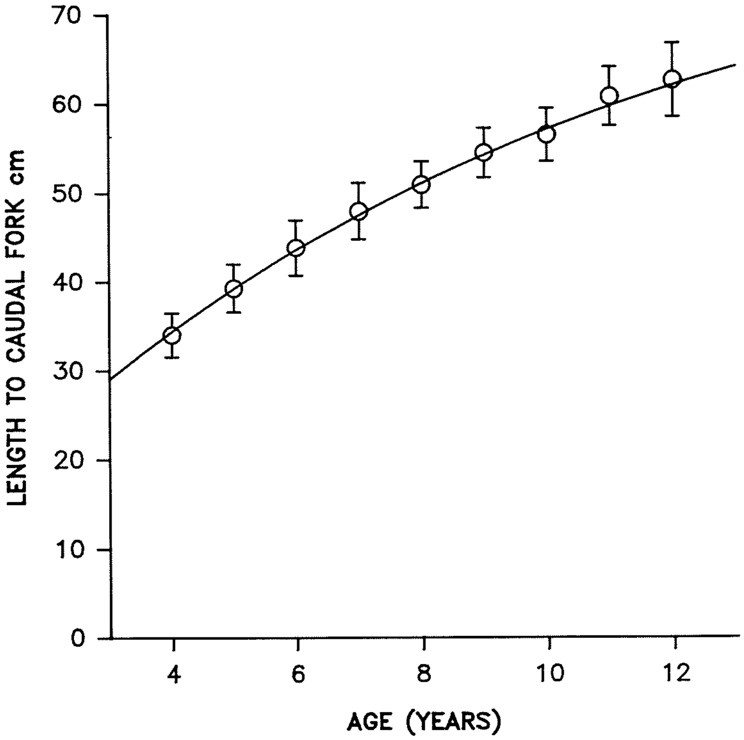

Figure 2. Mean length at age for pink snapper in the peak commercial fishery off Shark Bay; with standard deviations and the fitted von Bertalanffy growth curve. Ages were estimated by scale-reading.

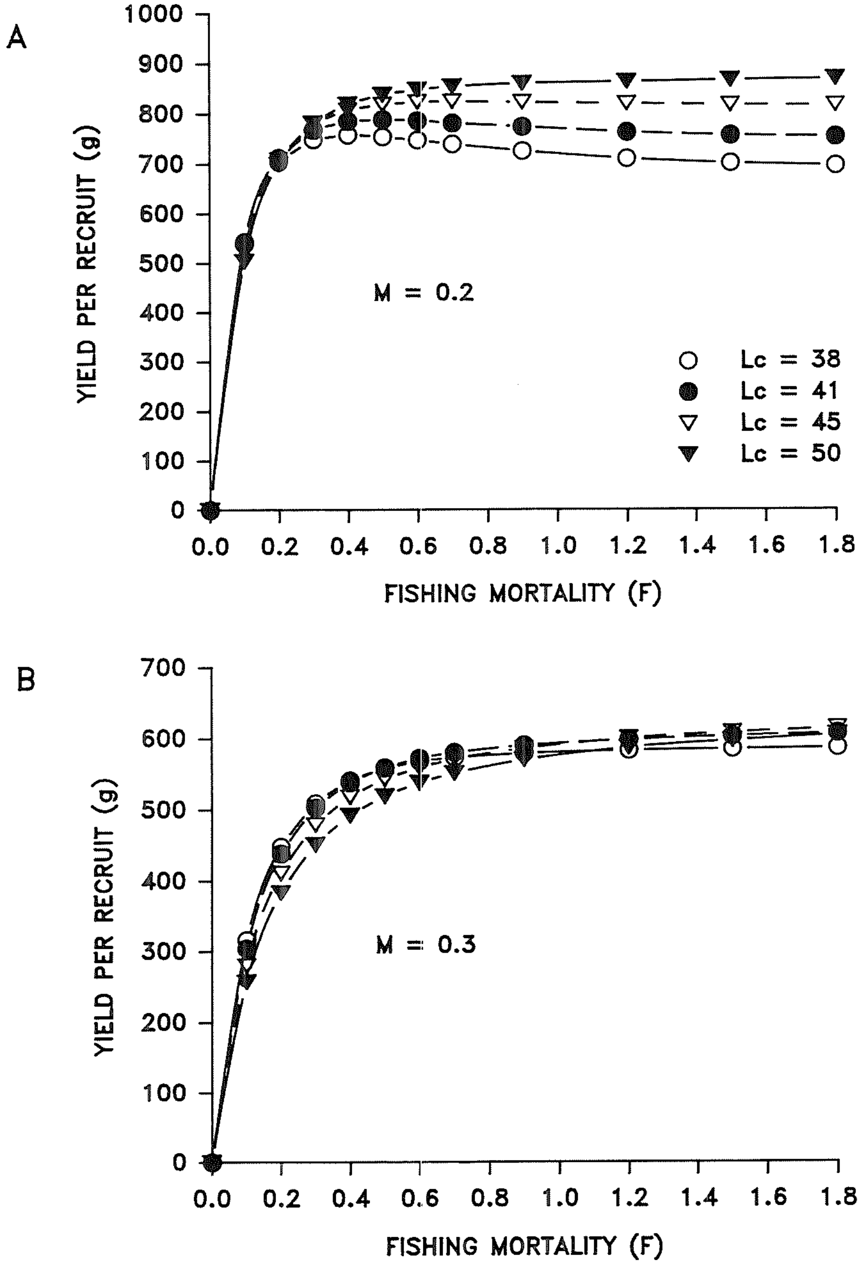

Figure 3. The effect of length at first capture L_c, as cm total length, on yield-per-recruit of snapper at various levels of fishing mortality: A, assuming natural mortality, M, = 0.2; B, assuming M = 0.3.

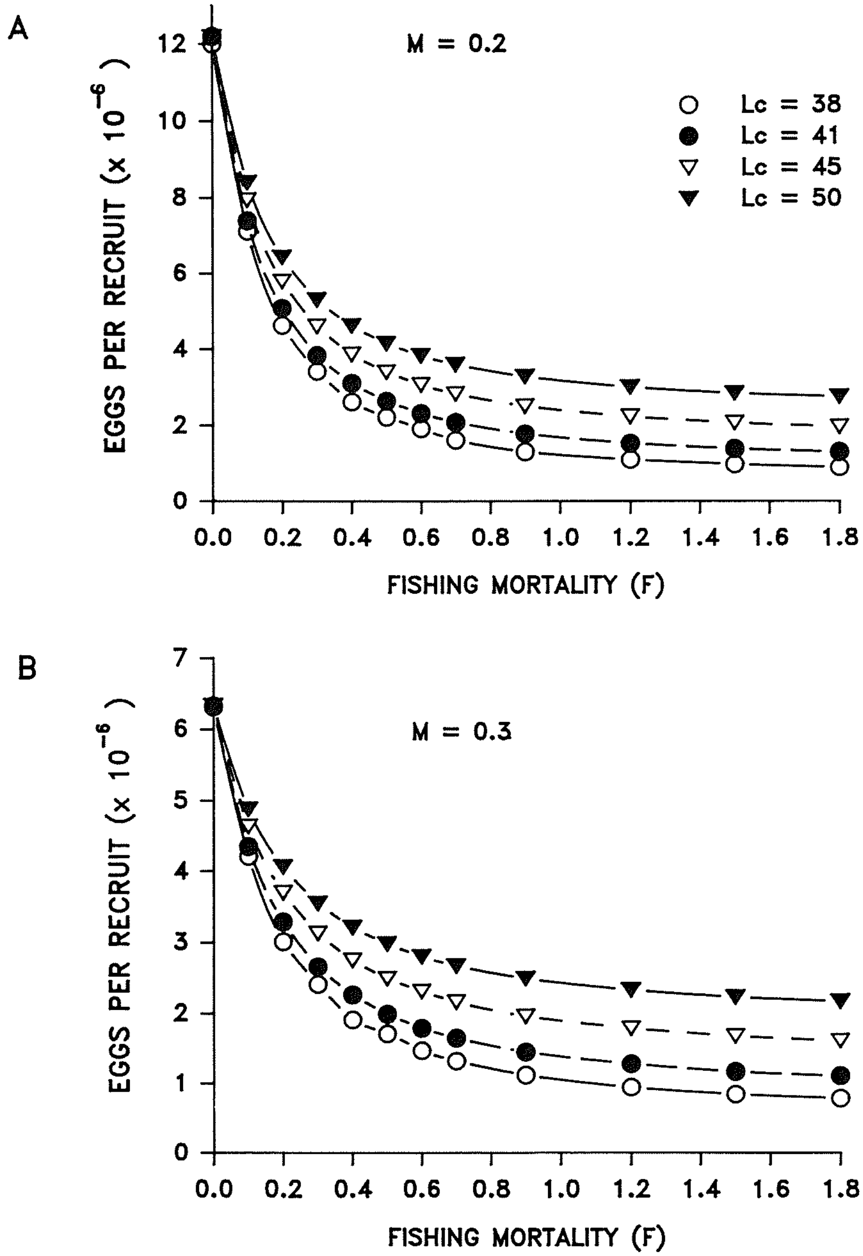

Figure 4. The effect of length at first capture, as cm total length, on eggs-per-recruit of snapper over a range of values of fishing mortality. Assuming natural mortality, M, = 0.2; B, M = 0.3.

Utility-per-recruit Modelling: an Alternative for Evaluating Minimum Size Regulations

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Abstract

Utility-per-recruit models are a generalisation of the traditional yield-per-recruit models. They allow for the incorporation of additional measures of value to the fishery other than weight of the catch. For certain fisheries, conclusions from yield-per-recruit analysis are markedly different from those of utility-per-recruit modelling. This paper identifies the type of fisheries most likely to benefit from the utility-per-recruit modelling approach to the evaluation of minimum legal size regulations.

Introduction: the Concept of Utility

The theory of utility is well established in operations research and economics. Quoting Fishburn's (1968) words,

"... on the practical level, utility theory is concerned with people's choices and decisions. It is concerned with people's preferences and with judgments of preferability, worth, value, goodness or any of a number of similar concepts."

The concept of utility is specially useful in dealing with problems where the outcome of a model may be judged differently by different groups of people. There, utility theory can be used as a framework for incorporating different opinions about the desirability of a prediction into a mathematical model for use in any decision-making process. In this context the concept of utility has been slowly incorporated into the fisheries literature (Keeney 1977; Healey 1985; Die *et al.* 1988).

Utility-per-recruit Models

In traditional fishery science the criterion used to evaluate regulations, including minimum legal size, has been catch weight. However, fishery managers have always made decisions on the basis of many other value measures related to economic returns, or even political or social acceptance (Waugh 1984; Peyton 1987). Beverton and Holt (1957) recognised the need to incorporate economic measures of value to fisheries models designed to provide advice to managers. The utility-per-recruit model (Die *et al.* 1988) is simply a recognition of the need for a general formulation that would encompass all 'per-recruit' fishery models.

The Beverton and Holt (1957) yield-per-recruit model which relates the steady-state yield in weight-per-recruit Y/R to abundance at age A_t, fishing and natural mortality F and M, age at recruitment t_r, first t_c and last t_u vulnerable age, and weight at age W_t,

$$U/R = e^{-M(t_c - t_r)} \int_{t_c}^{t_u} F\, U_t\, A_t\, dt$$

can be generalised by replacing weight at age with utility at age, U_t therefore obtaining the steady-state utility-per-recruit (Die *et al.* 1988).

$$Y/R = e^{-M(t_c - t_r)} \int_{t_c}^{t_u} F\, W_t\, A_t\, dt$$

The utility-at-age function U_t can be any function that would express the value of an individual fish of age t. This utility can be any number of things such as the total weight, the weight of the fillets, the price of the fish, the amount of money a recreational fisherman may be prepared to spend for the experience of catching the fish, or any other arbitrary measure that may describe the attitude of fishermen towards a certain size (hence age) of fish. It can also express more biological considerations such as reproductive potential measured by fecundity, or the number of times the animal has spawned.

Each fishery may have a different utility function. However, several simple functions (Die *et al.* 1988) can be used to model many of the most common per-recruit models (Table 1). Some of the resulting utility-per-recruit models have an analytical solution, and those that do not, can always be solved by numerical integration.

Providing advice to management about minimum legal sizes with the utility-per-recruit model rather than the yield-per-recruit model acknowledges the fact that these regulations are set for many different reasons. The utility-per-recruit model can be used to explore the implication of the establishment of minimum legal size on biological, economic and sociological variables of interest to the fishery manager. In fact evaluating minimum legal sizes with yield-per-recruit and utility-per-recruit models produces very different results. Die *et al.* (1988) showed that for a freshwater recreational line-fishery attitude-per-recruit would increase with an increase in minimum legal size, whereas yield-per-recruit would decrease. Unfortunately modelling attitudes and preferences of recreational fishermen is not a simple task, and may have to incorporate a multidimensional perspective (Harris and Bergensen 1985), rather than the simple unidimensional approach used by Die *et al.* (1988). Most authors have also reported that anglers' attitudes towards regulations are highly variable (Harris and Bergersen 1985; Renyard and Hilborn 1986). Therefore it may not be possible to find a commonly acceptable management strategy for all anglers.

Multiple Utilities

The fact that the theory of utility is geared towards decision making makes the utility-per-recruit approach to fishery problems very valuable, especially where the fishery manager has to consider multiple utility measures. Such examination of multidimensional utilities is routine in the context of utility theory, for both additive and non-additive utilities (Fishburn 1968).

An example of additive utilities in the fishery context was presented by Healey (1985) in his analysis of short-term and long-term revenue of a commercial fishery for Atlantic herring. Another example of additive utilities would be revenues obtained by two fishery user groups. The amount of conflict between the groups would be reflected in the way their two utilities could be added to get a single measure of utility for the whole fishery.

Cases where utilities are not additive are referred to as lexicographic utilities (Fishburn 1968). Combining egg-per-recruit with revenue-per-recruit results would be a good fishery example of multidimensional lexicographic utility analysis.

An important aspect of any utility-based modelling should be the recognition of time preferences. For many of the biological utilities, such as reproductive potential, preferences may not change with time. However most economic measures of value should consider the effect of time, and this was stressed by Healey's (1985) analysis. He showed that the choice of a short-term or long-term view on fishery returns may affect the preferences of commercial fishermen towards a certain type of regulation. Healey (1985) also showed that fishermen's perceptions about recruitment variability may be influencing the time scale of their revenue outlook. A fishery with high recruitment variability may lead to a short term revenue outlook, therefore making it harder to convince fishermen about sustainability-oriented regulations. However, as Brown *et al.* (1987) argue, the concept of sustainability is not limited to biological conservation, and should have a social component that could incorporate fishermen's economic survival.

Attitudes may also change with time because they tend to depend on the levels of use of the resource or on the presence of other alternative resources - as availability and levels of use of these resources change through time, attitudes may also change.

In summary, utility-per-recruit analysis offers an alternative to yield-per-recruit analysis which is well supported by the decision-making theory of utility. It should prove useful as a general model applicable to problems where several measures of value (e.g. biological, economical, sociological) have to be considered in the analysis. However like all per-recruit approaches, it is a steady state theory very sensitive to the time independence assumption.

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Table 1. Utility functions

Utility function Model	Type	Per-recruit model	Analytical solution
$a L_\infty^b \left[1 - e^{-k(t-t_0)} \right]^b$	Power of size	Total weight, fecundity	No
$\sum \beta_i t^i$	Polynomial of age	Value	Yes
$\sum \beta_i$	Stepwise of age	Value, number of spawnings	Yes
$\frac{1}{1 + e^{-\rho(t-t_*)}}$	Logistic of age	Attitude	No

Discussion of Case Studies: Problems Encountered

Recorded by A.J. Fowler

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Questions were addressed to individual speakers, and followed by more general discussion.

Campbell Davies asked *John Glaister*'s opinion about a maximum size just for the recreational fishery for barramundi, and was told that there is, at least in the Gulf district in Queensland, a *de facto* maximum limit anyway. There are prohibitions on using meshes above a certain size, so that large animals will break through commercial fishermen's nets. If the reports that the viability of eggs of Norwegian cod improves with size and age are relevant to barramundi, it would be an advantage to have a maximum legal size. Tim Wood commented that recreational anglers fish areas from which the mature animals have generally moved, such as billabongs, so that they are not accessing the commercial fishery. John Glaister responded that a proposal to allow suitable mesh sizes to fish large females off the coast was not approved.

Ross Winstanley told *Peter Young* that he wished the idea of setting aside an area as a resident pool of scallops, from which recruitment through spawning can occur, could have been effectively tested. Victoria had attempted to do the same thing but persistent fishing of the closed area by a minority of fishermen caused the project to be abandoned. Peter Young agreed that enforcement was an underlying problem. John Glaister advised that Mike Dredge had found that the lip of a scallop shell becomes damaged by trawling, leaving a thin black growth check. From sampling the closed areas he found that most of the scallops had been trawled about twice, sometimes more frequently, and that the closed areas were estimated to have 2.5 times the fishing pressure of open areas. David Molloy asked about the two size limits for scallops at different times of the year, and was told by John Glaister that the purpose was to deter capture before spawning. David Molloy further asked Peter Young if such an approach would be valid for Bass Strait, but was advised that a major problem would be the great variability in growth rates between areas.

Rob Day questioned *Steve Montgomery* on whether size-at-maturity of rock lobsters varies between northern and southern populations, but was told that Crowdy Head was the only sampling site where mature animals were found. Iain Suthers wondered whether the spawning stock is confined to Crowdy Head and supplies recruits to more southern regions, this being the reason why berried females are not found off Sydney. Steve Montgomery agreed that this could be one hypothesis which fitted in with New Zealand findings of extensive migrations. However, an alternative explanation would be that the spawning stock has been reduced in southern areas to numbers too low to be picked up by sampling. Don Hancock referred to the WA experience of fishermen wanting to conserve breeding stocks using a maximum size. There is already a prohibition on the taking of berried females, but should this be extended to "tar-spotted" females which have been successfully mated? Should there be a maximum size to stop the taking of the larger females which produce most eggs, or even the largest males which are needed to fertilise them? The fact is that, each time, a proportion of the catch would be relinquished, but without knowing its effectiveness. Perhaps the only convincing way to assess the value of each measure would be to make long-term simulations of the type described by Philip Sluczanowski (this meeting).

When *Mike Moran* had finished speaking about pink snapper in Western Australia, John Glaister referred to the way in which different lobby groups may want different things. For example, some commercial fishermen want to see the minimum legal size increased, but this would make most recreationally caught snapper illegal. On the other hand there are marketers who want the legal size reduced in order to send smaller snapper to Japan. Gary Hamer asked Mike Moran why, if he recommended 45 cm, the minimum size of 41 cm was introduced. Peter Millington responded that there was an additional factor, which was to enable the Shark Bay fishermen to maximise on the value per kilogram caught by exporting to the Japanese market which required a 41 cm minimum legal length. Dave Pollard enquired about different legal lengths for the south (28 cm) and north-west (41 cm) coasts. Mike Moran replied that a group of south coast fishermen argued that the stocks fished by them would never become part of a fishery for large fish, and would otherwise not be harvested. Their lobby was successful in retaining the lower minimum size of 28 cm. Murray MacDonald spoke of the dilemma in Victoria, where 70% of the fish caught by the recreational fishery in Port Phillip Bay are smaller than 40 cm TL, so there would be tremendous opposition to any suggestion of increasing the minimum size to 40 cm from 27 cm. This poses the question about what we are trying to achieve? Do we want to enhance the biological or population characteristics of the resource to ensure its survival - or is it in response to economic, social or aesthetic pressures - at the risk of either, at best, wasting a lot of time endorsing regulations which have no impact on the population structure, or, at worst, being counter-productive by compromising the longer-term maintenance of populations. This is an area which is very topical in Victoria because of a parliamentary enquiry into fisheries, in progress right now. Peter Millington responded that the objective of the new minimum legal size for pink snapper in Western Australia was a form of insurance policy, while Mike Moran added that the eggs per recruit would have been reduced to zero if the size was not increased, so this was a good alternative to changing fishery pressure and closing the fishery.

David Die's contribution on utility-per-recruit modelling was put into a general framework being undertaken by Philip Sluczanowski who concluded that the more one tries to change a minimum legal length the more pain the managers are going to face. Similarly, enforcement sections will have the same sorts of problems. To what extent can these aspects be brought into such an analysis, and who would do it? Can we offer a tool to help the people negotiating with the fishermen? Keith Sainsbury found it hard to define utilities in a real practical sense, and it is easy to get a utility-based analysis wrong. However, while it is a useful thing to develop, there should be a biological fall-back. David Die commented that social attitudes as applied to economics change greatly from year to year, and therefore an analysis may hold for only a very short time.

John Glaister at this point expressed interest in Keith Sainsbury's comment, because he had been hoping for some agreement on the objective for having a minimum legal size. If it relates to eggs-per-recruit or some other biological objective, managers and biologists will feel more comfortable with legal sizes than having them politically or community inspired. Dave Pollard stated that some emphasis has been given to community inspired legal sizes. For example, in the mid 1970s there was a minimum legal size in New South Wales for jewfish, but because these fish were being caught and discarded as by-catch from prawn trawlers, the minimum size was dropped. However, in the face of subsequent publicity the size was reintroduced. This was a multi-faceted case involving community attitudes and political expediency.

Rob Lewis urged that, while recognising that all these functional utilities are pragmatic reality, we must, as biologists, ensure that biological information is given proper recognition in decision making, and ensure that the issues are addressed and that resources are provided to ensure that estimates of eggs-per-recruit are accurate. This will determine the limits set by biological acceptability and an understanding of when things have gone too far. Keith Sainsbury commented that the ability to spawn once is one extreme of the eggs-per-recruit situation. There must be some biological bottom-line which is not buried in complicated analyses.

Chris Francis was curious about the manager's view on slowly increasing a minimum size. Would it really be possible to tell fishermen that last year's minimum legal size no longer applies, and is being replaced by another? Gary Hamer believed that industry was already convinced that something needs to be done about snapper, and is already discussing the need for a closed season each year. When the season reopens the minimum size will be higher than last year, but only a few millimetres each year, with a long-term view of reaching 150 mm. Rob Lewis agreed that industry is more likely to accept a step-wise change rather than a massive jump.

Gary Hamer further commented that managers appreciated a frank response from scientists in the event that they are unable to help, and not devaluing scientific advice with recommendations not based on knowledge. Ross Winstanley continued this line of thought with the plea that wherever a minimum size is introduced or changed, irrespective of whether it is scientifically based, proper scientific monitoring should follow to determine the effectiveness of the action. Keith Sainsbury was wholeheartedly in agreement with this - the models are not really exact and there are problems associated with them. It is therefore important for scientists to come up with something measurable on which to determine whether the change is working as predicted. He also questioned Terry Walker's earlier comment about long-lived fish - although generalisations can be useful they can also be very dangerous.

Philip Sluczanowski wanted to reopen the discussion on eggs-per-recruit, believing that sustainability is the main issue for biological advice. The traditional approach using stock/recruitment appears not to be supplying the answers - both the data requirements and their analysis are proving very difficult. In a 1984 paper on abalone, he had concluded that, with one minimum length, eggs-per-recruit would be compromised in some areas to benefit eggs-per-recruit in others. He proposed to look back at fisheries which had collapsed for recruitment and/or overfishing reasons, and to try to see what eggs-per-recruit existed before collapse, and what exists in a similar fishery which hasn't collapsed. The reason there has been little attention given to eggs-per-recruit is that a lot of mathematics is involved, but a good start could be made by encouraging the listing of stocks which have collapsed and their prior eggs-per-recruit, and comparing them with stocks which have survived. This could provide a good source of advice for managers, and might warrant a project funded by the Fishing Industry Research and Development Council.

Tony Sharp cautioned that, without some information on the destiny of the eggs, there is little that can be concluded from analysis of eggs-per-recruit. He doubted whether such consideration of fisheries which have and have not failed would identify many of the factors implicated in failure - failure or survival of a fishery may merely have been a consequence of the direction of water currents. Scoresby Shepherd suggested that abalone would be a good species to consider because the larvae are not transported far, and stocks of limited size of only a few hundred square metres can be considered. However, the differences in recruitment strength reported by Warwick Nash could be a complication.

Terry Walker agreed that although it is desirable to obtain a stock-recruit relationship this would be very expensive, and we would need to accept the next best indicator which is eggs-per-recruit, together with a look at yield-per-recruit, using the two to examine the effect of changing a minimum legal size. A small increase in yield-per-recruit which resulted in a large decrease in egg production would be ruled out, and so on.

Mike Moran referred to Gary Hamer's comment about scientists under pressure for advice, but not having the necessary data. When a minimum legal size was being considered for coral trout in the Abrolhos Islands the only biological data available was the State record length of 90 cm. On this basis the minimum size was set at 45 cm. Such rule-of-thumb methods were probably resorted to in the early days of fisheries management, and may still have a place where biological programs are not in place. For example, for a family of fish preliminary advice might be based on the relationship between length at first capture and length at maturity.

SESSION 4

General Discussion

Chairperson: R.H. Winstanley
Rapporteur: D.L. Carter

General Discussion

Recorded by D.L. Carter

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The Chairperson opened the General Discussion by commenting that there had been a full three days of workshops, with a particularly high level of participation in the Legal Sizes workshop and he was anticipating that this discussion session would continue in that vein.

He asked that, to assist Bob Kearney - who was leaving immediately after summing up the day's proceedings - contributors should keep their points concise.

John Harris opened the discussion by noting the difference between recreational fisheries and some of those previously discussed, particularly in view of the philosophy that has guided the setting of minimum legal sizes in the past, of allowing fish to spawn at least once. In recreational fisheries that are also regulated by numerical bag limits there is the possibility of shifting the emphasis in the catch from the larger older fish back to the smaller fish. By doing so, it will be possible to exploit the higher production of the younger age groups while offsetting their higher natural mortality.

When John Glaister asked if he was suggesting that a bag limit *replace* a size limit, John Harris replied that he was suggesting the complementary use of bag limits and size limits. He argued that there should be bag limits, particularly in the recreational fisheries he deals with; the emphasis in the catch on younger fish, will encourage better survival of larger, older fish with their exponential increase in fecundity with size. More serious consideration should be given to maximum size limits.

Rob Lewis gave support for the use of both size and bag limits, referring to the management of the South Australian recreational snapper fishery. In this fishery there is a bag limit of 5 for the smaller fish, and a bag limit of 2 for the larger sizes. The decision was based on the need to: (i) increase the eggs; (ii) produce greater weight, etc.

Eventually the difference in number of fish per size really came down to addressing the expectations of the recreational anglers. They wanted to get a certain number of fish so they were allowed to catch 5 smaller size fish. In this fishery for snapper the bigger the fish the higher the quality of angling, so that in order to protect the bigger fish a limit was placed on the number of large fish they could catch.

John Harris believed that there was a lot of scope for such an arrangement. In setting catch controls for the Australian bass fishery in N.S.W. a 5 fish bag limit is being considered. The suggestion is that there should be a maximum size and anglers may take 4 fish out of 5 below the limit with only 1 above to cater for the quality aspects of recreational fishing.

David Smith introduced the problem of high grading and discarding and asked to what extent this occurred in recreational fisheries when both size and bag limits are in place. David Pollard also expressed concern over this and suggested that if you allow anglers to catch 5 fish they may just catch the 5 and go home. If, however they know that they are really allowed to catch 2 large ones out of the 5 they may keep on fishing, keeping the biggest ones and throwing the dead smaller ones back. If they continue to do so they would achieve their target of 2 large, and 3 medium fish, at the expense of a number of discarded smaller ones.

Rob Lewis agreed that these concerns were valid, though less likely to occur in certain situations. For example in the S.A. snapper fishery the larger and smaller fish are in different schools so that fishers do not normally take 2 large and 5 small snapper from the same school. They would take 5 small fish from one school and the larger snapper from a separate school - and generally not on the same day or in the same location. Gary Hamer also emphasised the need to recognise the biology and spatial distribution of the stocks. The big snapper are not in the same place as the small ones, and this is generally also the case for jewfish. They are definitely not going to be caught in the same place at the same time so this reduces the likelihood of shopping around or high grading.

John Barker stressed that minimum legal lengths and bag limits are indirect management tools because they manage stocks by managing people. He referred to the recent review of the freshwater spiny crayfish fishery which has been closed in Victoria for 7 years. The fishery is to be reopened with the introduction of minimum legal lengths and bag limits. There are 3 main species of crayfish targeted by recreational fishers. Although the 3 species all mature at about the same size there are going to be 2 different size limits and also 2 different bag limits. The differences were not based on scientific or biological criteria but with the intention of directing the fishing effort away from the species which faces the greater environmental pressures; this species only occurs in one major river catchment whereas the other two are widespread. Therefore, he reiterated, it is managing stocks by managing people.

Chris Francis and Ross Winstanley both wondered how it could be possible to manage a fishery without managing people, while Kay Allen and Murray MacDonald both highlighted the problems of trying to accommodate the expectations of all users when managing a recreational fishery. Kay Allen referred to some work he had done in NZ with trout anglers many years ago. Anglers were asked to pick out which of a series of bags they would prefer to catch (all bags being of the same total weight). The majority of responses indicated that they wanted something similar to what they were already getting from the area they usually fished. If they usually got several smaller fish they would not feel happy with just one large fish etc. Regardless of what was designated as catch limits some would always want either more, or bigger, fish depending on what they were used to catching. Murray MacDonald took this idea further to say that when interviewing anglers you would get as many different views as people you interview, ranging from people who are just enjoying some fresh air, to those who will be satisfied with nothing less than a trophy fish.

Gary Hamer suggested that what recreational fishermen really want is a reasonable feed of edible fish with the outside chance of a whopper.

Murray MacDonald expressed concern that we are starting to talk about managing fisheries, particularly recreational fisheries, on the basis of what anglers perceive as the desirable minimum sizes or bag limits. He stressed that this cannot provide the basis for the maintenance, management or conservation of the resource; it can only cause more problems than it would solve.

Rob Lewis agreed that biological concerns must come first, and then socio-economic considerations can be adapted where possible. The decisions made in the SA snapper fishery were made primarily to remove the emphasis from the adult stock due to concerns about the very low number of large fish, and resulting low egg production. The expectation of anglers was overlaid on the biological concerns, not the other way around.

Alan Baxter commented that when questionnaires were sent out to Victorian angling clubs the results suggested that the majority of people go out fishing primarily for the experience, not to catch fish. He also brought up the possibility of anglers filleting fish on the boat. He asked whether there was a requirement for fish to be retained whole when size limits applied to the fishery.

Rob Lewis confirmed that in the S.A. snapper fishery it is an offence for recreational anglers not to land fish whole. They are not allowed to fillet on board the boat.

Richard Tilzey suggested that in order to determine the most effective catch control methods one must first consider how the stock is exploited. If it is exploited by size-selective methods, controls such as mesh size can be used. If the stock is exploited by non size-selective methods, as is the case with most recreational fisheries in Australia, then size and bag limits become an important tool.

Ross Winstanley remarked that minimum legal lengths are part of an overall strategy to achieve one or several aims and to some extent they can be used to complement each other's effects.

Richard Tilzey directed the discussion towards the competition between commercial and recreational fisheries, referring to the problems that may be created by generalised regulations. For example in the South Australian whiting situation, by raising the existing minimum legal length most of the fish are put out of the reach of the recreational fishermen, the smaller fish being found in the shallower waters. This would obviously produce a backlash from recreational fishers.

Rob Lewis disagreed with this view, stating that there had been no backlash from recreational fishermen in S.A., because both the recreational and commercial fishery are based on juvenile fish. The commercial fishers are forced to fish juvenile fish because there is a 5 metre depth limit and they cannot go outside that. He added that when the Danish seiners fishing for flathead started to catch the large remnants of escapees from the whiting fishery they had to be stopped from fishing for flathead to protect the escaped King George whiting. He added that by increasing the minimum legal size, which is what has been recommended now, there will, as shown on Philip Sluczanowski's graphs, be less fish available. These catch controls need to be sold to anglers by switching the emphasis to another factor such as weight per angler or greater egg production.

Richard Tilzey suggested introducing a bag limit for anglers and raising the legal size for commercial fishermen.

Ross Winstanley commented that in the case of these South Australian changes, there was a whole suite of measures introduced simultaneously, of which bag limits, restrictions on commercial fishing, and size limits, were three. He added that it may be inevitable that some casualties occur, for instance young anglers fishing off the jetty might not have the same opportunity to benefit by this new arrangement because the little ones are inshore. But you can't achieve your main objective and still keep everybody satisfied.

Mike Moran expressed surprise at the positive tone of the meeting, believing that he would have had to defend his proposal to increase the minimum size for snapper. He had expected a lot more concern about the usefulness of releasing fish after having caught them. In angling situations there is a mortality associated with throwing fish back. He referred to some North American studies which have incorporated mortality of released fish into yield/recruit and egg/recruit models. At least one of these studies concluded that there was no point in having a minimum legal length because the mortality of the fish thrown back was so high. He thought there would have been more interest in that mortality.

Dave Pollard questioned whether it is feasible to enforce minimum legal lengths. He referred to a creel survey carried out in Botany Bay in the late 1970's. Although Botany Bay is potentially one of the best enforced areas due to its size, location and the number of inspectors based there, the results of the survey indicated that 70-75% of snapper and 50% of bream caught were undersized. The minimum legal length for snapper in NSW was only 27 or 28 cm at the time of the survey. If, for example, you raised the minimum length to 40 cm you would not get a fish, yet they provide so much fun and recreation for people from the inner suburbs of Sydney. If you are not going to enforce it why bother?

Kevin Branden expressed concern about the high mortality rate of snapper (approx 80%). If the size limit is increased more fish are going to be returned to the water. He believes extension work and publicity is required to educate the fishermen so if they do return a fish to the water they try to make it survive. They have to be told that survival is vital to ensure that fish are going to be there for themselves, and for future generations.

Ross Winstanley agreed, saying that in order to promote the concept of minimum length to enhance production and conservation of a resource it was also necessary to promote the benefits of proper handling of fish.

Burke Hill introduced the subject of tolerances on enforcement to the discussion. He referred to the Queensland scallop fishery in which scallops are sorted on board the vessels using a mechanical grader. There is a tolerance on the minimum legal size which allows 5-10 % of the catch to be undersized. People were also allowed to have a certain number of undersized fish as a tolerance measure for youngsters fishing off jetties, etc.

Alex Schaap said that although tolerance levels had been considered in Tasmania, they were rejected because it was believed that a tolerance level of 5% soon becomes 6% and just keeps growing higher. The enforcement officers involved, although they perhaps have some discretion in terms of whether they charge someone or not, reject the idea of having a tolerance around the minimum legal size. He suggested that the reason Mike Moran succeeded with the minimum legal size for snapper was because he demonstrated that the minimum legal size could be valuable if fishermen changed their behaviour and fished in areas where their catches of small fish would be minimised. For example, we all have minimum legal size limits for flathead but we do not have any expectations that fishermen will strictly abide by legal size for flathead in a trawl fishery. However, if possible, fishermen will avoid catching small flathead because they do not want to have to sort their catch.

Alex Schaap highlighted the fact that minimum legal sizes have the capacity to change people's behaviour. In the case of a recreational fishery this requires substantial educational inputs, but commercial fishermen seem to quickly understand their importance. If there is any chance of them being apprehended they are generally able to help you out with the problems of undersize mortality.

Richard Beamish expressed concern that while it is very easy for people to understand the need for enforcement, it seems to be more difficult to convince people of the need to monitor or to evaluate any of the enforceable regulations. He believed there is much room for improvement in this area because if you have a regulation and you can convince people that you need to have enforcement, you have to have adequate monitoring.

Peter Young remarked that the situation has changed enormously over the last 20 years. At one stage data were not being collected, but now the Commonwealth is trying to get centralised collection of catch and effort statistics, log books etc, and age information will soon be collected routinely, but there is still a long way to go. He would like to see linkages established between the various State government databases and have at least electronic channelling whereby data can be accessed. On the environmental side there are only 3 long term environmental monitoring stations set up by CSIRO.

Rob Day introduced the problem of subdivided stocks. Many of the management models used, and new ideas developed, are based on models which produce an estimate of what would happen to a stock if the fishery is looked at as a whole. If, however, that stock is subdivided into several smaller substocks the effort of the fishery can shift from one to the other. This situation, coupled with various environmental conditions, could result in entirely different responses by the total fishery to the same management regime.

Ross Winstanley shared Rob's concerns, remarking that his enthusiasm for Philip's abalone model was tempered by the prospect of trying to apply it to the Victorian abalone situation where there are highly productive, fast growing stocks on exposed headlands and slow growing, perhaps under-utilised stocks in the sheltered waters in between. He believed that some careful consideration is needed about the applications of these models in such circumstances.

SESSION 5

Summary and Future Directions

Legal Sizes and Their Use in Fisheries Management: Summary and Future Directions

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Before proceeding with my evaluation of the major points put forward in today's presentations I would like to don my Fishing Industry Research and Development Council (FIRDC) hat for a moment. I believe it appropriate that on behalf of FIRDC I compliment the organisers of this workshop on the manner in which it has been planned, coordinated and carried out. I am confident that FIRDC has received very good value for its money, and suggest that the excellent rate of participation and the high standard of all papers presented is proof of this. The organisers of both workshops, namely John Glaister, Dave Smith, Don Hancock and Kay Allen deserve sincere thanks for their great efforts. I must add, however, that I will warn all FIRDC members of the chores that might come their way should they decide to attend any future workshops.

Secondly, I would like to echo the words of Don Hancock in paying great tribute to John Gulland, whose recent death has saddened us all. I was most fortunate to have had the pleasure and the privilege to have worked for John back in the FAO days, and subsequently to have worked closely with him on a number of projects. The world has lost a great man, and fisheries societies everywhere will feel this loss. We in Australia, are no exception, as many of us owe a great deal to John's contribution to fisheries and to his personal contribution to our training.

Now to the subject matter I have been asked to address: Legal Size Limits; a Summary, and Future Procedures.

This morning we had the benefit of Burke Hill's excellent and comprehensive coverage of the pros and cons of legal size limits as a fisheries management tool. Although I agree with Burke that Don Hancock's comprehensive list of the use of legal size limits in Australia should have preceded Burke's own presentation, I have no doubt that the two in combination leave few stones unturned. Don highlighted the purposes of legal size limits as follows: (1) to protect immatures; (2) to control harvests; (3) for economic advantage; (4) to optimise marketing; and (5) for aesthetic reasons. Burke obviously agreed that these were the true purposes, and in addition gave us his opinions on how successful they were in each of these categories.

Both Burke and Don drew attention to the fact that very few of the present legal size limits had been implemented as a result of the clear indications of science. Yet, when reviewed, most seem to be sensible and with a high degree of what Don called "correctness". Let me then consider the history of the introduction of legal size limits in Australia, and perhaps raise one question.

Although there is some slight disagreement over when the first legal size limit was introduced into Australia, it was certainly some time in the latter part of the last century. Even at that time there was little pretence that these limits were based on hard science, and it is more than likely that the people introducing them considered themselves to be natural historians rather than "fisheries scientists". It is probably true that most legal size limits were based on common sense rather than science, and yet most of them are still in place. Bearing in mind that the people who introduced them did not have the benefit of modern fisheries science, which we have been told did not really come of age until the 1950's, and that they certainly did not have the benefit of modern computers, nor therefore of "computer jocks" to drive them, and that we were told yesterday that most of our estimates of fish age and growth prior to the 1980's were wrong, how far has fisheries science really come in the last 100 years? I will refer again to this issue in my conclusions.

In his introduction to the first panel session Rob Lewis drew our attention to the community's demands for action on fisheries management and the fact that the general public are very comfortable with minimum legal sizes; they produce that warm inner feeling. Let's look then at what is the basis for fisheries management and why legal size limits are important.

The stated goal of most fisheries management is to optimise the benefits of, and returns from, fish resources. In reality managers are often forced to accept the real-time goal of "peace in our time". If one accepts these goals, then it is not surprising that legal size limits have their appeal to managers for the following reasons:

- Managers often have insufficient information to be confident of their decisions, and yet "no decision" is often an unacceptable alternative. Because legal size limits affect the whole fishing community, both commercial and recreational, they impact a lot of people, and their introduction is therefore widely seen by a large number of people to at least be doing something. Furthermore, as they have some impact on many people but seldom put any one sector out of business, as does a gear restriction or an area or seasonal closure, size limits are seldom completely unpalatable.
- Because of the points raised in the previous paragraph, legal size limits have what can be termed a "high comfort factor". This is an expression which Tony Harrison has used to describe the affection the research community has for tagging. I believe that legal size limits should have the same appeal to managers.
- The introduction of a legal size limit seldom has any long-term negative impact on the resource; in other words, in most cases *it can't hurt*.
- The presence of a legal size limit normally promotes the conservation ethic, even if such promotion is subconscious. A similarity exists with recreational tagging programs, which also promote conservation by encouraging people to release fish in the interests of science, with the added benefit of aiding stock conservation.

Terry Walker provoked considerable discussion with his contention that bigger is not necessarily better. He also was the first to focus attention on the differences between species. Although I completely agree with the underlying philosophy, I disagree with Terry's implementation of it when he lumped all tunas as being the same. This gives me the opportunity to explain in some depth the difference between various tuna species; a subject which is a hobby horse of mine. I have, for years, been stressing the difference between skipjack and southern bluefin tuna, and have on many occasions made the statement that these two species, from a population dynamics viewpoint, have nothing at all in common. An examination of five of the parameters commonly used in population dynamics assessments (Table 1) clearly shows the differences. I have gone so far as to say that from a population dynamics viewpoint southern bluefin are more like lobsters than they are like skipjack. I rest my case with Table 2.

There have been few cases of the successful use of legal size limits with tuna, although the Australian regulations on southern bluefin are often quoted in this context. In reality these Australian restrictions constrained the surface catch in some areas but were in themselves inadequate for the conservation of the total population. They were, however, correctly used as one tool in the total management kit.

Ross Winstanley reminded us that most minimum legal size limits were introduced about a hundred years ago for primarily marketing reasons. In spite of the improvement in fisheries science, biologists still haven't proven many of them to be incorrect. Ross also drew our attention to the growing pressure on resources, which must increase the pressure for review of the minimum or maximum legal size limits which are in place, and also increase pressure for the implementation of new ones. One assumes that this must in turn increase the pressure on biologists to provide the basic information. Yet when one looks at the number of people who are actually researching the effectiveness of legal size limits as a management tool, the lack of effort in this area is remarkable.

Philip Sluczanowski gave us a wonderful and colourful display of modelling the effects of altering legal size limits. There was tremendous support for his ideas, and wide acknowledgment of the progress he has made. But in spite of this, all he received for his presentation was a polite round of applause, whereas just an hour later he was given a bottle of wine just for asking a few questions! Is there no justice in this world?

The only question raised about Philip's work was the cautionary comment; beware of the black box. In Philip's case this was not particularly relevant, for surely we have risen to new heights and the caution should now be: beware of the kaleidoscopic box.

In general discussion John Harris raised the valuable point of the heritability of growth, and the impact on this if we introduce minimum or maximum size limits. In a subsequent discussion during the tea break John reminded me of the comparison to the aquaculture situation where the viability of eggs of female fish is progressively reduced with continuous use of injected hormones. I particularly liked John's reference to this as being pharmacological rape. I am uncertain whether I liked the reference merely because I liked the expression, or whether it was because it reminded me of the rape and pillage description of commercial exploitation and all the colourful discussion this has provoked. Certainly John Glaister's expressed concern about the possibility of senescence in fish in general, which he then followed up with a discussion of the possibility that the viability of eggs may also decrease with size with some species, makes the comparison with pharmacological rape more noteworthy.

John Glaister also highlighted for us the particular problems with barramundi being protandrous hermaphrodites and catadromous, with the resultant conflict between commercial and recreational exploiters. John also was the first to draw our attention to the particular difficulty of administering legal size limits in multi-species fisheries.

Peter Young presented Mike Dredge's work on scallops, and provoked continuing discussion on the problems with the use of size limits in scallop fisheries. It appears there are even more opinions than there are scallop fisheries; at the present state of the resources one could even question whether there are more opinions than there are scallops. The message I got from these different opinions was further confirmation of the need to consider the differences not only between species, but between the various fisheries which operate on the one species. The old issue of description of species, stocks and populations once again reared its head.

Steve Montgomery gave us a most relevant short data summary on the problems of having two or three fisheries on different stages in the life cycle of the same species. Steve's proposed use of both maximum and minimum legal size limits, and the step-wise changes to these, highlighted once again that fisheries management involves compromise. We are all aware that the final fisheries management decision is normally political, and must take account of not only the biological implications but also the economic, legal and social ramifications. Rob Lewis reminded us that fishermen normally would prefer gradual changes rather than sudden drastic management measures, and in this light Steve's proposed gradual increases in minimum legal size limits would appear valuable.

All States, with the exception of Tasmania and the Northern Territory, have a significant interest in the southern snapper fishery, and Mike Moran explained to us how size limits were an alternative to effort controls for this species. It was most significant that in Western Australia the industry had found effort controls unpalatable, and yet an output control in the form of a size limit was acceptable. This confirms my earlier point that the comfort factor of this management device is definitely one of its strong points.

I was surprised when Mike also suggested that the introduction of a legal size limit would make it easier for the resource to recover after it collapsed; are we already admitting that collapse is inevitable? Mike also highlighted for us the impact that a size limit, introduced to help manage a total fishery, can have on one small sector of the fishery. In this case it was the negative impact that a size limit for the total fishery had on the export of premium-grade small fish to the Japanese sashimi market. The value per recruit is then brought into question.

David Die highlighted the need to evaluate the utility-per-recruit in addition to the standard yield-per-recruit. David also emphasised the need for alternatives in management advice. One cannot help but wonder whether it is more alternatives that managers need or more alternatives that biologists need to consider before they give advice to managers! Keith Sainsbury contributed the concept of a biological fall-back position to this debate.

Many diverse points were raised during the general discussion and I felt two were worthy of further comment. Firstly, Dave Pollard's recall of the removal of the minimum size limit on mulloway in New South Wales supposedly because of the large kill of these small fish in trawl fisheries. If you have a problem with trawlers killing undersize fish the removal of a minimum size limit can only make the problem worse. This action does not address the problem, it merely makes it no longer illegal. Surely an area or a seasonal closure would be more likely to be effective. Removal of a size limit can in fact be counter-productive, for example where an area presently uneconomical to exploit because it contains fish marginally below the size limit, becomes economical to fish by removal of the limit.

Secondly, I thought Ross Winstanley's point on the need for scientific monitoring of management action, whether it be on legal size limits or any other matter, particularly important. Researchers who have the support of their managers are in possession of one of the most powerful research tools, that is the use of management for experimental purposes. What Ross, and many others, refer to as adaptive management is in practice monitoring the effects of trial and error. Because of their real-time influence on industry, changing management strategies will always be the subject of close scrutiny and must therefore be accompanied by adequate monitoring and, hopefully, be associated with an overall quality research plan.

Having reviewed where today's proceedings indicate we now are, what are the implications for future procedures?

We all accepted that many of our legal size limits had been introduced without the benefit of a great deal of science, and yet I believe there is need for great care before changing these limits, and certainly extreme caution before attempting to remove any of them. While several people have given specific examples of size limits which can have a negative impact there has been overall support for the concept of their use as a management tool, and general confirmation that they can be effective. Bearing in mind that minimum size limits appeal to the conservation streak in the human psyche, and the associated high comfort factor for managers, they have a lot of common appeal.

As pressure increases on all of our fish resources, management, and therefore researchers, will be required to increasingly investigate all possible alternatives. There is general agreement that legal sizes are largely irrelevant for deepwater fisheries and for many trawl fisheries where all animals captured are killed, but I believe there will be increased use of legal size limits in inshore fisheries. There is growing conflict between a variety of resource users, in particular commercial and recreational fishermen and developers, for the use of our estuarine and nearshore fish habitats. Managers are interested in any measure which gives "peace in our time", and politicians, who are the ultimate fisheries managers, are interested in votes. Legal size limits affect the total fishing community and are therefore very visible and potentially important vote winners. Perhaps even more importantly they affect both recreational and commercial fishermen and therefore create the feeling of "we are all in this together", which is not common to other management measures. I am therefore confident that legal size limits will become increasingly used in inshore fisheries and that research on their utility will increase accordingly. I believe such an increase in research is overdue. We have heard numerous times today that legal limits were in place a hundred years ago without the benefit of science. It has therefore taken science a hundred years to catch up. It is time we took the lead.

Table 1. Key population parameters for skipjack and southern bluefin tuna

	Skipjack	Southern bluefin
Maximum age	3 yrs	18 yrs
Age at first spawning	1 yr	8 yrs
Natural mortality (yr^{-1})	2.0	0.2
Exploitation rate	4%	>40%
K (von Bertalanffy) (yr^{-1})	2.0	0.13

Table 2. Key population parameters for skipjack and southern bluefin tuna, and western rock lobster

	Skipjack	Southern bluefin	Lobster
Maximum age	3 yrs	18 yrs	17 yrs
Age at first spawning	1 yr	8 yrs	7 yrs
Natural mortality (yr^{-1})	2.0	0.2	0.2
Exploitation rate	4%	>40%	60%
K (von Bertalanffy) (yr^{-1})	2.0	0.13	0.56

WORKSHOP PROGRAM

Legal Sizes and Their Use in Fisheries Management

(Friday 24 August)

0900 - 0915	Introduction	Dr John Glaister, President ASFB
0915 - 1000	**Keynote Address**	Dr Burke Hill, Senior Principal Research Scientist, CSIRO Fisheries, Cleveland, Qld
1000 - 1030	**Current Use of Size Regulations**	Dr Don Hancock, WA.
1030 - 1100	Morning tea	
1100 - 1230	**Basis for Setting Legal Lengths**	
	Chairperson:	Rob Lewis
	Panellists:	Terry Walker
		Ross Winstanley
		Philip Sluczanowski
1230 - 1330	Lunch	
1330 - 1500	**Case Studies: Problems Encountered (other than enforcement)**	
	Chairperson:	John Glaister
	Panellists:	Mike Dredge
		Steve Montgomery
		Mike Moran
		David Die
1500 - 1530	Afternoon tea	
1530 - 1615	**General Discussion**	
	Chairperson:	Ross Winstanley
	Panellists:	Keynote speakers
		Session Chairmen
1615 - 1715	**Summary and Future Procedures**	Dr Bob Kearney

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