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AUSTRALIAN SOCIETY FOR FISH BIOLOGY TAGGING WORKSHOP

SYDNEY, 21 - 22 JULY 1988

Editor:
D. A. Hancock

Department of Primary Industries and Energy
Bureau of Rural Resources

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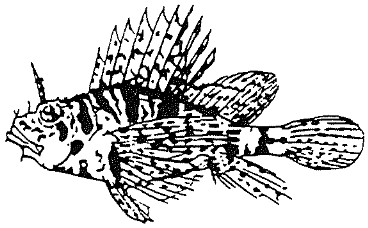
Tagging — Solution or Problem?



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FOREWORD

Scientific investigation uses many techniques. The array of available techniques changes over time as some are revised and new ones develop; some techniques stand the test of time better than others. Throughout the use of established techniques we must continually question the suitability, utility and cost-effectiveness of our methods. On occasions, the opportunity arises to hold a workshop such as the one reported in the present Proceedings and thereby explore many aspects of the application of a favourite, tried and tested research tool. The tool in question here is tagging or marking of animals in the cause of fisheries research.

Since reportedly first used in fisheries in the 1890s (Smith 1988), tag-recapture methods have continued to develop, not only in the technology of tag design but also in the mathematical analyses of results and the psychology of encouraging the fishers of our increasingly materialistic times to return recaptured tags.

The last comprehensive review of tagging in Australian fisheries was conducted by Thomson in 1962 (Thomson 1962). At its 1987 Annual General Meeting in Canberra, the Australian Society for Fish Biology (ASFB) rightly determined that the time had arrived to look anew at the use of tagging in fisheries. The workshop was held on 21-22 July 1988, in conjunction with the 1988 Annual Conference in Sydney.

Much thought, planning, and human and other resources went into making this 1988 ASFB workshop the success it was. The Bureau of Rural Resources (BRR) in conjunction with ASFB designed, distributed and processed a detailed questionnaire on fisheries tagging studies and projects over the last 30 years in Australia. Thanks to the enthusiasm of ASFB members, and especially the State coordinators, the response was excellent. To the best of our knowledge, very few projects were missed in the survey. The major findings are reported in the present Proceedings, and the results also provided the background for many workshop session discussions.

BRR provided funding for Dr Don Hancock to coordinate the planning of the workshop and to edit these Proceedings. The excellent final results, both the workshop and the Proceedings, fittingly reflect the diplomacy, persistence and intellectual insight which Don brought to the project.

As with the proceedings of the 1987 ASFB workshop (Williams 1988), publication costs were contributed by BRR. Albert Caton bore the brunt of the sometimes onerous task of organising publication at the Bureau as well as that of workshop organiser, coordinating rapporteur and liaison point between ASFB, BRR and Don.

A glance at the list of authors in these Proceedings will give an indication both of the large number of contributions to the workshop and of the wide range of projects and organisations represented. It will be evident, on further examination, that there is considerable disparity in size of contributions. Most were developed as summaries for elaboration during panel sessions but some contributors provided more background information. The proceedings are intended as a comprehensive record of the workshop and, therefore, the various offerings have been edited but not refereed.

In all, this has been a commendable collaborative effort which resulted in a worthy review of an important research tool in fisheries science. It is our hope that this will just be the latest in a continuing series of critical examinations of the methods and topics which form the basis of our research effort.

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M.J. Williams
Assistant Director (Fisheries Resources)
Bureau of Rural Resources
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SESSION 1

OPENING ADDRESS

M. Chaikin
Pro-vice-chancellor
University of New South Wales

Mr President, ladies and gentlemen, may I extend, on behalf of the University, a very warm welcome to you all as you are members of a society involved in an area of scientific endeavour of considerable significance, and increasing significance, both nationally and internationally.

This is the first time that we have hosted a fish biology conference and it is fitting that this should occur at a time when our University's teaching and research programs in marine science are in the process of being greatly strengthened; and, not only that, my secretary informed me last night that of the 73 lunches I hosted for visitors to the University this year, I ordered fish as the main course for 71 — which, if nothing else, qualified me to welcome you here today.

The establishment of the Centre for Marine Science within the University, just 2 years ago, has led to a much greater coordination of our marine science effort and, in the event, has created increased opportunities for the development of multidisciplinary approaches in our programs and for collaborative research with other organisations. And it is just such collaboration, particularly with industry, that has always been a high priority in this University.

I recognise that, throughout the country, research programs in the general area of fish biology, population dynamics and aquaculture have recently been expanded and further that all of these areas are now attracting external research funds. And, most important perhaps of all, high-calibre graduate students are being attracted to pursue careers as fisheries scientists and so perhaps we can look forward, in the years to come, to increasing successes in the application of science to the fishing industry.

May I then conclude by congratulating the organisers of the large attendance at this pre-conference workshop. It undoubtedly reflects an awareness of the importance of tagging as a fisheries tool and we should all be delighted to see so many here from industry, government and semi-government bodies, as well as from tertiary institutions.

After these workshop sessions, in the conference proper, I notice that a very wide array of papers will be presented which range from the use of electron microprobe analysis as a tool for investigating fish movement, stock discrimination etc., to a discussion of the orange roughy larvae, which I am given to understand is a very important topic for we perch eaters! There is little doubt that all the topics on the program will lead to lively and informative discussions, and it only remains for me to wish you all a most successful and enjoyable conference.

INTRODUCTION

C.M.J. Glover
President, ASFB
South Australian Museum
North Terrace
Adelaide SA 5000

Ladies and gentlemen, welcome to the National Fish Tagging Workshop!

When the Australian Society for Fish Biology was formed in 1971, it was with the intention to promote fish studies and the interchange of information between fish biologists in a relaxed but effective manner. Within a few years of the Society's inception its Annual Conference had become a regular event, providing a forum for fish workers around Australia to meet. Since the first Conference conducted by the Society in its own right, in 1975 at Port Stephens, succeeding conferences have continued to be conducted most successfully, and in a relatively informal atmosphere despite consistent growth in attendances and programs. The Society's membership, incidentally, now stands in excess of 500.

To enhance it's contribution to fish biology in Australia, the Society eventually decided to organise and hold workshops on specific topics, in conjunction with the annual conferences. The first such workshop, a 2-day event, on *Australian Threatened Fishes*, was held at the Arthur Rylah Institute, Melbourne, immediately prior to the Conference held in that city in 1985. That workshop was supported by several fisheries agencies and angling groups, and its proceedings were subsequently published by the Division of Fisheries, New South Wales Department of Agriculture.

The following year, in Darwin, two 1-day workshops were conducted in conjunction with the Conference held there: one on Advances in Aquaculture; the other on *The Use of By-Catch Resources in Australia.*

Last year's Canberra Conference was preceded by a 1-day workshop on Scientific *Advice for Fisheries Management: Getting the Message Across*. This highly successful event was conducted jointly by the Society and the Australian Bureau of Rural Science (as it was then termed), with funding, administrative resources and publication of the proceedings being provided by the Bureau. These proceedings have just been released and will be distributed during this Workshop.

Supplementary to these major workshops, another series of workshops, on fish collection management, organised independently by museum-affiliated members, but held under the auspices of the Society, was initiated with a 1-day program immediately after the 1985 Melbourne Conference. This first collection management workshop was supported by ABRS funding in order to specifically address the topic of computerisation of collections data. The second collection management workshop, dealing with more wide ranging curatorial matters, was held in conjunction with last year's Canberra Conference; and the third one will be held next Monday at the Australian Museum. One very useful spin-off from this series of workshops has been the establishment of an annual *Australian Newsletter of Systematic Ichthyologists.*

Thus, the Society's Annual Conference has become a catalyst for other productive communicating ventures held in conjunction with it.

The National Fish Tagging Workshop was originally proposed by John Beumer and Rick Morton. Following a proposal by John Glaister at last year's AGM it was agreed that tagging should be the topic of this year's workshop, so a working group was promptly formed to plan the event and to conduct the accompanying survey of Australian tagging studies.

The development of this workshop, including the tagging survey, has been mainly in the hands of John Beumer and (in the Bureau of Rural Resources) Albert Caton, with the able assistance of Richard Tilzey, Jim Stoddart and Phil Stewart; all of whom have been under the watchful eye of Meryl Williams of the Bureau.

The working group's State representatives have been primarily responsible for the tagging survey; these comprise John Beumer (for Qld), Julian Pepperell (for NSW), John Anderson (Vic.), Wayne Fulton (Tas.), David Hall (SA), Rod Lenanton (WA), John Glaister (NT); and also Nick Elliot (for CSIRO projects).

The very informative poster display outside, an integral part of this workshop, has been brought together by John Beumer assisted by Clive Keenan, Bob Lester, Albert Caton, John Anderson, Paul McShane, John Stevens, John Glaister, Rick Morton and Michael Hall.

Coordination of the preparatory work has been in the hands of Dr Don Hancock, as is the workshop itself. Tomorrow afternoon Don will summarise matters and will later coordinate publication of the proceedings as editor-in-chief.

We have been fortunate to have Don's assistance, and to be able to publish the proceedings, thanks to the generous support of the Bureau of Rural Resources. The Bureau has also established the tagging information base derived from the national survey, and has provided much of the infrastructure responsible for the workshop.

The cooperation and generosity of the Bureau in all these matters is to be applauded!

As will be noted from the program, the workshop will commence with a Keynote Address. This will be followed by a description and explanation of the National Tagging Register.

After morning tea the first of the Workshop's five *interactive sessions* will be held. These sessions are intended to be *participation sessions*, with the chairman and panellists of each providing introductory comments and discussion as a catalyst for ensuing questions and comments from the floor.

To assist the rapporteurs in making a comprehensive record of proceedings, all participants speaking from the floor are requested to identify themselves clearly.

The last session tomorrow afternoon will comprise a general discussion, with all chairmen participating, followed by a summing-up of proceedings.

INTRODUCTION OF KEYNOTE SPEAKER

C.J.M. Glover
President, ASFB
South Australian Museum
North Terrace
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It is now my pleasure to introduce Dr Bob Kearney, Director of the New South Wales Fisheries Research Institute.

Dr Kearney's training grounds were the surf beaches of northern New South Wales. In 1970 he moved to Papua New Guinea to take up the position of Biologist in the Department of Agriculture, Stock and Fisheries, later becoming Principal Biologist, and where he worked principally on tuna.

In 1974 he joined FAO, initially advising on Western Pacific Fisheries, later reviewing the fisheries of developing countries in the Indian Ocean.

In 1975 Dr Kearney joined the South Pacific Commission to set up and take charge of the Commission's skipjack tuna tagging project, which subsequently became the tuna and billfish assessment program. In a massive effort through the islands of the South Pacific that program resulted in 149 000 tuna *alone* being tagged. The resulting success of that work was largely, attributable to Dr Kearney's skills as a supervising scientist, and in being able to obtain financial support for what was inherently a very expensive operation. When costs of such magnitude are involved it is essential that the objectives and progress of the work are clear and effectively pursued, as they clearly were under Dr Kearney's direction.

In 1984 he joined the Inter-American Tropical Tuna Commission as Chief Scientist, later becoming Deputy Director.

Dr Kearney took up his present position in 1986.

With this background Dr Kearney is eminently experienced to present this Workshop's keynote address.

Ladies and gentlemen, Dr Bob Kearney!

KEYNOTE ADDRESS: TAGGING – SOLUTION OR PROBLEM?

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The title of this Workshop 'Tagging – Solution or Problem?' poses a question which we are being asked to answer. However, the word 'tagging', as used, seems to imply active participation by man in the placement of tags. If so, this would not encompass the utilisation of natural tags as marks, which already occur without man's deliberate intervention. Since natural tags should, and will, be included in the next two days' discussions, I suggest that the word 'tagging' as used in the title of this Workshop should be taken to mean 'the use of tags' in its wider sense.

While projects with which I have previously been involved include the use of natural tags in the form of biochemical genetic markers and parasite distributions in South Pacific skipjack, and micro-constituent analyses of Atlantic bluefin tuna, my present involvement in tagging is largely with the man-made form. This presentation shows that bias.

Back to the question at hand, 'Tagging – Solution or Problem?'. I have personally been a very strong advocate of the value of tagging for providing 'hard' information, i.e. factual information about individual fish. I also believe that carefully used under the right circumstances it often represents the best research alternative; sometimes the only solution. Undoubtedly tagging can provide solutions to some fisheries problems; but there are some problems it cannot help to solve and in some cases it can create problems for both researchers and managers. We have the next two days to debate the pros and cons of the tags that are available, which are appropriate and cost-effective, how they can and should be used, and how the results can be interpreted. I would like to start by considering the types of tags or tagging techniques available to us.

In 1962 Thomson stated that 12 different types of tags or marks had been applied to 183 113 aquatic animals in Australian waters. In fact he then listed 13 types of tags, which were almost all that were known at the time.

Since that time well in excess of 1 million aquatic animals have been tagged in Australian waters. A large number of additional tag types have been developed paralleling technological advances. They vary greatly in sophistication, and include the following:

- Anchor tags
- O-rings
- Ink marking
- Freeze branding
- Fluorescent pigment marking
- Coded micro-wire tags
- Visible implant micro-tags
- Passive integrated transponders (PIT)
- Ultrasonic tags
- Pulse-coded radio tags
- Smart tags

Many of you are familiar with most or all of these developments but perhaps I might elaborate a little on some of the more unusual. The second I mentioned was what I believe is the unique use of numbered plastic O-rings, approximately 3 cm in diameter, by the Japanese for tagging saury in short-term school dispersal experiments. The method of using them was to cast thousands onto the top of the water beneath bright lights to which schools of saury had been attracted. For some, as yet unexplained, reason the saury swam through the rings which were of a diameter such as not to fit over the whole body. The rings then became lodged, ideally behind the operculum. Naturally they are very restrictive in the size class of fish which they tag, and they obviously have a long-term effect on the growth of the individual. They were, however, particularly useful for the purpose for which they were designed, that is short-term school dispersal studies, as thousands of individuals could be tagged in 1 hour by one researcher.

At the other end of the scale we have 'smart' tags. Smart tags are a fisheries spin-off from micro-chip technology. In concept many of them are fantastic but several questions still remain on their practicality and cost-effectiveness. One smart tag type worthy of some discussion is the archival tag which was the brain-child of a collection of scientists meeting in North America to consider technological possibilities for tag development. In essence the archival tag involves a small cylinder about 9 cm long and slightly thicker than the average pen, which is attached externally to large fish or other aquatic animals. It contains a clock, light sensors, temperature and depth sensors and it records each of these variables at varying intervals, normally every few seconds or minutes. The tag was originally devised for work on migratory fish, such as tuna. The principle is that all three variables are monitored against the background of a continuous clock. The information is stored in micro-chip memory for recovery after tag return. Light intensity variation with time enables determination of sunrise and sunset. This information in itself gives the longitude of the animal at a particular time. Day length estimates can also be derived from sunrise and sunset, indicating latitude. This estimation is made more accurate by comparison of temperature and depth records with known oceanographic conditions. The archival tag would therefore represent a complete movement history for the animal for the whole of the period at liberty.

It is worth noting that some scientists in the US became extremely enthusiastic about the potential of this tag, so much so that they were successful in gaining a $US500 000 grant from the United States Government for a private firm, Northwest Marine Technology, to fully develop the tag for commercial use. It is most significant that after carrying out market surveys, this company handed the money back to the Government stating that, although it was technologically viable, the market was just too small to warrant development. What this means is that at a cost of between $US1000 and $US2000 per unit, research institutions considered archival tags of this type to be not cost-effective. Many factors contributed to this decision, including the possible influence of a tag of this size on the behaviour of individual fish or marine animals, the possible low recovery rate and therefore high cost of each return, and less obvious, but perhaps more important, was the concern by some senior researchers that a great deal of information on one individual fish is far less useful than less detailed information on many fish.

Additional technology which is already available can make the archival tag far more sophisticated. By having the tag pop up to the surface of the ocean from the back of the fish after a given period of time and transmit its information via satellites to receiver stations, the problem of low recovery rates can be overcome, but at the expense of further increases in the size and price of the tag. As technology advances further, and unit costs come down, this latter approach will undoubtedly be revitalised.

Although the types of tags to which I have already referred are all man-made and applied, many forms of natural tags also exist. These include:

1. Sequential marks on hard parts, such as annuli or daily rings on otoliths;
2. Discontinuities in hard parts;
3. One-off event markers, such as radio-active isotopes resulting from atomic testing, or other forms of 'natural pollutants';
4. Biochemical characteristics such as blood types and protein polymorphisms;
5. DNA and sequential polypeptide chains;
6. Parasites;
7. Micro-constituents of hard parts;

All of the above have many potential uses and many will be discussed in other sections of this workshop. One of my favourites is the study of micro-constituents of hard parts for aiding stock discrimination, migration and growth studies. I have been an admirer of the work of Dr John Calaprice of the Inter-American Tropical Tuna Commission (IATTC) in this field, and I believe that CSIRO scientists will, over the next few days, be presenting results of their work on this subject.

Having briefly covered the types of tags let me outline some of the problems with tagging. Here I refer predominantly to 'tagging' as in man's placement of tags. In any tagging experiment there are many assumptions. In all experiments with which I am familiar, some of these assumptions are violated. Unfortunately in some experiments virtually all of them are violated, often simply because the person conducting the experiment is ignorant of the assumptions implicit in the experiment. All of the assumptions pose problems.

In considering the problems with tagging and the planning necessary to minimise them, it is necessary first to consider the reasons why we tag. Unfortunately even this fundamental question is often overlooked or even deliberately ignored. There are many reasons for tagging and included amongst them are the following:

1. To obtain more information about fish and/or fisheries for a wide spectrum of reasons, such as to satisfy scientific curiosity or to help solve a management problem. The range of precise objectives in this category is broad and includes, for example, tagging to study migration and growth in wild fish or the identification of individual brood stock in enclosures.
2. To increase public awareness of research. Tagging is a highly visible aspect of research which the public at large find easy to relate to and in general are sympathetic with. It therefore has a significant public relations, and therefore intrinsic political, value.
3. It is a socially more acceptable alternative to the killing of fish, for example the tagging of marlin or trout by recreational fishermen. In this context tagging is actually used to justify the capture of individuals of a species with a high emotive value.
4. To provide tagged fish as targets for angling competitions.

Although all four reasons given above are used to support the need for tagging, only the first, i.e. to obtain more information about fish and fisheries, is of primary scientific merit.

We therefore have a most important, but unfortunately seldom recognised, division in the list of reasons for tagging, i.e. tagging for primarily scientific reasons and tagging for more socially oriented goals. In this presentation I will concentrate on tagging for scientific reasons.

Let me then pursue further what information we require and how we undertake a tagging program to obtain more information about fish or fisheries. If the intention is to increase our knowledge of fish it is normally for either personal goals, such as to obtain a degree, or a responsibility to a fisheries management authority such as a state or federal agency. In this latter, most common case, five variables are normally the primary targets of tagging experiments. These are, in decreasing order of common usage:

1. Migration; I am including here investigations of stock structure.
2. Growth; either direct estimation or validation of other estimates.
3. Mortality; fishing, natural or total, and sometimes differential mortality, such as between commercial and recreational users of the resource.
4. Stock size.
5. Stocking success.

This brings me back to the issue of assumptions. One of the major problems that we have when investigating any of these five variables is understanding what assumptions are implicit if we use tagging to study them, and ensuring that these assumptions are not violated, or at least not violated to the extent that the results are meaningless or, worse still, misleading. The following lists of assumptions are by no means exhaustive but merely cover those which I feel most commonly cause major problems. I have listed them as relative to the five variables tagging normally addresses.

1. Migration

(i) The most critical assumption is that the behaviour of the tagged individuals is the same as that of the untagged population. This assumption is almost always violated to some extent at least.

(ii) It is usually assumed that the tagged fish are released into the mainstream of the population and that their behaviour is representative of the population as a whole. Obviously this is not always the case.

(iii) It is assumed that the pattern of recoveries represents the pattern of distribution of the tagged individuals and therefore the population as a whole. This assumption is almost always violated, for very seldom, if ever, is recovery effort uniformly distributed over the total area of distribution of the resource. Tremendous biases can occur as a result of non-random or non-uniform distribution of effort, and seldom are fishing effort data good enough to enable appropriate corrections.

(iv) It is usually assumed that the number of fish tagged is sufficient not to miss major components of the population

2. Growth

(i) Again it is assumed that the behaviour of the individuals is not changed.

(ii) It is often assumed that the tag is no impediment to growth.

(iii) It is assumed that recoveries are not influenced by the size of the individual, and that size-specific recruitment can be accounted for.

(iv) It is assumed that all measurement errors are accounted for. Unfortunately this is seldom the case for, even at the time of tag release by scientists, human mistakes occur and parallax error commonly causes bias. At the time of recovery human errors are probably greater. For example the South Pacific Commission (SPC) Skipjack Program found that skipjack recovery lengths were consistently underestimated by commercial fishermen and processors, whereas it is normal for the pride of anglers to cause them to overestimate the recapture size of trophy species. Fork length is often measured when standard length is required, the effects of cleaning a fish cause problems, freezing causes shrinkage while thawing causes stretching, large individuals picked up by the tail will stretch, the wrong date is often reported, and on it goes.

3. Mortality

(i) Again normal behaviour is assumed.

(ii) Normal rates of natural mortality and vulnerability to fishing are assumed.

(iii) Emigration and, to a lesser extent, immigration are often ignored or inadequately accounted for.

(iv) It is usually assumed that tagged individuals uniformly represent the total population.

(v) It is also usually assumed that recovery effort is uniform over the total distribution of the population.

(vi) Estimates of tagging mortality and tag slippage, even if properly investigated for part of the experiment, are assumed constant throughout.

(vii) It is usually assumed that the percentage of tags which is recaptured and recovered is known and unbiased with time and area, and for the various interest groups recapturing them, for example commercial or recreational fishermen. *Tagging experiments tend to underestimate fishing mortality and overestimate natural mortality.* In combination these can be disastrous for they both tend to underestimate the effects of fisheries on stocks.

4. Stock size

(i) Again normal behaviour is assumed.

(ii) Complete mixing of tagged fish and uniform distribution over the total population are assumed.

(iii) Recovery effort is assumed to be uniform and to cover the total population.

(iv) Emigration and immigration are assumed to be constant and known.

(v) The percentage of tags returned from recaptured tagged fish is assumed to be known and unbiased.

(vi) It is assumed that the total catch is accurately known.

5. Stocking success

(i) Stocked fish are assumed to be completely identifiable in the natural population.

(ii) The percentage of tag recaptures reported is assumed to be known and unbiased.

(iii) The total catch is assumed to be known.

(iv) The size distribution of the catch is assumed to be known.

The many problems with the assumptions listed above occur after you have made the major decision that growth, mortality, stock size etc. are really the variables that you, or management, really need to measure. That is it assumes that you have correctly determined what information management, or whoever else is commissioning your work, really needs. It also assumes that you have worked out the numbers of tag returns required to do the job and that tagging is in fact the most cost-effective way of solving the problem. Ron Thresher's session on planning later this morning and Tony Harrison's session tomorrow will deal in much more detail with these particular aspects of assessment of tagging. But let me continue here by pointing out that if you have decided that tagging is 'the way to go' then you must have already decided that you have the resources, both manpower and money, to:

1. Design and plan the program.
2. Obtain the necessary equipment to do the tagging and to check on tagging mortality and tag slippage estimates.
3. Do the tagging.
4. Wait for tag returns.
5. Pay rewards and support the administrative structure necessary to check on recovery percentages.
6. Process, analyse and interpret results.

Let me give some brief comments on each of these.

1. To design and plan the program

It is amazing, and distressing, how often tagging programs are commenced without proper planning and without due attention to derivation of an appropriate experimental design, or even consideration of what the results will actually be used for. I have seen numerous tagging projects where, even though the number of tag returns approximated the goals, the results were still of little if any value in solving the real fisheries problems.

2. To obtain the necessary equipment

Equipment can be specialised, such as coded wire or visible implant tag applicators, but it is often simple. Let me give you an example of the problems you can come up against even with a simple system. I refer again to my experience with tagging skipjack in the South Pacific. Prior to commencing our tagging work at the SPC I had determined, based on previous experience with tagging skipjack in Papua New Guinea, that what we needed in the way of tags were yellow plastic dart tags of standard design but with the one extra requirement that they be temperature resistant. This was necessary to help overcome tag losses in minus 40 degrees to minus 60 degrees Celsius freezers used on modern tuna vessels. Tags were ordered from a noted international supplier in accordance with rather stringent specifications. Some of you might ask what could possibly go wrong with a simple yellow plastic tag 11 cm long with no movable parts. In fact in the first shipment of tags there were 13 things wrong. These were:

(i) The spelling of the inscription was incorrect. Enough people had trouble finding where Noumea was even when spelt correctly.

(ii) The duplicate numbers were not at each end of the tag but bunched towards the middle. This meant that broken sections of a tag did not necessarily have a whole number on them.

(iii) The numbering and lettering were not permanent.

(iv) The internal diameter was outside the specifications making it impossible to fit heads already purchased.

(v) The outside diameter was outside the specifications meaning that the tags did not fit the applicators.

(vi) Tags were not resistant to minus 40 degrees Celsius. In fact it cost an extra $US19 000 to solve this problem, but that is a story in itself.

(vii) The barbs on those supplied with heads were too soft.

(viii) Bubbles of glue were common at the join between the tag and the tag head so that the tags would not fit properly into the applicators.

(ix) The tag itself was too stiff and would not lie flat along the side of the fish.

(x) The sealant used on the tags did not set properly in the short term so that tags were often stuck together.

(xi) In the long term the glue used to fix the heads to the streamer became brittle, making it easier for the head to become detached.

(xii) The sequential numbering was not perfect, with occasional tags missing and, worse still, others duplicated.

(xiii) The alphabetic character used as a prefix was often separated from the number so that the person recovering the tag was not sure it was part of the number.

3. To do the tagging

To be done properly, tagging requires a great deal of skill in fish handling, and practice to ensure tags are properly located in individual fish and that *consistency* is maintained.

4. Wait for tag returns

Long-term tag recoveries proportionately have greatest effect on most mortality estimates and add precision to most growth estimates. In general, long-term returns are the most informative. Often it is necessary to wait years after tagging is completed to conclude the analyses.

5. To pay and service rewards

Appropriate rewards must be offered and made available to tag recoverers as quickly as possible. Tag reward systems must be in place and well publicised before any tagging commences. There is also a general reluctance to pay rewards of sufficient magnitude to ensure the enthusiasm of all people likely to recover a tag. Great care must also be taken to be consistent with existing tag recovery systems and not to cause problems for other, perhaps more important, tagging programs. I wish to stress this point as it is one of the most common ways in which tagging experiments actually create problems. Let me use the recent example of anglers who, with the very best of intentions, tagged tailor in northern New South Wales with tags supplied from interstate. NSW authorities, including fisheries inspectors who normally handle tag returns in country areas, and NSW anglers, were oblivious to these tag releases. When subsequent recoveries occurred tags were mostly taken to the local inspector who knew nothing of them and, when officials at Head-Office could not help, people began to get upset. Even when a little more information was gained the problem didn't go away, in fact it got worse! No reward is payable on angler-released tags in NSW (for the obvious reason that such a system is too open to abuse), and so people who returned them became disgruntled. The attitude towards returning tags in general changed and the normal system of $5 for a tag return became threatened. A great deal of work was necessary to mend the bridges, to say nothing of the rumours of large numbers of tailor making unusual migrations.

A further example was the problem caused for the IATTC tag recovery systems in North America when Papua New Guinea offered a $5 reward for its tagged skipjack, 20 or so of which found their way, in the freezers of ships, to America each year. The IATTC had people in place in each cannery who coordinated the recovery of hundreds of locally-used tags each year and paid the reward of $2. As soon as a few individuals received $5 for Papua New Guinea tags there was a growing tendency not to bother about IATTC tags. A tagging program on one side of the Pacific Ocean actually caused serious disruption to a much larger one on the other side of the Ocean. The problem was eventually overcome by IATTC handling all returns at a standard reward rate.

6. Process, analyse and interpret results

The processing of tag recovery information is quite simple in principle, and yet it can require great skill to get it right. Let me again refer to the SPC Skipjack Program as an example of how simple the analyses are in theory, but how much more complex they are in practice. The first slide in this series (Figure 1) shows the boundaries of the SPC, which was the area within which information on skipjack was required. It also shows the proportional distribution of 140 000 tags (approximately 400 tonnes of fish) across the study area. The second (Figure 2) shows the extent of movement and is one index of mixing of tagged fish in the total population.

Looking then at the recovery pattern over time (Figure 3) we find a wonderfully good relationship between time and the number of tags recovered. The estimate of the dilution of tagged fish at t_o (500/140 000) corrected for total tag loss and non-reporting (0.60) multiplied by the average monthly catch (19 000 tonnes), gives an approximation of the total biomass of 3 million tonnes. The slope of the line approximates a total mortality of 16% per month. From these you can calculate throughput and hence can estimate yields. Tag returns also enabled estimation of growth and, more importantly, migration, with all its implications for international management and coastal states versus fishing nation squabbles. Simple relationships between tag returns, time and space and simple models give all the required information. However, in order to get the precision required to be confident of the result, to present it to governments and for peer review and subsequent publication, the procedure becomes far more complex. The models necessary to take account of tag dispersion, type 1 and type 2 tag loss and non-reporting of tags etc., are shown (Table 1). Obviously these are more demanding mathematically. The end result (Figure 4) is a model which fits the total data set extremely well (as did the straight line in Figure 3), and gives the same intercept of 500 tag returns per month.

Let me now show you the recovery pattern from a subset of the total data (Figure 5), in this case in the Solomon Islands where tag and effort distribution are neither random nor uniform. Here we have data on more than 6000 releases with more than 500 recoveries, and yet the problems of fitting a model which was developed for the same species in the same general area and at the same time are obvious; a sobering example of the problems encountered when tagging part of a larger population.

In concluding my discussion on the problems and advantages of tagging I would add that far too often tagging is carried out because researchers are not sure of what else to do, and believe that at least if they are tagging they are seen to be doing something about a problem. Again far too often planning is inadequate and follow-up procedures are neglected. On other occasions tagging has been used as a unique, relatively simple and magnificently effective solution to complex fisheries problems. Tagging tends to be most effective when used with other techniques as part of a total research strategy.

Having then looked at many of the problems with tagging experiments, and a few examples of the benefits, what can we conclude about tagging as a solution or a problem? My conclusion is that tagging is a tool. As a tool it is a means to an end, not an end in itself. It is not the tagging itself, nor the number of fish released, which is important. It is the end result of the tagging exercise that counts. Like other tools tagging can, if correctly used, provide solutions to problems, but if not used correctly it can create problems. The simplest analogy is to the common hammer which, in the hands of a master craftsman with a detailed plan and right timber and nails and other tools with which to work, can be used to create a masterpiece; in the hands of a novice the hammer can only be used to create mediocrity and products which tend to be temporary and require constant repair; in the hands of an idiot, or even a child, the hammer can be destructive.

References

Kearney, R.E. (1983). Assessment of the skipjack and baitfish resources in the central and western tropical Pacific Ocean: a summary of the skipjack survey and assessment programme. (South Pacific Commission: Noumea.) 37pp.

Kleider, P., A.W. Argue & R.E. Kearney (1987). Assessment of Pacific skipjack tuna (*Katsuwonus pelamis*) resources by estimating standing stock and components of population turnover from tagging data. *Can. J. Aquat. Sci.* **44**, 1122-34.

Thomson, J.M. (1962). The tagging and marking of marine animals in Australia. CSIRO Div. Fish. Oceanog. Tech. Pap. No. 13, 39pp.

Table 1. Models used for estimating population parameters. Reproduced from Kleider *et al.* (1987; table 1)

Parameters	Model
Z_c P	$r_i = \frac{\alpha\beta N_0 c_i}{P(Z_c+\psi)} e^{-i(Z_c+\psi)}\left[e^{(Z_c+\psi)} - 1\right]$
Z_f q	$r_i = \frac{\alpha\beta N_0 q f_i}{(Z_f+\psi)} e^{-i(Z_f+\psi)}\left[e^{(Z_f+\psi)} - 1\right]$
Z_c T	$r_i = \frac{\alpha\beta N_0 Z_c c_i}{T(Z_c+\psi)} e^{-i(Z_c+\psi)}\left[e^{(Z_c+\psi)} - 1\right]$
Z_c F_c	$r_i = \frac{\alpha\beta N_0 F_c c_i}{\bar{c}(Z_c+\psi)} e^{-i(Z_c+\psi)}\left[e^{(Z_c+\psi)} - 1\right]$
Z_f F_f	$r_i = \frac{\alpha\beta N_0 F_f f_i}{\bar{f}(Z_f+\psi)} e^{-i(Z_f+\psi)}\left[e^{(Z_f+\psi)} - 1\right]$
Z_c H_c	$r_i = \frac{\alpha\beta N_0 Z_c H_c c_i}{\bar{c}(Z_c+\psi)} e^{-i(Z_c+\psi)}\left[e^{(Z_c+\psi)} - 1\right]$
Z_f H_f	$r_i = \frac{\alpha\beta N_0 Z_f H_f f_i}{\bar{f}(Z_f+\psi)} e^{-i(Z_f+\psi)}\left[e^{(Z_f+\psi)} - 1\right]$
$\alpha\beta$ M q	$r_i = \frac{\alpha\beta N_0 q f_i}{(M+qf_i+\psi)} e^{-\left[iM + q\sum_{j=1}^{i} f_j + i\psi\right]}\left[e^{(M+qf_i+\psi)} - 1\right]$

Desired parameters	
P	standing stock
T	throughput
q	catchability
Z_c, Z_f	total attrition
F_c, F_f	fishing mortality
M	natural attrition
H_c, H_f	harvest ratio
Nuisance parameters	
α	type 1 tag retention and survivorship
β	proportion of recaptured tags that are reported and useful
ψ	type 2 tag slippage and mortality
Input data	
r_i	tag returns in time period i
c_i	catch in time period i
f_i	effort in time period i
$\bar{c}$	average catch per time period
$\bar{f}$	average effort per time period
N_0	number of tags released

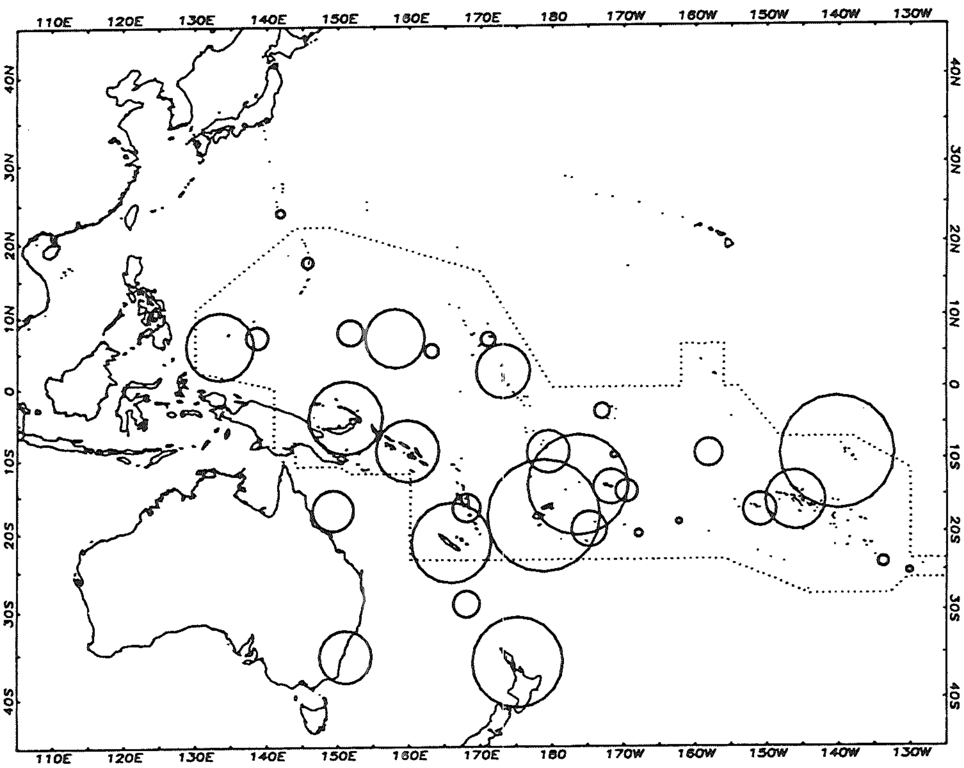

Figure 1. Distribution of tag releases (circles) and boundaries of the South Pacific Commission Region (dotted line). The circles are centred on each sub-area in which tags were released. The areas of the circles are proportional to the number of tagged skipjack released. Reproduced from Kleider *et al.* (1987; figure 1).

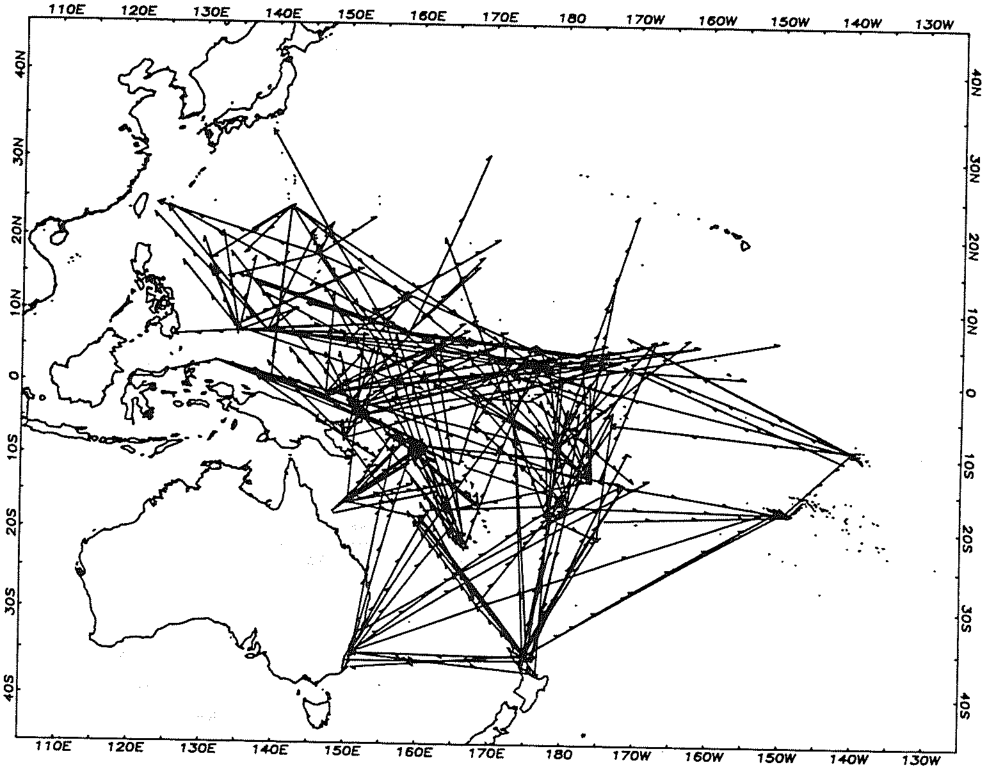

Figure 2. Straight line representations of movements of skipjack tagged by the skipjack program and subsequently recovered. Movements plotted have been selected to show no more than two examples of movement wholly within any ten-degree square. Tick marks on the arrows represent time-at-large with one tick mark per 90-day interval. Reproduced from Kearney (1983; figure 1).

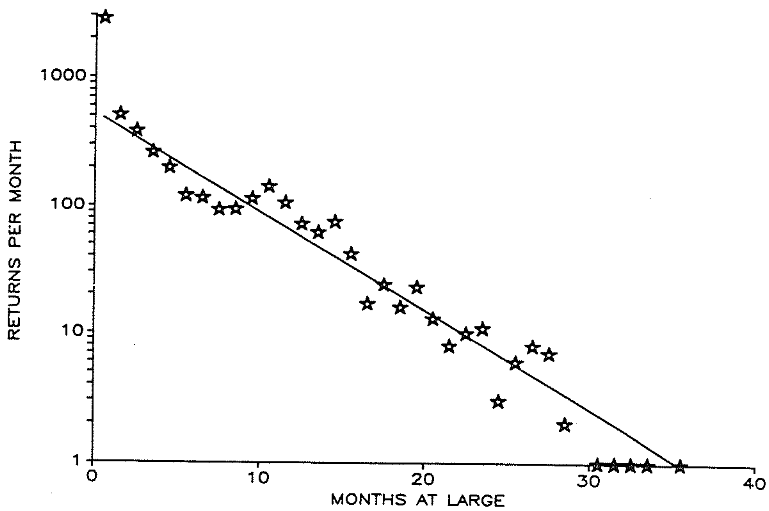

Figure 3. Numbers of skipjack tag recoveries versus months at large. The y-axis is a logarithmic scale. Reproduced from Kearney (1983; figure 3).

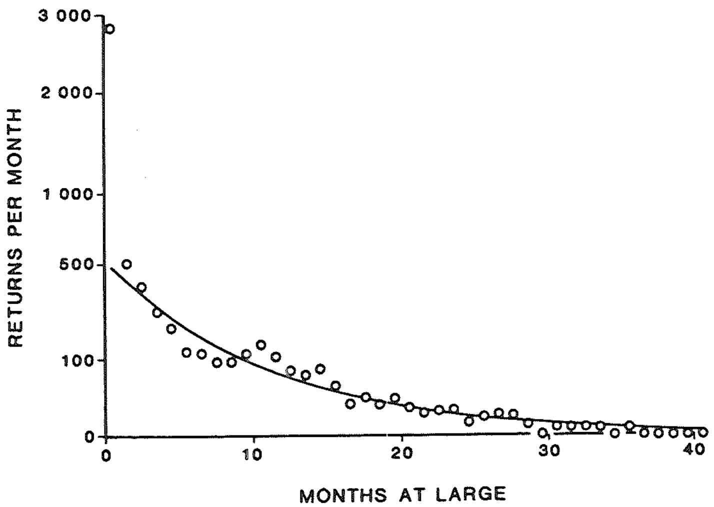

Figure 4. Aggregate tag attrition curve. Points are the aggregate tag return rates. The solid line gives the expected values based on the best fit of first model form in Table 1. The y-axis is a square-root scale. Reproduced from Kleider et al. (1987; figure 4).

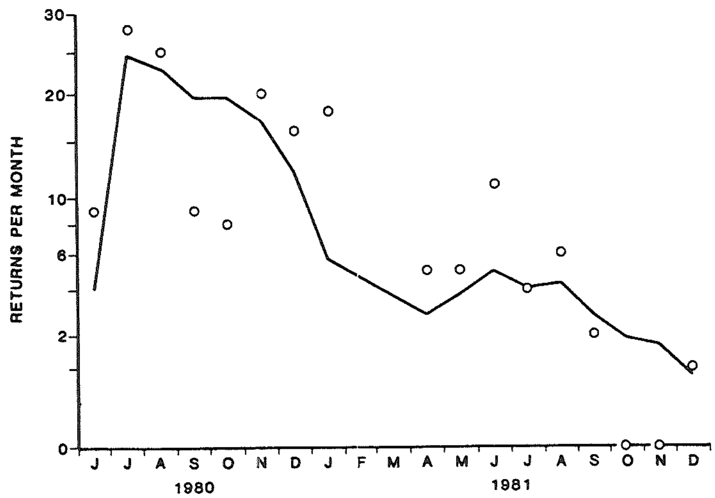

Figure 5. Tag attrition curve for a sub-area (Solomon Islands, 1980). In other aspects, this figure is similar to Figure 4. Reproduced from Kleider et al. (1987; figure 5).

DISCUSSION OF KEYNOTE ADDRESS

Recorded by A.E. Caton
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In response to an enquiry from Peter Young as to whether results of simplistic analysis and detailed analysis of the skipjack recovery data were different, Bob Kearney advised that, for the data as a whole, the simplistic and complex analyses produced similar results. The examination of data sub-sets separately produced substantial differences, but examination in conjunction with results from the total data set permitted identification of the sources of difference. He mentioned, in passing, that the supplier of the 'problem' tags was not an Australian company. He added that ultimately the skipjack tagging techniques were very effective, with (on the basis of two double-tagging experiments) less than 3% tag loss.

Geoffrey Kesteven drew attention to the tendency, psychologically, to treat as assumptions many of the aspects of tagging projects which should in reality be the subject of investigations by the projects. Notwithstanding Bob Kearney's response that, despite this, most normally tended to be taken as assumptions, Kesteven emphasised the need for scientists to highlight such errors during the project planning stage of a tagging study.

INTRODUCTION OF J. A. STODDART

C.J.M. Glover
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Our next segment, concerning the National Tagging Register, is to be presented by Dr Jim Stoddart, Acting Assistant Director, Fisheries Resources Branch, Bureau of Rural Resources.

Jim's 1983 PhD Thesis, at the University of Western Australia, was on the population genetics of corals.

In 1984 he joined the Australian Institute of Marine Science, Townsville, to undertake genetic studies designed to answer taxonomic and ecological questions for a range of species, including sponges, corals, crown-of-thorns starfish and clupeid baitfish.

This year Jim moved to the Bureau of Rural Resources to take responsibility for coordinating research upon those Northern Fisheries for which the Commonwealth is responsible.

Ladies and gentlemen, Dr Jim Stoddart!

THE NATIONAL TAGGING REGISTER

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One of the legitimate functions of any scientist is the creation of information. Science proceeds through the production of information according to certain rules, followed by the promulgation of this information. As scientific knowledge involves a cumulative function it soon becomes difficult for a working scientist to keep track of the results of past studies, or of present studies, in a large field. Fisheries biology is no exception.

Fisheries biology in Australia has grown rapidly over the past two decades to a situation where it is no longer possible to assume that researchers are personally acquainted with the work of each other and past workers. In this environment, a centralised data repository provides an effective method of dealing with the mushrooming product from the information-generating side of science.

As part of its role in fisheries research, the Bureau of Rural Resources (BRR) promotes and participates in the development of a national infrastructure for research. One aspect of this work involves the production and maintenance of databases which relate to issues involving, or of interest to, many States. The National Tagging Register clearly falls into this category and BRR was pleased to be able to take on this project, which had initially been started by the Australian Society for Fish Biology (ASFB) at the request of the Standing Committee on Fisheries.

Over the next two days, the present workshop will consider various benefits and pitfalls in the principles and practice of tagging. Many of these will have been met before and some of their characteristics will be captured in the tagging database. The retrieval of information can never be expected to equal the value of discussing the issues at first hand. However, the Register will present, on demand, a largely complete history for perusal by anyone planning a new study or analysing the use of tagging in Australia.

Compilation

To interpret information extracted from the database it is necessary to consider how it was compiled.

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Questionnaires

To cope with the diversity of information relevant to the planning and interpretation of tagging studies, the questionnaire was divided into five forms (Appendix 1*). Each form addresses a distinct section of information.

Form 1. Overview: agencies involved, funding details, start-finish dates, aims, results, problems, fishery/species involved, capture-recapture methods, estimation of tag loss/mortality/non-reporting and details of publicity.

Form 2. Tagging details: species, number tagged and recaptured, information derived, time free and distance travelled, tag type and tag problems.

Form 3. Detailed list of species.

Form 4. Register of tag details: make, type, colour and legend.

Form 5. Bibliography of the project.

Distribution

Forms were distributed through State coordinators and, thus far, the answers from 80 respondents have been logged. Coordinators were ASFB members, usually employed in a State fisheries department. The scope of the database was intended to be extensive, incorporating tagging studies of any marine fauna. Initial coverage was restricted to scientists whose tagging work was known to coordinators. Subsequent publicity of the workshop and database should extend this coverage to include studies conducted outside the traditional fisheries sphere.

Uses

The potential uses of the information within the database can be categorised into two headings:

Historical: retrieval of information on specific topics to provide the user with a record of the successes and failures of past studies. Such applications will be useful to workers in the planning stage of a tagging study or in using existing information to compile a better picture of the biology of a particular species.

Analytical: retrieval of information for use as data points in an appraisal of general parameters concerning tagging, such as success rate against various aims, cost effectiveness, tag problems etc. Again, a useful exercise for someone planning a tagging study and also of particular concern to those interested in fisheries research and development funding.

Due to the great variety of studies covered in the database, some care must be taken in interpreting the results of summary statistics derived for analytical purposes. For instance;

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* Appendixes 1-3 may be found at the end of these Proceedings.

estimates of recapture rate will be misleading if they include studies designed to monitor tag performance in captive fish; what does a mean for cost per tag return of $1361 imply when the range is from $1.98 to $25 000?

Preliminary Results

Some compilations of preliminary results are given in Tables 1-9. A list of projects and responsible organisations included in the National Tagging Register is given in Appendix 2*. Appendix 3* gives a list of tagging references provided in response to Form 5 of the questionnaire.

Future Developments

Following the initial compilation of the tagging database, BRR will continue its efforts to widen the base and update the register with new studies and the progress of existing projects. We are presently attempting to reach the wider audience of marine biologists through the Bulletin of the Australian Marine Science Association and are pursuing the data from a number of studies by scientists who have since retired.

The dissemination of information in the database will be carried out through the provision of hard copies (in these Proceedings and in biennial productions) and through the distribution of copies of the database on computer disk. A quick scan of the material derived from the database will prove most thought provoking. It should help those enquiring whether tagging studies are a solution or a problem to focus on the critical issues of this question, and should go part way to supplying an answer.

* Appendixes 1-3 may be found at the end of these Proceedings.

Table 1. Distribution of aims listed as of either major or moderate importance for the purpose of each study. Numbers in parentheses are the percentage of each category which reported results for that aim as 'highly successful'

Aim	Purpose	
	Major	Moderate
Tag development	4 (75)	9 (33)
Tag effects	5 (60)	8 (13)
Tag performance	7 (57)	19 (47)
Growth, age validation	42 (55)	22 (9)
Movement, migration	55 (60)	15 (33)
Stock delineation	25 (44)	14 (14)
Population size	14 (21)	15 (7)
Stocking success	1 (100)	2 (0)
Recruitment	8 (25)	10 (10)
Mortality rate	28 (32)	10 (0)
Fishery interaction	13 (54)	19 (5)
Activity patterns	8 (50)	10 (0)
Physiology	1 (0)	1 (0)

Table 2. Number of studies assessing various methodological assumptions

Assumptions and methods of assessment			No. of studies
(a) Tag-induced mortality			
	Method	- Holding experiments	25
		- Other	6
	Not assessed		50
(b) Tag loss			
	Method	- Holding experiments	22
		- Double tagging	31
		- Direct observation	144
		- Other	2
	Not assessed		30
(c) Non-reporting			
	Method	- Salting experiments	4
		- Interviews	10
		- Via catch rates	9
		- Other	2
	Not assessed		56

Table 3. Number of studies using various publicity media

Media	No. of studies
Poster	58
Radio	27
Press	54
Television	17
Personal liaison	66
Newsletters	23
Other	8
Not applicable	9

Table 4. Rewards for tag returns used by studies

Rewards	No. of studies
Clothing	9
Money	54
Lottery	9
Tokens	4
Gifts	3
Letter of acknowledgment	37
Other	9

Table 5. Problems listed as detrimental to success

Problem	No. of studies
Insufficient numbers marked	26
Insufficient numbers returned because of:	
- poor publicity/reporting	17
- poor mark visibility	13
- marking mortality	6
- insufficient fishing	12
Insufficient period at liberty	15
Inappropriate experimental design	7
Inappropriate mark:	
- causing mortality	3
- affecting behaviour	1
Inappropriate marking/handling methods	3
Assumptions violated	15
Explicable disasters	4
Unknown factors	4

Table 6. Taxonomic breakdown of studies by (a) major grouping and (b) genus

Taxa	No. of studies
(a) Major grouping	
Crustacean	20
Mollusc - Bivalve/Gastropod	5
Mollusc - Cephalopod	1
Elasmobranch	4
Teleost	50
Dipnoan	1
(b) Genus	
Acanthopagrus	2
Amusium	1
Anguilla	1
Arripis	3
Chrysophrys	4
Cyprinus	1
Galaxias	1
Haliotis	3
Jasus	2
Katsuwonus	1
Lates	5
Lutjanus	1
Macquaria	3
Metapenaeus	2
Mustelus	2
Neoceratodus	1
Oreochromis	1
Panulirus	4
Pecten	1
Penaeus	6
Platycephalus	1
Pomatomus	4
Portunus	2
Salmo	2
Scomberomorus	1
Sepioteuthis	1
Sillaginodes	3
Sillago	3
Thenus	1
Thunnus	2

Table 7. Breakdown of studies by (a) habitat and (b) geographic area (see Appendix 1*)

Types of studies	No. of studies
(a) Habitat	
Estuarine	14
Marine/coastal	40
Marine/oceanic	2
Marine/reef	5
Lentic	10
Lotic	5
Marine/freshwater	5
(b) Geographic area	
N-E coast	7
S-E coast	7
Tasmanian	1
Murray-Darling	9
Coastal Timor Sea	3
Australia - all AFZ	1
Bass Strait	7
Gulf of Carpentaria (GOC)	2
Great Australian Bight	6
N-W Australia	1
South Australian Gulfs	7
Torres Strait	10
Queensland other	5
Great Barrier Reef	4
Other South Australia	5
Tasmania other	3
S-W Australia	10
Not applicable	3
Northern Territory (not GOC)	2
Northern coast	1
Southern coast	1
Coral Sea	1

* Appendixes 1-3 may be found at the end of these Proceedings.

Table 8. Total funding and its primary source for each study

Primary source	<$1000	$1001-$10 000	$10 000-$100 000	>$100000	Total
Commonwealth		4	4	5	13
State	1	13	30	16	60
University	1	3	1	1	6
Other		1		1	2
Total	2	21	35	23	81

Table 9. Number of captures v. number tagged. Individual numbers represent species

	Number recaptured							
Number tagged	<100	101-250	251-500	501-1000	1001-2500	2501-5000	5001-10 000	>10 000
<200	35							
201-500	20	2						
501-1000	12	4	1					
1001-5000	9	9	9	3	2			
5001-10 000	2	3	6	2	2	2		
10 001-20 000		1	2	2	2	3		
20 000	2	1		1		4	1	1
Total species	80	20	18	8	6	9	1	1

DISCUSSION OF NATIONAL TAGGING REGISTER

Recorded by A.E. Caton
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Geoffrey Kesteven commented that, while the cost of maintaining the register and servicing enquiries for information from it might not be large, he would expect that very few enquiries would be made. For this reason it might not be justified on a cost/benefit basis. By the time the scientist reached the point of tagging he should already, and independently, have done his homework from the literature. Peter Young suggested that the register would probably be used by funding agencies to check whether proposed projects might be repeating previous work. Commenting on the extent to which CSIRO tagging projects were represented on the register, he pointed out that research officers associated with some earlier projects no longer worked with the organisation; there might only be sketchy details on hand about the number of tags released and recovered, costs etc. Jim Stoddart responded that it would, nevertheless, be desirable to enter on the register a project name, details of species and bibliographic details of any relevant publications. In response to an enquiry by John Anderson about intentions for updating the register and providing details to people holding disks of register data, he advised that the Bureau of Rural Resources intended to revise the register, annually at first, and would pass on details to disk holders.

SESSION 2

PLANNING AND IMPLEMENTATION

Session Chairman:	R.E. Thresher
Session Panellists:	J. Majkowski
	P.C. Young
	J.Harris
	J.D. Stevens

CHAIRMAN'S INTRODUCTION

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Fundamentally, there are only two reasons to tag an animal. Each involves a different class of tags. The first is to obtain short-term information on behaviour or physiology on a more-or-less continuous time scale. Such studies involve 'active' tags, which signal their location and which may also transmit (or store for later retrieval) data on the individual being tracked. The second, and more common, reason for tagging is to identify individuals (or classes of individuals) unambiguously. Such tagging studies involve a wide variety of 'passive' tags, which do little more than specifically identify the subject.

Each of these classes of tagging studies involves sets of problems specific to them, in terms of program design, implementation and analysis, and a common, fundamental assumption. Active tagging, which in an aquatic environment usually means sonic transmitters that may or may not be coupled to environmental or physiological sensors, involves minimal problems for analysis (though perhaps not for interpretation) but often considerable logistical difficulties. There are often major problems in handling live organisms for sometimes prolonged periods, successfully implanting the transmitter and sensors, and tracking and recording data from a freely moving, often uncooperative organism. Such studies involve electronic technology and aspects of aquatic acoustics that are typically outside the realm of comfortable competency of most biologists. Despite recent advances in miniaturisation and increased power of transmitters, such transmitters and associated receiving systems are often prone to inexplicable equipment failure and limited ranges, particularly in the acoustically heterogeneous shallow water environment of highest interest to many biologists.

Passive tagging studies usually involve fewer obvious technical problems, in part because of the often less 'sophisticated' objectives of the studies. Design, implementation and, particularly, analysis of data generated, however, can be far more complex than those involved in a program of active tagging. The specific nature of these problems depends largely on the objectives and scope of the program. At the simplest level, passive tagging of a few focal organisms is a frequently employed methodology used by behaviourists and ecologists to ensure positive identification of individuals during field studies. At this level, design problems involve primarily choice of tag type to be used, implementation is straightforward, and analysis trivial. At the other extreme, broad-scale fisheries programs often involve implantation of tens of thousands of tags, of which only a few percent are likely to be recovered. Regardless of initial objectives, the logistical focus of such tagging programs quickly becomes that of maximising returns, coordinating recreational, commercial and scientific collecting efforts, assessing reliability of data from these returns (which are often based on opportunistic or voluntary recovery), and determining biases associated with the tag and recovery procedures. Even at the level of its simplest objectives, such as documenting movement to point B of individuals tagged at point A, sampling problems involved in the tagging and recovery procedures can be horrendous. What starts off as a modest biological program can rapidly become an exercise in statistics and fitting models. Accurate interpretation of tag recoveries must begin with an understanding of the classes of models involved, and design of field programs to fit the assumptions inherent in these models.

Hence, tagging studies all involve problems requiring technology, logistics and analysis. Beyond these, however, there remains the fundamental assumption of 'biological believability'. The assumption is often made that tagging does not alter the behaviour of tagged individuals. The assumption is rarely tested, and is always wrong. Every artificial tag distorts the biology of the animal tagged. The question is not 'Does tagging affect behaviour?', but rather 'How much is behaviour affected?'. 'Is the distortion at an acceptable level?', and 'Can the effect of the distortion be quantified or compensated for?' Experimental assessment of the effects of tagging are usually done at a very crude level, by comparing mortality rates following handling alone versus handling plus tagging. That a tagged animal can survive the process does not seem to be a particularly sensitive index of whether or not that animal's behaviour is normal. Rather, potential effects of tagging on behaviour are either ignored or decisions are made on the basis of the type of tag used, its size relative to the animal, and qualitative observations of untagged individuals in the field. To be blunt, unless the long- and short-term effects of tagging on behaviour are assessed, I doubt the reliability of any study involving artificial tagging. Questions addressed by tagging studies must be carefully considered keeping in mind the potential distorting effects of the tags.

COMMENTS ON THE DESIGN AND IMPLEMENTATION OF TAGGING PROGRAMS

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A precise determination of the objective(s) for a tagging program is the first step towards achieving its success. A design of tagging that is ideal for one objective clearly may be completely unsatisfactory for accomplishing another one. In such a case, priorities for achieving the individual objectives have to be determined and the design may need to be compromised if possible to satisfy, at least, those that are most important. Alternatively, different experiments corresponding to the individual objectives or to groups of objectives need to be designed. The latter may considerably increase the cost of tagging, but it may be the only way of accomplishing all the objectives.

In some cases, several different scientific methods requiring different designs of tagging programs can be suitable for achieving the same objective. In such situations, the selection of the most appropriate method should be made in the context of:

(i) the remaining objectives for the tagging program; and
(ii) the cost of the differently designed experiments.

The design of a tagging program consists of the determination of:

(i) the geographical and temporal pattern and intensity of tagging; and
(ii) the method of tagging individual fish.

This design should depend not only on the objective(s) of the program and the selected scientific method to be used, but also on the pattern and intensity of fishing, the expected rates of recaptures, non-reporting and tag-shedding, and the biological characteristics of the population.

Ensuring that all the required information on recaptures is passed on from commercial and sport fishermen and fish processors to the organisers of the tagging program is equally as important as the proper design and implementation of the tagging program. Securing the information required is a very difficult and, in fact, expensive task, but unless enough attention is paid to it the overall program will not be successful.

The above-mentioned aspects of the design and implementation of tagging programs will be examined during the discussion with references to experiences with tagging southern bluefin tuna off the Australian coast mainly in the 1960s and 1983-84. During these periods about 50 000 and 10 000 fish were tagged, with reported recapture rates of about 15% and 40% (many more recaptures expected), respectively.

CSIRO'S SCALLOP TAGGING PROGRAM

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CSIRO commenced a scallop tagging program in Bass Strait during 1985, and continued to release tagged scallops until February 1986.

The primary aims of the tagging program were:

1. To determine the growth rates (in shell size) of scallops in two areas of Bass Strait, i.e. off King Island, and in Banks Strait (Figure 1);
2. To examine, by means of a reciprocal transplant, the differences in growth in flesh weight between the two areas, by determining the differences in growth rate in transplanted and control groups of animals;
3. To determine rates of natural mortality in both areas;
4. To determine the fishing mortality rates in both areas.

Determination of the mortality rates also required a knowledge of tag shedding rates, and this was examined by a double tagging experiment.

Methods

Early on, it was decided to use a multiple-release, multiple- recapture strategy. The two release locations were fished for about 3 weeks after the first releases. Thereafter the fishery was closed for about 8 months, but batches of about 1000-2000 scallops were released at each locality each month in the interim. The tags were made of plastic-coated stainless-steel wire, with CSIRO's name and telephone number on them. To attach them, a hole was drilled in the ear of the shell with a modified chainsaw sharpener, and the wire passed through and twisted around itself. The three scallop fishermen's associations were visited, talks given to special meetings, and also their A.G.M.'s, and circulars sent through the post to every licence holder. The text of the circular is in Attachment 1. Scallops were held in baskets immersed in free-flowing sea water in special live-holding tanks, between capture by the dredge and subsequent release. They were usually released within 1 day of capture.

Scallops used for the transplant experiment were held for up to 3 days in these tanks, and between 500 and 1000 animals were used for each treatment. Flesh weights were determined by subsampling a number of animals from the catch at each location, and determining the flesh weight, total weight, and shell height to determine relationships. Experimental animals were shaken to remove water, blotted dry, total weight determined, and shell height measured. From the subsample, estimates were determined of the initial flesh weight. For the double-tag experiment tags were put through each ear of the scallop. Attempts were made to retrieve all scallop shells as intact animals.

Problems encountered

1. No rewards, therefore very little interest from processor workers or casual deck hands.

2. Results from the double tagging gave twice the returns of the single tags that were released at the same time and at the same locality.

3. The program was identified with Tasmania, with the result that some of the Victorian fishermen, who were excluded from the Tasmanian grounds, smashed tagged scallops that they had caught from the much less productive King Island grounds.

4. The returns were all in within a year because of the intensity of fishing, and growth was slow for animals at the tagged (commercial) size. Consequently shell abrasion and growth variability made growth rate estimation difficult.

5. Fairly wide differences occurred between the recovery of live scallops between releases. A progressively greater percentage return of live scallops from the releases should have been expected as the time of release neared the time of the season opening (12 June); this did happen, but was not at all pronounced (Figure 2). This means that if natural mortality is to be estimated from the ratio of releases, then many more releases should be made.

6. Fishing intensity on the grounds was very intense, and the method of fishing produced a great deal of incidental mortality which would increase the rate of 'natural' mortality. Because of this, independent estimates of fishing and natural mortality need to be estimated from recaptures plus fishing effort, so daily effort figures are required as the effort falls off during the season as the catch declines (Figure 3).

7. The rate of shedding of tags from double-tagged animals appears to have been inconsistent (Table 1). The returns suggest that the tag shedding rate increased and then decreased.

Attachment 1. CSIRO Bass Strait Scallop Tagging Program

In 1985 the CSIRO Division of Fisheries Research commenced a study of the commercial scallop in the Bass Strait region with funding provided by the Fishing Industry Research Council. The aim of this study is to improve the long term viability of the industry by providing scientific information to assist in the management of the Bass Strait scallop fishery.

An important aspect of this study is a large scale tagging program which will provide information on growth and death rates of scallops in their natural environment.

An initial pilot tagging program undertaken just prior to the closure of the Banks Strait beds in September, 1985, indicated that with only limited fishery effort, the scallop fleet could recapture nearly 5% of tagged scallops released on a bed. Since then over 20 000 tagged scallops have been released in known commercial beds at King Island and in Banks Strait. It is anticipated that a large number of these tagged animals will be recaptured by the scallop fleet in the weeks immediately following the opening of the scallop season on June 12th.

Scallops are tagged with either one or two tubular plastic tags wired to the upper shell as shown in the accompanying diagram. Tags are a red/orange colour with a yellow tip. Each tag is 3.5 cm long and bears a 4 digit number, the letters CSIRO and a telephone number (002) 206-222. Fishermen finding tagged scallops are asked to contact this telephone number and arrangements will be made to collect the tagged shells. All calls to the CSIRO Marine Laboratories in Hobart concerning tagged scallops can be made reverse charge but callers should immediately indicate the reason for calling to the CSIRO operator. It is important for the success of the program that all tagged scallops found are retained irrespective of size or condition. All live scallops should be frozen as soon as possible after capture and it is suggested that dead shells be treated in the same way to minimize the chances of misplacing tagged shells. It would be of considerable benefit to the program if some record could be kept of where tagged shells were caught and the number of drags carried out in the area. All such information will be treated in the strictest confidence. It is hoped that any commercial sized scallops not noticed by fishermen will be detected by splitters and retained by the processors. At this stage it is not anticipated that a reward will be offered for the return of tagged shells.

The success of this program will depend to a large extent on the co-operation received from commercial fishermen working in the area. Any inquiries concerning the CSIRO scallop program should be directed to Peter Young, Dick Martin or Richard McLoughlin at the CSIRO Marine Laboratories, GPO Box 1538, Hobart 7001 (Ph. (002) 260-222).

Table 1. Recoveries of double-tagged animals

Days out	Tags remaining on shell		% shed
	One tag	Two tags	
78-79	1	16	6.25
121-143	16	108	14.8
148-204	0	31	0

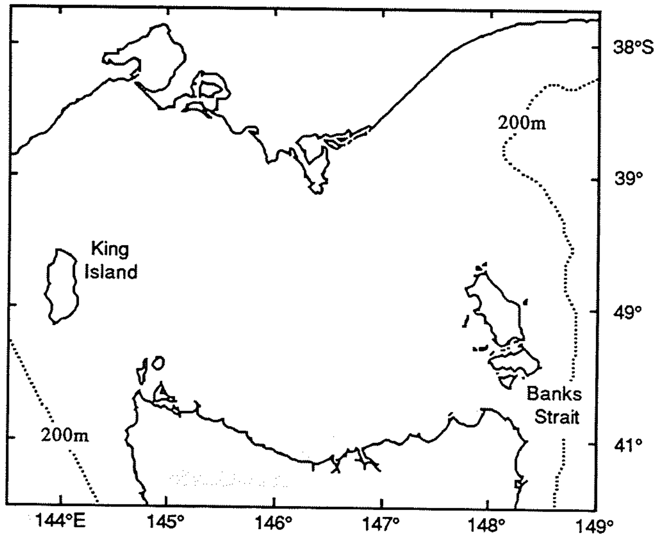

Figure 1. Bass Strait showing release locations.

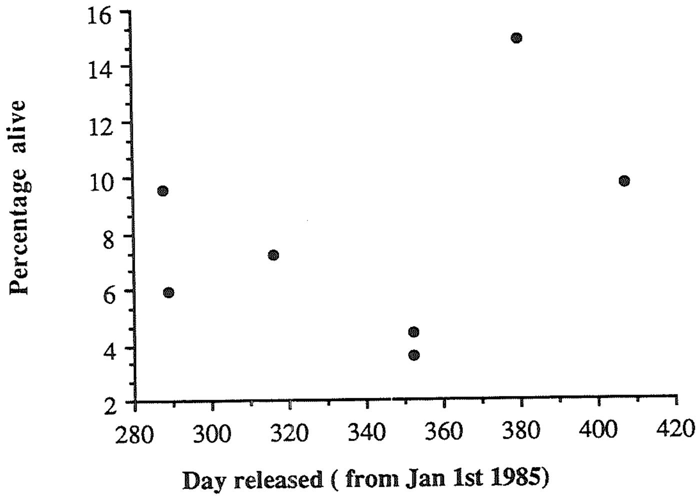

Figure 2. Percentages of live scallops recaptured from tagging experiments.

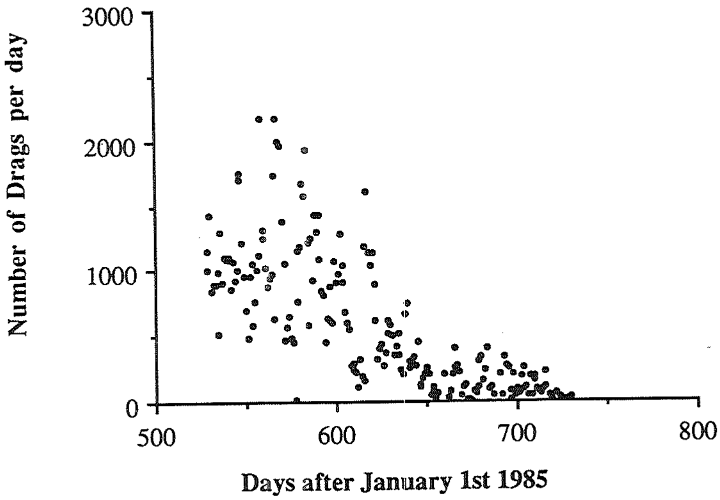

Figure 3. Fishing effort Banks Strait, 1986.

PLANNING OF MARK–RECAPTURE EXPERIMENTS TO ESTIMATE POPULATION ABUNDANCE IN FRESHWATER FISHERIES

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Several ratio-type procedures for estimating population abundance from mark–recapture experiments have been developed in freshwater fisheries studies. The most basic of these is the Petersen (1896) ratio method, in which a sample of fish is marked and released, then the population is subsequently resampled. The population is then estimated from the relationship:

$$\frac{\text{Number marked}}{\text{Population size}} = \frac{\text{Number recaptured}}{\text{Recapture sample size}}$$

Derivations of the Petersen procedure include multiple mark–recapture experiments, and binomial sampling methods as in scuba-diver observation or angling catch-and-release programs, with marked fish populations.

These ratio procedures are subject to a set of assumptions that can lead to problems. Mortality of marked fish must be at the same rate as the unmarked population; tags or other marks must not be lost or missed in sampling; catchability of marked and unmarked fish must be equal; marked fish (or at least the recaptures) must be randomly or uniformly distributed; and there must be no recruitment in the period of the experiment. These assumptions can be hard to satisfy, or the necessary estimates of deviation from them, for example rates of mark loss or recruitment, can be difficult to derive. But the problems may be less severe in freshwater fisheries because the habitats are often relatively small or more or less enclosed, and fish movements can more easily be monitored than in marine fisheries. Clearly though, in any habitat type there is a need to minimise the period between marking and recapture, provided sufficient time has elapsed to allow the return of marked fish to normal behaviour patterns.

Variance can be estimated for abundance estimates and, if there is some indication of the likely population size, this can be used to give the sample sizes required for the marked and recapture groups. Published charts giving such sample sizes are available (Robson and Regier 1964). These, together with knowledge on the catch rates of sampling gear, enable reasonably good project budgeting.

Furthermore, such preliminary rough calculation can help to avoid the negative bias associated with small samples, since the bias falls to acceptable levels when the product of the marked and recaptured samples exceeds four times the population size.

The type of mark to be used needs to be considered in relation to the assumptions of the method. If tags are used that influence activity rates at the recapture time, for example by suppressing feeding, or through persistent tag-wound irritation caused by tag movement or materials that are not physiologically inert, then catchability of marked and unmarked fish will not be equal for most types of sampling gear. Similarly, large tags or other radical marks may cause unnaturally high rates of predation among marked fish.

Therefore it is important to choose the marking system least likely to disturb the behaviour of the fish, consistent with the ability to detect marks at recapture time. The in-dwelling magnetised micro-wire tag and, in short-term studies, simple fin-clipping procedures, appear to be particularly suitable. Both marks have the added advantage of being suitable for use in small fishes.

Some fish-marking programs use anaesthetics and antiseptic baths. But anaesthetics prolong the process and introduce a potent new stressor of the fish. Similarly, the use of antiseptics prolongs handling time, may have adverse physiological effects, and contributes little. Better results are available through selecting the best marking system, using reasonable hygiene, and reducing all forms of handling to the absolute minimum.

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SPECIFIC TAGGING PROBLEMS RELATED TO SHARKS AND OTHER LARGE PELAGICS

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One of the first problems in any tagging experiment is the ability to capture sufficient numbers of animals. Sampling methods for sharks and other large pelagics are generally limited to hook and line or gillnet. Most large pelagics either avoid trawls or are not abundant at depths fished by this gear.

Hook-and-line fishing, such as longlining, is generally subject to low catch rates, which is compounded by generally lower densities associated with apex predators. Hook-and-line methods need to exploit any schooling or aggregating behaviour of the target species, such as burleying or pole-and-line fishing.

Although gillnets are often efficient at catching large pelagic species they also result in higher fishing-induced mortality. Many pelagics employ ram-jet ventilation and die fairly quickly if immobilised by a gillnet. Lengths and setting times for gillnets have to be a compromise between catching sufficient numbers and maintaining suitable condition for tagging. Capture stress may also be greater in pelagic species which tend to be more active and which in some cases have higher metabolic rates. In the case of large sharks, removing them from their supporting medium may cause internal rupture due to the weight of the internal organs. This may limit the tagging method and tag type to one which can be used while the species is still in the water. In the Northern Pelagic Program the return rate was significantly higher from hook-and-line-tagged sharks than from ones caught by gillnet. Growth rates from tagging were lower than those obtained from vertebral ageing, suggesting capture stress or that the tag was adversely affecting the sharks in some way.

Experiments to evaluate tag mortality and tag shedding are complicated by the difficulties in keeping large pelagic species in captivity. Many sharks and some billfish also present a real hazard to the unwary tagger, and may necessitate specific handling methods.

DISCUSSION OF SESSION 2

Recorded by W.S. Hearn* and A.E. Caton[+]
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In expanding on his written panel presentation, Jacek Majkowski used the CSIRO southern bluefin tuna tagging program to illustrate various aspects of the planning process. General information on a population, i.e. stock structure, growth, mortality rate and migration patterns, tend to be first addressed by tagging programs; then, more specific problems on fishery interaction and/or yield-per-recruit are considered. This was the case for southern bluefin tuna. In the 1960s CSIRO looked at fish movements, migrations, total mortality, and so on. However, yield-per-recruit and fishery interaction questions could not be reliably addressed. Jacek explained that as a consequence the 1983-84 southern bluefin tuna project used the groundwork from the 50 000 fish tagged during the 1960s, but was specifically oriented towards yield-per-recruit and fishery interaction aspects. Releases were necessary off Western Australia and South Australia to examine the impact of each of those fisheries on the other. In contrast, a study of patterns of recruitment might be examined by annual releases of tagged fish off the west coast of Western Australia alone. Jacek used these two examples to highlight how different objectives would demand different operational plans; furthermore, a project design addressing the yield-per-recruit/interaction objectives might be quite inadequate for examining patterns of recruitment. While it was not imperative that preliminary pilot studies, be they small or substantial, should precede more specific projects, the background experience from the 1960s southern bluefin tuna work, with its ongoing tag recoveries for many years, had enabled the incorporation of valuable design adjustments in the subsequent, more specific project. For example, the number of fish tagged from each school was restricted, so that tagging and releasing would be spread through more schools, thereby improving representativeness. It was also possible to improve considerably on technical and publicity/liaison aspects of the work, thereby reducing tag shedding by a factor of three and improving reporting rate. Returning to general considerations of the tagging project design, Jacek emphasised the need to determine the number of fish to be released to provide acceptable levels of precision in population parameters obtained. He pointed out that pilot studies provided a basis for estimating likely rates of recaptures, tag shedding, tagging mortality, non-reporting etc., so that a follow-on project would have more chance of achieving objectives.

Referring to Jacek's comments about the special problems posed by the study of long-lived animals, Albert Caton mentioned the long time-frame in which previous southern bluefin tuna tag recoveries were received by CSIRO. He asked how, in the planning phase for the recent project, CSIRO approached the dilemma of ensuring that the project would survive in the organisation for the many years necessary to obtain the long-term recoveries required for a thorough yield-per-recruit analysis. Jacek Majkowski commented that the fact that CSIRO had had an ongoing, though fluctuating, commitment to southern bluefin tuna research since 1938 gave scope for optimism, during the planning phase for the new project, that support would continue. However, he acknowledged the difficulty of ensuring ongoing resources for processing and analysing information in the present reality, especially where external funding had been required for the work. CSIRO was trying to ensure continued support, but could not guarantee it. Peter Young added that no research organisation could guarantee continuing interest in today's work; furthermore, today there is an increasing emphasis on applied research, to the extent that funding for research tends to be controlled by catchers. From that viewpoint, if the information is required by industry, it should be funded by levy, and the provision of long-term support may ultimately be the responsibility of the relevant management group rather than a scientific organisation. He pointed out that a similar philosophy had already been adopted for the maintenance of logbook collections. Jacek Majkowski cautioned that, like priorities of research organisations, management priorities could also change, with implications for long-term projects.

Tony Harrison referred to the planning oversight in the scallop project, where provision had not been made to alert processing staff about the presence of tags. He commented that the problems encountered highlighted the need, when planning, to know not just the biology of the animal and how it might respond to tags, but also to understand the nature and outlook of the tag finders. Richard Tilzey was amazed that in the scallop project tag-finders were not offered some form of reward; if returns were to be promoted from 'outsiders' then rewards would be paramount. He emphasised that reward costs were negligible compared with the overall expenses usually associated with tagging programs. Julian Pepperell drew attention to the desirability, when planning, of making suitable allowance for data quality. He had recently attended a tagging symposium in Washington where assessment of data quality was considered. Double punching and random audits of data had decreased the incidence of data entry errors from 9.86/1000 to 0.4/1000 at very low cost relative to cost of release of the tagged fish or cost per tag recovery. While accepting Julian's point about the desirability of making suitable provision for data quality, Jacek Majkowski suggested that cost per tag recovered was an inappropriate measure of a tagging project's effectiveness. He reiterated Bob Kearney's comment that tagging is a tool. Consequently, evaluation of the success of a tagging project should be addressed in the context of the entire cost of getting the information required, that is by looking at the final product and its cost. A project may have been carried out cheaply, with a high recovery rate, yet may not have successfully provided the information for which it was established.

Complications associated with the analysis of tag recovery data were raised. Terry Walker remarked that age-curves obtained from tagging can be biased. For example it was necessary to be cautious of the effects of net selectivity when examining growth of gillnet-caught fish; small fish swim through the net, at an older age they become vulnerable, then later they bounce off the net. Overall there is a greater tendency for slow growers to be vulnerable for a longer period, so that generating an age-length relationship from tag recoveries tends to underestimate growth. John Glaister asked for Jacek Majkowski's impressions about the Peterson approach of using tagging for estimating population size. Jacek did not think there had been many successful attempts to estimate absolute abundances from tagging. In the Petersen approach, complete mixing of tagged and untagged individuals is required, but this mixing condition was often not satisfied. This was the case when he had attempted to estimate the local abundances of southern bluefin tuna off Western Australia, South Australia and New South Wales from tagging. Ron Thresher asked the audience if anyone had successfully estimated population size from tagging. Only Bob Kearney and John Harris replied in the affirmative. David Gwyther suggested, and Peter Young agreed, that a more useful indication of scallop abundance could be obtained from the number of vessels operating and the number of bags of scallops landed, given the localisation and relatively short duration of the fishery.

The Session's emphasis was on planning and implementation of projects, but the presentations prompted several questions on techniques. John Glaister asked if recovery rates for scallops were affected by the time of day when they were tagged - there could be predator implications. Peter Young replied that that aspect had not yet been analysed. John Beumer mentioned, and John Harris agreed, that when tagging eels, night or day, one could not practically avoid the use of anaesthetics. John Anderson asked if there was any published evidence of anaesthetics and antiseptics not giving a better recovery rate. John Harris was not aware of comparative studies but indicated that in some instances there could be an adverse effect with the anaesthetic MS222 in physiological studies. He felt it better not to risk imposing such an additional stress. Adam Smith noted that yellowtail kingfish that were handled without anaesthesis would often damage themselves. John Harris suggested that there was probably a time component, particularly with fish that tended to 'drum' and hence damage themselves. Ron Thresher advised that in some experiments the use of MS222 and quinalone on captive fish had no short-term effect but there had certainly been long-term major differences.

Turning to techniques employed for tagging sharks, Julian Pepperell asked if tags with steel heads inflicted more damage than those with nylon dart heads, particularly on large sharks. John Stevens thought that tag head type was not a problem for sharks up to 5-6 feet. Beyond that size the main consideration was not tag types but the fact that, given the sheer physical difficulty of removing sharks from the water, they may suffer internal damage because of the lack of the water's support. In response to David Hall, he indicated that there were significantly higher recoveries from sharks caught for tagging by hook and line rather than gillnets. John Beumer inquired if there was any consideration of line breaking-strain and time played with respect to stress. John Stevens advised that usually a strong handline had been employed in his project and sharks were hauled in quickly; however, it was possible that damage might still result after a short tussle if the sharks were subsequently very active on deck. He mentioned in passing, that a number of sailfish recaptures had involved fish which had been tagged and released after they had been played for a considerable time on light tackle.

In closing Session 2, Ron Thresher commented that there were indications from the presentations during the session that all tagging programs seemed to involve compromise to some degree: what objectives to address, what parameters to determine, the tags available etc. Hence, interpretation was always likely to be compromised to some degree. It also appeared that there could be advantages in carrying out multiple experiments, initially to get an overview and conducting more 'refined' and directed projects.

SESSION 3

TAGS: TYPES AND USES

Session Chairman:	R.J. Tilzey
Session Panellists:	J.G. Pepperell
	B.A. Ingram
	P. Jernakoff
	J.P. Glaister
	P.E. McShane
	C.M. MacDonald

CHAIRMAN'S INTRODUCTION

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As the erudite Dr Glaister will be detailing in his introduction to Session 4, the first recorded observations on marking fish were by Dame Juliana Berners (alias Izaac Walton) in 1653, who commented on the habit of piscatorial poms attaching ribbons and the like to startled seabound salmon. However, it is only in this century that fish tagging has been practised extensively, beginning with Petersen's experiments on North Sea plaice. After experimenting with punched holes and other mutilations, Petersen devised a pair of discs to mark each plaice, and tags of that type still bear his name. In those days necessity was very much the mother of invention. Continuing innovation, together with an expanding range of suitable artificial materials and improved technology, have resulted in a wide choice of marking devices for today's scientists. The question of whether Dame Juliana was in fact Izaac is still deliberated by fishy bibliophiles. The question of what type of tag to select for the task in hand now requires increasing deliberation because of the wide variety available. In general, the type of tag selected is very much dependent upon the species to be marked and the nature and objectives of the experiment.

Thomson's (1962) review of the marking of marine animals in Australia listed 11 types of tag (excluding fin-clipping, hole-punching etc.). Whereas the questionnaire used to gather the data for today's workshop only contains 10 tag categories (again excluding fin-clips, tetracycline marking etc.), it should be remembered that some categories contain a wide variety of tags and the number of 'types' is considerable. Spaghetti tags, for example, embrace numerous anchoring devices from a simple barb or T-bar to metal heads of varying complexity. A glance at the range of marks on display produced by the Australian company Hallprint Pty Ltd suffices as an indication of the variety of so-called 'standard' tags available.

Today's techniques go far beyond simply affixing a mark onto the study animal. The announcement papers for the International Symposium and Educational Workshop on Fish-Marking Techniques held at Washington University on 27 June - 1 July 1988 noted that 'Fish marking technologies have rapidly improved and diversified in recent years. They embrace physics, electronics, chemistry, genetics and morphology'. One of the panellists, Julian Pepperell, attended this symposium and is thus in a position to inform us of the information tabled. One of the first questions to be asked is that of whether a technological gap exists between overseas researchers and those in Australia, i.e. are the most recent technologies available in Australia?

An appraisal of the subject matter of some of the papers under consideration for the above Symposium serves as a useful guide to the directions in which fish marking technologies may be heading. The session on 'External Tags and Marks' covered attachment tags, mutilation, meristic characters, branding, pigments and dyes, and scale patterns; that on 'Internal Tags and Marks' included non-chemical otolith marks, parasites, and several papers on coded wire tags (CWT) which embraced a wide species range; that on 'Electronic Tags' included passive integrated transponder (PIT), ultrasonic and radio tags, the last two being largely used for behavioural and physiological studies and PIT tags for a variety of purposes; that on 'Genetic Marks' included protein-coding genes, genetic marks in mixed stocks, mitochondrial and nuclear DNA, chromosomes, intentional genetic marking and immunogenetic marks, with most studies centring on the identification of cultured as against wild stocks; and that on 'Chemical Marks' included natural and induced marks using tetracycline, fluorescent calcein etc.

From an Australian perspective, the number of fish marked in some North American programs is extremely large. For example, coded wire tags (CWTs) are now used to mark about 42 million fish per year in north west America alone. Although about 250 000 mark combinations are available for these tags, the sheer number used necessitates a marking committee, comprising members from the States involved, limiting new code use to 1600 per annum. The main aim of this program is to assess the contribution of hatchery releases to wild salmonid stocks and, as 319 hatcheries are involved, the mean number of codes per hatchery is thus only 5 per annum. Over 25 million Alaskan salmon fingerlings have been marked with CWTs thus far. Such large releases have been facilitated by the development of this cheap (about 10 cents per fish), easily applied tag suitable for marking fish as small as 0.22 g whole weight.

PIT tags are another recent advance, being both suitable for marking fish as small as 1.3 g and having a virtually unlimited number (34 billion) of code combinations. However, it should not be assumed that such 'high-tech' marks are infallible, or markedly superior to more 'standard' marks, under all conditions. PIT tags have only been in use since 1986 and their longevity under field conditions has not yet been proven. A recent study of striped bass off the east coast of North America garnered 500 recaptures from 1.3 million CWT-marked fish, as against 500 recaptures from only 23 000 external-anchor-tagged fish. The detection of recaptures of CWT- and PIT-marked fish is usually limited to specific venues containing specialised electronic detectors through which the fish must pass. Once again, it is very much a case of 'horses for courses', with the most suitable tag type for a particular experiment usually being determined by a number of practical considerations, of which the mode of recovery is only one.

It is evident that many of the marks referred to above have yet to be assessed or employed in Australia. The proposed US Manual of Fish Marking Techniques, which will in part emanate from the above symposium, may well prove to be of substantial use in evaluating the suitability of such marks/techniques for Australian fisheries. PIT tags, for example, would appear eminently suitable for use with many Australian species but have, to my knowledge, only been tried in crown of thorns starfish thus far. The further question of Australia producing a separate manual or offering information for inclusion in the US Manual should be addressed by this workshop.

The choice of tag ultimately depends on the question(s) to be addressed by its use and the type of beast to be marked. The panellists' experience embraces a wide range of tag types and a wide range of taxa. Julian Pepperell will provide an update on the fish marks described during the US Symposium, as well as considering the use of external spaghetti tags in marine gamefish. Brett Ingram will describe the use of binary-coded wire tags for small freshwater fish, and Peter Jernakoff the electromagnetic tagging of rock lobsters. John Glaister will summarise prawn tagging, and Paul McShane the tagging of abalone.

Jasper Trendall, who is unable to attend the Workshop, has provided a report on anchor, loop and adhesive tags for rock lobsters. Clive Keenan and Murray MacDonald will prepare a report on genetic tags for incorporation in the Workshop Proceedings. The panellists' summaries do not encompass the utilisation of chemical or parasitic markers, but hopefully the ensuing debate will touch upon these subjects.

Reference

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TAGS USED ON COOPERATIVE TAGGING PROGRAMS: PROS AND CONS

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The Australian cooperative gamefish tagging program is modelled on the successful system pioneered in the 1950s by Frank Mather III of the Woods Hole Oceanographic Institute, Massachussetts (Mather 1963). The system relies on recreational anglers voluntarily tagging large marine gamefish which would otherwise be prohibitively expensive to attempt.

All recognised species of marine gamefishes are eligible for tagging under the program, but the main species tagged are: yellowtail kingfish (9600), black marlin (9500), skipjack tuna (7000) and dolphin fish (6500).

During the program, which commenced in 1974, over 9000 individuals have tagged a total of 66 000 marine gamefish, of which more than 1300 have been recaptured.

Gamefish are tagged around most of the Australian coast, as well as around Papua New Guinea, the Persian Gulf and Kenya.

The program has assisted considerably in determining movements and stock structure of a number of species, including black marlin, yellowtail kingfish and yellowfin tuna.

Three quite different types of plastic dart/anchor tags have been used. These include several variants of the standard nylon barbed tuna dart tag, T-bar anchor tags and stainless-steel-headed dart tags.

Evaluation of tag types throughout programs such as this can be, and probably have been, confounded by a number of uncontrolled variables, including: changes in susceptibility to recapture with time of a given species; changes in geographic localities of tagging activities; changing tagging personnel; changes in size distributions of a given species tagged; and changes in proportions of recaptures actually reported.

Because of these potential effects, I have concentrated on large differences in tag performance, as measured by recapture rate, and rate of decline of reported recaptures with time.

Some clear-cut advantages and/or disadvantages could be determined which may assist in choosing tags to be used in future studies. In this case, tuna dart tags with robust, stiff-barbed heads gave the best results. A new solid, polyethylene dart tag performed as well as, if not better than, tubular polyvinyl models. T-anchor tags, while showing good recapture rates, suffered very rapid declines in recaptures with time, and are therefore not recommended for long-term angler-based programs. Recapture rates for steel anchor tags were at least as high as for tuna dart tags, and retention rates were better. Tag separation of steel anchor tags suggests that their design can still be improved, and a new model is now in use.

The program has shown that cooperative tagging by recreational anglers can and does provide information which would otherwise be very difficult to achieve.

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AN OVERVIEW OF THE INTERNATIONAL FISH-MARKING SYMPOSIUM, SEATTLE, WASHINGTON, 27 JUNE – 1 JULY 1988

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The International Symposium and Educational Workshop on Fish-Marking Techniques was held at the University of Washington, Seattle from 27 June through 1 July 1988. Sponsored by the American Fisheries Society and the US Fish and Wildlife Service, the meeting brought together over 300 participants from 22 countries. In all, 75 papers were presented and 43 posters displayed, and all major tag and equipment manufacturers were represented.

The location of the venue (the north-western United States) ensured a strong input from salmonid workers, but many other fisheries were covered, including tuna, billfish, mackerel, drum, bass, sturgeon, herring, prawns, crabs and lobsters.

Most external and internal fish-marking methods were covered, from natural marks such as parasites, through fluorescent dyes, freeze-brands, tattoos and, of course, physical tags.

Some exciting developments were outlined which will no doubt be applied to Australian situations in the near future. These include:

1. *Thermalotolithography.* This is a somewhat facetious term describing the 'marking' of otoliths in newly hatched captive fish by manipulating their thermal environment in a predetermined pattern. 'Designer' otoliths can be produced in batches of fish which will be instantly recognisable later. The main drawback of the method is the time taken to process otoliths for reading, about 25 per day at present.

2. *PIT, or Passive Integrated Transponder tags.* Recent advances in construction have produced a glass-encapsulated tag measuring 12 x 2.1 mm. There are 34 x 109 individual codes possible, and exhaustive tests on salmonids indicate very high retention of internally inserted tags. No effects on mortality or growth rates have been detected after 19 months. Costs continue to come down, with small quantities now costing $US5-$US8 per tag, or orders of 60 000 or more costing $US3.25 per tag. Costs are expected to reach about $US1.00 per tag in the near future. The main limitation of the system at present is the maximum distance for activation and response of the tag: at present the tagged fish must pass within 8 cm of the activator.

3. *Coded wire tags.* These continue to be used in increasingly wide applications, but most effort by far is directed towards salmonids. Last year, 42 million salmon, as small as 0.22 g, were tagged from 319 hatcheries along the western seaboard of North America. Over 1600 new codes are used each year, and a central mark-processing centre was seen as an urgent need! Millions of spiny-rayed fishes, such as striped bass, are also tagged in hatcheries with coded wire tags. A suitable identifying external mark has, however, yet to be found.

Good design of tagging experiments was often stressed, but one paper touched on an often overlooked area, that of quality control and assurance during field tagging exercises. A standard operating procedures manual, together with independent field audits and double keypunching, reduced error recording rates from 9.86 per 1000 to 0.4 per 1000 for as low as 1% of the field budget.

Rewards for tagging programs, follow-up, port sampling and so on, were often stressed. Hats were found to be desirable rewards for several large-scale programs, while lotteries increased tag reporting, especially in developing countries.

The Proceedings of the Symposium will take the form of one volume of fully peer-reviewed papers, and will be published in 1989 by the American Fisheries Society. In addition, a manual of tagging methods will be condensed from the Symposium and also published in 1989.

I believe that these publications will be very important additions to the libraries of all individuals and organisations engaging in fish identification both now and in the future.

USE OF BINARY-CODED WIRE TAGS FOR MARKING JUVENILE FISH

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Magnetised stainless-steel binary-coded wire tags (Northwest Marine Technology Inc.) have been used to mark a wide variety of animals including polychaetes, shellfish, prawns, lobsters, crabs, reptiles and fish. They have been particularly successful in the large-scale tagging of small salmonids where normal tagging rates are between 500 and 800 fish per hour and retention is as high as 94% after 2 years. The main advantage of wire tags is that large numbers of small fish can be batch-tagged quickly and easily, which makes them ideal for assessment and management of fisheries stocks, particularly to identify groups of stocked fish released into the wild. Tags are biologically inert and are reported not to affect survival, growth and behaviour. They offer a viable alternative to the use of stains and dyes.

The tag injector automatically cuts tags from a wire spool, magnetises and injects tags through a 24-gauge needle. The standard tag size is 1.07 mm long by 0.25 mm diameter but lengths of 0.53 mm, 1.6 mm and 2.13 mm can be selected by the user. The standard tag can carry up to 262 144 different notched codes. Tagging sites used in fish include the snout cartilage (such as with salmonids), body and cheek muscle, and the body cavity. Tags are detected by either X-ray or electronic metal detector. Generally, tags are batch-coded though serial tags are available but expensive. One disadvantage of implanted wire tags is that once a tag is detected, the fish has to be sacrificed to retrieve the tag. A more expensive internal tag, which can be read by X-ray, is also available.

In April 1988, preliminary experiments were carried out at the Inland Fisheries Research Station to determine the suitability of binary-coded wire tags for marking fish prior to stocking. Golden perch fry (length range, 19.9-34.1 mm; average length, 28.0 mm) and fingerlings (length range, 54.0-71.2 mm; average length, 60.6 mm), and silver perch fry (length range, 24.0-34.8 mm; average length, 31.5 mm) and fingerlings (length range, 49.7-67.4 mm; average length, 60.0 mm) were used. To determine short-term tag retention and survival, 60 fish of each species and size were anaesthetised and tagged in either the right cheek muscle or the caudal peduncle. Fry were too small for caudal peduncle tags to be implanted. Equal numbers of control fish were kept without tags. All fish were held in aquaria for 30 days after tagging. A further 400 fish of each species and size were tagged in the right cheek muscle and transferred to fry ponds to determine tag retention over 12 months.

Tagging trials involved three operators: an anaesthetist, plus one to tag fish and another to verify implantation and supervise recovery. Fingerlings could be tagged at a rate of 330-480 per hour and fry at 120-460 per hour. For every 30 fish tagged, 1-4 were rejected due to excessive handling, incorrect implantation or failure to recover.

After 30 days, no significant difference in survival ($p > 0.05$) was observed between tagged and non-tagged fish. No tagged fish showed signs of infection of the wound. However, the majority of both tagged and control silver perch fingerlings died due to white spot infections, which were probably brought on by handling and overcrowding. Tag retention was significantly affected by size of fish ($p < 0.05$). Golden perch and silver perch fingerlings retained 100% of cheek-implanted tags. In comparison, tag retention was 55.2-89.6% in golden perch fry and 75.0-85.7% in silver perch fry. Tag retention in fingerlings tagged in the caudal peduncle was 96.7-100% in both species.

High tag retention in salmonids is achieved by implanting tags in the snout cartilage. Snout tagging is not practicable for golden perch and silver perch due to their small size and low proportion of cartilage in the snout. Tags implanted in muscle tissue are liable to migration and, if implanted close to the skin, may fall out. Thus, poor positioning of tags in the smaller fish probably accounted for the higher tag loss. Tag retention in fingerlings tagged in the caudal peduncle was high but this site was not preferred as it is not suitable for fry. Moreover it is part of the edible portion of the fish and may pose a health problem. Though the larger fish were more suitable for tagging, it is expected that both tag retention and tagging rate could be improved for smaller fish as operators become more proficient.

The feasibility of binary-coded wire tags appears to be limited by the size and number of fish that can be tagged effectively, although these preliminary results compare favourably with those obtained using other species.

ELECTROMAGNETIC TAGS FOR ROCK LOBSTERS

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Electromagnetic tags have been used to track the movement of rock lobsters in areas where sonic methods are inappropriate. For example, Ramm (1980) first developed and used electromagnetic tags to plot the den positions of the southern rock lobster (*Jasus novaehollandiae*) in areas where sonic tags, with a nominal maximum range of detection in water of 1-2 km, proved to have a range of less than 2 m. The tags have also been successfully used to study the foraging movements and activity of the western rock lobster (*Panulirus cygnus*) (Phillips *et al.* 1984; Jernakoff 1987 a, b; Jernakoff *et al.* 1987; Jernakoff and Phillips 1988). *P. cygnus* lives in habitat similar to that of the southern rock lobster, i.e. in caves and under ledges of limestone reefs surrounded by seagrass.

Electromagnetic tracking is based on the transmission and detection of low frequency (31 kHz) electromagnetic pulses. The tags are about 4 cm long, 3 cm wide and 2 cm high. They are enclosed in araldite and are neutrally buoyant. They are saddle-shaped to fit onto the carapace of rock lobsters and are attached with an epoxy glue that sets under water. Each tag is powered by a lithium battery activated by a magnetic switch. Battery life is about 3 weeks of continuous transmission but this varied depending upon the duration of the signal pulse, which can range from about 1 s to about 4 s.

The electromagnetic tags, like sonic tags, require a tracking system. Signals from the tags are picked up by aerials laid on the seabed. As the detection distance of the tags is only 6 m, aerials are usually laid in a grid network with each aerial unit comprising a 12-m x 12-m square with a 6-m gap between it and adjacent aerials. Thus if a lobster is within an aerial unit, its signal is picked up by at least one side of the square; if it is between aerials, its signal is picked up by both aerials.

While tag design has remained basically the same since the tags were first designed, the sophistication of the tracking system has increased. The signals from the tags were originally decoded manually with an oscilloscope. Development of an automated tracking system means that up to 14 tagged lobsters can be tracked simultaneously. In addition, the automated system can identify up to six different (and unique) tag signals within one aerial unit. Thus a major advantage of the tags and associated tracking system is that they can continuously collect quantitative data on movements and activity.

The disadvantage of the tags and tracking system is that the small detection range of the signals means that many aerials are needed to cover a representative area of sea floor. Also, cables must connect the aerials to the tracking system on the shore, and both cables and aerials require extensive maintenance to counteract damage by wave action and currents. Thus this tag-tracking system is feasible only in comparatively calm and shallow environments.

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TAG TYPES AND USES – PENAEID PRAWNS

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Tagging has long been a principal technique in the study of movements, growth and mortality of aquatic animals. Penaeid prawn tagging is a more recent innovation probably originating in the Gulf of Mexico in the 1930s (Lindner and Anderson 1956). Prawns present several technical problems. First, they are small and easily damaged, so tagging, itself, can cause mortality. Second, prawns grow by moulting and may shed the tag, while any disturbance to the moulting process (by the tag) can produce additional mortality. Finally, there is always the problem of non-reporting of tagged animals, especially from such a small animal, caught and handled in bulk.

Publicity, liaison, reward for tagged prawns, and supplying information on their recovery, improve the reporting rate for tags. Further liaison, including industry feedback, needs to be continued after the last reported recapture, to ensure public awareness for the duration of the study. As tagging results are useful in management decisions the cooperation of industry is generally affirmed, and the reporting of tags assumed to be maximal.

Two main tagging methods allow either individuals or groups (batch tagging) to be distinguished. Examples of the latter method include immersion in, or injection of, vital stains or pigments, as used by Racek (1956) and Klima (1965). However, growth studies usually require individual recognition. Some workers have used small, numbered internal tags coupled with a recognition dye (e.g. Neal 1970). However, most work has concentrated on the use of external tags.

Lindner and Anderson (1956) applied Petersen discs to *P. setiferus.* Dawson (1957) and Allen and Costello (1962), however, suspected the Petersen tag of causing physical damage and retarding swimming ability. The wound repair process with Petersen tags has been described by Fontaine (1971), Fontaine and Lightner (1973) and Fontaine and Dyjak (1973); it involves the inward projection of the exoskeleton with successive moults until a complete tube is formed and the tag pin becomes external to the prawn's tissues. They have further suggested that long-term survival is related to the success of this repair. Although recognised as having an inevitable effect on moulting, Petersen tags (and their derivatives) have been widely applied in the USA (Lindner and Anderson 1956; Iversen and Jones 1961; Neal 1969), on the Ivory Coast (Garcia *et al.* 1973), in Madagascar (Le Reste and Marcille 1976) and Australia (Lucas *et al.* 1972; Penn 1975; Potter 1975). Application of prophylatic wide-spectrum antibiotic cream to the tagging needles has also been recommended to reduce necrosis at the wound site.

A tag thought to be less traumatic in its effect on prawns was first trialed in 1873 by Atkins on Atlantic salmon (Jakobsson 1970). When applied to prawns a nylon thread passed through the abdominal musculature is tied in a loop and attached to a numbered plastic disc. This tag has been experimentally successful in the USA (Allen and Costello 1962), and in Australia (Ruello 1970, 1975, 1977; Glaister 1978). A derivative of the Atkins tag which is simply tied around the carapace has also been reported as successful by Tiews (1967). Ruello (1970) reported zero initial tagging mortality and optimistically suggested that the tag did not adversely affect long-term survival. Glaister (1978), however, found an initial mortality of 8% and a further 4% over a 96-h period, due to the effects of tagging. Glaister further reported, as did Penn (1975), that the injury inflicted by the tagging process on some prawns was severe. The flexibility of the nylon thread was, however, thought to be a considerable improvement over the rigid pin of the Petersen tag when considering the extent of wounding. A further development in this regard has been the flexible vinyl streamer tag of Marullo *et al.* (1976). This tag had the advantage of a reduction in handling time, of not damaging the abdominal tissues excessively, and not hindering mobility of the prawns (Garcia and Le Reste 1981). To date it appears to be the most effective external tag for marking of prawns (Garcia and Le Reste 1980) and is now available in a range of sizes, shapes, colours and needle gauges. Penn (1981) provided a comprehensive description of the principal Australian prawn tagging studies.

Small, monel-metal,numbered eyestalk tags have been tried with some success in the identification of individual broodstock prawns in aquaculture experiments (I. Smith, pers. comm.). Care, however, is needed in application as damage to the eyestalk can cause mortalities or hormonal imbalance. Recent innovations in binary-coded wire microtags also offer opportunities for successful tagging of penaeid prawns. However, tag detection remains a problem in any large-scale wild-stock experiments. This would also be the case for genetic markers.

In most examples cited above, when authors have accepted the possibility of mortality due to the tagging process, they have been optimistic regarding the longer-term effects, although most concede an initial mortality. Penn (1975) suggested initial mortality could be reduced by holding tagged prawns for 1-2 h to eliminate weaker prawns prior to release. Conversely, other workers have suggested that unnecessary delay in release of tagged animals can lead to higher mortalities as a result of overcrowding stress (Lucas *et al.* 1972). A certain degree of tag mortality is implicit in all tagging experiments directed towards estimates of total mortality and fishing mortality (Garcia and Le Reste 1981).

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TAGGING ABALONE

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Abalone are herbivorous shellfish common on coastal reefs in temperate waters of the world (Cox 1962; Mottet 1978). The considerable commercial value of abalone has prompted many studies of their population biology. Tagging is a time- honoured technique used by fisheries biologists to estimate various population parameters such as growth and mortality. The problem with tags is that they fall off, get eaten, get hidden, or change the behaviour of the animal to which they are attached. In this regard abalone are no different from any other 'fish'.

On the positive side, abalone are relatively easily tagged because adults have a large shell to which tags can be attached. The presence of respiratory pores in the shell simplifies the use of threaded tags. Furthermore, the sedentary behaviour of abalone means that, in general, individuals remain in the area where they were first tagged (Newman 1968; Poore 1972; Beinssen and Powell 1979; McShane 1986) and they can be captured without excessive trauma. Nonetheless, studies involving tagging of abalone have been frustrated by poor recovery of tagged individuals and a failure to satisfactorily tag juveniles. The advantages and disadvantages of various tagging methods applied in studies of abalone are summarised below.

Crofts (1929) first tagged abalone by means of silver wire and celluloid tags. Since then, wire tags have been widely used in studies of growth of abalone (Poore 1972; Shepherd *et al.* 1982; Shepherd and Hearn 1983; McShane *et al.* 1988). Tags attached to wire are attacked by fish and tag loss is considerable (e.g. Shepherd *et al.* 1982; Shepherd and Hearn 1983). Spaghetti tags (Floy Inc.) used by Poore (1972) also attract fish which cause unacceptable tag loss. The advantage of wire tags is that they can be attached underwater with minimal disturbance to the abalone. The main disadvantage is that the tag and wire acts like a 'ball and chain' and may retard growth (McShane *et al.* 1988).

Tags attached to the shell by glue are commonly used for tagging abalone. Various glues have been used including epoxy (Forster 1967; Shepherd and Hearn 1983; McShane *et al.* 1988), underwater-setting glue (Sainsbury 1982; Shepherd *et al.* 1982) or 'superglue' (McShane and Smith 1986). Because most glues need to be applied out of water some disturbance to the abalone is inevitable. But provided the abalone are returned to their natural habitat promptly (within 30 minutes or so), tagging mortality is negligible (McShane and Smith, in press). There can be problems when abalone are removed from the substrate to be tagged. In some cases, where predators are abundant, recently tagged abalone are more susceptible to predation (McShane and Smith 1986). Moreover, in studies of movement, tagging can cause disturbance that prompts spuriously high movement after the tagged abalone have been replaced (Beinssen and Powell 1979). However, glued tags have the advantage that smaller individuals (down to 7 mm shell length) can be successfully tagged (McShane *et al.* 1988).

Polyethylene tags of 6 mm diameter with a four digit number were developed by Hallprint Pty Ltd following a request for small robust tags which could be easily identifiable and recorded underwater. After being glued on, these tags fit close to the shell surface and are more resistant to abrasion and fish attack than the stiffer tags, for example 'dymo' tape or some of the large plastic tags (e.g. Floy Inc.). Even so, loss of glued tags has been estimated as about 20% per annum (McShane and Smith, in press). Most of the tags become detached in the first day or so, but our studies have shown that losses can be minimised if the tags are glued adjacent to the spire and the epibiota has been removed. The biggest problem with small, glued tags is that they can become overgrown with epibiota. Tags on abalone in open, rather than cryptic, habitat are most susceptible to being overgrown. After a year or so tags are, in some cases, found only by scraping the epibiota from the region of tag attachment. Poore (1972) was unable to use glued tags for New Zealand species of abalone because shells were so encrusted with epibiota.

Recently Prince *et al.* (pers. comm.) have used disc tags attached by a plastic rivet through a respiratory pore. This tagging method is similar to that used by Newman (1968) who attached tags to the inside of shells of abalone by means of a nickel pin through a respiratory pore. This technique, together with underwater-setting glue and threaded wire tags, has the advantage of *in situ* application. A disadvantage with these methods is that they are practicable only for adult abalone.

Other tagging methods have been less commonly employed. A novel method of tagging abalone was employed by Tutschulte (1968, 1976). Tiny luminescent beacons were cemented to the shell of abalone, and time-lapse cinematography was used to record the nocturnal excursions of individual abalone. We have used paint, applicable underwater, to mark abalone *in situ* (McShane and Smith, in press). This method is an effective means of monitoring the short-term movements of a population of abalone. The paint is, however, very messy to use and individual abalone are difficult to distinguish.

Leighton (1968) and Tutschulte (1976) filed a notch in the shell margin of abalone so that a small triangular patch of nacre remained exposed on the shell surface following shell growth. Thus the growth rate of 'marked' individuals could be determined by the increase in shell length.

Although abalone are in effect sedentary animals, they live in a heterogeneous habitat. Abalone can hide under boulders, in crevices or can be obscured by seaweed. This occupation of cryptic habitat, and the movement of some abalone away from the study area, contributes to the relatively low recovery rate of tagged abalone even with careful searching.

In conclusion, the choice of tagging method depends on the aims of the study. However, in general the use of small glued tags is recommended because it is the only method employed to date that is applicable to adults and juveniles alike.

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INFLUENCE OF TAG TYPE ON RECAPTURE RATES IN THE TROPICAL ROCK LOBSTER, PANULIRUS ORNATUS*

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Summary

The most commonly used method for studying the movements of spiny lobsters involves tagging or marking individuals and using recapture information to estimate the extent of movements. Many different tagging techniques have been tried, including brands, appendage clips, external attachments, and ultrasonic tags. The interference with the animal that commences with its capture will affect its subsequent behaviour, and the extent to which any behavioural trauma affects the movements of rock lobsters will limit the amount of information on movements that can be inferred from recaptures. Many studies involving tagged rock lobsters have commented on the possibility of tag effects but there have been few attempts to quantify the nature or importance of behavioural changes induced by tagging.

In order to investigate the influence tagging might have on estimates of short-term movements a series of field experiments was undertaken to examine the effects of three tag types (anchor, loop and adhesive tags) on the recapture rates of rock lobsters in the field.

In Tudu Lagoon the standard injection or anchor toggle-tag was associated with a reduction in the observed density of rock lobsters in the study area. It is not possible to say whether this occurred because the rock lobsters moved out of the area or because they retreated into dens inaccessible to divers. During the 6 days of the survey only one tagged lobster was caught by fishermen outside the study area and, although some animals undoubtedly moved, there was no indication that large numbers of tagged rock lobsters left the area. A low-trauma adhesive tagging technique confirmed that capture and handling of the rock lobsters had resulted in immediate changes in behaviour. A much higher proportion (18%) of tagged rock lobsters was recaptured, despite the fact that the survey area was small and few lobsters were tagged.

The different results that were obtained from the anchor and adhesive tags are an indication of the fact that the two types of tag perform different functions and answer different questions. Specifying the effects and limitations of the various types of tags used in mark and recapture studies provides the best possible basis for interpreting the results of fieldwork.

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* Panel presentation requested by Session 3 Chairman. The author was unable to attend.
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Introduction

Most species of palinurid lobster appear to move regularly over distances of up to several kilometers (Herrnkind 1980), and several species are known to undertake larger-scale movements of 100 km or more (Street 1971; Herrnkind and Kanciruk 1978; Moore and MacFarlane 1984). The most commonly used method for studying the movements of spiny lobsters involves tagging or marking individuals and using recapture information to estimate the extent of movements. Many different tagging techniques have been tried, including brands, appendage clips, external attachments, ultrasonic tags and, probably the most widely used, plastic anchor tags inserted dorsally between the cephalothorax and the first abdominal segment (Chittleborough 1974).

The process of tagging a rock lobster usually involves its capture and removal from the water, measurement of carapace length (CL), and determination of its sex and perhaps moult stage. Before the rock lobster can be returned to the water there is further handling and often some unavoidable physical damage associated with injection of the tag. The interference with the animal that commences with its capture will affect its subsequent behaviour. The extent to which any behavioural trauma affects the movements of rock lobsters will limit the amount of information on movements that can be inferred from recaptures. Although almost every study involving tagged rock lobsters has commented on the possibility of tag effects there have been few attempts to quantify the nature or importance of any behavioural changes that are associated with tagging. Tag effects are generally evaluated in terms of direct physical effects, e.g. mortality due to tagging, tag loss, tag mutilation, and the effect of tagging on growth and moulting (Chittleborough 1974; Weingartner 1982). In those studies in which behavioural effects were considered, the work did not attempt to define the types of behavioural changes. For example, Morgan (1974) found that tagged rock lobsters that had been caught in pots were more likely to be recaptured in pots than to be recaptured by scuba divers. Cooper (1970) observed the behaviour of tagged *Homarus americanus* for several hours immediately following release but was unable to detect lasting behavioural changes.

During the course of a program of fieldwork on *Panulirus ornatus* in the Torres Strait, between Australia and Papua New Guinea, it became apparent that, despite regular diving surveys of the area, rock lobsters that had been tagged and released were rarely observed again. One possible explanation was that tagged rock lobsters were moving out of the study area. However, this was not supported by the returns from fishermen of lobsters that were tagged at Tudu Island (Figure 1). Over a period of 18 months, 953 rock lobsters were tagged and 169 returned. Ninety-four percent of recaptured rock lobsters were taken within 2 km of the release site.

In order to investigate the influence tagging might have on estimates of short-term movements a series of field experiments was undertaken to examine the effects of three tag types on the recapture rates of rock lobsters in the field.

Methods and Materials

Three types of tag were used in the fieldwork (Figure 2). Anchor tags were the principal means of tagging lobsters. Rock lobsters larger than 70 mm CL were tagged with western rock lobster tags (Chittleborough 1974), and Hallmark anchor tags were used for lobsters

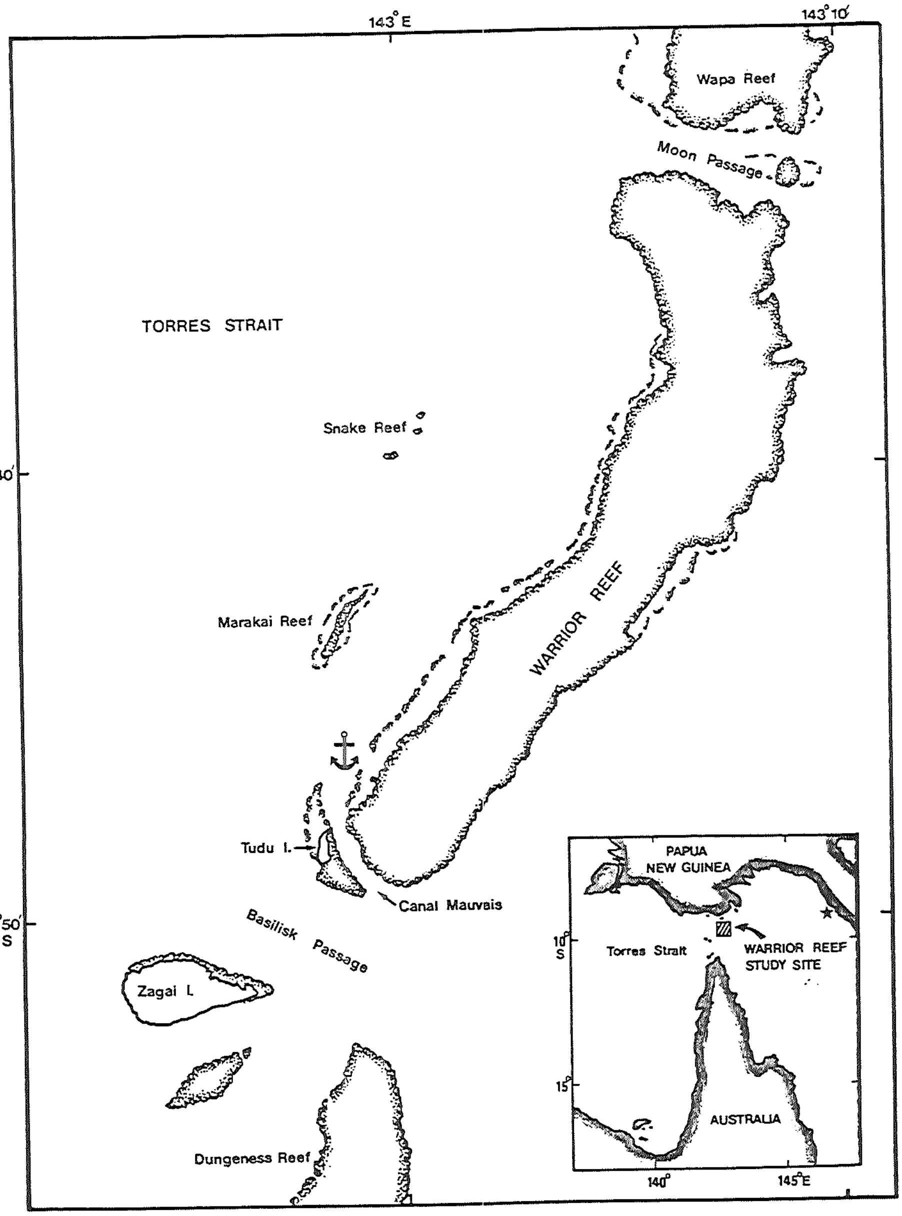

Figure 1. Map indicating the location of Tudu Island and the area in which the study was undertaken.

smaller than 70 mm CL (Figure 2a). These tags were applied out of the water and could not easily be seen by a diver underwater. Two types of antennal tags were used:

1. *Loop antennal tags*. Numbered plastic cable ties looped tightly around the base of the antenna and wedged between the spines (Figure 2b). These tags allowed rock lobsters to be visually identified by divers without removing the animal from its den but could only be applied after removing the rock lobster from its den. All rock lobsters that were injected with anchor tags were also marked with loop tags.

2. *Adhesive antennal tags*. A combination of two-part epoxy and adhesive plaster used to attach numbered streamer tags to the antenna of a lobster (Figure 2c). These tags were capable of lasting for at least 2 weeks and possibly longer. The greatest risk of loss was from breakage of the antenna if the tag became caught among the rocks or coral. Adhesive antennal tags could be applied underwater without removing the rock lobster from its den and they could be easily seen by a diver.

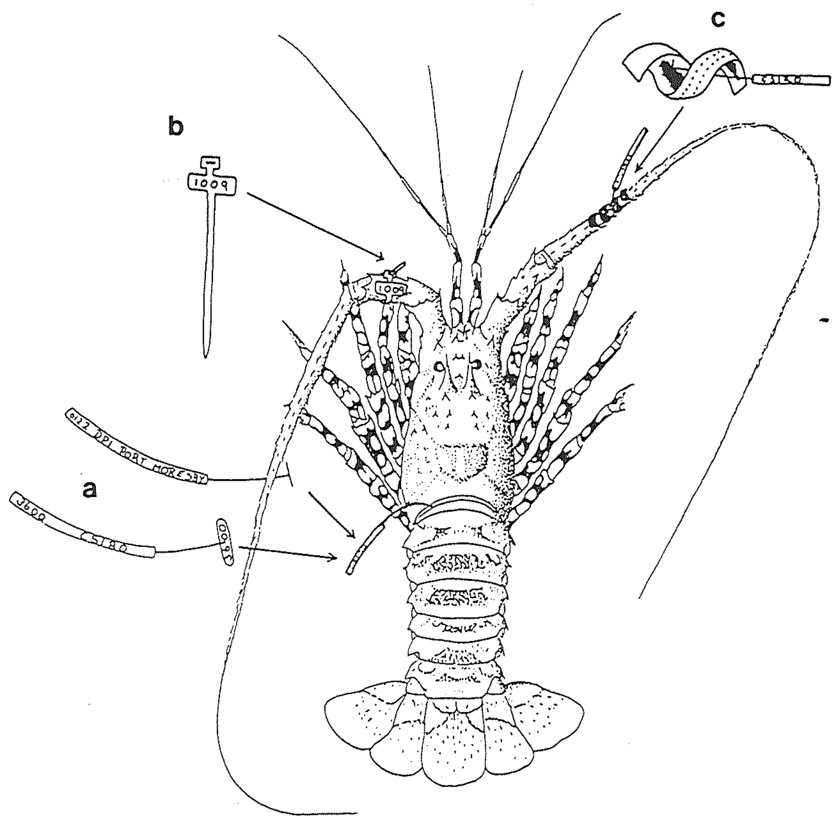

Figure 2. The different types of tags used in the study and their approximate position on the rock lobster: (a) anchor tags; (b) loop antennal tags; (c) adhesive antennal tags.

Sampling Design

The work was undertaken at several sites in the vicinity of Tudu Island in the Torres Strait (Figure 1).

(i) *Anchor tagging*

For 6 consecutive days all the dens in Tudu Lagoon were visually surveyed by divers. The number of rock lobsters in each den was recorded and an attempt was made to catch all animals. If a rock lobster was caught it was taken immediately to a boat, measured, tagged and returned directly to the den from which it had been taken. Once they had been returned some tagged rock lobsters remained in the den but others left shortly afterwards. No attempt was made to record or follow these movements. All the rock lobsters were tagged with both anchor and loop tags. The loop tags allowed divers in subsequent surveys to identify previously tagged animals. No attempt was made to survey areas outside the boundaries of Tudu Lagoon, but records were kept of all tagged animals caught by commercial fishermen working in the vicinity.

(ii) *Loop tagging*

This was carried out in the same area as the anchor-tagging survey but approximately 2 weeks later. For 6 consecutive days all dens in Tudu Lagoon were visually surveyed by divers. The number of rock lobsters in each den was recorded but no attempt was made to catch or disturb animals. On the second and third days of the survey additional rock lobsters (14 and 15 respectively), that had been caught outside the survey area, were loop-tagged but not anchor-tagged and then introduced to a single large den in the centre of the survey area. The visual survey of dens was continued for 3 days after these introductions.

(iii) *Adhesive Tagging*

An area at Outer Rocks was visually surveyed for rock lobsters for 6 consecutive days. Dens were identified with plastic tape and an attempt was made to mark all rock lobsters with adhesive tags.

Results

(i) *Anchor tagging*

In all, 238 rock lobsters were observed over the 6-day survey and of these, 148 were caught, tagged and returned to their original den (Table 1). There were eight occasions on which tagged lobsters were subsequently observed in the survey. This involved five separate individuals, one of which remained in the same den and was observed on 4 consecutive days. No rock lobsters were recaptured until day 3, at which time a total of 74 rock lobsters had been tagged and released in the survey area. An important aspect of this survey was the constant decrease in the total number of rock lobsters observed in the study area. The number of animals in the survey area declined at a rate of about 15-20% per day until, at the completion of the study, the number of rock lobsters observed was less than one-third of the number observed at the start of the survey.

Table 1. Number of rock lobsters observed, tagged and recaptured during anchor-tagging survey in Tudu Lagoon

	Day number						
	1	2	3	4	5	6	Total
No. observed	65	56	42	36	21	18	238
No. tagged	41	33	28	23	13	10	148
No. recaptured		0	2	2	2	2	5*

* One individual was recaptured on all four days

Table 2. Number of rock lobsters observed and recaptured during loop-tagging survey in Tudu Lagoon. Tagged rock lobsters were caught elsewhere and introduced to the survey area

	Day number						
	1	2	3	4	5	6	Total
No. observed	38	19	22	19	26	31	155
No. tagged		14	15				29
No. recaptured			0	0	0	0	0

(ii) *Loop tagging*

Fewer rock lobsters were observed in the study area during this period, with a total of 155 rock lobsters counted. None of the animals that were introduced to the single den in the area were recaptured during the survey (Table 2).It was expected that by loop-tagging rather than anchor-tagging the rock lobsters the physical trauma of the tagging process would be reduced, perhaps resulting in a higher recapture rate. The introduction of the tagged rock lobsters into a single den meant there was minimal disturbance of the resident population. As a result, the total number of rock lobsters observed during the survey remained fairly constant, with almost as many occupants observed at the end of the work as were observed at the beginning. In this work any tag effects may be confounded by translocation effects in which the introduction of the tagged rock lobsters to an unfamiliar area may have induced movement.

(iii) *Adhesive tagging*

The adhesive-tagging survey covered a smaller area and involved fewer rock lobsters, with a total of 76 animals observed and 32 tagged (Table 3). However, there was a higher proportion of recaptures, with the first two tag returns being made on the second day after only six rock lobsters had been tagged. There were nine occasions when tagged rock lobsters were visually recaptured and one instance in which a tag was seen but could not be read. These recaptures involved six different animals with one rock lobster occupying the same den for all 6 days. The number of rock lobsters in the area varied from day to day and initially increased but subsequently declined to just below the original density. The increase in numbers of residents took place during the period in which most of the tagging was carried out.

Table 3. Number of rock lobsters observed, tagged and recaptured during adhesive-tagging survey at Outer Rocks.

	Day number						
	1	2	3	4	5	6	Total
No. observed	10	16	15	17	10	8	76
No. tagged	6	6	9	7	3	1	32
No. recaptured		2	1	2	3	2	6*

* One individual was recaptured on all five days

Discussion

The abundance of rock lobsters in any given area of reef can change from day to day, sometimes increasing and sometimes decreasing (Trendall and Bell, in press). However, without fishing or other disturbance the daily changes in abundance are usually small and erratic, and quite different from the consistent and large decrease in the number of rock lobsters observed in Tudu Lagoon during the course of the anchor-tagging survey.

In Tudu Lagoon the primary tag effect was a reduction in the observed density of rock lobsters in the study area. It is not possible to say whether this occurred because the rock lobsters moved out of the area or because they retreated into dens inaccessible to divers. During the 6 days of the survey only one tagged lobster was caught by fishermen outside the study area and, although some animals undoubtedly moved, there was no indication that large numbers of tagged rock lobsters left the area. Less than 4% of the tagged rock lobsters were recaptured and their behaviour must be viewed with caution.

The changes in abundance of rock lobsters during the loop-tagging survey were typical of an undisturbed area. No loop-tagged rock lobsters were recaptured but any tag effect is likely to be complicated by the possibility of translocation effects. Theoretically these rock lobsters, because the tag was not physically inserted into the muscle, should have been less traumatised. However, there was effectively no difference between the recapture rates of anchor-tagged and loop-tagged rock lobsters, which indicates that the process of capture and handling is enough to induce a short-term tag effect. The important point is that recaptured rock lobsters cannot be used to differentiate between behavioural changes caused by tagging and behavioural changes caused by translocation.

The adhesive-tagging survey confirmed that capture and handling of the rock lobsters resulted in immediate changes in behaviour. A much higher proportion (18%) of tagged rock lobsters was recaptured, despite the fact that the survey area was substantially smaller than Tudu Lagoon. There was movement within the survey area, as well as movement across its boundaries, with some animals being recaptured 2 or 3 days later. In addition the total number of animals observed in the survey area actually increased in the early part of the survey. There was no evidence of disturbance equivalent to that observed in the anchor-tagging survey.

The trauma involved in anchor tagging rock lobsters induced immediate behavioural changes which would affect estimates of the distribution and abundance of rock lobsters in the field. This limits the information that can be obtained on movements immediately following release. Most importantly, there is no quantitative means of deciding whether a recaptured rock lobster has been behaving in a 'normal' manner. This problem is of particular concern when the proportion of recaptured rock lobsters is less than 10% of the released animals. Explanations of the basis for observed patterns of movement in tagged rock lobsters (e.g. deciding whether a movement is real, an artifact of tagging or an artifact of translocation) will remain conjectural until the behavioural changes associated with tagging and handling become better understood.

The different results that were obtained from anchor and adhesive tags are an indication of the fact that the two types of tag perform different functions and answer different questions. Anchor tags will be retained between moults and are capable of providing information on growth as well as long-term movements. Adhesive tags involve minimal disturbance to the rock lobster in the field, and can be used to follow short-term, local movement patterns. However, they are external tags and will be lost at the next moult. Specifying the effects and limitations of the various types of tags provides the best possible basis for interpreting the results of fieldwork.

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Stewart Bell, Clive Turnbull and Lyle Squires were essential and highly proficient members of the research team. This work was undertaken by the CSIRO, Division of Fisheries, Tropical Rock Lobster Project and was funded by the Commonwealth Department of Primary Industries and Energy, Torres Strait Research Fund.

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GENETIC TAGGING

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Introduction

In comparison with terrestial fauna, the tagging of aquatic fauna is difficult. A general lack of distinct morphological marks within aquatic species, and the greater logistic difficulties of tracking or recapturing tagged individuals in an aquatic environment has necessitated the development of special marking procedures, both natural and artificial. Many of the commonly used artificial methods, which are difficult and expensive to apply, often result in significant losses of marks or mortalities of tagged individuals. Similarly, many of the natural marks which have been used in the past, including scale features, parasite fauna, elemental chemical composition, and morphometric and meristic characters, are subject to environmental variation and require regular re-evaluation (Pella and Milner 1987). A notable exception, however, is the successful use of fin and tail damage as unique visible marks to identify cetaceans.

Genetic characters are not subject to such environmental variation, and therefore can provide a useful natural 'tag' (Shaklee 1983). Procedures that identify genetic characters are now readily available. Genetic characters (particularly allelic polymorphisms at individual gene loci that can be detected by various biochemical methods) can be used:

1. As markers to identify individuals or groups of organisms;

2. To determine population structure within a species;

3. To identify separate species;

4. To trace the evolutionary relationships of groups of species.

In a fisheries and aquaculture context some of the advantages of genetic methods over mark-release-recapture methods are:

1. Genetic variants can be used to study animals that are too small to be marked with artificial tags, or where it is desirable to take non-destructive biopsy samples (Carmichael *et al.* 1986; McAndrew 1981).

2. Genetic marks can be used to study very abundant animals, where the probability of recapturing tagged individuals is low.

3. Genetic analyses of wild populations do not rely on recapture of marked individuals and are therefore not affected by possible biases arising from tag loss, tagging mortality or uneven distribution of fishing effort.

4. Genetic methods are relatively inexpensive compared with mark-recapture-release methods and can often provide useful results in a much shorter time span.

5. Genetic methods are more appropriate for estimating some population parameters (e.g. breeding structure) than are traditional methods.

Use of Genetic Marks

Studies of Wild Populations

Much of the biochemical genetic research applied to fisheries resources to date has been designed to delineate discrete breeding populations and/or species (Table 1). However, genetic data are also of value in estimating the degree of mixing of discrete breeding populations, and in determining sources of recruitment to a given area, e.g. Milner *et al.* (1985). Research that combines genetic studies with traditional tagging work has provided very informative results, e.g. on snapper in the Shark Bay region of Western Australia (Moran 1987) and on barramundi across northern Australia (Shaklee and Salini 1985; Davis 1986 and 1987; Salini and Shaklee 1988). As indicated in Table 1, genetic data alone are not usually sufficient to estimate biomass, levels of fishing pressure, movements of individuals, growth, or mortality in wild fish populations. However, genetic studies can contribute information towards these estimates. For instance Seeb *et al.* (1986) conducted a Petersen mark-recapture experiment, using genetically tagged fish, to census the population of chum salmon smolts in an area. This study was also used to estimate the contribution of these marked fish to subsequent spawning runs.

An essential prerequisite to the use of genetic tagging methods is the detection and characterisation of existing genetic variation within and between the (natural) populations under consideration. This research, which is of primary importance to the understanding and management of a commercial fishery, allows the identification of separate breeding populations and provides a summary of population structure. Once this information is known, studies of the distribution and degree of mixing of discrete populations can be undertaken, as discussed below. An example of the use of population gene frequency information as a cost-efficient method, compared with traditional tagging techniques, for the estimation of the composition of mixed populations of Pacific salmon, *Oncorhynchus* spp., is provided by Milner *et al.* (1985). It should be noted, however, that if no genetic variation can be detected then genetic methods will not be able to provide insights into population structure.

Studies of Cultured Populations and Stock Enhancement Programs

Natural biochemical marks involving allelic variants have advantages over traditional tagging methods in fish breeding and restocking studies (see Table 1). Mechanical tagging of larval and juvenile forms, usually by fin clipping or more recently using binary-coded wire tags, is often impractical because of physical damage and mortality. Biochemical marks do not involve mortality due to marking and handling, and very large numbers of individuals, e.g. a complete spawning batch can be marked with little effort . Moreover the biochemical mark is present throughout the life cycle of an individual and is passed on to subsequent generations. The success of introductions or restocking, and the reproductive success of such stocking can be monitored simply at low cost.

Two approaches to the development of marked stocks can be made. The simplest requires the monitoring of gene frequencies in the natural and hatchery-bred populations. Relative changes in population structure can then be quantified. Murphy *et al.* (1983) used this approach to examine the stocking success of fish into a reservoir. Another example of this method applied to hatchery-produced fingerlings of *Macquaria ambigua* (golden perch or yellowbelly) in Queensland is provided below. A longer-term approach is the breeding and selection of broodstock to provide offspring that are homozygous for a rare allele. The identification of offspring from such broodstock is more readily made as only single locus variation needs to be examined. However, good hatchery practices that minimise inbreeding must also be used.

This latter approach has been taken by Joerstad *et al.* (1987), to develop homozygous broodstock of cod (*Gadus morrhua*). They selected 70 parental fish, all heterozygotes for a rare phosphoglucose isomerase allele. The fish spawned naturally and about 25% of the offspring were homozygous for this allele. 847 homozygous individuals are being raised as broodstock to develop a genetically tagged strain that will be used in farming and/or stock enhancement programs.

Example of Hatchery Yellowbelly (Macquaria ambigua)

Subsamples from two sets of fingerlings that were stocked into impoundments in south-eastern Queensland were examined for known polymorphic enzyme systems (Musyl and Keenan, in prep.). Gene frequencies for the natural and stocked populations are presented in Table 2 and comments on these results are made below.

The parental stock of the hatchery fish stocked into Callide Dam (population 3) are obviously derived from the Murray-Darling River system as these fingerlings express alleles that are only observed from that system [ADH(100), EST-E(95)]. Likewise, the parental stock of the Theresa Creek stocking (population 4) is derived from the Fitzroy River system as they possess alleles unique to the same river [ADH(110), ADH(20), G3PDH(120), SOD(60) and MP-1(70)]. Both sets of hatchery-produced fingerlings have lower heterozygosity levels than their respective parent populations because they do not express low frequency alleles found in the parent populations. This may, however, be merely a reflection of smaller sample sizes. Gene frequencies at the Est-E locus in population 3 and the G3pdh locus in population 4 are significantly different from those found in their respective parental populations and provide a good genetic tag for these populations.

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Table 1. Possible areas of application for genetic marks in fisheries research

Type of fishery	Initial biomass	Catch history	Stock I.D.	Population size		Mortality			Growth	Recruitment/ movement
				Absolute	Relative	M	F	Z		
New	+	-	+	+	-	+	-	-	+	-
Declining	-	+	+	+	+	+	+	+	+	+
Established	-	+	+	+	+	+	+	+	+	+
Artificial tags										
Application	N	N	D	P	?	D	D	D	D	P/D
Timing	-	-	M	M	?	L	M	S	M	S/M
Genetic marks - wild populations										
Application	N	N	D	N	P	N	N	N	N	P/D
Timing	-	-	S	-	S	-	-	-	-	S/L
Genetic marks - aquaculture										
Application	N	D	D	P	D	D	D	D	D	D
Timing	-	S/L	S	S	S	S/L	S/L	S/L	S/L	S/L

+ = estimate possible; - = estimate not possible;
P = poor application; N = no application;
D = direct application; S = short term (1-3 years);
M = medium term (3-5 years); L = long term or life-time (>5 years).

Table 2. Allele frequencies of yellowbelly from the Fitzroy and Murray-Darling systems

Locus	Population 1	2	3	4
ADH				
(N)	35	75	15	12
A(100)	0	1.0	1.0	0
B(110)	0.257	0	0	0.375
C(20)	0.743	0	0	0.625
EST-E				
(N)	40	80	15	12
A(100)	1.0	0.663	0.267	1.0
B(95)	0	0.338	0.733	0
G3PDH				
(N0	27	78	15	12
A(100)	0.519	1.0	1.0	0.958
B(165)	0.315	0	0	0
C(120)	0.167	0	0	0.042
GPI-1				
(N)	41	80	15	12
A(100)	1.0	1.0	1.0	1.0
GPI-2				
(N)	41	80	15	12
A(100)	1.0	0.988	1.0	1.0
B(50)	0	0.012	0	0
MDH-1				
(N)	41	80	15	12
A(100)	1.0	0.981	1.0	1.0
B(70)	0	0.019	0	0

Locus	Population 1	2	3
MDH-2			
(N)	41	80	15
A(100)	0.951	1.0	1.0
C(40)	0.037	0	0
MPI			
(N)	33	78	15
A(100)	1.0	0.923	1.0
B(110)	0	0.077	0
SOD			
(N)	41	80	15
A(100)	0.976	1.0	1.0
B(60)	0.024	0	0
MP-1			
(N)	41	79	15
A(100)	0.878	0.987	1.0
B(85)	0	0.013	0
C(70)	0.122	0	0
MP-2			
(N)	41	80	15
A(100)	1.0	1.0	1.0

KEY TO POPULATIONS

1 - Fitzroy River (Fairburn Dam, Dawson and Nogoa Rivers)
2 - Murray-Darling system (Keepit Dam, Condamine and Murray Rivers)
3 - Hatchery bred population stocked Callide Dam, Feb. 1988
4 - Hatchery bred population stocked Theresa Creek, Feb. 1988

DISCUSSION OF SESSION 3

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In addition to the panel presentations, Mike Hall made the following comments on tag design. 'Hallprint' was initially established to assess whether the manufacture and performance of 'conventional' tag-types, largely imported from N. America, could be improved upon. Subsequent design and manufacturing improvements resulted from the close collaboration between Australian fisheries biologists using these new tags and the Hallprint Company. Despite the superficial similarity between some Hallprint products and imported 'off-the-shelf' tags, innovative manufacturing techniques have resulted in significantly improved performances by Hallprint tags. Earlier (i.e. pre-Hallprint) assessments of durability, loss-rates, etc., for certain tag types should thus be reappraised. Scope still exists for further improvements in tag design, and fisheries biologists should be aware of this challenge because of the input they can make. Ongoing collaboration between Hallprint and fisheries researchers is encouraged. Probable future directions in tagging methodology include the marking of smaller and smaller animals; increasing research into marking methods for deepwater species; the development of more appropriate tags and procedures for tagging by recreational fishermen; and 'please-release-me' tags. Increasing development of specific tags for single fish species can also be anticipated.

The discussion following Julian Pepperell's presentation covered problems encountered with various 'spaghetti' tags especially with reference to anchoring devices and durability.

Dave Smith mentioned problems he had encountered in tagging morwong in New South Wales waters, where the tubing had separated from the T-bar head. Julian Pepperell commented that he had not found the same problem with T-bars but some nylon barbs used in tuna had separated from the tubing. The main problem with T-bars in the gamefish program had been that recreational fishermen were not experienced in anchoring the head between the neural fin rays, and loss of the whole tag occurred frequently.

The subject of tag visibility and the durability of different plastics was raised by Mike Cappo in reference to his studies on Australian salmon. He had considered the use of fluorescent coloured tags to ensure identification of tagged fish, but in discussion with Mike Hall discovered that the fluorescent plastic had a shorter life and was therefore unsuitable for a long-term project. PVC tags were also found to become brittle after about 1 year and polyethylene proved to be a more durable material.

Julian Pepperell found that the recovery rate from 5000 red tags early in the New South Wales based gamefish program was the same as that for yellow tags, so it was decided to continue with yellow. He agreed that the brittleness of PVC was a problem as the period at liberty got longer. Abrasion was also a factor in tag loss, especially in yellowtail kingfish, which habitually brushed against the substrate to remove ectoparasites.

Richard Tilzey referred to the Tagging Register which showed that 55 projects had used yellow spaghetti tags, 10 had used orange, followed by dark-blue. He pointed out that colour and visibility were important considerations where recoveries were not made by the research team which released the fish. He also mentioned that some United States studies on striped bass had suggested increased predation upon tagged, as against unmarked, fish.

On the subject of tag-induced predation, Julian Pepperell commented that he had never had a tag returned which had obviously been bitten by a fish, even though this is considered a common occurrence in schooling predatory species. He added that the tags quickly became covered with marine growths, such as epiphytes or weed, which would probably make the tubing less attractive to predators. Rick Morton recounted an incident where a tailor tag was found in the stomach of a mackerel, but believed that the main cause of tag damage in tailor was abrasion on offshore reefs.

Dave Hall referred to previous comments on the suitability of some tags for use by sportfishermen. His studies had shown good retention of T-bar tags provided the heads were inserted behind the fin-rays, a requirement which he agreed makes the T-bar less suitable for sportfishermen. Recent tagging of fish as small as 15 cm in length with small dart tags had proved quite successful and he considered these tags to be more appropriate for use by sportfishermen on smaller species.

While introducing Brett Ingram's presentation Richard Tilzey observed that little experimentation appeared to be done prior to commencing tagging studies and that trials of proposed tag types should increase the chance of success in a subsequent full-scale program.

Brett's description of micro-coded wire tags and their application at the Inland Fisheries Research Station, Narrandera, NSW stimulated discussion of the cost benefits and range of applications for this method. Frank Prokop prompted Brett to elaborate upon the major problem with this tag type, namely the need for a detection instrument when recovering tags. At the present time the research station has only one detection instrument, and its use has logically been restricted to the scientific and technical staff. The involvement of anglers in a tag-recovery program is precluded by the nature of the operation, not only by the technique of insertion but the need for sophisticated detection equipment. However, it could be possible to arrange a system for collecting fish heads from anglers, thus allowing a more extensive tag-release project.

John Glaister agreed with the conclusion that tag loss was largely attributable to placement when tagging, rather than migration of the tag through muscle. The same conclusion had been reached by Texas Parks and Wildlife researchers tagging red drum.

Terry Ruxton enquired about the cost of the necessary equipment, and was told that the wire applicator and one detector cost approximately $20 000 (including a dozen spools of coded wire). Each additional detector would cost approximately $3000.

John Anderson was interested in the lower size limit for tagging golden perch and the expected mortality during tagging in 20-30 -mm fish. Brett considered 20 mm to be 'pushing' the limits of the technique as trials had shown retention rates of only 55-89% (after 30 days) for the 20-35-mm size class. He thought that 30 mm was a realistic minimum tagging size for golden perch. During the trials, between 1 and 4 fish were rejected from batches of 30 due to excessive handling or inadequate insertion of tags.

Following John Glaister's panel contribution on tag types suitable for prawns, Peter Young recalled a visit he had made to Florida in 1970 where coded wire tags were being injected into prawns prior to release. Tagged prawns were recovered at processing plants where detectors were located on conveyor belts. John replied that he was not aware of any micro-coded tags currently being used for tagging of prawns. Peter Jernakoff commented that some work on tagging juvenile prawns with micro-coded tags had been carried out by Derek Staples in Queensland, but the throughput of product in processing plants was too great to effectively monitor recaptures.

A few of the unique problems encountered when tagging molluscs were discussed following Paul McShane's review of tags used for abalone. Jack Hannan asked if any workshop participant had experience with tagging mud oysters, because a colleague had tried attaching numbered discs to the shells with various glues and found persistent tag loss. David Gwyther commented that studies on oysters usually involved batches of shell held in cages, and since mean size measurements suffice, this obviates the need for individual tagging.

The flaky exterior of Sydney rock oyster shell presented the main problem for tag attachment in that species according to Ian Smith. Researchers at the NSW Brackish Water Fish Culture Research Station at Port Stephens had overcome the problem by brushing the shells with a wire brush prior to attaching the tags, thus providing a firmer surface for adhesives.

Adam Smith suggested that the problem of epiphytic growth hampering the identification of tagged abalone could be overcome by application of an antifouling agent. Paul McShane pointed out that since his study was concerned mainly with determining growth rates it was not so important to recognise every recapture, as long as sufficient animals were recovered to provide adequate growth data.

Rod Lenanton asked Jeremy Prince what rate of tagging he had achieved when tagging abalone underwater, and was told that the operation was just as quick as onboard a vessel (approximately 3 shells per minute for two taggers/recorders), but searching for abalone took up the majority of time.

Richard Tilzey, as chairman, concluded the panel session with a few comments on current trends in the use of tags in Australia. He mentioned chemical marks such as tetracycline, and natural marks such as mitochondrial DNA, which were not covered by the papers presented at the workshop.

Tagging studies could be divided into two basic categories. There were those where the researcher was dependent on the public or commercial fishermen for tag returns. This type of project typically required an external tag with high visibility, but also with the associated risks of comparatively high loss rates, predation on tagged individuals etc.

On the other hand, where the recovery of tagged animals is made by researchers involved in the tagging operation, some form of internal tag, which typically exhibit lower loss rates than external tags, is more appropriate.

Richard had previously raised the question of whether a technological gap existed between Australian and overseas methods of tagging. He concluded that the gap did not exist as such, since the technology was available here but, rather, a reluctance to use the recently developed techniques was evident.

The tendency has also existed in the past for biologists to use imported 'off the shelf' tags without adequate experimentation to determine their suitability or any need for modification. On a more optimistic note, cooperation between a local tag manufacturer (Hallprint) and researchers in tag development had alleviated many structural problems associated with 'traditional' tag types.

Richard Tilzey closed Session 3 by thanking the panellists for their worthwhile contributions to the workshop, and introduced John Glaister as chairman of the session on tagging techniques, which was next on the agenda.

SESSION 4

TAGGING TECHNIQUES

Session Chairman:	J.P. Glaister
Session Panellists:	K.F. Williams
	J.H. Diplock
	R.M. Morton
	J.G. Pepperell
	J.R. Anderson
	D. Smith
	D. Gwyther
	J.I. Walker
	K.H.H. Beinssen

CHAIRMAN'S INTRODUCTION

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Tagging techniques have changed since the seventeenth century when Sir Francis Bacon observed, 'The age of a salmon exceeds not ten years, so let me tell you, that his growth is very sudden: it is said, that, after he is got into the sea, he becomes, from a Samlet not so big as a Gudgeon, to be a Salmon, in as short a time as a gosling becomes to be a goose. Much of this has been observed, by tying a ribbon, or some known tape or thread, in the tail of some young Salmons, which have been taken in weirs as they have swimmed towards the saltwater, and then by taking a part of them again, with the known mark, at the same place, at their return from the sea, which is usually about six months after' (Walton 1653). Developments in tag design and synthetic materials have similarly broadened the scope of tagging experiments designed to gather information on growth, behaviour and population dynamics to include a range of species.

The success of tagging experiments is dependent on the physical as well as the physiological condition of the tagged animals at release (Jakobsson 1970). It is thus appropriate that consideration is given to tagging techniques such as catching and holding, application of tags, observations on tagged animals and other such practicalities facing the intrepid tagger. To this end the panel members have been selected to represent a diversity of species and tagging methodologies.

Kevin Williams and John Diplock will be presenting some of their knowledge of tagging smaller pelagics, mainly tunas. These speedsters have their own inherent problems and perhaps more so than in any other species, handling is critical.

Rick Morton is currently undertaking a tailor (bluefish) tagging program in estuarine/ coastal habitats in south-eastern Queensland. Rick's experiences will be of interest to those who have participated in tagging programs with estuarine species, particularly since he has co-opted recreational anglers to assist.

Julian Pepperell has been involved in the New South Wales tagging program for gamefish since the mid-1970s. His experience in problems of tagging large pelagics will be of special interest.

John Anderson is our token freshwater representative. John's experience has included a range of methods for marking freshwater fishes, and he will highlight the perennial problem of marking small fish.

Dave Smith will describe tagging studies in the south-eastern trawl fishery. These species include flathead, morwong, whiting and redfish, and problems encountered differ from the more shallow environments.

David Gwyther has worked on a range of animals from prawns and fish in Papua New Guinea to scallops in Port Phillip Bay. David's observations on tagging invertebrates are certain to generate useful discussion.

Terry Walker has worked with sharks for a number of years as have a number of other people here today (John Stevens, Julian Pepperell). Skin and teeth characteristics present special problems and Terry will describe techniques.

Certainly the topic is large and one can imagine innumerable specific difficulties for particular species. Some of the points we may cover could include fishing gears and their effects. For example, do the active gears (trawls, seines) require modifications to lessen physical damage? Are there ways of minimising the swim bladder problem? Once the animal is onboard (or onshore) its condition may or may not result in further stress during the tagging operation itself: a lively vibrating tuna versus a serene scallop for example. Are there ways of restraining such activity? In some situations, particularly the freshwater examples, larger numbers of animals are the exception rather than the rule, so collection of sufficient numbers of individuals for tagging may be a problem. What is the degree of damage (loss of scales, fin damage, exoskeletal marks) able to be tolerated by the animal and the researcher? Once tagged, how do we get them back? Some workers advocate release at the bottom: again the swim bladder concern. Once released, how many die? Endocrine changes have been well documented for salmon (Mazeaud *et al.* 1977) and cryptic post-release mortality is currently being debated with reference to tag-and-release-only sport fisheries in the USA (Florida Marine Fisheries Commission, pers. comm.).

It is highly likely that many of these problems are species specific and unique solutions are needed. However, we will endeavour to focus on methodologies which may have a common relevance.

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SOUTHERN BLUEFIN TUNA

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This is a description of the techniques used when tagging southern bluefin tuna in Australia during the last 10 years. While this work was restricted to southern bluefin tuna, the methods are applicable to most of the smaller tunas

Latterly (1980s), only fish caught by pole and line were tagged, i.e. not troll-caught fish. No attempt has yet been made to tag purse-seine-caught fish. Earlier experiments indicated that troll-caught southern bluefin tuna were more affected than pole-caught southern bluefin tuna, and never fully recovered. Pole-and-line-caught southern bluefin tuna were back to normal soon after tagging. The reasons and evidence for this should be addressed elsewhere .

Fish were never held on deck, e.g. in tanks. Tunas do not lend themselves to effective tank holding. All fish were tagged very soon after capture and returned to the water immediately.

The tags used were dart tags with moulded nylon heads glued to polypropylene tubing (of some description). Tag numbers, inscription etc. were printed on the tubing. The tubing used was yellow for most experiments, but for some double tagging a different colour as well as yellow was used, e.g. red one side, yellow the other side of the fish.

The fish were usually poled carefully onto the deck and then picked up by the tail, steadied with the other hand and placed in a tagging cradle. The cradle is a smooth vinyl sling laced over a metal frame to facilitate fish handling. The cradle design was developed over many years and utilised the findings of other tuna tagging organisations, particularly those in Papua New Guinea and at the South Pacific Commission as well as our own experiences.

The vinyl in the cradle was marked so that fish length could be measured while the fish was in the cradle. This calibration was re-checked throughout the tagging operation. The tags were applied while the fish were in the cradle and the tag number(s) and fish length noted.

The tags were inserted into the musculature of the fish slightly behind and below the second dorsal fin. The tags were applied with sharpened stainless-steel-tubing applicators, which were withdrawn after tag insertion. Ideally the tag(s) should be lodged in the pterygiophores (fin ray extensions) of the fin. The tags were inserted at an angle of about 45 degrees to the longitudinal axis of the body, facing forward. In double tagging experiments one tag was inserted on each side of the body. Care must be taken not to cut off the one already inserted with the application of the second tag. The fish was tossed (pushed off the cradle) back into the water.

All the obvious, important information was recorded on a tagging sheet. Tag numbers, fish length, position, vessel, date, tagger(s), time of day and general comments about the fish, the school, environmental conditions etc.

Observations on the fish were restricted to very general ones only. If the fish was damaged (at all), was heavily landed, had any obvious abnormality etc., it was not tagged. This eliminates the problems associated with having descriptions of many basically similar sets of circumstances that are too subjective anyway. If the fish did anything abnormal after having been returned to the water this was noted, and in some cases the fish was eliminated from the data set.

For most of the returns, i.e. those from fishermen, the only information requested was the date and position of capture, and length (LCF) of the fish (and of course the tags).

If any of the tagging operatives was present when many tags were being landed in a port, then extra information was collected, e.g. weights and lengths of tagged fish plus those of others from the same school, hard parts for ageing and tetracycline marking etc.

If tagged fish were recaptured during tagging operations they were usually measured and re-released. Some fishermen also re-released small tagged fish and kept one tag as a record (we didn't encourage this). Both situations led to multiple captures (3-4 times) of the same fish and provided interesting data.

The reward paid has varied considerably over the years and is currently $5 per tag. A monetary reward has always been the main incentive. Extra incentives have included T-shirts, posters and recently a lottery. The main methods, apart from rewards, of encouraging tag recovery have been extensive liaison, reward posters and mail blitzes. A visible presence in the appropriate ports is the most successful.

Yellowfin Tuna

Approximately 1000 yellowfin tuna were tagged off New South Wales in 1986-87, 940 by pole and line and 60 by longline, basically following CSIRO techniques for poled fish. Longlined fish were larger and most were tagged in the water. We believe this was successful but the numbers tagged were small. There was no trouble unhooking large (up to 35 kg) fish, and their condition appeared good.

Tag application was by placement into second dorsal fin pterygiophores of poled fish, and into the dorsal musculature of longlined fish.

Twenty fish have been returned so far, all from pole-caught taggings (2%). This return rate is satisfactory compared to other yellowfin tuna taggings around the world. Most returns were from recreational fishermen and longliners. There were no Japanese returns. The pattern of recaptures is cyclical, with fish moving south from the tagging site during autumn then being found sequentially up the coast during winter. This group appeared to follow the movement of warm water being entrained against the coast.

(A 5-minute video of tagging techniques demonstrated off Greenwell Point, NSW was shown at the Workshop.)

TAGGING TAILOR IN QUEENSLAND

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Tailor is an important fish to both recreational and commercial fishermen in Queensland and other Australian States. The recreational fishery for tailor can be divided into different coastal regions, surf beaches and headlands (targeting adults) and estuaries (targeting adults and juveniles). Commercial fishermen concentrate upon taking adults by means of beach seines on surf beaches. In response to concern over falling adult catch rates in Queensland, a major 3-year tagging program was initiated in 1987 to investigate aspects of tailor biology related to management of the fishery.

The catching technique used in the Queensland tailor tagging program differs slightly from most other estuarine/coastal fish tagging programs conducted by fisheries management agencies. Recreational anglers have been involved in all tagging operations by catching fish for tagging by research staff. Two types of commonly used external tags, anchor (T-bar) and loop (spaghetti) tags, were used on adult (> 30 cm fork length) tailor. Juvenile (> 16 cm fork length) tailor were tagged only with anchor tags. Problems observed with these tags include tag loss, tag rotation, heavy algal growth on tags, and non-healing/infection of tag entry site. However, both tag types were relatively easy to attach (especially anchor tags), retained for long periods, highly visible upon recapture, and able to carry sufficient return information.

A reporting system for recaptured tailor, involving the use of a 008 (toll free) telephone number printed on the tag, was implemented due to the highly mobile nature of tailor. To encourage fishermen to assist in the capture of tailor for tagging and to report recaptured fish, a 'tailor' T-shirt was printed to serve as a reward. Experience in the tailor program and in other tagging programs in Queensland has shown that T-shirts are a particularly effective way of promoting return of tags and encouraging cooperation with the programs.

To date, 3192 tailor have been tagged and 339 recaptured (10.6% of total tagged). Juvenile tailor have moved only relatively small distances (< 60 km) whereas several adult tailor have moved more than 200 km. The farthest distance recorded to date for a tagged tailor has been from Fraser Island (Qld) to Newcastle (NSW), a distance of 990 km. Estimates of growth from tagging data are widely variable and it is possible that fish growth may be adversely affected by the tag.

Even though still in the early stages, the tailor tagging project has already yielded useful information on fish stock geographical boundaries, and relative catch rates by professional and recreational fishermen, and indicated a high exploitation rate on juvenile (< 30 cm) tailor in southern Queensland. A minimum legal length for tailor in Queensland was introduced on the basis of tag return data obtained from this project.

TAGGING TECHNIQUES FOR LARGE PELAGIC FISH

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The tagging of large pelagic fish presents special problems in most of the practical areas associated with fish marking. These include capture, handling, measuring, and tag design and placement.

By 'large' fish, I mean a size too large to be removed from the water, usually over about 20 kg.

The problem was addressed in the late 1950s when giant bluefin tuna were thought to be on the decline. Frank Mather III of the Woods Hole Oceanographic Institute at Massachussetts developed a dart tag suitable for 'spearing' into the shoulder of such large fish whilst being held alongside the boat (Mather 1963). Variations on the design of this type of tag have been developed since but, surprisingly, the stainless steel anchoring head designed by Mather has proven to be excellent for its purpose, that is, anchoring firmly into muscle. Several hundred thousand fish have been tagged with these tags over the past 25 years. Recently, the National Marine Fisheries Service in Miami, Florida has been experimenting with a large nylon head for such tags. Early results suggest that these may be 'accepted' by the fish better than the steel heads, and may therefore show lower long-term rejection.

Capture of fish for this method is usually by means of handline or rod-and-reel trolling, although the method lends itself to free-tagging (i.e. tagging of free-swimming fish), especially sharks and swordfish. 'Playing' a fish for long periods is often thought to cause excessive mortality, although some fisheries based on light tackle angling for billfish achieve quite high recapture rates (3%) of tagged fish, compared with fisheries based on heavy tackle (1%). Of course, fishing effort must be taken into account when making such comparisons, but reasonable survival of mouth-hooked fish is likely. Sonic tagging of sailfish caught by normal angling methods demonstrated high survival probability (7 out of 8 fish up to 72 hours after release), while billfish have been recaptured in a healthy state after being released in apparently poor condition (e.g. bleeding from the gills, belly-up, stomach everted etc.). In any case, if tagging is the object, anglers are advised to bring the fish to the boat quickly.

Handling. Because the fish is not removed from the water, this method negates most associated problems. However, if the hook cannot be easily removed, the trace is cut, leaving the hook and some trailing tackle *in situ*. Tagged black marlin and sailfish have been recaptured up to 1 year after release with corroding hooks still embedded in their bills. Some of these have been noted to be in relatively poor condition, while others are apparently unaffected. The great majority of fish recaptured, however, bear no sign of the hook left in place at release. Very large fish, especially sharks, should not be removed from the water because of the potential for internal damage caused by gravity. This area has never been seriously studied, and warrants some research, even for small fish.

Measuring large fish in the water is very difficult and, hence, estimates only are usually given. Experienced anglers and captains are presumably better 'guesstimators', but this is debatable, based on available data. Estimates of size at release can be particularly useful in cases involving the tagging of small fish (say less than 10 kg) and subsequent recaptures when the fish have grown considerably.

Tag placement seems not to be absolutely critical, provided that the tag anchors firmly in the dorsal musculature, preferably angled backwards. It is unwise to offer monetary rewards for the return of tags from volunteer cooperative programs. Tags are freely available, and so the possibility of collusion and consequent error exists if financial gain is perceived. Rather, certificates and jacket patches are awarded, and are received with pride by reporters of tags. Curiosity is often the overriding motive for returning a tag, and release information and a memento in return is appreciated.

Because large pelagic fish are often highly mobile, with recaptures likely from widespread locations, continuous and saturation publicity regarding the tagging are very difficult. The media (specialist and general) should be used as often as possible, and awareness of the tagging program should be stressed internationally whenever possible. Thought should even be given to the inclusion of foreign language legends on tags.

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FRESHWATER FISH

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T-bar, anchor and dart tags are used for tagging native fish, either during the course of surveys or for specific purpose studies to monitor fish movement patterns to assist in fishery management. Success varies from excellent (36% return) in one waterbody to poor in others, primarily in response to the attitude of the anglers on whom we depend for returns. Double tagging is used to assess tag loss rates and these can be high. No estimates are available on mortality but the high return at some sites suggests that this is low. Strict handling procedures are observed during tagging to minimise mortality.

Fin clipping is used extensively in trout releases in Victorian waters as a label for distinguishing stocked fish from the natural population, and for distinguishing between various stockings. This method has been used to modify stocking schedules and to identify waters which have viable self-sustaining populations. Reliability of the fin-clipping varies, especially when voluntary labour is used. The clipping can be inconsistent, allowing regeneration of the clipped fin, or the fish can be damaged. For practical purposes the technique is only applicable to relatively large fish (fingerlings or yearlings).

Another objective is to find a batch technique for marking large numbers of native fish prior to release. The main problem is that pond-reared native fish are generally released at a size of 20-30 mm (or smaller) because it is not feasible to rear them on to a larger size in ponds without using intensive rearing techniques. These have not so far been developed for fish such as golden perch or Murray cod. The mark therefore has to be applied to very small fish, and yet be detected several years later when the fish have grown to 6 or 7 kg. Ideally the mark should be easily recognisable by anglers to increase the chance of return, and to be used in creel surveys etc. A large number of different marking methods was tried with generally poor results, either because of low retention rates or excessive damage to the fish (golden perch 20-30 mm).

The methods used included:fin clipping (with and without freeze branding to inhibit regeneration); freeze branding; hot-wire branding; dye-injection (Panjet); fluorescent powder sprays; oxytetracycline (through food, injection and immersion).

The most promising technique appeared to be the oxytetracycline method. Initial uptake rates were good even with 4-8-h immersion. The method had the advantage of requiring minimum handling, and could be used to treat large batches of fish. Long-term retention times have yet to be determined. Health considerations have limited its application overseas.

Other possible methods which could be used are binary-coded wire tags and PIT (Passive Integrated Transponder) tags. Both of these methods are used extensively overseas, and they have potential for application for both trout and native freshwater fish. New South

Wales Fisheries is currently investigating the application of binary-coded wire tags for releases of Murray cod and golden perch. The size of the fish remains a problem, and it appears that this may limit its feasibility. Detection of the tags is also a problem requiring special equipment. Trials underway at the moment will show whether or not it is feasible from the point of view of the injection of the tag, mortality and retention rates.

No suitable method is yet available which combines ease of application in a batch mode, long retention times, minimum damage to the fish, and ease of detection.

Radiotelemetry and ultrasonic telemetry provide an efficient means of obtaining detailed movement data, and habitat preference data, in waters which make the application of conventional techniques difficult.

Radiotelemetry techniques are being applied to the investigation of the habitat preferences, behaviour and movement patterns of Murray cod in larger rivers and streams in Victoria. The technique is also applicable to other species such as golden perch, Macquarie perch, trout cod, silver perch and freshwater catfish. There are two basic approaches, as follows.

Broad-scale tracking. This involves using single 'pingers' and using direction-finding techniques to track the fish's movement, and to identify the localities it uses for various activities.

Fine-scale habitat preference studies. In larger rivers portable antennae do not provide the spatial resolution required for detailed work. 'Smart' transmitters (transmitters which provide environmental information) are used to not only provide the general location but to transmit key environmental or habitat selection information such as depth, temperature or light level (cover use). Simple 'pingers' can provide the necessary spatial resolution only when sophisticated and more or less permanent antenna arrays can be established.

Each of these methods is under investigation in Victoria. Ultrasonic methods also have application particularly in marine environments when radiotelemetry methods cannot be used due to transmission losses. Sophisticated antenna array systems are available commercially and are being used in marine habitats.

The major problems are the expense, the technical sophistication required to operate the equipment, the trade-off between battery life, size and transmission range, and the field time required for the tracking. Attachment techniques and the difficulty of overcoming the biases involved in capture, handling and attachment are difficult to evaluate. Physical interference with swimming and other activities such as feeding, associated with attachment, are likewise difficult to overcome and assess.

TAGGING STUDIES IN THE SOUTH-EASTERN TRAWL FISHERY

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Introduction

The south-eastern trawl fishery (SET) is a multi-species finfish fishery, and the main supplier of fresh fish to the Sydney and Melbourne fish markets. In recent years there has been increased processing for the local market and the development of export markets, notably to the USA and Japan. Landings in 1986-87 were about 25 000 tonnes valued in excess of $40 million to fishermen in Victoria, New South Wales, Tasmania and South Australia.

Tagging experiments on south-eastern trawl fish have concentrated on the continental shelf species. Early research, on what was then the east coast trawl fishery, was undertaken by CSIRO. From 1945 to 1955, over 6000 tiger flathead (*Platycephalus richardsoni*) were tagged and released off the south coast of New South Wales and north-east coast of Victoria by CSIRO researchers (Kurth 1957; Rowling 1983). The fish were tagged with opercular strap tags. Approximately 1% were recaptured.

More recently, as part of programs to assess the trawl and Danish-seine fisheries of New South Wales and Victoria, tagging studies have been conducted on tiger flathead, jackass morwong (*Nemadactylus macropterus*), and red spot (school) whiting (*Sillago bassensis flindersi*) (Hobday and Wankowski 1983a; Rowling 1983; Smith 1985; Wankowski *et al.* 1985; Smith and Rowling 1986). From December 1985 to December 1986, the Division of Fisheries, NSW, undertook tagging studies on redfish (*Centroberyx affinis*) off the New South Wales coast (Rowling 1987).

Tagging Methods and Recaptures

General

A major aim of most tagging methods is to minimise the inevitable mortality associated with the catching, handling and tagging process, without reducing too greatly the number that can be tagged. For deepwater demersal species there are specific problems which have to be overcome. Firstly, fish experience a significant pressure change when being brought to the surface, which, in susceptible species or individuals, can lead to swimbladder distension and internal damage. Secondly, fish may be damaged by the capture method itself. Loss of scales is common in trawl-caught fish, caused by abrasion with the net and codend, and by being landed on board the vessel. The tagging methods outlined below were designed to reduce these problems.

For experiments aimed at providing population and survival rates some estimate of tagging mortality must also be made. Tag-related mortality can be viewed as having two components; firstly the effect of catching and handling, and secondly the insertion or attachment of the tag. The latter is fairly easy to investigate, being a matter of comparing the survival of tagged and untagged fish experimentally, where both groups of fish are handled similarly.

Mortality induced by catching and handling is more difficult to investigate. When dealing with demersal deepwater species it is very difficult to construct controlled experiments. Long-term stabilisation of fish in aquaria is a useful approach (if possible), but experiments such as these do not fully simulate tagging conditions. However, when considering the effects of catching and handling, it is logical to assume that the condition of fish at release will have some bearing on subsequent recapture. Recording specific details on the condition of individuals at release or formalising this into an index of condition provides the basis for an estimate of this mortality.

The other major areas of concern, which are common to all tagging studies, are tag shedding and the non-reporting of recaptured fish. In tagging studies on SET species, standard methods have been used.

Tiger Flathead and Jackass Morwong

New South Wales

In October 1981, researchers from NSW State Fisheries (now Division of Fisheries) tagged and released 380 tiger flathead and 2508 jackass morwong off southern New South Wales, of which 3.5% of the tiger flathead and 4.8% of the morwong have been recaptured. Tagging methodology is described by Rowling (1983), and results and analyses by Smith and Rowling (1986) and Smith (1987).

Two Danish-seine vessels operating out of Eden were chartered for the tagging operations. Fish caught in Danish-seine nets are generally acknowledged to suffer less damage than fish caught in otter trawls, showing little scale damage and appearing livelier after capture. Shots were of normal duration but winching was slowed to minimise damage to individual fish. The catch was landed on deck and lively individuals placed into 400-litre holding tanks, with circulating seawater. Fish swimming normally and showing no signs of swimbladder damage were caught with a small scoop net, measured, tagged with Floy anchor tags (FD76c), and then released after details had been recorded.

Of the jackass morwong released, 543 (22%) were double-tagged to estimate tag loss (Rowling 1983). There was no evidence of anchor-tag shedding until 2 years after release, when 3 double-tagged fish were returned in which only the monofilament T-section of the anchor tag was in place. This points to disintegration of these tags with time. No individuals were recaptured with the entire tag shed. Two individuals were recaptured with the opercular tag missing. It was estimated that 30% of tagged morwong 'lost' anchor tags after 2 years and that the probability of losing both tags was 4% (Smith 1987).

A comparison of the distribution of condition factors recorded for jackass morwong at release with the condition of recaptured fish at the time of release showed that condition, as measured by the criteria used, did not have a significant effect on the probability of recapture (Smith and Rowling 1986). Cage experiments were conducted in Twofold Bay, and showed a tagging mortality of approximately 10% (Smith and Rowling 1986).

Although considerable publicity followed the tagging, and a reward of $2 plus the market value of the fish was given for returned fish, the level of reporting was low. Seeding experiments indicated 60% were reported at the wholesale and retail levels (Smith and Rowling 1986).

In October 1984, a further 740 jackass morwong were tagged and released off north-east Victoria on grounds exploited by the New South Wales fishing fleet. Of these, 11 have been recaptured (K. Rowling, Division of Fisheries, NSW, pers. comm.).

Victoria

Between 1982 and 1985, 7554 tiger flathead and 5041 jackass morwong were tagged and released off north-east Victoria, by researchers from the Marine Science Laboratories (Fisheries Division, Vic.). Of these, 3.7% of tiger flathead and 0.2% of jackass morwong were recaptured (Wankowski *et al.* 1985).

The development of methods of tagging these species is described by Hobday and Wankowski (1983a). Initially fish were captured using the F.R.V. 'Sarda' and a chartered Danish-seine vessel. However, fish caught by Danish seining were found to be in better condition than those taken by trawling using 'Sarda', even though a number of modifications were made to the trawl gear. These included the use of knotless netting to reduce abrasion, and the construction of a cage to fit inside the codend, to reduce crushing. Subsequently the bulk of the tagging was done from the seine vessel. The only modification to the seine gear was to reduce warp length. This resulted in marginally smaller catches and less damage to fish.

As in the New South Wales study, fish were landed on the deck and quickly transferred to holding tanks with circulating seawater. Tagging cradles were designed specially for each species and, on the seine vessel, fitted to the side of the holding tank.

Initially, two types of tags were used on flathead, Floy FD68-B anchor tags and Floy FT-2 dart tags. Although both had similar return rates, the dart tags were used subsequently as they were found to be easier to use. Morwong were all tagged with the anchor tags. Approximately 15% of both species were double-tagged (D. Hobday, Fisheries Division, Victoria, pers. comm.).

The tagging study was publicised throughout the fishing industry in east Victoria and south-east New South Wales, and a reward of $5 was given for return of tags and/or tagged fish.

Red Spot (School) Whiting

The tagging of red spot whiting proved less successful. This species is particularly susceptible to injury during catching and handling, commonly showing severe swimbladder distension and scale loss.

Victoria

In February 1983, 622 whiting were tagged and released off Lakes Entrance (Hobday and Wankowski 1983b). Whiting were captured and handled using the methods described above and tagged with yellow Floy streamer tags (FTSL-73). Fish were tagged underwater and briefly removed and measured. The tags were inserted through the body musculature, posterior to the dorsal fin. No tagged fish were recovered and the tagging of whiting was discontinued (Wankowski and Hobday 1984).

New South Wales

Between November 1984 and May 1986, over 6000 whiting were tagged and released off the NSW coast, using F.R.V. 'Kapala', as part of a study undertaken by the Division of Fisheries, NSW, on the New South Wales red spot whiting fishery (Smith 1985). This fishery overlaps with the south-coast trawl fishery.

Whiting were tagged with modified blue streamer tags (Hallprint), blue being a more suitable colour than yellow for this particular species. A number of measures were developed to reduce tagging mortality: trawl duration and speed were reduced, and the net retrieved more slowly; steel hoops were fitted to the codend to reduce crushing; the catch was emptied directly into a 260-litre deck tank prior to active whiting being transferred to other tanks for tagging (Gorman *et al.* 1985). Each fish was measured, tagged and a condition factor given. Tagged whiting were placed in holding tanks for 1-3 hours prior to release, and only those that showed no apparent ill-effects were released (Smith 1985). From October 1985 onwards, to avoid predation by seabirds, tagged whiting were lowered in a cage to about 10 m before being released (Gorman *et al.* 1986).

Despite these measures, recoveries were low, with 36 being recovered from 790 released on the mid-coast of New South Wales. No fish were recovered from the areas of highest fishing intensity (Smith 1987).

Redfish

Redfish were captured using F.R.V. 'Kapala' and chartered otter trawlers (Rowling 1987). This species is distributed out to the upper continental slope, but tagging was concentrated on the continental shelf (< 150 m) (Gorman and Graham 1987). Of the 29 314 tagged, 120 have been recaptured (K. Rowling, pers. comm.).

Redfish were tagged with blue Hallprint anchor tags. Tagging methodology on 'Kapala' was similar to that described for whiting (Gorman and Graham 1987) and on chartered vessels as described for morwong and flathead (K. Rowling, pers. comm.).

A reward of $5 is given for the return of tagged fish. Seeding experiments were conducted by Rowling (1987), and showed a very low level of reporting at the wholesale and retail levels, with about 20% reported.

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SCALLOP TAGGING

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Each species presents its own particular problems for the application of tags. In having a hard outer shell, which does not moult or easily reject tags, scallops present fewer problems than many other invertebrates. The main difficulties are that scallops have limited mobility, and tagged individuals do not become randomly distributed throughout the population once released. Thus some of the conventional objectives of tagging projects, such as determination of mortality rates, cannot be applied to scallop populations without careful planning of experiments.

In Victoria, tagging studies on scallops (*Pecten*) were first conducted in 1967 when plastic disc tags were attached to the upper flat valve of the scallop by steel wire passing through holes drilled in the 'wing' of the shell. These tags had to be sufficiently visible for sorters on the decks of scallop boats to detect. The objective was to determine growth rates.

In more recent tagging studies of scallops in Victoria, a similar tagging method was initially applied, since the first experiments had apparently worked reasonably well. These later studies were designed to measure growth and natural mortality in an unfished population, and all recoveries were made by divers. Some problems were, however, encountered with the use of these tags:

1. Tags and/or the wire sometimes became jammed between the valves, preventing their closure, interfering with normal swimming activity, and therefore contributing to mortality.
2. Tags floated upwards from the shell like flags, and could have attracted predators.
3. Tags became fouled with tube worm, which could have interfered with swimming movement.
4. The tags could only be used on scallops of about 30 mm shell height or more.
5. Tags were lost, as evidenced by recovered scallops with holes drilled.

A new type of tag was developed in conjunction with Hallprint, which consisted of a slim moulded plastic marker attached to narrow-gauge stainless-steel wire. This was a very unobtrusive tag, which overcame most of the above problems.

However, it subsequently became necessary to tag scallops too small to drill, and glued tags were used. Notwithstanding fierce arguments over the efficacy of superglue versus marine epoxy resins, superglued dymo-tape tags worked well, with very little tag loss. Some juvenile scallops of shell size <20 mm showed signs of distress (even death) after application of aqua-epoxy paint, possibly as a result of the contained volatile fractions.

In retrospect, the Hallprint tags were entirely successful for scallops >25 mm. However, superglue was also successful, and could probably have been used for the entire experiment.

METHODS OF TAGGING ADOPTED IN THE SOUTHERN SHARK FISHERY

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Abstract

Methods adopted by the CSIRO and the Victorian Fisheries Division for tagging several species of sharks harvested in the southern shark fishery are described. Tags inserted internally were more successful than those attached externally to fins, and the recapture rates were high for tagged sharks caught initially by baited hooks on longlines or hand lines, and for those caught by gill nets. There are major problems associated with evaluating tags by holding experiments because the sharks in this fishery are long-lived and cannot be held long enough to observe the retention of tags, and because of infections and stress induced by the conditions of captivity.

Introduction

The southern shark fishery began in the mid-1920s and is based on several species of temperate-water sharks: a common-property resource consisting mainly of gummy shark (*Mustelus antarcticus*) and school shark (*Galeorhinus galeus*). The fishery currently produces annually about 5000 tonnes, live weight, of shark valued at more than $17 million to fishermen in Victoria, Tasmania and South Australia.

Initially, fishermen targeted the school shark, and used several hundred baited hooks attached to a sinking main-line up to 10 km long. In 1964, Victorian fishermen introduced gill nets into the fishery, and by the early 1970s most of the catch was taken by this method. After adoption of gill nets, gummy shark replaced school shark as the predominant species in the shark catch. At the same time, common saw shark (*Pristiophorus cirratus*), southern saw shark (*Pristiophorus nudipinnis*), elephant fish (*Callorhynchus milii*), and several other less familiar species began to be taken in appreciable quantities, and now jointly constitute about 15% of the catch.

Tagging and biological studies on school shark were undertaken by the CSIRO during the 1940s and early 1950s (Olsen 1953, 1954, 1984; Grant *et al.* 1979; Stanley 1988). Later, during the mid-1970's, the then Fisheries and Wildlife Division of Victoria (now the Fisheries Division) undertook similar studies on gummy shark and, to a lesser extent, on school shark (Kirkwood and Walker 1986; Walker 1984). In 1985, the Fisheries Division began further biological work on these two species (Walker 1985, 1986; Walker *et al.* 1987) and funds are presently being sought to undertake a comprehensive tagging program throughout southern Australia from Albany in Western Australia to the New South Wales-Victoria border.

Tagging during 1942-56

Of the 6495 school shark tagged and released by CSIRO, 2590 were double-tagged with an external Petersen disc tag and an internal tag, 3569 were tagged only with an external Petersen disc tag, and 337 were tagged only with an internal tag. Recapture and reporting of these sharks by fishermen are continuing. By early May 1988, 587 (9.0%) had been recaptured, of which 76 had been externally tagged only, 50 had been internally tagged only, and 461 had been double-tagged. Of the 461 double-tagged sharks recaptured, 375 (81.3%) had lost the external tag at the time of recapture, and only 86 were reported with both tags.

The CSIRO, concurrently with the work on school sharks, also tagged and released 587 gummy sharks (220 internally and 367 double-tagged) of which 59 (10.1%) were recaptured and reported by fishermen. Of the recaptured sharks, 31 had been internally tagged only and 28 had been double-tagged. Of the 28 double-tagged sharks recaptured 21 (75.0%) had lost the external tag at the time of recapture and only 7 were reported with both tags. The last recaptured gummy shark was reported in 1969.

To capture sharks in offshore waters, hooks attached to longlines were used from F.R.V. 'Derwent Hunter', whereas in shallow inshore areas hand lines were used. For external tagging, a numbered Petersen disc tag, 16 mm in diameter, 1 mm thick and constructed of either white plastic, grey plastic or clear celluloid, was attached with 0.84-mm silver wire to the first dorsal fin of each shark tagged. This method of tagging was adopted after a series of successful preliminary tests in the experimental pool of the former CSIRO Marine Biology Laboratory at Cronulla, NSW. However, it was found later that most of these tags were lost within 2-3 years because they tore the fin tissues. Consequently, in 1949 a white plastic internal tag was adopted and from then on most sharks were double tagged. Of the double-tagged sharks recaptured, not one had lost its internal tag. The internal tag had been used on the small number of sharks tagged during 1942-45 but not extensively because it is not visible externally. When the internal tag was used alone, fishermen became aware of the tag only when gutting the shark, by which time the shark had usually been decapitated, and its total length could not be measured. The internal tag was inserted into the coelomic cavity through an incision on the left flank parallel to the muscles in the lower half of the body immediately below the posterior half of the first dorsal fin where the body wall is relatively thin. Two sizes of internal tag were used, and both were slightly tapered and rounded at one end. The smaller tag was 35 mm long and 10 mm wide at the wider end, and the larger tag was 40 mm long and 23 mm wide. The smaller tag was used for sharks of total length less than 750 mm, and the larger tag was used for longer sharks.

Tagging during 1973-76

Between 8 June 1973 and 29 November 1976, staff of the former Fisheries and Wildlife Division of Victoria tagged and released 1525 gummy sharks, 631 school sharks, 293 common saw sharks, 247 southern saw sharks, and 299 elephant fish. By the end of May 1988, 397 gummy sharks (26.0%), 115 school sharks (17.3%), 9 common saw sharks (3.1%), 24 southern saw sharks (9.7%), and 11 elephant fish (3.7%) had been recaptured and reported by commercial and recreational fishermen.

Sharks were captured for tagging on board F.V. 'Moondara' and F.R.V. 'Sarda' by fishing at 150 sites on the continental shelf between Streaky Bay, SA, Gabo Island, Vic.,and Hobart, Tas. The fishing gear consisted of 12 gill nets and 400 hooks attached to two longlines. Each gill net was 250 m long and 1.7 m deep, and the hooks were clipped 5-20 m apart to sinking super saran rope of the longlines by way of 1-m snoods with monel wire traces. Eight of the gill nets had a hanging coefficient of 0.60 and mesh sizes ranging from 51 to 229 mm (2-9 inches), and in steps of 25 mm (1 inch) (Kirkwood and Walker 1986); two had a hanging coefficient of 0.53 and mesh sizes of 152 mm (6 inches) and 178 mm (7 inches); and two had a hanging coefficient of 0.67 and mesh sizes of 152 mm and 178 mm. All of this fishing gear or components of it were set on the seabed, usually between 0400 and 0600 h, at depths ranging from 5 to 79 m. One size (Mustad 11/0) of long-shank, and nine sizes (Mustad 2/0-10/0) of short-shank hooks were used. Mean fishing times were 5.8 h for gill nets and 3.8 h for hooks.

Before being tagged, sharks were held in a round tank 1.8 m in diameter and 1.0 m deep. Because sharks captured by hooks tend to be in better condition that those captured in gill nets, most sharks captured by hook were tagged and released. Of sharks caught by gill nets, only those judged by their liveliness to be in good condition were tagged.

Sharks longer than about 700 mm were tagged with 50-mm by 20-mm serially numbered, yellow plastic internal tags, whereas smaller sharks were tagged with 33-mm by 9-mm white plastic internal tags. One end of the tag was rounded and a red plastic streamer about 150 mm long and 2 mm thick was attached at the other end. Each tag was inserted into the coelomic cavity through an incision, a little shorter in length than the width of the tag, made in the tough skin covering the myoseptal fold between the lateral and ventral musculature of the body wall. The tag was pushed firmly through the incision so that the curved end of the tag tore the connective tissue and the myosepta of the fold while minimising loss of blood and damage to the internal organs, most notably the liver and musculature. The red plastic streamer was allowed to protrude through the body wall. A curved needle was used to close the incision with a single stitch of soluble, surgical catgut and to thread the free end of the streamer under the skin for 5-12 mm, depending on length of the shark, and back out again. The free end of the streamer was then tied to the protruding section of the streamer near the incision to prevent the streamer from slipping inside the shark. The streamer was intended to alert fishermen to the presence of an internal tag. Red plastic cord similar to the streamer was also threaded through two holes 5 mm in diameter punched near the base of the anterior margin of the anterior dorsal fin. The cord was tied with a reef knot on each side of the fin. Finally the incision and the holes were disinfected with a solution of absolute alcohol containing a trace of malachite green. The sex, length, and condition of each shark, and the position and the date of its release were recorded.

The tagging program was publicised throughout the shark fishing industry in Victoria, Tasmania and South Australia, and shark fishermen were issued with specially printed self-addressed postage-paid forms, with facility for recording position and date of recapture, and total length of recaptured sharks. Fishermen were asked to enclose the tags with these forms and to send the recaptured sharks to the Melbourne Fish Market where they could be inspected and measured by research staff. If fishermen decapitated a tagged shark before measuring its total length, they were encouraged to report the shark's partial length from the fifth gill-slit to the base of the tail.

Tag-induced mortality is difficult to estimate for sharks because of infections and stress caused by the conditions of confinement required to observe the sharks. Tagged gummy sharks usually died within a few days when held in two available aquarium tanks established for commercial public viewing, each more than 15 m long, 10 m wide and 2 m deep, and circulated with natural seawater from the sea. About 15% of tagged sharks died within 2 days when held in an underwater cage (1.8 x 1.8 x 1.8 m) constructed of multi-filament nylon fish net webbing of 30 mm mesh-size and filament of 1.2 mm diameter. The mortality of the sharks in the aquarium tanks is attributed to infection due to lack of hygiene, and much of the mortality in the underwater cages is attributed to stress caused by confinement.

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NOTES ON TAGGING CORAL REEF DEMERSAL FISH SPECIES*

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Background

Over the late months of 1986, Queensland National Parks and Wildlife Service staff conducted an experiment to measure the 'catchability' of several coral reef demersal fish species at Boult Reef. Boult Reef is a coral reef which lies at the southern end of the Great Barrier Reef Marine Park. A principal technique used was tagging.

This note briefly sets out the lessons learned during the project, relating to tagging.

Additionally, some preliminary impressions of trials to test a newly developed 'body cavity' tag for use with demersal coral reef species are outlined.

Tagging Methods Used at Boult Reef in 1986

For this experiment, experienced commercial fishermen were employed to catch fish to be tagged. Fish were hooked using conventional methods, then placed in the folds of a 'bean bag' where they could be easily restrained and tagged. The tagging operation took less than 30 seconds, in most cases.

Tags used were 'loop tags' (Figure 1) manufactured by Hallprint in Adelaide. No problems in applying these tags were encountered. However, it soon became evident that tags applied to the head end of coral trout (*Plectropomus leopardis*), the principal target species, were being shed rapidly as some fish caught showed clear evidence of having been tagged earlier.

Coral trout, in particular, are often scarred above the head in the region where the loop tag is applied, and it is now clear that their habit of swimming through coral makes a loop tag particularly vulnerable to being snagged and lost.

When this became evident, all coral trout subsequently caught were double tagged, with the second loop tag being applied to the tail end of the fish. These loop tags were much less vulnerable to being shed (Table 1).

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* Document prepared for Poster Session but included here because of its relevance to Session 4
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Table 1. Releases and recoveries of single- and double-tagged coral trout in 'loop' tag experiment

Total number of coral trout caught	604
Coral trout released with tags	576
Coral trout tagged with a single tag at the head end	201
Such trout returned	3
Coral trout released with two tags (head and tail)	375
Such trout returned with both tags	26
Such trout returned with tail tag only	52
Such trout returned with head tag only	5

Note. These figures relate to tags returned by the fishing public during a 2-week period following the re-opening of Boult Reef to fishing after a three and a half year closure. During this period, the survey team was continuously present at the reef, and issued log books and information on the experiment to all people fishing in the area. Consequently, non-reporting of recaptures can be disregarded as a bias.

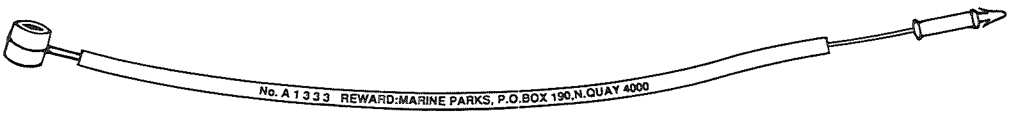

Figure 1. Loop Tag.

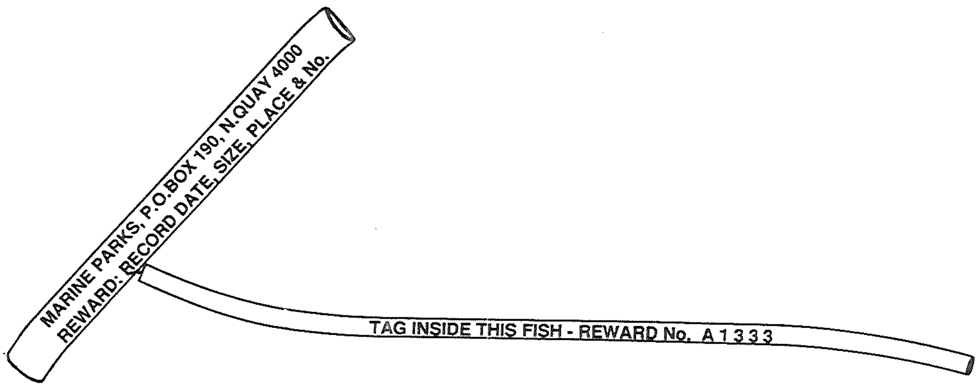

Figure 2. Body cavity tag.

A correction factor for those fish which had lost both tags, and were therefore unrecognisable in the catch, can be calculated (Seber 1982, Section 3.2.3). This factor is 1.12, and the total number of fish recaptured of those initially double tagged is therefore 93. Thus, over a period of up to a maximum of 90 days at large, 72% of coral trout initially double tagged had lost one tag or both.

A second observation on the use of loop tags was that since they tended to move continuously in the fish, the tagging wound tended not to heal well and, in fact, severe ulceration frequently resulted.

Recent Trials with 'Body Cavity' Tags

A tag is needed which persists long term and in particular does not snag on coral. After discussions with Michael Hall of Hallprint in Adelaide, a 'body cavity' tag was designed for trial (Figure 2).

In May 1988, trials using this tag type were started. Thirty fish were tagged at Sykes Reef, a coral reef at the southern end of the Great Barrier Reef.

Three of these fish were caught and returned by a commercial fisherman the day following tagging. It is of interest that these fish had sufficiently recovered to take bait the day after being tagged. Two of the three tags returned were reported to be solidly in place. The third was easily pulled out when the streamer was tugged, because the body cavity 'toggle' was not properly positioned. Three further fish were subsequently returned after several weeks at large. All these fish were reported to have been in good condition with their tags firmly in place.

The tags were easy to apply, and caused less wounding than body cavity tags made of flat plastic, which the author had previously used on estuarine species in Victoria. The tag streamer emerging from the body wall appears to be less mobile than the loop tag so that the tag wound is likely to heal quickly. Note that all tags are applied with Neosporin ointment.

Although trials will continue, it is felt that body cavity tags of this design are likely to be well suited for tagging coral reef species. The author is happy to provide further information on the trials, and can be contacted at the above address or by telephone on (055) 23 1730.

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DISCUSSION OF SESSION 4

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John Glaister briefly summarised the issues raised during the Session 4 panel presentations, and felt that tag rewards, liaison with fishermen and subsequent feedback, fish condition at tagging, tagging mortality, and handling/tagging techniques, were matters which were worthy of broader discussion.

David Smith drew attention to non-reporting as a crucial factor influencing population parameter estimates derived from tagging. He suggested that attempts to establish its extent were essential in a tagging project. He had found, as a result of a 'seeding' experiment, a non-reporting rate of 80% for redfish despite a high-profile project with attractive rewards. Julian Pepperell suggested that, although seeding experiments offered one approach, they suffered a possible inadequacy because of the small sample sizes commonly involved.

Mike Cappo, strongly supported by Kevin Williams, pointed out that, regardless of rewards offered, there may be political incentives for non-reporting because of concern that disclosure may disadvantage the group recovering tags. Recreational versus commercial interests might be one example or, for the tuna fishery, conflicting interests of Japanese longline, and domestic commercial and recreational fisheries on a common resource. John Diplock advised that all recoveries from the New South Wales Fisheries Research Institute yellowfin tuna releases had been made by commercial or recreational fishermen in New South Wales in what seemed to be a cyclical pattern following the movement of warm water north and south along the coast. Japanese longline vessels had returned two tags from the general area of Lord Howe Island. One fish had been released in that region, and one off coastal New South Wales as part of the gamefish tagging program. No other recoveries have been reported by Japanese longliners. Albert Caton suggested that current operations by the Japanese longline fleet along the central and northern New South Wales coast would be those most likely to recover tagged fish, so reports might be anticipated over the next few months.

Commenting on the importance of publicity and rewards if good reporting of recoveries was to be assured, Bob Kearney noted that there was a tendency to concentrate on a cash reward (usually grossly inadequate compared with the scientific value of returns) for individual recoveries. A combination of rewards was usually more appropriate because of the variety of recovery sources. A combination of T-shirts and a lottery had been effective in the South Pacific Commission skipjack project. In particular, because reporting rate had tended to decline after research personnel had left the fishing area, follow-up lotteries helped to 'drag tags out of the woodwork'. Frank Prokop noted the different motivations associated with commercial and recreational fishermen; many of the latter needed opportunities for bragging as a means of substantiating their prowess.

Rod Lenanton mentioned the importance of feedback of information about recoveries to people returning tags. He stressed the importance also of convincing fishermen about reasons for returning tags, citing one case in Western Australia where salmon fishermen will not return tags until research staff can prove to them that it is to the fishermen's advantage. Gary Henry, Rod Nurthen, Rick Morton, Julian Pepperell and David Hall reinforced the view that regular liaison and feedback was essential to keep reporting rate high. While confirming, on the basis of his own experience, the value of Gary Henry's and Rick Morton's approach of generating cooperation through angling clubs, Julian Pepperell pointed out that the majority of recreational anglers were not club members. Special and *ongoing* publicity was needed to target this group. David Hall mentioned the success generated by South Australia's 'TAG WATCH' approach, where a regular radio program reporting on releases and recoveries, and offering caps with logos and a range of prizes, kept the tagging research in high profile. Frank Prokop suggested that, in view of this, scientists may need to concentrate on the scientific aspects of tagging projects, and seek assistance from more appropriately qualified personnel for promotion and publicity.

John Glaister sought comments on the value of the involvement of recreational fishermen in tagging projects or in capture-mark-release fisheries, suggesting the possibility of substantial tagging mortality as a drawback. Alan Baxter drew attention to the lobby developing against recreational angling on the grounds of cruelty; tagging had also been categorised in that way. In that regard, capture-mark-release fisheries could face growing opposition. Rick Morton mentioned that when tagging tailor on surf beaches he had occasionally received criticisms about the cruelty of tagging. John Harris stressed that in view of the small size of most Australian freshwater fish populations, it would be desirable to encourage catch and release fisheries, as distinct from catch and retain, fisheries. However, the mortality associated with tagging by amateurs and the lack to date, as far as he was aware, of any useful results from amateur tagging and release work argued against actively encouraging it. John Anderson and Julian Pepperell favoured the contrary view, pointing to the incentive provided by the presence of a tagged trophy fish, and citing as one example a tagged sturgeon in the USA which had been caught on four occasions, each time setting a new record. John Glaister saw similar advantages for marine fisheries when strong amateur awareness was established; prospects for substantiating the need for research work and obtaining research funds were much greater with a supportive amateur lobby. Bob Kearney expressed the opinion that, in relation to tagging *per se,* a more objective approach would be to consider what extra information would be obtained as a result of tagging by amateurs, and to weigh against that the percentage of fish that would be killed in the process.

Condition of fish at the time of tagging may be an important factor in subsequent mortality as a consequence of tagging. David Gwyther and Peter Gehrke suggested that ambient temperature at the time of tagging was important, Peter Gehrke adding that time between removal from water and return was the major consideration. Cessation of effective respiration while the animal is out of water lowered blood pH etc., and could contribute to mortality rates. Jim Stoddart compared this with operations involving anaesthetics, where time under anaesthesia was the major consideration. Peter Gehrke and Terry Walker drew attention to the considerable variation between species in relation to tolerance of time out of water, Terry Walker indicating that Port Jackson sharks survived effectively after

4 hours, in contrast to school sharks, which succumbed after 10 minutes removal. Kevin Williams emphasised that it was particularly important to decide before commencing a project whether fish identified as in poor condition would be tagged and released. In general he favoured an approach where animals in poor condition were not tagged because the assignment of condition was quite subjective in these instances. Bob Kearney suggested that provided suitable records were made of apparent condition of fish at release, and of success of tag implantation, it could be useful to release 'imperfects' to check if there were differences in recapture rates. Richard Tilzey added that objectives of the releases were also important; if movement was of interest then condition at release was probably of less relevance than if quantitative studies on recoveries were intended. Julian Pepperell suggested that the gamefish project was an example where movements were the main interest. Some fish might be tagged poorly or might be in poor condition but this was a small price in contrast to the benefits achieved from development of liaison and cooperation with anglers. Mike Cappo cautioned that, for Australian salmon, the time fish had been held in the bunt of the net prior to tagging and release seemed to influence subsequent migration, with those fish subject to considerable delay subsequently postponing migration west by a year. Albert Caton mentioned that, while discussions had emphasised condition of the fish at tagging, another important consideration was the skill of the tagger; he felt that data sheets should clearly identify the persons involved. Bill Hearn added that allowance for different shedding rates associated with different taggers may need to be made in modelling and analysis.

Aquarium studies or holding cage experiments had occasionally been used to examine survival of fish after tagging. Bob Kearney mentioned his experiences using shipboard procedures (chumming and poling) to tag skipjack tuna in a large aquarium in Hawaii. Very little mortality occurred: only two (one tagged and one untagged) of the 20 tagged and 20 control animals died during the month of observations, despite the fact that during the first 4 days all tagged fish had visible bruises. Terry Walker described particularly high mortality for school shark in an aquarium. In contrast, John Stevens reported that a South African aquarium trial with tagged carcharinid sharks resulted in low mortalities. He felt the size of the aquarium might be the pertinent factor. Gary Henry cautioned that experiments on time taken to die may not be of sufficient duration. Some untagged snapper that he held in an aquarium showed no sign of trauma after capture but died after a week or two. John Anderson observed that, as holding in enclosures itself tended to generate mortality, tag effects could be masked. David Hall suggested that telemetric tags might provide a useful alternative to aquaria for studying the response of animals to tagging.

Mortality trials in crustaceans had been carried out by Steve Montgomery, who had reported that most deaths seemed to occur within 72 hours after tagging. Subsequently, virtually no effect was apparent. John Glaister mentioned that Jim Penn in Western Australia had had similar results, but a second mortality peak occurred when the animals next moulted.

Problems of condition of fish caught at considerable depths and brought to the surface for tagging were mentioned. David Smith had experimented with cages in trawl cod ends, knotless netting in the trawl, and reduced trawl time, in the course of his tagging work on tiger flathead, red fish, morwong and red spot whiting. Fish damage (air bladder distension, scale loss) was still considerable, whereas fish taken by Danish seine were far superior in condition. Kim Drummond reported much more encouraging results in his New Zealand project using knotless-trawl-caught snapper, where a 30% recovery rate had been achieved. Rod Lenanton had pierced distended air bladders of deep-caught snapper before releasing them, and mortality did not seem to be a problem but growth rate was slowed. David Smith indicated that he had pierced the air bladders of red spot whiting before releasing them and lowered them in a cage in attempts to reduce predation. Peter Young advised that Keith Sainsbury had used detachable cod ends on the north-west shelf in an attempt to speed up handling and reduce damage to fish. He also drew attention to New Zealand experiments with detachable-hook tags as a means of avoiding the decompression problems associated with tagging at the surface. David Smith pointed out that their drawback was the uncertainty about species tagged and the lack of growth information. Rod Lenanton mentioned that Western Australian experiments with hook tags had been less successful than hoped because of corrosion of the tag within 1 year.

Richard Tilzey queried the low recovery rate of tiger flathead tags, suggesting that it might represent a high mortality at the time of tagging rather than a low fishing mortality rate. Jacek Majkowski compared this with the results of the southern bluefin tuna project where returns were in excess of 40%. The low tiger flathead recovery rate could reflect high mortality at the time of tagging, low effort (perhaps unlikely given apparently heavy fishing pressure in the south-east trawl fishery) or high rate of non-reporting of recoveries. Rick Morton, mentioning recovery rates of 11% for adult and juvenile tagged tailor from surf and estuaries respectively, indicated that 8% of the recoveries were made within the first few months. Loss of tags may have been a factor in the subsequent reduced rate of returns because of indications of rubbing on returned tags.

In response to an enquiry by Terry Walker about the extent of necrosis or infection observed around the anchor used for tagging large gamefish, Julian Pepperell advised that signs of infection were extremely rare. However, there were indications that the tag generated a reaction because a hard plug of collagenous material was laid down around it. Peter Speare, who had been able to examine some recovered tagged gamefish, confirmed that the tag sites showed no change in histology except for fibrous tissue similar to the connective sheath observed around parasites dead *in situ*. At the other extreme, Peter Gehrke, commenting on the micro-wire tagging of fingerling golden and silver perch, explained that susceptibility to handling seemed more important with fish of that size than the effect of the micro-wire tag. John Anderson, responding to an enquiry by Johann Bell, explained that the spine clipping experiments he described had not incorporated an attempt at binary coding of individuals but was simply a general examination of the permanence of spine clipping as a marker for fingerlings. He hoped to be able to develop a spine-based ageing procedure using oxytetracycline and spine sampling.

The potential for using genetic markers was highlighted by Clive Keenan, who saw these as a means of marking without mortality. He also drew attention to the fact that the marks could be passed on to subsequent generations. Aquaculture and stocking projects seemed appropriate candidates for application of 'natural' markers like these.

Use of cyanoacrylate glue ('superglue') was commented on by several participants. Michael Hall explained that the glue could be produced with different solvent proportions. Solvent added to the standard commercial pack made the glue less viscous and enhanced its penetrative capacity. For shellfish this gave a much better bonding performance. Phillip Gibbs described his initial problems with dymo-tape markers which, because of the stiff material, were prone to lifting at the corners. Use of the material developed by Hallprint for prawn streamer tags overcame the problem. Cockles down to 5 mm in size had been tagged effectively. Tag shedding, on the basis of double tag experiments, was estimated at 4% over a 5-year period. Michael Hall advised that cyanoacrylate was carried into the surface layers of shell with the solvent but did not penetrate to flesh level; in any case the glue was inert once hardened. John Harris pointed out that the substance was used in orthopaedic surgery because of its low toxicity. Don Hancock added that it was used for insertion of half-nuclei in pearl culture. He mentioned David Heald's technique of applying a tag a set distance from the edge of scallop shells so that the growth increment can be measured. While David Gwyther had been involved predominantly with scallop tagging work, he mentioned in passing some fascinating attempts to tag beche-de-mer with FLOY T-bar tags. The tough exterior of the animals made penetration of the tag extremely difficult and, subsequently, the animal would evert itself and eject the tag.

In closing Session 4, John Glaister thanked all panellists for their contributions. He reminded participants that there would be further opportunities for general comments in the session prior to the end of the workshop.

SESSION 5

ANALYSIS, LIMITATIONS AND MANAGEMENT

Session Chairman:	A.J. Harrison
Session Panelists:	K.R. Allen R.J.H. Lenanton W.S. Hearn P.W.R. Sluczanowski

CHAIRMAN'S INTRODUCTION

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Next to the absolute abundance of a stock of fish the manager is most interested in fishing mortality and its relationship to current levels of effort. Thus the use of tagging to derive mortality estimates is a common objective of research programs conducted by organisations with a management responsibility. Despite this objective most Australian tagging programs seem to have provided more reliable information on growth and migration than on mortality. The question that might be addressed by this Session is whether this is due to the methods of analysis.

When statisticians look at a set of tagging returns they inevitably call for more returns and sometimes for more releases; however, the number of tags released and returned is often proportional to the funds made available to the project. The Session will attempt to derive estimates for the cost of each valid (usable) tag returned in some Australian tagging projects. Rewards and other expenditure directly designed to improve the recovery of tags may be very low when compared to the value of an additional valid data point.

The Session will also attempt to determine whether Australian tagging programs have proved to be cost-effective and whether other techniques which may appear prohibitively expensive on first examination may in fact provide a more cost-effective means of obtaining the same information.

Cost/benefit analysis is a necessity in present-day research. Governments have long ceased listening to the claim that research is inherently good and useful, and should therefore be funded. In light of this prevailing critical climate, I want to challenge workshop participants to re-examine entrenched views on the value of tagging as a tool in fisheries research, and to consider two fundamental questions:

1. Is tagging of any use?
2. Is it worth the money?

For fisheries management, two types of information are required:

1. Basic information on the stock, such as size and growth parameters.
2. Estimates of the impact of fishing on the resource.

Can tagging provide all or some of the answers? Can the same information be derived from alternative methods of research? In this session, the presentation of papers and subsequent discussions should be aimed at addressing such crucial issues.

The fishing industry has had an increasing involvement in fisheries management. Management decisions are therefore only partly governed by current research; the lobby strength of industry opinion should not be underrated in an era where industry increasingly shoulders the costs of research.

With regard to funding, I want to question whether tagging costs are indeed as low as is generally believed. Jim Stoddart, speaking on the National Tagging Register, told us that the average cost of one unit of 'useful information' is approximately $1300. I am, however, of the view that the real costs of tagging are frequently underestimated in budget projections.

I want also to examine the reasons behind the popularity of tagging amongst fisheries scientists. Tagging is often a comforting form of research, because of the immediate satisfaction of a returned tag. Tagging studies draw extensive, usually positive, publicity in industry and the wider community. They suggest scientific competence and give the image of 'doing something'. In conclusion, we need to remember that industry's willingness to *tolerate* research should not be confused with it's willingness to *fund* research.

THE USE OF TAGGING IN POPULATION ASSESSMENT

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Tagging experiments can provide information valuable to the management of marine aquatic animals in several different ways. In particular these experiments can contribute to knowledge of population sizes, of individual growth rates, and of migratory movements and stock identification.

The large whales provide an example of a group of animals which have been subject to marking experiments for a long time over a wide area, but with very limited results. Tagging of whales started under international arrangements in the early 1930s and to date, about 20 000 animals of various species have been tagged. Approximately 1500 recaptures have been recorded. Most of the early work was done on the summer aggregations of baleen whales, particularly fin and humpback whales, in Antarctic waters. More recently schemes have been concentrated on sperm whales in the north Pacific and southern oceans, and on minke whales in the Antarctic.

Despite the amount of data, the earlier studies gave no useful estimates of population sizes. This was largely due to the scattered nature of the tagging operations, and the difficulty of evaluating tagging success and tag loss. Useful population estimates of minke whales along the Antarctic ice shelf have, however, been obtained. These agree reasonably well with figures derived from direct ship-based counts. The estimation of growth rates based on tagging has also been unsuccessful; this is because individual animal size could generally not be estimated accurately at the time of tagging. Tagging has, however, contributed usefully to the understanding of the seasonal migration patterns and population structure of several whale stocks. On the local scene, for example, tagging showed that the humpback whales in the Australian region formed two distinct stocks, one off Western Australia and the other off the east coast of Australia; the latter also pass along the New Zealand coast.

While the prohibition of the commercial hunting of whales has cut off the acquisition of further data from the earlier marking schemes, comparable data are now beginning to become available through the recognition by observers of individual animals from distinctive natural markings on their bodies. Repeated observations have shown, for example, that known animals have migrated between Hawaii and Alaska,and between the Caribbean and New England coasts.

In considering the value of tagging programs to fisheries management, it is useful to begin by examining the kind of information fisheries managers need for providing a general basis for management regimes. The most common need of managers is for an estimate of the maximum continuing catch which can safely be taken in a fishery, and the first three columns of Table 1 summarise the main approaches which can be used to obtain such estimates.

For this purpose fisheries can be divided into four categories which differ in the kinds of data which are available for them, and therefore in the approaches which can be used. These categories are:

1. *New* fisheries where no previous fishing history is available.
2. *Declining* fisheries where catch per unit effort and/or average size have declined, but total catches have not changed greatly.
3. *Threatened* fisheries where declines have been large and catches may be on the point of collapse.
4. *Stable* fisheries, where catches, catch rates and sizes have remained fairly constant over a substantial period.

In view of competing demands for limited research resources, managers have generally to be content to concentrate on the first three categories, and only these are therefore included in Table 1.

The first approach, '*Initial Biomass* x *Magic*', refers to obtaining an estimate for unexploited population size by such means as trawling or acoustic surveys, and multiplying the estimate by a factor derived from a simple population model, generally incorporating an estimate of natural mortality (M) (e.g. Gulland's proposal to use 0.5M as the factor). In older fisheries *catch history*, if possible including effort data, can be used to attempt to estimate sustainable catch levels. Used without the support of population dynamics studies these methods can be dangerously misleading; there are many examples of fisheries in which catch levels and sometimes also apparent catch rates have been maintained for some years, but have ultimately been followed by a sudden complete collapse.

Stock identification, although of no direct use in the estimation of stock size, can sometimes be an essential management tool. In fisheries which contain several stocks with different levels of exploitation, an understanding of stock structure is vital to setting rational catch quotas. The last grouping in the table, *population analysis*, covers a range of analytical methods which are based on the determination of critical population parameters. These parameters fall into four categories:

1. *Stock size* estimates, expressed as either *absolute* biomass, or as *relative* to the initial biomass.
2. *Mortality* estimates, including natural mortality (M), and fishing mortality (F); these may also be combined as exploitation rate (E).
3. *Growth* rate estimates.
4. *Recruitment* rate estimates.

As indicated in Table 1, not all population analysis methods can be applied to any one category of fisheries. Parameters which are based on population changes over time, such as changes in population size, F and E, cannot be ascertained in new fisheries. Similarly, no direct assessment of the initial or virgin biomass is generally possible for declining or threatened fisheries.

The remainder of the table summarises the *usefulness* of *tagging* in these various approaches. In stock identification tagging studies are undoubtedly of great benefit. The pattern of tag recoveries is still the best indicator of seasonal and migratory movements throughout the life cycle of a species. However, even in this case, tagging should be viewed as only one of a number of possible approaches, whose results should be integrated. Biochemical and parasitological studies are among those valuable to the understanding of fish stock structure, particularly in the pelagic and juvenile stages where tagging experiments cannot be conducted.

Table 1. The use of tagging in the assessment of populations with differing levels of exploitation

	Fishery			Tagging	
	New	Declining	Threatened	Use	Timing
Initial biomass x 'magic'	#	X	X	N	-
Catch history	X	#	#	N	-
Stock identity	#	*	*	D	I
Population analysis					
Stock size					
Absolute	#	+	+	P	I
Relative	X	#	#	?	?
Mortality rate					
M	#	+	+	D	L
F	X	+	+	D	I
E	X	+	+	D	S
Growth	#	*	*	D	I
Recruitment	X	#	#	N	-

KEY

Method:
- # applicable
- X not applicable
- * tagging makes valuable contribution
- + tagging makes minor contribution

Tagging:
- N not relevant
- P poor
- D direct

Timing
- S short (1-3 yrs)
- I intermediate
- L life-time

The value of tagging in estimating absolute population size is often disappointing. Wide error margins are introduced by uncertainties associated with tagging techniques and by assumptions in analysis. However, it seems likely that tagging results could be of greater use in the estimation of relative abundance. Many of the uncertainties in the estimates of population size take the form of unknown biases rather than of random errors. If it can be shown that these biases are reasonably likely to be more or less constant from year to year, then the uncertainties in estimates of changes in relative population size could be much smaller than those in estimates of absolute size. Combination of these relative estimates with other population dynamics data could provide a useful alternative to the traditional use of catch-per-unit-effort data in assessing the status of some stocks. Such studies would require extended tagging programs in which the same techniques were applied to the same stock components for a number of years so as to obtain a time series of data in which biases could be held fairly constant. Too many tagging experiments in the past have been one-off efforts, and I suggest that more serious consideration should be given to planning continuing or recurrent tagging programs in cases where the state of the stock is the primary objective.

The final column of Table 1 examines in general terms the *time* required to obtain useful data on the various approaches by means of tagging. The quickest estimates to be obtained by tagging are those for fishing mortality or exploitation rate; these are often available in 1-3 years. Good estimates of natural mortality rate may, however, take much longer since they require observations to continue until almost no survivors of the tagged group of fish remain. Growth data generally need returns over a moderate period so that the fish have grown by an amount which can be measured with reasonable accuracy, but on the other hand differences in rate of growth with age have not been smoothed out. Data on population size and stock identity improve with the quantity of observations, and thus become more valuable as time goes by.

In conclusion, therefore, tagging is at times a very useful research tool, but it should not be relied on alone for the determination of population parameters. If it is used in conjunction with other population analysis methods, parameter estimates are strengthened, and increased confidence can be given to their validity.

TAGGING IN WESTERN AUSTRALIA

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The question I was asked to address was how effective (including cost effectiveness) has tagging been in facilitating worthwhile stock assessment and fisheries management in Western Australia?

Worthwhile stock assessment requires a knowledge of stock identity (and movement), age structure and growth, population size (and recruitment), and mortality rates.

During the following brief discussion I have tried to focus on some of the positive contributions tagging has made to an understanding of each of these processes in the context of Western Australian managed fisheries.

Stock Identity (and Movement)

Tagging is one of a number of techniques available which can be used to identify the extent of distribution of a unit stock for stock and recruitment assessment. Morphometrics, electrophoresis, parasitic infection rates, trace metal levels in hard structures, and comparisons of biological characteristics such as growth parameters, are examples of other methods commonly used. Provided the tagging program is designed to meet the particular objective, and the distribution of fishing effort is adequately understood, then tagging can be used to define the extent of a unit stock. Possibly the best recent example in Western Australia has been the use of tagging to define three separate stocks of snapper in the Shark Bay area of Western Australia; one oceanic stock, and two independent stocks within Shark Bay, a result confirmed using the other independent techniques mentioned above. Tagging has also been extensively used to study movement within important commercial stocks in Western Australia. The rates of offshore movement of rock lobster with increasing age have been extensively reported. Tagging has also increased our understanding of the extent of the distribution of the western species of Australian salmon, and recent returns have provided good data on movement rates between South Australia and Western Australia, which greatly affect catch rates in Western Australia.

Age Structure and Growth

Tagging is one of the few methods available to estimate growth rates in situations where age determination is not possible. For example the best estimates of growth of the western rock lobster have been provided by tagging; these could, however, still be improved by more extensive tagging.Provided that the assumption is made that tagging does not affect growth rate (which appears to be the case with the robust rock lobster), provided that tags are distributed throughout the size range of the population, and provided that reasonable numbers of recaptures are obtained over time, then good estimates of growth are possible.

A major problem is tag durability, i.e. the rate at which rock lobsters eat the identification streamers off the tags. There is also the problem of tagging mortality caused by displacement of tagged animals away from their preferred habitat, which is more acute the deeper the water. These sources of bias need not be a problem for growth if sufficient numbers of tagged animals are released initially, and the release strategy is well designed.

Tagging has also been useful in the validation of ageing. With Shark Bay scallops, for example, research tagging has confirmed that daily growth rings were laid down on the shell. Once the animals become older, and daily rings become more difficult to identify, tagging has provided the only growth data. Snapper from the deep-water oceanic stock marked with external tags showed extremely slow growth rates when compared with growth rates calculated from scale reading. Thus although L_∞ was similar from both techniques, K calculated from tagging was relatively much lower. Persistent infection associated with the tag wound was thought to be the reason for the slow growth. However, internal tags used in shallow-water snapper stocks produced an L_∞ similar to that from scale reading, but a much higher K. The difference between the Ks in this case was found to be due to scale readers interpreting false checks as annuli.

Population Size and Mortality Rates

Most attempts at the estimation of population size and mortality rates have been unsuccessful, due at present to unmeasurable bias resulting from initial and long-term tag mortality, tag loss, under-reporting of tag recoveries, behavioural changes, selectivity of fishing gear, emigration and immigration, and non-random mixing of marked animals. This was true of prawns where initial (short-term) tagging mortality was particularly high due to the capture process, and long-term recaptures were very low, due to very few tagged animals surviving beyond the first moult after tagging. Variable catchability associated with recovery of tags was also difficult to measure. However, some particularly encouraging estimates of population size, and fishing and natural mortality rates, and catchability were obtained when a closed unexploited population was tagged and experimentally fished. Further, experiments on rock lobster in a small research area near Rat Island (one of the Abrolhos Islands) using multiple release and recapture techniques gave good estimates of population size and catchability for that region.

Attempts at the estimation of population size and mortality rates for snapper were not successful due primarily to a substantial fishing (i.e. capture) induced mortality for deep-water fish, which contributed to a large and unknown initial tagging mortality. However, the real success story was scallops. These animals are robust, easy to mark, relatively immobile, and have very high tag detection rates. Thus the above sources of bias proved not to be a problem, and worthwhile estimates of fishing and natural mortality, and of catchability have been determined for the Shark Bay population.

Although population size and mortality rates are amongst the least satisfied parameters in stock assessment, there are instances where absolute precision is not essential. In Wilson Inlet, a barred estuary on the south coast of Western Australia, there was a requirement to estimate the relative exploitation rates of commercial and recreational fishermen targeting King George whiting during the period when the entrance channel was closed to the sea. The Petersen method was used to provide exploitation rate estimates of 2 and 10%, respectively. Although some of the assumptions of tagging were violated, particularly the uniform mixing of marked animals throughout the unmarked population, the important conclusions for the community were that the overall rate of exploitation was low, and recreational fishermen were the major exploiters. Whether they took five or two times more than the commercial fishermen was less important.

Other Management Applications

Some other applications which have been useful to management include the marking and multiple recapture of rock lobster over the breeding season to monitor catchability changes, and more recently the changing reproductive state of individual females. Together with data on commercial catch rate (relative abundance) this is now being used to refine the annual index of the size of the spawning stock, and thus improve the stock-recruitment relationship.

Tagging has also been used successfully to determine the magnitude of the fishery-induced mortality generated by various handling techniques for undersize rock lobsters returned to the sea.

The enforcement branch of the Fisheries Department have also 'seeded', with marked undersize individuals, the rock lobster catches of those suspected of trading in undersize rock lobsters.

Costs

In situations such as the valuable (>$180 million per year) rock lobster fishery, where the data must be obtained, and no other methods are appropriate, then the low cost of tagging relative to the value of the industry is entirely justified. However, in less valuable fisheries, such as the snapper fishery, where the necessary information can be obtained using other techniques, then the application of tagging needs to be rigorously reviewed.

It is appropriate to note here that it often takes relatively longer for worthwhile tagging results to become available to managers. For example, it took 4 years before the results of tagging could be confidently used to identify Shark Bay snapper stocks. The results from eletrophoresis, parasite infection rates, and methods used to estimate growth parameters were all available much sooner.

However, in this day and age, with the availability of vastly improved models, and the computing capacity and sophistication to cope with complex and extensive data sets, a simulation of the effects of a wide range of tagging strategies can be evaluated to determine which, if any, are appropriate. Supplemented by, and using feedback from, pilot studies, or more appropriately and at very little cost, data from the Tagging Register, these simulations allow the cost and potential benefits of a full-scale tagging study to be carefully explored.

Tagging by Recreational Fishermen

It is clear from reports of the results of tagging programs on recreationally important resources that well-supervised support from recreational fishermen can be both cheap and reliable.

Nevertheless, recreational fishermen are increasingly being encouraged to independently mark and release a range of recreationally important fish species.

Some useful data from the actual tagging operation may come from independently tagging large, robust fish such as marlin.

However, the view held to date by the Western Australian Fisheries Department is that this type of tagging provides very little information that is useful to fisheries managers. Recreational fishermen on the whole are unskilled, and are unsupervised during such activities. Thus tagging methodology is highly variable, the suitability of individual species is rarely considered, and the application of tags inconsistent between operators. Mostly they are motivated by fishing rather than fisheries science, and thus they are more prone to making recording and measurement errors. Rather than reduce fishing mortality, catch and release probably generates additional mortality because fishermen need not observe bag limits and can fish and release tagged fish indefinitely, provided they do not keep their catch. Indeed the potential for violation of most of the basic assumptions which need to be satisfied to achieve the objectives of such tagging experiments is great.

Nevertheless, there are a number of indirect benefits which flow from actively involving the recreational fishing community in tagging projects. There is a longstanding community perception that, unless researchers are seen to be undertaking tagging, then they are not doing all of the research necessary as a basis for the responsible management of recreational fisheries resources. Thus institutional support of such projects can result in improved relations between fishermen and 'the Government', making fishermen more willing to provide good catch and effort data, which is generally lacking for recreational fisheries.

Such support can also generate interest in, and promote an increased understanding of, fish biology.

Thus although very little useful information may come from such tagging, the recreational catch and effort data base may be substantially improved.

ANALYSES OF SOUTHERN BLUEFIN TUNA TAG-RECAPTURE INFORMATION

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Fish tagging programs require: (i) justification, either from a scientific or management perspective; (ii) careful planning; (iii) rigorous standards of tagging and recovery of tags, especially if fishermen return tags; and (iv) mathematical models that are appropriate to the realities of fishing operations.

The Fishing Industry Research Trust Account (FIRTA) granted $57 5000 to CSIRO to conduct the 1983-84 southern bluefin tuna (SBT) tagging program in which 10 179 fish were tagged off Western Australia and South Australia. Subsequently, tags have been returned by Australian fishermen from 4033 fish and by Japanese fishermen from 30 fish (Table 1). Only a few more are expected to be captured by Australian fishermen but it is hoped that hundreds more will be caught by Japanese longliners.

The cost of CSIRO's contribution (tagging personnel, supervision, tag rewards, data processing, analysis and overheads) plus inflation brings the expenditure so far to more than $1 million at today's prices. The 4063 tagged tuna recaptured to date (Table 1) have therefore cost more than $250 each. The cost of developing new analytical methods was not included.

This experiment confirmed the results of analyses of commercial catch statistics that SBT were heavily fished by the Australian fishery. That 40% of tagged fish were caught and reported, within 4 years of tagging, is difficult for fishermen, managers and scientists to argue against. The proportion recovered is still a high 32% if recaptures within 3 months of tagging are ignored.

Injury of fish due to tagging, failure of tag-finders to report tags with reliable recapture information, and tag loss/shedding, are the major reasons why tagging programs are difficult to interpret, and considerably reduce their cost-effectiveness.

Ray Hilborn, a leader at a recent population dynamics workshop, believes that as much money and staff should be dedicated to recovering tags from fishermen as is dedicated to tagging fish. On this basis it would appear that the current $5-per-tag reward is low. However, the most important factor in the return of tags is to convince fishermen that a tagging program is worthwhile, and to have close contact with them. In this regard Kevin Williams has made an outstanding contribution to the SBT tagging program. The effectiveness of the experiment can be doubled if all tags are returned by the Japanese but I am not optimistic that this can be achieved without a Japanese equivalent of Kevin Williams.

Table 1. (a) Number of southern bluefin tuna tagged off Esperance, Albany and South Australia during 1983-84, and numbers of tagged fish caught during each calendar year by Australian fishermen

Tagged off	Number tagged	No. of tagged fish caught during: 1983	1984	1985	1986	1987	1988	Total
Esperance	4590	1126	372	153	48	5	-	1704
Albany	2366	281	404	150	94	19	1	949
South Aust.	3223	-	613	471	265	30	1	1380
Total	10179	1407	1389	774	407	54	2	4033

Table 1. (b) Numbers of southern bluefin tuna tagged off Esperance, Albany and South Australia during 1983-84, and numbers of tagged fish caught during each calendar year by Japanese longline vessels

Tagged off	Number tagged	No. of tagged fish caught during: 1984	1985	1986	1987	1988	Total
Esperance	4590	3	2	-	3	-	8
Albany	2366	3	1	-	-	-	4
South Aust.	3223	1	8	5	3	1	18
Total	10179	7	11	5	6	1	30

The following is about a paper I am preparing on tag shedding in double-tagging experiments with co-authors George Leigh of CSIRO Division of Mathematics and Statistics and Professor Ray Beverton of the University of Wales Institute of Science and Technology. This originated from a comment by Beverton after comparing the tag-shedding model used in one of my papers with approaches he had used (Beverton and Holt 1957, pp 202-8).

The purpose of a double-tagging experiment is:

1. To reduce the probability of a tagged fish losing all its tags.
2. To measure the extent to which tags are shed from fish by observing the ratio of recaptured fish with only one tag to those with two tags. This allows an estimate of the very often unobservable number of fish that have lost both tags.

It is assumed that natural and fishing mortality rates, and migration are independent of how many tags are attached to a fish.

Importantly, it is assumed that the probability of a tag being shed is independent of other tags, particularly of the other tag on the same fish. The probability of shedding can then be determined in terms of the numbers of recaptured fish having one and two tags. If the probability is plotted against time, then the tag-shedding rate is proportional to its time differential, the slope of the curve.

In Figure 1 (J. Hampton and G. Kirkwood, unpublished data), the probability of shedding is plotted against the period at liberty for the CSIRO 1964-69 tagging program off South Australia. During years 1-4 the slope is apparently *negative*. (A negative tag-shedding rate means that tags spontaneously re-attach themselves to fish, which is scientifically unacceptable, or the assumption of independence is violated.)

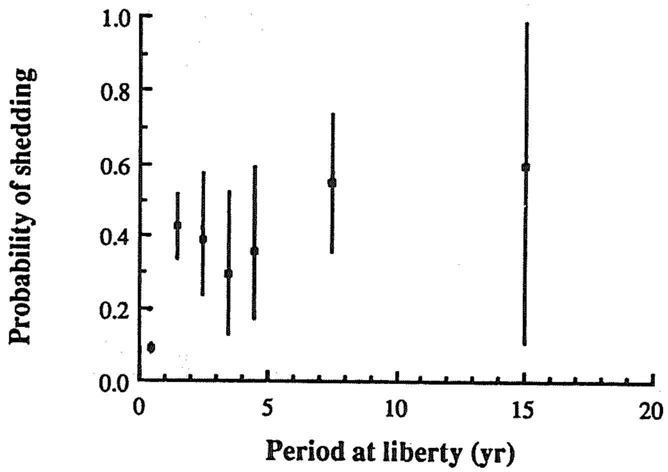

Figure 1. Relationship between the probability of tag shedding and period at liberty for the CSIRO 1964-69 tagging program off South Australia. The bars represent 95% confidence intervals.

One explanation (there are others) for this apparent anomaly is that a major proportion of fish may be tagged less proficiently than the remainder. During the first year the graph is dominated by captures of fish that quickly shed tags. But after about 5 years these fish may have lost all their tags and cannot be accounted for thereafter. Upon further investigation it was indeed found that there are substantial differences in shedding rates from fish tagged by various taggers.

In less extreme cases the only evidence of this problem may be a flattening of the curve during the transition stage, which can alternatively be interpreted as a distribution of shedding rates among tags as suggested in Kirkwood (1981), and Davis and Reid (1982). Consequently, biases can be unsuspected and large, so beware.

This kind of bias is substantially reduced if tag shedding is kept low and tagging techniques are uniform.

The field work for the 1983-84 tagging program was led by Kevin Williams. Hampton and Kirkwood (in prep.) demonstrate that tag-shedding is much lower for this program than for previous ones. There is little doubt that proficient tagging has substantially contributed to the high percentage of tags returned in the 1983-84 tagging program. Bob Kearney reports even less tag shedding in his double-tagging program (Skipjack Programme 1981).

It is evident that practical aspects are most important in coping with tag shedding. Mathematical models and adjustments are the last line of defence.

Analytical Methods

New analytical methods have been developed by Jacek Majkowski of CSIRO Division of Fisheries, Ron Sandland of CSIRO Division of Mathematics and Statistics and myself to analyse SBT tag-recapture data from the 1983-84 tagging program (Majkowski *et al.* 1984, 1988; Hearn 1986; Hearn *et al.* 1987). These methods estimate natural and fishing mortality rates, yield per recruit, and interactions among fisheries. They do not model the fishing operation nor require a parametric model of growth, and are valid for non-homogeneous populations. Notably the interaction method does not require the construction of a model for migration between geographically separated fisheries.

Fishing Mortality Rates

The fishing mortality rates due to the Australian fishery are estimated by a modification of the forward cohort analysis method. These rates tend to be higher than those estimated from cohort analysis of the global commercial catch statistics. This is expected, because tagging deals with fish that pass through Australian waters, which make up only a fraction of the global stock. Lower fishing mortality rates for fish tagged off Albany and Esperance indicate that only a portion of these fish migrate to South Australian waters.

Interactions among Fisheries

Knowledge of interactions between components of a fishery is essential for management of the fish stock, and the resolution of conflicts between fishermen belonging to these components. The basic idea behind the method is that tagged fish represent those fish that fishermen would be required to catch in addition to their present catches if a quota increase is being considered, or abstain from catching if a quota reduction is desired. That is, tagged fish represent a proposed change to a fishery. The capture of tagged fish at a later time, when they may be much larger and in another fishing ground, represents the effect of the proposed change.Twenty percent of SBT tagged in Western Australia were caught by the South Australian fishery but only 1% of those tagged in South Australia were caught by the Western Australian fisheries off Esperance and Albany. Table 2 basically shows that Western Australian catches have a large effect on South Australian catches.

For fish tagged off Western Australia and recaptured off South Australia the estimated level of interaction is much higher for the 1983-84 tagging program than that estimated from the previous tagging.

Table 2. Predictions of the effects of changing the catches of one southern bluefin tuna fishery upon the catches of another fishery and the entire Australian fishery.

	Effect (%) of increasing, by one unit, the weight of the catch of the fishery component listed in the first column upon the catches of:			
Component changed	Esperance	Albany	South Aust.	Australia
Esperance	-	-12	-72	17
Albany	-4	-	-88	8
South Aust.	0	0	-	100

I have anticipated the electronic tag revolution (mentioned by Bob Kearney) in my paper (Hearn *et al.* 1987) on a method for estimating natural mortality from tagging. This approach can be dramatically improved if, at some suitable time, the number of live fish with tags can be counted by 'draining or by rotenone poisoning, or, perhaps in the future by telemetric means'. For example an accurate estimate of the natural mortality rate of SBT could be a by-product of a program, involving a few hundred pop-up satellite communicating tags, to test conjectures that SBT have another spawning ground or that they swim through Drake Passage (Harden Jones 1984).

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THE DEVELOPMENT OF FISH TAGGING PROJECTS

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Introduction

Fish tagging is a widely used fisheries research technique. Data obtained from the recapture of tagged fish are combined with information from other sources, and analysed to yield information useful to fisheries managers, such as stock identity, movement, growth and mortality, and relative use of the resource by each fishing sector.

An assessment of past programs shows that, while there have been many valuable tagging projects, there are doubts about others. Better planning improves the cost effectiveness of projects.

This paper outlines the planning process of a tagging project as part of an ongoing fisheries research program.

A Tagging Project as Part of the Fisheries Research Program

The fisheries research program contributes to management by providing information on the fishery, including stock biology, population dynamics and the industry. Fish tagging is one of the important methods of obtaining answers to questions such as:

1. Will fishing in one area affect stocks in another? (Stock identity)
2. How? (Movement)
3. At what rate do fish grow? (Growth)
4. At what rate does a group of fish die? (Mortality)
5. How is the catch split between the commercial and recreational sectors? (Resource share)

Figure 1 shows the stages involved in planning and carrying out a tagging project and how it fits into the fisheries research program, as follows.

Problem Definition

At the fisheries management level, the state of knowledge about a fishery is constantly being reassessed. Management objectives need to be confirmed as they are affected by changing social, economic and political conditions. At the same time, opportunities for improved management are sought. Tagging is one of the methods available for increasing the level of understanding of the fishery. If a tagging project is considered potentially worthwhile, resources should be allocated to planning. Figure 1 shows why the duration of the planning period can vary. It is a feedback process whereby a project plan is sequentially improved. The planning phase extends through the feasibility study into the detailed project planning stage which follows the decision to proceed.

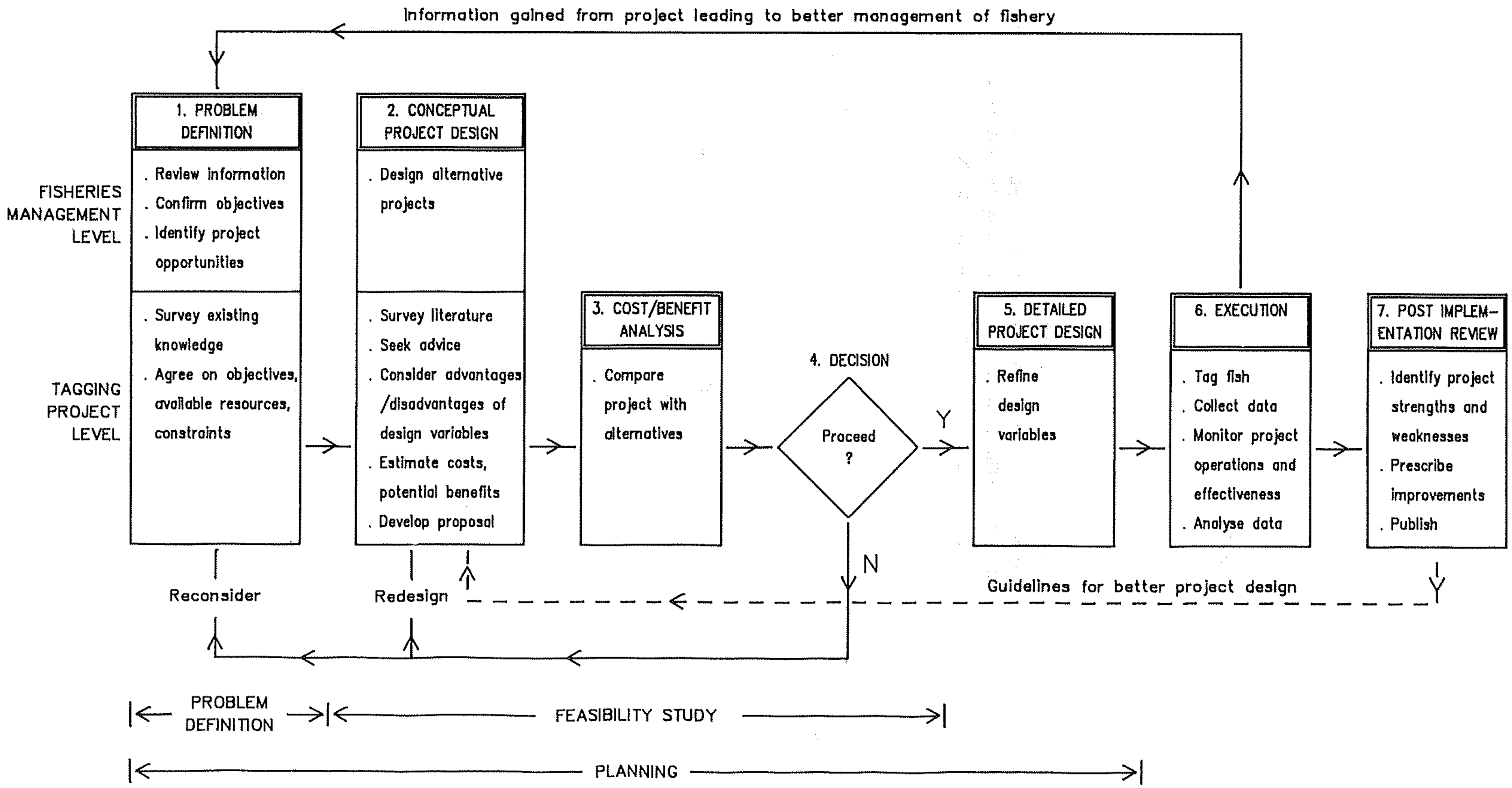

Figure1. Stages involved in planning and carrying out a tagging project in a fisheries research program.

The following points should be discussed with the fisheries managers:

1. potential benefits of the work;
2. availability of resources (funds, personnel, equipment);
3. timeframe;
4. likelihood of achieving objectives;
5. alternative projects.

The results of these discussions will set the framework for further planning.

Conceptual Project Design

Alternative research projects using different techniques such as size-frequency analysis or catch and effort analysis should be considered at the same time as the tagging project. They would have different potential benefits, timeframes and costs. They may be part of the tagging project, or may increase its value by adding to or independently checking its results.

If the researcher is familiar with tagging projects, or if the problem is not difficult, the conceptual design phase may not be detailed. Experience may make costing and design easier. The research manager must judge the level of planning necessary before approving the project or halting it.

In any tagging project, there are *a priori* conditions (such as species, type of data gatherer, and availability of information on fishing effort and gear selectivity) which will help determine further details of the design see 'Detailed Project Design'. A literature search should gather information on projects involving similar species or conditions. Expert advice is especially beneficial at this stage.

A project has a number of design variables (e.g. tag type, number of tags, reporter reward) which the experimenter must choose. Each affects the quality of the data, the ability to analyse the data, costs, and the likelihood of obtaining benefits.

These should be analysed and various combinations considered. Computer simulation techniques can assist this process. The design variables are altered to improve the cost/benefit ratio until a formal project proposal is developed. It includes objectives, justification, rationale, plan (methods, schedule) and budget.

A special type of fish tagging project is one which is designed to provide information for better project design (e.g. double tagging can measure rate of tag shedding; tagging landed fish before processing can measure rates of tag reporting by processors). Pilot tagging projects may be necessary to gain basic information about a stock that would help determine the feasibility of a full-scale project.

Cost/Benefit Analysis

The potential benefits of all the projects being developed are considered in relation to costs.

Decision

The project is formally approved and funds are allocated to it.

If it is not approved, the project should be redesigned, reconsidered or abandoned.

Detailed Project Design

The combination of design parameters is further refined, depending on the degree to which the design process has been carried out in the earlier conceptual design phase.

A project management system is set in place. It includes a schedule, allocation of tasks and budget.

Execution

The plan is set in motion. Ongoing review and monitoring of project operations and effectiveness should be part of its execution.

Execution involves three distinct activities, details of which are determined by the project design mix:

1. catching fish and tagging them;
2. finding tagged fish and obtaining data;
3. analysing data to gain information.

The information gained from the project is fed back to the managers, who use it for the benefit of the fishery.

Post-Implementation Review

This stage is frequently omitted. A fundamental law in control theory states that you can only learn by making mistakes. The purpose of a post-implementation review is to review a project systematically and to teach others through publication.

At the conclusion of the project, the benefits obtained should be identified (and quantified if possible), and compared with prior expectations and the cost of the project.

Most importantly, the reasons for the success (or otherwise) of the project should be analysed and proposals formulated for improving future tagging projects.

The Design of a Tagging Project

One Philosophy

'It is easy to score some tags, go fishing, whack them in, bung up some reward posters and wait for results.'

Another Philosophy

Project design is an art. The task is as follows:

1. While bearing in mind
   (a) the range of objectives;
   (b) the results of previous research projects on the fishery, and known stock population dynamics;
   (c) other research projects proceeding in parallel;
   (d) species biology (susceptibility to tag material, physical structure of animal, stress from tagging, method of growth and susceptibility to predation on release);
   (e) types of tagged-fish finders and their effort; distribution (commercial or recreational fishers, processors, diners);
   (f) state of the fishery;
   (g) attitude, degree of organisation, education level of fishing sectors;
   (h) lessons learned from past studies on similar species or conducted under similar conditions;

2. Select
   (a) tag type (quality, retention, durability; effect on mortality, growth, vulnerability and behaviour; detection ability, visibility);
   (b) legend printed on tag (clear, durable, facilitating reporting e.g. 008 phone number);
   (c) types of taggers (researcher, commercial or recreational fisher);

3. Decide
   (a) number of tags;
   (b) space framework for tagging;
   (c) time framework for tagging;
   (d) size-category framework for tagging;

4. Develop procedures for
   (a) checking the effects of tagging on fish (e.g. death immediately after tagging, increase in natural mortality, change in migration behaviour, change in vulnerability to fishing, mixing with untagged population);
   (b) checking the effectiveness of tags in obtaining the required information (e.g. tag loss rate);
   (c) catching a sufficient number of fish of the required size where and when they need to be tagged;
   (d) selecting those which will be tagged;
   (e) handling them;
   (f) applying the tag(s) (how, where, how many and 1 or 2 ?);
   (g) releasing the tagged fish;
   (h) collecting, if relevant, sampling effort information;
   (i) estimating, if necessary, the selectivity of fishing gear;
   (j) training taggers;
   (k) motivating taggers;
   (l) checking the quality of taggers' work;
   (m) reporting tag recoveries and associated data;
   (n) verifying tag recoveries;

(o) rewarding tag recoveries and providing feedback;
(p) informing potential tagged-fish finders and reporters of the tag reporting procedures (publicity, directed at correct group, sufficient coverage, understood by group);
(q) motivating potential tagged-fish finders and reporters; (cash, lottery, T-shirts, goodwill, as a routine part of a commercial fishing business,certificates, badges, photos, press coverage, fun);
(r) monitoring the effectiveness of the tag reporting procedures (e.g. seeding experiments);
(s) recording and storing data;
(t) analysing data, including an assessment of the extent of different types of errors;
(u) project management;
(v) publication;
(w) extension of results;
(x) post-implementation review;.

5. Analyse the effect of each of these on
   (a) cost;
   (b) accuracy of a data item;
   (c) information content of a data item;
   (d) ability to analyse the data (methods, mathematicians);
   (e) likelihood of achieving certain benefits;
   (f) risk;

6. Select that combination which achieves the minimum cost/benefit ratio.

Costing a Tagging Project

A feasibility study involves the development of alternative projects and a subsequent choice based (usually) on a cost/benefit analysis (Figure 1).

The cost of a tagging project can be estimated by splitting it into four components: planning, tagging, data collection and analysis. Figure 2 shows their cost flows during a tagging project. Note:

1. the rapid increase of total expenditure immediately after tagging commences;
2. the allocation of funds to various design variables will determine the overall effectiveness of the project the resulting 'project mix' may be more important than the absolute level of funding;
3. analysis of tagging data may continue indefinitely.

The long-term cost of the project can be determined in a number of ways. For example, the total project cost could be spread over a period (e.g. 30 years) at an appropriate interest rate.

The long-term benefit of a project is the increase in benefits resulting from it (taking account of interest rates). It is difficult to quantify, even in a post-implementation review.

However, any cost/benefit analysis should take full account of the overall long-term value of the fishery.

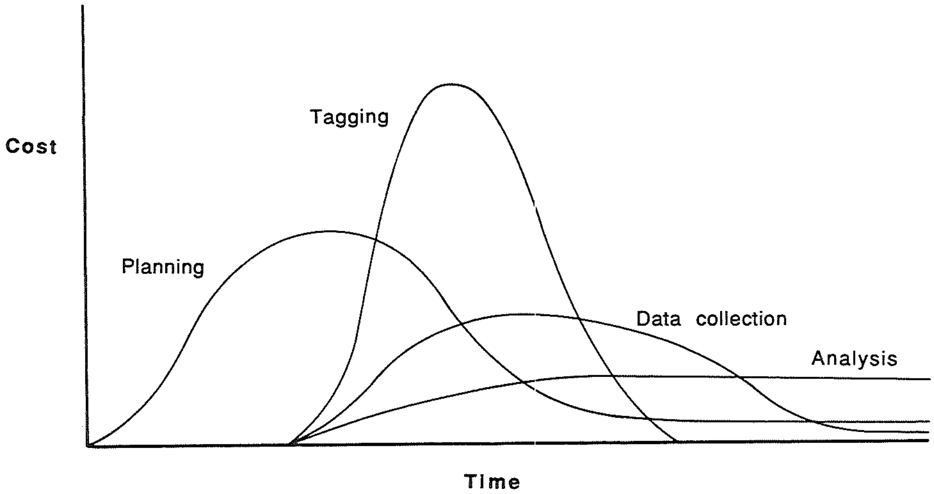

Figure 2. Cost flows during a tagging project.

Discussion

The design of a tagging project should be viewed as part of an ongoing fisheries research program. Detailed design is a difficult task, and may be assisted by the use of computer modelling techniques. The ability to develop 'good' designs depends on the amount of information already available. Pilot studies aimed at improving this information base may be worthwhile prior to commencing a large-scale project. At the conclusion of the design process, a decision to commit funds to the execution of the project should be based on a comparison of the potential benefits, costs and risks.

The systematic design of tagging projects, and increasing the resources dedicated to planning would improve the cost effectiveness of fish tagging as a management tool.

Post-implementation review and publication of results should be regarded as an essential part of a fish tagging project. Besides distributing the information gained, they improve scientists' ability to design better tagging projects in future.

DISCUSSION OF SESSION 5

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The Session Chairman opened the discussion on Kay Allen's presentation by re-emphasising the time delay between tagging operations and achievement of results, particularly in light of management's need for immediate answers.

Peter Young commented on Tasmania's scallop fishery. Monthly research by CSIRO has shown that natural mortality in unfished stocks of scallops differs from that in fished stocks. This phenomenon has been documented elsewhere in the world. He argued that tagging, in such a situation, is the only method for estimating natural mortality in unfished populations.

Kay Allen's suggestion that tagging studies were of no direct relevance to recruitment estimates, was taken up by CSIRO representatives. Jacek Majkowski fundamentally agreed with this generalisation, but cited an example of where tagging studies had proven to be the quickest and most certain method of identifying a decline in recruitment. The Western Australian tuna fishery comprises predominantly young fish. Fluctuations in catch rates are a direct result of fluctuations in levels of recruitment. The last tagging study conducted by CSIRO on this resource was done at a time of high catch rates, and an estimate of fishing mortality, F, was derived.

Jacek Majkowski and Bill Hearn agreed that, if this tagging study were to be repeated now, at a time when catch rates have declined by more than 50%, a new value for F would be obtained. The difference between the two values should be explained by the difference in catch rates. If the difference is larger than the relative decline in catches, then a decline in recruitment must be deduced. Kay Allen agreed with this statement, but pointed out that in this example recruits were effectively being tagged.

Jim Stoddart indicated that fisheries managers were more likely to be interested in the choice of feasible alternatives, rather than appropriate application, when considering population assessment techniques. Referring to Kay Allen's Table 1, he requested clarification on situations when tagging studies were the most feasible tool for deriving population parameters (see * and + in Table). This comment generated much discussion. Bob Kearney pointed out that tagging studies provide information on all population parameters simultaneously. Dave Smith added that, in the absence of long-term data sets on age structure within a given fishery, tagging is the only immediate means of obtaining estimates of exploitation rate and natural mortality. Peter Young disagreed with Jim Stoddart's statement. He discussed the issue of scientific validity, and advocated the use of an array of population analysis methods to enhance the confidence of parameter estimates. In this age of scientific accountability 'the value of being right' should be seriously weighed against 'the cost of being wrong'. David Hall raised the point that, in established fisheries,

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no 'control' generally exists, i.e. fishing effort cannot be manipulated and unfished grounds do not exist. Under those circumstances, he argued, tagging is the only means of estimating fishing mortality.

The Chairman concluded the discussion of Kay Allen's paper with the comment that undoubtedly numerous examples could be cited, where tagging does appear to be the only feasible population assessment tool, notwithstanding the cost and delay in obtaining the data.

In opening discussion on Rod Lenanton's presentation the Chairman commented that the author had just presented the workshop with numerous examples of tagging successes in Western Australia, which should add ammunition for the 'pro-tagging lobby'.

Frank Prokop expressed interest in the Shark Bay study, where it appears that increased recreational fishing for snapper has displaced the commercial fishery. He questioned whether the impact and relative economics of both fisheries had been examined. Rod Lenanton could not give a definitive answer due to a lack of reliable time-series data on catch and effort.

Dennis Reid inquired why fishermen in Western Australia were so strongly in favour of shark tagging studies. Rod Lenanton pointed out that, except for the whaler species, very little is known about the biology and population dynamics of sharks in Western Australia. Industry sees tagging as being of great benefit in stock assessment, while attributing little merit to the collection of catch and effort data. The Chairman indicated that this was a good example of fishermen perceiving tagging as one of the few worthwhile research activities.

Bill Hearn expressed concern about the use of tagging as a law enforcement tool in the lobster industry, and questioned the implications if this practice were to spread. It is indeed a very controversial issue, Rod Lenanton agreed. Don Hancock added that it was introduced as a desperate measure to stop the persistent infringement by a small number of freezer boats. It should not be regarded as regular practice. The Chairman was of the opinion that the deliberate withholding or falsification of log book data is a violation of equally grave concern, and should be strongly discouraged.

Julian Pepperell questioned if recreational fishermen are indeed a group of irresponsible amateurs, who misuse tagging programs to by-pass bag limits. He indicated that his experience has shown them to be mostly conscientious and meticulous when participating in such surveys. He also challenged the notion that no useful data are ever derived from these unsupervised tagging studies, citing a billfish study in the United States as a case in point. Rod Lenanton responded that he by no means intended to slander the Western Australian recreational fishermen, but would merely like to stress the need for supervision in such tagging programs.

The Session 5 discussion following the lunch break was designed to examine direct and indirect costs in tagging programs, and to evaluate their benefits in strictly economic terms. The Chairman had requested those workshop participants who had been responsible for past tagging studies, to detail the cost of their programs in terms of:

1. *Marginal costs*, i.e. non-core funding costs
2. *Operational costs*, i.e. direct cost of the tagging program
3. *Capital costs*, i.e. base cost to the research institute.

A request from Dave Smith to state the total value of the research program, as a means of comparison, was accepted.

The Chairman commenced the discussion by indicating the difficulties in evaluating research projects. He was of the opinion that any worthwhile consideration should include the following components:

1. *Value* of the fishery (past, present and future)
2. *State* of the fishery (new, stable, threatened or declining)
3. *Publicity value* to the government

He then presented two equations for calculating the future monetary value for a given fishery.

The first approach estimates potential value in terms of an optimal future level of exploitation which may be reached with proper fishery management, i.e. value (**V**) equals the difference between maximum potential yield ($\mathbf{Y_{max}}$) and current yield ($\mathbf{Y_c}$) of that fishery.

$$V = Y_{max} - Y_c \quad ....(1)$$

The second approach estimates potential value in terms of the losses incurred if a fishery were to decline as a result of inappropriate management, i.e. value (**V**) equals the difference between current yield ($\mathbf{Y_c}$) and lower future yield ($\mathbf{Y_f}$).

$$V = Y_c - Y_f \quad ....(2)$$

In the case of a fishery collapse the potential future yield ($\mathbf{Y_f}$) will be zero. Note that yield is expressed in dollar terms.

Having established two possible mathematical definitions for the value of a given fishery, he then presented a simple economic model for the projected nett value of a tagging program over time:

$$V = a\,[NPV \textstyle\sum t\,(Y_{max} - Y_c)] - COST \quad ....(3)$$

Where:

'a' is a tagging index between 0 and 1. It is derived by contrasting tagging with alternative methods of population assessment; i.e. if tagging is the only available research tool then **a** = 1, but if tagging is one of many possible options then **a** is a corresponding fraction of 1.

'NPV' is the nett present value of the fishery. All estimates of the future value of a fishery must be based on **NPV**.

't' is the time period over which the benefits accrue.

'COST' is the entire cost of the tagging program.

This model is a simple equation that allows quick evaluation of the likely cost/benefit outcome in a situation that requires a choice of research avenues. The difference between values for equations (1) and (2), if substituted in equation (3), will provide the nett value in adopting a certain management option.

The use of this model was strongly criticised by Kay Allen, who opposed the notion that tagging benefits could be evaluated through contrast with other population assessment techniques. He argued that the value of tagging research was enhanced by the interaction of other available research tools, and that the confidence in tagging results was thus strengthened. He recommended that tagging costs be viewed as the percentage costs of the entire research program. The Chairman expressed partial agreement, but argued that the tagging index, **a**, did accomodate the objections raised. John Glaister commented that, in the absence of long-term data bases on catch and effort, age structure and size distribution, tagging was generally a pioneering approach in population assessment. The Chairman pointed out that the tagging index, **a**, equals 1 in such a situation.

The discussion then turned to the cost of intervention in situations where a fishery faced collapse. The Chairman emphasised that costs of active intervention need to be viewed as being additional to research costs. He also pointed out that, in a declining or collapsing fishery, the future value, **V**, is substantially discounted by the time lapse between the start of a tagging program and the implementation of interventive measures based on research results.

Peter Young commented on the 'retrospective' value of tagging, if the results of a tagging program were to be applied to other future fisheries. Under such circumstances, he argued, there is no **COST** involved. The Chairman stressed that the tagging index, **a**, always needs to be calculated in light of existing information. Bill Hearn raised the point that tagging is an important research tool in situations where immediate, short-term answers on exploitation rates are required for the assessment of current fishing impact.

Geoff Gordon pointed to a mathematical problem in the described equation. As the value, **V**, is based on an arbitrary summation over time, **t**, the cost of research (generally conducted over a few years only) becomes infinitesimally small when, **t**, becomes extremely large. He recommended that a discount factor **[1/(1+i)t]** be included in the formula, where **i** is the discount rate. The Chairman agreed that, if a tagging program did prevent the collapse of a fishery, then a full and long-term entitlement for the value of that research was permissible.

Ian Smith commented on the 'flow-on' value of tagging research to other forms of research.

In concluding this session, the Chairman reminded the audience of the continual need to assess the value of tagging. He warned against the tendency to underestimate the value of a fishery by equating it to its annual catch. He stressed that it should be at least equated to the value of the total biomass.

The Chairman opened the session on Phillip Sluczanowski's paper with the observation that so far it had been clearly shown that the costs of a tagging program do not merely equal the costs of tag release. He requested a response to his survey, and a show of hands indicated that approximately half the workshop participants had not included costs beyond the operational costs in their budget estimations.

Bill Hearn was concerned about the wider benefits of tagging research, and questioned how 'benefits to the world' could be given a monetary value. The Chairman countered that, as was highlighted by Phillip Sluczanowski, such issues had to be addressed in the design costs of a tagging program.

John Glaister pointed out that operational costs may vary substantially depending upon the design of the tagging study. For example, the costs of developing tagging programs (i.e. experimental tags, use of research vessel, fishing on uncharted fishing grounds) are considerably higher than the costs of conducting well-established tagging programs (i.e. regular tags, use of commercial fleet). The Chairman conceded the point, but again stressed that the evaluation of such developmental costs must be included in the overall budget.

Work by the South Pacific Tuna Commission on skipjack tuna, the costing of which had been detailed in Phillip Sluczanowski's paper, received much attention. Bob Kearney, as the former head of the Commission's skipjack program, indicated that the study was never designed purely as a tagging program. Little had been known about the extent and biology of skipjack tuna. Spanning 25 countries, this study was a major piece of research in the fields of biology, population dynamics and population genetics, whilst pioneering tag design and the use of biological tags.

The Chairman added that tagging costs should not be viewed in isolation, but rather as a constituent part of all concurrent research costs. He also indicated that a ratio should exist between total research costs and the potential value of that fishery, suggested by some to be 2% of the gross annual production of that fishery.

Peter Young was of the opinion that estimation of research costs was relatively simple for those researchers frequently engaged in industry negotiations. The real problem, he stressed, lay in the evaluation of future benefits. To illustrate the point, he referred to Ricker's statistical work, and questioned if its application to fisheries research could have been predicted at the time. He argued that conceivably a lower level of benefits could be set, but he expressed doubts about being able to estimate an upper level. The Chairman responded that it was crucial to consider a level of benefit, be it upper or lower, in the design phase of tagging programs.

Peter Young advocated a post-program analysis of benefits, as opposed to a less effective pre-program analysis. He questioned if scientists could predict the impact on the gemfish fishery if current research were to be stopped. Bob Kearney responded that industry would undoubtedly be affected, but that no-one could predict the magnitude of such an effect. John Glaister added that we would also sacrifice one of the few long-term and continuous data bases kept on an Australian fishery. The Chairman pointed out that in most fisheries, annual catch rates can only be sustained, without a depletion of resource, if research and management are provided. If a fishery is regulated without the necessary research, or if a fishery is neither managed nor researched, then a decline in yield must be expected over time until final collapse. In the latter situation the decline would be more rapid.
Bob Kearney added that this scenario only holds true if the sustainable yield is less than the current annual catch rate.

Geoff Gordon asked firstly, if any value was being ascribed to 'pure scientific research results' and secondly, if costly research programs could be compensated for with less costly research. Phillip Sluczanowski reflected on the wider benefits of research, stating that even 'failed studies' are useful if the reasons for failure are demonstrated and documented. He suggested the use of cost-benefit analyses to determine the economic benefits of research (i.e. the difference between revenue curve and cost curve), but added that potential revenue can only be guessed prior to research.

Bob Kearney cited the skipjack tuna program as an example of a study where the initial 'guess' of stock size was clearly erroneous. Before research was carried out, catch rates in the central and western Pacific equalled 150 000 tonnes per year. Current catches have risen to 400 000 tonnes per year, at a value of $US500 million. He maintained that the fishery is still grossly under-utilised, suggesting a minimum post-recruit stock size of 3 million tonnes and a potential yield of $US6 billion. Drawing an analogy with cockroach populations, he indicated that the population dynamics of skipjack tuna were more similar to algal populations than to other fish populations, and that it was virtually impossible to deplete the stocks through overfishing. He stressed that the greatest value of the skipjack tuna study lay in the stabilisation of South Pacific politics. Funded entirely on a foreign-aid budget, the study showed that the resource could sustain an indigenous and foreign fishing fleet without conflicting interests. Great political and economical benefits were derived from negotiations for access rights and foreign fishing licences.

Peter Young expressed reservations about the deterministic approach in cost/benefit analysis to justify research. He warned that such simplistic models can be highly misleading, because they provide single answers. Recommending a more stochastic approach, through risk analysis, he argued that a range of probabilities should be examined in the evaluation of research. Phillip Sluczanowski agreed that a risk-decision table should be considered in the design and planning stage of research programs.

Pointing to the ever increasing costs that need to be met, additional to core funding, the Chairman welcomed the use of any type of analysis in the evaluation of research. Geof Gordon questioned the justice in continually having to seek funding and needing to justify research, without being credited for past research of benefit to the fishing industry. The Chairman countered that external, non-core funding, which may constitute up to 50% of total funding, always has to be justified. He perceived merit in the simplistic approach, because of the ease of application, the monetary value that can be placed on research, and the perspective gained on research costs versus benefits to the fishing industry.

Peter Young raised the difficulty of evaluating the economic benefits from obtaining 'greater confidence' in the assessment of population parameters through increased research. Dennis Reid questioned the implications for future funding if predicted benefits are not achieved. Phillip Sluczanowski pointed out that risk-decision theory should predict the likelihood of such a scenario.

The Chairman suggested that external funding sometimes resulted in short-termed and trivial projects.

Bill Hearn enquired as to the fate of tagging programs, which showed signs of being unsuccessful after commencement. The Chairman and Bob Kearney agreed that budget allocations should be returned under such circumstances. This notion gave rise to a further line of argument. Bob Kearney suggested that it was time for a more honest approach in population dynamics by admitting to funding organisations that population parameter estimates are, at best, an informed guess.

Mike Cappo, citing Australian salmon research, indicated that a lack of long-term funding commitment may result in patchy research and a subsequent stigma for 'bad research'. Bob Kearney agreed, and added that this was yet another example of increasing scientific accountability in an era where fisheries are seen to be in need of regulation and management.

The Chairman questioned workshop participants on the costs of pioneering new techniques which yield parameter estimates similar to those yielded by tagging studies. Ron Thresher mentioned microconstituent analysis of otoliths as a secondary approach to gathering migrational information, but he stressed that it did not replace tagging as a research tool. Although a cost/benefit analysis has not been done on this process, he did point out that the prohibitively high costs of this technique were predominantly establishment and installation costs. In the case of southern bluefin tuna, the costs of processing one otolith compared favourably with the cost of recovering one tag ($2000-$3000 and $1300, respectively), once a routine procedure has been established. Peter Young added that such novel approaches were increasingly encouraged, as was indicated by the Fishing Industry Research Committee's willingness to fund microconstituent analysis.

Phillip Sluczanowski reiterated an issue that had been raised in his paper. He mentioned that most of the design costs of a tagging program are channelled into the evaluation of tag type and tagging methods. He stressed that a very important component of the design parameters, the 'people component', is frequently neglected and had led to failure in many tagging programs. Compared to the total costs of establishing such a study, the cost of training program participants is minimal.

The Chairman concluded Session 5 with the prediction that future tagging studies will need to place greater emphasis on the quality of tag data and the calculations based upon them. He warned that more discretion should be exercised in conducting tagging studies, and the analysis of why such studies fail should be more careful. In seeking funds for tagging programs a full and honest cost projection should be detailed, which includes an allowance for the time delay before results are available. The costs should thus be compared with the likely benefits of the study. In assessing the benefits, credit may be given to the avoidance of accumulated losses, which would otherwise be incurred if one program were not undertaken.

SESSION 6

GENERAL DISCUSSION, SUMMING-UP AND CLOSE

GENERAL DISCUSSION

Chairman: C.J.M. Glover

Recorded by A.E. Caton
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For this general discussion, the Chairman had asked each of the session chairmen and the keynote speaker to first present, in turn, a 2-minute re-cap of their respective sessions.

He would then throw the session open for questions from the floor, asking that enquirers first indicate to whom they are directing their question initially, and that they remember to identify themselves.

If any particular part of the discussion wandered too far from the point, or carried on excessively at the expense of questions waiting to be asked, the Chairman would exercise his discretion as chairman and go to the next question.

The Chairman then invited Bob Kearney, Jim Stoddart and each of the session chairmen (Ron Thresher was represented by Jacek Majkowski) to summarise very briefly the main issues addressed in their presentation or sessions:

Bob Kearney reiterated his caution that tagging was a tool; at times it could offer a solution to problems but at others it could create problems. Adequate planning of projects was essential if such pitfalls were to be avoided.

Jim Stoddart expressed his hope that workshop participants would be among the users of the tag register established by the Bureau of Rural Resources, reminding them that the database is available to them and would be updated regularly .

Jacek Majkowski recalled the broad coverage of the workshop, from large oceanic pelagics, to freshwater species, to shellfish. He pointed out that all presented difficulties for tagging programs, with the resolution of logistics frequently as demanding as the resolution of scientific aspects. He highlighted the value of pilot studies as an aid to planning and implementation of broader projects.

Richard Tilzey also expressed satisfaction about the range of species types covered but noted that initially many projects had relied on 'off the shelf' imported tags without sufficient attention to their suitability. Recent major progress in design, reflected in the diversity of tags now manufactured by Hallprint, was encouraging. However, he saw scope for further development, especially with marks such as coded wire tags, PIT tags, 'smart' tags, and also by the use of 'natural' markers.

John Glaister reminded participants that the session on tagging techniques addressed a broad range of issues including fish condition at release, tag rewards, tagging mortality, long-term effects of tag construction materials, fish size considerations, and handling techniques. He commented that, on the other hand, the session had not really covered innovative techniques.

Tony Harrison, noting that there seemed to be a tendency for inordinate use of tagging, emphasised evaluation of possible alternatives, in the light of thorough cost/benefit examinations, as an essential precursor to a tagging project. Once a decision to proceed with a tagging project had been made, thorough and systematic planning was essential. He pointed to the useful Western Australian case studies of successes and pitfalls with tagging projects.

The Chairman opened the session for general comment and discussion. Several participants commented on positive aspects of tagging as a research tool. Terry Walker expressed the view that tagging was virtually essential for obtaining indicators of fish movement and longevity. He was supported by John Glaister who commented that, while tagging could be expensive in some circumstances, there were situations when it was the most appropriate approach, especially where a first approximation was required. He believed it important to keep in mind the long-term value of resources under study when considering the expense of tagging projects on them. David Gwyther suggested that high-profile, high-cost projects might have tended to override considerations of the value of tagging work. Some small projects with specific objectives had had useful results. This emphasised the need for case-by-case evaluation of projects rather than generalisations about value or otherwise of tagging. Ron Thresher pointed out that projects involved an identifiable starting point with release of a tagged individual. In contrast the major weakness of studies using micro-probes or genetic markers was the lack of certainty about a starting point and history. Tagging provides a base line against which data from the other studies can be compared. Peter Speare added that significant contributions could be made by studies involving genetic, parasite or other 'natural marks'; they can be much more effective in some circumstances than the 'artificial' tags that had been the subject of most aspects of the workshop.

Problems associated with tagging were highlighted by other participants. John Stevens, noting that movement and migration data could be assembled from tagging projects, pointed out that quantitative analysis and interpretation of the data still represented a major problem. Tony Harrison suggested that a good example of such a problem was the case where part of a population was mobile and part was localised. Other considerations, such as rate of non-reporting of tags, could also present major analytical complications, especially for the estimation of mortality rates. In such circumstances, techniques other than tagging may be more appropriate. Phillip Sluczanowski drew attention to the interaction between fish movement and fishing effort, and their effect on location and rate of recovery of tags. There was always a problem of determining whether there had been random fish movement and localised effort, or directed fish movement and random effort. Both could explain release-recapture relationships. Jim Stoddart suggested that an inherent danger with tagging studies was the fact that they always permitted parameter estimation, even in the event of no recaptures. While he accepted David Smith's comments that tagging represented one approach for addressing the uncertainties associated with fisheries science, he stressed the need for careful consideration of objectives. Otherwise there was a danger that 'to tag fish' might become the default objective.

Jacek Majkowski believed that tagging projects offered quite valuable lines of approach for some fisheries problems. He mentioned, as an example, the approach developed by CSIRO to examine aspects of fishery interaction and yield-per-recruit for southern bluefin tuna. Mathematical models could be developed to simulate interactions between components of the fishery but tagging provided a much more direct experimental approach, avoiding the need to incorporate quantitative representations of distribution, migration, and fish movements in modelling. John Glaister pointed out that the duration and nature of the workshop had not really facilitated adequate consideration of techniques for analysis of tag data. Tony Harrison cautioned that research workers taking tag recovery data to mathematicians for advice on what analyses could be undertaken were 'putting the cart before the horse'. The prudent approach would be more thorough pilot work rather than attempting after the event to cover analytical requirements. While accepting Julian Pepperell's proviso that practical realisation of anticipated releases could not be assured, Jacek Majkowski indicated that statistical techniques were available to provide a basis for determining the number of individuals necessary for tagging and release, if parameter estimation objectives were to be satisfied. The involvement of mathematicians at an early stage in tagging project planning was essential in this regard.

Frank Prokop sought comment on how the cost/benefit equation raised in Session 5 might be adopted to evaluate tagging projects in recreational fisheries. Tony Harrison suggested that a 'Y' value could be adopted for a recreational fishery, incorporating the broad value indicators determined in studies of the economics of recreational fisheries. It would be important not to restrict value to the landed value of the catch.

INTRODUCTION OF D. HANCOCK

C.J.M. Glover
President ASFB
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We now come to the finale of these proceedings, with a summary from the special consultant to the Workshop, Dr Don Hancock.

Dr Hancock was for many years Director of Western Australia's Department of Fisheries Marine Research Laboratories at Waterman. As senior scientist and administrator for overseeing many research programs there, he is well experienced to undertake the formidable task of bringing together all that has transpired over these past 2 days.

Ladies and gentlemen, Dr Don Hancock!

SUMMING-UP AND CLOSE BY WORKSHOP COORDINATOR

D.A. Hancock
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Some 20 years ago I was invited to be the Rapporteur of a Session on Aquaculture of Shrimps and Prawns. Later I was challenged by a participant who clearly was piqued because he felt he should have been chosen. When he asked me my qualifications for the task, my spontaneous response was 'Well! I can *write*!'.

As coordinator of this Tagging Workshop I perhaps need to offer better *bonafides* than that. The slide shows me painting whelks in England 30 years ago; the results were published in the Proceedings of the 1961 North Atlantic Fish Marking Symposium, which contained not only Jim Thomson's paper on Australian tagging and marking, but also one by Kay Allen, who confessed to us this morning that he had last tagged a fish more than 40 years ago!

Before whelks, I marked oysters and American oyster drills with paint, and dye-stained starfish on freezing English oyster beds. Later still I was involved in crab tagging and a De Lury experiment on scallops in the English Channel. I helped John Gulland tag hake in the Irish Sea, helped Ray Beverton with plaice in the North Sea, and assisted with an attempt at tagging cod in an Arctic winter - if you were not quick enough the fish froze; by the time that had been sorted out the water in the holding tank had frozen over!

So I can vouch from personal experience that tagging is exciting and challenging, and calls for innovation and ingenuity, the return for which is the anticipation and fulfilment of recaptured animals.

However, I wonder how many of us, having delighted in the intellectually satisfying exercise of a tagging experiment, in all its various aspects, have then had to face up to the fact that somehow what we have achieved has not corresponded to the requirements of the analytical methods available, and is therefore not of any real value to the management exercise to which it has been addressed. Judging from the various comments over the past 2 days this has not been an uncommon experience.

Bob Kearney likened tagging to a hammer, an analogy which was referred to frequently during discussion. In retrospect, tagging can be like taking a dose of medicine *before* looking at the bottle to see what the dose should have been; *or*, more importantly, what it was *for*!. Having decided that we had missed out on both counts we shrug our shoulders and say 'Well! after all it *was* medicine, so it's bound to have done *some* good!'.The past few days have provided an important opportunity for heart-searching and taking stock, during which we have frankly exposed various weakness and difficulties with marking and tagging as a research tool. These will be noted by the wider community, including funding agencies, who can be expected to question these concerns with greater understanding and relevance to the costs involved. Our credibility as scientists will rest heavily on our ability to convince the wider community that we have addressed those issues, and can offer carefully planned solutions to them. Research supervisors and funding agencies, as a result of these two days, may be better equipped to ask a series of questions, such as:

Has your program been properly planned with statistical and mathematical advice?
Can you meet the assumptions of the analytical models you have chosen?
Has tagging been an effective tool for similar species and for what purposes?
How do you propose to overcome any deficiencies so far experienced?
How do you intend to evaluate causes of bias?
Can the same result be achieved, possibly more cheaply, by means other than tagging?
And so on!

Our first response must be to point out the dangers of generalisation, because in some areas we have been specially encouraged by what has been achieved, while in others we have not only been able to examine problems but, from our shared experience, to point to solutions.

I believe we have been witnessing a change of attitude from 'better than nothing' to 'nothing but the best'. We have seen not only how tagging continues to be exciting and to exercise our wits, but how many of the early challenges have been, and are being, met.

The Australian Society for Fish Biology is to be congratulated on its timely initiative in promoting this National Review of Tagging Projects, a need which has been independently identified by Standing Committee on Fisheries. Clearly, since the last review of Australian tagging was undertaken by Jim Thomson as long ago as 1961 such a review is not before its time. Jim, incidentally, sends his apologies and best wishes for the Workshop.

The American Fisheries Society with the U.S. Fish and Wildlife Service announced its 'International Symposium and Educational Workshop on Fish-Marking Techniques' for June 1988 as 'the first international meeting to bring together fisheries biologists and managers with equipment manufacturers to discuss all aspects of marking and tagging fish'. We have been fortunate to have received feedback from Julian Pepperell and Michael Hall who attended that meeting.

This National Review has, as its starting point, both this Tagging Workshop, and the National Tagging Data Base, the latter being sponsored by the Bureau of Rural Resources. It seems to me that there has been a marvellous response ever since the Workshop was first mooted - from its Planning Committee, its Chairmen, Panellists and Rapporteurs, and through its excellent Poster coverage. I calculated that at least half of the number of participants had one or more of these roles in the Workshop, which has encouraged a sense of intimate involvement. I should mention here that chairmen were given the responsibility for the conduct of their session and appointment of Panellists and Rapporteurs within broad guidelines, and I think you will agree that they have provided us with an interesting mix.

It will not be easy for me to summarise 2 days in half an hour without duplicating some of what has been already said, particularly in the final General Discussion session so ably chaired, as has been the whole meeting, by the Society's President Mr John Glover.

However, first of all I want to point out some areas in which we have been encouraged, and to perhaps learn something from them. For example:

1. We do now have in Australia our own manufacturers of tags who are prepared to discuss and work for the specific needs of scientists, to the extent that tags now being used are far in advance of those used previously. There is no longer any need to use 'off the shelf' tags just because they have always been used before.

2. Tuna tagging programs are now yielding 40% or more recaptures. We learned from this that recent successes rely heavily on experience gained from past, less successful tagging, so this has been at some cost. The results are still not, however, useful for making population estimates.

3. Experiences of tagging in freshwater situations have been most encouraging. For example, 94% tag retention rate in small salmonids after 2 years makes binary-coded wire tags a viable alternative to stains and dyes; and despite the suggestion that population estimates based on tagging have 'gone out of fashion', success was claimed for the Petersen Index in freshwater fisheries where simple tagging techniques have been used to great effect. Our Keynote Speaker also defended his population estimates of tuna.

4. Tagging techniques for molluscs, notably scallops and abalone, have been greatly improved, now with an ability to tag *in situ*, though some problems of tag adhesion do still occur.

5. We were encouraged by a paper reported from the Seattle meeting, which described how, by quality control techniques, careful planning could reduce errors of recording from 9.86 to 0.4 per thousand, with minimal percentage cost to the program.

6. A record 35 years at liberty has been achieved by a CSIRO-tagged shark!

But not all that we heard was encouraging. Just to highlight a few of the reservations expressed by Chairmen and Panellists:

1. Our Keynote Speaker, in his comprehensive and thought-provoking review, challenged our motives for tagging. Is it from personal curiosity, or to satisfy an identified management need? Do we really understand the basic assumptions, to see that they are not violated and the results meaningless, or worse still, misleading? He emphasised that tagging is a tool, and as such is of lesser importance than its value to management. He warned us not to allow our tagging programs to become an embarrassment to other users, and gave examples.

2. Ron Thresher pointed to doubts about the reliability of any conclusions where attempts have not been made to evaluate the effects of the tag on the behaviour of the animal.

3. Jacek Majkowski warned that unless the appropriate time and money can be expended to reduce non-reporting of tags, even though it may prove to be time-consuming, expensive and tedious, an experiment can be rendered useless. Indeed, some very disturbing cases of non-reporting of tags, sometimes associated with inadequate tag rewards, emerged

during the various sessions. Nothing adequately replaces a 'presence' in the ports for effective tag recovery. The 1963 ICNAF Symposium cited the oceanic tagging of Pacific salmon, where requests on posters, without a reward, led to 2% being returned; a reward of \$5 yielded 5%, and \$25 resulted in the return of 80% of tags accompanied by the fish. Imagine the bias to the results! This was cited over 25 years ago, and clearly there is more to the setting of reward levels than an arbitrary or budgetary decision.

4. Richard Tilzey reminded us, through some characteristically colourful references, that tagging has been practised for a very long time, indicating that we should perhaps lift our game. He was initially very critical of the lack of experimentation to find suitable tags for the immediate purpose, but after hearing later submissions he modified his view somewhat. Nevertheless, he believes that, although the wide ranging technologies available to U.S. scientists are known to Australian workers, more of them could be tried.

5. Rick Morton reported some remarkable successes in using recreational fishermen to catch and return tailor, including the use of an 008 telephone number on the tag. But he believes that the actual tagging should be done by trained personnel, even to the removing of fish from the anglers' hooks, and warned against issuing tags to untrained workers or club fishermen. Examples of doing this were given in different sessions. I had a personal experience north of Perth where an excited angler reported a fish tagged in a distant State. His disappointment that it had been released by a local angler would not have provided good publicity for other, more important tagging exercises. Some speakers suggested special tagging training programs, but I believe the debate about using unsupervised operators has not yet been fully resolved.

6. Rapid response and payment of rewards is essential to stop interest from flagging, and T-shirt prizes seem to have been an effective means for this.

7. David Gwyther reminded us that, although molluscs seem to have everything going for them, they suffer from the perennial problem of non-randomisation of tagged animals, and non-random (targeted) application of fishing effort.

8. Terry Walker pointed out the advantage of sharks as a vehicle for tags; they are large, they don't have a swim bladder, and fishermen handle them one-by-one so that tags are readily seen. Even so, initial tagging mortality remains high, causing underestimates of F and overestimates of M. John Stevens gave visual evidence of other dangers from tagging sharks (from the Great Australian Bite!).

The second day started a more free-flowing discussion of problems associated with tagging techniques. John Glaister used his panellists and questions from the floor to good advantage to re-examine a number of important issues touched on yesterday:

1. The use of adhesives on molluscs;
2. The question of tag rewards;
3. Tagging mortality;
4. The importance of fish condition at release;
5. Non-reporting of tags.

Tag rewards should be just part of an array of ways of encouraging the return of tags. The meeting was told of lotteries for gold bars and smoked salmon, the wide use of T-shirts and lottery tickets, as well as monetary rewards, all geared to specific situations, both recreational and commercial. The importance of adequate feedback of information about recaptures was again stressed, in particular the purpose of the tagging, as well as the results obtained. Serious cases of non-reporting have occurred through lack of understanding, and suspicion, about the object of the exercise, the results of which may be seen to pose a threat to future fishing practice. Equally, remarkable successes have accompanied effective publicity and proper feedback.

The debate on tagging mortality was wide-ranging and included modifications to the method of capture, holding time and observations on condition of the fish, all of which will be reported fully in the proceedings of the Workshop.

Matters which were not dealt with included natural marks, and it was questioned as to whether the Tagging Register should be expanded to include this. Genetic marking was not specifically addressed, but it is intended to include a section on both of these topics in the report of the meeting.

Tony Harrison started off the session on 'Analysis Limitations and Management' in a provocative mood, with the questions 'Is tagging any use?' and 'Is it worth the money?'. His aim was to challenge the idea that tagging is really as useful as the past day and a half have suggested.

He began by warning us that attitudes to research and funding have been rapidly changing, and quoted a recent speaker who said 'Governments have long since stopped listening to the claim that research is inherently good and therefore should be funded'. It reminds me of a statement to the ANZAAS Conference in the early 1970s that only 'useful' research was likely to receive funds in the future. There is no doubt that this is a situation we have to plan for, and Tony reminded us that we must not confuse industry's *toleration* of research with its *support* for research, especially if it is being asked to pay for it, which is the current trend.

His first panellist, Kay Allen, made the only contribution about the tagging of whales and its relative usefulness, and then reviewed, in tabular form, the use made of tagging to obtain the different sorts of information needed to manage fisheries at their various levels of exploitation, from new to threatened.

There is no doubt that tagging really helps with assessing movements and stock delineation. It makes a unique contribution which other methods cannot provide, but remember that analysis of movement data can be very complex.

However, because we have other sources of data does not mean that it is not worthwhile going after data provided by tagging. Any parameter estimation is strengthened when used with other sources of data, a view which was reiterated during discussion. A number of specific situations of the proven usefulness of tagging reminded the meeting again not to over generalise.

Kay went on to point out that, notwithstanding failures to estimate population size from tagging, proper consideration still needs to be given to the use of repeat tagging to establish relative abundance, if that is an answer of use to management.

Rod Lenanton had been asked to comment on the value of tagging to the management of fisheries in Western Australia. Here again, except in segments of fisheries, such as for prawns and scallops, while tagging had not been useful in assessing population size, there had been many and varied successful usages. The ability to accurately determine boat position at sea has opened up the possibility for successfully calculating population size and mortalities of scallops. Sub-populations of snapper have been identified; growth, migrations, fishery-induced mortality, catchability and multiple spawning of rock lobsters have been successfully studied; salmon movements plotted; and age and growth of scallops and rock lobsters validated. Proportions caught by recreational and commercial fishermen have been established in at least two fisheries. He concluded that tagging has played a useful role in management, which then needed to be related to the value of the fishery concerned.

Bill Hearn contributed to the question of limitations of analysis with reference to some novel mathematical approaches to tag shedding using double tagging.

This afternoon Phillip Sluczanowski treated us to a detailed and thoughtful anatomy of a tagging program, which included a check-list of design parameters which any tagging planner would do well to go through. He maintained that we should view ourselves as project managers as well as experimental biologists. The purpose of his presentation was to remind the meeting quite clearly about the many hidden costs which must be associated with a tagging program. He further questions whether it would be desirable to work towards a 'Code of Tagging Practice' which might go some way towards pre-empting ethical concerns about tagging.

Phillip's contribution formed part of an attempt by Tony Harrison to model the costing of a research program in relation to the long-term value of a fishery. Too often in 'selling' a program the costs of tagging were related to a fishery's annual, rather than its perennial, value. It was a thought-provoking session, during which participants were invited to review their own situations. It brought us into close contact with the real world and its attitudes, and we need to take care that his suspicion that tagging is over-used is not, in fact, the case.

'Solution or Problem?' To use Bob Kearney's words 'Tagging is a tool — it may be the *only* solution to some problems. On the other hand it can *itself* be a cause of problems'. I have the feeling that, at the end of the day, fisheries scientists are not going to give up their hallowed territory of tagging without a struggle.

But if our discussion has achieved nothing else, apart from the exchange of a formidable amount of most fascinating information and views, it is the need for a greater sense of accountability - for planning and for results — which will clearly be a focal point for winning support for tomorrow's tagging.

CLOSING REMARKS BY WORKSHOP CHAIRMAN

C.J.M. Glover
President, ASFB
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Ladies and gentlemen, before closing these proceedings, my warm thanks to all who have participated: speakers, panellists, chairmen, session rapporteurs, organisers, coordinators, all others who have been involved, especially Pat Dixon and her helpers, and of course yourselves for your attendance and enthusiastic involvement! Particular thanks must go to Don Hancock for his overall coordination of matters – thank you Don! Thanks must, of course, also go to the Bureau of Rural Resources for its generous support of this Workshop.

Finally, some brief thoughts on future workshops! Those of you who will be attending the Society's AGM on Sunday afternoon will see that Council is looking well-ahead, and envisages that such workshops as this one should continue on a regular basis. Workshop topics already mooted include 'Fish Nutrition and Culture' and 'Age and Growth in Fishes'.

Clearly such mainstream workshops can only continue with adequate outside funding, particularly if maximum benefit is to be derived by publishing their proceedings. Funding *might* continue on an *ad-hoc* basis, derived from one or more interested agencies or organisations, as has been the case to date (and most successfully, I should add); *or* funding might be on a more continuing or guaranteed basis. These matters are yet to be addressed and resolved, but the goal is clear!

Chairmen and rapporteurs are reminded that there will be a short meeting straight after the Workshop, in the Marine Science Centre on the 6th floor, where you met yesterday.

These proceedings are now closed!

POSTER DISPLAYS

A range of posters was prepared for the workshop and displayed in the conference foyer. Although posters were photographed, the wide range of font sizes used on each poster and the different contrast values of the posters made inclusion of the photographs in this report impracticable. A summary of posters, authors (see participants list for contact addresses) and a brief indication of content is provided below for information; please address any enquiries to the authors. One poster for which contents are included in full is that displaying the bibliography developed as part of the Bureau of Rural Resources Tag Register. (For addresses of authors of posters, see 'List of Participants at end of these Proceedings').

HALLPRINT TAGS

M. Hall

A display of the range of tags developed by Hallprint, with an indication of the species that have been tagged and countries where the tags are in use.

QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES TAILOR TAGGING PROJECT 1986–89

R. Morton

An outline of methods, publicity, and results for juvenile and adult releases and recaptures.

PENAEID PRAWN TAGGING IN PAPUA NEW GUINEA 1978–80

S. Frusher and D. Gwyther

An outline of project aims, tag type, application, tag performance, results, publications and recommendations.

TELEOST TAGGING IN AUSTRALIA

J. Beumer

A summary from the tag register, tabulating tag types, fishes tagged, recapture rates, tag loss rates, tag durability, current status of projects and periods at liberty.

RESEARCH INTO THE FATE OF ADULT AUSTRALIAN SALMON (ARRIPIS TRUTTA ESPER) IN SOUTH AUSTRALIAN WATERS

M. Cappo

Details of the life history and location of Australian salmon in South Australia, and of movements of adults within that State and to the Western Australian fishery region.

STREAMER TAGGED PRAWNS – APPLICATION METHODOLOGY AND EFFECT OF TAG

J. Glaister, T. Lau and V. MacDonall

An illustration of the application of streamer tags to king prawns and their subsequent effect.

SAILFISH STOCKS, PARASITE DISTRIBUTIONS, BLACK MARLIN MIGRATIONS

P. Speare

An illustration of the potential for using parasites as indicators of sailfish stocks off northern Australia, and of black marlin movements.

EEL TAGGING PROJECT 1975–1987

J. Beumer

An outline of tagging methods, release locations, numbers tagged, recaptures and results from the Victorian eel tagging project.

TAGGING SANDCRABS (PORTUNIS PELAGICUS)

G. Smith, W. Sumpton and M. Potter

An illustration of methods used in the Queensland tagging project on sand crabs, with reference to the tag lottery introduced to encourage returns.

PARASITES AS BIOLOGICAL TAGS

R. Lester

Comments on potential for using the parasite fauna of fish as biological markers for studies of stock structure etc.

GENETIC TAGGING

C. Keenan

An outline of the nature of genetic markers, their advantages and possible uses.

TETRACYCLINE MARKING

S. Davenport and J. Stevens

A summary, using studies with two northern shark species as an example, of the use of tetracycline as a stain for hard parts of fish and its use as a tool for ageing techniques.

NEW TECHNIQUE FOR TAGGING ABALONE

J. Prince

Details of a new tag for abalone, fixed through a respiratory pore and avoiding adhesives, with a summary of its advantages.

RADIOTELEMETRY TAGS

J. Anderson

A description of the principles of radiotelemetric tags, and an indication of the scope for their use.

NORTHERN SHARK TAGGING

K. McLaughlan and S. Davenport

The approach adopted for the tagging of northern shark species, with an indication of results and some of the dangers.

STREAMER TAGS AND JUVENILE EASTERN KING PRAWN SURVIVAL

S. Montgomery

A description of the application of streamer tags to juvenile prawns, and an outline of their effects.

EFFECTS OF THREE TAGS ON J.VERRAUXI SURVIVAL

S. Montgomery

A description of tags used in the New South Wales project on the eastern rock lobster, with an outline of their effects.

REWARD POSTERS

J. Glaister and J. Pepperell

An assemblage of posters used to publicise tagging projects, recovery data required, and rewards for a range of Australian and overseas tagging projects.

TAG REGISTER

J. Stoddart

A summary of establishment of the Tag Register, the questionnaire used, and tabulations of some of the data gathered (further details about the register are presented in Dr Stoddart's address and in the Appendixes to the workshop report).

TAGGING REGISTER BIBLIOGRAPHY

P. Stewart

A list of items in the bibliography developed during establishment of the tag register, for comment and update (the bibliography is included in Appendix 3 to the workshop report).

FREE TAGGING LARGE EXTINCT MESOZOIC SHARKS IN THE JAVA TRENCH OFF NORTHERN AUSTRALIA

W. Sassenarch Jnr, A. Pongase and R. Yorque

An optimistic account, with photographs, of the tagging of large extinct sharks with larger extant floating tags.

USEFUL REFERENCES

A. Caton

Useful references about tags and tagging (included below for information):

Anon. (1932). A Guide to Fish Marks (used by members of theInternational Council for the Exploration of the Sea, and by some Non-participant Countries). *J. Cons. int. Explor. Mer* 7, 133-65.

Anon. (1953). A Guide to Fish Marks (used by members of theInternational Council for the Exploration of the Sea, and by some Non-participant Countries). *J. Cons. int. Explor. Mer* **19**, 241-89.

Anon. (1953). A Guide to Fish Marks (used by members of theInternational Council for the Exploration of the Sea, and by some Non-participant Countries). *J. Cons. int. Explor. Mer* **30**(1), 87-160.

Emery and Wydowski (1987). 'Marking and Tagging of AquaticAnimals - An Indexed Bibliography.' U.S. Department of Interior, Fish and Wildlife Service. Resource Publication 165pp.

Penn, J.W. (1981). A review of mark-recapture and recruitment on Australian penaeid shrimp. *Kuwait Bulletin of Marine Science* **2**, 227-47.

Thomson, J.M. (1962). 'The Tagging and Marking of MarineAnimals in Australia.' CSIRO Division of Fisheries and Oceanography Technical Paper No. 13, 39pp. (prepared for 'Symposium on Fish Marking' International Commission for the Northwest Atlantic FisheriesMay 24-27, 1961. Woods Hole, Massachusetts, USA.)

WORKSHOP PROGRAM

WORKSHOP PROGRAM

Day 1 (21 July)

0900 - 0915 Introduction. Mr J Glover, President, ASFB.

SESSION 1

0915 - 1000 Keynote Address. Dr R Kearney, NSW Fisheries Research Institute.

1000 - 1020 The National Tagging Register. Dr J Stoddart, BRR. An explanation of the questionnaire, objectives and a broad summary of results; future of register.

1020 - 1030 'In-house' announcements.

1030 - 1000 MORNING TEA

SESSION 2

1100 - 1230 Planning and Implementation

Session Chairman: Dr R Thresher.
Panellists: Jacek Majkowski
Peter Young
John Harris
John Stevens

'What are the considerations involved in designing and implementing (including recapture & analysis) a tagging project?' Rationale; models; schedule; budget.

1230 - 1330 LUNCH

SESSION 3

1330 - 1500 Tags: Types and Uses.

Session Chairman: Mr R Tilzey.
Panellists: Julian Pepperell
Brett Ingram
Peter Jernakoff
John Glaister
Paul McShane

Types and use (species considerations); tag design problems; nature of information generated.

1500-1530 AFTERNOON TEA

SESSION 4

1530 - 1700	Tagging Techniques. Session Chairman: Dr J Glaister. Panellists: Kevin Williams John Diplock Rick Morton Julian Pepperell John Anderson Dave Smith David Gwyther Terry Walker Catching and holding; tag application; observations on tagged/marked individuals; returns and recaptures.

Day 2 (22 July)

0900 - 1030	Tagging Techniques (continued).
1030 - 1100	MORNING TEA

SESSION 5

1100 - 1230	Analysis; Limitations; and Management. Session Chairman: Mr T Harrison. Panellists: Kay Radway Allen Rod Lenanton Bill Hearn Philip Sluczanowski Analytical techniques; limitations; cost/benefit and alternatives; value to management.
1230 - 1330	LUNCH
1330 - 1500	Analysis; Limitations; and Management (continued).
1500 - 1530	AFTERNOON TEA

SESSION 6

1530 - 1630 General Discussion.

Chairmen of all sessions under chairmanship of Mr J Glover.

1630 - 1700 Summing up and Close - Dr D Hancock.

* Sessions 2 to 5 will be under the control of chairmen with 5 panellists.
* Chairmen should open a session with a 5-10-minute presentation, and spaced through the session, invite 5-minute presentations from each panellist.
* Audience participation by way of questions or observations will be encouraged.
* Each session will have a rapporteur.
* Workshop proceedings will be published.

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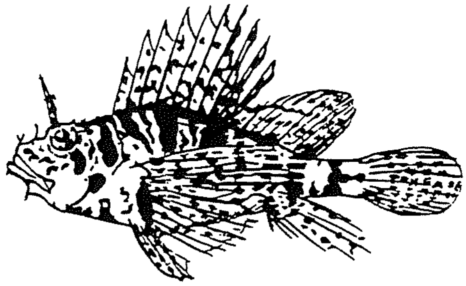
APPENDIXES

APPENDIX 1

AUSTRALIAN SOCIETY

FOR FISH BIOLOGY



NATIONAL REVIEW OF TAGGING PROJECTS

Project No.: [_[_[_[_[_[_] (Office Use Only)

Today's Date: [_[_[_[_[_[_] e.g. 880217
Y Y M M D D

Full Name & Address for Project Contact Person: ______________________

Telephone No: ______________________

Full Project Title: ______________________

Short Project Title (please use this title on all Forms): ______________________

General Instructions:

1. Please use UPPER CASE characters.

2. Please use a BLUE or RED pen.

2. When indicating choice or choices in multiple-choice questions, please CIRCLE the appropriate number(s), thus:

[1]
[2]
[3]

3. Please return completed questionnaires to:
The Assistant Director,
Fisheries Resources Branch,
Bureau of Rural Science,
Department of Primary Industries and Energy,
GPO Box 858,
Canberra. ACT. 2601.

NATIONAL REVIEW OF TAGGING PROJECTS

Tagging is an important research tool and one which is widely used in studying natural populations in aquatic environments. In Australia, the last national review of tagging studies was undertaken by Thomson in 1962 (CSIRO Division of Fisheries and Oceanography Technical Paper No. 13).

The Australian Society for Fish Biology feels that it is time to once more review tagging studies on a national scale. Consequently, the Society has chosen this as the theme for a workshop to be held immediately prior to its Annual Conference in July 1988 at the University of New South Wales. A workshop sub-committee has developed a questionnaire in conjunction with the Bureau of Rural Science, which will process the returns. If sufficient questionnaires are returned by the end of March, the answers provided will deliver valuable background information for the workshop. Properly maintained, the national database will serve as a reference point on past and current studies, their uses and outcomes.

ASFB members and other contributors to the database and review will benefit through an ability to directly compare their own projects with other similar projects as well as through the amalgamation of data on all projects.

The Standing Committee on Fisheries of the Australian Fisheries Council has independently highlighted the need for documentation of details of the various fish tags in use around Australia. The questionnaire and the database established from it should satisfy that requirement also.

The aims of the National Review of Tagging Projects, therefore, are to:

1) Assess the objectives, methodologies and success of research projects using tags/marks.

2) Establish a centralized national reference for tagging studies.

3) Help prevent duplication of research projects and duplication of tag serial numbers in Australian tagging projects.

ASFB envisages that the tagging workshop in 1988 will be the first in a series dealing specifically with fisheries topics and to be jointly sponsored by ASFB and various Government fisheries research agencies. The next is planned for Townsville in 1989 and the topic will be decided finally at the 1988 Annual Conference in Sydney.

The Questionnaires:

Designing a questionnaire or set of questionnaires which would meet the needs of all possible project designs has not been easy. The set provided here represents the best attempt under tight time constraints. Since the review will be essentially ongoing, any feedback on problems with the questions, format and structure are welcomed.

If at first the questionnaires look dauntingly long, this is because as many questions as possible have been made multiple choice and therefore quick and easy to answer. Pilot tests have indicated that for an average, uncomplicated tagging project, less than 30 minutes will be required to complete the questionnaire.

The "Project" is considered to form the basic unit for the purposes of this review. The questionnaire structure reflects this in that it consists of a number of different Forms, all cross-referenced to the "Project". Briefly, the Forms are:

FORM 1:	Project Details:	One copy only per project. Must be completed.
FORM 2:	Species/Group Details:	Up to 10 copies (one per species/group) to be completed for each project. At least one must be completed.
FORM 3:	Complete Species List:	Will only be required in cases where more than 10 species have been tagged in the one project.
FORM 4:	Tag Register:	Tag code and type details which will form the basis of a national tag code register.
FORM 5:	Bibliography Form:	Major publications arising from the project will be given on these forms. Will provide a reference to more detailed information on the conduct and outcomes of projects.

Return of Questionnaires

To be able to present preliminary findings from the questionnaire at the tagging workshop in July, **questionnaires need to be returned to the Bureau of Rural Science by the end of March.**

Although failure to meet this deadline will mean that such questionnaires will not be included in formal data summaries, you are urged to submit late questionnaires at the earliest date so that the opportunity remains for manual extraction of data relevant to the workshop and early inclusion into the compiled database.

Questionnaires should be addressed to:

The Assistant Director,
Fisheries Resources Branch,
Bureau of Rural Science,
Department of Primary Industries and Energy,
GPO Box 858,
Canberra. ACT. 2601.

NATIONAL REVIEW OF TAGGING PROJECTS: Proj. No:[_[_[_[_[_[_] (Office use only)

FORM 1: PROJECT DETAILS

NOTE: The words "TAG" AND "TAGGING" are used in a generic sense and should also be read to encompass "MARK" AND "MARKING", unless otherwise specified.

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1. SHORT PROJECT TITLE:

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

****

AGENCIES UNDERTAKING PROJECT:

2. NAME OF PRIMARY AGENCY:

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

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3. PRIMARY AGENCY TYPE:

Commonwealth Dept./Authority ... [1]
State Dept./Authority .... [2]
Local Government .... [3]
University or other tertiary ... [4]
Private Consultant .... [5]
Professional Fishermen .... [6]
Recreational Fishermen/Public .. [7]
Other type (please specify) .... [8]

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4. NAMES OF OTHER AGENCIES:

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

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5. OTHER AGENCY TYPES (in Q. 4):
(More than one choice permitted.)

Commonwealth Dept./Authority ... [1]
State Dept./Authority .... [2]
Local Government .... [3]
University or other tertiary ... [4]
Private Consultant .... [5]
Professional Fishermen .... [6]
Recreational Fishermen/Public .. [7]
Other type (please specify) .... [8]

****

FUNDING AGENCIES:

6. NAME OF PRIMARY FUNDING AGENCY:

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

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7. PRIMARY FUNDING AGENCY TYPE (i.e. Agency providing most funds)

Commonwealth Dept./Fund .... [1]
State Dept./Fund .... [2]
Local Government .... [3]
University or other tertiary .... [4]
Commercial .... [5]
Other type (please specify) ..... [6]

---

8. NAMES OF OTHER FUNDING AGENCIES:

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

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9. OTHER FUNDING AGENCY TYPES (in Q.8):
(More than one choice permitted.)

Commonwealth Dept./Fund .... [1]
State Dept./Fund .... [2]
Local Government .... [3]
University or other tertiary .... [4]
Commercial .... [5]
Other type (please specify) ..... [6]

---

10. TOTAL FUNDS ALLOCATED TO PROJECT:

Less than $1,000 .... [1]
$1,001 - $10,000 .... [2]
$10,001 - $100,000 .... [3]
More than $100,000 .... [4]

****

PROJECT PERSONNEL:

11. PROJECT LEADER'S NAME:
(Title, Initials, Family Name:
e.g. DR AJ SMITH)

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

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12. CURRENT CONTACT PERSON (IF NOT PROJECT LEADER): (Format as above.)

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

****

PERIOD OF PROJECT:

13. APPROX. START DATE FOR TAGGING IN PROJECT: e.g. 8409

[_[_[_[_]
Y Y M M

---

14. IS TAGGING COMPLETED?

Yes ..[1]
No ..[2]
Unsure ..[3]

---

15. IF YES, APPROX, DATE OF FINAL TAGGING?

[_[_[_[_]
Y Y M M

---

16. ARE TAGGED ANIMALS STILL BEING RETURNED/OBSERVED?

Yes ..[1]
No ..[2]
Unsure ..[3]

---

17. IF NO, APPROX. DATE OF LAST RETURN/OBSERVATION?

[_[_[_[_]
Y Y M M

****

PURPOSE AND EVALUATION OF PROJECT:

18. MAJOR AIM OF PROJECT IS/WAS TO SUPPORT -

Fisheries Management -
Commercial Fisheries only......[1]
Fisheries Management -
Recreational Fisheries only....[2]
Fisheries Management -
Comm. & Recreational Fish......[3]
Other Natural Resource Manag.....[4]
Private Enterprise R & D [5]
Other (please specify)...........[6]

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19. TOPICS ADDRESSED BY PROJECT AND RESULTS ACHIEVED:
In boxes under PURPOSE, indicate appropriate code from following:
0 = not relevant
1 = minor topic
2 = moderately important topic
3 = major topic
In boxes under RESULT, indicate appropriate code from following:
0 = not relevant
1 = poor
2 = reasonably successful
3 = highly successful
4 = unknown at this stage

	PURPOSE	RESULT
Tag development.........	[_]	[_]
Study of tag generated effects.......	[_]	[_]
Evaluation of tag performance.............	[_]	[_]
Growth, Age Validation..	[_]	[_]
Movement, Migration.....	[_]	[_]
Stock Delineation.......	[_]	[_]
Population Size.........	[_]	[_]
Stocking Success........	[_]	[_]
Recruitment.............	[_]	[_]
Mortality Rates.........	[_]	[_]
Fisheries Interactions..	[_]	[_]
Activity Patterns.......	[_]	[_]
Physiology..............	[_]	[_]
Other (please specify)..	[_]	[_]

---

20. WERE ANY OF THE FOLLOWING DETRIMENTAL TO THE COMPLETE SUCCESS OF THE PROJECT?
(More than one choice permitted.)

Insufficient nos. marked.........[1]
Insuff. nos. returned -
poor publicity, reporting rates[2]
Insuff. nos. returned -
poor mark visibility...........[3]
Insuff. nos. returned -
excessive marking mortality....[4]
Insuff. nos. returned -
insufficient fishing effort....[5]
Insuff. av. period at liberty -
recaptures soon after release..[6]
Inappropriate experimental design[7]
Inappropriate mark -
mortality due to tagging.......[8]
Inappropriate mark -
mark affected behaviour........[9]
Biological assumptions violated -
e.g. unequal catchability,
unsuspected behaviour pattern.[10]

(Q. 20 cont'd)

NATIONAL REVIEW OF TAGGING PROJECTS: Proj. No:[_[_[_[_[_[_] (Office use only)

20. (cont'd)
Inappropriate marking/ handling methods..............[11]
Explicable disasters............[12]
Unknown factors.................[13]
Other (please specify)..........[14]

---

21. WERE ANY OF THE RESULTS OF THE PROJECT USEFUL, DIRECTLY OR INDIRECTLY, FOR MANAGEMENT PURPOSES?

Yes ..[1]
No ..[2]
Don't know ..[3]

IF YES, FOR WHICH FISHERY?

****

GEOGRAPHIC, ECOLOGICAL AND TAXONOMIC RANGE OF PROJECT:

22. MAIN GEOGRAPHIC AREAS OF PROJECT:
(Refer to Geographic Area Codes on Attachment A.)

Code [_[_]

---

23. MAIN ECOSYSTEM TYPE:(one only)
Estuarine ....[1]
Marine - Coastal, shelf..........[2]
Marine - Oceanic, slope ....[3]
Marine - Reef (coral, other).....[4]
Freshwater-Lentic (still water)..[5]
F'water-Lotic (running water) ..[6]
Mar.& f'water e.g.diadromous spp.[7]

---

24. BROAD TAXONOMIC CATEGORY OF SPECIES MARKED:
Crustacean ....[1]
Mollusc - bivalve, gastropod ....[2]
Mollusc - cephalopod ....[3]
Echinoderm ....[4]
Elasmobranch ....[5]
Teleost ....[6]
Reptile ....[7]
Mammal ....[8]

---

25. IS THERE ONE PRIMARY TARGET SPECIES IN THIS PROJECT?

Yes ..[1]
No ..[2]

IF NO, GO TO NEXT QUESTION.

(Q.25 cont'd)

GENUS:_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
SP.: [_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

SYNONYMS (IF ANY):

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

---

26. COMPLETE LIST OF SPECIES MARKED INCLUDING PRIMARY TARGET SPECIES, IF ANY. ONE COPY OF FORM 2 IS TO BE COMPLETED FOR EACH SPECIES/GROUP LISTED IN THIS QUESTION, UP TO A MAXIMUM OF 10 SPECIES. IF MORE THAN 10 SPECIES WERE STUDIED IN THIS PROJECT, ALSO COMPLETE FORM 3 GIVING FULL SPECIES DETAILS AND REDUCE LIST HERE TO 10 SPECIES/TAXONOMIC GROUPS.
i)
ii)
iii)
iv)
v)
vi)
vii)
viii)
ix)
x)

****

PROJECT CAPTURE-RECAPTURE DETAILS:

27. CAPTURE & RECAPTURE METHODS.
(More than one choice permitted.)

	CAPTURE	RECAPTURE
Demersal Trawl	[1]	[1]
Midwater Trawl	[2]	[2]
Danish Seine	[3]	[3]
Beach Seine	[4]	[4]
Purse Seine	[5]	[5]
Gill, Mesh Net.......	[6]	[6]
Pole and Line	[7]	[7]
Rod and Line	[8]	[8]
Handline	[9]	[9]
Trolling	[10]	[10]
Dropline	[11]	[11]
Longline	[12]	[12]
Dredge	[13]	[13]
Traps/Pots	[14]	[14]
Collection - Diving.	[15]	[15]
Other (pls specify).	[16]	[16]

---

28. PERSONS TAGGING AND MAKING RECAPTURES:
(More than one choice permitted.)

	TAGGING	RECAPTURING
Research team	[1]	[1]
Commercial F'men ...	[2]	[2]
Recreational F'men..	[3]	[3]
Other (pls specify).	[4]	[4]

____

****

PROJECT METHODOLOGIES:

WERE THE FOLLOWING POSSIBLE SOURCES OF ERROR ESTIMATED/CALCULATED?

----

29. TAG LOSS:

Yes .. [1]
No .. [2]

IF YES, WERE LOSS RATES ASSESSED BY:

Holding Experiments .... [1]
Double Tagging .... [2]
Direct Observation e.g. scars ... [3]
Other (please specify) .... [4]

____

APPROX. PERCENT TAG LOSS [__]%

APPROX. PERIOD OF OBSERVATION (months) [___]

----

30. TAGGING MORTALITY:

Yes .. [1]
No .. [2]

IF YES, WAS TAGGING MORTALITY ASSESSED BY:

Holding Experiments .... [1]
Other (please specify) .... [2]

____

----

31. NON-REPORTING OF TAGS:

Not applicable .. [1]
Yes .. [2]
No .. [3]

IF YES, WAS NON-REPORTING RATE ASSESSED BY:

"Salting" Experiment .... [1]
Interviews .... [2]
Comparisons of catch rates ...... [3]
Other (please specify) .... [4]

____

APPROX. NON-REPORTING RATE [__]%

----

32. OTHER CALCULATED SOURCES OF ERROR. PLEASE DESCRIBE BRIEFLY.

____
____
____
____

----

33. WERE ANAESTHETICS USED WHEN MARKING THE MAJORITY OF ANIMALS?

Yes .. [1]
No .. [2]

----

34. WERE ANTIBIOTICS USED WHEN MARKING THE MAJORITY OF ANIMALS?

Yes .. [1]
No .. [2]

****

PROJECT PUBLICITY:

35. PUBLICITY MEDIUM:
(More than one choice permitted.)

Not applicable .... [1]
Poster .... [2]
Radio .... [3]
Press (Newspapers, Magazines) ... [4]
Television .... [5]
Personal Liaison .... [6]
Newsletters .... [7]
Other (please specify) .... [8]

____

----

36. REWARDS FOR RETURNS:
(More than one choice permitted.)

Clothing e.g. t-shirt, cap ...... [1]
Money .... [2]
Lottery .... [3]
Tokens e.g. certificates, badges. [4]
Gifts e.g. boomerangs .... [5]
Acknowledgement letter........... [6]
Other (please specify) .... [7]

____

NATIONAL REVIEW OF TAGGING PROJECTS: Proj. No:[_[_[_[_[_[_] (Office use only)

FORM 2: SPECIES DETAILS.

SPECIES/GROUP NO.: __ OF __.

A SEPARATE FORM 2 SHOULD BE COMPLETED FOR EACH SPECIES/GROUP TAGGED. IF MORE THAN 10 SPECIES WERE TAGGED, THEN SPECIES SHOULD BE GROUPED IN THE MOST CONVENIENT WAY E.G. BY GENUS, FAMILY OR OTHER TAXONOMIC GROUP, SO THAT NO MORE THAN 10 COPIES OF FORM 2 ARE USED FOR EACH PROJECT.

---

1. SHORT PROJECT TITLE: (AS SHOWN ON FORM 1.)

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

---

2. SPECIES OR GROUP NAME (AS SHOWN IN Q. 26 OF FORM 1):

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

****

NUMBERS OF ANIMALS TAGGED AND RECAPTURED:

3. TOTAL NUMBER OF ANIMALS TAGGED:

Fewer than 200 ....[1]
201 - 500 ....[2]
501 - 1,000 ....[3]
1,001 - 5,000 ....[4]
5,001 - 10,000 ....[5]
10,001 - 20,000 ....[6]
More than 20,000 ....[7]

---

4. EXACT (OR NEAR EXACT) NUMBER (IF KNOWN):

[_____]

---

5. TOTAL NUMBER OF ANIMALS RECAPTURED:

Fewer than 100 ....[1]
101 - 250 ....[2]
251 - 500 ....[3]
501 - 1,000 ....[4]
1,001 - 2,500 ....[5]
2,501 - 5,000 ....[6]
5,001 - 10,000 ....[7]
More than 10,000 ....[8]

---

6. EXACT (OR NEAR EXACT) NUMBER IF KNOWN:

[________]

---

7. APPROXIMATE PERCENT RECAPTURED:

[_____]%

****

COLLECTED AND DERIVED INFORMATION ON TAGGED AND RECAPTURED ANIMALS:

INDICATE WHICH OF THE FOLLOWING SAMPLES AND/OR MEASURES WERE COLLECTED ON TAG AND RECAPTURE IN A MAJORITY OF CASES.

---

8. WHOLE SPECIMEN:

Yes ..[1]
No ..[2]
Don't know ..[3]

---

9. TAG:

Not applicable ..[1]
Yes ..[1]
No ..[2]
Don't know ..[4]

---

10. SCALES/OTOLITHS/OTHER HARD PARTS:

Not applicable ..[1]
Yes ..[2]
No ..[3]
Don't know ..[4]

---

11. BASIC SIZE DATA E.G. LENGTH, WEIGHT:

Actually measured ....[1]
Guessed ....[2]
Not collected ....[3]
Don't know ....[4]

---

12. RECAPTURE LOCATION DEFINED BY:

Latitude, Longitude ....[1]
Grid Position ....[2]
Approximate region ....[3]
None Given ....[4]
Don't know ....[5]
Other (please specify) ....[6]

____

13. DATE/TIME AVAILABLE?

Yes ..[1]
No ..[2]
Don't know ..[3]

---

14. OTHER INFORMATION:
(Please specify.)

____
____
____

****

BASIC INFORMATION DERIVED FROM RESULTS:

15. MAXIMUM PERIOD AT LIBERTY:
(Months) ..[___]

---

16. MAXIMUM DISTANCE BETWEEN RELEASE AND RECAPTURE SITES. GIVE STRAIGHT LINE DISTANCE IN MOST CASES, ACTUAL DISTANCE IF TELEMETRY PROJECT.

(Kms) ..[___]

****

BASIC TAG DETAILS:

FULL DETAILS OF ALL TAGS AND MARKS USED SHOULD BE SUPPLIED ON FORM 4. ALL QUESTIONS ON THIS FORM REFER TO THE MOST COMMONLY USED TAG TYPE IN THE PROJECT.

---

17. TAG MANUFACTURER:

Not applicable ....[1]
Floy ....[2]
Hall ....[3]
Purpose Built (non-commercial) ..[4]
Commercial Other ....[5]
Name: ______________________

IF COMMERCIAL TYPE, WAS TAG USED AS SUPPLIED BY THE MANUFACTURER OR AFTER MODIFICATION?

Modified ....[1]
Unmodified ....[2]

IF MODIFIED, GIVE BRIEF DETAILS:

____
____

---

18. MODEL NUMBER (IF APPLICABLE):

[_[_[_[_[_[_[_[_[_]

---

19. GENERAL TYPE OF MOST COMMONLY USED TAGS:

Mark - clipping or other mutilation ....[1]
Mark - by external substance e.g. paint ....[2]
Mark - by internal substance ....[3]
Spaghetti Tag (dart, t-bar) .....[4]
Loop Tag ....[5]
Streamer Tag ....[6]
Disc ....[7]
Strap ....[8]
Fully Internal - non-magnetic ...[9]
Internal with External Flag - non-magnetic ....[10]
Magnetic ....[11]
Sonic ....[12]
Electromagnetic ....[13]
Radio ....[14]
Other (please specify) ....[15]

____

---

20. TAG COLOUR(S) OF TAG REFERRED TO IN Q.17:

Not applicable ....[1]
Dark Blue ....[2]
Light Blue ....[3]
Green ....[4]
Orange ....[5]
Red ....[6]
White ....[7]
Yellow ....[8]
Brown ....[9]
Grey ....[10]
Pink ....[11]
Lilac ....[12]
Clear ....[13]
Other (please specify) ....[14]

____

---

21. WAS TAG DURABILITY A PROBLEM IN THE PROJECT?

Yes ..[1]
No ..[2]

IF YES, DID ANY OF THE FOLLOWING FACTORS AFFECT LEGIBILITY?

Illegible - epiphytic growth ...[1]
Illegible - mechanical abrasion.[2]
Illegible/unavail. - breakage...[3]
Illegible - fading ....[4]
Other (please specify) ....[5]

____

NATIONAL REVIEW OF TAGGING PROJECTS: Proj. No:[_[_[_[_[_[_] (Office use only)

FORM 3: COMPLETE SPECIES LIST

NOTES:

1. THIS FORM SHOULD ONLY BE COMPLETED IF MORE THAN 10 (TEN) SPECIES HAVE BEEN TAGGED IN A SINGLE PROJECT AND, THEN, ONLY FOR THOSE SPECIES WHICH ARE GROUPED.
2. "SPECIES/GROUP REFERENCE NO." IS THAT NUMBER UNDER WHICH EACH SPECIES IS CLASSED IN Q.26 OF FORM 1.

SPECIES/GROUP REFERENCE NUMBER:	SPECIES NAME:

(Append extra pages as required.)

NATIONAL REVIEW OF TAGGING PROJECTS: Proj. No:[_[_[_[_[_[_] (Office use only)

FORM 4: TAG REGISTER

TAG REGISTER FORM __ OF __:

THE INFORMATION REQUESTED WILL BE USED TO COMPILE A NATIONAL TAG REGISTER OF TAG TYPES AND CODES USED OR IN USE.
A SEPARATE COPY OF FORM 4 SHOULD BE COMPLETED FOR EACH TAG TYPE USED.

---

1. SHORT PROJECT TITLE: (AS SHOWN ON FORM 1.)

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

---

2. SPECIES OR GROUP NAME (AS SHOWN IN Q. 26 OF FORM 1). IF TAG CODE SEQUENCES WERE USED ACROSS ALL OR SEVERAL SPP./GROUPS, INDICATE BY "ALL" OR THE NUMBERS OF THE SPECIES/GROUPS FROM Q.26 OF FORM 1.

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

---

3. TAG MANUFACTURER:
Not applicable .... [1]
Floy .... [2]
Hall .... [3]
Purpose Built (non-commercial) .. [4]
Commercial Other .... [5]
Name: ____________
IF COMMERCIAL TYPE, WAS TAG USED AS SUPPLIED BY THE MANUFACTURER OR AFTER MODIFICATION?
Modified .... [1]
Unmodified .... [2]
IF MODIFIED, GIVE BRIEF DETAILS:

____
____

---

4. MODEL NUMBER (IF APPLICABLE):

[_[_[_[_[_[_[_[_[_]

---

5. GENERAL TYPE OF TAGS:
Mark - clipping or other mutilation .... [1]
Mark - by external substance e.g. paint .... [2]
Mark - by internal substance .... [3]
Spaghetti Tag (dart, t-bar) ..... [4]
Loop Tag .... [5]
(Q. 5 cont'd)

(Q. 5 cont'd)
Streamer Tag .... [6]
Disc .... [7]
Strap .... [8]
Fully Internal - non-magnetic ... [9]
Internal with External Flag - non-magnetic .... [10]
Magnetic .... [11]
Sonic .... [12]
Electromagnetic .... [13]
Radio .... [14]
Other (please specify) .... [15]

____

---

6. TAG COLOUR(S) OF TAG IN Q.3.
Not applicable .... [1]
Dark Blue .... [2]
Light Blue .... [3]
Green .... [4]
Orange .... [5]
Red .... [6]
White .... [7]
Yellow .... [8]
Brown .... [9]
Grey .... [10]
Pink .... [11]
Lilac .... [12]
Clear .... [13]
Other (please specify) .... [14]

____

---

7. TAG LEGEND. SPECIFY AS WRITTEN ON EACH TAG.

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]
[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

---

8. START CODE NUMBER:

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

---

9. FINISH CODE NUMBER:

[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_[_]

NATIONAL REVIEW OF TAGGING PROJECTS: Proj. No. ☐☐☐☐☐☐
(Office use only)

FORM 5: REFERENCES
(Please include only major publications of the project.)

FORM N0.: ___ OF ___.

AUTHOR/S ....

TITLE ....

JOURNAL TITLE or PUBLISHING ORGANISATION ....

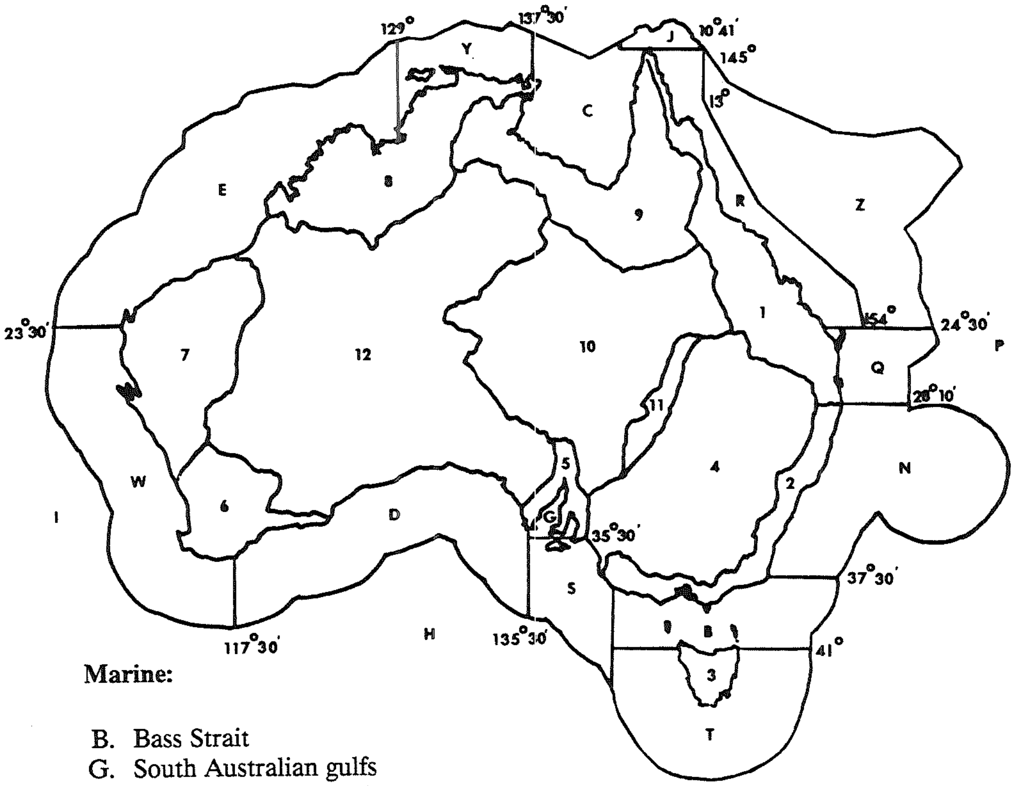
YEAR OF PUBLICATION ....

REPORT NO. or JOURNAL VOL. .... PAGE NUMBERS ....

COPY ENCLOSED ? **YES** ☐ **NO** ☐

OFFICE USE ONLY ....

ATTACHMENT A: GEOGRAPHIC AREA CODES



Marine:

- B. Bass Strait
- G. South Australian gulfs
- D. Great Australian Bight
- S. Other South Australian waters
- W. South-west Australia
- E. North-west Australia
- Y. Northern Territory except Gulf of Carpentaria
- C. Gulf of Carpentaria
- J. Torres Strait
- R. Great Barrier Reef - outer limit defined by GBRMPA Act
- Z. Coral Sea
- Q. Other Queensland waters
- N. New South Wales
- T. Other Tasmanian waters
- H. Southern Ocean
- V. Antarctica - south of 60°S
- P. Pacific Ocean
- I. Indian Ocean
- A. Australia - everywhere within 200 nautical miles of AFZ
- X. Not applicable

Freshwater:

1. North-east coast
2. South-east coast
3. Tasmanian
4. Murray-Darling
5. South Australian gulfs
6. South-west coast
7. Indian Ocean
8. Timor Sea
9. Gulf of Carpentaria
10. Lake Eyre
11. Bulloo-Bancannia
12. Western Plateau.

APPENDIX 2. List of projects and responsible organisations included in the National Tagging Register

(Presented in order of project number recorded in the register.) * Present location of contact in parentheses

PROJECT TITLE	ORGANISATION	CONTACT
Lake Eucumbene trout fishery research	NSW State Fisheries	Richard Tilzey (BRR) *
Premanagement study of barramundi	CSIRO	Dr T. L. Davis
Biology of tiger prawns in N.W. Gulf of Carpentaria	CSIRO	Dr I. Somers
Yellowfin bream in Smiths Lake	University of NSW	Janice May
Tag loss and mortality in small tropical fish	CSIRO	A. W. Whitelaw
Australian salmon juvenile tagging	CSIRO	Dr C. A. Stanley
Western king prawn - growth, mortality and movements	S.A. Dept of Fisheries	Bruce Wallner (CSIRO)
Tagging studies on the blue endeavour prawn	N.T. Dept of Industries and Development	Rik Buckworth
Feeding range of western rock lobsters	CSIRO	Dr Peter Jernakoff
Yellowfin bream research	Queensland Dept of Primary Industries	Dr B.R. Pollock
Tailor tagging project	Queensland Dept of Primary Industries	Rick Morton
Fishes of a tidal inlet to a saltmarsh	Queensland Dept of Primary Industries	Rick Morton
Tagging of summer whiting at Bribie Island, Queensland	University of Queensland	Rick Morton
Studies on Australian lungfish	Macquarie University	Dr Jean Joss
Fisheries and biology of snapper	NSW Dept of Agriculture and Fisheries	Gary Henry
Microtagging of post-puerulus in western rock lobster	CSIRO	Dr B.F. Phillips
Recreational sportfish tagging programme	Queensland Dept of Primary Industries	Brad Zeller
Lake Keepit fish study	NSW Dept of Agriculture and Fisheries	S.C. Battaglene
Lake Burrinjuck fish study	NSW Dept of Agriculture and Fisheries	S.C. Battaglene
Tailor research, 1978-81	Queensland Dept of Primary Industries	Dr B.R. Pollock
Northern shark tagging	CSIRO	Dr John D. Stevens
Tagging *Portunus pelagicus*	Queensland Dept of Primary Industries	Dr Meryl Williams (BRR)

Metapenaeus macleayi in Clarence River, N.S.W.	NSW Dept of Agriculture and Fisheries	Dr J.P. Glaister (QDPI)
Dynamics of eastern king prawns	NSW Dept of Agriculture and Fisheries	Dr J.P. Glaister (QDPI)
Growth of banana prawns	N.T. Dept of Ports and Fisheries	Dr J.P. Glaister (QDPI)
Bass Strait scallop program	CSIRO	Dr P.C. Young
Penaeus merguiensis tagging in the Gulf of Papua, PNG	Australian Institute of Marine Science	Stewart Frusher
Biology of exploited stocks of abalone	Tas. Dept of Sea Fisheries	Tracy Brothers
Tilapia in Australia	Griffith University, Qld	David Bluhdorn
Biology of bay lobsters, *Thenus spp.*	Queensland Dept of Primary Industries	Clive Jones
N.S.W. trawl fish study	NSW Dept of Agriculture and Fisheries	Kevin Rowling
Victorian rock lobster	Vic. Dept of Conservation, Forests & Lands	Ross Winstanley
Victorian snapper	Vic. Dept of Conservation, Forests & Lands	Ross Winstanley
Barramundi of Fitzroy River, Qld	Capricornia Institute of Advanced Education	L.A. Unwin
Queensland gillnet fishery assessment	Queensland Dept of Primary Industries	D.J. Russell
Australian salmon tagging studies in W.A.	W.A. Dept of Fisheries	Dr Rodney Lenanton
Whiting tagging, Shark Bay, W.A.	W.A. Dept of Fisheries	Dr Rodney Lenanton
King George whiting tagging, Wilson Inlet, W.A.	W.A. Dept of Fisheries	Dr Rodney Lenanton
Prawn fisheries research, W.A.	W.A. Dept of Fisheries	Dr J.W. Penn
Shark Bay snapper	W.A. Dept of Fisheries	Dr Michael Moran
Fishery induced mortality of undersize rock lobster	W.A. Dept of Fisheries	R.S. Brown
Western rock lobster breeding studies	W.A. Dept of Fisheries	Dr Christopher Chubb
Biology of saucer scallops	W.A. Dept of Fisheries	Dr Lindsay Joll
Lake Eucumbene study	NSW Dept of Agriculture and Fisheries	R.A. Faragher
Southern calamary	S.A. Dept of Fisheries	Keith Evans
The fate of South Australian salmon	S.A. Dept of Fisheries	Michael Cappo
Tagging studies - S.A. prawn fisheries	S.A. Dept of Fisheries	Neil Carrick
South Australian abalone growth	S.A. Dept of Fisheries	S.A. Shepherd
Studies on southern rock lobster in S.A.	S.A. Dept of Fisheries	R.K. Lewis

Coorong tagging program	S.A. Dept of Fisheries	David Hall
King George whiting tagging program	S.A. Dept of Fisheries	David Hall
Monitoring of Googong Reservoir fishery	A.C.T. Parks and Conservation Service	Dr K.D. Williams
Aquatic vertebrates diet study	A.C.T. Parks and Conservation Service	Dr K.D. Williams
Longevity and movement of *Galaxias olidus*	A.C.T. Parks and Conservation Service	Dr K.D. Williams
CSIRO tuna tagging program, 1983-84.	CSIRO	Dr Jacek Majkowski
Great Lake rainbow trout	Inland Fisheries Commission, Tasmania	Dr P.E. Davies
Gamefish tagging	NSW Dept of Agriculture and Fisheries	Dr J.G. Pepperell
New South Wales tailor tagging	NSW Dept of Agriculture and Fisheries	Dr J.G. Pepperell
Dusky flathead tagging	NSW Dept of Agriculture and Fisheries	Dr J.G. Pepperell
Biology of *Anguilla spp.*	Queensland Dept of Primary Industries	John Beumer
Movements of yellowfin whiting	S.A. Dept of Fisheries	Dr G.K. Jones
Growth and movements of snapper	S.A. Dept of Fisheries	Dr G.K. Jones
Growth, movements and mortality in King George whiting	S.A. Dept of Fisheries	Dr G.K. Jones
South-eastern shark tagging	Vic. Dept of Conservation, Forests & Lands	T.I. Walker
Lake Macquarie fish study	NSW Dept of Agriculture and Fisheries	Peter Scanes
Skipjack survey and assessment programme	South Pacific Commission	Dr R.E. Kearney (FRI)
Victorian abalone stock assessment	Vic. Dept of Conservation, Forests & Lands	Paul McShane
Blue crab fishery	S.A. Dept of Fisheries	R. Grove-Jones
Eastern Bass Strait trawl fishery	Vic. Dept of Conservation, Forests & Lands	David Hobday
Northern Victorian freshwater fish	Vic. Dept of Conservation, Forests & Lands	Sandy Morison
Native fish survey	Vic. Dept of Conservation, Forests & Lands	Sandy Morison
Carp programme	Vic. Dept of Conservation, Forests & Lands	Sandy Morison
Freshwater fish tagging	S.A. Dept of Fisheries	David Hall
Spanish mackerel tagging	Queensland Dept of Primary Industries	Geoff McPherson
East coast tuna and billfish	NSW Dept of Agriculture and Fisheries	John Diplock
Torres Strait prawns	Queensland Dept of Primary Industries	Dr R.A. Watson

CSIRO gummy shark tagging	CSIRO	Dr C.A. Stanley
Movements of juvenile eastern king prawns	NSW Dept of Agriculture and Fisheries	Steve Montgomery
Australian bass study	NSW Dept of Agriculture and Fisheries	Dr J.H. Harris
Barramundi biology - Northern Territory	N.T. Dept of Ports and Fisheries	Roland K. Griffin
Amateur barramundi tagging programme	N.T. Dept of Ports and Fisheries	Roland K. Griffin
Evaluation of binary-coded wire microtags	NSW Dept of Agriculture and Fisheries	Brett A. Ingram
Yabby growth	NSW Dept of Agriculture and Fisheries	H.T. Johnson
Marine turtles, Western Australia	W.A. Dept of Conservation and Land Management	Dr R.I.T. Prince

APPENDIX 3. Bibliography of Tagging Studies

Anon. (1984). An assessment of the skipjack resources of eastern Australia. Skipjack Survey and Assessment Programme, Final Country Report No. 16. South Pacific Commission, New Caledonia, 59pp.

Beumer, J.P. (1979). Feeding and movement of *Anguilla australis* and *A. reinhardtii* in Macleods Morass, Victoria, Australia. *J. Fish. Biol.* **14**, 573-92.

Brown, R.S. and N. Caputi (1983). Factors affecting the recapture of undersize western rock lobster *Panulirus cygnus* George, returned by fishermen to the sea. *Fish. Res.* **2**(2), 103-28.

Brown, R.S. and N. Caputi (1985). Factors affecting the growth of undersize western rock lobster, *Panulirus cygnus* George, returned by fishermen to the sea. *Fish. Bull.* **83**(4), 567-74.

Brown, R.S. and N. Caputi (1986). Conservation of recruitment of the western rock lobster (*Panulirus cygnus* George) by improving survival and growth of undersize rock lobsters captured and returned by fishermen to the sea. *Can. J. Fish. Aquat. Sci.* **43**(11), 2236-42.

Brumley, A.R., A.K. Morison and J.R. Anderson (1987). Revision of the conservation status of several species of warmwater native fish after surveys of selected sites in northern Victoria (1982-1984). Arthur Rylah Institute for Environmental Research, Tech. Rep. No. 33, Dept of Conservation, Forests and Lands, Victoria, 93pp.

Buckworth, R.C. and D.E. Kelly (1984). Endeavour prawns tagged in Groote Eylandt study. *Aust. Fish.* **43**(10), 9-10.

Cappo, M.C. (1987). The fate and fisheries biology of sub-adult Australian salmon in South Australian waters. S.A. Dept of Fisheries Report, 162pp.

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