FRDC FINAL REPORT

NATIONAL STRATEGY FOR THE SURVIVAL OF RELEASED LINE CAUGHT FISH: MAXIMISING POST-RELEASE SURVIVAL IN LINE CAUGHT FLATHEAD TAKEN IN SHELTERED COASTAL WATERS

J.M. Lyle, I.W. Brown, N.A. Moltschaniwskyj, D. Mayer, and W. Sawynok

November 2006

FRDC Project No. 2004/071

Australian Government

Fisheries Research and Development Corporation

Queensland Government

Department of Primary Industries and Fisheries

Released Fish SURVIVAL

National Library of Australia Cataloguing-in-Publication Entry

Lyle, Jeremy Martin, 1955 -

National strategy for the survival of released line caught fish: maximising post-release survival in line caught flathead taken in sheltered coastal waters

Bibliography.
Includes index.
ISBN 1 86295 369 4.

1. Fishery management - Australia. 2. Fish populations - Australia. 3. Platycephalidae - Effect of stress on - Australia. 4. Platycephalidae - Mortality - Australia. I. Lyle, J. M. II. Tasmanian Aquaculture and Fisheries Institute.

639.2750994

Published by the Marine Research Laboratories – Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Private Bag 49, Hobart, Tasmania 7001.

E-mail: Jeremy.Lyle@utas.edu.au Ph. (03) 6227 7277 Fax: (03) 6227 8035

The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a statutory authority within the portfolio of the federal Minister for Agriculture, Fisheries and Forestry, jointly funded by the Australian Government and the fishing industry.

FINAL REPORT

NATIONAL STRATEGY FOR THE SURVIVAL OF RELEASED LINE CAUGHT FISH: MAXIMISING POST-RELEASE SURVIVAL IN LINE CAUGHT FLATHEAD TAKEN IN SHELTERED COASTAL WATERS

J.M. Lyle, I.W. Brown, N.A. Moltschaniwskyj, D. Mayer, and W. Sawynok,

November 2006

FRDC Project No. 2004/071

Tasmanian Aquaculture and Fisheries Institute and Queensland Department of Primary Industries and Fisheries

TABLE OF CONTENTS

2004/071 National strategy for the survival of released line caught fish: maximising post-release survival in line caught flathead taken in sheltered coastal waters

PRINCIPAL INVESTIGATOR: Dr J.M. Lyle
ADDRESS: University of Tasmania
Tasmanian Aquaculture and Fisheries Institute
Private Bag 49
Hobart TAS 7001
Telephone: 03 6227 7277 Fax: 03 6227 8035

OBJECTIVES:

1. Estimate post-release survival (PRS) rates for key flathead species associated with current hook and line fishing practices.
2. Evaluate the suitability of circle and non-traditional hooks in terms of enhancing PRS and minimising hooking damage.
3. Based on objectives 1 and 2 develop protocols that can be readily applied to maximize PRS in flathead.

NON TECHNICAL SUMMARY:

Flathead represent the largest catch of any fish group taken by recreational fishers in Australia and, after bream, account for the greatest numbers of fish released by recreational fishers (National Recreational Fishing Survey). Flathead are taken around Australia, with catches concentrated in the eastern states, including Tasmania. Sand flathead (*Platycephalus bassensis*) is the dominant species taken in estuarine and sheltered inshore waters of Tasmania and Victoria whereas dusky flathead (*P. fuscus*) is the main species taken from NSW and southern Queensland. Legal minimum size and bag limits apply for flathead, though there is little consistency between jurisdictions.

A review of post-release survival (PRS) in line caught fish (McLeay *et al*. 2002) identified flathead as a priority group, with research to focus on the effects of handling and hook damage on survival. The present study represents a component of the National Strategy for the Survival of Released Line Caught Fish.

The principal objectives of this study were to estimate the short-term post-release survival rates for sand and dusky flathead, and to determine whether there was any survival benefit in the use of circle hooks rather than conventional hook patterns. Recognising the increasing uptake of lures (especially soft plastics) for flathead, the potential impact of their use on post-release survival was also assessed. Using the results of this research we have been able to develop protocols that can be readily applied by recreational fishers to maximise the survival of flathead.

The study involved experiments in which flathead (sand flathead in Tasmania and dusky flathead in southern Queensland) were captured by angling and then held in aquaria for several days to assess short-term survival. In addition, catch rates and hooking locations for a range of hook types were compared. Volunteer anglers also provided hooking information for flathead captured using bait and lure fishing methods.

Anatomical hooking location was determined to be the major factor contributing to mortality in flathead. Fish hooked in the throat or gut (deep-hooked) suffered greater mortality than those hooked in the lip or mouth (shallow-hooked). The short-term survival rate for shallow-hooked fish was almost 100% for sand flathead and 96% for dusky flathead, whereas survival rates for deep-hooked fish were significantly lower, around 64% for sand flathead and 73% for dusky flathead.

Mortality in deep-hooked fish was generally associated with injuries to vital organs (gills, heart, liver) and survival was lower if bleeding was associated with the hooking injury. For sand flathead the odds of survival for deep-hooked fish were eight times greater for non-bleeders. Data for dusky flathead were limited but also exhibited a trend towards lower survival rates in bleeders.

Cutting line rather than removing the hook can increase survivorship in deep-hooked fish. Although survival rates for deep-hooked sand flathead were higher for hook left in (81%) than for hook removed (60%), differences were not significant, reflecting the small sample sizes involved. Very limited data were available for dusky flathead so the impact of cutting the line on survival could not be assessed reliably. We did observe evidence that some survivors (both species) expelled hooks within a short time after capture. Despite the absence of definitive evidence of the benefits of cutting the line in gut-hooked flathead we conclude that the practice should be promoted.

Besides hooking location, the only other factor significantly implicated in the survival of dusky flathead was ‘surface interval’ – the time period between capture and placement of the fish in the experimental tanks. During this period the fish were kept on board the catching boats in small holding tanks that varied in capacity, structure and water flow characteristics. As holding times were much greater than would be expected under a typical catch-and-release scenario this factor was seen as an experimental artefact.

Circle hooks have been promoted widely as ‘fish friendly’ on the expectation that post-release survival rates are higher than for other conventional hook types, due largely to the high frequency of jaw hooking and low incidence of deep hooking. We found significantly lower deep hooking rates for circle hooks (1-4%, depending on species) compared with other conventional hook types (up to 16%). In order to gain acceptance from anglers, however, it is important that circle hooks are at least as effective as conventional hook types. Over two fishing trials we established that circle hooks were at least as effective as conventional hook types for sand flathead. By contrast for dusky flathead, high variability in a small data set obscured any real effect of hook type on catch rate, although results did suggest that the performance of lures probably exceeded that of circle hooks and conventional J-hooks. Further trials with circle hooks would be required to more fully evaluate their relative efficiency for dusky flathead. In practice, the shift from bait to lure fishing for dusky flathead (and to a lesser degree sand flathead) would suggest that the uptake of circle hooks may be low amongst anglers, especially in Queensland and NSW.

Volunteer angler hooking information was available for flathead taken in Tasmania (sand flathead, bait and lure fishing), Victoria (sand flathead – bait fishing, dusky flathead – bait and lure fishing), NSW (dusky flathead – bait and lure fishing) and Queensland (dusky flathead – bait and lure fishing). Fishing with lures resulted in significantly lower deep hooking rates than for bait. Size was also identified as an important factor in deep hooking rates, being lowest in the smallest (effectively sub-legal) size groups.

For both flathead species, regression models revealed significant state effects, either as a main or interaction effect, implying that factors other than method and fish size influenced deep hooking. High deep hooking rates for sand flathead in Victoria (25%) appear to have been related to fishing practice, specifically the use of small hooks to target species other than flathead. Reasons for high deep hooking rates (35%) for bait caught dusky flathead in Queensland were less obvious.

By integrating experimentally determined survival rates with hooking information derived from anglers, the potential impact of catch and release on survival was estimated. Survival rates ranged between 94-99% for most method/state combinations for the two flathead species. Notable exceptions were bait-capture of sand flathead in Victoria and dusky flathead in Queensland. The lower survival rate (91%) associated with the Victorian sample highlights the impact of non-targeted fishing, especially when small hooks are employed. The low survival rate (88%) estimated for bait-caught dusky flathead in Queensland was not considered representative. Consistency between Victorian and NSW survival rate estimates for bait-caught dusky flathead, and those based on the Queensland survival experiment (all about 94%) support this conclusion.

Overall our results indicate that sand and dusky flathead are robust species and that for released fish survival rates are high, supporting the efficacy of current management strategies based on size and bag limits and the practice of catch-and-release fishing. The switch from bait to lures or adoption of circle hooks for flathead are likely to provide benefits for stocks, enhancing the survival of released fish.

Recommendations to maximise survival of released flathead

In developing protocols that can be readily applied to maximize survival in flathead (Objective 3) we developed the “Flathead Survival” information sheet that builds on the results of this project and the “Recfish Code of Practice on Releasing Fish”. The key messages for flathead are:

Survival

- Flathead hooked in the jaw have a very good chance of survival if released.
- Survival is lower if fish are hooked in the gills or gut and particularly if deep hooking is associated with bleeding.
- For gut-hooked fish, cutting the line and not removing the hook improves the likelihood of survival.

Tackle

- For bait fishing use hook patterns such as circle hooks to maximise the likelihood that fish are hooked in the jaw.
- For conventional hook types, keep line tight to make it less likely that fish will swallow the hook.

The information sheet has been widely distributed and has attracted very positive feedback from anglers.

OUTCOMES ACHIEVED

Key factors influencing post-release survival in sand and dusky flathead have been identified, with hooking location and specifically the incidence of deep hooking (throat or gut) emerging as the most important factor.

Overall, survival rates for sand and dusky flathead have been determined to be high, supporting the efficacy of current management strategies based on size and bag limits and the practice of catch-and-release fishing.

An information pamphlet highlighting protocols that can improve survival potential for flathead has been developed and is being distributed widely to anglers through a range of networks, including Fishcare Volunteer Programs and the National Strategy for Released Fish Survival extension program.

KEYWORDS: Sand flathead, dusky flathead, post-release survival, hooking damage, circle hooks, recreational fishing practices.

ACKNOWLEDGEMENTS

The efforts of Alastair Morton (TAFI) and Mark McLennan (DPI&F) and other TAFI and DPI&F (Queensland) staff who assisted in the fishing trials are gratefully acknowledged. The project team is also indebted to all the anglers who willingly participated in the fishing trials and/or provided information about their flathead fishing activities. Particular thanks are extended to Stan Konstantaras (ANSA) for coordinating the NSW angler diary and to Simon Conron (PIRVic) for providing Victorian research angler diary data.

The support of Sea World Theme Park (Gold Coast) in providing access to aquaria and infrastructure was crucial to the overall success of the project.

We are also grateful to DPI&F staff for amending the Queensland DPI&F General Fisheries Permit PRM0260D to enable us to conduct the experiment using recreational anglers, and to Brett Davidson, skipper of the RV *Tom Marshall*, for his support.

This work was carried out in accordance with Animal Ethics approval (University of Tasmania A0007982; Department of Primary Industries and Fisheries, Bribie 55/05/05).

BACKGROUND

The National Survey of Recreational Fishing (National Survey) estimated that about 13.5 million flathead (various species) were caught by recreational fishers in Australia during 2000/01 and that of this total, almost 45% (6.0 million fish) were released or discarded (Henry and Lyle 2003). The retained component of the harvest was estimated to be equivalent to about 2,300 tonnes.

Numerically, flathead represented the largest catch of any fish group taken by recreational fishers and, after bream, accounted for the greatest numbers of fish released by recreational fishers (Henry and Lyle 2003). Flathead are taken around Australia, with catches concentrated off Victoria, NSW, Tasmania and Queensland. In all but the latter, flathead were the most common, by number, recreationally caught finfish in each state. Nationally, line fishing methods accounted for over 99% of the catch with over half (57%) taken in estuarine waters and the bulk of the remainder (40%) from coastal (< 5km offshore) waters. Flathead also have significance to commercial fisheries, though catches are largely taken by demersal trawl or mesh net; trawl fisheries operate primarily in offshore waters and mesh nets inside estuaries (Kailola *et al*., 1993).

A number of flathead species are taken by recreational fishers and although species was not routinely specified in the National Survey (reflecting limitations in the ability of recreational fishers to correctly identify their catch to the species rather than group level), other studies indicate that sand flathead (*Platycephalus bassensis*) is the dominant species taken in estuarine and sheltered inshore waters of Tasmania and Victoria (Coutin *et al*. 1995, Lyle and Campbell 1999, Lyle *et al*. 2002) whereas dusky flathead (*P. fuscus*) is the main species taken from NSW and southern Queensland (Kailola *et al*. 1993, Williams 2002; Broadhurst *et al*. 2005; Steffe *et al*. 2005). Tiger flathead (*Neoplatycephalus richardsoni*) and blue spotted flathead (*P. caeruleopunctatus*) are of secondary importance but tend to be more prevalent in near shore and open waters (Steffe *et al*. 1996, Lyle and Campbell 1999, Lyle *et al*. 2002).

At the state level, the proportion of the flathead catch that was released ranged from 36% (Tasmania) to 51% (Queensland), with intermediate release rates for NSW and Victoria (44 and 48%, respectively). The fate of those fish that are released/discarded is currently unknown but may represent a significant source of unaccounted and possibly avoidable mortality.

Legal minimum size and bag limits apply for flathead in each of the eastern States, though there is little consistency between jurisdictions. For example, the minimum size limits for sand flathead are 25 cm in Victoria and 30 cm in Tasmania, with bag limits of 30 fish for both States[1]. Minimum size limits for dusky flathead range from 25 cm in Victoria, to 36 cm in NSW and 40 cm in Queensland. In addition, a maximum size limit of 70 cm applies in Queensland. Bag limits for dusky flathead are more restrictive than for sand flathead, with limits of five in Victoria (only one fish being larger than 70

[1] Note in Tasmania the bag limit is also the possession limit.

cm) and Queensland, and 10 (only one fish being larger than 70 cm) for NSW. In this regard, the regulated release of flathead is not just restricted to undersized or small fish.

The FRDC funded a review of information relating to post-release survival (PRS) in line caught fish (McLeay *et al*. 2002) as part of the National Strategy for the Survival of Released Line Caught Fish. The review identified that a number of factors affect survival, they include fisher and non-fisher influenced factors. This review also established that there have been very few previous studies on PRS in Australia and recommended that research should be based on ecologically-linked species. In respect to temperate sheltered coastal ecosystems, priority species were identified as bream, snapper and flathead. Aspects of PRS are being addressed in the former two species by research being undertaken by PIRVic (FRDC Project 2003/074) and NSW DPI (e.g. Broadhurst *et al*. 2005).

NEED

Recreational fishers release fish for a variety of reasons, including adherence to size and bag limits, closed seasons and/or for ethical reasons (including catch and release fishing). Many factors can influence the subsequent survival of a released fish, including fisher influenced (level of exertion during capture, damage due to hooking, handling practices) and non-fisher influenced (fish condition, environmental conditions) factors.

Recognising the national significance of flathead to the recreational fishery, being the largest catch of any fish group taken by recreational fishers, and the level of released catch, in terms of numbers second only to bream, there is a clear need to evaluate factors that might influence post-release survival (PRS) and examine practical options, for example hook type and handling practices, that will maximize PRS. Several species of flathead are taken by recreational fishers with sand flathead dominating catches in Victoria and Tasmania and dusky flathead the main species in NSW and Queensland. This study examines factors affecting PRS in these key flathead species.

The need for an assessment of PRS in flathead has been identified as a high priority in the FRDC National Strategy for the Survival of Released Line Caught Fish and the present study addresses The National R&D Plan for the Recreational Sector strategy relating to understanding the effects of fishing activities on fish and their ecosystems.

OBJECTIVES

1. Estimate post-release survival (PRS) rates for key flathead species associated with current hook and line fishing practices.
2. Evaluate the suitability of circle and non-traditional hooks in terms of enhancing PRS and minimising hooking damage.
3. Based on objectives 1 and 2 develop protocols that can be readily applied to maximize PRS in flathead.

CHAPTER 1: EFFECTS OF HOOKING DAMAGE AND POTENTIAL IMPACT OF HOOK TYPE ON POST-RELEASE SURVIVAL OF SAND FLATHEAD (*PLATYCEPHALUS BASSENSIS*)

Jeremy Lyle, Natalie Moltschaniwskyj, David Mayer and Alastair Morton

1.1 Introduction

Sand flathead (*Platycephalus bassensis*) are distributed from central NSW to eastern South Australia, including Tasmania, inhabiting shallow coastal waters and bays over soft substrates (Gomon *et al*. 1994). The species is a demersal ambush predator that is commonly captured by recreational line fishers, especially in Tasmania and Victoria. The National Recreational Fishing Survey (National Survey) established that flathead were the most commonly harvested finfish group in both states, with 3.32 million flathead taken in Victoria and 1.38 million in Tasmania (Henry and Lyle 2003). Although the species of flathead was not specified in Victorian catches, sand flathead are known to represent a major component of the recreational catch (Coutin *et al*. 1995). For Tasmania about 94% of the flathead harvest was identified as sand flathead, with tiger flathead (*Neoplatycephalus richardsoni*) accounting for most of the remainder (Lyle 2005). The dominance of sand flathead in Tasmanian catches has also been confirmed from creel surveys (Lyle and Campbell 1999; Lyle *et al*. 2002).

In addition to the retained catch, the National Survey provided estimates of a further 2.66 (45% of total catch) and 0.76 (36% of total catch) million flathead being released/discarded by anglers in Victoria and Tasmania, respectively. While the reasons for release were not canvassed, minimum size and bag limits apply in both jurisdictions. The minimum legal size limit for flathead in Victoria is 25 cm total length (TL) and compares with 30 cm TL in Tasmania. A bag limit of 30 fish applies in both states[2]. Significantly, creel surveys conducted in Tasmania found that 30-40% of the retained sand flathead were below the minimum legal length (Lyle and Campbell 1999; Lyle *et al*. 2002), indicating that strict observance of the size limit would result in a substantial increase in the proportion of the catch that is released.

Whether fish are released as a result of adherence to regulations or due to the practice of catch-and-release fishing, it is assumed that the majority will survive. The survival of released fish depends on a number of factors including the nature of the hooking injury, fishing and handing practices and environmental conditions (see reviews by Muoneke and Childress 1994; McLeay *et al.* 2002; Bartholomew and Bohnsack 2005). Anatomical hooking location has been identified in many studies as the most important factor influencing survival, with throat, oesophagus, stomach, and in some instances eyes, representing critical locations. Terminal tackle (bait or lure), hook type and size,

[2] In Tasmania the bag limit is administered as a possession limit.

fishing practices (active or passive fishing) and fish size have been shown to influence the probability of deep hooking (i.e. throat, oesophagus or stomach), and in turn influencing the risk of damage to vital organs (e.g. gills, heart, liver) and survival rates. As well as hook induced injuries, factors such as water temperature, playing and handling times, and depth of capture influence the level of physiological stress experienced by fish, further affecting the potential for survival. Barotrauma or pressure-related injuries are not, however, likely to be important contributors to post-release mortality in sand flathead since the species is normally captured in relatively shallow coastal waters (< 10 m) and does not possess a swim bladder (Gomon *et al.* 1994).

An understanding of post-release survival (PRS) is required in order to evaluate the impact on fish populations of regulations that require fish to be released (size and bag limits, closed seasons) and also to fully account for fishery-induced mortality in stock assessments. In addition such information can help promote awareness amongst anglers of their impacts on fish stocks, as well as highlighting improvements in fishing practices. To date there have been relatively few PRS studies in Australia but a review by McLeay *et al.* (2002) and the establishment of the National Strategy for the Survival of Released Line Caught Fish have focused attention on this issue.

In this study we examine the relationships between hooking injury and PRS, and hook type and hooking injury in sand flathead. Circle hooks have been promoted widely in the recreational angling media and by some management agencies (particularly in the US and Canada) as a conservation measure to reduce mortality rates in released fish. Circle hooks tend to result in lower rates of deep hooking compared with other more conventional hook types (reviewed by Cooke and Suski 2004). However, even if survival benefits can be demonstrated, anglers need to be convinced that circle hooks at least match the performance of conventional hooks in terms of catch rates if they are to be adopted. Recognising this important point, we compared catch rates for circle hooks with more conventional hook types.

1.2 Methods

This study involved three related components; post-release survival experiments in which the relationships between hooking damage and short-term survival were examined; structured fishing trials in which the effect of hook type on catch rates and hooking damage were assessed; and a diary survey involving volunteer anglers in which the effects of hook type and hooking damage were evaluated.

1.2.1 Post-release survival experiments

The primary objective of the post-release survival experiments was to determine the relationship between hooking location and survival in sand flathead. Three separate experiments were conducted, two during summer (January and February 2005) and one in winter (June 2005). Fish handling protocols were applied consistently for each experiment and survival was assessed over a four-day post capture holding period.

Sand flathead were captured by hook types commonly used by recreational anglers in Tasmania (J-style and octopus hooks, sizes 1/0 to 2/0), baited with fish or squid flesh. For each experiment boat-based fishing was undertaken over two consecutive days in the Derwent Estuary (42°57'S, 147°21'E). Once hooked, fish were reeled in quickly (mean play time of 10 ± 6 s [s.d.]), unhooked or line cut and length measured to the nearest centimetre rounded down. A system of dorsal spine clips was used to identify the location of hook penetration and whether bleeding was observed from the wound site. Hooking sites were classified as lip, mouth, eye (where the hook had penetrated the eye socket or the eye itself from inside the mouth), throat or gut. Externally hooked fish were classified as foul hooked. As targets for each hooking site/size group (sub-legal or legal) combination were established at the commencement of each experiment not all hooked fish were retained. All flathead that were hooked in the eye, throat and gut regions were retained.

Fish were held on board in plastic tubs with approximately 40 l of aerated seawater that was refreshed periodically. Up to eight fish were held in each tub with a maximum holding period of about one hour before transfer to shore and a larger tank containing approximately 250 l of aerated seawater. Fish were immediately transported to the aquarium facility at the Marine Research Laboratories and transferred to one of four 4000 l tanks, each filled with approximately 1500 l of seawater. This process generally took less than 15 minutes to complete. A flow-through sea water system was maintained with supplementary aeration, providing ambient conditions of salinity and temperature. The maximum stocking density was 43 fish per tank (with an overall mean of 35 fish per tank). Water temperature was monitored continuously during the holding period using a temperature logger.

Within about six hours of initial capture the tanks were inspected and any dead fish removed. Tanks were inspected twice daily thereafter (morning and afternoon) during the holding period and dead fish removed. Fish were not fed during the holding period. Each mortality was measured to the nearest millimetre, hook location (based on spine clips) noted and autopsied to determine the extent and location of any obvious hook damage. At the end of the holding period, all surviving fish were anaesthetised using clove oil (1 ml per 30 l), measured to the nearest millimetre, inspected for hook damage and either revived and released or euthanased with an overdose of clove oil. Just under half (46%) of all survivors recorded as throat or gut hooked were euthanased and autopsied. For the purpose of analysing fish size effects, final length measurements were used as these were considered more accurate than those obtained when the fish were captured.

After examination at the completion of the second experiment (February 2005), all surviving flathead were revived and held for a further 25 days, representing a minimum post capture holding period of 29 days. During this time fish were fed on commercially available salmon pellets and inspected daily. At the end of this period the fish were anaesthetised, measured and again examined for evidence of hooking damage.

In an attempt to provide experimental controls, sand flathead were collected using beach seine (haul) nets fished in shallow water (<2m) over sand/seagrass substrate. Fish were removed from the net whilst still in the water and handled in a manner similar to the hook caught fish, being transferred into holding tanks along with experimental fish. Seine net fishing was conducted at night.

1.2.2 Fishing trials

Two fishing trials were conducted in North West Bay south of Hobart (43°04'S, 147°16'E) to compare catch rates and hook damage for a range of hook types, including circle, J-style, octopus and wide gap. Both trials were conducted during summer (January and December 2005), with three hook types compared in each trial. Experienced volunteer anglers and fisheries research staff were provided with a standard paternoster rig and fished for specified periods with a single hook baited with squid. Anglers using circle hooks were instructed not to strike at the bite but rather increase the pressure on the line steadily until the hook had either set or the fish escaped.

A total of 20 anglers participated in the first trial; three per boat for all but one vessel that had two anglers. Within each boat, anglers were allocated one of three hook types - circle, J-style or wide gap - and asked to fish for 2.5 hours, recording all fish caught, their length and hooking site (lip, mouth, eye, throat, gut or foul). Anglers were randomly allocated a hook type to use. The second trial involved 12 anglers, three per boat, with circle, J-style and octopus hooks compared. In this trial anglers were instructed to fish in three 45-minute sessions using each of the three hook types in succession in such a way that at any given time all three hook types were fishing. Allocation of the initial hook type to an angler was undertaken in the manner of the first fishing trial. For the second fishing session, the angler was randomly allocated one of the two remaining hook types and in the final session the unused hook type was fished.

Hooks compared included circle (Mustad Demon circle 39951 NPBLN 5/0), standard J (Mustad O'Shaughnessy 34007 2/0), wide gap (Gamakatsu Shiner 51411 1/0) and, in the second trial, octopus (Gamakatsu Octopus 02311 1/0) was used in place of the wide gap hook (Fig. 1.1). Octopus hooks had a 15° offset whereas the other hook types had no offset. Octopus hooks are a form of J hook that is commonly used by recreational anglers in Tasmania to target a range of finfish species.

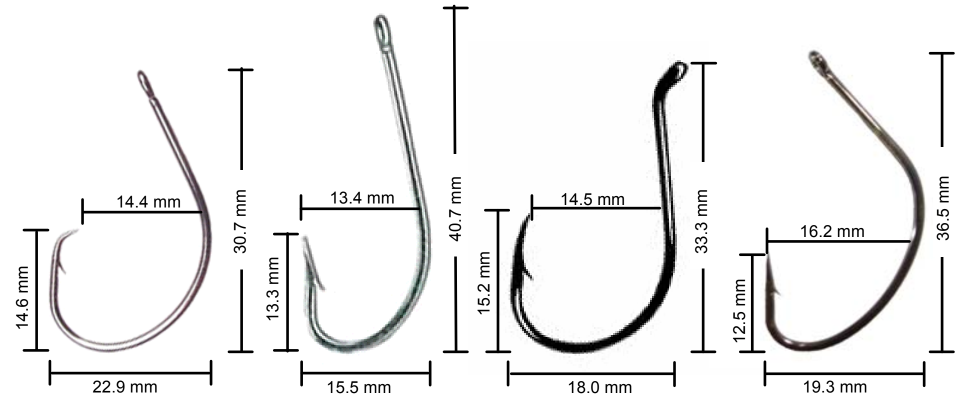


Fig. 1.1 Hook patterns used in the fishing trials with nominal dimensions. From left to right: circle, J, octopus and wide gap.

1.2.3 Fishing diary

Volunteer anglers, identified through angler networks and clubs, were invited to participate in the study. Anglers were issued a diary, measuring tape and hooks (circle, J and wide gap identical to those used in the fishing trials), and asked to report the following details for any flathead captured: fishing method (bait, lure or fly); hook type; hook size; fish length; and hooking site (lip, mouth, eye, throat, gut, foul). Hook size was determined by reference to a key indicating the width or gape of the hook (tip of the hook point to the shaft), as being small (< 15 mm), medium (15-19 mm) or large (> 19 mm). This approach was taken in preference to using manufacturers hook size categories, which are not standardised. In addition, trip details including date, location, fishing platform, number of anglers, total catch by species, and bait type were recorded.

Anglers were encouraged to use the hook types provided as well as terminal tackle they would normally use to target flathead. Where the entire catch was not recorded, diarists were instructed to select fish randomly, for example take the first ten fish caught only or every third capture. Diarists reported fishing activity between December 2004 and January 2006.

1.2.4 Data Analysis

For the purpose of data analysis, hooking location was categorised as 'shallow' (lip, mouth, eye or foul hooked) or 'deep' (throat or gut) following conventions used by other authors (e.g. Skomal *et al*. 2002, Millard *et al*. 2003, Conron *et al*. 2004, Jones 2005). In addition, fish were classified as sub-legal or legal sized, based on the minimum legal size limit of 30 cm TL for sand flathead in Tasmania.

Post-release survival

A binomial generalised linear model (GLM) with logit link (McCullagh and Nelder 1989) was used to examine effects of treatment (deep-hooked, shallow-hooked or seine-caught), experiment number, and size group (sub-legal or legal) on survival (GenStat

2005). Treatment was fitted first, and then step forward selection of main effects was employed. Interaction terms were also tested but removed if non-significant, the exception being two-way interactions that involved significant main effects. Pair-wise significance testing using Student's *t*-test was undertaken to compare probabilities (adjusted means) of survival for the significant factors. As an alternative analysis, length was also modelled as a continuous variable to examine whether there was an underlying size relationship that was masked by the legal/sub-legal size grouping.

Similarly, the influence of bleeding and hook removal on survival was evaluated for deep-hooked fish using GLM analysis, with fish size and experiment as additional fitted terms. The decision to restrict this analysis to deep-hooked fish was based on the low incidence of bleeding in shallow-hooked fish (7%) compared with deep-hooked fish (71%) and the fact that there were no mortalities amongst shallow-hooked in which bleeding was observed. Furthermore, the decision to cut the fishing line, leaving the hook in place, was only applied to deep-hooked fish.

Odds ratios were also examined to interpret the lack of independence among selected factors (Quinn and Keough, 2002).

Hook type and catch rates

The effect of hook type on catch rate was examined using analysis of variance, with fishing trials treated separately. The combined catch of sand flathead taken by a given hook type and vessel were treated as replicates when calculating and comparing catch rates.

Hook type and deep hooking

Hooking location (deep or shallow) was treated as the response variate, with the fitted model terms being data source (fishing trial or diary), hook type (circle, J, wide gap or octopus), and fish size (legal or sub-legal, or actual length). Data for the two fishing trials were combined and only bait fishing information from the fishing diary was used in this analysis. A binomial GLM with logit link was used to test the significance of the various factors, with hook type fitted first and step forward selection of the main effects (GenStat 2005). Interactions between factors were also tested, with those involving significant main effects or testing significant incorporated in the final model. Pair-wise significance testing using Student's *t*-test was undertaken when comparing the probability (adjusted mean) of deep hooking for significant factors.

1.3 Results

1.3.1 Post-release survival experiments

General observations

In total 369 hook-caught and 46 seine-caught sand flathead were held in aquaria to examine post capture survival (Table 1.1). Overall 28 hook caught flathead died within the four-day holding period, 21 (75%) within the first 4-6 hours, a further six within 24 hours of capture (i.e. 96% within 24 hours). The remaining mortality occurred during the fourth day. With the exception of a single mouth hooked fish, all mortalities occurred amongst fish that had been hooked in the throat or gut regions. Most of the mortalities were associated with obvious puncture wounds to the gills, pericardium or internal organs, including liver. There were six mortalities amongst the seine sample, all of which occurred within 24 hours of capture (Table 1.1).

Table 1.1 Numbers of sand flathead by size group and treatment, fish lengths and water temperature by experiment.

Values in parentheses represent the number of mortalities within the 4-day holding period

	Experiment 1 Jan 2005		Experiment 2 Feb 2005		Experiment 3 Jun 2005	
Treatment	Sub-legal	Legal	Sub-legal	Legal	Sub-legal	Legal
Lip	20	17	8	12	12	26
Mouth	28 (1)	11	20	35	22	32
Eye	7	3	24	4	3	3
Foul	0	0	2	2	0	1
Shallow-hooked	55 (1)	31 (0)	54 (0)	53 (0)	37 (0)	62 (0)
Throat	13 (6)	8 (4)	9 (5)	15 (4)	10 (3)	10 (1)
Gut	1	3 (2)	0	6 (1)	0	2 (1)
Deep-hooked	14 (6)	11 (6)	9 (5)	21 (5)	10 (3)	12 (2)
Total	69 (7)	42 (6)	63 (5)	74 (5)	47 (3)	74 (2)
Mean length (cm)	26.5	32.2	26.1	32.3	27.3	33.2
Range (cm)	17.8 –29.7	30.0 – 38.6	**17.5 – 29.8**	30.0 – 38.0	17.4 – 29.8	30.0 – 41.7
Seine net	18 (1)	3 (1)	18 (4)	7	-	-
Mean length (cm)	25.4	31.4	23.8	32.4		
Range (cm)	17.8 – 29.3	30.7 – 32.3	17.5 – 29.5	30.1 – 35.6		
Water temperature						
Mean (^{o}C)	16.7		16.8		11.4	
Range (^{o}C)	15.0 - 18.0		14.5 - 19.4		10.5 - 11.9	

External evidence of hook related damage was apparent at the completion of the holding period in some survivors. For instance, 14 (32%) of 44 fish hooked in the eye region manifested injuries that included haemorrhaging and/or swelling of the eye, 12 (13%) of 95 lip hooked fish had obvious lip damage that included extensive tearing of the buccal membrane and dislodgement of the maxilla (e.g. Fig. 1.2), and 19 (13%) of 147 mouth hooked fish had obvious puncture wounds in the snout region, some clearly ulcerated. In addition, eye injuries were evident in one mouth hooked and one throat hooked flathead.

Fig. 1.2 Torn maxilla of a hook caught sand flathead, 29 days post capture (Experiment 2).

There were no further mortalities within the extended holding period (additional 25 days) at the completion of Experiment 2. At the end of this period all fish were re-examined and most exhibited no obvious hook injuries or showed evidence of wound healing. Eye injuries (haemorrhaging and/or swelling) were still evident in a small number of fish (seven of 28 eye hooked and two non-eye hooked) (e.g. Fig. 1.3).

Fig. 1.3 Sand flathead exhibiting swelling of the left eye, 29 days post capture (Experiment 2).

Although not a primary objective of this study, it was possible to make some observations about the practice of not removing hooks in deep-hooked fish. Across the three experiments the line was cut and hooks left embedded in 12 deep-hooked flathead. Two of these fish died with hooks still intact (in one the point of the hook had passed through the upper oesophageal wall, back into the mouth and penetrated the gills while in the second the stomach wall had been punctured). Of the remaining ten fish that survived, five still had hooks embedded at the end of the experimental period, in four the points had penetrated the oesophageal wall (e.g. Fig. 1.4) while in the fifth the hook had penetrated the stomach wall. In one individual within the former group, the hook had been rotated and the shank of the hook was in the stomach. There were three instances where hooks had been expelled while in another the hook was free (unattached) within the stomach. The status of one other survivor was uncertain since it was not autopsied at the completion of the experiment.

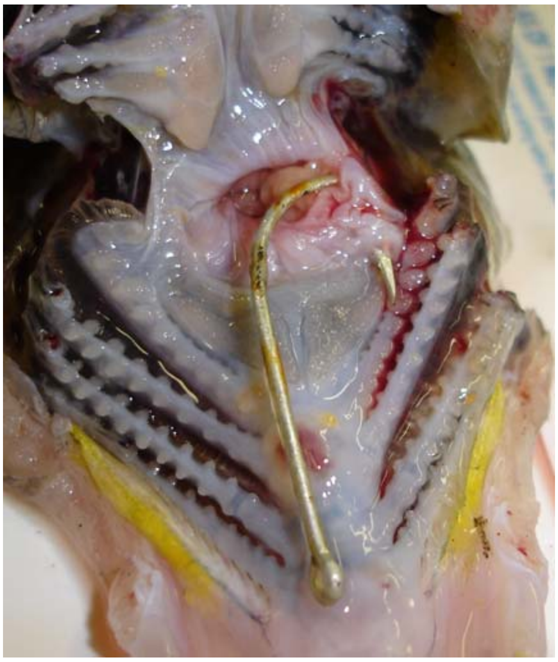


Fig. 1.4 Sand flathead survivor with hook embedded in the upper region of the oesophagus, 29 days post-capture (Experiment 2). Note the limited evidence of hook corrosion.

Effects of treatment on survival

Survival rates based on raw scores for each of the shallow-hooked locations, i.e. lip, mouth, eye and foul hooked, were effectively 100% whereas throat and gut hooked survival rates were 56-73% and 64-100%[3], respectively depending on size group (Fig. 1.5). *Post mortem* examination of the 23 dead fish classified as throat hooked revealed that four (17%) had obvious puncture wounds to the oesophagus. Furthermore, amongst 16 throat hooked survivors that were euthanased at the end of the holding period, three (19%) also had puncture wounds in the oesophagus. These observations suggest some difficulty in distinguishing between throat and gut hooking, particularly where the hook was lodged in the upper oesophagus as opposed to well into the stomach (when much of the hook would not have been visible). Alternatively, initial hook penetration may have occurred in the gut with final hook lodgement in the throat area. Notwithstanding this potential confusion, for the purpose of analysis throat and gut categories were combined. Overall survival rates for deep-hooked fish were 58 and 70% for sub-legal and legal sized flathead, respectively (Fig. 1.6). Survival rates for seine caught flathead ranged between 86% for sub-legal and 90% for legal sized individuals.

[3] The 100% survival rate for gut hooked sub-legal flathead was based on a single specimen.

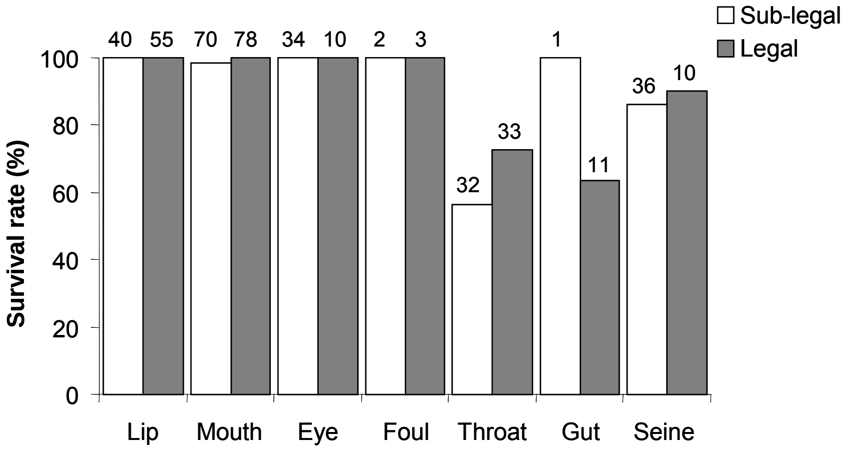


Fig. 1.5 Short-term survival rates for sand flathead based on hooking location or capture method and size group. Numbers represent sample sizes.

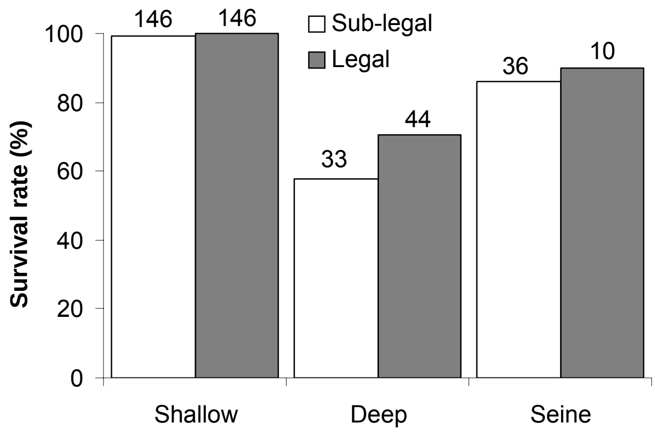


Fig. 1.6 Short-term survival rates for sand flathead based on treatment categories and size group. Numbers represent sample sizes.

The generalised linear model revealed that survival was highly dependent on treatment ($P < 0.001$), with size group, experiment and interaction terms non-significant factors (Table 1.2). Mean survival rates (± standard error) adjusted for all other terms in the model were 99.7 ± 0.3% for shallow-hooked fish, 64.0 ±5.5% for deep-hooked fish, and 89.9 ± 4.8% for seine caught fish. Significance testing established that adjusted means were significantly different ($P < 0.05$) for each pair-wise comparison. Odds ratios indicated that shallow-hooked flathead were 157 times (95%CI 20.9-1182.7) more likely to survive than deep-hooked flathead.

In the alternative analysis, with length as a continuous variable, treatment ($P < 0.001$) and length ($P = 0.004$) were significant factors. Survival rate increased with length in a non-linear fashion, the rate of change decelerating with size (Fig. 1.7). At lengths smaller than about 30 cm, however, the confidence interval was particularly wide and this presumably contributed to the observed lack of significance when length was categorised as sub-legal or legal.

Table 1.2 Accumulated analysis of deviance for GLM investigating factors that influence survival in sand flathead

Source	d.f.	Deviance	Mean deviance	**Approx.** P (χ^2)
Treatment	2	86.523	43.262	<.001
Size group	1	1.948	1.948	0.163
Experiment	2	3.030	1.515	0.220
Treatment×size group	2	0.831	0.416	0.660
Residual	407	142.933	0.351	
Total	414	235.266	0.568	

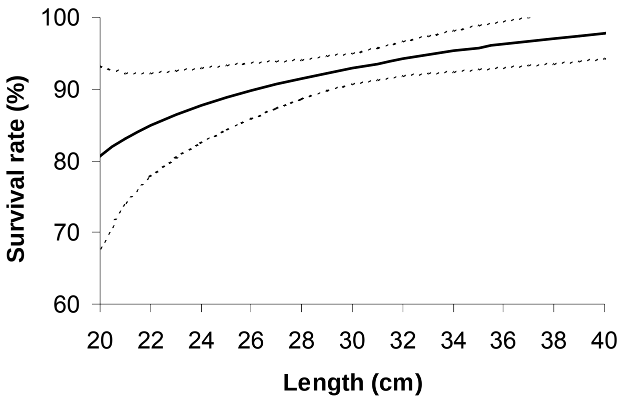


Fig. 1.7 Survival rate by length for sand flathead; solid line is adjusted mean, dotted lines represent upper and lower 95% confidence limits (truncated at 100%).

Effects of bleeding and hook removal on survival

Across the three experiments 77 flathead were deep-hooked, 55 (71%) of which had bleeding injuries and 12 (16%) had the line cut and hook not removed (Table 1.3). For deep-hooked fish, survival was dependent on whether or not the individual was bleeding ($P = 0.001$) (Table 1.4), with adjusted mean survival rates for non-bleeding fish of 84.8 ± 8.4% compared with 53.7 ± 6.9% for bleeding fish. The odds of survival for deep-hooked fish were 8.3 times (95%CI 1.8 – 39.2) greater for non-bleeders compared with fish that had obvious bleeding injuries.

Although the adjusted survival rate for individuals with the hook left in (81.5 ± 1.9%) was higher than that for those with hook removed (60.1 ± 8.4%), these differences were not significant ($P > 0.05$), in part reflecting the small sample size of the hook left in group. Of the other factors, size group and experiment were non-significant factors but there was a significant interaction between size group and bleeding ($P = 0.014$). While adjusted means for the sub-legal size group were similar for bleeders (67.2 ± 18.2%)

and non-bleeders (62.7 ± 8.3%), there was a significant difference for legal sized fish with mean survival rates of 99.9 ± 0.2% for non-bleeders compared with 50.8 ± 9.8% for bleeders. This result was, however, strongly influenced by the fact that there were no mortalities amongst the legal sized non-bleeders (*n* = 16) and the small sample size of sub-legal non-bleeders (*n* = 6) (Table 1.3).

Table 1.3 Numbers of deep-hooked sand flathead by bleeding and hook removal status, and size group.

Values in parentheses represent the number of mortalities.

	Hook removed		Hook left in	
Bleeding	Sub-legal	Legal	Sub-legal	Legal
Yes	26 (12)	21 (11)	1 (0)	7 (2)
No	5 (2)	13 (0)	1 (0)	3 (0)

Table 1.4 Accumulated analysis of deviance for GLM investigating factors that influence survival in deep-hooked sand flathead

Factor	d.f.	Deviance	Mean deviance	**Approx.** P (χ^2)
Bleeding	1	10.574	10.574	0.001
Size group	1	0.370	0.370	0.543
Hook left in	1	1.876	1.876	0.171
Size group×Bleeding	1	6.065	6.065	0.014
Bleeding×Hook removed	1	0.328	0.328	0.567
Size group×Hook removed	1	0.493	0.493	0.483
Experiment	2	1.168	0.584	0.558
Residual	68	78.896	1.160	
Total	76	99.769	1.313	

1.3.2 Hook types – catch rates and deep hooking

General

In the two fishing trials a total of 551 sand flathead were captured[4], about 55% of which were sub-legal (Table 1.5). Within the diary dataset, information was available from 22 diarists and was based on 128 fishing trips. Records for 1126 bait caught sand flathead included full details of hook type, fish size and hooking location, 46% of which were sub-legal (Table 1.5). There was some variability in the size of J and octopus hooks used by diarists, though in each case the majority of the flathead were taken with hook sizes consistent with those used in the fishing trials. Hook size was not treated as a factor in subsequent analyses.

4 In addition, six non-target species were captured.

Table 1.5 Numbers of sand flathead caught by hook type for fishing trials and bait fishing reported in the fishing diary.

Numbers in parentheses indicate the number of deep-hooked individuals.

	Trial 1		Trial 2		Diary	
Hook type	Sub-legal	Legal	Sub-legal	Legal	Sub-legal	Legal
Circle	75 (2)	79 (1)	31 (0)	24 (0)	67 (0)	84 (1)
J	66 (2)	48 (7)	41 (2)	14 (1)	225 (6)	277 (14)
Wide gap	50 (2)	54 (4)	-	-	152 (4)	162 (12)
Octopus	-	-	41 (3)	28 (3)	70 (6)	89 (8)
Total	191 (6)	181 (12)	113(5)	66 (4)	514 (16)	612 (35)

Hook type and catch rates

A key objective of the fishing trials was to compare the performance of circle hooks against conventional (J, octopus and wide gap) hook types. Since there were minor differences in sampling protocols (refer Methods) between trials, data have been considered separately. Mean catch rates (flathead per boat) in Trial 1 varied between 16.2 for J-style and 22.0 for circle hooks and in Trial 2 between and 13.8 for circle and J-style patterns and 17.3 for octopus hooks (Fig. 1.8). Relatively wide standard errors reflect the considerable between boat variability in catches and, in both trials, catch rates did not differ significantly based on hook type (Trial 1: $F_{2,17} = 0.41$, $P = 0.672$; Trial 2: $F_{2,9} = 0.12$, $P = 0.885$).

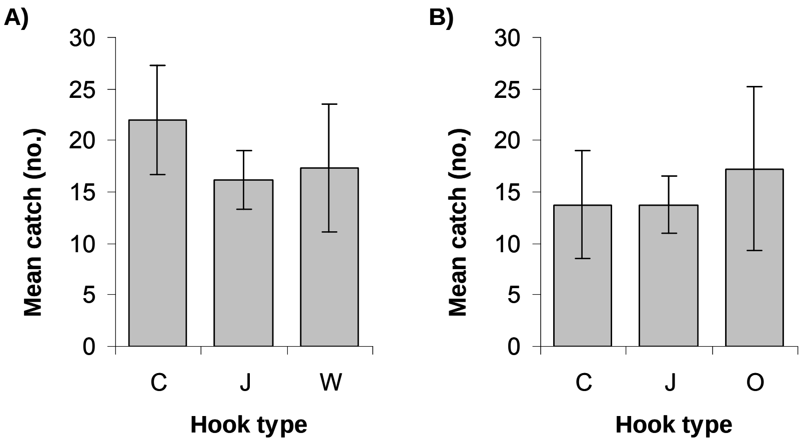
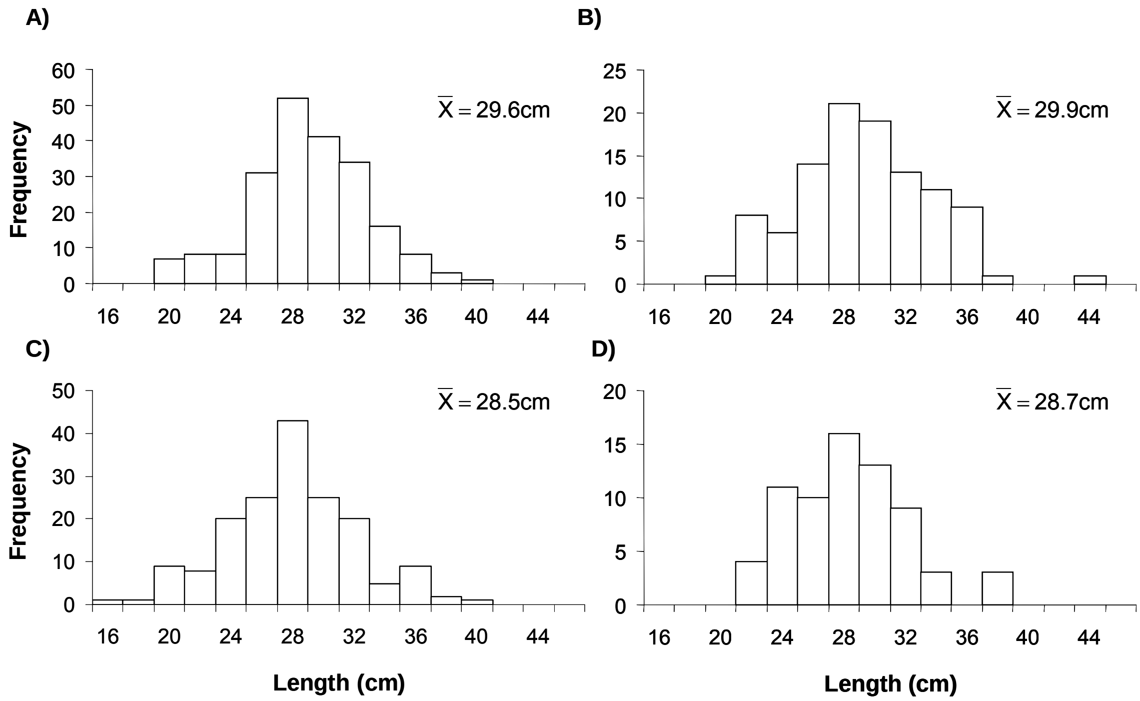


Fig. 1.8 Mean catch of flathead per boat by hook type for: A) Trial 1 (Jan 2005), and B) Trial 2 (Dec 2005). Error bars represent one standard error. Hook types: C Circle; J J-style; W Wide gap, and O Octopus.

Size compositions by hook type for the combined fishing trial dataset revealed unimodal distributions, with peaks in the 28.0-29.9 cm size class and mean lengths varying by just over 1 cm, between 28.5 cm (J-style) and 29.9 cm (wide gap) (Fig. 1.9). Kolmogorov-Smirnov tests failed to detect significant differences in length frequency distributions in each pair-wise comparison (Table 1.6).



Fig, 1.9 Sand flathead length frequency distributions (2-cm size classes) and mean lengths based on fishing trials. A) Circle, B) Wide gap; C) J-style, and D) Octopus hook.

Table 1.6 Paired comparisons of fishing trial length frequency distributions of sand flathead, based on Kolmogorov-Smirnov test

Comparison	*Z*-score	*P*
J v Circle	1.218	0.103
J v Wide gap	1.223	0.101
J v Octopus	0.663	0.772
Circle v Wide gap	0.646	0.798
Circle v Octopus	1.035	0.234
Wide gap v Octopus	1.076	0.197

Hook type and deep hooking

Deep hooking rates for bait-caught sand flathead by hook type, data source (fishing trial or diary) and size group (sub-legal or legal) are presented in Fig. 1.10. Overall, deep hooking rates based on raw data were relatively low, being lowest for circle hooks (<2%) and only exceeded 10% for J-style and octopus hooks (legal sized fish).

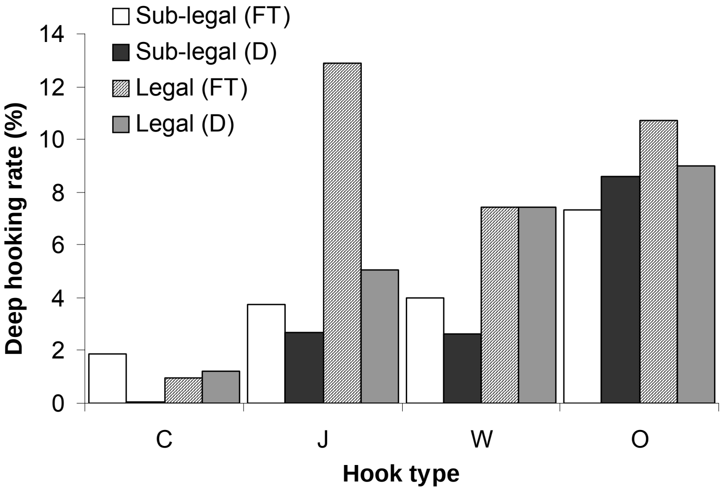


Fig. 1.10 Deep hooking rates by hook type, size group and data source for bait-caught sand flathead. Data source: FT fishing trial; D diary. Hook types: C Circle; J J-style; W Wide gap; O Octopus.

Hook type ($P < 0.001$) and size group ($P = 0.008$) significantly influenced the rate of deep hooking in sand flathead, data source was a non-significant factor (Table 1.7). The lack of significance in the hook type × size group interaction indicates that with respect to deep hooking these two factors acted independently. The adjusted mean deep hooking rate for circle hooks (1.0 ± 0.5%) was significantly lower than for any of other hook types tested. Deep hooking rates for the other hook types (J-style – 4.9 ± 0.9%; wide gap – 5.4 ± 1.1%; and octopus hook – 8.9 ± 1.9%) were not significantly different. The size effect indicated that there was a significantly greater probability of deep hooking in legal sized flathead (6.2 ± 0.8%) than sub-legal fish (3.3 ± 0.6%). In order to examine this relationship in more detail the model was re-run with length as a continuous variable, again hook type ($P < 0.001$) and length ($P = 0.004$) emerged as significant factors. The deep hooking rate increased non-linearly with size, from about 3% at 20 cm to 4.5% at 30 cm and to 9% at 40 cm (Fig. 1.11).

Table 1.7 Accumulated analysis of deviance for GLM investigating factors that influence deep hooking in sand flathead

Source	d.f.	deviance	Mean deviance	**Approx.** P (χ^2)
Hook type	3	21.824	7.275	<.001
Size group	1	6.939	6.939	0.008
Data source	1	2.712	2.712	0.100
Hook type×Size group	3	2.050	0.683	0.562
Residual	1681	598.640	0.356	
Total	1689	632.164	0.374	

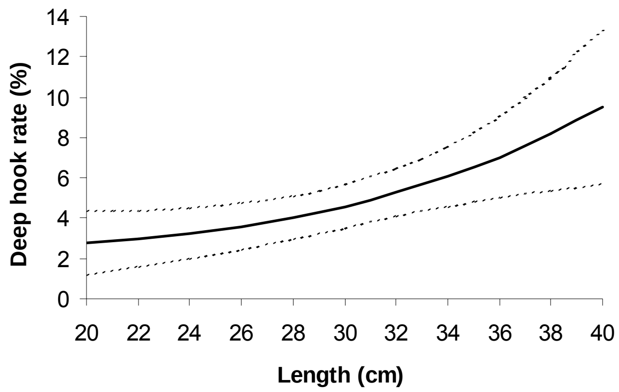


Fig. 1.11 Deep hooking rate by length for sand flathead; solid line is adjusted mean, dotted lines represent upper and lower 95% confidence limits.

1.4 Discussion

Anatomical hooking location, specifically deep hooking, has been identified as the most important factor influencing survival in hook caught fish across a range of studies (refer reviews by Muoneke and Childress 1994; McLeay *et al*. 2002; Bartholomew and Bohnsack 2005). In this study virtually all observed hook related mortalities were associated with deep hooking, the survival rate for shallow-hooked fish being 99.7% compared with 64% for deep-hooked fish. Mortalities were typically associated with obvious puncture wounds to the gills, pericardium or internal organs, including liver. These survival rates are comparable with those determined for dusky flathead (Chapter 2).

Most post-release survival studies have determined that hooking related mortality occurs very soon after capture, typically within 24 hours (Muoneke and Childress 1994, Schill 1996, Taylor *et al*. 2001, Bartholomew and Bohnsack 2005). Our findings were consistent with this observation, with 96% of sand flathead mortalities recorded within 24-hours (and most within 6 hours). Broadhurst *et al*. (2005) examined post-release mortality in the related dusky flathead and observed up to 10% mortality within 4 hours, possibly indicative of hooking induced mortality. However, their experiment was compromised by problems with confinement and delayed mortalities were also recorded 4 to 10 days after capture (they used floating sea-cages and most subsequent mortalities manifested non-hook related injuries, consistent with abrasions arising from contact with the sea-cage). In our second PRS experiment, sand flathead were held in aquaria for almost a month with no additional mortalities after the initial holding period. Delayed mortalities, at least within this timeframe, are unlikely to be a significant problem for sand flathead.

The relationship between fish size and survival appears to be species specific. Reviews of PRS research have identified that survival rates in some species tend to increase with size, in others rates decrease with size, while yet in others survival rates are unaffected by size (Muoneke and Childress 1994, Bartholomew and Bohnsack 2005). In sand flathead the relationship between size and survival was ambiguous. The GLM indicated no significant size effect when legal and sub-legal size groups were considered whereas there was a significant relationship between size and mortality based on actual length, with higher survival rates for the larger size classes. This apparent inconsistency appears to due to the increased uncertainty in model estimates, reflected in wide confidence limits, especially for sizes less than about 30 cm.

Bleeding is a significant factor affecting the survival of released fish (Wertheimer 1988, Bendock and Alexandersdottir 1993; Schisler and Bergersen 1996; Lindsay *et al*. 2004) and is usually associated with deep hooking (Skomal *et al*. 2002; Cooke *et al*. 2003a). Our findings are consistent with these observations, with 71% of deep-hooked fish manifesting bleeding injuries compared with just 7% for shallow-hooked fish. Vincent-Lang *et al*. (1993) observed that in coho salmon bleeders experienced lower survival rates regardless of hook location, and that survival rates for deep-hooked fish were 75% for non-bleeders compared with 43% for bleeders. Nelson (1998) established that the degree of bleeding influenced survival in striped bass, with 91% survivorship for non-bleeders or very slight bleeding, 67% for light bleeders and just 25% for heavy bleeders. Comparable results were found for sand flathead, with deep-hooked fish experiencing survival rates of about 85% for non-bleeders compared with 54% for bleeders. For flathead there was also an interaction between size and bleeding, with no significant bleeding effect on survival of sub-legal fish but a significant effect for legal sized fish. This result was, however, based on small sample sizes and in order to establish how robust the relationship is further research would be necessary.

Cutting line rather than removing the hook can increase survivorship in deep-hooked fish (e.g. Schisler and Bergersen 1996, Schill 1996, Taylor *et al*. 2001, Tsuboi *et al*. 2006), with some hooks eventually being shed and often within a relatively short period (Bugley and Shepherd 1991, Schisler and Bergersen 1996, Schill 1996, Diggles and Ernst 1997, St John and Syers 2005, Tsuboi *et al*. 2006). Schisler and Bergersen (1996) demonstrated that cutting the line significantly improved the survival rate for deep-hooked rainbow trout, from 45% for hook removed to 79% for line cut. Similarly, Schill (1996) observed an increase in survival rates for deep-hooked rainbow trout when line was cut, from 26 to 53%, with almost three quarters of line cut survivors having shed hooks within two months. Based on recaptures, Tsuboi *et al*. (2006) established very high survival rates (about 93%) for deep-hooked white-spotted charr that had the line cut. Furthermore, about one third of these fish had evacuated the hooks prior to recapture, with clear evidence of *in situ* corrosion and, in some, disintegration of the hooks. Although mean survival rates of deep-hooked sand flathead were higher for hook left in (81%) than for hook removed (60%), these differences were non-significant, a conclusion influenced by small sample sizes. We did observe evidence that survivors expelled hooks, with at least three of ten survivors having evacuated the hook and another where the hook was free within the stomach. Nevertheless, these findings suggest a benefit for survival of cutting the line in deep-hooked sand flathead.

DuBois and Dubielzig (2004) identified that hooking injuries to the eye also represent a potential source of vulnerability to mortality, arising from reduced capacity to avoid predators and feed successfully. In our study none of the flathead hooked in the eye region died within the holding period, although obvious eye injuries, including haemorrhaging and swelling, were observed in 32% of individuals at the completion of the experimental period. DuBois and Dubielzig (2004) reported that cases of extra-orbital and choroidal haemorrhage were reversible within a 2-3 day holding period in several salmonid species and the comparatively low rate of obvious eye injuries in our study appear to corroborate this observation for sand flathead. Further research would be required to formally investigate the nature and extent of eye damage and healing in flathead as well as investigating possible sublethal effects on long-term survival and growth.

Water temperature has been identified as a major factor influencing survival in a number of species, with survival typically inversely related to temperatures (e.g. Muoneke and Childress 1994, Nelson 1998, Schisler and Bergersen 1996, De Lestang *et al*. 2004). Of the three PRS experiments conducted in this study, the first two were carried out during summer and experienced very similar temperature ranges (mean almost 17^{o}C) whereas the third experiment was conducted during winter (mean 11^{o}C). The lack of a significant experiment effect on survival, implies that temperature may not be an important factor for sand flathead survival. Taylor *et al.* (2001) also concluded that temperature did not influence survival in common snook.

The importance of controls to correctly estimate survival or mortality rates in PRS studies has been highlighted by Wilde *et al*. (2003). In the present study seine caught sand flathead were treated as a non-hook caught control but since survival rates were significantly lower than for shallow-hooked flathead we conclude that they were not effective in this context. Rather, the high survival rate of the shallow-hooked fish (~100%) implies that mortality, when observed for hook caught flathead, could be attributed to hooking related injuries and was not confounded by other factors (e.g. handling and confinement), a problem experienced by Broadhurst *et al*. (2005) for dusky flathead. The inclusion of the seine caught fish does, however, provide some insight into PRS for that method. For instance, previous studies have demonstrated that post-release survival of seine caught fish can be low, especially where fish become meshed in the net (Kennelly and Gray 2000). Although not a key objective of this study, our data suggest that there may be unaccounted mortality (about 10%) for flathead associated with seining. In Tasmania, commercial and recreational fishers target a range of species using beach seines; Australian salmon and garfish dominate the commercial seine catch (Lyle *et al*. 2005), whereas mullet are the principal species targeted by recreational fishers (Lyle 2000). There have been no studies in Tasmania to assess by-catch levels in seine nets but sand flathead are a common catch.

Internationally and nationally there has been considerable interest in the use of circle hooks as a ‘fish friendly’ tackle. Circle hooks are promoted on the expectation that post-release survival rates are higher than for other hook types, due largely to the high frequency of jaw hooking and low incidence of deep hooking (Cooke and Suski 2004). However, apart from St John and Syers (2005) who examined PRS in dhufish, there have been no previous Australian studies examining the effectiveness of circle hooks. Unfortunately the effect of hook type on dhufish survival was inconclusive since very few individuals were caught on circle hooks.

Cooke and Suski (2004) reviewed available research on circle hooks and their meta-analysis confirmed that circle hooks were more likely to result in shallow hooking than conventional hook types and that survival rates were generally higher or at least equal to rates for other hook types. Our findings support this conclusion, with a significantly lower deep hooking rate (1%) for circle hooks compared with conventional hook types (5-9%). Furthermore, since most hook induced mortalities result from injuries due to deep hooking, it can be inferred that circle hooks have the potential to produce higher survival rates for released sand flathead. Deep hooking rates for J-style, octopus and wide gap hooks were not significantly different from each other, and indicate that the overall rate of deep hooking in sand flathead captured by bait fishing was relatively low.

Several authors have observed that deep hooking rates tend to increase with fish size, presumably because larger fish are more able and likely to swallow the hook (Ayvazian *et al.* 2002, Conron *et al.* 2004). In sand flathead, the deep hooking rate more or less doubled between sub-legal (3%) and legal size groups (6%), though as most legal sized fish are probably not released, this would have limited overall impact on the survival of that portion of the catch that is released.

Circle hooks differ from more conventional hook designs in that the hook bends back in towards the shank with the point more or less perpendicular to the shank. By contrast the point in conventional hook types such as J-style hooks tends to be parallel to the shank (Fig. 1.1). Functionally, circle hooks are designed to be swallowed and as pressure is exerted on the line the hook moves forward in the mouth and rotates setting the point of the hook in the jaw (Cooke and Suski 2004). The fact that the point is directed inwards reduces the likelihood of hooking in the gut or throat area when swallowed. In practice, fishing with circle hooks may require some modification to angling technique in that to hook a fish, gentle pressure should be applied rather than striking vigorously on the bite. In this respect circle hooks can be effective when lines are fished passively or for inexperienced anglers.

It is important that circle hooks are perceived to perform at least as effectively as conventional hook types in terms of capture efficiency or catch rates to gain acceptance from anglers. In this respect the performance of circle hooks has proven variable, with several studies finding that circle hooks do not perform as effectively as other hook types (e.g. Orsi *et al*. 1993, Cooke *et al*. 2003a,c, Meka 2004, Jones 2005). Capture efficiency has two components, hooking efficiency, that is the proportion of strikes that result in hook up, and landing efficiency, the proportion of hook ups that are landed (Cooke and Suski 2004). Cooke *et al*. (2003c) found that capture efficiency for circle hooks in large mouth bass was about half of that for octopus hooks. Meka (2004) compared artificial flies with circle hooks and J-style hooks and established that proportionally more hooked rainbow trout were lost on circle hooks (48%) than J hooks (36%). Jones (2005) noted lower hooking and landing efficiencies for walleye taken on circle compared with octopus hooks. Cooke *et al*. (2003a) concluded that capture efficiency, based on the number of casts per landed fish, for rock bass was lower for circle hooks than other conventional hook types. In our study, capture efficiency was assessed directly as catch rate (number of fish caught per time period). Over the two fishing trials we detected no significant differences in catch rates for circle or conventional hook types, with size compositions comparable between hook types. Our findings indicate that for bait fishing, circle hooks are at least as effective as conventional hook types for sand flathead. Their successful adoption would require some modification to fishing techniques and it is this latter aspect that is more likely to result in some resistance to the uptake of the gear, particularly from experienced anglers but also from anglers who are increasingly using lures to target flathead.

Based on hooking mortality, as estimated from the PRS experiments, and deep hooking rates we conclude that post-release survival in sand flathead is high, greater than 99% for circle hooks and between 94-97% for the other hook types. Comparable survival rates have also been determined for several other fish species inhabiting similar marine habitats in Australia. For instance, survival rates of around 97% for tailor (Ayvazian *et al*. 2002) and King George whiting (Kumar *et al*. 1995), 95% for pink snapper (Conron *et al.* 2004), 94% for sand whiting (Butcher *et al*. 2006) and black bream (Conron *et al.* 2004) have been reported. By contrast, survival rates as low as 64-72% have been observed for yellowfin bream, pink snapper and silver trevally (Broadhurst *et al*. 2005).

Overall high survival rates for sand flathead support the efficacy of current management strategies based on size and bag limits and also the practice of catch-and-release fishing. Our data also indicate that there would be some conservation benefit from the use of circle hooks and, importantly, that circle hook performance is at least comparable to conventional hook types.

CHAPTER 2: EFFECTS OF HOOKING DAMAGE ON POST-RELEASE SURVIVAL OF DUSKY FLATHEAD (*PLATYCEPHALUS FUSCUS*)

Ian W Brown, Mark McLennan, David Mayer, Jeremy Lyle, and Alastair Morton

2.1 Introduction

Dusky flathead (*Platycephalus fuscus*) represent one of Queensland's major estuarine angling species. Landed recreational catches in Queensland have been variously estimated to be in the vicinity of 200 and 290 tonnes in 1999 (Williams 2002 and Dichmont *et al*. 1998 respectively); and 0.79, 0.67 and 0.57 million fish in 1997, 1999 and 2002 respectively from three DPI&F recreational fishery diary surveys (Higgs 1998, 2001 & pers. comm.). In Queensland waters it is also taken commercially in the inshore net fishery, with annual catches over the past two decades ranging between approximately 50 and 80 t (CEFISH database, DPI&F). The species ranges from Lakes Entrance in Victoria to Princess Charlotte Bay in northern Queensland (Kailola *et al*. 1993), and is also a very important component of the recreational fish catch in NSW and eastern Victoria (Henry and Lyle 2003). While dusky flathead are by far the dominant component of the flathead catch in Queensland waters, small quantities (estimated to be less than 5%) of several other morphologically very similar species are also taken, chiefly bar-tail flathead (*P. indicus* and *P. endrachtensis*) and northern sand flathead (*P. arenarius*). It is likely that many anglers fail to differentiate between these various platycephalid species.

In recent years attention has been focussed on the fate of fish that are released from line fisheries because they are under (or in some cases over) legislated size limits, over bag limits, or are the target of recreational tag-release or catch-and-release programmes. This interest has been stimulated by a substantial increase in the application of minimum (and sometimes maximum) size rules as a fisheries management tool, and a generally upward re-evaluation of previously existing minimum size limits in line with increasingly precise information about reproductive chronology and sizes at maturity. At the same time, improved estimates of the numbers of fish that are discarded or released as a result of these management arrangements and changes in angling ethos have highlighted the potential for a high level of cryptic fishing mortality if survival rates amongst released fish are low. Attempts are being made to quantify their survival rates so that best practice arrangements can be made available to the recreational fishery to ensure that cryptic fishing mortality is minimised (Henry and Lyle 2003, Muoneke and Childress 1994, Schaeffer and Hoffman 2002). Around half of the flathead (primarily dusky flathead) caught recreationally in Queensland are released (Higgs 1998, 2001, National Recreational Fishing Survey database), suggesting that if post-release survival were low, this could represent a significant source of cryptic fishing mortality.

The survival of released line-caught fish can be influenced by capture and handling stress, physical tissue damage due to hook penetration, and the various direct and indirect effects of barotrauma or pressure-related injury. However in the case of dusky flathead and its close relatives, barotrauma is likely to be a far less important contributor to cryptic post-release mortality than hook damage, because these species do not possess a swimbladder (Gomon *et al*. 1994), and are normally captured in quite shallow waters (the mean capture depth for all platycephalid records in the Suntag tag-and-release database is 1.9 m).

The comprehensive review and meta-analysis of research into the relative effectiveness of circle hooks by Cooke and Suski (2004) cites their apparent conservation benefit as being the main reason why these types of hooks have engendered so much interest over the last decade. Reduction in the incidence of deep hooking (i.e. in the lower oesophagus, throat and gut) is seen as a benefit because of the associated risk of critical tissue damage to the vital organs, particularly heart, gills and liver, and much of the literature (e.g. Cooke *et al*. 2003b, Bacheler and Buckle 2004, Meka 2004, St John and Syers 2005) relates to the potential benefits of circle hooks. However in some sectors of the Queensland recreational fishery there has been a significant trend away from bait-fishing and towards lure-fishing in recent years, particularly for freshwater and estuarine species, including flathead (Sawynok and Sorrell 2005). In the past five years nearly 92% of the flathead capture records on the Suntag tagging database relate to capture by lure, while only 8% relate to capture with a baited hook. Nevertheless there are still dedicated flathead anglers, not necessarily associated with tagging clubs, who use conventional baited (and frequently ganged) J-hooks to target dusky flathead and significantly, in 2000/01 over 85% of the Queensland flathead catch by numbers was bait-caught (National Recreational Fishing Survey database).

The overall aim of this study was to determine the effect of hook type on the short-term survival of dusky flathead. Of particular interest was whether circle hooks cause less physical damage to the fish than traditional J- or straight-shank hooks. If this were the case, then it would also be desirable to demonstrate whether or not the use of the different hook designs resulted in appreciable differences in catch rate. Although the use of soft plastic lures has not taken off in other States to the extent it has in Queensland, the increasing popularity of this rig amongst anglers – particularly in the estuarine environment – meant that we needed to include lures in the range of hook/rig types to be compared.

2.2 Methods

Because of the non-aggregated distribution of dusky flathead throughout the Southport Broadwater and southern Moreton Bay, we recruited a team of cooperative recreational anglers to catch the fish, using their own boats and fishing tackle. The management staff at the Sea World Theme Park (Southport) allowed us to use their holding tank facilities for the period of the experiment.

It was initially planned to undertake the experiment during the course of the 2005 annual *Flathead Classic*, a significant recreational angling competition specifically targeting dusky flathead in the Southport Broadwater area. However it became apparent that, under its new protocols, the *Classic* would not provide us with the information we needed, primarily because participants were restricted to using lures (not baited hooks), and it was to be a catch-and-release only event (i.e. with no tagging).

As an alternative we considered the *Tagfish 2005* event, scheduled for 22-24 July. We contacted 14 angling clubs in the greater Brisbane region whose members might be planning to take part in this event, outlining the project and asking whether they would be prepared to participate in the experiment. The response to this was rather disappointing, but understandable in terms of the fact that this is not the optimum time for targeting dusky flathead. Many of the top flathead anglers intended to target other species (e.g. yellow-fin bream) which are more numerous and thus more attractive to competitive taggers. After more consultation with expert flathead anglers we re-scheduled the experiment to a more appropriate time (20-24 August) when the ‘season’ was likely to be more advanced, and therefore there was a greater likelihood that we would be able to capture a sufficient number of fish for the experiment.

2.2.1 Study area

Angling activities were focused on the Jumpinpin area between North and South Stradbroke Islands. However it included the northern part of the Southport Broadwater and the network of mangrove creeks and channels between Russell and Woogoompah Islands, encompassing a total area of approximately 60 km^2 (Fig 2.1). This is a popular estuarine area for flathead angling, and is relatively close to the Sea World facility which was identified as the most appropriate site for conducting the experiment.

2.2.2 Angler involvement

Project staff established contact with the executives of all major salt-water angling clubs between the Gold Coast and Bribie Is., including the greater Brisbane region, explaining the objectives of the experiment and inviting participation by their members. In the many instances where the initial response was positive, follow-up visits were made to club meetings to explain the procedures in greater detail and identify specific anglers willing to be involved.

Ultimately 34 recreational anglers, with access to 15 boats were committed to the catching phase. Most of the participating anglers were members of the Brisbane, Bribie Island, North Brisbane, South Brisbane, and Gold Coast Sports Fishing Clubs.

Some boats belonging to dedicated tag-release anglers were equipped with holding tanks; those that were not were supplied with 60 l plastic bins with lids to hold the fish prior to collection by project staff. In accordance with Animal Ethics approval requirements, the volume of the holding tank on each boat was recorded, and whether or not it was fitted with a flow-through water system.

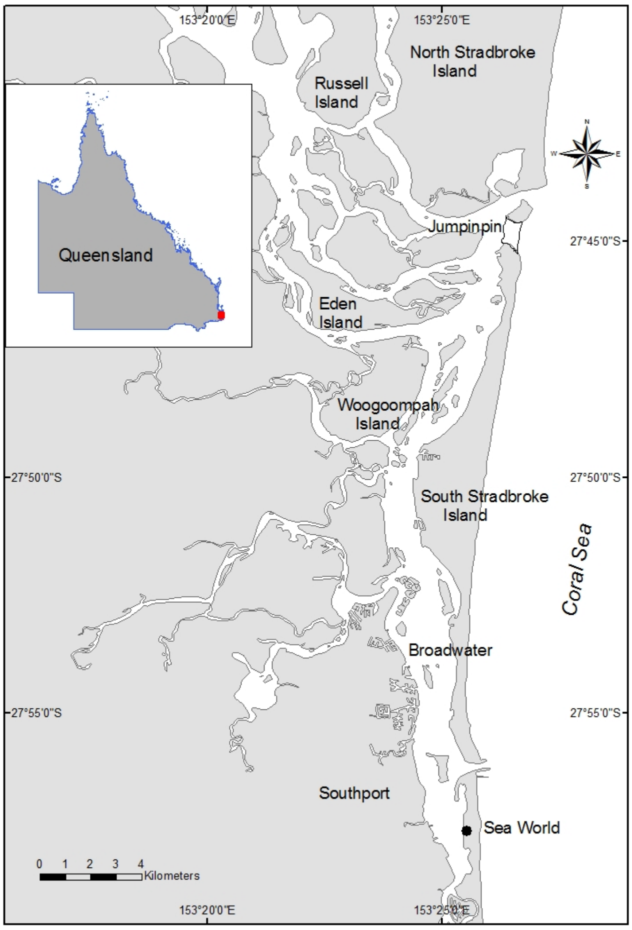


Fig. 2.1 Study area in south-east Queensland, showing location of Sea World Theme Park where the tank experiment was conducted. Note that most of the flathead angling took place in the region from Jumpinpin to Woogoompah Is.

2.2.3 Experimental protocol

Catching protocols were designed to ensure that enough data would be collected on fish caught by traditional baited-hook methods, and (optimistically) that sufficient of these fish would have been deep-hooked to enable some comparison of survival rates between fish that were shallow and deep-hooked. A set of standard J hooks (Mustad 4190 4/0) and circle hooks (Mustad 39951 NPBLN 4/0) (Fig. 2.2), were provided to each boat, in addition to a supply of frozen packs of bait (white pilchards).

Anglers were asked to fish in 30-minute sessions using three types of gear in succession – J hooks, circle hooks and their own preferred jigs or lures. The sequence was fixed, but the starting gear-type was randomized for each boat and day. All anglers within a boat were asked to use the same gear simultaneously, and record session starting and finishing times, and numbers of anglers fishing. The intention here was to collect data on fishing effort (hook-hours) that could be used to compare catch rates between hook types. This is important, as the performance of a particular hook type or rig will be expected to at least match that of conventional rigs if the new device is to gain acceptance among anglers (Cooke and Suski, 2004).

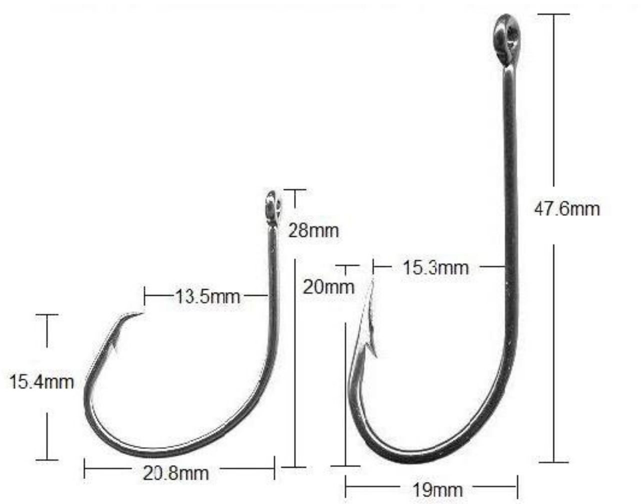


Fig. 2.2 Hook patterns used in the experiment with nominal dimensions – (a) Mustad 39951 (circle) and (b) Mustad 4190 (J). The rated size of both hook patterns was 4/0.

As most of the anglers had indicated a familiarity with tagging procedures, they were asked to tag their catch (of flathead) and record the capture and tag details according to the standard Suntag protocols. After a fish was tagged it was to be placed in the holding tub and arrangements made for its collection by Project staff. In situations where the angler was unwilling or unable to do the tagging, project staff tagged the fish instead, usually at the time the fish was collected from the catching vessel.

The DPI&F 14.5 m research vessel RV *Tom Marshall* was based at anchor close to shore in the Broadwater about 2 km south of Jumpinpin. Two smaller outboard-powered vessels, the RV *Marshall's* tender and a 6 m Torres Fisher, were used by Project staff to collect fish from the catching boats as soon as practicable after capture and notification by mobile phone or radio. Each of these vessels was equipped with a large insulated container (85 and 500 l capacity respectively), with the facility for pumped water exchange. These tanks were used for transporting the fish back to the *Tom Marshall*, where they were transferred to one of two larger tanks with constant flow-through seawater.

Fishing was conducted over two days (20-21 August 2005) and late in the afternoon of each day, following completion of the angling operations, the *Tom Marshall* was steamed about 23 km down the Broadwater to the Sea World Theme Park and moored at the facility's jetty. The tagged fish were then dip-netted out of the tanks and carried in plastic fish boxes half-filled with clean seawater some 40 m to the Sea World research tank shed, where they were assigned sequentially to one of three 3000 l circular tanks supplied with filtered flow-through seawater. The water temperature in one of the tanks was monitored using a small Tidbit © temperature logger.

The fish were inspected at least twice per day, and any dead individuals removed and preserved, until the conclusion of the experiment on the afternoon of 24 August. At that time the fish were removed (by dip-netting), checked for damage or signs of injury, transported back to northern end of the Broadwater, and released. Dead fish were preserved, and several fish that had been deep-hooked were sacrificed for post-mortem analysis.

2.2.4 Data collection

Each participating boat was assigned a number, and provided with a packet containing a grid-chart of the area, contact details for the DPI&F vessels (mobile telephone and radio), tag data sheets and a set of fish transfer slips. The tag data sheet made provision for recording angler and taggers' names, tag number, time of capture, hook type, bait type, hook lodgement location, bleeding, tissue damage and release condition. As an insurance against accidental loss of the primary data sheet, anglers were asked to supply a waterproof transfer slip showing the boat number, angler, fish length and tag number with each transfer – usually one to three fish at a time.

2.2.5 Data analysis

The principal factors effecting survival were assumed to be the type of hook or terminal rig used, the anatomical location of hook lodgement and any observable tissue damage related to the hooking process. The response variate was simply a binary variate indicating whether the individual captured fish was alive or not at the end of the holding period (minimum of 3 days). The explanatory variate *hook type* was categorized as C (circle), J (conventional straight-shank J-hook; baited) or L (lure; either hard- or soft-bodied, with J-hook or treble rig). *Hooking site* was categorized as L (lip), M (mouth), T (throat; hook visible), G (gut; hook not visible), or O (other; principally foul-hooked). *Bleeding* was categorized as N (no observable bleeding), L (light bleeding) or B (severe bleeding). *Injury* was categorised as N (no observable injury), J (some damage to the jaw [maxilla or mandible]), or G (gill damage). To increase confidence in the statistical significance of the results, some of these variates were combined into a smaller number of sets with larger sample sizes prior to analysis.

Some other factors which were considered to be of possible influence to the survival of flathead in this experiment were also included in the analyses. These included angler experience, the characteristics of the tanks used to temporarily hold fish on the catching boats (*viz.* tank type, capacity and water circulation), the length of time the fish were held in the holding tanks, and fish size.

An index of angler experience was derived from the numbers of flathead each person caught during the experimental period. Anglers were allocated to one of five classes (a-e) on the basis of the numbers of flathead (minimum = 1), the class limits being ≥40, 30-39, 20-29, 5-19, and <5 fish respectively. We hypothesised that a skilled angler may be more likely to (a) catch a greater number of fish, and (b) handle the fish more appropriately (with commensurately higher survival rates) than a less skilled angler.

Tank type was descriptive and not used in the final analysis; capacity was expressed as a continuous variate (actual volume) and also categorised as <85 l and ≥85 l; and circulation was a binary variate describing whether or not any flow-through circulation system was used. The surface interval, or time the fish were in the holding tank, was calculated as the difference between the time of capture (reported by the angler) and the time of collection by research staff, and allocated to one of four categories (1: <30 min; 2: 30-59 min; 3: 60-119 min; 4: ≥120 min). Fish size, a continuous variate (total length in millimetres), was ultimately grouped into 'sub-legal' (< 40 cm TL) or 'legal' (≥ 40 cm TL) categories.

A binomial Generalised Linear Model (GLM) with logit link (McCullagh and Nelder 1989) was used in GenStat v. 8.1 to test the significance of the various explanatory variables on the binary response variate (survival). An initial step-forward multiple model procedure (Type I sums of squares) was used to identify which of the variates were influential in combination with others and to ensure that the most significant terms were fitted first. As none of the multiple models were significant the explanatory terms were deemed to be acting independently, so the terms were fitted successively in separate models. A separate GLM was run to assess whether the release condition was a good estimator of subsequent survival. Release condition was a subjective rating (on a scale of 1 = excellent to 5 = dead) of how well the fish appeared either when in the large tank on RV *Tom Marshall* or when released into the experimental tanks at Sea World. The model was again binomial with logit link, as it involved the same two-state response variate.

2.3 Results

The catching phase of the experiment ran from dawn on 20th to mid-afternoon on 21st August 2005. Weather conditions were excellent, and virtually all the anglers who had indicated their willingness to be involved fished for either one of the two days, or both.

2.3.1 Catch characteristics

Throughout the weekend 176 flathead, ranging in size from 21 to 71 cm TL (Fig. 2.3), were caught and tagged. Of these, 73.9% were below the 40 cm minimum legal size, 1% were above maximum legal size (70 cm), and the remaining 26.1% were legal sized. One fish escaped from the catching vessel immediately after tagging, leaving 175 'experimental' individuals. Catch rates varied considerably between boats, with 42% of the total catch being taken by two anglers in one alloy runabout, while the occupants of several boats only caught 2-3 fish over the whole weekend. Included in the flathead catch were two bar-tailed flathead (*P. endrachtensis*; both 27.0 cm TL) and one northern sand flathead (*P. arenarius*; 25.5 cm TL). As these were well within the range of dusky flathead lengths and were very similar in morphology, we opted to include their data in the dusky flathead data set.

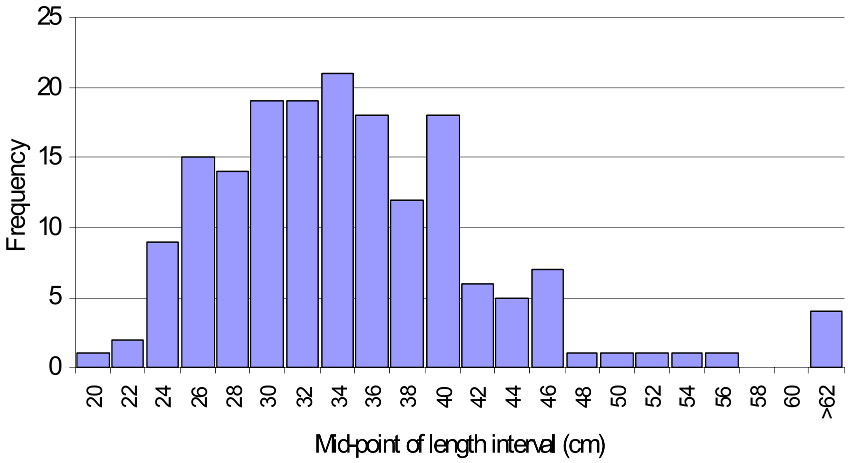


Fig. 2.3. Size-frequency of all flathead caught during the experimental period. Note that the minimum legal size for *P. fuscus* is 400 mm and the maximum legal size 700 mm.

Summary data: catch by hook type

One third of the catch was taken on lures, 27% on circle hooks and 39% on J-hooks (Fig. 2.4). However these values should not be taken as reflecting the relative ‘efficiency’ of the different gear types. Because of the high numbers of lure-caught fish obtained on Day 1 the participating anglers were asked to restrict their fishing activities to the use of baited hooks on Day 2 in order the increase the sample size of fish potentially more susceptible to deep hooking.

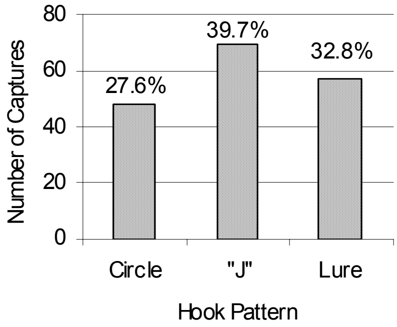


Fig. 2.4 Number and percentages of flathead taken on each of the three hook types or patterns.

Effect of hook pattern on hooking location

The great majority of fish were lip-hooked, regardless of hook type (Fig. 2.5), although the largest proportion (80%) of lip-hooked fish was taken on lures. Hook type appeared to have no appreciable effect on the proportion of fish hooked in the mouth, but of those hooked in the throat, by far the greatest number (11.6%) had been taken on J hooks. A little over 4% of J-hooked fish were classified as gut-hooked, but no lures or circle hooks had been swallowed.

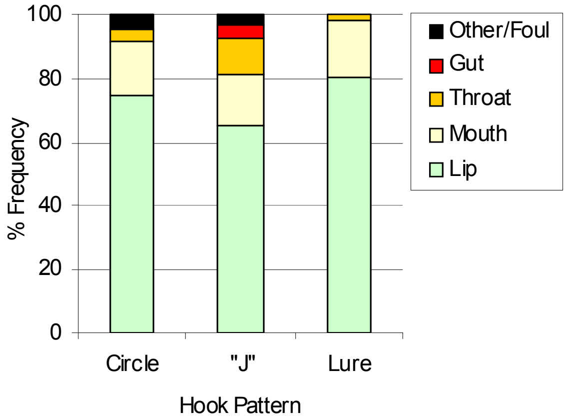


Fig. 2.5. Effect of hook type or pattern on the anatomical location of hook lodgement (raw data).

For consistency with other studies, and because the numbers of observations in some categories were very low, the various hooking sites were pooled into two groups for further examination and analysis. Throat- and gut-hooked fish were classed as 'deep-hooked' and all other categories were pooled into the 'shallow-hooked' group.

Over all, only 14 (8%) of the total 175 fish were classed as having been deep-hooked (Table 2.1), the majority of these being attributable to the use of 'J' hooks. Nearly 16% of J hooks lodged in the throat or gut, while fewer than 5% of the fish caught on circle hooks or lures were similarly deep-hooked. The observed differences in *hook location* among the three hook patterns was statistically significant (Pearson $\chi^2 = 9.98$, d.f. 2, $P = 0.007$), although the test should be considered approximate due to the low numbers of some expected values.

Table 2.1 Effect of hook type on anatomical hooking location. Percentages are shown in parentheses.

Hook Location	HookType			n
	Circle	J-style	Lure	
Shallow	46 (95.8)	58 (84.1)	57 (98.3)	161
Deep	2 (4.2)	11 (15.9)	1 (1.7)	14
Total	48 (100)	69 (100)	58 (100)	175

2.3.2 Post-release survival experiment

The raw scores from the survival experiment (Table 2.2) indicated relatively little difference in the survival rates of fish caught on different hook types. Over the 4-day period of the experiment a total of twelve fish died, representing an overall survival rate of just over 93%. Five of these fish had been taken on J hooks, four on circles and three on lures. About 93% of the J-hooked fish, and 92% of circle-hooked fish survived. The mortality rates among fish that had been caught with different hook types lodged in different locations were quite variable (Table 2.2). One of the two fish foul-hooked with a J-hook died. A small number of mortalities were due to deep hooking (throat or gut) with baited hooks (J or circle). Interestingly, there were no mortalities among the mouth-hooked fish, regardless of the type of hook used, while 7 (6%) of the lip-hooked fish died. The fact that there were very similar proportions across hook-types suggests that at least some of the mortality may be attributable to factors other than hooking damage (e.g. stress during on-board holding or transportation).

Table 2.2 Relationship between hook type, anatomical hooking location and survival

	Hook type							
Hook site/	J		C (circle)		L (lure)		Total	
Location	Survived	Died	Survived	Died	Survived	Died	Survived	Died
Lip	43	2	34	2	43	3	120	7
Mouth	11	0	8	0	10	0	29	0
Foul	1	1	1	1	0	0	2	2
No data	0	0	0	0	1	0	1	0
Shallow	*55*	*3*	*43*	*3*	*54*	*3*	*152*	*9*
Throat	7	1	1	1	1	0	9	2
Gut	2	1	0	0	0	0	2	1
Deep	*9*	*2*	*1*	*1*	*1*	*0*	*11*	*3*
Total	64	5	44	4	55	3	163	12

Of the fish that died, two still retained the hook. One (tag# P55908) had been gut-hooked and the other (tag# R06979) had been throat-hooked. These fish were in poor condition when released into the experimental tanks (release condition = 4).

A more detailed tabulation of the summary data (Table 2.3) shows the numbers of fish exposed to the various ‘treatments’ that survived and the numbers that died. A first scan of this table confirms that the survival rate of the dusky flathead was quite high, and reveals that few of the tested factors had a particularly influential effect on survival. The data suggest that hooking location and bleeding may be significant predictors of survival, and release condition and surface interval category may be also, but perhaps to a lesser extent.

Other factors of interest, which may potentially have influenced the survival of the fish, included angler rating, fish size, the type and capacity of holding tank on the catching vessel, and whether or not the holding tank was equipped with a flow-through seawater system. While the raw scores suggested that these factors had little effect on mortality rates, a full generalised linear regression model (GLM) was required to test the significance of these observations statistically.

An initial multiple or ‘step-forward’ model was run with the binomial response variate being simply whether or not the fish survived. The fitted model terms were: hook location, bleeding, hook left in, tank category, tank flow, total length category, angler rating, injury, surface interval, hook type, and hook type×hook location interaction. Two of these terms stood out as contributing significant effects in the multiple model: hook location ($P = 0.02$) and surface interval ($P = 0.05$) (Table 2.4).

As the order of inclusion of the terms can have an effect on the outcomes (depending on whether or not adjustments have been made for significant terms), the variates were ranked from most to least significant (Table 2.5). However re-ordering of the terms did not result in any of the initially non-significant terms becoming significant, nor did it appreciably change the statistical significance of either hook location or surface interval (Table 2.5). The lack of significance of the hook type×location interaction indicates that with respect to survival rates these two factors acted independently. Thus each modelled term could be tested independently, and adjusted means derived directly from the fitted data. The two significant variables were therefore modelled in the absence of all non-significant terms to estimate the adjusted means.

Table 2.3 Raw score observation of the numbers and percentages of fish surviving at the end of the experimental period, tabulated by primary categorical variate.

Variate	Survived	Died	Total	% survival
Hook type				
Baited				
J	64	5	69	92.8
C	44	4	49	91.7
Unbaited				
Lure	55	3	58	94.8
Hook Location				
Shallow				
Lip	120	7	127	94.5
Mouth	32	2	34	94.1
Deep				
Throat	9	2	11	81.8
Gut	2	1	3	66.7
Bleeding				
Nil	151	10	161	93.8
Slight	6	1	7	85.7
Heavy	1	1	2	50.0
Injury				
None	156	12	168	92.9
Jaw/lip	2	0	2	100
Gill	2	0	2	100
Release condition				
1	156	6	162	96.3
2	6	0	6	100
3	1	0	1	100
4	0	3	3	0
5	0	3	3	0
Surface interval category				
1	59	2	61	96.7
2	59	2	61	96.7
3	30	4	34	88.2
4	12	2	14	85.7
Deep-lodged hook left in				
Y	4	2	6	66.7
N	7	1	8	87.5
Holding tank circulation				
Y	32	2	34	94.1
N	131	10	141	92.9
Holding tank volume (l)				
<85	62	7	69	89.9
≥85	101	5	106	95.3
Experimental tank i/d				
A	55	4	59	93.2
B	55	1	56	98.2
C	50	2	52	96.2

Table 2.4 Initial multiple model analysis of deviance table.
Significant terms are indicated by asterisks.

Source	d.f.	deviance	mean deviance	approx P (χ^2)
Hook location	1	5.063	5.063	0.024*
Bleeding	2	3.966	1.983	0.138
Tank category	1	2.396	2.396	0.122
Hook left In	1	1.395	1.395	0.238
Tank flow	1	1.852	1.852	0.174
Size group	1	0.186	0.186	0.666
Angler rating	4	3.840	0.960	0.428
Injury	2	0.074	0.037	0.964
Surface interval	3	7.74	2.58	0.052*
Hook type	2	2.148	1.074	0.342
Hook type×Hook location	2	0.647	0.323	0.724
Residual	143	46.018	0.322	
Total	163	75.323	0.462	

Table 2.5. Re-ordered multiple model analysis of deviance table
Significant terms are indicated by asterisks.

Source	d.f.	deviance	mean deviance	approx P (χ2)
Hook location	1	5.063	5.063	0.024*
Surface interval	3	9.222	3.074	0.026*
Tank category	1	0.004	0.004	0.947
Bleeding	2	4.395	2.197	0.111
Tank flow	1	2.198	2.198	0.138
Hook left In	1	2.473	2.473	0.116
Hook type	2	1.006	0.503	0.605
Angler rating	4	3.135	0.784	0.536
Size group	1	1.156	1.156	0.282
Hook type×Hook location	2	0.646	0.322	0.724
Injury	2	0.008	0.004	0.996
Residual	143	46.018	0.322	
Total	163	75.323	0.462	

Effect of hook location and surface interval on survival

Mean survival rates for deep and shallow-hooked fish, adjusted for all other terms in the model, were 73.3% and 95.6%, respectively (Fig. 2.6). This provides clear evidence of the importance of the location of hook lodgement, and presumably the impact of associated tissue damage, on the survival chances of dusky flathead. The disparity between the standard errors is a function of the relative sample sizes, which were quite small in the case of the deep-hooked fish.

Surface interval is an artefact of the experimental procedure, and would not normally be considered an important feature of typical angling activities. As it was identified as a potential contributor to mortality in the experiment, it was included in the model so that its effect (if significant) could be removed from that of the main factors of interest. For time intervals of less than an hour (classes 1 and 2) the effect was minimal, with adjusted mean estimated survival rates of around 97% (Fig. 2.7). With increasing time intervals there were a few more mortalities, reducing survival rate to 86% (1-2 h) and 85% (≥ 2 h).

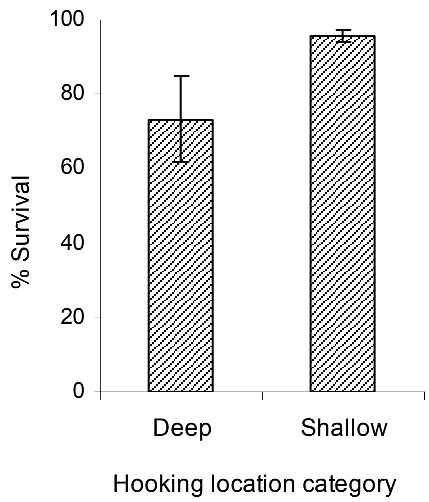


Fig. 2.6. Adjusted mean survival rates (± s.e) for shallow- and deep-hooked dusky flathead.

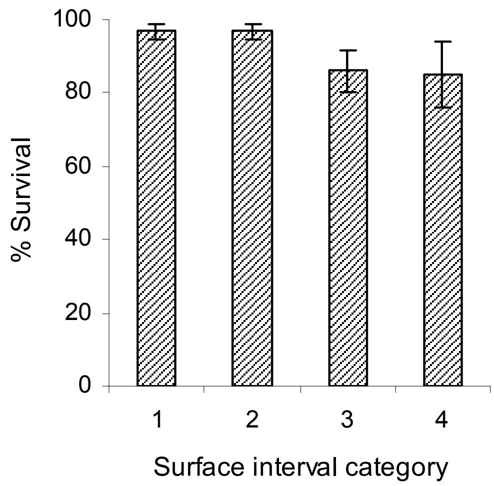


Fig. 2.7. Adjusted mean survival rates (± s.e.) for dusky flathead contained for varying lengths of time in holding tanks aboard the catching vessels. The interval categories ranged from <30 min (class 1) to ≥2 hr (class 4).

Having identified the significant factors in the model, it is now of interest to examine the adjusted means of the non-significant terms. Firstly it was necessary to identify which of the various terms covaried or interacted with each other (i.e. were confounded), so that only the non-interacting significant terms were included in the prediction models. The Genstat 'Tabulate' function was used to test the significance

(Pearson's χ^2) of association between individual pairs of variates, which are shown in Table 2.6.

Table 2.6. Table of probabilities from Pearson's chi-square test of association between pairs of modelled variates. Significant P values (< 0.05) are highlighted**.**

	Hook location category	Surface interval category	Tank category	Bleeding	Tank flow	Hook left In	Hook Type	Angler rating	Size group	Injury
Hook location category	X	0.64	0.16	**<0.001**	0.8	**<0.001**	**0.01**	0.11	0.12	0.06
Surface interval category		X	**<0.001**	0.41	0.35	0.09	0.49	**<0.001**	**0.03**	0.5
Tank category			X	0.52	**<0.001**	0.51	**<0.001**	**<0.001**	0.31	0.91
Bleeding				X	**0.01**	0.51	0.53	**0.03**	0.64	**<0.001**
Tank flow					X	0.12	**0.003**	**<0.001**	0.62	0.26
Hook left In						X	**0.003**	0.08	0.72	0.88
Hook Type							X	**0.05**	0.11	0.15
Angler rating								X	0.12	0.53
Size group									X	0.52
Injury										X

Effect of tank volume category on survival

Tank volume was confounded with surface interval (Table 2.6), probably because the smallest holding tanks were on the smallest catching boats. Because of their small size, these boats were able to access the more remote (and protected) mangrove creeks, which took longer for the project crew to locate and reach. Thus the non-confounded factor hook location was modelled to predict the effect of holding tank volume on survival.

After adjusting for the effects of hooking location, there was very little effect due to holding tank volume, which was categorised either as less than 85 l or greater than or equal to 85 l (Fig. 2.8). The significance of the very marginal difference was low ($P >$ 0.9), reflecting the low standard errors.

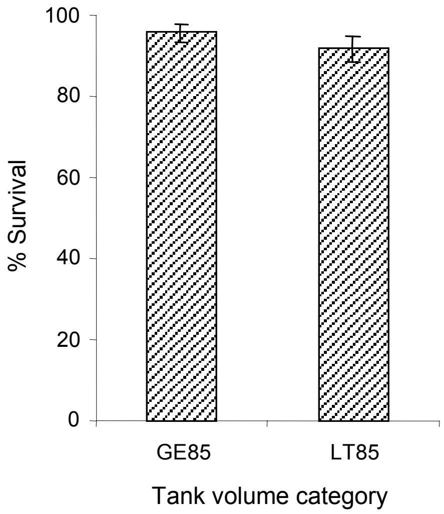


Fig. 2.8. Adjusted mean survival rates for dusky flathead temporarily retained in on-board holding tanks of large (≥85 l) and small < 85 l) capacity.

Effect of bleeding on survival

Bleeding was confounded with hook location (Table 2.6); all shallow-hooked fish exhibiting light or no bleeding while two of the 13 deep-hooked fish were recorded as showing heavy bleeding. Thus the effect of bleeding on survival was modelled in conjunction with the non-confounded factor surface interval.

While in the multiple model bleeding was not significant at the 95% level, its significance was marginal ($P = 0.11$). The adjusted means are certainly indicative of a trend in the data (Fig. 2.9), with a much reduced expected survival rate (34%) amongst fish showing signs of heavy bleeding. The extreme standard errors in that category are due to there being only two individuals in the ‘heavy bleeding’ class, one of which survived and the other died (see Table 2.3).

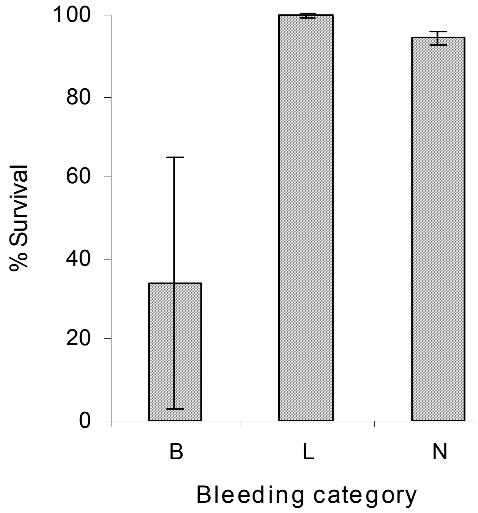


Fig. 2.9 Adjusted mean survival rates of dusky flathead exhibiting various levels of bleeding (B = heavy, L = light, N = none).

Effect of Tank flow on survival

Tank flow (i.e. whether or not the catching vessel's holding tank was equipped with a flow-through system) was confounded neither with hook location nor surface interval, so both hook location and surface interval were included as explanatory variates in predicting the effect tank flow on survival.

Whether the catching vessel was or was not equipped with a water circulation system on its holding tank appeared to make very little difference to the survival of the dusky flathead. After adjusting for other factors the residual mortality effect was negligible (Fig. 2.10). Again, the tight error bounds suggest that this is a robust conclusion.

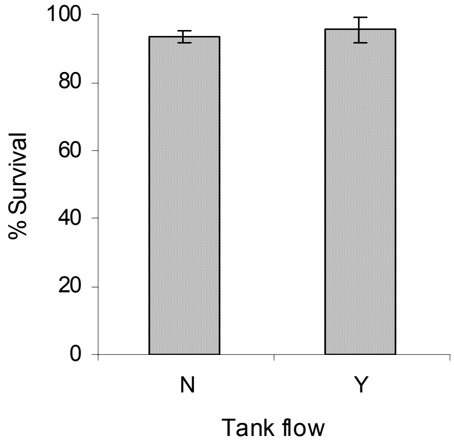


Fig. 2.10 Adjusted mean survival rates of fish housed temporarily in holding tanks without (N) and with (Y) a flow-through water system.

Effect on survival of leaving deep-lodged hook in situ.

As would be expected, the term 'hook left in' was confounded with hook location, because it is generally only deep-hooked fish where the line is cut, leaving the hook in place to reduce the risk of major tissue damage. Surface interval was therefore modelled as a covariate to examine the effect of hook removal on survival.

The results of this test were somewhat counterintuitive, in that the higher survival rate (95%) was estimated for fish from which the deep-lodged hooks had been removed (Fig. 2.11). In contrast, leaving hooks in place seemed to have a detrimental effect, with survival estimated at only 65%. However it is unlikely that these results are reliable, since there were only 14 deep-hooked fish in total, and of these three died (two in which the hook had been left in and one where the hook had been removed). With such low numbers the signal is particularly weak, and the observed differences could easily have been due to chance events.

Post mortem examination of the two mortalities in which the hook was left in place revealed that in both cases the (J) hooks had penetrated the gut wall (Fig. 2.12). There was no obvious evidence of additional damage to internal organs.

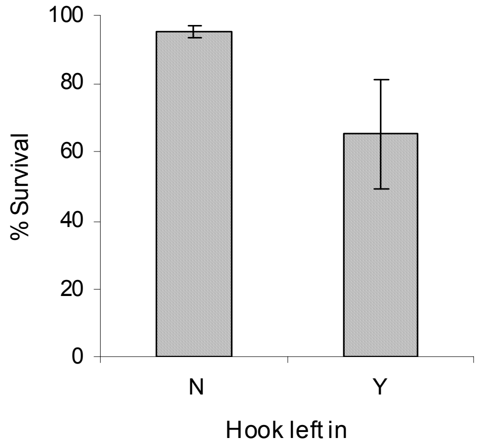


Fig. 2.11 Adjusted mean survival rates for deep-hooked dusky flathead where the hook was left in place (Y) or removed (N).

Fig. 2.12 Post-mortem dissection of a dusky flathead (tag # R06979) with hook left in, which died during the experimental period. The hook had penetrated the gut wall.

Five surviving fish were sacrificed for *post-mortem* examination at the termination of the experiment. One of these (tag# R04388) had been gut-hooked but the (J) hook had been removed by the angler. There was no evidence of any major internal damage to this fish resulting from hook removal. While in the experimental tank another fish, which had been hooked in the mouth, 'threw' the (J) hook which was later collected from the bottom of the tank.

All three remaining fish examined *post-mortem* had the hooks left in place. In one (tag# P55916) the 4/0 J-hook had penetrated the gut wall and the hook had completely pierced one lobe of the liver (Fig. 2.13). In another (tag# R06965) the 1/0 J-hook shank was visible in the oesophagus, and the point had penetrated the gut wall and back out through the body wall through the base of the right-hand branchial arch (Fig. 2.14). The fish can evidently sustain this sort of hook damage – at least in the short term – provided none of the critical vital organs (e.g. heart, arteries or gills) are affected.

Fig. 2.13. Extent of hook penetration through the gut wall and liver in a surviving flathead (tag# P55916).

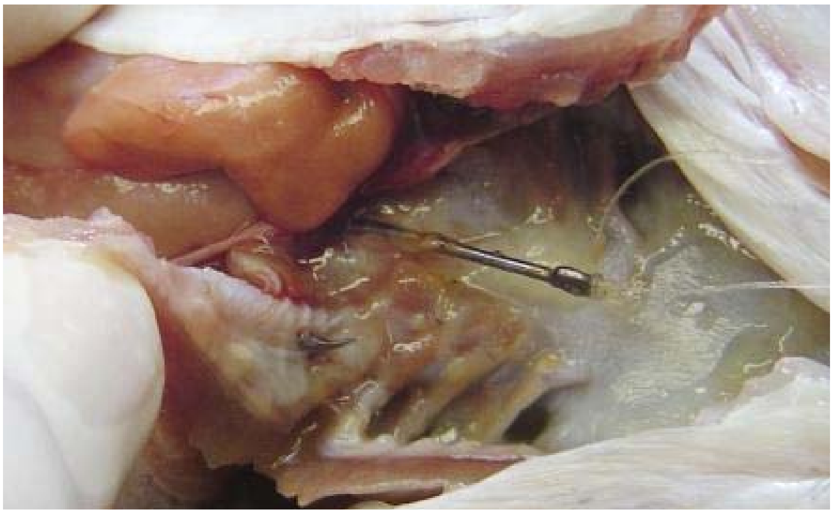


Fig. 2.14 Hook penetration through the gut and body wall in the gill region, in a fish which had survived the experimental period without any apparent adverse effects (tag# R06965).

Effect of hook type on survival

Because hook type and hooking location were confounded (Tables 2.1 and 2.6), the other significant factor (surface interval) was used to adjust the mean survival rates with respect to hook type or pattern.

After adjusting for other influential factors, there was no residual effect of hook type, with all three patterns resulting in survival rates between 92 and 95% (Fig. 2.15).

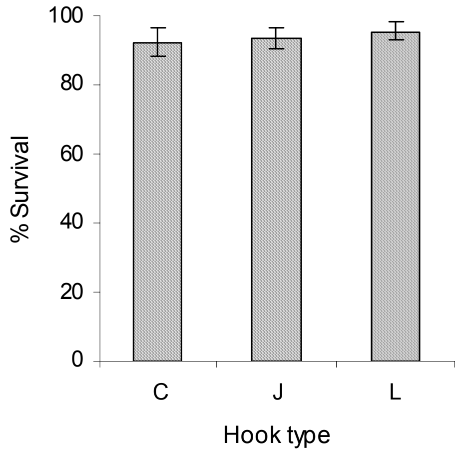


Fig. 2.15 The effect of hook pattern on adjusted survival rates. Hook patterns were: C = circle, J = conventional J-hooks, and L = lures.

Effect of angler rating on survival

The fact that angler rating was confounded with surface interval is not surprising, as the anglers who rated highest (because of the number of fish they caught over the catching period) were fishing relatively close to the project's base vessel, and they tended to stay in the one area. This meant that the project's pickup boats were frequently visiting them; so surface interval times were short. Survival rates were therefore adjusted for the non-confounded factor (hook location) to determine the effect of angler rating.

There appears to have been a weak tendency for higher survival rates amongst fish caught by notionally more 'skilled' anglers (as indicated simply by the size of their catch) than by their less 'skilled' colleagues (Fig. 2.16). However the regression χ^2 was non-significant (P = 0.487 with 4 d.f.), probably because of the very low overall mortality rates.

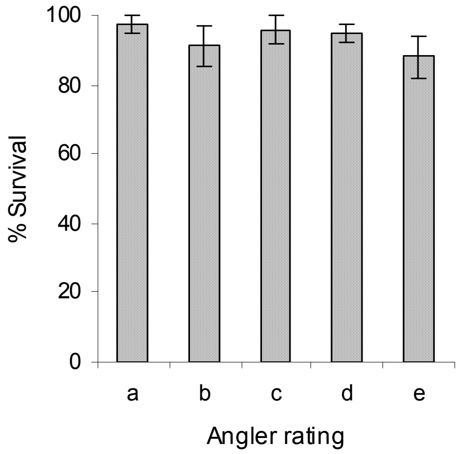


Fig. 2.16 Influence of angler rating on adjusted mean survival rates of experimental flathead. Angler ratings are based on the numbers of fish caught over the experimental period (a: highest catches through to e: lowest catches). Adjusted means ± s.e. are shown.

Effect of fish length on survival

Size group (<40 cm and ≥ 40 cm) was associated with surface interval (P = 0.03; Table 2.6), so hook location was modelled to estimate the effect of length on survival.

After adjustment for other factors, the total length of flathead had no significant effect on mortality, with sub-legal and legal sized dusky flathead being equally susceptible to short-term mortality at 6% (Fig. 2.17).

Effect of visible injury on survival

As the variable 'injury' was confounded neither with hook location nor surface interval, both these categorical variables were used as covariates to predict the effect of injury on survival rate.

Not surprisingly, the lack of significance of this factor in the initial multiple GLM analysis (P = 0.96; Table 2.4) reflects the similarity between adjusted mortality estimates (Fig. 2.18). However this test lacked power, as only four of the 172 fish for which there were records were recorded as having sustained an injury, and none of these four fish died.

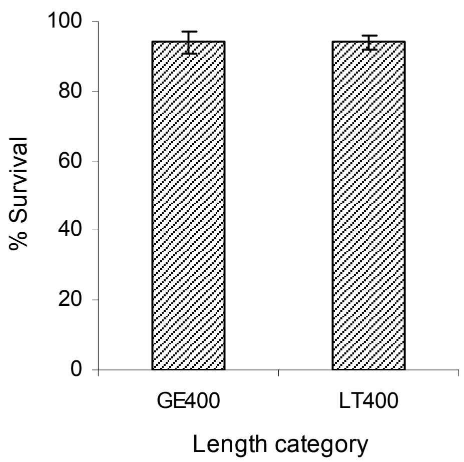


Fig. 2.17. The effect of fish size on adjusted survival rates. Fish sizes were categorised as legal (GE400) or sub-legal (LT400).

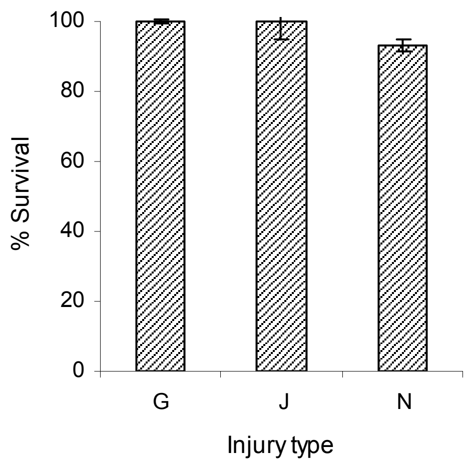


Fig. 2.18. Adjusted mean survival rates of flathead showing tissue damage injury to the gills (G), the jaw (J) and no damage (N).

Effect of hook type on catch rates

To examine whether the three basic hook types (J, circle and lure) were influential in determining catch rates of dusky flathead, we used the data set from a single catching vessel. This was the most comprehensive and reliable subset of data from this study, and it included 42% of the fish caught over the weekend. The two highly skilled and competent anglers involved were conscientious in their recording and kept close to the experimental protocols with respect to gear rotation and fishing session times.

The analysis was performed with a GLM, where fish number (per session) was the response variate with Poisson distribution and logarithmic link function, and day number (1 or 2), Ln(session time in hours) and hook type (C, J or L) the fitted terms.

None of the three explanatory variables had a significant effect ($P > 0.05$) on the numbers of fish caught per fishing session (Table 2.7). It is not surprising that time was not significant, as there was little contrast in the session-time data (mean: 0.56 h; range: 0.50-1.25 h; $s^2 = 0.03$), and there is no *a priori* reason to suspect that the response of flathead to the different gears should be different on two successive days. After adjusting for these (non-significant) effects of time and day, the effects of hook type were still non-significant ($P = 0.5$). However examination of the adjusted means (Fig. 2.19) indicates a potential underlying trend in the data, with lures outfishing circle hooks and possibly J-hooks. Note that the estimates in this figure are derived from the adjusted mean number of fish caught at the mean Ln(time) (-0.6088) by back-transforming the time scale and converting to a more conventional ‘fish per angler hour’ measurement.

Table 2.7 Accumulated analysis of deviance (ANODE) of the effect of hook type and covariates on catch rate (numbers of fish per [approx.] 30 min session).

Source	d.f.	deviance	mean deviance	deviance ratio	approx chi pr
Day	1	0.487	0.487	0.2	0.659
LnTime	1	4.319	4.319	1.79	0.198
Hook Type	2	3.475	1.738	0.72	0.5
Residual	17	40.922	2.407		
Total	21	49.203	2.343		

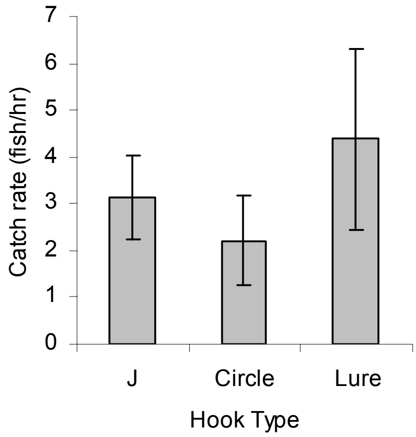


Fig. 2.19 Effect of hook type on adjusted hourly catch.

2.4 Discussion

Our experiments using dusky flathead caught by anglers in a shallow subtropical estuarine environment indicate that, at least in the short term, survival rates are quite high. The principal factor contributing to mortality was the anatomical location at which the hook was embedded: fish hooked in the throat or gut suffered greater mortality than those hooked in the lip or mouth.

The overall observed survival rate of dusky flathead over the four-day experiment was 93%, which is at the upper end of the range of survival rate estimates from a large number of studies reviewed by Muoneke and Childress (1994) and Cooke and Suski (2004). Most estimates tend to fall within a broad range from 50 to about 100%, depending on species and capture method (Cooke and Suski, 2004).

One significant difference between dusky flathead and most freshwater and marine fish species that have been the subject of hooking mortality studies (but see Kaimmer and Trumble 1996) is the absence of a hydrostatic organ or swimbladder. As ambush predators, these well-camouflaged fish spend much of the time buried just below the surface of the substrate (usually muddy sand at shallow depths), emerging with swift forays to capture passing live prey. Their lack of need for a pressure-compensating swimbladder to maintain neutral buoyancy means that the species is not susceptible to barotrauma, which is an important contributor to post-release mortality in many other species, particularly those caught in deep water (McLeay *et al*. 2002, St John and Syers 2005). For this reason the factors likely to result in mortality were assumed to be related simply to hooking damage and associated stresses due to capture and handling.

The principal objectives of this study were to estimate the short-term post-release survival rate of dusky flathead captured in a shallow-water estuarine recreational line fishery, and to determine whether there was any survival benefit in the use of circle hooks rather than traditional straight-shank baited J-hooks or lures, which have gained wide acceptance in a number of Queensland's recreational fisheries. As it is the tissue damage associated with the anatomical location of hook penetration that results in the mortality, rather than the hook design or pattern itself, we need to look first at the influence of hooking location on mortality, then see whether hook design is influential in determining where penetration is likely to occur.

Following Skomal *et al*. (2002), Millard *et al*. (2003), Conron *et al*. (2004), Broadhurst *et al*. (2005) and others we collapsed anatomical hooking location into two categorical 'depths' – shallow (lip or mouth) and deep (throat or gut) - to determine the effects of hooking location on survival. When dusky flathead were deep-hooked, adjusted survival rates were significantly lower (73%) than when shallow-hooked (96%). This is consistent with our findings for sand flathead (64% and ~100% respectively; refer Chapter 1) and for other Australian estuarine species such as small pink snapper and black bream (77-78% and 98% respectively; Conron *et al*. 2004) and yellowfin bream (<55% and 97% respectively; Broadhurst *et al*. 2005). Broadhurst *et al*. (2005) were unable to test the effect of hooking location on mortality of dusky flathead in their study in a NSW estuary because of complications relating to the unsuitability of their experimental apparatus.

Very few fish exhibited significant external injury or tissue damage that might be expected to result in mortality – in fact only four fish were recorded as having any visible injuries at all. Two of these had sustained damage to the jaw or lip, and the other two had some gill damage, but all four nevertheless survived to the end of the experiment. Because of the need to minimise the amount of time the fish were out of the water, inspection for injury was restricted to the outer surface of the fish, and did not include any examination of the interior of the mouth or outer oesophagus. It is therefore quite possible that potentially serious injuries resulting from the removal of hooks from those areas may have gone un-noticed. Thus it appears that in this flathead species, at least, categorisation of observed injury is of limited value in predicting likely survival.

Given that so few instances of tissue damage were observed, it is not surprising that the number of fish exhibiting even slight bleeding was also low, or that there was a strong association ($P < 0.001$) between the two variates. Although half of the heavily bleeding fish died, the small size of the sample ($n = 2$) meant that the test had no statistical power, and any real difference that might exist would have been obscured by the high variance. Fish categorised as showing 'slight' bleeding survived well, and because of the rather larger sample ($n = 7$) it is justifiable to conclude that they suffered no greater mortality than fish exhibiting no bleeding at all.

After accounting for other variables in the GLM, we determined that hook type *per se* had no direct measurable effect on the short-term mortality rate of dusky flathead. One of the perceived conservation benefits of circle hooks over J-hooks is that they reduce the incidence of deep hooking. Our results indicated a strong association ($P < 0.01$) between hook type and hooking location, with deep hooking being much more frequent when J-hooks were used (16%) than when alternate terminal gear such as circle hooks (4%) or lures (2%) were used. Based on odd ratios (Quinn and Keough 2002), J-hooks were over four times more likely to result in potentially damaging (possibly lethal) gut-hooking than circle hooks, and over ten times more likely than lures. The reduced deep hooking rate for circle hooks compared to J-hooks is consistent with results relating to a range of species including juvenile Atlantic salmon (Skomal *et al*. 2002), red drum (Aguilar *et al*. 2002), striped bass (Lukacovic and Uphoff 2002; Millard *et al*. 2003), largemouth bass (Cooke *et al*. 2003c), grouper (Bacheler and Buckel 2004), and sand flathead (Chapter 1). It should be noted however that in studies on summer flounder (Zimmerman and Bochenek 2002) and yellowfin tuna (Falterman and Graves 2002) there was no significant difference between circle and J-hooks in either critical (deep) hooking location or post-release mortality. We did not observe the eye damage from circle-hooks reported for small bluegills by Cooke *et al*. (2003b), possibly because of the relatively large size of the flathead caught compared to the size of the hooks. Because the deep hooking rates were so low in our study, the direct impact of hook type on post-release mortality rate could not be estimated with any statistical reliability.

Relatively few studies have investigated the effects of major differences in terminal rigs – e.g. artificial lures vs. baited hooks – and the results are not entirely consistent. Bartholomew and Bohnsack (2005) reviewed six studies which reported higher post-release mortality rates in fish caught on natural baited hooks than lures or flies (e.g. Diggles and Ernst, 1997; Diodati and Richards, 1996; Wilde *et al*., 2000), but there were also four where no mortality rate differences were observed. Our results indicate that while lures *per se* are not the cause of reduced post-release mortality rates in dusky flathead, the advantage with this type of terminal rig lies in the fact that it causes far less deep hooking, which is the critical mortality-related factor (refer also Chapter 3).

Besides hooking location, the only other factor significantly implicated at the 95% confidence level in the survival of dusky flathead was 'surface interval' – the time period between capture and placement of the fish in the experimental tanks. During this period the fish were kept on board the catching boats in small holding tanks that varied in capacity, structure and water flow characteristics. In the circumstances of our experiment the holding times were much greater than would be expected under a typical catch-and-release scenario, even when the fish are kept on board prior to tagging. We considered it important to take this and other possible experimental artefacts into consideration, to compensate for the fact that we were unable to obtain control fish that had not been subjected to some form of capture stress or other. The importance of using controls in these sorts of experiments has been highlighted by Wilde *et al*. (2003), but the complications that can arise from using fish that have been caught by other methods, and may be subject to all sorts of different injuries and stresses, are equally clear from studies such as Broadhurst *et al*. (2005) and our findings for sand flathead (Chapter 1).

As might be expected, the shorter the period during which the fish was held in the catching vessel's tank, the more likely it was to survive. There was little difference in adjusted survival rates (~97%) between surface time categories of <30 min and 30-60 min, but at longer intervals (>1 h) there was a significant drop in adjusted survival to around 85%. It is likely that the negative effect of extended surface times on survival was manifest through increased water temperature and reduced oxygen in the holding tanks, although these variables were not monitored. Broadhurst *et al*. (2005) reported that extended confinement in the holding tank significantly reduced the survival prospects of trevally. No similar effect was observed in pink snapper or bream, although data for the latter species did exhibit a trend in the expected direction.

After accounting for the effect of surface interval, other potential experimental artefacts that we examined appeared to have no significant effect on survival rates. These factors included experimental tank, the capacity of the catching vessel's holding tank, and whether or not the tank had a circulation system to stabilise water temperature and maintain high oxygen levels.

As pointed out by Cooke and Suski (2004), for a new type of hook or terminal rig to gain acceptance among anglers, it must not only be shown to have superior conservation value, but must also perform at least as well as conventional gear. Although our study did not establish a significant direct link between hook pattern and survival of dusky flathead, both circle hooks and lures did result in significantly lower deep hooking rates than J-hooks, and deep-hooked fish did exhibit significantly poorer survival prospects than those hooked in the lip or mouth.

High variability in the small data set probably obscured any real effect of hook type on catch rate, although differences between the adjusted means suggested that the performance of lures probably exceeded that of circle hooks. The difference in catch rate adjusted means between circle and J-hooks was smaller, and of interest in the fact that the model predicted a lower catch rate for circle than J-hooks. In a review of 18 studies that assessed the capture efficiency of circle vs. conventional hooks, Cooke and Suski (2004) found that nearly half (48%) rated circle hooks equally efficient as conventional hooks. In 42% of the studies circle hooks were rated as less efficient, while in only 10% were they found to be more efficient.

In our study it is probable that the observed differences may even have been artificially increased by angler skill. In Queensland there has been a substantial trend amongst recreational anglers in recent years towards the use of lures, in particular soft-bodied devices commonly referred to as 'soft plastics' which are readily available in a wide variety of shapes and sizes. Many tag-and-release anglers have adopted these lures, partly because of the lack of need to carry baits, and also because of anecdotal reports on their effectiveness. Many of the anglers involved in our experiment were very proficient lure-fishers, and it became apparent that they preferred to use lures over baited hooks, whether the traditional J-style or circle pattern. As different fishing techniques are required in using soft plastic lures and circle hooks to maximum effect, it is possible that the lure-orientation of our anglers contributed to the (apparent) high catch rates from this type of terminal rig. The fact that, to be effective, lures have to be continually 'worked' with a taut line is no doubt a major contributor to the low deep hooking rates observed with this gear (refer also Chapter 3).

High survival rates for dusky flathead indicate that the species is robust and, in the short term at least, well able to survive the stresses of capture by current angling methods. Therefore, management strategies based on size and bag limits and promotion of catch-and-release fishing for dusky flathead would appear to be well founded. Furthermore, adoption of circle hooks or lures by the recreational fishery would enhance the survival of dusky flathead and contribute to the sustainability of the east coast flathead stock.

CHAPTER 3: DEEP HOOKING AND POTENTIAL EFFECTS FISHING WITH BAIT AND LURES ON POST-RELEASE SURVIVAL IN FLATHEAD

Jeremy Lyle, Ian Brown, David Mayer, Natalie Moltschaniwskyj and Bill Sawynok

3.1 Introduction

In the preceding chapters we have examined post-release survival in sand and dusky flathead and the potential benefits of circle hooks over conventional hook patterns. Survival experiments clearly established the significance of hooking location in the subsequent survival of released flathead, with deep hooking and associated damage to critical organs, representing the main mortality risk. Limited information presented in Chapter 2 indicated that hook type (J-style, circle or lure) was not a significant factor in the survival of dusky flathead, with survival rates of between 92-95% for each of the hook types. In recent years the use of lures, especially soft plastics, for flathead has been widely promoted in the recreational media and their use is believed to have grown dramatically, highlighting the need to consider the impacts of this development when assessing post-release survival in flathead.

The National Recreational Fishing Survey (National Survey) established the importance of line fishing for flathead (Henry and Lyle 2003). Although species of flathead was not routinely specified (with the exception of Tasmania), catches can be further disaggregated into those taken by bait or lure fishing. Given our focus on sand and dusky flathead, data were re-assessed to include only catches taken in estuarine and inshore coastal waters, the primary habitat for these species. Furthermore, only catches from southeastern Queensland (south of Gladstone) were included, reducing the likelihood that tropical flathead species may have been involved. This analysis confirmed the importance of bait fishing which accounted for over 85% (up to 98% in Victoria) of the flathead catch (numbers kept and released) in each state (Table 3.1). Lures contributed less than 5% of the catch in each state apart from Queensland, where lures accounted for about 9% of numbers. As some fishing trips involve both bait and lure fishing it was not possible to attribute catches by method. Such trips typically accounted for less than about 5% of the total state catches, Tasmania being the exception where over 10% of the flathead catch fell into this category. Since the completion of the National Survey in 2001, however, the use of lures is believed to have grown dramatically, particularly in New South Wales and Queensland. There are no contemporary data available to indicate how the relative catch proportions may have changed based on method but it is likely that there has been a significant shift to lures.

Table 3.1 Estimated recreational flathead catch (kept and released) during 2000/01 taken by line fishing in estuarine and inshore waters off eastern Australia, indicating the proportions taken by fishing method (based on National Survey data).
* based on reported sand flathead catches. ** restricted to catches taken from south-east Queensland (south of Gladstone)

	State			
	Tasmania*	Victoria	NSW	Queensland**
% by method				
Bait	85.9	97.8	90.5	87.3
Lure	3.2	0.3	4.6	9.3
Bait/lure	10.9	1.9	5.0	3.4
Total catch (no.)	1,723,054	5,847,985	4,103,410	645,903

In this chapter we seek to extend the consideration of post-release survival to the general recreational fishery by linking experimental and fishery data to assess the potential impacts of bait and lure fishing on post-release survival in sand and dusky flathead.

3.2 Methods

3.2.1 Data sources

Four data sources were available to assess the relationships between fishing method, fish size and hooking location (deep or shallow-hooked) in flathead. As outlined in Chapter 1, volunteer anglers in Tasmania completed a fishing diary that provided information about fish length, fishing method (bait or lure), hook type, hook size, and hooking site (lip, mouth, eye, throat, gut and foul hooked). Diarists were encouraged to report details for their entire catch or at least systematically sub-sample catches to avoid potential biases in the selection of fish. Only sand flathead were captured by Tasmanian diarists. Twenty-two diarists reported hooking details for flathead, four of whom accounted for 56% of the total sample, with information collected between December 2004 and January 2006.

The Victorian Department of Primary Industries has established an angler diary program (Conron and Bridge 2004) that provided information about sand and dusky flathead catches from that state. Details reported include fishing method and tackle used, hooking site (lip/mouth, throat, gut, and foul hooked) and fish length. Fifteen anglers reported capture details for flathead between February 2002 and November 2005, with one fisher accounting for 55% of the sand flathead sample and a different fisher 90% of the dusky flathead.

Australian National Sportfishing Association (ANSA) volunteers in New South Wales and Queensland provided information about dusky flathead catches including fish size, fishing method, hook type and size, and hooking site (consistent with categories used in the Tasmanian diary). Data for Queensland was derived from the Suntag tagging database and involved reports from 118 fishers, although just three anglers captured 70% of the total sample. Queensland data was available for the period August 2000 to

November 2005 and related solely to flathead that were tagged and released. In NSW, information was collected specifically in support of the current project, with data available between November 2004 and February 2006 and included details from one fishing competition.

3.2.2 Data analysis

For the purpose of data analysis, hooking sites were grouped into two hooking locations, 'shallow' (lip, mouth, eye and foul hooked) or 'deep' (throat and gut) hooked. Several data elements were not consistently reported by anglers across the entire dataset, namely bleeding, hook type and hook size and thus these potential factors were not included in subsequent analyses. Species (sand or dusky), hooking location (deep or shallow), fishing method (bait, soft plastic lure, hard body lure) and fish length were available from each data source. Based on size, sand flathead were grouped into two size groups, < 30 cm and ≥ 30 cm, whereas three size groups were recognised for dusky flathead, namely < 40 cm, 40-49 cm and ≥ 50 cm.

A binomial generalised linear model (GLM) with logit link (McCullagh and Nelder 1989) was used to examine effects of fishing method, data source (state), and fish size on hooking location for sand flathead and dusky flathead separately (GenStat 2005). Method was fitted first, then step forward selection of main effects was employed. Interactions were tested for significance but were removed because of non-significance, the exception being two-way interactions that involved significant main effects. Pair-wise significance testing using Student's *t*-test was undertaken to compare probabilities (adjusted means) of deep hooking for the significant factors.

Odds ratios were also examined to interpret the lack of independence among selected factors (Quinn and Keough 2002).

3.3 Results

3.3.1 Sand flathead

General

Hooking details for 1656 sand flathead were provided by diarists in Tasmania and Victoria, 90% of which were taken by bait fishing, with soft plastic lures accounting for the remainder (Table 3.2). A wide range of sizes was represented, with between 40 - 46% of the samples (by state and method) less than 30 cm. Size compositions were unimodal, with modes and means at around 30 cm (Fig. 3.1). There were, however, significant differences between distributions for the bait-caught samples (Kolmogorov-Smirnov two-sample test, $Z = 1.762$, $P = 0.004$) and within the Tasmanian sample based on method (K-S test, $Z = 1.295$, $P = 0.070$). Such differences presumably reflect the influence of a range of factors including gear selectivity, fisher behaviour and population structure (i.e. size availability, particularly relevant for the comparison between states).

Table 3.2 Diary samples by method and state for sand flathead with proportions of deep-hooked. Values in parenthesis represent number of deep-hooked flathead.

		< 30 cm		≥30 cm		Total	
Method	**State**	No.	% deep-hooked	No.	% deep-hooked	No.	% deep-hooked
Bait	TAS	514 (16)	3.1	612 (35)	5.7	1126 (51)	4.5
	VIC	155 (28)	18.1	209 (62)	29.7	364 (90)	24.7
Soft plastic	TAS	66 (4)	6.1	100 (1)	1.0	166 (5)	3.0

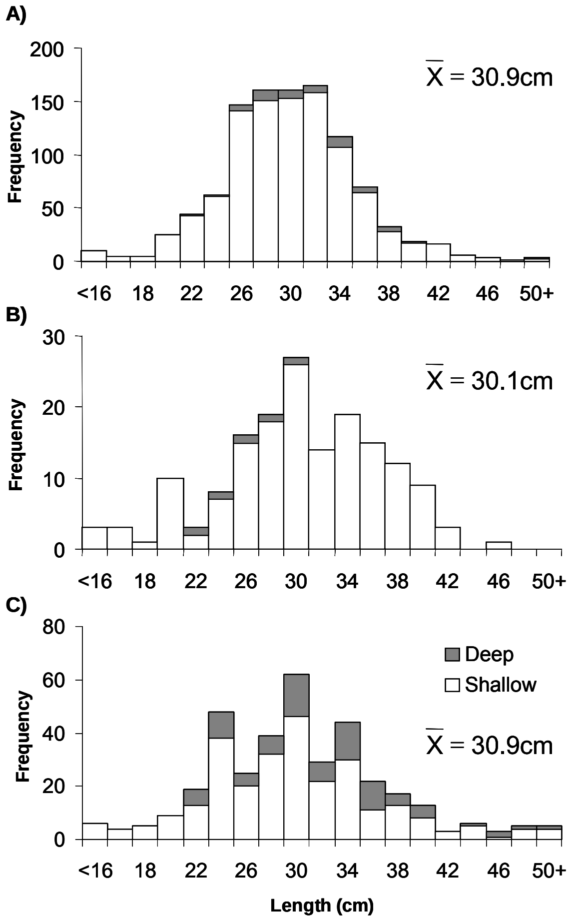


Fig. 3.1 Sand flathead length frequency distributions (2 cm size groups) based on diary data, indicating numbers of deep and shallow-hooked fish. A) Tasmanian bait-caught fish, B) Tasmanian lure-caught fish, and C) Victorian bait-caught fish.

Factors influencing deep hooking

Deep hooking rates were typically below 6% for bait and lure fishing methods in the Tasmanian samples but were up to 30% in the Victorian bait-caught sample (Table 3.2).

The GLM analysis investigating factors influencing the rate of deep hooking identified method, size group, and state as significant main effects (Table 3.3). The method×size group interaction was also significant, indicating that these two factors do not act independently. Mean deep hooking rates (± s.e.) adjusted for all other terms in the model were significantly greater for bait, 8.9 ± 0.7% compared with 6.3 ± 2.5% for lure-caught flathead, and increased with fish size, from 6.9 ± 0.9% for fish <30 cm to 10.1 ± 0.9% for the ≥ 30 cm size group. This latter relationship was particularly influenced by the interaction between method (specifically bait fishing) and size group. The adjusted mean deep hooking rate for bait capture increased with size group from 6.4 ± 0.9% to 11.0 ± 1.0% whereas for lures, despite a decline in deep hooking from 11.5 ± 4.9% to 2.2 ± 2.0% with size, the size effect was non-significant.

The significantly higher deep hooking rate for Victoria (23.8 ± 2.3%) compared with Tasmania (4.4 ± 0.6%) implies that factors other than method and size influenced the probability of deep hooking. One such factor may have been fishing practice, specifically targeted as opposed to non-targeted fishing effort. In Tasmania, volunteer anglers were specifically requested to record catch details for trips when fishing for flathead and therefore hook types and sizes used were appropriate for the target species. By contrast, the Victorian angler diary is a general fishing diary and, based on reported targeting, the majority (79%) of the sand flathead recorded were captured whilst targeting other species, in particular King George whiting. Small, long shank hooks (sizes 4-6) are typically used for King George whiting (Simon Conron, PIRVic pers. comm.) and not unexpectedly the deep hooking rate for these hooks was higher (28%, *n* = 194) than when larger hook sizes (1/0 and greater) were used (21%, *n* = 170).

For Tasmania, the odds of deep hooking in sand flathead were even for bait and lure fishing, indicating that there would be little advantage to reducing deep hooking rates through the use of lures in place of bait (largely due to low deep hooking rates for both methods).

Table 3.3 Accumulated analysis of deviance for GLM investigating factors that influence deep hooking in sand flathead

Source	d.f.	Deviance	Mean deviance	**Approx.** P (χ^2)
Method	1	9.890	9.890	0.002
Size group	1	9.365	9.365	0.002
State	1	109.609	109.609	<.001
Method×Size group	1	6.266	6.266	0.012
Size group×State	1	0.001	0.001	0.974
Residual	1650	852.739	0.517	
Total	1655	987.870	0.597	

3.3.2 Dusky Flathead

General

Hooking details for 3461 dusky flathead were available, with soft plastic lures accounting for 70%, hard body lures a further 12%, and just 18% were taken by bait fishing (Table 3.4). Fish smaller than 40 cm dominated the overall sample (52%), followed by the intermediate size group (31%) and the largest size group (17%). Size compositions exhibited considerable variability between methods and states (Fig. 3.2), with significant differences between states for each two-way comparison of fishing method (Table 3.5). In addition, with the exception of bait and hard-body lures (Queensland), within state length frequency distribution comparisons were also significantly different based on method. Mean lengths ranged between 38 and 48 cm, with individual fish of over 90 cm reported. While it is unclear whether size compositions are representative of the recreational catches, it is assumed that deep hooking rates relative to fishing method, region and fish size are representative.

Table 3.4 Numbers of dusky flathead by size group and state and method and gear type.
Values in parentheses represent number deep-hooked.

		<40 cm		**40-49 cm**		**≥ 50 cm**		**Total**	
Method	**State**	No.	% deep-hooked	No.	% deep-hooked	No.	% deep-hooked	No.	% deep-hooked
Bait	VIC	176 (13)	7.4	68 (0)	0.0	22 (2)	9.1	266 (15)	5.6
	NSW	44 (7)	15.9	84 (3)	3.6	26 (0)	0	154 (10)	6.5
	QLD	93 (26)	28.0	67 (28)	41.8	35 (15)	42.9	195 (69)	35.4
Soft plastic	VIC	5 (0)	0	7 (0)	0	3 (0)	0	15 (0)	0
	NSW	152 (3)	2.0	245 (17)	6.9	242 (29)	12.0	639 (49)	7.7
	QLD	1135 (25)	2.2	453 (24)	5.3	191 (7)	3.7	1779 (56)	3.1
Hard body	QLD	187 (4)	2.1	147 (7)	4.8	79 (4)	5.1	413 (15)	3.6

Table 3.5 Comparison of dusky flathead length frequency distributions by method and state, based on the Kolmogorov-Smirnov test

Factors	Comparison	*Z*-score	*P*
Method			
Soft plastic	QLD v NSW	8.990	<0.0001
Bait	QLD v NSW	1.774	0.004
	NSW v VIC	2.173	<0.0001
	QLD v VIC	3.713	<0.0001
State			
NSW	Soft plastic v Bait	2.354	<0.0001
QLD	Hard body v Soft Plastic	3.409	<0.0001
	Soft plastic v Bait	2.322	<0.0001
	Hard body v Bait	0.821	0.510

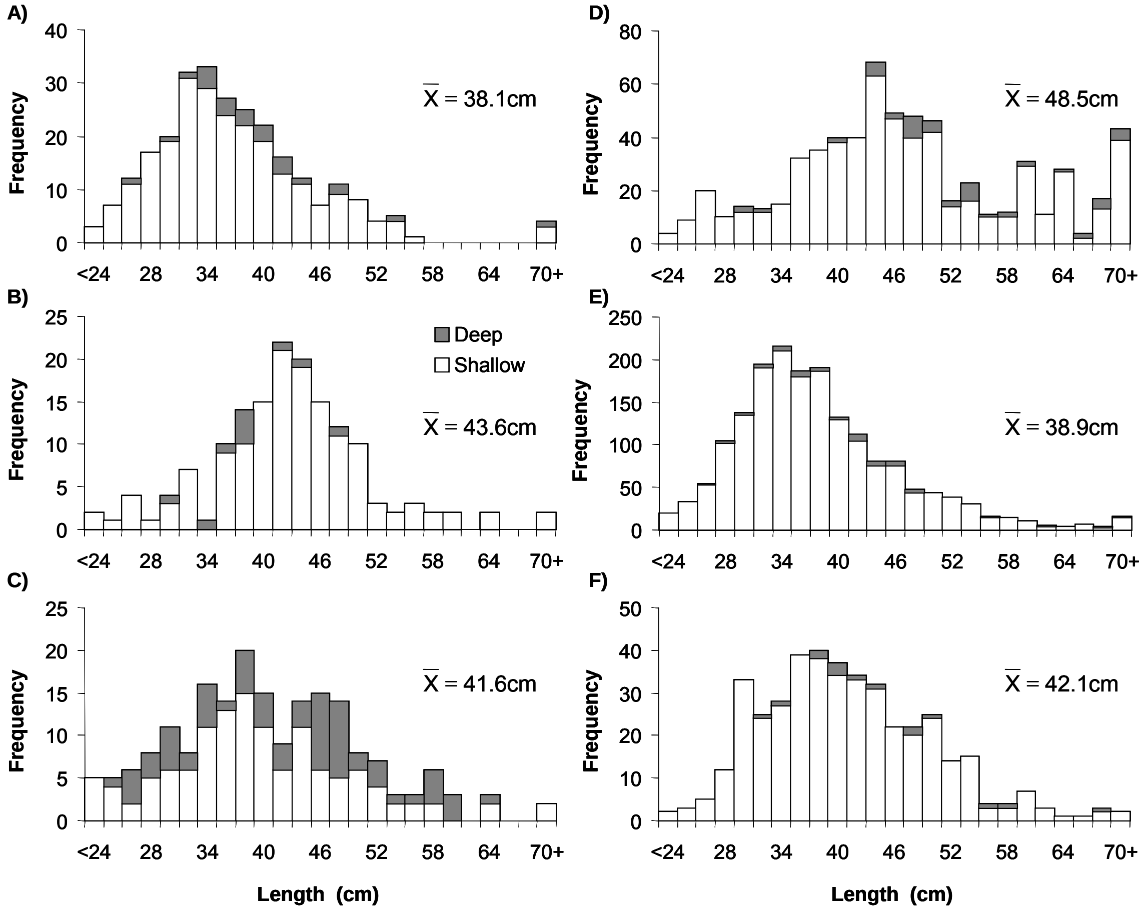


Fig. 3.2 Dusky flathead length frequency distributions (2 cm size groups) based on diary data, indicating numbers of deep and shallow-hooked fish. Bait-caught samples for A) Victoria, B) New South Wales, and C) Queensland; soft-plastic lure samples for D) New South Wales, and E) Queensland; and hard-body lure sample for F) Queensland.

Factors influencing deep hooking

The combined model incorporating the diary information for dusky flathead revealed that deep hooking was highly dependent on fishing method, size group, and state (Table 3.6). In addition, interactions between method and size group and method and state were significant, indicating that the main effects do not act independently. The adjusted mean deep hooking rate for bait-capture (26.6 ± 2.4%) was significantly higher than for either hard body (3.4 ± 0.9%) or soft plastic lures (3.9 ± 0.4%), which in turn did not differ significantly (*t*-test, $P = 0.05$). A significantly lower rate of deep hooking (6.4 ± 0.7%) for the smallest size group (< 40 cm), compared with either of the two larger size groups, was responsible for the size group effect; there was no difference in the deep hooking rate between the two larger size groups (9.8 ± 1.0% for 40-49 cm, and 9.9 ± 1.4% for ≥ 50 cm). Deep hooking rates were significantly different between states, being highest for the Queensland sample (9.1 ± 0.7%), intermediate for New South Wales (6.3 ± 1.0%), and lowest for Victoria (2.0 ± 0.6%).

Adjusted means for the significant interaction terms are summarised in Table 3.7 and provide insight into the underlying relationships influencing the observed main effects. For instance, the size effect was largely influenced by data for soft plastic lures. While there were no significant size effects for bait or hard body lures, deep hooking rates were significantly lower for soft plastics in the < 40 cm size group compared with either of the two larger size groups. The Queensland bait-caught sample had significantly higher deep hooking rates than either of the NSW or Victorian samples, differences were non-significant for the latter two groups. A deep hooking rate of about one in three bait-caught flathead in the Queensland sample clearly exerted a strong influence on the observed method and state main effects. Deep hooking rates for soft plastic lures differed significantly between states, the highest rate for the NSW sample. The particularly low rate for Victoria was based on a very small sample size and may not be reliable.

The reason for such a high deep hooking rate for bait fishing in Queensland is difficult to explain, especially since the Suntag database is based on fish that have been tagged and released. If anything, it would be expected that deep-hooked fish would have been under-represented since such fish are less likely to survive. Contrary to the situation for sand flathead, the majority (73%) of the bait-caught dusky flathead in the Victorian sample were taken as a target species and this presumably contributed to the substantially lower deep hooking rate for dusky flathead.

Table 3.6 Accumulated analysis of deviance for GLM investigating factors that influence deep hooking in dusky flathead

Source	d.f.	Deviance	Mean deviance	**Approx.** P (χ^2)
Method	2	104.185	52.093	<.001
Size group	2	30.501	15.250	<.001
State	2	19.085	9.542	<.001
Method×Size group	4	14.829	3.707	0.005
Method×State	2	48.652	24.326	<.001
Size group×State	4	4.477	1.119	0.345
Residual	3444	1432.580	0.416	
Total	3460	1654.308	0.478	

Table 3.7 Adjusted mean and standard error (se) deep hooking rates (%) for method and size group and method and state interactions.

	Bait		**Soft plastic lure**		**Hard body lure**	
	Adjusted mean	se	Adjusted mean	se.	Adjusted mean	se.
Size group						
< 40 cm	24.3	3.5	2.3	0.5	2.1	1.1
40-49 cm	29.7	4.1	5.3	0.8	4.8	1.8
≥ 50 cm	27.8	5.7	5.9	1.1	5.1	2.5
State						
VIC	9.5	1.9	0.1	0.5	-	-
NSW	7.1	2.3	6.2	1.0	-	-
QLD	35.1	3.4	3.5	0.5	3.5	0.9

Based on data for Queensland, the odds of deep hooking for dusky flathead were 16.8 (95%CI 11.3-25.0) and 15.5 (95%CI 8.0-26.3) times greater for bait compared with soft plastic or hard body lures, respectively. In NSW, the odds of deep hooking were also significantly higher for bait as opposed to soft plastic lures but only in the smallest size group (< 40 cm), where the odds were 9.4 (95%CI 2.3-38.1) times higher for bait.

3.4 Discussion

Fishing with lures resulted in significantly lower deep hooking rates than for bait in both flathead species. Previous studies comparing survival for bait and lure fishing methods have demonstrated that, depending on the species in question, bait fishing either results in survival rates that are equivalent to or lower than for lures (reviewed by Muoneke and Childress 1994, Bartholomew and Bohnsack 2005). Lower survival rates for bait fishing are typically the result of higher deep hooking rates. The only other Australian study that has compared survival rates for bait and lures is that of Diggles and Ernst (1997). They found higher survival rates were associated with lures (~99%) compared with bait (~95%) for wire netting cod and yellow stripey, the difference being linked to higher rate of deep hooking in bait caught fish.

The relationship between survival and fish size has been found to be variable and apparently species specific (Muoneke and Childress 1994, Bartholomew and Bohnsack 2005). Survival in brook trout (Nuhfer and Alexander 1992) and red drum (Childress 1989 [cited in Muoneke and Childress 1994] has been found to decrease with size, for black sea bass (Bugley and Shepherd 1991) and Chinook salmon (Wertheimer 1988) survival was positively correlated with size, whereas in striped bass (Nelson 1998), rainbow trout (Schisler and Bergersen 1996), blue cod (Carbines 1999), and common snook (Taylor *et al*. 2001) there was no relationship between survival and size. For flathead, size was identified as a significant factor in determining deep hooking rates, being lowest in the smallest (effectively sub-legal) size groups. The higher rate of deep hooking in the larger size groups is presumably a morphological response, with larger fish more capable of swallowing hooks. Behaviourally, being an ambush predator it is also possible that larger flathead may be more aggressive than smaller individuals when attacking bait or lures. Ayvazian *et al*. (2002) for tailor and Conron *et al*. (2004) for black bream, also found that deep hooking rates increased with fish size, although the relationship only held when small hook sizes were used for tailor. In contrast to black bream, Conron *et al*. (2004) reported no deep hooking size effect for pink snapper, which given the morphological similarity between black bream and pink snapper was perhaps unexpected.

For both flathead species, logistic models revealed significant state effects and interactions between method and size group, influenced to some extent by unbalanced sample sizes but also differences in deep hooking rates between methods and states. For instance, the deep hooking rates for bait increased with size group for sand flathead whereas there was no significant size effect for lures. For dusky flathead, although deep hooking rates did increase between the smallest size group (<40 cm) and the two larger groups for each of the fishing methods, differences were only significant for soft plastic lures. Considering raw data for bait fishing, deep hooking rates increased from around 28% for the smallest size group to about 42% in the two larger size groups in the Queensland sample. By contrast, deep hooking rates effectively declined in the larger size groups for bait caught samples from NSW and Victoria. For dusky flathead, there was also a significant method×state interaction, with significantly higher deep hooking rates in Queensland for bait fishing (there was no difference for Victoria and NSW) as well as significant differences for soft plastic lures between each of the states.

State, acting as either a main or interaction effect, indicates that factors other than method and fish size also influenced deep hooking. Other factors that could influence deep hooking include hook size, bait, and fishing mode (i.e. active or passive fishing). The use of small hooks has been shown to increase the probability of deep hooking when compared with larger hooks in a number of species, including black sea bass (Bugley and Shepherd 1991), blue cod (Carbines 1999), tailor (Ayvazian *et al*. 2002), and black bream (Conron *et al.* 2004). Bait type was identified as a significant mortality factor in sand whiting (Butcher *et al*. 2006), with higher mortality rates arising from capture on beach worms (soft bait) than yabbies. Studies on rainbow trout (Schill 1996, Schisler and Bergersen 1996,) and black bream (Conron *et al*. 2004) demonstrated that deep hooking rates were higher when the bait was fished passively rather than actively. Note passive (slack-line) fishing relates exclusively to bait fishing, lures by contrast need to be worked actively to be effective.

The particularly high deep hooking rate for sand flathead in Victoria appears to be related to the use of small hooks to target species other than dusky flathead (e.g. King George whiting). Reasons for the very high deep hooking rates for bait-caught dusky flathead in Queensland are less obvious, although a wide range of hook sizes was used, implying that at least some flathead may have been taken as non-target species. Notwithstanding this, the high rate of deep hooking is unexpected since the Queensland data relate solely to fish that were tagged and released and in this regard any potential bias would be towards under-reporting of deep hook fish (based on the assumption that such fish would be in poorer condition). By comparison, deep hooking rates for bait-caught dusky flathead in the Queensland PRS trial (Chapter 2, 4.5-15.9% depending on hook type) were substantially lower and more consistent with rates for bait capture in NSW (7.1%) and Victoria (9.5%), implying that the Queensland angler data for bait-capture may not be representative of the general fishery.

By integrating experimentally determined survival rates with hooking information derived from anglers, the potential impact of catch and release, regardless of reason for release, on survival can be estimated (e.g. Conron *et al*. 2004, Lindsay *et al*. 2004). This analysis is based on three key assumptions: firstly that the relationship between survival and hooking location is not influenced by hook type or gear used; secondly that the relative distribution of hook locations are representative (by method, region, etc); and thirdly that fish handling practices in the general fishery do not differ substantially to those applied in the survival experiments. In relation to the first assumption we have no empirical data to test its validity and there have been few such attempts in the literature. As suggested above, it is likely that at least some hooking data may not be representative and should be considered indicative only. Finally, survival experiments involved additional handling of the catch (including on board holding) that may in fact have resulted in additional stresses over those experienced in a typical catch and release situation. Despite such uncertainties, estimated survival rates exceeded 94% or, conversely, mortality rates were less than about 6% for most method/state combinations for the two flathead species (Table 3.8). Notable exceptions were the bait-capture of sand flathead in Victoria (91%) and dusky flathead in Queensland (88%). The lower survival rate in the former instance appears to be influenced by non-targeted fishing activity whereas in the latter the data may simply not be representative. Consistency between survival estimates for bait-caught dusky flathead in Victoria and NSW, and the rate (just under 94%) implied from deep hooking data for the bait caught sample in the PRS experiment (Chapter 2) lend support to this conclusion.

Table 3.8 Proportion of the sample and survival rate for deep and shallow-hooked flathead with overall predicted survival rate by method and state.

	Method	Deep-hooked Proportion (%)	Deep-hooked Survival (%)	Shallow-hooked Proportion (%)	Shallow-hooked Survival (%)	Predicted Survival rate (%)
Sand flathead						
TAS	Bait	4.5	64.0	95.5	99.7	98.1
	Lure	3.0	64.0	97.0	99.7	98.6
VIC	Bait	24.7	64.0	75.3	99.7	90.9
Dusky flathead						
VIC	Bait	5.6	73.3	94.4	95.6	94.4
NSW	Bait	6.5	73.3	93.5	95.6	94.2
	Soft plastic	7.7	73.3	92.3	95.6	93.9
QLD	Bait	35.4	73.3	64.6	95.6	87.7
	Soft plastic	3.1	73.3	96.9	95.6	94.9
	Hard body	3.6	73.3	96.4	95.6	94.8

As interest in catch and release will undoubtedly continue to grow in Australia, so to will the proportion of the recreational catch that is released, a general phenomenon that has been documented over a two decade period in the United States (Bartholomew and Bohnsack 2005). Overall our results indicate that sand and dusky flathead are resilient to the stresses of capture and that survival rates are high, supporting both the efficacy of current management strategies based on size and bag limits and also the practice of catch-and-release fishing. In a meta-analysis of hooking mortality studies, Bartholomew and Bohnsack (2005) reported that the median mortality rate was 11% (equivalent to a survival rate of 89%), which places sand and dusky flathead at the lower end of the mortality distribution and on par with several other species inhabiting similar marine habitats in Australia with survival rates exceeding 90% (e.g. tailor, Ayvazian *et al*. 2002; King George whiting, Kumar *et al.* 1995; sand whiting, Butcher *et al*. 2006; black bream and pink snapper, Conron *et al.* 2004).

Probably the most significant current development in the recreational fishery for flathead is the switch from bait to lures, especially for dusky flathead. Our data suggest that lures will provide positive benefits in terms of improved survival potential, a benefit that could, however, be eroded if catches increased substantially as a result of the alleged improved catching efficiency conferred by lures. A similar outcome for survival at least could also be achieved amongst bait-users if anglers were to adopt circle hooks in place of conventional hook patterns.

BENEFITS

Our assessment of post-release survival for the key recreational flathead species has confirmed the efficacy of management strategies that require flathead to be released (size and bag limits), along with the potential benefits of catch-and-release fishing. Furthermore, this study contributes to a more comprehensive assessment of fishery-induced mortality, by identifying the potential impacts of post-release mortality.

Circle hooks provide a conservation benefit (reduced deep hooking) over conventional hooks and, for sand flathead in particular, are equally efficient as conventional hook patterns in terms of catch rates. This knowledge should provide a firm basis for the uptake of these hooks by recreational fishers.

The study also offered insight into the impacts on post-release survival of the recent shift from bait to lures for flathead, particularly for dusky flathead. The use of lures characteristically resulted in lower rates of deep hooking compared with bait fishing, suggesting that this development would result in improved survival opportunities for those fish that are released.

FURTHER DEVELOPMENT

An important area for further development relates to describing recreational fishing practices, including tackle used (hook types and sizes, bait and lure types) and fish handling practices. Such information would need to be collected through on-site surveys. Uncertainty surrounding how representative the Queensland bait fishing data were and apparent impacts of non-targeted fishing identified in the Victorian sand flathead data highlight this need. In addition, it is noteworthy than the vast majority of the hook location information was derived from boat fishing. Shore-based fishing is, however, important in Queensland and NSW (39 and 15% of flathead numbers, respectively, National Recreational Fishing Survey), and it is possible that fishing practices may differ sufficiently (e.g. incidence of slack line fishing) to influence survival rates.

Dusky flathead grow to particularly large sizes (up to 1.2 m and 15 kg). Bag limits of one fish greater than 70 cm apply in both Victoria and NSW while a maximum size limit 70 cm applies in Queensland. Given their size it is feasible that handling stresses may be more pronounced than for the smaller size groups, related to the increased difficulty in handling such large fish. Further research into the impacts of catch and release on ‘trophy sized’ fish is warranted.

The focus of this study was on short-term survival. There is scope to examine sub-lethal and longer-term impacts of capture and release in flathead, including effects on growth and reproductive capacity.

PLANNED OUTCOMES

Planned outcomes include changes to fishing behaviour of recreational fishers through the adoption of fishing gear and handling practices that maximise survival of released flathead, thus reducing typically unaccounted fishing mortality.

The primary beneficiaries of this research will be recreational fishers in that the project will contribute to sustainable resource utilization. Resource managers will also benefit through improved knowledge regarding the impacts and effectiveness of size and bag limit regulations on flathead stocks.

CONCLUSION

The principal objectives of this study were to estimate the short-term post-release survival rates for sand and dusky flathead, and to determine whether there was any survival benefit in the use of circle hooks rather than conventional hook patterns. Recognising the increasing uptake of lures (especially soft plastics) for flathead, the potential impacts of their use on post-release survival were also assessed. Using the results of this research we have been able to develop protocols that can be readily applied by recreational fishers to maximise the survival of flathead in general.

The study approach was to undertake survival experiments in which flathead (sand flathead in Tasmania and dusky flathead in southern Queensland) were captured by angling and then held in aquaria for short periods to assess survival. Key parameters recorded at the time of capture included hooking site (lip, mouth, eye, throat, gut, or foul hooked), evidence of bleeding, hook removal and fish size. Other experimental factors, such as hook type, on board holding interval and holding tank characteristics were recorded for the Queensland trials. In addition, trials comparing catch rates and hooking locations for a range of hook types were undertaken for sand flathead. Volunteer anglers also provided hooking location information for sand and dusky flathead captured using bait and lure fishing techniques. By integrating experimentally determined survival information with hooking information derived from anglers, the potential impact of catch and release on the survival in flathead was assessed.

Anatomical hooking location was determined to be the major factor contributing to mortality in flathead. Fish hooked in the throat or gut (deep-hooked) suffered greater mortality than those hooked in the lip or mouth (shallow-hooked). The short-term survival rate for shallow-hooked fish was 99.7% for sand flathead and 96% for dusky flathead, whereas survival rates for deep-hooked fish were significantly lower, around 64% for sand flathead and 73% for dusky flathead.

Mortality in deep-hooked fish was generally associated with injuries to vital organs (gills, pericardium, liver) and survival was lower if bleeding was associated with the hooking injury. For sand flathead the odds of survival for deep-hooked fish were 8 timers greater for non-bleeders. Data for dusky flathead were limited but also exhibited a trend towards lower survival rates in bleeders.

Cutting line rather than removing the hook can increase survivorship in deep-hooked fish. Although mean survival rates of deep-hooked sand flathead were higher for hook left in (81%) than for hook removed (60%), differences were not significant, reflecting the small sample sizes involved. Very limited data were available for dusky flathead so the impact of cutting the line on survival could not be assessed reliably. We did observe evidence that some survivors (both species) expelled hooks within a short time after capture.

Besides hooking location, the only other factor significantly implicated in the survival of dusky flathead was 'surface interval' – the time period between capture and placement of the fish in the experimental tanks. During this period the fish were kept on board the catching boats in small holding tanks that varied in capacity, structure and water flow characteristics. In the circumstances of our experiment the holding times were much greater than would be expected under a typical catch-and-release scenario and thus possibly represented an experimental artefact.

Circle hooks have been widely promoted as 'fish friendly' gear because of their tendency to result in very low rates of deep hooking. For sand flathead, our results established a significantly lower deep hooking rate (1%) for circle hooks compared with other conventional hook types (5-9%). Although our study did not establish a significant direct link between hook pattern and survival of dusky flathead, both circle hooks and lures did result in significantly lower deep hooking rates (4% and 2%, respectively) than J-hooks (16%), and deep-hooked fish did exhibit significantly poorer survival prospects than those hooked in the lip or mouth.

In order to gain acceptance from anglers it is important that circle hooks perform at least as effectively as conventional hook types in terms of catch rates. Over two fishing trials we established that circle hooks were at least as effective as conventional hook types for sand flathead. By contrast for dusky flathead, high variability in a small data set obscured any real effect of hook type on catch rate, although results suggested that the performance of lures probably exceeded that of circle hooks and J-hooks. While circle hooks proved effective for sand flathead, further trials would be required to more fully evaluate their relative efficiency for dusky flathead. Notwithstanding this observation, the apparent shift away from bait to lure fishing for dusky flathead would suggest that uptake of circle hooks for flathead may be low amongst anglers in Queensland and possibly NSW and Victoria.

Volunteer angler hooking information was available for flathead taken in Tasmania (sand flathead, bait and lure fishing), Victoria (sand flathead – bait fishing, dusky flathead – bait and lure fishing), NSW (dusky flathead – bait and lure fishing) and Queensland (dusky flathead – bait and lure fishing). Fishing with lures resulted in significantly lower deep hooking rates than for bait in both flathead species. Size was also identified as an important factor in deep hooking rates for flathead, being lowest in the smallest (effectively sub-legal) size groups. Larger fish are more likely to swallow hooks.

For both flathead species, regression models revealed significant state effects, either as a main or interaction effect, implying that factors other than method and fish size influenced deep hooking. Other potential factors include hook size and fishing mode, i.e. whether lines are fished actively or passively. Active or passive (slack-line) fishing relates exclusively to bait fishing, lures need to be actively worked to be effective. High deep hooking rates for sand flathead in Victoria (25%) appear to have been influenced by the use of small hooks targeting species other than flathead. Reasons for high deep hooking rates for bait caught dusky flathead in Queensland (35%) were less obvious but may not be representative. Deep hooking rates for bait caught dusky flathead in the Queensland post-release survival trial were substantially lower and more consistent with rates for bait capture in NSW and Victoria.

By integrating experimentally determined survival rates with hooking information derived from anglers, the potential impact of catch and release on survival was estimated. Survival rates exceeded 94% for most method/state combinations for the two flathead species. Notable exceptions were bait-capture of sand flathead in Victoria and dusky flathead in Queensland. The lower survival rate (91%) associated with the Victorian sample highlights the impact of non-targeted fishing, especially when small hooks intended for other species are employed. The low survival rate (88%) estimated for bait-caught dusky flathead in Queensland was not considered representative. Consistency between Victorian and NSW survival rate estimates for bait-caught dusky flathead, and those based on the Queensland survival experiment (all around 94%) support this conclusion.

Overall our results indicate that sand and dusky flathead are resilient to the stresses of capture and that survival rates for released fish are high, on par with several other species inhabiting similar marine habitats in Australia. High survival rates support the efficacy of management strategies based on size and bag limits and also the practice of catch-and-release fishing. The switch from bait to lures or adoption of circle hooks for flathead are likely to provide benefits for stocks, enhancing survival of released fish.

Recommendations to maximise survival of released flathead

In developing protocols that can be readily applied to maximize survival in flathead (Objective 3) we developed the information sheet "Flathead Survival" (Appendix 3) that builds on the results of this project and the "Recfish Code of Practice on Releasing Fish" (Anon 2004). In addition, the key message has been incorporated in the Tasmanian Recreational Sea Fishing Guide that is circulated widely amongst anglers.

To date copies of the information sheet have been distributed to Fishcare Volunteers (Tas), Inland Fisheries Service (Tas), ANSA (Tas), SpotOn Fishing Connection (Hobart), Department of Primary Industry (Vic), Fishcare Victoria, Port Phillip Region Fishcare Program (Vic), Drysdale Sport Fishing Club (Vic), Brentwood Secondary College (Vic), *Fishing Victoria Monthly*, Nature Conservation Council of NSW, Sunfish Angler Education (Qld), Queensland Fishing Events (Boyne Tannum Hookup and Emu Park Expo), South Australian Game Fishing Association, Western Australian Department of Fisheries, and *Fishing Australia* (Win TV). Feedback has been extremely positive, especially from Fishcare Volunteers, who have been distributing the information sheet to anglers.

Key messages

Survival

- Flathead are a robust species and if hooked in the jaw have a very good chance of survival if released.
- Survival is lower if fish are hooked in the gills or gut and particularly if deep hooking is associated with bleeding.
- For gut-hooked fish, cutting the line and not removing the hook improves the likelihood of survival. Flathead are capable of expelling hooks within relatively short periods.

Tackle

- For bait fishing use hook patterns such as circle hooks to maximise the likelihood that fish are hooked in the jaw.
- For conventional hook types, keep line tight to make it less likely that fish will swallow the hook.
- (Lures can be very effective for flathead and result in lower deep hooking rates than bait-fishing, thereby enhancing the likelihood of survival)

Handling and releasing fish

- When handling fish, use a damp towel, cloth and/or gloves.
- Use a de-hooker, pliers or fish grip device when removing hooks
- Fish should be released as soon as possible after capture.

REFERENCES

Anon (2004) Recfish code of practice on releasing fish. http://www.info-fish.net/releasefish/files/385/Recfish%20COP.dpf

Aguilar, R. Rand, P.S., and Beckwith, G.H. Jr. (2002) Quantifying catch-and-release mortality rate of adult red drum in the Neuse River estuary. North Carolina Fisheries Resource Grant Program, Final Report 01-FEG-07, Raleigh, NC. (Cited by Cooke & Suski 2004).

Ayvazian, S.G., Wise, B.S., and Young, G.C. (2002) Short-term hooking mortality of tailor (*Pomatomus saltatrix*) in Western Australia and the impact on yield per recruit. *Fisheries Research* **58**: 241-248.

Bacheler, N.M., and Buckel, J.A. (2004) Does hook type influence the catch rate, size and injury of grouper in a North Carolina commercial fishery? *Fisheries Research* **69**: 303-311.

Bartholomew, A., and Bohnsack, J.A. (2005) A review of catch-and-release angling mortality with implications for no-take reserves. *Reviews in Fish Biology and Fisheries* **15**: 129-154.

Broadhurst, M.K., Gray, C.A., Reid, D.D., Wooden, M.E.L., Young, D.J., Haddy, J.A., and Damiano, C. (2005) Mortality of key fish species released by recreational anglers in an Australian estuary. *Journal of Experimental Marine Biology and Ecology* **321**: 171-179.

Bugley, K., and Shepherd, G. (1991) Effect of catch-and-release angling on the survival of black sea bass. *North American Journal of Fisheries Management* **11**: 468-471.

Butcher, P.A., Broadhurst, M.K., and Brand, C.P. (2006) Mortality of sand whiting (*Sillago ciliata*) released by recreational anglers in an Australian estuary. *ICES Journal of Marine Science* **63**: 567-571.

Carbines, G.D. (1999) Large hook reduce catch and release mortality of blue cod *Parapercis colias* in the Marlborough Sounds of New Zealand. *North American Journal of Fisheries Management* **19**: 992-998.

Conron, S., and Bridge, N. (2004) Statewide angler fishing diary program 1997-2003. Primary Industries Research Victoria, unpublished report, 43p.

Conron, S., Gritxi, D., and Morison, A. (2004) Assessment of mortality of under-size snapper and black bream caught and released by recreational anglers. Primary Industry Research Victoria, Internal Report, 15p.

Cooke, S.J., Barthel, B.L., and Suski, C.D. (2003a) Effects of hook type on injury and capture efficiency of rock bass, *Ambloplites rupestris*, angled in south-eastern Ontario. *Fisheries Management and Ecology* **10**: 269-271.

Cooke, S.J., and Suski, C.D. (2004) Are circle hooks an effective tool for conserving marine and freshwater recreational catch-and-release fisheries? *Aquatic Conservation: Marine and Freshwater Ecosystems* **14**: 299-326.

Cooke, S.J., Suski, C.D., Barthel, B.L., Ostrand, K.G., Tufts, B.L., and Philipp, D.P. (2003b) Injury and mortality induced by four hook types on bluegill and pumpkinseed. *North American Journal of Fisheries Management* **23**: 883-893.

Cooke, S.J., Suski, C.D., Siepker, M.J., and Ostrand, K.G. (2003c) Injury rates, hooking efficiency and mortality potential of largemouth bass (*Micropterus salmoides*) captured on circle hooks and octopus hooks. *Fisheries Research* **61**: 135-144.

Coutin, P., Conron S., and MacDonald, M. (1995) The daytime recreational fishery in Port Phillip Bay 1989-94. Department of Conservation and Natural Resources Victoria, Technical Report.

De Lestang, P., Griffin R.K., and Allsop, Q.A. (2004) Assessment of post-release survival and stress physiology of barramundi (*Lates calcarifer*). FRDC Project No. 2002/039. NT Department of Business, Industry and Resource Development, Fishery Report No. 73, 45p.

Dichmont, C.M., Haddon, M., Yeomans, K., and Kelly, K. (eds) (1999) Proceedings of the South-east Queensland Stock Assessment Review Workshop 16-18 August 1998. Department of Primary Industries Conference and Workshop Ser. QC99003. 179 p.

Diggles, B.K. and Ernst, I.H. (1997) Hooking mortality of two species of shallow-water reef fish caught by recreational angling methods. *Marine and Freshwater Research* **48** 479-483.

Diodati, P.J., and. Richards, R.A (1996) Mortality of striped bass hooked and released in salt water. *Transactions of the American Fisheries Society* **125**: 300-307.

DuBois, R.B., and Dubielzig, R.R. (2004) Effect of hook type on mortality, trauma, and capture efficiency of wild stream trout caught by angling with spinners. *North American Journal of Fisheries Management* **24**: 609-616.

Falterman, B., and Graves, J.E. (2002) A preliminary comparison of the relative mortality and hooking efficiency of circle and straight-shank ("J") hooks used in the pelagic longline industry. *American Fisheries Society Symposium* **30**: 80-87.

GenStat (2005) GenStat for Windows, Release 8.1, Eighth Edition. VSN International Ltd., Oxford.

Gomon, M.F., Glover, J.C.M., and Kuiter, R.H. (eds) (1994) *The fishes of Australia's south coast*. State Printer, Adelaide, 992p.

Henry, G.W. and Lyle, J.M. (eds) (2003) The National Recreational and Indigenous Fishing Survey. FRDC Project No. 99/158, NSW Fisheries Final Report Series No. 48, 188p. ISSN 1440-3544

Higgs, J. (1998) Experimental recreational catch estimates for Queensland residents: results from the 1997 diary round. RFish Technical Report. No.2, Queensland Fisheries Management Authority, Brisbane, Queensland. 55 p.

Higgs, J. (2001) Recreational catch estimates for Queensland residents: results from the 1999 diary round. RFish Technical Report. No.3, Department of Primary Industries, Brisbane, Queensland. 62 p.

Jones, T.S. (2005) The influence of circle hooks on the capture efficiency and injury rate of walleyes. *North American Journal of Fisheries Management* **25**: 725-731.

Kailola, P.J., Williams, M., Stewart, P., Reichelt, R., McNee, A., and Grieve, C. (1993) Australian Fisheries Resources. Bureau of Resource Sciences and the Fisheries Research and Development Corporation, Canberra, Australia. 422 p.

Kaimmer, S.M., and Trumble, R.J. (1997) Survival of Pacific halibut released from longlines: hooking location and release methods. In: Proceedings of fisheries bycatch: consequences and management. Fairbanks, Alaska. 101-105 (Alaska Sea Grant Report 97-02).

Kennelly, S.J., and Gray, C.A. (2000) Reducing the mortality of discarded undersize sand whiting *Sillago cilliata* in an estuarine seine fishery. *Marine and Freshwater Research* **51**: 749-753.

Kumar, M.S., Hill, R., and Partington, D. (1995) The impact of commercial hauling nets and recreational line fishing on the survival of undersized King George whiting (*Sillaginodes punctata*). SARDI Research Report Series No. 6. ISSN 1324-2083. 60pp.

Lindsay, R.B., Schroeder, R.K., Kenaston, K.R., Toman, R.N., and Buckman, M.A. (2004) Hooking mortality by anatomical location and its use in estimating mortality of spring chinook salmon caught and released in a river sport fishery. *North American Journal of Fisheries Management* **24**: 367-378.

Lukacovic, R., and Uphoff, J.H. Jr. (2002) Hook location, fish size, and season as factors influencing catch-and-release mortality of striped bass caught with bait in Chesapeake Bay. *American Fisheries Society Symposium* **30**: 97-100.

Lyle, J.M. (2000) Assessment of the licensed recreational fishery of Tasmania (Phase 2). Tasmanian Aquaculture and Fisheries Institute, FRDC Final Report Project No. 1996/161, 102p.

Lyle, J.M. (2005) 2000/01 survey of recreational fishing in Tasmania. Tasmanian Aquaculture and Fisheries Institute, Technical Report Series No. 24. 97p.

Lyle, J.M., and Campbell, D.A. (1999) Species and size composition of recreational catches with particular reference to licensed fishing methods. Tasmanian Aquaculture and Fisheries Institute, Final Report to Marine Recreational Fishery Advisory Committee, 46p.

Lyle, J.M., Forward, J., and Morton, A. (2002) Species and size composition of recreational catches based on 2000/2001 creel surveys. Tasmanian Aquaculture and Fisheries Institute, Internal Report, 29p.

Lyle, J.M., Haddon, M., Ziegler, P.E., and Tracey, S.R. (2005) Tasmanian scalefish fishery – 2004. Tasmanian Aquaculture and Fisheries Institute Fishery Assessment Report, 79p.

McCullagh, P. and Nelder, J. A. (1989) *Generalized Linear Models* (2nd ed.). Chapman and Hall, London.

McLeay, L.J., Jones, G.K., and Ward, T.M. (2002) National strategy for the survival of released line-caught fish: a review of research and fishery information. South Australian Research and Development Institute. ISBN 0730852830. 122 p.

Meka, J. (2004) The influence of hook type, angler experience, and fish size on injury rates and the duration of capture in an Alaskan catch-and-release rainbow trout fishery. *North American Journal of Fisheries Management* **24**: 1309-1321.

Millard, M.J., Welsh, S.A., Fletcher, J.W., Mohler, J., Kahnle, A., and Hattala, K. (2003) Mortality associated with catch and release of striped bass in the Hudson River. *Fisheries Management and Ecology* **10**: 295-300.

Muoneke, M.I. and W.M. Childress (1994) Hooking mortality: a review for recreational fisheries. *Reviews in Fisheries Science* **2**: 123-156.

Nelson, K.L. (1998) Catch-and-release mortality of striped bass in the Roanoke River, North Carolina. *North American Journal of Fisheries Management* **18**: 25-30.

Nuhfer, A.J., and Alexander, G.R. (1992) Hooking mortality of trophy-sized wild brook trout caught on artificial lures. *North American Journal of Fisheries Management* **12**: 634-644.

Orsi, J.A., Wertheimer, A.C., and Jaenicke, H.W. (1993) Influence of selected hook and lure types on catch, size, and mortality of commercially troll-caught Chinook salmon. *North American Journal of Fisheries Management* **13**: 709-722.

Quinn, G.P., and Keough, M.J. (2002) *Experimental design and data analysis for biologists*. Cambridge University Press, Cambridge, UK 537p.

St John, J., and Syers, C.J. (2005) Mortality of the demersal West Australian dhufish, *Glaucosoma hebraicum* (Richardson 1845) following catch and release: the influence of capture depth, venting and hook type. *Fisheries Research* **76**: 106-116.

Sawynok, B., and Sorrell, J. (2005) Fishtag 2005: Tagging, catch rates and hooking. Infofish Services Report No. ST200505. 17 p.

Schaeffer, J.S., and Hoffman, E.M. (2002) Performance of barbed and barbless hooks in a marine recreational fishery. *North American Journal of Fisheries Management* **22**: 229-235.

Schill, D.J. (1996) Hooking mortality of bait-caught rainbow trout in an Idaho trout stream and a hatchery: implications for special-regulation management. *North American Journal of Fisheries Management* **16**: 348-356.

Schisler, G.J., and Bergerson, E.P. (1996) Postrelease hooking mortality of rainbow trout caught on scented artificial baits. *North American Journal of Fisheries Management* **16**: 570-578.

Skomal, G.B., Chase, B.C., and Prince, E.D. (2002) A comparison of circle hook and straight hook performance in recreational fisheries for juvenile Atlantic bluefin tuna. *American Fisheries Society Symposium* **30**: 57-65.

Steffe, A.S., Murphy, J.J., Chapman, D.J., Tarlington, B.E., Gordon, G.N.G., and Grinberg, A. (1996) An assessment of the impact of offshore recreational fishing in New South Wales waters on the management of commercial fisheries. NSW Fisheries Final Report, FRDC Project No. 94/053.

Steffe, A.S., Murphy, J.J., Chapman, D.J., and Gray, C.C. (2005) An assessment of changes in the daytime recreational fishery of Lake Macquarie following the establishment of a 'Recreational Fishing Haven'. NSW Department of Primary Industries – Fisheries Final Report Series No. 79, 103p. ISSN 1449-9967

Taylor, R.G., Whittington, J.A., and Haymans, D.E. (2001) Catch-and-release mortality rates of common snook in Florida. *North American Journal of Fisheries Management* **21**: 70-75.

Tsuboi, J., Morita, K., and Ikeda, H. (2006) Fate of deep-hooked white-spotted charr after cutting the line in a catch-and-release fishery. *Fisheries Research* **79**: 226-230.

Vincent-Lang, D., Alexandersdottir, M., McBride, D. (1993) Mortality of coho salmon released using sport tackle in the Little Susitna River, Alaska. *Fisheries Research* **15**: 339-356.

Wertheimer, A. (1988) Hooking mortality of Chinook salmon released by commercial trollers. *North American Journal of Fisheries Management* **8**: 346-355.

Wilde, G.R., Muoneke, M.I., Bettoli, P.W., Nelson, K.L., and Hysmith, B.T. (2000) Bait and temperature effects on striped bass hooking mortality in freshwater. *North American Journal of Fisheries Management* **20:** 810-815.

Wilde, G.R., Pope, K.L., and Strauss, R.E. (2003) Estimation of fishing tournament mortality and its sampling variance. *North American Journal of Fisheries Management* **23**: 779-786.

Williams, L.E. (ed.) (2002) Queensland's Fisheries Resources: current conditions and recent trends 1988-2000. Queensland Department of Primary Industries, Information Series QI02012, 180p.

Zimmerman, S.R. and Bochenek, E.A. (2002) Evaluation of the effectiveness of circle hooks in New Jersey's recreational summer flounder fishery. *American Fisheries Society Symposium* **30**: 106-109.

APPENDIX 1: INTELLECTUAL PROPERTY

This is not applicable to this project.

APPENDIX 2: STAFF

Dr Jeremy Lyle, Marine Research Laboratories, Tasmanian Aquaculture and Fisheries Institute, University of Tasmania

Alastair Morton, Marine Research Laboratories, Tasmanian Aquaculture and Fisheries Institute, University of Tasmania

Dr Natalie Moltschaniwskyj, School of Aquaculture. Tasmanian Aquaculture and Fisheries Institute, University of Tasmania

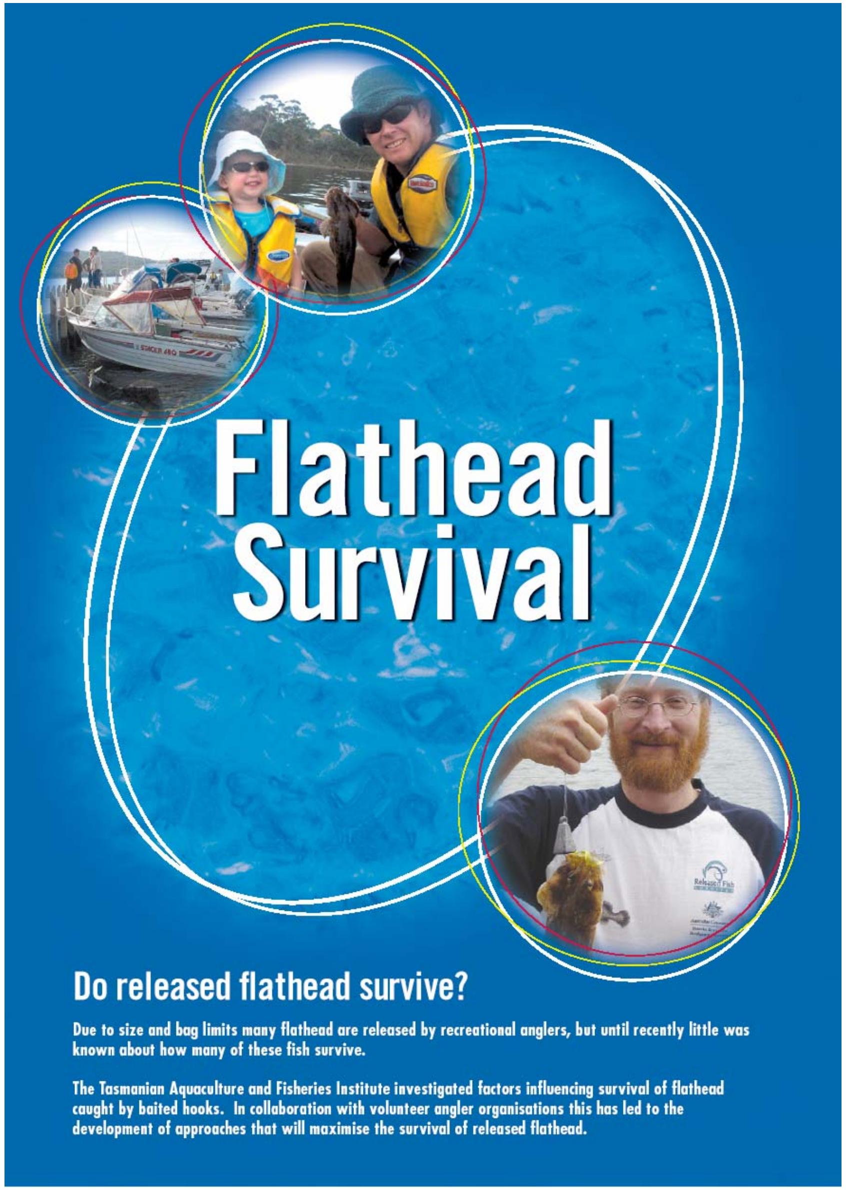
Dr Ian Brown, Southern Fisheries Centre, Department of Primary Industries and Fisheries

Mark McLennan, Southern Fisheries Centre, Department of Primary Industries and Fisheries

Dr David Mayer, Animal Research Institute, Department of Primary Industries and Fisheries

Bill Sawynok, Australian National Sportsfishing Association, Infofish Services

APPENDIX 3: FLATHEAD SURVIVAL BROCHURE



Flathead Survival

Do released flathead survive?

Due to size and bag limits many flathead are released by recreational anglers, but until recently little was known about how many of these fish survive.

The Tasmanian Aquaculture and Fisheries Institute investigated factors influencing survival of flathead caught by baited hooks. In collaboration with volunteer angler organisations this has led to the development of approaches that will maximise the survival of released flathead.

Research findings

Hooking damage is the most significant factor relating to whether flathead survive – survival is lowest for fish hooked in the gills or gut (deep-hooked). Additionally, fish that are bleeding stand a reduced chance of survival. Overall, however, flathead are robust and, if hooked in the lip or mouth (shallow-hooked), have a very good chance of survival if released.

Shallow-hooked

Deep-hooked

Bait fishing for flathead

A range of hook types and sizes, including "J" and "Suicide" hooks are commonly used when bait fishing for flathead. Circle hooks represent an alternative to traditional hook types, and are gaining popularity in Australia for a range of species.

Circle hooks

Our research shows that circle hooks are just as likely to catch flathead as the more commonly used hook types but, importantly, are far less likely to deep-hook fish.

Circle hooks are designed in such a way that fish hook themselves and are less prone to being swallowed than more commonly used hook types. Using circle hooks does require an adjustment to fishing practices in that you do not need to strike on the bite.

J-hook Suicide Circle

What can you do to increase survival of released fish?

Switching to circle hooks can increase the likelihood of the fish you release surviving since deep-hooking rates are extremely low, thus contributing to the health and sustainability of the flathead fishery.

For traditional hook types try to keep the line tight as this makes it less likely that fish will swallow the hook.

Deep-hooked fish

If the flathead is gut-hooked, cut the line and leave the hook in place. Attempts to remove the hook may cause considerable damage to the fish. Our research shows that the likelihood that a fish will survive increases if the hook is not removed, with some fish able to expel hooks within a short period.

Handling fish

Use a damp towel, cloth and/or gloves when handling fish as this helps protect the mucous layer on the fishes skin, and reduces the chance of injuring yourself on the spines.

Use a de-hooker, pliers or fishgrip when removing hooks.

Release fish as soon as possible after capture.

Released Fish

RECFISH AUSTRALIA

Australian Government
Fisheries Research and Development Corporation

Tasmanian Aquaculture & Fisheries Institute
University of Tasmania