Movement and Exploitation Rates of Blue and Spotted Warehou - A Pilot Tagging Study

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Objectives

1. To develop tagging methods for blue and spotted warehou, including catching and handling techniques and tag types.
2. To determine handling and tagging mortality.
3. To validate assigned ages

Non-Technical Summary

Blue and spotted warehou (*Seriolella brama* and *S. punctata*) are important commercial species in eastern Australia and blue warehou are becoming an increasingly important recreational target species in some coastal waters. There have been a few studies on the biology of warehou but little is known about their population dynamics and stock structure in Australian waters. Tagging is a potentially useful method of addressing some or all of these questions, particularly given the apparently limited value of fishery catch/effort data and fishery-independent surveys as indicators of trends in biomass or other population characteristics of warehous. Whilst it is possible that an intensive tagging program could help answer many questions about the stock structure of these species, it was first necessary to undertake a preliminary study to evaluate whether a viable and cost-effective technique for catching, tagging and releasing warehous could be developed and trialed.

Successful methods of administering OTC injections at concentrations which left a fluorescent band on the otoliths were developed. This could be used to validate the assigned ages of warehou, but fish were not retained or recaptured after a long enough period to be used in age validation. Given the low recapture rate and limited time at liberty of fish tagged

in the wild, the most effective technique for age validation will probably rely on more extensive and long-term tank trials.

Significant progress was made in the development of tagging methods for blue warehou but spotted warehou were not generally caught in a condition suitable for tagging. In addition, increased concerns over the state of blue warehou stocks during the period of the project (Smith 1995) warranted higher priority for investigations of this species. As a result, the research into tagging spotted warehou was not continued.

Using angler-caught fish and variety of tank trials, a successful method of handling and tagging blue warehou was developed. T-bar tags were considered to be the most suitable and tagging mortality in tank trials was less than 15%. Difficulties in extrapolating the tagging mortality in tank trials to fish released in the field are discussed.

A number of commercial methods of catching warehou were considered. Industry reported that commercial hooking methods including longlines and droplines were unlikely to produce large quantities of fish suitable for tagging and these methods were not trialed. Negligible numbers of warehou were caught in trials using fish traps. Whilst warehou were caught by gill nets and Danish seines, the fish were generally too badly damaged to be used for tagging. Trawling, however, was able to produce large numbers of blue warehou suitable for tagging. The use of short (<10 minute) shots in shallow waters targeting schools consisting almost entirely of blue warehou, regularly produced between 100 – 300 fish in excellent condition for tagging. Such conditions exist around August in coastal waters off Portland, and about 2300 blue warehou between 30 – 45 cm length were tagged and released using this method.

The other successful method of capturing blue warehou suitable for tagging involved the use of anglers to catch juvenile fish when they aggregated in shallow coastal waters. Although cheaper than trawling, this method was more labour intensive and not as large numbers were able to be caught over short periods. Nevertheless, the fish were in excellent condition and around 1500 fish were tagged and released using this method in both Stanley (Tasmania) and Portland (Victoria) over two years.

Tag recapture rates were low (<1%) for angler-caught fish and most occurred within a short time and distance from their release. Only one of the tagged fish captured by modified

trawling techniques was recaptured. A variety of hypotheses are provided to explain the low recapture rates, but the actual reasons will remain unclear unless further research is conducted.

In addition to the low recapture rates, there are a number of aspects of the spatial and temporal dynamics of warehou stocks and their availability for successful tagging that limits the potential of tagging as a viable stock assessment tool. These are discussed.

It was concluded that although the study demonstrated that in certain circumstances, good numbers of blue warehou can be tagged following capture by anglers or in modified trawl shots, without substantial further development, tagging is not a viable stock assessment tool for warehou. As a pilot study, it was important that the problems that may be encountered in using tagging to elucidate warehou stock dynamics were elucidated prior to committing considerable resources to a large-scale tagging project.

Table of Contents

Background

Blue and spotted warehou (*Seriolella brama* and *S. punctata*) are common on the continental shelf and upper slope waters of south-eastern Australia (Smith 1994a, 1994b). Large stocks of both species are also found off New Zealand, where they support valuable fisheries (Annala *et al.* 1998). Both species have a pelagic juvenile stage, commonly occurring in association with jellyfish in open coastal waters (Gavrilov and Markina 1979), and sub-adults often occur in the sheltered waters of large marine embayments (Last *et al.* 1983). Adult blue warehou are caught in depths to 500 m, although most commercial catches occur from 50 m to 300 m. Spotted warehou frequent deeper offshore waters to depths of 650 m (Gomon *et al.* 1994). Growth in both species is rapid. Blue warehou reach a mean length of about 20 cm caudal fork length (LCF) after one year and have a maximum age of about 10 years (Smith 1989). They begin to mature at around 30 cm LCF at an age of between 2 - 3 years. Spotted warehou attain a mean length of around 30 cm LCF in their first year and have been aged up to 14 years old (Gavrilov 1974). Growth is negligible after about 10 years and estimates of L_∞ are between 50–60 cm LCF (Gavrilov 1974; Horn and Sutton 1995). They are a highly fecund fish (Gavrilov, 1975) with maturity occurring around 40 cm after 3 - 4 years (Smith 1994).

Over the last decade, blue and spotted warehou have become important commercial species in Australia, as significant components of trawl catches in the South East Fishery (SEF) as well as various gill net fisheries. Blue warehou is also becoming an increasingly important recreational target species in some coastal waters of Victoria, Tasmania and southern NSW. The two species are closely related which has lead to confusion and they were often grouped together in catch records as warehou or "Tassie trevally".

Catches of warehou increased dramatically during the 1980's and total landings of the two species in the early 1990's were in excess of 4000 tonnes per annum, with an annual landed value of about $10 million. The combined catch of these species has since stabilised around this tonnage, but the proportion of the more valuable blue warehou (by weight) dropped from about 70% to 40% during the mid-1990s. This was accompanied by declining blue warehou catch rates in both the trawl and non-trawl sectors and lead to concerns over the status of blue warehou stocks (Smith 1998). In 1997, the total catch (trawl and non-trawl) of blue warehou was around 1000t with a value of $1.5 million. The total catch of spotted warehou was 2800t with a value of $3.9 million (Tilzey 1998).

There have been no studies on the stock structure of either of these species in Australian waters but they are perceived to be highly mobile with a broad distribution of breeding locations, so each species is assumed to comprise a single stock for fisheries assessment and management purposes. Gavrilov and Markina (1979) reported that blue warehou, like spotted warehou, undertake major migrations. It was considered possible that an intensive tagging program could help answer many questions about the stock structure and population dynamics of these species, but it was deemed prudent to first undertake a pilot study to determine if tagging was a feasible research technique.

Need

Some biological and fishery data were available for both warehou species, but questions remain concerning the size (biomass) of warehou stocks, current rates of commercial and recreational exploitation, patterns of movement, recruitment of fish into the commercial fishery, the number and distribution of discrete stocks within each warehou species, and the validity of recently developed methods for ageing warehou. Tagging is a potentially useful method of addressing some or all of these questions, particularly given the apparently limited value of fishery catch/effort data and fishery-independent surveys as indicators of trends in biomass or other population characteristics of warehous. Although full-scale tagging projects can yield enormous benefits in terms of our understanding of a resource and its dynamics, they are generally expensive. For this reason, the present research was undertaken as a pilot study to develop and test viable and cost-effective techniques for catching, tagging and releasing warehous. Ultimately, such research will determine the suitability of a tagging project as a tool for the stock assessment of warehous.

Of particular interest was the relationship between stocks east and west of Bass Strait - these two areas currently provide 50% - 75% of total annual commercial catches. The declining catches and catch rates of blue warehou in both of these areas has been of significant concern to fishery managers, especially since little was known about the population dynamics or stock structure of this species. Furthermore, because most of the gill net catch has consisted of larger blue warehou caught off the east coast of Australia (Smith 1998), uncertainty about the stock structure has caused conflict between the various sectors of the Industry.

Objectives

This pilot project was designed primarily to identify, develop and trial tagging methods for blue and spotted warehou. The stated objectives were:

1. To develop tagging methods for blue and spotted warehou, including catching and handling techniques and tag types.

2. To determine handling and tagging mortality.

3. To validate assigned ages

Specific tasks arising from these objectives included:

i). Field investigations to determine the feasibility of capturing live warehou for tagging using commercial otter trawl, Danish seine, mesh (gill) net and set line methods, and recreational hand lining (Objectives 1 & 2).

ii). Aquarium or tank experiments to determine suitable tag types and the best methods for handling fish during the tagging and OTC injection process (Objectives 2 & 3).

iii). Aquarium or tank experiments to determine optimum OTC injection dosages for warehou (Objective 3).

iv). Tank or cage experiments to estimate mortality rates associated with tagging and OTC injection, and to provide a preliminary indication of tag loss rates (Objective 2).

v). Field trials to demonstrate the viability and cost effectiveness of developed tagging methods. This will include the release of double tagged fish to provide a more realistic estimate of tag loss rates (Objective 1).

The first milestone report submitted to FRDC in June 1995, identified the growing concern about the status of the blue warehou resource following five years of declining catch rates in the trawl and non-trawl sectors of the South East Fishery. As a consequence, it was decided that the project should focus on the tagging of blue warehou rather than spotted warehou. It was agreed that spotted warehou would only be tagged on an opportunistic basis for the remainder of the project.

Methods

The structure of the Methods and Results sections reflects the various project components which needed to be tackled to determine whether tagging would be a viable means of investigating the movement and exploitation of warehou. In line with the objectives and goals of the project, various aspects of capture, handling and tagging techniques, OTC marking for age validation, tagging mortality and tag loss were investigated, and we undertook a pilot field-based tagging experiment.

i) Investigation of capture methods

Initial observations and trials were undertaken on commercial and research vessels to determine the best methods to capture warehou of a suitable condition for tagging and release. A variety of commercial methods including mesh (gill) nets, otter trawls, Danish seines, longlines and droplines were trialed off the Victorian and Tasmanian coasts. Initially, catches of warehou taken by commercial vessels were monitored during normal fishing operations to determine the condition of the fish with respect to tagging and what improvements could be gained through changes in fishing and handling techniques. Similar observations and trials were undertaken on the catches taken by recreational fishers using handlines.

Gill nets

In October 1994, observers were placed on board two commercial gill net vessels chartered by CSIRO to conduct shelf ecosystem studies near "Gabo Reef", about 12 nautical miles south-east of Gabo Island, Victoria (Fig. 1). A fleet of gill nets with mesh sizes from 2" to 7" were set in depths of 120 m to 160 m for 6 to 18 hours per shot. Fish traps were also set in this area for similar durations.

Gill net sampling was undertaken at a number of sites off south-eastern Tasmania using the 6 m research vessel, *Mallanna*. Monofilament gillnets, generally of 30 m length and a range of mesh sizes (64, 89, 105, 130, 133 mm) were deployed. Set duration was generally restricted to 2 hours or less.

Five trips were also undertaken in Tasmanian waters on commercial vessels working inshore gill nets between November 1994 and March 1995. Off the east coast, primarily between Maria Island and the Tasman Peninsula (Fig. 1), the nets generally range in length from 50 - 500 m with mesh sizes of 112-135 mm (4.5-5"). Fish taken from the north-west coast,

primarily between Smithton in the west and the Tamar River in the east, were typically small (<40 cm fork length) and tend to be targeted with nets of smaller mesh size (89 mm or 3.5") than used off the east coast. A feature of the inshore Tasmanian fishery is that schools of warehou move into shallow waters, in depths of less than 5 m, and it was considered that gillnetting might be a suitable method to capture live fish.

Trawl nets

In November 1994, observations were made on 12 demersal trawl shots carried out at 120 m - 260 m depth in waters off Portland. Areas known to have produced warehou in the past were targeted, although significant aggregations of warehou were not considered likely at that time of year.

After the initial trials, a number of anecdotal reports offered some prospect that trawling, under certain circumstances, may provide warehou suitable for tagging. First, in May 1995, a trawl operator had landed live blue warehou in Portland up to two days after the fish had been captured. Second, a skipper of a trawler working out of Portland indicated that he knew where large schools of blue warehou could be regularly targeted in shallow water over a period of 3 months to produce clean shots of live warehou. Third, on-board observers employed with the Integrated Scientific Monitoring Program (ISMP) of the SEF verified these comments and reported these conditions usually exist off Portland from May to September and that blue warehou caught in short shots from these shallow waters were landed on deck in apparently perfect condition.

Based on these reports, trials were undertaken off Portland in August 1997 using short shots to target the blue warehou schools in shallow (200 - 270 m) water. These schools, which consist largely of blue warehou (≈ 85% of the catch by weight), develop around mid year on an annual basis, but only last for about 3 months before disaggregating. The larger schools form very apparent and distinctive "marks" on the sounder and they were well known and regularly targeted by local SEF fishermen during this time. A commercial vessel using standard trawl gear with a 90 mm codend mesh was chartered and requested to specifically target these marks using extremely short shots. This modified trawling method depended heavily on the skill and local knowledge of the skipper of the chartered vessel. He used his experience together with visual output from both the sounder and netsonde to gauge the position of the trawl gear relative to the school and to endeavour to catch only about 500 kg of

fish. The net was hauled to the surface in the normal manner. The date, time, position and depth of each shot was recorded.

Danish seine

Juvenile warehou (almost exclusively blue warehou) are occasionally taken as a by-catch by Danish seine operators in eastern Bass Strait during operations targeting flathead or school whiting. In November 1994, a Lakes Entrance Danish seiner was chartered to sample areas of eastern Bass Strait from which catches of warehou had recently been recorded.

Eight shots were observed over 24 hours in depths of 60 m - 120 m. Shots were 30 - 40 minutes duration and the nets were brought quickly to the surface. It was therefore hoped that warehou caught this manner would be in better condition than those taken in commercial trawls.

Commercial Drop lines and Long lines

It was originally suggested that commercial set line methods would be one of a suite of methods assessed for producing warehou in suitable condition for tagging. Preliminary discussions with commercial fishers, however, indicated that these line methods were not particularly efficient or effective in catching warehous and that these species were generally only a small by-catch in the commercial line fisheries. It was concluded that such methods would be unlikely to produce large quantities of warehou in suitable condition for tagging on a reliable basis. The use of drop lines or long lines was not investigated any further.

Angling

Blue warehou are becoming an increasingly important seasonal target species for recreational line anglers in shallow coastal waters of western Victoria (especially around Portland), southern New South Wales (especially around Eden), north-western Tasmania (around Stanley and Wynyard) and parts of south-eastern Tasmania (Tasman Peninsula)[1]. Warehou are landed by anglers fishing from boats or jetty/breakwaters, reportedly in very good condition for tagging and release. Although small (18 cm - 36 cm LCF) compared with catches by commercial vessels, the fish tend to be lively and have very little scale loss and can

[1] In Tasmania, blue warehou are also an important target species for recreational gill netters.

remain that way if handled carefully during de-hooking. Large numbers of warehou can be caught in a short period of time using baited hooks and light fishing tackle when the fish aggregate in shallow waters during summer, autumn and winter months. The timing and size of such warehou "runs", however, can fluctuate substantially from season to season and year to year.

To investigate the potential of angling to catch warehou for tagging, we spoke to various anglers and angling clubs in Tasmania and Victoria to determine the preferred fishing areas and times of year when the warehou were most abundant.

The possibility of damaging fish during de-hooking was highlighted as an area of concern. To address this, commercially purchased de-hooking devices were used to remove barbed hooks from the mouths of warehou with minimum damage, and fish were dropped into a temporary holding tank without having to touch them. This was achieved by holding the fishing line in one hand about 15 cm from the hook; using the other hand to run the crook of the de-hooking device down the line to the curved part of the hook in the mouth of the fish; holding the hook upside down by the curved part using the de-hooker; and allowing the weight/movement of the fish to remove the barb and point of the hook with a minimum of damage to the mouth. Fish which were deeply hooked (more than 2 cm inside the mouth), or which were bleeding, or which had significant mouth damage (eg. detached premaxilla), were rejected for tagging purposes.

ii) Tag Type and Tagging Method

Only plastic dart and T-bar tags were considered appropriate to test on blue warehou. The flesh of warehou was quite soft and in juveniles, the skin was comparatively easy to puncture or tear. Loop tags were unlikely to be suitable because the drag and vibrations they would create in a fast-swimming fish would probably result in unacceptable rates of tag loss, or at least significant ulceration around the tag insertion points. Internal tags were not considered because of concerns about tag loss, and because of the extra time required for the surgical implantation procedure.

T-bar and dart tags were obtained from Hallprint™, South Australia and applied using standard applicators.

iii) OTC Injection Trials

OTC or oxytetracycline is an antibiotic which, when injected into fish, is absorbed into bony structures, appearing as a fluorescent band under ultraviolet light. OTC was used to assist with age validation studies.

The first OTC experiment was carried out in October 1994 on 18 blue warehou to determine the OTC dosage level which produced a clearly visible fluorescent mark on otoliths and other bony parts. Hypodermic injections of 30, 45 or 60 mg OTC per kilogram wet weight of fish were administered using disposable plastic syringes and 23 gauge needles. Injections were given in the visceral cavity for some fish and in the caudal musculature for others. Three replicates of each dosage × injection method were used. The fish were kept in captivity for as long as possible and when they died, the deposition of both an OTC mark and subsequent growth increments on the otoliths was examined.

A second batch of juvenile blue warehou were injected with 45 mg/kg OTC in January 1995, and a small proportion of these remained alive in captivity after more than 130 days.

The following procedures were used to examine the OTC marks in fish from both of the above experiments. Sagittal otoliths were stored dry in envelopes and kept in the dark until they were examined. Otoliths from 71 fish were examined for evidence of OTC marks including 37 fish which had been injected with OTC, 31 fish which were controls, and one fish which had lost a tag. The examiner did not know which fish had been injected at the time of examination. Most otoliths were prepared by sectioning after embedding in polyester resin. The otoliths of two fish were prepared separately by individually grinding them after embedding in a thermoplastic resin.

Sectioning

One otolith from each pair was transversely sectioned using a three stage process; embedding, sectioning and mounting. To embed the otoliths, a thin layer of clear polyester casting resin was poured on to the base of a mould and left to partially cure. Otoliths were arranged in sequential order in two columns. Resin blocks were labelled and coated with another layer of resin.

Otolith sections were cut using a Gemmasta™ lapidary saw fitted with a diamond impregnated blade. From each column of otoliths, four sections were taken (less than 350 μm) to ensure

the primordium of each otolith was included. Sections were cleaned using alcohol and stored in vials. For identification, each vial contained a fish reference label.

A small amount of resin was poured on to a glass slide (50 x 75 mm). Otolith sections were immersed in the resin and the identification label placed at the top of the slide. Once the resin had semi-cured, further resin was placed on each slide and a coverslip applied over the sections.

Grinding

Otoliths were also prepared individually using a hand-grinding process. Sagittae were ground down in a two stage process to obtain transverse sections ≅ 300 μm thick. Sagittae were attached to heated glass slides using a clear thermal glue (Crystal Bond™). Otoliths were arranged with the proximal face down, the primordium at the slide edge and the rostrum projecting over the slide edge. The rostrum was ground away to the primordial region using waterproof sandpaper (800 and 1200 grit size). The slide was reheated and the remaining otolith half removed. The ground face of the otolith was attached to a second heated slide with the posterior end facing upward. The otolith was then ground down until the primordium was reached. During this stage the otolith was continually checked using a dissecting microscope between grindings until the otolith was at a stage where growth increments were visible over the whole section. Resin was placed on each slide and a coverslip applied over the section.

Viewing

The presence of oxytetracycline marks were assessed by examination for fluorescence under a Leitz Laborlux compound microscope fitted with an incident light 100 W ultraviolet light source, and a Leitz D Block to suit the fluorescent properties of OTC (Birk 1984): 355-425 nm excitation filter, a LP460 barrier filter, and a RKP455 dichroic mirror. The sections were examined at 100-400 times magnification.

iv) Tagging Mortality

For the purposes of this study, tagging mortality was defined as any death which occurred within 14 days of the date of tagging and/or OTC injection. This definition was based on the assumption that mortalities within 14 days were likely to be related to the tagging and OTC

injection procedure, whereas mortalities which occurred after 14 days were more likely to be due to factors other than tagging or OTC injection (eg. stress from handling, inadequate or inappropriate diet, adverse aquarium or tank conditions, infections etc.).

The initial tagging experiment at VFRI Queenscliff in October 1994 resulted in a tagging (14-day) mortality rate of 44% (Table 1). This unacceptably high rate was probably due to poor handling, tagging and injection techniques which in turn were due to lack of experience with blue warehou.

A subsequent experiment undertaken in Portland in January 1995 involved more refined handling techniques, including the use of cotton gloves, a plastic bowl for weighing, a tagging cradle, a foam rubber cover, and smaller quantities of injected OTC solution (0.3 - 0.6 ml per fish). 150 juvenile blue warehou (24 cm - 31 cm LCF) were caught using rod and line near Lawrence Rocks, transported back to Portland Harbour and transferred into large, square, concrete flow-through tanks at a commercial fish processing facility. The fish were acclimatised in the large tanks for five days before being further handled. During this period four fish died. The fish were just beginning to accept food items (squid and fish) when experiments were commenced.

Surviving warehou were divided into three groups, each of which was treated in one of the following ways:

i) Controls - fish handled the same as other treatments but not tagged or injected (n = 52);

ii) Tagged Only - fish tagged with T-bar tags but not injected (n = 46); and,

iii) Tagged and OTC Injected - fish tagged with T-bar tags and also injected with 45 mg/kg OTC solution (n = 48).

v) Tag Loss Rate

Within a tagging experiment, tag loss rates are usually determined by placing two tags in a certain number of the fish that are released (Wetherall 1982). Simplistically, the tag loss can be calculated by working out the proportion of these "double tagged" fish that are recaptured with only one tag remaining. Whilst such experiments can be conducted in tanks, it is often difficult to extrapolate their validity in the field situation. In this pilot tagging project, we monitored the retention of tags in all fish maintained in aquaria. In addition, about 60 of the 1485 tagged fish released by anglers in the field tagging trials were double tagged.

vi) Field Tagging Trials

Based on the results of the initial trials of capture methods, two options for field-based pilot tagging projects emerged as the most likely to succeed: recreational angling; and a modified form of commercial trawling.

Angling

Although anecdotal reports of large seasonal influxes of blue warehou to inshore waters range throughout their distribution, there were only a few areas which provided a cost-effective base from which an angling tagging project could be undertaken. Portland, in southern Victoria, was chosen because it was easily and quickly accessible by project staff, had a large number of keen recreational fishermen willing to assist and had regular reports of large numbers of blue warehou entering the harbour. Stanley was selected in north western Tasmania based on the continual reports of anglers catching large numbers of small blue warehou.

The first field-based angler tagging was conducted in late April 1995 and involved research staff and recreational anglers fishing from the Stanley wharf. Further tagging trials were undertaken between March and April 1996. Tagging took place on the wharf. Fish were de-hooked, measured, tagged and returned to the water (3m below the wharf) using a bucket on the end of a rope.

More extensive tagging by anglers was undertaken around Portland harbour between 17th and 30th January 1996 and again from 27th to 29th March, 1996. During these episodes, 4 anglers used sport fishing rods with 6-8kg monofilament line and long-shanked hooks to catch blue warehou and place them in a holding tank on the tagging boat. A team of two trained taggers conducted the tagging, OTC injection and recording. The tagged fish were released over the side. Rates of capture of blue warehou by anglers were limited, when necessary, to minimise the time individual fish spent in the holding tanks prior to tagging.

Modified commercial trawling

As mentioned in the investigation of capture methods, in an operation undertaken off Portland in August 1997, standard commercial trawling techniques were modified to make extremely short shots targeting shallow blue warehou schools. Blue warehou captured in this manner were hauled to the surface, the codend was quickly lifted and released over fish bins which were immediately emptied into two 1.5 ton tanks full of circulating seawater (Plates 1 and 2).

About 5 fish bins were placed in each tank. Tagging commenced immediately. Fish were removed as they swam to the top of the tanks, then placed in a cradle, measured and tagged with a numbered T-bar tag inserted below the dorsal fin (see details in Tagging Method below). All fish that appeared lively and had minimal scale loss (0 - 15%) were tagged. The fish were immediately returned to the sea, as it seemed that containment within the tanks caused continued loss of scales. The vessel kept steaming during all tagging operations to reduce the loss of fish to seals.

Publicity

The success of any tagging project relies on the return of tagged fish, preferably with information on the length of the fish, and time and position of recapture. As such, there needs to be good publicity of a tagging project and incentives for the return of tagged fish. This was an important aspect of the field tagging trials. In both of the angler trials, information pamphlets were provided to the local angling clubs (eg. Appendix 1) and press releases were published in the local newspapers (Appendix 2). Anglers were given rewards for the return of tagged fish or their names were entered into a "tag lottery" from which they could receive a substantial prize.

Methods of publicity were slightly different for the fish tagged using modified commercial trawling. Because these fish were most likely to be recaptured in large numbers by commercial trawlers, most skippers and crew were made aware of the need to search for tagged fish while they were sorting the catch. This was done predominantly by word of mouth, using the on-board observers and fish measurers employed in Portland as part of the SEF Integrated Scientific Monitoring Program. Due to the likelihood that tags would not be found amongst a large catch (5-10 t) of blue warehou, it was also necessary to inform the fish processors and marketers of the presence of tagged fish. This was achieved by placing waterproof pamphlets in the boxes of blue warehou as they were packed to be transported from Portland to the market. A copy of the pamphlet is provided in Appendix 3. In addition to the above, caps which promoted the tagging project were given to various people involved in the capture, transport and transport of blue warehou.

Detailed Results

The initial project was aimed at trialing tagging methods for both blue and spotted warehou, but as mentioned previously, the project changed within the first year to focus predominantly on blue warehou. In addition, initial attempts to tag spotted warehou were unsuccessful for a number of reasons. The main problem was that spotted warehou are generally caught in deeper offshore waters from 100 to 600 m (Tilzey 1994). As such, they do not form an important component of the recreational catch and they are usually dead or injured when landed by either gill nets or trawls. One exception was catches of spotted warehou landed in good condition amongst the blue warehou (~5% of the catch) during the modified trawling off Portland. Nevertheless, as a general rule spotted warehou were rarely landed in a condition suitable for tagging and consequently, the following results relate to blue warehou unless stated otherwise.

i) Investigation of Capture Methods

Of the numerous capture methods tested, only two provided substantial quantities of fish in a condition suitable for tagging: angler caught fish, or those caught by commercial trawlers using short, shallow shots. Results of the various capture techniques are detailed below.

Gill-nets

The commercial gill net vessels which target blue warehou off eastern Victoria use 6 – 7 inch mesh and generally catch fish between 45 and 55 cm LCF (Fig. 2a). Warehous were not specifically targeted by the gill-net vessels chartered to work off the eastern Victorian coast, but small quantities of both blue and spotted warehou from about 20 cm to 42 cm LCF were meshed. Even after the shorter shots of 6 hours at about 150 m depth, all specimens had lost virtually all of their scales and some were damaged/bleeding around the gill area. Many were already dead when brought aboard, and the rest were considered unlikely to survive more than an hour or two. The fish traps used during these cruises did not catch either species of warehou.

The results of the research gillnet fishing in Tasmania on the research vessel *Mallanna* were disappointing. Very few warehou were caught and only a single fish was tagged.

Commercial gillnet fishers working in inshore waters off Tasmania caught significant amounts of warehou between November 1994 and March 1995 (Table 2). The size

distribution of warehou caught by the these gillnets reflects the different sized mesh being used in different areas of Tasmania (Fig. 2b,c). Blue warehou from the north-west were between 25 and 35 cm LCF whilst the bulk of the catch from south-east Tasmania was comprised of 35-45 cm fish.

Although the Tasmanian gill net shots were generally of a shorter duration and in shallower water than those described above for Victoria, our observations revealed that scale loss was still extensive and no specimen survived in holding tanks for more than a few hours after capture. It was apparent after initial hauls, that warehou were particularly susceptible to net damage and most fish landed were already dead. Many of the fish remaining alive appeared lively but had lost considerable quantities of scales and mucous and were, therefore, considered unsuitable for tagging.

Overall, the observations above indicated that normal commercial gill netting operations would have to be modified if this method was to produce warehou in good enough condition to tag and release. The condition of meshed warehou may be improved if nets were set for shorter time periods and warehous were specifically targeted. One Lakes Entrance-based gill net operator claims to have kept meshed warehou alive in on-board holding tanks for up to 12 hours after capture, suggesting that further investigation of the gill net capture method was warranted. The circumstances under which short, targeted gill net shots might be successful, however, were difficult to predict and may be relatively infrequent. Ultimately, the reliability and cost-effectiveness of this capture method for tagging purposes were considered too low to warrant further investigation.

Trawl Nets

Several hundred warehou (blue and spotted) from 30 cm to 50 cm LCF were caught in the commercial trawl shots undertaken off Portland in November 1994. These were the usual size fish caught by commercial trawling in this area (Fig. 2d). The liveliest specimens were placed in a temporary flow-through holding tank on deck to observe survival. All specimens caught had lost virtually all of their scales, including the lively ones placed in the holding tank. No specimen placed in the holding tank survived for longer than six hours, and most had died within two hours. All shots lasted at least two hours and in all cases significant quantities of species other than warehous were also caught. These two factors probably contributed

significantly to warehou stress and damage. Another possible factor was the effect of changes in water pressure and temperature when bringing fish up from depth.

After these observations, it was considered that if trawling was to produce warehou in a condition suitable for tagging the following modifications should be considered:

- Target warehou so that 'clean' (warehou only) catches can be made.
- Much shorter trawl shots - preferably retrieving the trawl immediately after observing fish enter the net.
- Dip net live warehou out of the trawl cod end before winching a heavy catch on board.
- Assess the suitability of a cod end with knotless mesh and with a rigid frame to reduce crushing damage to fish.

These issues were addressed during the trials of modified trawling (short shots) targeting the schools of blue warehou off Portland during August 1997.

Fifteen shots were undertaken over 2 days using the modified trawl method. Most of the shots caught between 300 and 800 kg of fish, which usually resulted from the net only being on the bottom for between 3 and 10 minutes. One shot caught 3,000 kg from which most of the fish were crushed or damaged and only 7 fish were tagged. Generally, however, the small catch weights minimised injury to the fish were not crushed when the codend was hauled out of the water. As a result fish caught using this modified trawling technique were extremely lively and had minimal scale loss when they were landed on the deck. They were considered to be in a suitable condition for tagging. As discussed later, however, the lack of fish recaptures suggests that there may be some problems in this capture and release method.

Danish Seines

Overall, several hundred warehou (virtually all blue warehou) from 8 cm to 28 cm LCF were caught using Danish seines. The liveliest specimens were placed in temporary flow-through holding tanks on deck to observe survival. All specimens caught had lost virtually all their scales, including the lively ones placed in the holding tanks. No specimen placed in the holding tanks survived for longer than 12 hours, and most had died within six hours.

Contrary to expectations, seined warehou were not in significantly better condition than trawled warehou. Two factors probably contributing to warehou stress and damage during Danish seine shots were; (i) significant quantities of other species - particularly spiky globefish - in the net, and (ii) the lifting and dumping of large catches on the deck. Another possible factor was the effect of changes in water pressure and temperature when bringing fish up from depth, although this did not seem to be a problem with trawl-caught warehou. If Danish seining is to produce warehou in a condition suitable for tagging the following modifications will have to be considered:

- If possible, target warehou so that relatively 'clean' (warehou only) catches can be made.
- Dip net live warehou out of the seine net before winching a heavy catch on board.
- Assess the suitability of a cod end with knotless mesh and with a rigid frame to reduce crushing damage to fish.

Danish seine operators based at Port Albert have indicated that it may be possible to target aggregations of juvenile blue warehou in shallow waters east of Wilsons Promontory during autumn and winter months. This possibility could be investigated.

Angling

In Tasmania, blue warehou have been taken every autumn (especially between April and May) off Stanley and Wynyard and although there was variability in catches within a season and between years, catches were reasonably predictable. Fair catches were also taken from the south-east, in particular in Fortescue Bay on the Tasman Peninsula, though the occurrence of fish in this area was apparently less predictable than off the north-west coast.

Basically, although recreational angling seemed a viable means of collecting warehou for tagging, a few minor difficulties needed to be addressed.

- Anglers were required to target large runs of warehou to ensure that catch rates were sufficient for a cost effective tagging episode.
- A method of de-hooking the fish which minimises handling needed to be developed.
- A large portable holding tank with the facilities for flow-through water supply is required on site during tagging.

ii) Tag Type and Tagging Method

Based on previous tagging experiments conducted on a variety of different fish species, potentially appropriate tags and tagging methods were trialed. As a result, an acceptable tagging method was developed which could be used for either of the standard tag types.

Initial attempts to handle, tag and inject warehou resulted in significant bruising and scale loss, followed in some cases by tissue necrosis, fungal infection and death within days of tagging. After trial and error the following procedure was developed for experimental tagging of line-caught blue warehou. Fish to be injected with OTC were individually dip netted from the holding tank into a plastic bowl for weighing on calibrated electronic scales, and then transferred to a soft vinyl tagging cradle. Fish to be tagged-only were dip netted directly onto the cradle. Once on the cradle the fork length of the fish was measured, a T-bar or dart tag inserted and, if required, OTC was injected in the sub-cutaneous caudal musculature immediately above or below the lateral line. Fish were not anaesthetised, but where necessary a piece of wet foam was placed over the eyes and head to quieten the fish during tagging and injection, and thus minimise bruising or scale loss. Tags were inserted 1 - 2 cm below the base of the mid part of the soft dorsal fin. Each tag was carefully checked to ensure that it was locked behind either dorsal fin pterygiophores or the neural spines of vertebrae. Fish were then slid off the tagging cradle into holding tanks to recover. Cotton gloves were worn to avoid direct contact with mucous and scales.

Both T-bar and dart tags appeared to be satisfactory for tagging blue warehou, but T-bar tags were preferred because they were slightly easier to apply to small warehou, and it was suspected that they may provide slightly superior tag retention in circumstances where the tag was not locked behind a bony structure.

The on-board tagging procedure for field trials was the same as that described above, except a spring balance was used to weigh fish to determine OTC dosages, and tagged/injected fish were released directly back into the water.

iii) OTC Injection Trials

Based on a series of tank trials, optimum OTC concentrations were established for blue warehou and OTC injection was determined as a successful means of marking otoliths for age validation.

In the first experiment, fish that survived less than 30 days after injection showed no clear signs of deposition of a fluorescent OTC mark on their otoliths. Some of the fish that survived between 30 and 100 days had deposited unmistakable OTC marks at the edge of their otoliths, but there had been no further marginal growth increments. This was consistent with evidence that most of these fish did not increase in length or weight during the first few months after tagging and injection. The three fish that survived for longer than 100 days (see Table 1) showed some sign of growth (increase in length and/or weight), and this was reflected by marginal increments outside the OTC mark in their otoliths.

Both visceral cavity and caudal musculature injections produced satisfactory OTC marks on otoliths. Caudal musculature was the preferred injection location, however, because visceral cavity injections carry some risk of direct damage to visceral organs (eg gonads), or of rapid excretion of OTC if injected directly into the intestine. Clearly discernible OTC marks were produced by injections of both 45 and 60 mg OTC/kg fish weight. It was therefore decided that a 45 mg OTC/kg wet weight injection into the caudal musculature would be the standard injection for blue warehou, because this was the best compromise between minimising the amount of injected OTC solution and maximising the chances of obtaining a discernible fluorescent mark. This was applied to fish used in the second experiment and all fish that were OTC injected and released in the field tagging trials.

The results of the second experiment provided confirmation that the optimum OTC injection dosage was appropriate, as described below.

The otoliths examined were extracted from fish which had lived for between 6 and 109 days after tagging. An OTC mark was detected on only 10 otoliths of the 37 marked fish examined (Table 3). The OTC marks were detected on otoliths from an increasing proportion of fish as the range of times since tagging increased (Fig. 3). The OTC marks were very faint on all fish, and the strongest mark (for a fish which had survived for 103 days after tagging) is shown in Figs. 4 and 5. This mark was very narrow, confined to the proximal side of the otolith, and strongest adjacent to the inferior crista.

Two of the control fish were also recorded as having some a very faint OTC mark, which was probably attributable to a misinterpretation of the strong autofluorescence at the otolith margin. Autofluorescence was observed at the margins of all otoliths, presumably due to

dried endolymph or tissue. This fluorescence was a green colour and was usually distinct from the yellow fluorescence which is typical of OTC (see Fig. 5).

The absence of any distinct OTC marks on the otoliths of fish which survived less than 30 days was not unexpected. In order to be able to distinguish OTC fluorescence from edge autofluorescence, the otolith must grow significantly during the period between marking and death. A period of less than 30 days was not long enough to allow for sufficient material to be deposited outside any OTC mark.

The presence of faint OTC marks indicates that the marking has been partially successful. The success of marking method could be improved with some further developments. These might include a larger dosage of OTC, or injecting a different formulation of OTC which stays in the body longer.

It was possible that OTC marks may have been present on a larger proportion of the samples examined than were recorded but they may not have fluoresced at a level which could be detected by eye. The OTC band in the photomicrograph (Fig. 5) appears much brighter than when observed directly, because the long exposure time (4 minutes) enhances its brightness.

iv) Tagging Mortality

Significant quantities of body mucous and small patches of scales were lost during the weighing, tagging and OTC injection procedures. Nevertheless virtually all fish immediately regained their balance and began actively swimming upon being returned to the large concrete holding tanks. The treated fish were subsequently fed daily on fresh fish pieces. Very little ulceration developed around tag insertion points either during or after the initial 14 day experimental period.

Mortalities within 14 days of the tagging and OTC injection are shown in Table 4. These results indicate that tagging mortalities for properly handled line-caught blue warehou are, at most, about 15%, and should be less for tagged and released fish which were not subjected to the additional trauma of repeated handling and prolonged confinement under experimental conditions. It was not possible, however, to determine whether warehou which have been tagged/injected and released suffer increased mortality because they were at least temporarily more vulnerable to predation (eg by seals or sharks) and/or less able to compete for available food resources. This is discussed later.

v) Tag Loss Rates

It was not appropriate to realistically assess tag loss rates by maintaining tagged warehou under experimental aquarium conditions. Tag loss rates may be exaggerated, for example, by abrasion against aquarium walls, or by the prolific growth of algae on the tag streamer, producing unnecessary drag and tissue erosion during swimming. Nevertheless, it was clear that unless T-bar or dart tags were properly located between the fin pterygiophores or neural spines of warehou then there was a significant risk of tag loss.

Post mortem examination of fish involved in the first tagging experiment in October 1994 revealed that in 11 out of 18 cases (61%) inserted tags were located in flesh only, and had not been properly locked behind fin pterygiophores or neural spines. In three out of these 11 cases the tags had been lost within four months of the tagging date. In several other cases the tags were obviously working their way out from the original insertion location and were only loosely retained by skin or flesh at the time of death. Although the small sample size precludes rigorous statistical analyses, there was no obvious difference between T-bar or dart tags in either the proportion of tags correctly inserted or the retention of tags inserted in flesh only. Nevertheless it was suspected that the T-bar tag, with its more complex head configuration, may perform slightly better than dart tags in these two areas.

The above results emphasise the need to have trained taggers in order to maximise tag retention through correct insertion of the tags.

It was hoped that more realistic estimates of tag loss rates might be obtained by the recaptures of double-tagged fish released during the angling field trials. Unfortunately, only a small number of fish were double tagged, and to date, tag return rates have been insufficient for this to occur.

vi) Field Tagging Trials

Pilot field-based tagging trials were undertaken using fish caught by anglers and modified trawling. Whilst the actual tagging procedures appeared to be successful, tag recapture rates were low. Details of the results of these trials are outlined below.

Angling

Overall, 1485 blue warehou captured anglers were tagged and released in Stanley and Portland during 1995 and 1996. Most of the tagging in 1995 was undertaken at Stanley, where 207 fish were tagged and released during late April. These fish ranged in size from 16 cm to 36 cm LCF, but most were small immature fish around 20 cm LCF. In contrast, those tagged in the following year at Stanley were around 30 cm LCF (Table 5, Fig. 6a). Most of the tagging around Portland was undertaken in January and March 1996, with over 1000 fish tagged and released. These fish generally ranged between 24 and 36 cm LCF, and the mean and mode was around 28 cm LCF (Table 5, Fig. 6b).

Modified Commercial Trawling

The fish obtained from short, targeted shots on shallow schools of blue warehou off Portland were generally in good condition for tagging. A total of 2,321 fish caught in this manner were tagged and released from 14 shots over a period of 2 days in August 1997 (Table 6). The fish ranged between 30 and 45 cm LCF with a mode at 37 cm LCF (Fig. 7). If more than a few hundred kilograms of fish were caught in any shot, the fish at the bottom of the codend were usually crushed, with extensive scale loss and were consequently in poor condition for tagging. These fish were not tagged. In the first two shots, we noticed that seals were preying on any fish that were thrown back into the water. To overcome this problem, the trawler continued to steam while the fish were being tagged to minimise the loss of tagged fish to seal predation.

Tag Recaptures

To date, the number of tag recaptures has been disappointing. Seventeen of the 1,485 fish caught and tagged by anglers were recaptured, whilst only one of the 2,321 caught using modified trawling has been recaptured.

One fish tagged off Stanley wharf in April 1995 was recaptured several kilometres from the tagging site by an inshore commercial mesh net operator after being at liberty for almost a month. Most of the tag recaptures, however, were from the fish caught by anglers around Portland and they were recaptured within a few kilometres of the tagging site. The longest time at liberty was 70 days, but most fish were recaptured within a month of tagging (Fig. 8).

The recapture of the tagged fish caught using modified trawling was by another commercial trawler. It was working in a similar region and caught the fish after 40 days at liberty. The fish was not noticed until it was being unloaded from the vessel, but it appeared to be in good condition, with little degradation of the tissue around the tag, which was well secured.

Table 1. Preliminary tagging and OTC injection trials undertaken in October 1994 on blue warehou kept in tanks at MAFRI. Eight of the fish in this experiment died within 14 days of tagging, providing a tagging mortality of 44%.

Tag Type	Length (cm)	Weight (kg)	OTC Dose (mg/kg)	Date died	Days tagged
Dart	21.9	0.208	30	26/10/94	0
Dart	12.6	0.206	45	31/10/94	6
Dart	22.2	0.240	60	29/10/94	4
T-Bar	16.7	0.087	30	26/10/94	0
T-bar	22.3	0.238	45	27/10/94	2
T-bar	22.8	0.251	60	11/02/95	109
Dart	21.5	0.184	30	14/11/94	20
Dart	22.8	0.346	45	14/02/95	112
Dart	22.5	0.245	60	17/11/94	23
T-Bar	21.5	0.215	30	26/01/95	93
T-bar	22	0.243	45	28/10/94	3
T-bar	22.0	0.234	60	05/02/95	103
Dart	22.5	0.197	30	28/10/94	3
Dart	20.8	0.191	45	31/01/95	98
Dart	22.2	0.250	60	04/12/94	40
T-Bar	21.8	0.225	30	15/01/95	82
T-bar	21.7	0.236	45	22/01/95	89
T-bar	22.2	0.203	60	02/11/94	8

Table 2. Summary of commercial gillnet trips monitored by research officers to determine the potential of this method for tagging blue warehou off Tasmania.

Dates of trip	Area	N° net sets	Depth range (m)	Set duration (hours)	Av. set duration (hours)	N° blue warehou	
						Caught	Tagged
15-18/11/94	Tasman Peninsula, Maria Is.	22	4 - 32	3.8 – 12.7	8.9	395	0
8-10/12/94	Tasman Peninsula, Maria Is.	15	9 - 20	3.0 – 19.8	10.3	248	2
14-15/12/94	Tasman Peninsula	22	4 – 25	3.6 – 18.8	8.4	43	1
17/3/95	Table Cape (Wynyard)	1	13	12.5	12.5	10	0
29-31/3/95	Tasman Peninsula, Maria Is.	11	6 – 41	6.1 – 15.1	9.8	0	0

Table 3. Numbers of injected and control fish examined and the number which showed OTC marks.

OTC Injected	OTC mark visible		
	Yes	No	Total
Yes	10	27	37
No	2	31	33
Not known	0	1	1
Total	12	59	71

Table 4. Tagging mortality estimates for blue warehou from the second experiment undertaken on fish caught by anglers and held in tanks in Portland during January 1995.

Treatment	Number	No. dead within 14 days	% Tagging Mortality
Control Group	52	4	7.7%
Tagged Only	46	2	4.3%
Tagged and OTC	48	8	16.7%

Table 5. The number and mean length of blue warehou tagged and released in Tasmania and Victoria after capture using angling methods.

State	Position	Date	Number tagged	Mean Release Length (cm LCF)	Number recaptured
Tasmania	Stanley Wharf	21/04/95	23	24.1	
		22/04/95	48	18.1	
		23/04/95	20	31.5	1
		24/04/95	4	18.2	
		25/04/95	9	21.5	
		26/04/95	103	18.4	
		24/03/96	7	30.1	
		25/03/96	5	29.8	
		08/04/96	23	29.3	
		11/04/96	19	30.4	
		15/04/96	14	29.6	
Total			275	22.4	1
Victoria	Portland Harbour	25/05/95	38	20.9	
	Portland Harbour	10/01/96	4	24.6	
	Lawrence Rock	17/01/96	66	27.9	1
		18/01/96	182	28.9	
		19/01/96	313	29.8	
		23/01/96	193	28.2	
		24/01/96	25	27.2	
		30/01/96	24	28.4	
	Portland Harbour	27/03/96	159	27.0	13
		28/03/96	46	26.6	2
		29/03/96	2	27.0	
	Little Reef	16/10/96	158	27.5	
Total			1210	28.2	16
Grand Total			1485	27.1	17

Table 6. Summary of number of fish tagged using modified trawling techniques targeting shallow schools of blue warehou off the Victorian coast near Portland.

Date	Shot	Approx. shot weight (kg)	Depth (m)	No. tagged fish	Comment
29/8/97	1	1200	216	124	Fish at bottom of codend in bad condition
29/8/97	2	140	216	80	Excellent condition
29/8/97	3	200	216	127	
29/8/97	4	3000	270	7	Fish crushed
29/8/97	5	-	225	66	
29/8/97	6	-	243	115	
29/8/97	7	200	218	5	Not a clean shot
29/8/97	8		252	136	Excellent condition
29/8/97	9		243	280	Excellent condition
30/8/97	1		252	212	Excellent condition
30/8/97	2		270	111	Excellent condition
30/8/97	3		270	256	Excellent condition
30/8/97	4		252	288	Excellent condition
30/8/97	5		256	267	50% not tagged – in bad condition
30/8/97	6		243	227	Excellent condition
Total				2301	

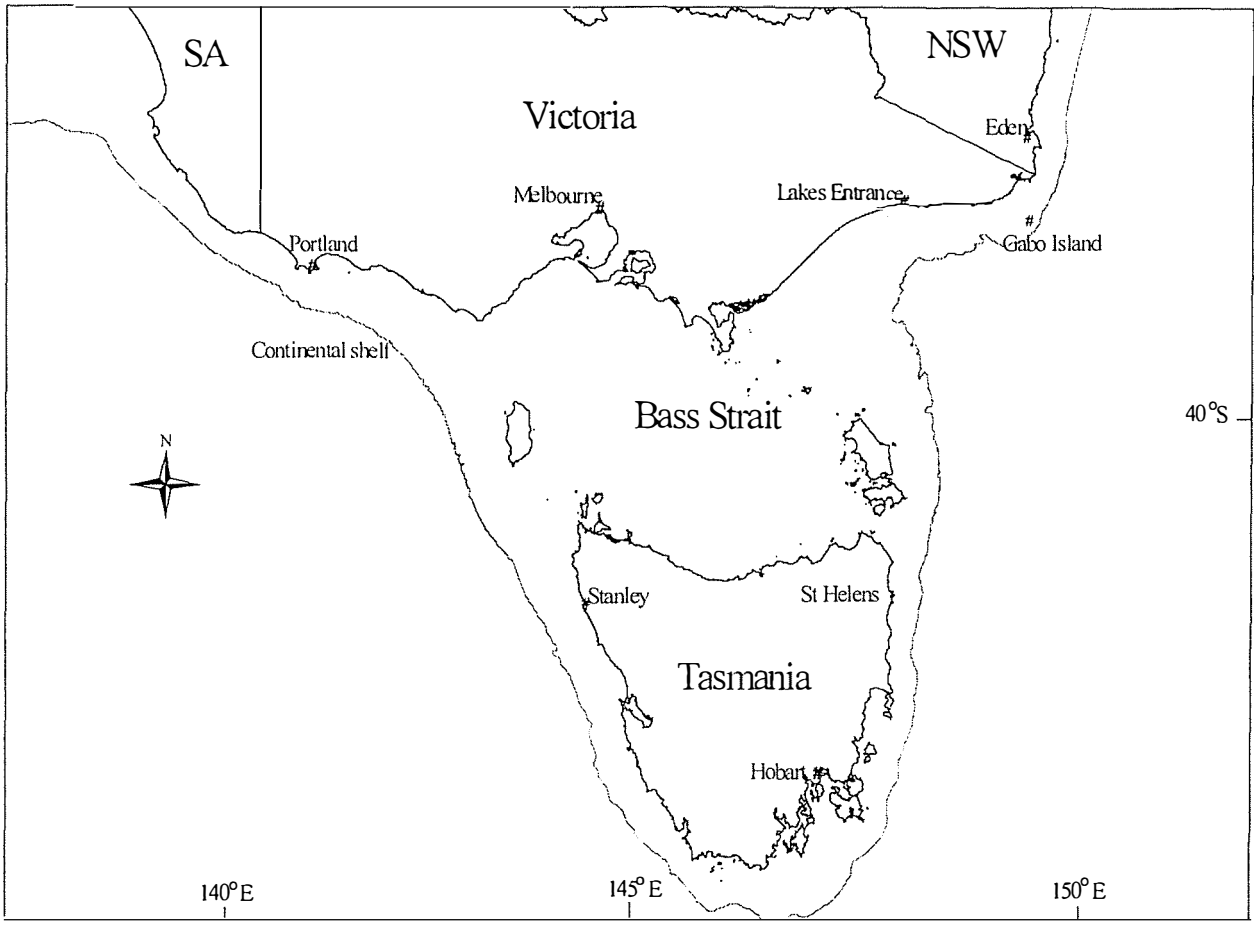

Figure 1. Study area off south eastern Australia in which the pilot tagging studies of blue warehou were undertaken.

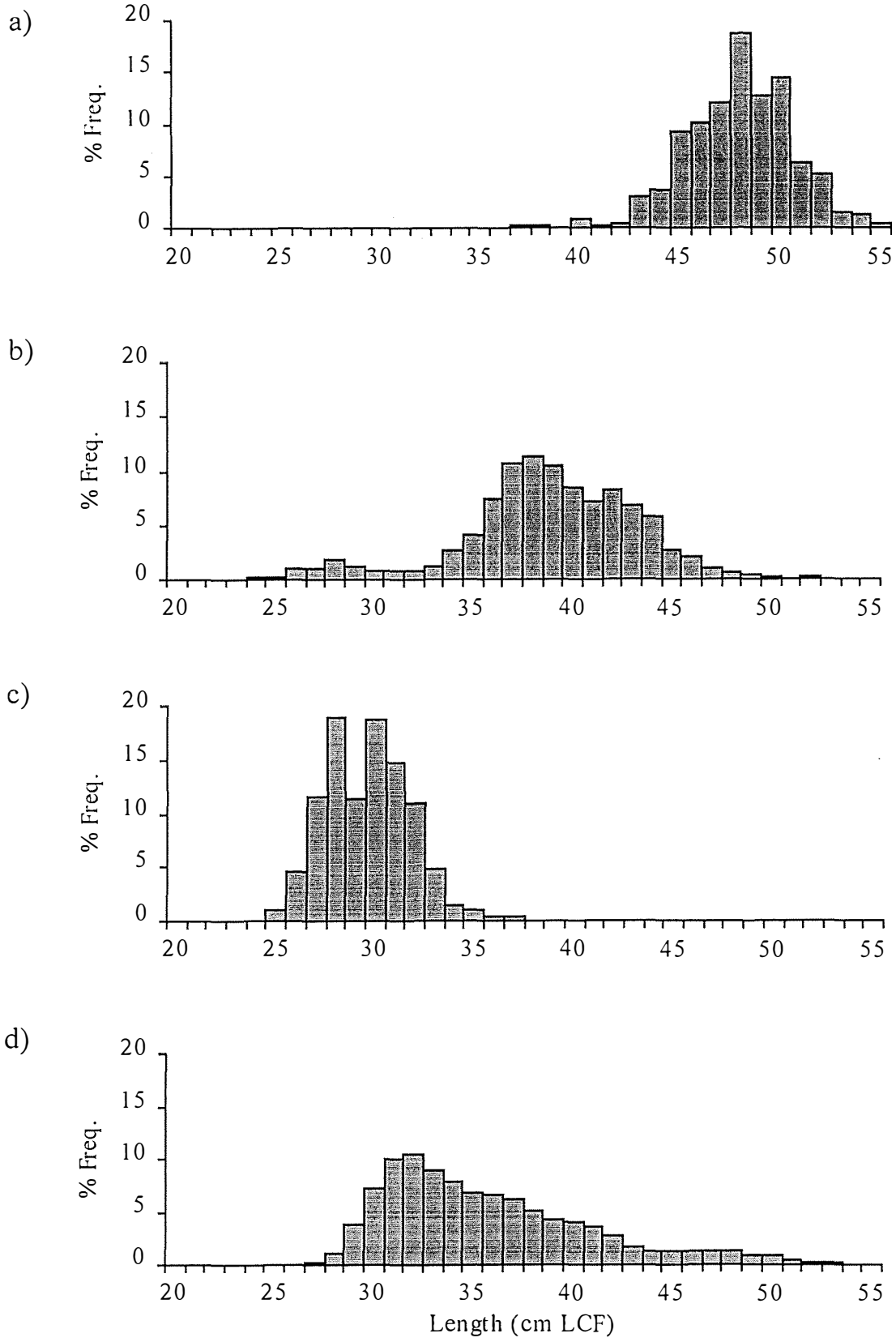

Figure 2. Length-frequency histograms of blue warehou caught by commercial fishing methods during 1995 to 1996 using: a) 6 – 7 inch gill net off Lakes Entrance, Victoria; b) 4.5 to 5 inch gill net off southeast Tasmania; c) 3.5 inch gill net off northwest Tasmania; and, d) trawl gear with 90 mm codend off Portland, Victoria.

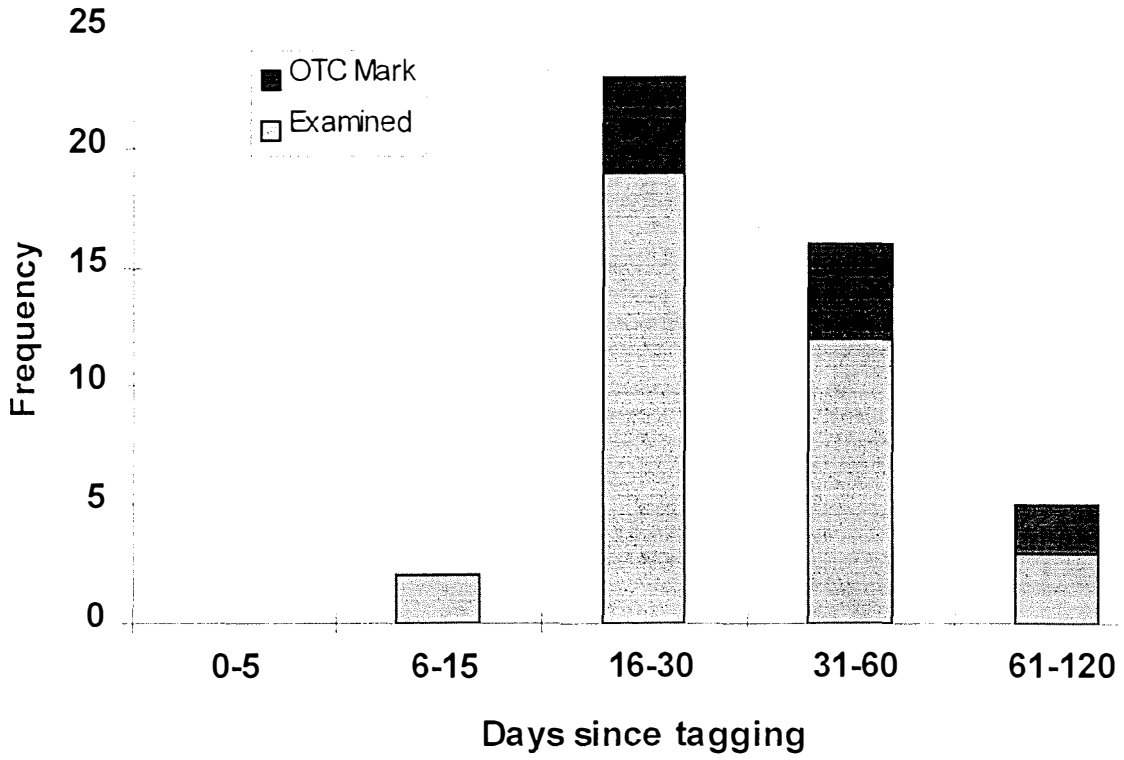

Figure 3. Number of fish examined and those which displayed visible OTC marks from 0 to 120 days after tagging and injection.

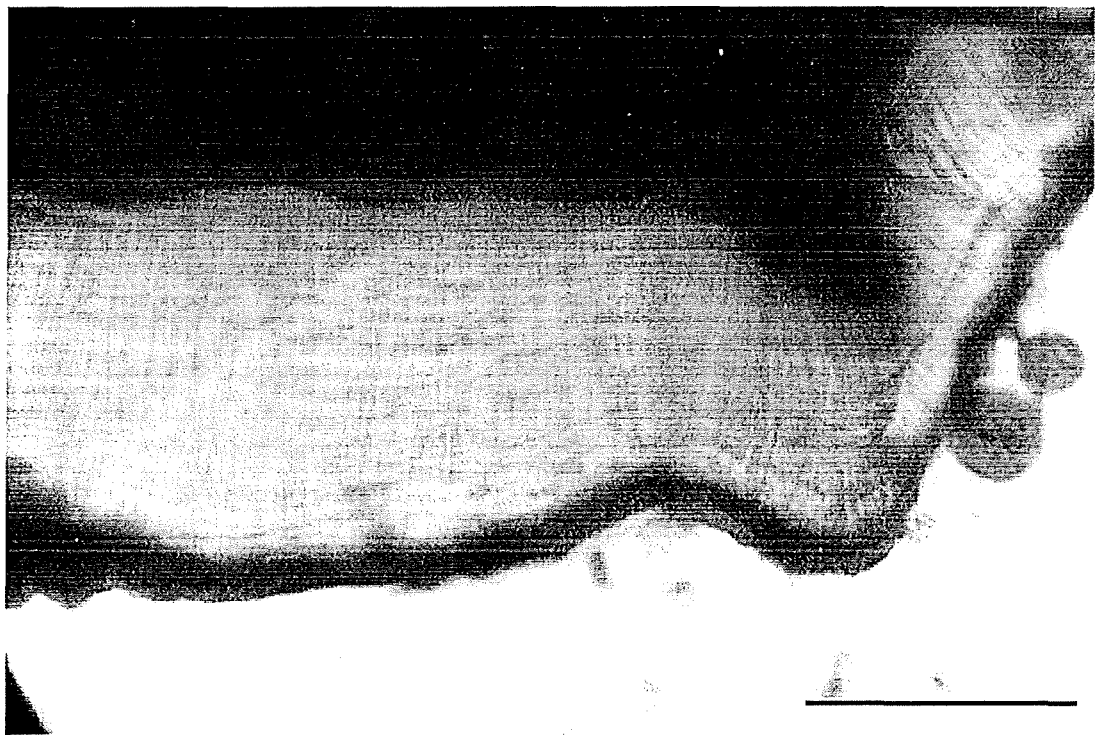

Figure 4. The proximal / ventral quadrant of a transversely sectioned blue warehou sagitta viewed with transmitted light (tag number 537, fork length = 23.5cm). Scale bar = 200 microns.

Figure 5. The same fish and section as in Fig. 4, viewed with epifluorescent illumination. The fish had been injected with 60mg/kg of oxytetracycline and had survived for 103 days after injection. Arrow indicates position of OTC mark. Scale bar = 200 microns.

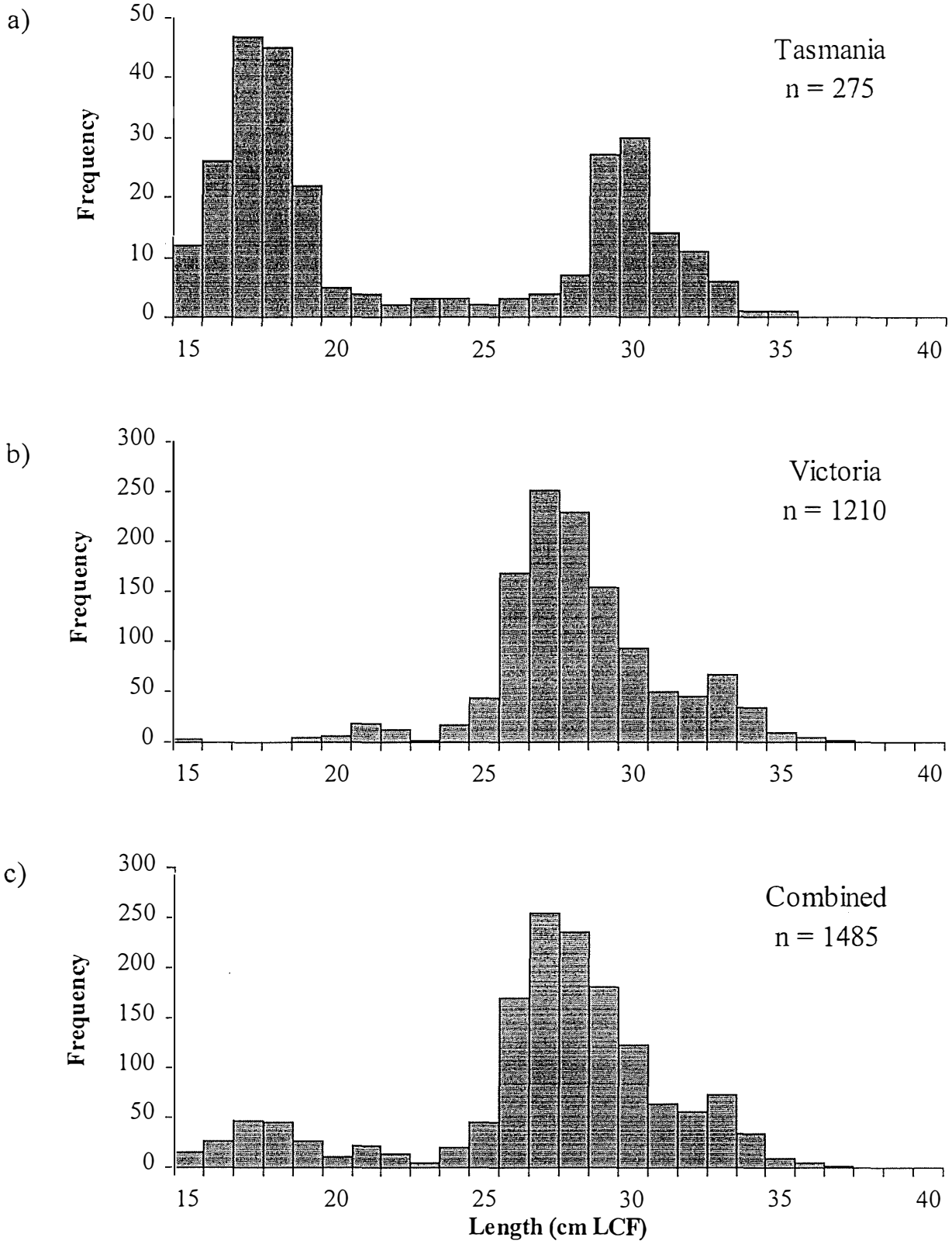

Figure 6. Length-frequency histograms and numbers of blue warehou tagged using angling in a) Stanley, Tasmania; b) Portland, Victoria, and; c) both areas combined.

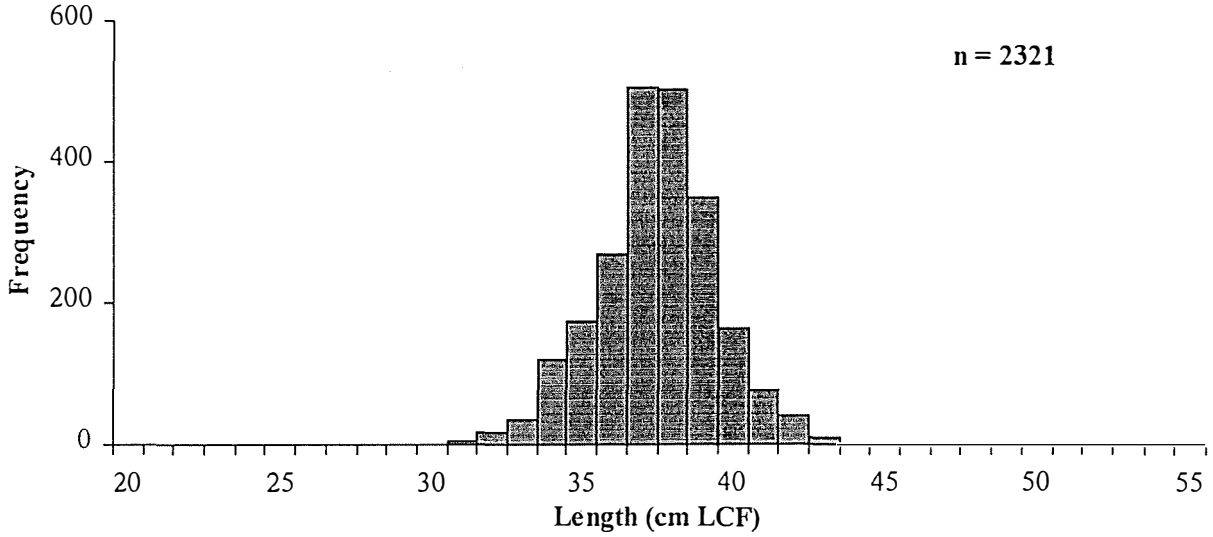

Figure 7. Length-frequency histogram of blue warehou tagged using modified commercial trawling in shallow waters off Portland, Victoria.

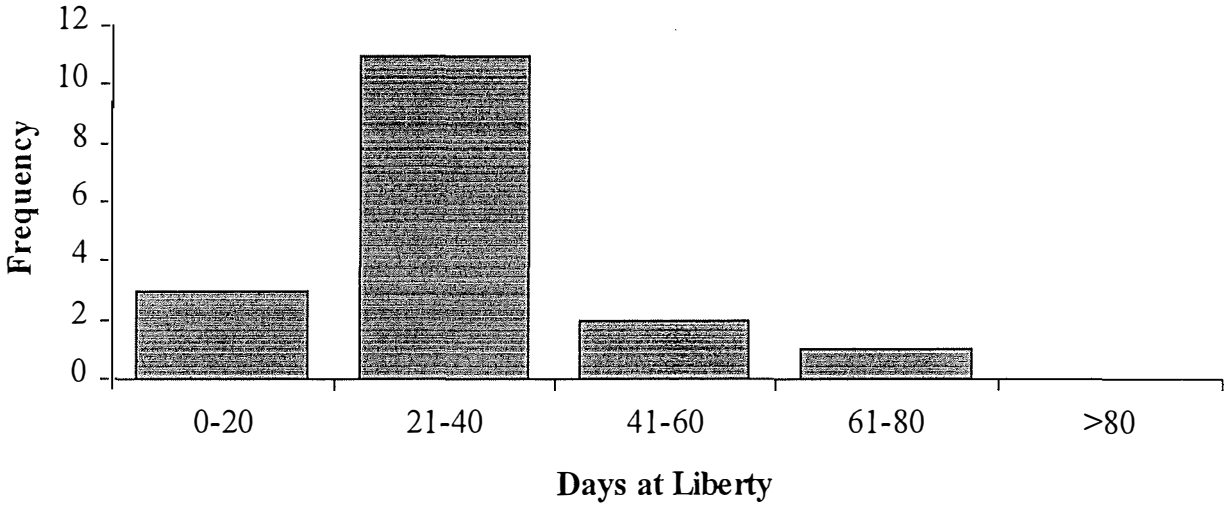

Figure 8. Frequency histogram of the days at liberty of recaptured blue warehou tagged using recreational angling in Victoria and Tasmania combined.

Discussion

Tagging projects are usually implemented to elucidate certain aspects of a species population biology, such as growth, movement or mortality. Ultimately, this is reflected in the particular spatial and temporal design of the tagging project. Nevertheless, all tagging projects are expensive and some basic techniques need to be developed to ensure a successful tagging project. As outlined in the objectives of the present study, foremost among these were the identification of appropriate fish capture, handling and tagging methods.

This pilot project made significant progress towards achieving these objectives for blue warehou, but not spotted warehou. This was mainly because, after the project started, concern over the continued decline in blue warehou catch rates made this species a priority. Also, during the preliminary trials, spotted warehou were generally in poor condition when caught by either gill net or trawl vessels working deeper, offshore waters and they did not form an important component of the inshore recreational catch. Although most commercial methods also damaged blue warehou to an extent that they were unsuitable for tagging, fish in good condition for tagging could be captured by shore-based anglers or by commercial trawlers using short, shallow shots. As long as care was taken to quickly remove the hook from the fish, angler-caught fish were more likely to be in optimum condition for tagging. Anglers caught blue warehou in shallow water and handled them one at a time, so the fish were unlikely to be damaged from contact with nets or other fish and there should not have been any major pressure-related problems. With trawling — even the modified form used in the current study — there was a greater possibility of damaging the fish. Size of the trawl shot was crucial to condition of the fish. Once shots were greater than a few hundred kilograms, damage to the fish was readily apparent, mainly from crushing and scale loss. Fish may still have been damaged in smaller shots, but it was not obvious. Only fish with little or no scale loss that were actively swimming in the holding tanks were tagged.

Once the fish had been captured, the handling methods developed to tag and release the blue warehou were similar to those adopted in many fish tagging experiments. Most of the modifications merely reflected adaptations to the particular environment in which the fish were being tagged. An essential feature was the use of a holding tank to store the fish between capture and tagging. Scale loss did occur while the fish were in these holding tanks and there was risk of oxygen starvation. This was more apparent in the holding tanks used on the trawlers, as large numbers of fish were collected in a short time. To minimise these

problems, stocking levels were usually kept at less than one fish per 10 litres, flow-through seawater circulation was adopted and the time that fish used for tagging were held in tanks was limited to a maximum of about 20 minutes.

Tank trials of angler caught fish indicated that once correct handling procedures were developed, tagging mortality could be reduced to less than 10%. These tagging techniques were adopted for the fish caught by modified trawling. It was, however, difficult to determine the potential level of tagging mortality in the field-based trials. Extrapolation of mortality estimates from tank trials to mortality in the natural environment could well be invalid due to factors such as reduced ability of a fish to compete for food or to avoid predation (eg. seals). Although this may not have been apparent in the controlled environment of a tank trial, it could have affected survival in the natural environment. This is mentioned further in the discussion of tag recapture rates.

Whilst adequate capture techniques and tagging methods were able to be developed for blue warehou, there remains a number of major impediments to the use of tagging as a means of determining movement and exploitation rates. The limited number of tag recoveries is obviously high among these, but other factors such as the spatial and temporal "patchiness" of fish available for tagging and the selectivity of differing capture techniques are important to consider.

A crucial factor in the success of any tagging project is the rate of tag recapture. Recapture rates of less than 10% are common and should be expected, although the reasons for low figures may be varied. In the current study, recapture of angler-tagged fish was around 1%. All of the recaptures, however, were in the same general region in which they were tagged and occurred over a relatively small time scale (< 3 months). Furthermore, the size range of fish that were tagged by this method is well below that which would be caught by commercial methods. This is because juveniles and sub-adults (20–30 cm LCF) are often found in coastal waters where they can be caught by anglers, but adults tend to be in deeper offshore waters (Smith 1994a). As such, mean length often increases with depth and may reflect a time-lag of one to two years as the fish grow and move into deeper waters. Thus, although mortality could have caused the lack of tag recaptures of these small fish, it may also have resulted from movement of the sub-adults away from coastal waters. None of these fish, however, were recaptured in the commercial fishery. Moreover, only one of the 2300 tagged fish captured by

modified trawling was recaptured. Such a low recapture rate highlights a problem in the use of tagging as method to elucidate stock movements, exploitation rates and especially abundance estimates. At the time that these fish were tagged, the blue warehou form dense schools which are subject to considerable targeting. A better recapture rate was therefore expected. A simple answer could be that mortality of tagged fish was high despite being in good condition when released. This was not supported by the mortality rates observed in tank trials, but may have resulted from factors relating to their release at sea. In general, mortality rates for blue warehou are thought to be relatively high, at around 0.5 $year^{-1}$ (Smith 1998).

One possibility for the low recapture rates was that during this schooling phase, the release of single tagged fish into the water may make them more vulnerable to predation. These single fish were observed to be very vulnerable to seals until we began to steam during the tagging. Possibly, they remained vulnerable to predation despite steaming, but the mortality was merely unobserved. Alternatively, it could be that extremely large numbers of fish were associated with these schools and relatively low exploitation rates resulted in the lack of recaptures. Another interpretation is that aggregations of these fish during schooling may result in an "all or none" scenario with respect to tag recaptures, and that the schools containing a large number of tags have yet to be caught. Yet another alternative is that tagged fish were recaptured but not reported. Although the tagging project was well publicised in several sectors of the commercial industry, a few tagged fish would be difficult to observe in large catches (sometimes >3000 kg). The one tagged fish that was recaptured was only noticed by a Departmental fish measurer after being handled twice by the crew. Also, as a result of the quota system and market demand, large numbers of fish are sometimes discarded at sea without even being sorted by the crew.

Overall, the study demonstrated that in certain circumstances, good numbers of blue warehou can be tagged following capture by anglers or in modified trawl shots. It is difficult to determine the reasons for the low tag recoveries without further information. Nevertheless, this aspect of the tagging pilot study highlights the problems that may be encountered in using tagging to elucidate warehou stock dynamics.

Even if better recapture rates were achieved, the limited number of areas and times during which blue warehou can be caught in a condition suitable for tagging needs to be considered if tagging is to be a feasible stock assessment tool. The tagging field trials were only

"successful" at very specific places and times during the year. This has important implications for a stock that is considered to span south eastern Australia, but probably supports at least three distinct sub-fisheries based on gear type and spatial and temporal patterns of catches (Smith 1998). Unless fish can be tagged over a much wider geographical range, interpretation of fish movements could be significantly biased. Furthermore, exploitation rates vary considerably within the different sub-fisheries (Smith 1998), so restrictions in the portion of the population that is "available" for tagging within these subfisheries will curtail extrapolation of results as a means of estimating exploitation rates.

The other main objective of the project was to validate the assigned ages. We were successful in developing methods of administering OTC injections at concentrations which left a fluorescent band on the otoliths. These methods are similar to those developed for other fish species (Leaman and Nagetaal 1987; McFarlane, and Beamish 1987). Although this could have been used to validate the assigned ages of warehou, unfortunately we were unable to retain or recapture fish which had been at liberty for a long enough period to be used in age validation. The low recapture rate and time at liberty of fish tagged in the wild, suggests that the most effective technique for age validation will probably rely on more extensive and long-term tank trials.

Benefits

Whilst the main positive outcome of the project was the development of techniques which can be used for the tagging and age validation of blue warehou, another benefit was that potential difficulties in conducting a tagging project were highlighted. This finding highlights the importance of undertaking a pilot study prior to committing considerable resources to a large-scale tagging project. Given the results of this pilot study, it is concluded that without substantial further development, tagging is not a viable stock assessment tool for warehou.

Further Development

Although at this time, we do not consider tagging to be a viable stock assessment tool, there are numerous areas of further research which could be undertaken to improve the value of a tagging project. One of the most important would be to determine, and if necessary, improve the survival of warehou that are tagged and released in the field. Whilst good survival could

be achieved in tanks, in a schooling species, the vulnerability to predation of single fish released back into surface waters could be high. The use of sea cages to aggregate and return the fish to the bottom prior to release could prove useful in this respect. Also, it may be useful to assess the extent of under-reporting in commercial fishing operations.

The present study was initiated as a means of starting to reduce uncertainties about warehou stock structure and population dynamics. Although we have established that this is unlikely to be achieved through a tagging project, these uncertainties still exist. As such, beneficial areas of further development are likely to include alternative methods of determining stock structure and population dynamics. Along these lines, research projects which use methods such as morphometrics or DNA analysis may be appropriate.

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Appendix 1 Publicity of tagging projects

Copy of the information sheet distributed to angling clubs in Tasmania, promoting the tagging operation off Stanley. Similar sheets were produced for the tagging in Portland.

TAGGING OF BLUE WAREHOU (SNOTTY TREVALLA) AT STANLEY

As part of a study of the movement and exploitation rates of blue warehou, often referred to as snotty trevalla, the Tasmanian Marine Resources Division is undertaking an intensive tagging operation mainly in the north west of the state.

Blue warehou are common on the continental shelf and upper slope of south-eastern Australia, and provide a significant component of the scale-fish catch taken by Tasmanian inshore fisheries.

While warehous are taken primarily by gill-net and trawl methods, there also exists a significant recreational fishery. The Tasmanian fishery is highly seasonal with best catches taken in summer and autumn, but this may fluctuate during the season and between years.

Although some biological and fishery information is already known, stock size and structure, current exploitation rates, movements and growth rates need to be addressed.

Why tag fish?
Tagging has shown to be the best short-term method of estimating current exploitation rates, and provides information about fish movements and growth rates. This information is important if the stock structure is to be more clearly understood.

Where and how is tagging taking place?
Fish up to 40cm are commonly taken by anglers in Estuaries and can be successfully tagged and released. Since mid April fisheries officers have been tagging warehou off Stanley wharf and will continue while fish are available.

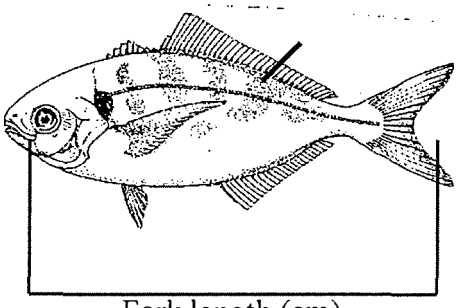
Tags are yellow T-bar tags with 5cm in length, with an 'F' prefix followed by a four-digit number and 'TAS FISH'. Tags are inserted just below the dorsal fin, usually towards the back half of the fish.

What do you do if you catch a tagged fish?
If you catch a tagged fish, please note the tag number, location and date of capture. If possible, measure the size of the fish from the tip of the snout to the tail fork.

If the fish is alive and in good condition, fishers are urged to return the fish to the water as soon as possible after recording the above details. Re-releasing fish may enable the movements of individuals to be tracked over a long period.

Is there a reward?
At this stage, a reward for tagged fish recaptures has not been finalised but will most likely be entry into a tag lottery. All recaptures will be acknowledged with details of the history of the individual fish.

Fishers requiring further information about this study or with information about recaptures should contact either John Kitchener, Jeremy Lyle or Carl Waterworth of the Marine Research Laboratories, Taroona on (002) 277 277 or in writing to the Department of Primary Industry and Fisheries, GPO Box 619F, Hobart 7001.



PRESS RELEASE

Minister for Natural Resources

TAGGING WAREHOU - WHATS THE CATCH?

The Minister for Natural Resources, Geoff Coleman, today appealed for the help of fishers around Portland in a project to tag and study the warehou fish, known locally to many people as "haddock".

The project will involve tagging and recapturing juvenile warehou caught by anglers in shallow waters, as well as larger, adult fish caught in offshore waters by commercial fishers.

Mr Coleman said the warehou was a popular target for both local and visitors fishing in marine waters around Portland, and an increasingly important commercial fishery, worth close to $10 million in the last financial year.

"With increasing fishing pressure on warehou stocks, there is now a real need to determine population characteristics and migration patterns so we can develop sensible management plans to ensure conservation of stocks".

Successful tagging, release and recapture of fish will provide the scientists with information about growth and mortality rates, migration patterns and the relative impact of commercial and recreational fishing on warehou stocks.

Scientists from the Victorian Fisheries Research Institute and the Tasmanian Department of Primary Industries and Fisheries will carry out trial tagging exercises in waters off Victoria and Tasmania throughout 1995 to identify the best methods of catching, tagging and releasing warehou.

Researchers will also hold warehou in tanks or cages to observe rates of recovery after catching and tagging, and to determine which types of tags are most suitable.

A full-scale warehou tagging program will commence if suitable tagging methods are developed during the current trial phase.

Some tagged warehou will be injected with a dye before release to validate the current method of ageing individual fish by examining growth rings in their otoliths or ear bones.

Mr Coleman said trial tagging experiments would be conducted near Portland and in other Victorian and Tasmanian locations throughout this year.

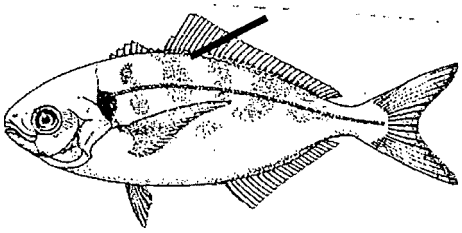
"The co-operation and assistance of both recreational and commercial fishers will be vital for the successful conduct of this research program", he said.

Media Inquiries:
Liz Brown, CNR Media Liaison, Ph (03) 412 4152
Tony Cudmore, Press Secretary, Ph (03) 651 5799

Copy of the pamphlets placed in fish boxes with commercial catches of blue warehou landed in Portland and shipped to markets and processors throughout the South East Fishery.

Tagging Snotties ?

FISHERIES RESEARCH & DEVELOPMENT CORPORATION



MARINE & FRESHWATER RESOURCES INSTITUTE

Supporting Research!

Blue warehou (also known as black snotties) are an important commercial species caught off the south east coast of Australia. Uncertainties about fish movements and concerns about the sustainability of current catches prompted a pilot project to investigate the feasibility of tagging blue warehou for research into migration and growth. In August 1997 over 2200 fish were tagged and released in the trawl grounds off Portland. Small, targeted trawl shots were used to catch the fish and they were released in good condition, but as yet we are uncertain of the effectiveness of this tagging method. Please help us in our research by reporting the details of any tag recaptures. A reward is offered for the return of tagged fish. Contact Ian Knuckey (03) 5258 0111 or Ken Smith 019 430 587.

Appendix 2 Intellectual Property

No intellectual property has been gained as part of this study.

Appendix 3 Staff

The project formally commenced in November 1994 when Dr Murray MacDonald (VFRI Queenscliff) replaced Dr David Smith as Principle Investigator and scientist conducting the Victorian component of the project. Dr Jeremy Lyle (MRD Marine Research Laboratories, Taroona) remained as the co-ordinator of the Tasmanian component. A senior VFRI Technical Officer was appointed part-time on the Victorian component of the project since its commencement, and a second Technical Officer was appointed to the Tasmanian component of the project commencing early December 1994. Dr Murray MacDonald finished his involvement with the project in 1996 and he was replaced by Dr Ian Knuckey who conducted the modified trawl tagging and produced the final report.

Dr David Smith	Principal Investigator (MAFRI)
Dr Murray MacDonald	Principal Investigator (MAFRI)
Dr Jeremy Lyle	Co-Investigator (Tas DPIF)
Dr Ian Knuckey	Senior Scientist (MAFRI)
Mr Ken Smith	Field Technician (MAFRI)
Mr John Kitchener	Field Technician (Tas DPIF)

We wish to thank the skippers and crews of the Florence Nightingale, Maggie Rose, Desperado, Starfire and Erin Jay for their help with the field observations on the potential of commercial fishing methods to capture warehou for tagging. Special thanks to the owner - John Sealey, skipper - Ross Mills and "Sudsie" and "Pickles" of the Gail Jeanette for their expertise and patience during field tagging trials using modified commercial trawling. Otolith sectioning, mounting and fluorescent microscopy for the OTC trials was performed by Corey Green. Ken Smith, John Kitchener, Graeme Cottier and Damian Heran provided excellent support and organisation of the angler tagging trials. The project staff wish to thank the FRDC for funding the project and the SEF fishers for their support of this research.