Survival of snapper and black bream released by recreational hook-and-line fishers in sheltered coastal temperate ecosystems

S. D. Conron, D. Grixti and A.K. Morison

State Government Victoria Department of Primary Industries

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NON-TECHNICAL SUMMARY

2003/074 Survival of snapper and black bream released by recreational hook-and-line fishers in sheltered coastal temperate ecosystems

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Objectives:

1. Estimate and evaluate the post-release survival rates of under-sized snapper and black bream associated with current hook-and-line methods in the main Victorian recreational fisheries.
2. Where required, develop and test changes to procedures and/or gears that improve problematic post-release survival rates for these species.

Non Technical Summary:

Legal-minimum length (LML) and daily bag limits (DBL) are common management tools for recreational fisheries. Management using LML and DBL assumes that the survival rate for released fish is high. Low survival rates after capture and release will result in the under-estimation of fishery total mortality. The National Recreational and Indigenous Fishing Survey (NRIFS) estimated that nationally, more than 11 million bream and snapper were caught and released during 2000/01 from recreational hook-and-line fisheries (Henry and Lyle 2003). There was a need to obtain objective information on the post release survival (PRS) of these fish to ensure fishery sustainability.

The principal objectives of this study were

- to estimate and evaluate the post-release survival rates of under-sized black bream (*Acanthopagrus butcheri*) and snapper (*Pagrus auratus*) associated with current hook-and-line methods in the main Victorian recreational fisheries and,
- where required, develop and test changes to fishing methods that improve PRS rates.

Parameters that affect PRS rates of under-sized black bream and snapper associated with current hook-and-line methods in the main Victorian recreational fisheries were initially evaluated using repeated field-based experiments. Fish were caught with fishing gears and angler practices identified as commonly used in the fisheries of interest. After capture, released fish condition was monitored in holding tanks close to the capture area. Anatomical hooking location was found to be the principal factor to influence PRS. Total survival was considerably higher for shallow-hooked fish (95% for black bream, 97% for snapper) than deep-hooked (74 % for black bream, 48% for snapper). The inclusion of post mortem examinations in the present study improved the accuracy and enhanced the understanding of the factors affecting fish survival.

To determine the estimated PRS rates impact at the fishery level, data were collected from existing programs used to monitor and assess key recreational fisheries and fish stocks. Anglers participating in a fishing diary program recorded both fish length and the anatomical hooking location for under-size black bream and snapper caught with a range of fishing gears across Victorian estuaries between 1998 and 2005. Black bream length strongly influenced the rate of shallow-hooking, with shallow-hooking decreasing as fish length increased. For snapper the shallow-hooking rate was not found to be related to fish length or hook size. The hook size for snapper was typical of the King George whiting (*Sillaginodes punctata*) fishery and would be considered a small hook for targeting legal sized snapper.

PRS rates estimated for under-size black bream and snapper according to hooking location were then integrated with relevant fishery information collected as part of on-site angler catch surveys undertaken for the shore and boat-based black bream fisheries in the Gippsland Lakes and the King George whiting boat-based fishery in Port Phillip Bay (for under-size released snapper). The results showed that PRS rates for these important Victorian hook-and-line fisheries are high (>80 %). Integration of PRS rates and catch information indicated the likely efficiency of LMLs management in limiting recreational fishing impacts. For the boat-based King George whiting fishery in Port Phillip Bay release rates of under-size snapper were similar to retained King George whiting catch rates. The post-release mortality component was only a small percentage of the released snapper. For the black bream recreational shore-based and boat-based fisheries in the Gippsland Lakes, release rates of under-size fish were many times higher than retained catch rates. The high release rates resulted in a released catch mortality component as large as the total retained catch even though PRS was high.

A series of fishing experiments were undertaken to determine the extent to which alternative fishing gear and techniques could increase PRS and reduce catch rates for under-size black bream. Different hook sizes were compared by anglers fishing with rods with slack or tight line. Shallow-hooking rates increased and under-sized fish catch rates decreased as hook and bait size increased. Fishing with a tight line instead of a slack line also increased shallow-hooking rates, although this benefit was partly off-set by increased catch rates of under-size black bream.

These findings support the current use of LMLs as a tool for protecting these fish stocks. Fishing methods that maximise the survival of under-size released black bream were outlined in information products and extended to the fishing community through a "Gently Does It Releasing Snapper and Bream" pamphlet and segment on the "Gently Does It #2" DVD.

Outcomes Achieved to Date

Parameters that affect Post Release Survival (PRS) rates of under-sized snapper and black bream associated with current hook-and-line methods in the main Victorian recreational fisheries were identified and evaluated using repeated field-based experiments.

The results from this study indicate that PRS rates for under-size released black bream and snapper were high (>80 %) and support the use of size and bag limits as tools for protecting fish stocks. The project identified the potential benefits of reducing the high numbers of under-sized black bream that are caught and released.

Information brochures and a DVD explaining fishing practices that improve PRS rates for under-size snapper and bream have been released widely through the National Strategy for Release Fish Survival extension program and the Victorian Fishcare Volunteer Program.

Keywords: Snapper, black bream, post-release survival, recreational fishing

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FINAL REPORT

2003/074	Survival of snapper and black bream released by recreational hook-and-line fishers in sheltered coastal temperate ecosystems

Introduction

This report is in two parts. Part 1 deals with the survival of snapper and black bream released by recreational hook and line fishers. Part 2 examines alternative fishing gears and practices that could increase survival of released fish.

Part 1 - Survival of snapper and black bream released by recreational hook- and line- fishers in sheltered coastal temperate ecosystems

Background

Legal-minimum length (LML) and daily bag limits (DBL) are common management tools for recreational fisheries (King 1995). In all Australian jurisdictions, LML regulations prohibit the retention of smaller fish of each species and a DBL restricts the total catch. Large numbers of under-size fish are caught and released every year (Henry and Lyle 2003), some as bycatch when anglers target a different species and others when under-size and legal-sized fish of the same species mix together.

In Victoria, more than 30 marine, estuarine and freshwater fish species are managed using these tools. Management by limiting LML and DBL is based on the assumption that the survival rate for released fish is high (McLeay *et al*. 2002). There is evidence from previous studies (McLeay *et al*. 2002), and the perception among many stakeholders, that many fish released after capture by current hook-and-line methods may die. The stakeholders include recreational and commercial fishers, tourism organisations, conservationists and fisheries managers. Despite these widespread concerns, there is little scientific data on the actual post release survival (PRS) rates (also called "hooking mortality") for line-caught fish in sheltered coastal temperate ecosystems in Australia. Low survival rates after capture and release will result in under-estimation of total mortality of fisheries, compromising their management (Coggins *et al.* 2007) for commercial and ecological sustainability.

The National Recreational and Indigenous Fishing Survey (NRIFS) estimated that nationally, more than 11 million bream and snapper were caught and released (comprising over 10% of the total released catch) from recreational hook-and-line fisheries during 2000/01 (Henry and Lyle 2003). This project was designed to test the hypothesis that there is a high level of previously unaccounted fishing mortality associated with hook and line catch and release practices in these fisheries.

Preliminary capture and holding experiments (Conron *et al.* 2004) demonstrated that hook location and holding time were important for survival rates in black bream and snapper. Additional experiments showed that hook size and design and fishing technique (tight v. slack line) influenced hook location. The design and methods of the present more extensive study were developed from these pilot investigations.

Need

In Victoria, angler creel surveys and angler fishing diary programs have shown that under-size snapper are a common bycatch of anglers targeting King George whiting (*Sillaginodes punctata*) (Conron and Kirwin 2000). Under-size black bream have been shown to comprise over 80% of the total number caught for anglers targeting black bream (Conron and Bills 2000: Morison and Conron 2001). Fisheries Victoria (Victoria's fisheries management agency) determined that the assessment of PRS was a higher priority for snapper and black bream than for any other Victorian species.

Hence there was a clear need to investigate PRS rates for snapper and black bream, identify the deleterious hooking, handling and release procedures, examine ways to improve PRS, and incorporate realistic estimates of PRS into fishery and stock assessments.

Survival rate of released fish must be maximised for ecological sustainability of Australia's commercial and recreational hook and line fisheries. The effectiveness of LML and DBL as management tools and changes to them cannot be assessed effectively because of the lack of information on survival rates for the majority of Australian species. For example, in Victoria during the late 1990's, the LML for black bream was increased to conserve fish stocks in the Gippsland Lakes. This change protected a proportion of the stock from being harvested, but increased the under-size and discarded proportion to 80% of the black bream catch (Morison and Conron 2001). The LML for black bream was increased again in 2003 in response to further indications of stock decline and evidence of continued poor recruitment. If the PRS of the released black bream is low, these increased LML may be of little value in terms of conserving fish stocks and deliver a poor social value to anglers.

There are similar concerns for snapper. The recreational fishery for snapper in Port Phillip Bay has a distinct peak season in spring and summer when anglers target mature snapper in deeper waters (≥ 10 m) of the bay. After the peak snapper season many anglers begin to target King George whiting using considerably smaller hooks and lighter gear than that used for mature snapper. Angler catch survey data (Conron, unpublished) suggested that the highest catch rates of under-size snapper in the bay are from anglers targeting King George whiting. If deep-hooking rates of under-size snapper are high then the PRS rate estimates from the pilot study would suggest a need to be concerned. At the time this study commenced, Fisheries Victoria was planning to review the LML for snapper which, at 27 cm total length (TL), is low compared to other States and which yield-per-recruit analyses suggest is less than optimal for maximising yield (Coutin, 1998). Knowledge of the PRS rates of snapper is critical for evaluating the benefits of any change to the current LML.

McLeay *et al.* (2002) highlighted the need to coordinate research projects and to develop a standardised system for classifying stress, the condition of fish, the injuries they may incur, and the stressors applied during catch-and-release procedures. By expanding and refining the field-based pilot experiments supported by Victorian recreational licence funds, the present project takes further important steps towards addressing these needs.

Objective

The objective of this research was

1. To estimate and evaluate the post-release survival (PRS) rates of under-size snapper and black bream associated with current hook-and-line methods in the main Victorian recreational fisheries.

Materials and Methods

Commonly used fishing platforms, gear and fish release practices

Shore based and boat based anglers fishing in the popular black bream fishing regions of the Gippsland Lakes were surveyed over a three year period from 2003 to 2005. Boat based anglers targeting King George whiting in Port Phillip Bay were surveyed for a six month period from November to April each year from 2003 to 2005.

Hook size and bait combinations or lures were recorded for anglers targeting black bream in the Gippsland Lakes and releasing those that were undersized. Similar data were recorded for boat based anglers targeting King George whiting in Port Phillip Bay and releasing undersized snapper.

Release practices were identified while shore based anglers were fishing for black bream in the Gippsland Lakes between December 2003 and October 2004. They were asked to describe how they handled shallow hooked and deep hooked undersized black bream that they caught and released.

Fish capture holding experiments.

Experimental design

Over a three year period, eight black bream and five snapper post release survival (PRS) experiments were conducted. Black bream experiments were conducted on the Glenelg River. This river was chosen because it had higher under-size black bream numbers than the Gippsland Lakes (DPI unpublished data). Experiments were conducted in both cooler and warmer months to investigate water temperature as a potential influence on PRS. Snapper PRS experiments were conducted in Port Phillip Bay during summer months which are the main King George whiting fishing months.

Black Bream were caught in the field experiments using size 4 long shank, offset, barbed hooks (Dynatec, Red-Line) attached to a running sinker rig (size 0 sinker and 60 cm long 3.8 kg leader) and light (2–4 kg) rod and reel outfit. Experienced anglers caught fish for each experiment using their usual fishing practices, the standardised gear and a podworm (*Australonereis sp.*) bait.

The snapper field experiments used size 6 long-shank, barbed, offset, hooks (Gamakatsu) with a running sinker rig (size 1 sinker and 60 cm long 5.5 kg leader) and light (2–4 kg) rod and reel outfit. Experienced anglers caught fish for each experiment using their usual fishing practices, the standardised gear and a typical mixture of shelled pipi (small bivalve), pilchard and squid baits.

All captured fish had their total length (TL) recorded to the nearest (rounded down) centimetre. A series of fin clips was used to indicate the site of hook penetration for each fish. After the second black bream experiment and first snapper experiment, the fin clipping regimen was modified to also indicate whether the hook was or was not removed and the extent of any external bleeding. Hooking location categories were condensed for analysis to "shallow hooked" (lip or mouth) and "deep hooked"(throat, gill, oesophagus or gut).

Anglers decided whether to remove the hook or cut the line based on hook position. If the hook eye was approximately $\leq$1 cm inside the mouth (from the tip of the lips) then the hook was removed by hand. If the eye was >1 cm inside the mouth the line was cut as close to the hook as possible. This method was used because anglers reported that they generally elected to remove the hook from under-size fish when they could reach it with their fingers.

Fish were categorised as bleeding or not bleeding. Handling time (recorded to the nearest 5 seconds) and fight time (estimated as <20, 20–39 or >40 seconds) were recorded at the time of capture for all fish.

Initial PRS (survival within one hour after capture) was assessed by keeping captured fish beside the anglers' boats in holding cages (soft mesh cage, 70 cm x 62 cm x 62 cm). Initial mortalities were identified by a lack of operculum movement or, if the fish was motionless and unresponsive, to touch stimuli. After one hour survivors were placed in aerated, water-filled, 50 L plastic tubs and transported by boat. Black bream of TL 15 to 25cm and snapper 15 to 26cm were randomly allocated to one of four floating cylindrical polyethylene holding cages (110 cm deep and 110 cm diameter) moored to a jetty near the fishing area The walls and floor of each holding cage were perforated with holes (25 mm diameter) to allow water exchange. A haul seine net was used to catch control fish near the angling area. Control fish of the same size were fin clipped and placed in a holding cage for one hour before being transferred to holding tanks. The holding cages contained a total of 40 fish with a minimum of three control fish. The number of deep-hooked fish within the required size range were always limited, so all those available were used. Shallow-hooked fish made up the balance of the 40 fish capacity. Transport times between the sites of capture and holding where similar for both the angled and control fish (5–10 mins). Fish in the holding cages were monitored at 0700h and 1700h each day for 72 hours and the numbers of dead fish were recorded. Water parameters (temperature ˚C, salinity ppt, and dissolved oxygen % saturation) were measured within and outside the tanks during each experiment using a YSI (inc) Model 85/100FT. water testing meter.

Post-mortem (PM) examinations (Appendix 3) were performed for all mortalities, all surviving deep-hooked fish, and samples of five shallow-hooked and five control fish surviving. Live fish were euthanased in an ice water bath before dissection. Variables recorded during PM examinations were scale loss, evidence of predation during capture (eg. teeth punctures), hooking location, hooking injuries, whether a fish had shed a retained hook, retained hook degradation, sex, and reproductive condition.

Statistical analysis
Angler Variables

One-way ANOVAs tested differences in the mean handling times for captured fish across hooking locations (shallow-hooked and deep-hooked) and hook removal methods (hook removed and hook not removed with shallow-hooked fish excluded from the analysis). The appropriateness of the ANOVAs were determined by inspection of box and whisker plots of the response variables against predictor variables, by Kolmogorov-Smirnov tests of normality, and by Levenes variance homogeneity tests. Where required, a normal distribution was achieved via a log transformation.

Survival (including PM fish)

The probabilities (and standard errors) of initial, delayed and total survival were calculated using an adaptation of the methods outlined by Wilde *et al.*(2003). These methods were designed for fishing tournament studies where all the fish caught in the tournament are monitored for initial survival and represent 100% of the population; thus the method does not provide an error around the estimate of initial survival. An error was included for the initial survival estimate (SE of a proportion) in the present study because these fish did not represent 100% of the population. The delayed survival probabilities included a finite population correction.

Simple logistic regression and frequency G-test analysis were used to compare initial and delayed survival across independent variables one at a time. These independent variables were hooking location, water temperature, hook removal (deep-hook fish only) and bleeding (deep-hook fish only). Contingency table (G-test) analyses were used to assess associations between bleeding and hook removal, fish sex and survival. Many snapper were too immature to determine sex so the last analysis was not carried out for this species.

Assumptions of normality and homogeneity for ANOVA and high cell frequencies for the G-test were checked by inspecting box and whisker plots, Kolmogorov-Smirnov tests, Levenes tests and counting cell frequencies. All assumptions were met and no transformations were required.

Results are given as mean ± SE unless otherwise stated.

Applying post release survival and mortality rates to recreational fisheries

Average retained and released catch rates were obtained from on-site angler catch surveys. This provided the number of retained fish and the number of undersized fish released. Estimates were made of the proportion of those released that would have survived and died (i.e. post release mortality rate).

During on-site surveys, information on target species, fishing location, fishing effort, bait-hook size and type, number of species of fish kept and released, length measurements of retained fish (and handling techniques for the shore-based black bream fishery) was collected. However, hooking location for under-size fish could not be collected during on-site surveys because these fish had generally been released prior to the interview, making it difficult for anglers to accurately recall this information.

The hooking location and fish length data required, were provided by anglers participating in a Fishing Diary Program (Conron and Bridge 2004, Bridge and Conron inprep.) from 2003 to 2005. This program recorded trip date, target species, fishing location, fishing effort, hook size and type, number of species of fish kept and released, and length for both retained and released fish. Anglers catching black bream and snapper also recorded hooking locations (as per the capture and holding experiments).

The application of the analysis to recreational fisheries is detailed in Appendix 4.

Results

Commonly used fishing platforms, gear and fish release practices.

Gear descriptions were obtained from 454 boat-based and 1,064 shore-based fishing parties who reported releasing under-size black bream when interviewed as part of the Gippsland Lakes angler survey program between 2003 and 2005. Almost all fishing parties who had reported releasing black bream had fished with baits (boat-based 95% SE +5%, shore-based 99% SE +1%), with the remaining anglers indicating that they had fished with lures. A size 4 hook with soft bait (e.g. sand worm) was the most commonly used hook-bait combination by both boat-based and shore-based anglers (Figure 1). Longshank and baitholder hooks were the most commonly used hook types (Appendix 5, Figure 17).

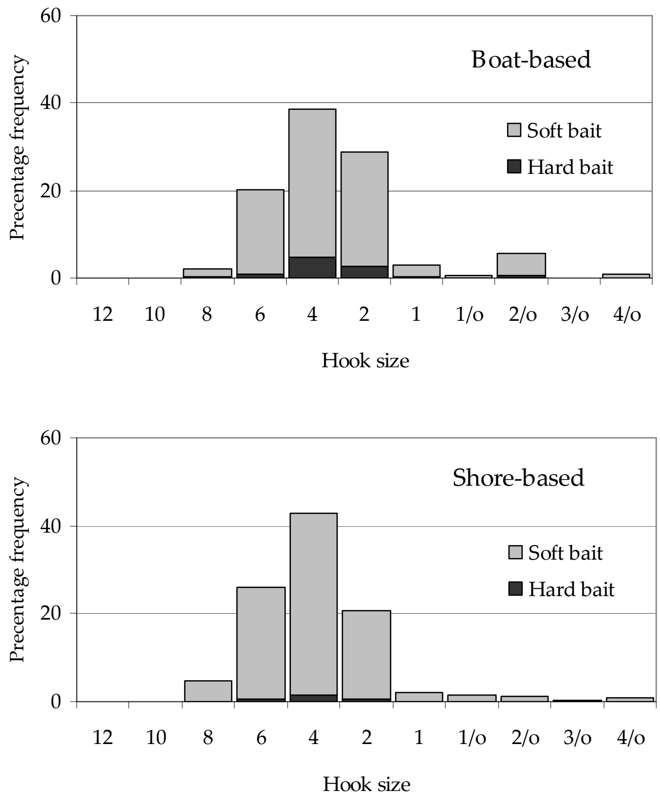


Figure 1. Distribution of hook sizes (ordered from smallest, (12), to largest, (4/O)), by bait type, for boat and shore-based anglers who reported releasing under-size black bream in the Gippsland Lakes during 2003-05 (number of hooks described = 2,542).

Gear descriptions were obtained from 381 boat-based fishing parties who had targeted King George whiting and reported releasing under-size snapper in Port Phillip Bay between 2003 and 2005. All the fishing parties surveyed had line fished with soft baits (e.g. shelled pippi, squid or pilchard). A size 6 longshank shaped hook was the most commonly used for King George whiting (Figure 2).

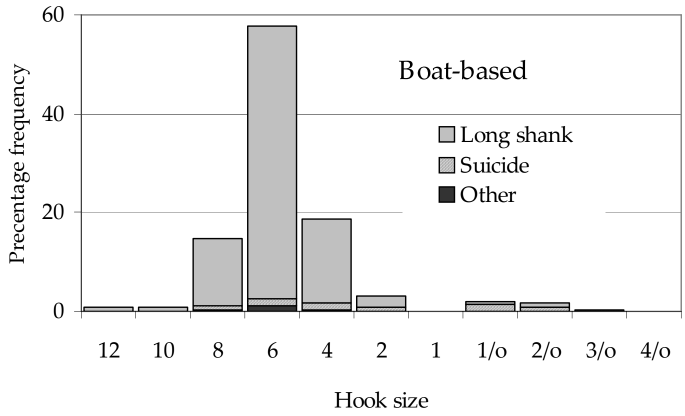


Figure 2. Distribution of hook sizes (ordered from smallest, (12), to largest, (4/O)) for boat -based anglers who reported targeting King George whiting and releasing under-size snapper in Port Phillip Bay during 2003-05 (number of hooks described = 832).

When anglers were asked to describe their handling practices for releasing black bream, they indicated a clear preference for using just their fingers (hand) to remove the hook, as opposed to a de-hooking implement, when fish were shallow-hooked. For deep-hooked black bream the anglers indicated a preference for removing hooks they could still reach with their fingers, otherwise they cut the line and left the hook lodged in the fish (Appendix 5, Figure 17).

Fish capture and holding experiments

Black bream

Survival and factors associated with fish length, fishing technique and conditions

The length distribution of the 1868 black bream caught by hook and line is shown in Figure 3. Mean length was 17.5 $\pm$ SE 0.07 cm with 98% of fish under the 26cm Victorian size limit.

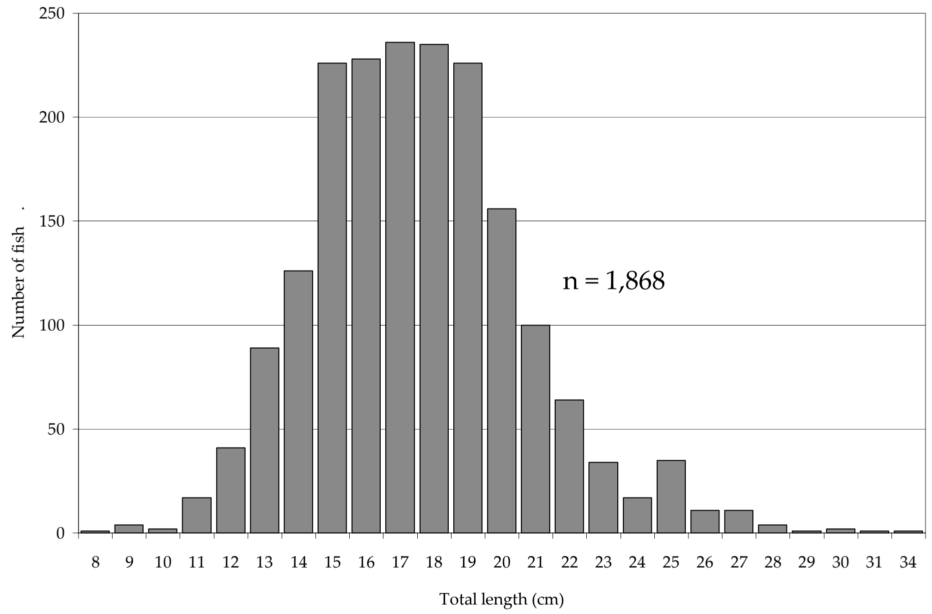


Figure 3. Length-frequency distribution for all captured black bream. *Note:* only fish 15–25 cm were monitored for survival.

Capture time was significantly (P<0.001) longer for deep hooked fish. Handling time was significantly shorter for shallow hooked than for deep hooked fish (Table 1). There was no significant effect on handling time of removing or not removing a hook (Table 1).

Table 1. Mean handling times (s) and ANOVA results by hook locations and hook removal methods for black bream fishing experiments.

	Handling time (mean ± 1 SE)	*P*-value
Hooking location		
Shallow-hooked	23 (0.34)	***
Deep-hooked	40 (1.24)	
Hook removal method		
Deep-hooked removed	38 (2.56)	
Deep-hooked not removed	41 (1.54)	

*= P-value <0.05, **= P-value <0.01, ***= P-value <0.001

Water characteristics for warm and cold conditions are given in Table 2.

Table 2. Mean (± 1 SE) water temperature (C°), salinity (ppt) and percentage dissolved oxygen (DO) for the sampling treatments warm and cold water.

Sampling treatment	Water temp. . Mean (± 1 SE)	Salinity . Mean (± 1 SE)	DO* % . Mean (± 1 SE)
Warm water (n=4)	19.5 (1.5)	20.4 (2.5)	107.6 (4.1)
Cold water (n=4)	11.6 (1.5)	7.6 (2.3)	81.8 (2.1)

* DO recording errors in one experiment in each of the four warm and cold water experiments meant that these measurements were removed.

The effects of hooking location, water temperature, hook removal of deep hooks and the presence of bleeding on survival are shown in Table 3. Initial and delayed survival were significantly lower for deep hooked than for shallow hooked fish and under cold water compared with warm water conditions (Appendix 5 Table 15). Removal of hooks from deep hooked fish significantly reduced delayed survival compared with leaving them in. Lower initial and delayed survival was associated with bleeding in deep hooked fish (Table 3).

Table 3. Initial (within 1 hour), delayed (1–72 hours) and total (0–72 hours) PRS estimates for black bream. Note: deep-hooked fish from experiments 1 and 2 could be used in hook removal or bleeding summary because these variables were added after experiment 2.

Independent Variable	Response Variable				
	Initial survival %		Delayed survival %		Total survival %
Hooking location	Num.	Mean (± SE).	Num.	Mean(± SE)	Mean (± SE)
Shallow-hooked	1309	97.0 (0.5)	710	98.5 (0.3)	95.5 (0.8)
Deep-hooked	248	85.9 (2.2)	213	86.2 (1.1)	74.0 (3.0)
Control	266	100.0 (0)	265	99.6 (0.0)	99.6 (0.0)
Water Temperature					
Warm	629	96.7(0.8)	513	99.2 (0.2)	95.9 (0.9)
Cold	928	94.2 (0.7)	659	94.7 (0.5)	89.2 (1.1)
Hook removal (deep-hooked only)					
Hooks removed	61	83.6 (4.8)	51	69.5 (3.7)	58.9 (5.9)
Hooks not removed	124	84.7 (3.2)	105	92.7 (1.4)	80.9 (4.3)
Bleeding (deep-hooked only)					
None	96	90.6 (3.0)	86	88.1 (1.6)	79.8 (4.3)
Bleed	89	77.5 (3.8)	69	74.6 (3.3)	57.8 (5.7)

Shallow hooking rates significantly decreased as fish length increased with the odds of shallow hooking reducing by 22% for every 1cm increase in length (Appendix 5 Figure 19 and Table 15). Shallow hooking was significantly higher in warm water experiments than in cold water experiments. Hook removal rates for deep hooked fish decreased significantly as fish length increased with 20 % less chance of hook removal for every 1cm increase in length. Bleeding was significantly more prevalent when the hook was removed than when the hook was left in (Appendix 5 Table 15).

Increasing fish length reduced the chance of initial survival with 24% less chance of survival for every 1cm increase in length (Appendix 5 Table 15).. Delayed survival showed the same trend with 21% less chance of survival for every 1cm increase in length but this was not significant (p=0.059). Fish sex did not significantly affect initial survival (males 90%, females 89%) or delayed survival (males 86% females 90%).

Post mortem

There were 124 deep hooked black bream that retained a hook after capture of which 97% still retained the hook after death or at the end of the experiment. Eighty five per cent of the 124 survived the 72h holding period. Survival was lowest when the throat or gill region sustained injury (Table 4). These hooking injuries were more severe when a hook was removed than when it was not removed. Fish deeply hooked in the stomach, liver or septum transversum and that did not have the hook removed accounted for the most deep hooked survivors (Table 4).

Table 4. Survival of black bream associated with shallow and deep-hooking injuries observed during PM examinations.

Injuries categories	Initial period			Delayed period			Total surv.	% in injury category
	Mort.	Surv.	% Surv.	Mort.	Surv.	% Surv.	% Surv.	
None	8	146	NA	5	141	NA	NA	100%
Shallow injuries								
Slight maxillary	1	28	NA	0	28	NA	NA	27%
Moderate maxillary	2	51	NA	8	43	NA	NA	49%
Major maxillary	1	8	NA	0	8	NA	NA	8%
Roof of mouth	1	16	NA	0	16	NA	NA	16%
Deep injuries								
Slight perforation of throat	1	6	86%	0	6	100%	86%	4%
Extensive perforation of throat	9	4	31%	2	2	50%	15%	7%
Punctured gills	2	4	67%	1	3	75%	50%	3%
Broken gills	6	3	33%	2	1	33%	11%	5%
Broken gills and perforated throat	16	5	24%	2	3	60%	14%	12%
Pierced liver	3	23	88%	4	16	80%	71%	14%
Pierced liver and septum transversum	4	51	93%	6	45	88%	82%	30%
Pierced liver, septum transversum and heart	10	14	58%	3	11	79%	46%	13%
Pierced heart	3	9	75%	7	2	22%	17%	7%
Pierced stomach wall	1	8	89%	0	8	100%	89%	5%

Note: NA means that the estimate was not applicable (all dead shallow-hooked fish examined but only a sample of shallow-hooked survivors had a PM examination conducted so % survival could not be calculated correctly)

In all, 75% of deep-hooked fish with a retained hook were thought to be throat/gill-hooked at capture, but PM examination found that only 5% were actually hooked in the throat or gills and 95 % were hooked in the oesophagus or gut (7).

Table 5 shows the hooking location recorded at capture and injuries observed during PM examination for survivors and mortalities. Fish with no PM-determined injuries (no shallow-hook or deep-hook injuries) were not compared in this table. A total of 32% of mortalities were categorised as shallow-hooked (lip/mouth), but only 24% of mortalities had lip or mouth injuries. This suggests that the hooking location was actually deep-hooked for 8% of shallow-hooked mortalities.

Table 5. Hooking location and hooking injury validation for black bream. Hooking location validation not possible for shallow-hooked fish or fish that were deep-hooked and had the hook removed.

Validating hooking location	Percentage of fish determined at each hooking location		
	Lip/mouth	Throat/gill	Esophagus/gut
Deep-hooked fish with the hook not removed			
Hooking location determined at capture	NA	75%	25%
Hooking location determined at PM	NA	5%	95%
Injuries			
Hooking location determined at capture for mortalities	32%	57%	11%
Injury to area determined at PM for mortalities	24%	68%	8%
Hooking location determined at capture for survivors	43%	40%	17%
Injury to area determined at PM for survivors	51%	11%	38%

Note: NA means that the estimate was not applicable.

In summary, survival of black bream was reduced by increased length of fish, cold water, deep hooking, especially with injury to the throat or gills, removal of deep hooks and the presence of bleeding.

Snapper

Survival and factors associated with fish length, fishing technique and water quality conditions

The length distribution of the 677 snapper caught by hook and line is shown in Figure 4.

Mean length was 20.1 $\pm$ 0.13 cm with 98% of fish under the 27cm Victorian size limit.

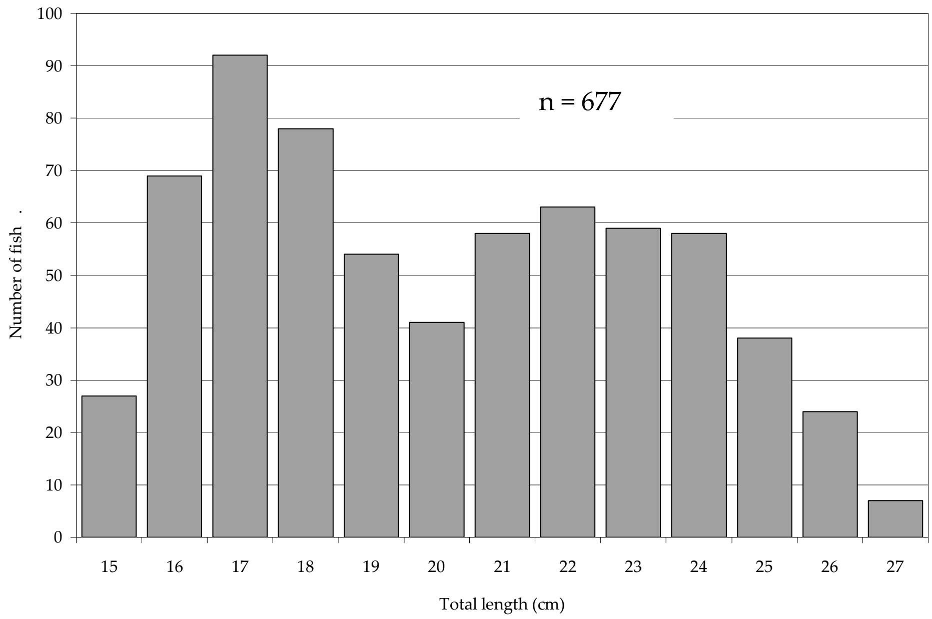


Figure 4. Length-frequency distribution for all captured Snapper. ***Note:*** **that only fish 15–26 cm were monitored for survival**.

The capture times for snapper were < 20 secs for 82% and 83% of shallow-hooked and deep hooked fish respectively. There was no effect of hook location on capture time. Handling time was significantly lower for shallow-hooked than deep-hooked fish but removing or not removing a deep hook had no effect on handling time (Table 6).

Table 6. Mean handling times and ANOVA results of hook locations and hook removal methods for snapper capture and holding experiments.

	Handling time (mean ± SE)	*P*-value
Hooking location		
Shallow-hooked	33 (2.69)	***
Deep-hooked	51 (3.72)	
Hook removal method		
Deep-hooked removed	48 (3.79)	*
Deep-hooked not removed	59 (3.17)	

*= P-value <0.05, **= P-value <0.01, ***= P-value <0.001

There was little variation in water quality during the experiments (temperature 20.4 ± 0.4 ^{0} C, salinity 37.9 ± 0.2 ppt and oxygen saturation 94 ± 4.6 % (means ± SE).

Of the 677 snapper captured by hook and line 620 (91%) were monitored for initial survival. The survey results for hook location and removal and the presence of bleeding in deep hooked fish are shown in Table 7. Initial survival was significantly higher for shallow hooked than deep hooked fish.

Table 7. Initial (within one hour), delayed (1–72 h) and total (0–72 h) PRS estimates (and associated standard errors) for snapper capture and holding experiments. *Note:* Table numbers are from the at-capture recording, not PM.

Independent variable	Response variable				
	Initial survival (%)		Delayed survival (%)		Total survival (%)
Hooking location	n	Mean (± SE).	n	Mean (± SE).	Mean (± SE).
Shallow-hooked	516	98.3 (0)	368	99.2 (0)	97.5 (0.0)
Deep-hooked	104	54.8 (0.5)	43	88.4 (0.4)	48.4 (0.7)
Control	200	100.0 (0)	200	100.0 (0)	100.0 (0.0)
Hook removal (*deep-hooked only*)					
Hooks removed	29	48.3 (1.8)	16	87.5 (1.0)	42.2 (2.3)
Hooks not removed	58	51.7 (0.9)	20	85.0 (1.2)	44.0 (1.5)
Bleeding (*deep-hooked only*)					
None	36	80.6 (1.1)	23	87.0 (0.6)	70.0 (1.6)
Bleed	51	29.4 (0.9)	13	84.6 (2.2)	24.9 (1.6)

None of the 200 control snapper died during either the initial or delayed survival period. Total initial survival was significantly higher for shallow-hooked (98%) than deep-hooked fish (48%) (Table 7). Fish length did not significantly influence initial survival, but did significantly affect delayed survival (Appendix 5 Table 16), with the odds ratio indicating 1.24 greater chance of survival for every one cm increase in total length. Fish length and hooking location interactions were not significant for either initial or delayed survival. Shallow-hooking was not significantly related to fish length (Appendix 5 Table 16). Deeply engulfed hooks were removed on 49% of occasions. The probability of a hook being removed from deep-hooked fish decreased significantly as fish length increased, with the odds ratio indicating 0.8 less chance of a hook being removed for every 1 cm increase in total length. Initial survival for deep-hooked fish was significantly lower if the hook was removed than if the line was cut and the hook not removed (Table 7, Appendix 5 Table 16). Initial survival for deep-hooked fish that bled (29%) was significantly lower than for fish that did not bleed (81%) (Table 7, Appendix 5 Table 16). There was a significant difference between the percentage of deep-hooked fish that did not bleed when the hook was removed (28%) compared to when it was not removed (58%) (Table 7, Appendix 5 Table 16).

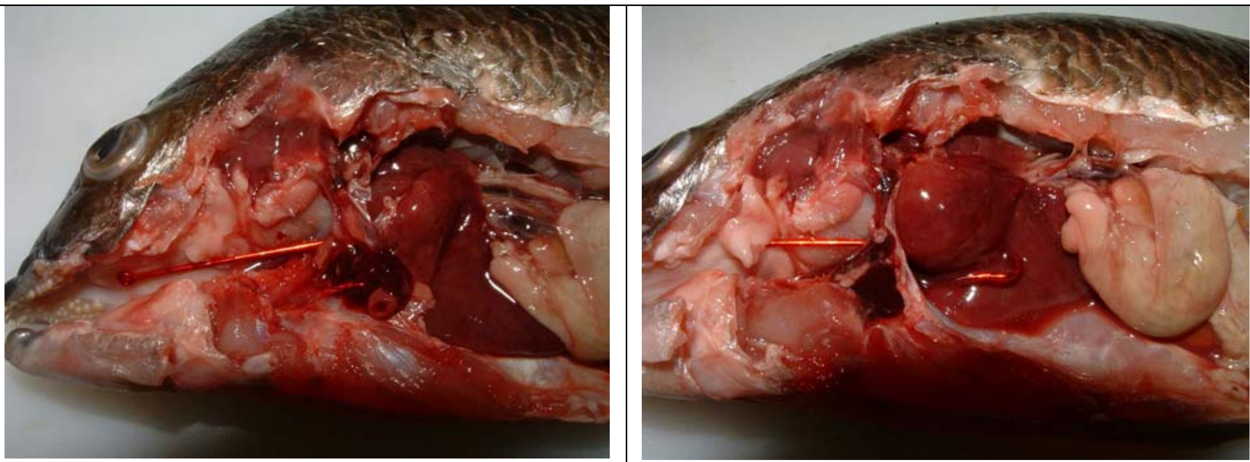
Post mortem
Table 8 shows the survival information for snapper with different types of hooking injury.

Table 8. Shallow-and deep-hooking injuries observed during PM examinations.

Injuries categories	Initial period			Delayed period			Total surv.	% in injury category
	Mort.	Surv.	% Surv.	Mort.	Surv.	% Surv.	% Surv.	
None	13	56	NA	1	55	NA	NA	100%
Shallow injuries								
Slight maxillary	3	35	NA	1	34	NA	NA	38%
Moderate maxillary	2	45	NA	1	44	NA	NA	48%
Major maxillary	0	10	NA	0	10	NA	NA	10%
Roof of mouth	1	16	NA	0	16	NA	NA	4%
Deep injuries								
Slight perforation of throat	0	1	100%	0	1	100%	100%	1%
Extensive perforation of throat	12	1	8%	1	0	0%	0%	17%
Punctured gills	0	3	100%	2	1	33%	33%	4%
Broken gills	1	0	0%	0	0		0%	1%
Broken gills and perforated throat	9	0	0%	0	0		14%	11%
Pierced liver	1	18	95%	0	18	100%	71%	23%
Pierced liver and septum transversum	3	15	83%	0	15	100%	82%	22%
Pierced liver, septum transversum and heart	9	2	18%	1	1	50%	46%	13%
Pierced heart	4	1	20%	1	0	0%	17%	6%
Pierced stomach wall	0	2	100%	0	2	100%	100%	2%

Note: NA means that the estimate was not applicable (all dead shallow-hooked fish examined but only a sample of shallow-hooked survivors had a post mortem examination conducted so % survival could not be calculated correctly)

Throat and/or gill injuries were seen in 33% of deep-hooked fish. These fish had a low survival rate. Removing the hook from deep-hooked fish caused more severe throat and gill injuries than when the line was cut and hook not removed. The deep-hooked fish that survived were mostly those which had been hooked through the oesophagus, liver and often the septum transversum (i.e. the thin membrane that separates the heart and stomach cavities). When the hook was not removed from a deep-hooked fish, the hook point always faced down towards the fish's ventral area (Figure 5). When a hook penetrated the septum transversum the hook point remained in the pericardial cavity very close to or piercing the heart. In all, 13% of the 59 deep-hooked snapper that retained a hook were able to shed the hook before death or within the holding period. Given the time frame of the experiment, hook regurgitation seemed the most likely removal means. The amount of degradation to retained hooks after 72 hours, or at the time of death, was recorded at 5% degradation intervals by visual inspection of the hook. In all, 44% of retained hooks had 0% degradation, while 55% showed 5% degradation. The 5% degradation was generally a removal of the hook's outer coating and/or slight wearing of the hook shank from the gill arches. The percentage of scale loss (10% intervals) was categorised during PM examination for fish that died during the 72-hour holding period and for the survivors that were euthanased at the end of the holding period. No scale loss was recorded for 85% of angled fish, while 10% and 20% scale loss was recorded for 9% and 6% respectively. Of the control fish, 86% were categorised as having no scale loss with 14% as 10% scale loss. Because only a sample of shallow-hooked survivors were examined, it was not possible to give an absolute survival estimate for each scale-loss category, but notably all fish with 20% scale loss died.



a) Hook has punctured the heart

b) Hook has punctured the liver

Figure 5. Examples of hook orientation and injuries to the heart (a) and liver (b) in deep-hooked black bream.

At the time of capture, 63% of deep-hooked fish that retained a hook were thought to be throat/gill-hooked. However, PM examination found that none were actually hooked in the throat or gills. The oesophagus or gut were the actual hooking locations.

All deep-hooked mortalities had an injury found during PM examination, while 30% of survivors (mostly shallow-hooked fish) had no noticeable injuries. No injuries were found in a few deep-hooked survivors with a retained hook, in which case the hook was loose in the gut cavity and no punctures were apparent along the digestive tract. Fish with no injuries, as determined during PM, were not compared with assessments made at capture.

Discrepancies were found between shallow- and throat/gill-hooking locations (throat/gill-hooked mistaken for shallow-hooked [hook always removed]) and between throat/gill- and oesophagus/gut-hooking location (oesophagus/gut-hooked mistaken for throat/gill-hooked [generally hook not removed]). In all, 34% of all mortalities had been categorised as shallow-hooked (lip/mouth) at capture; however, PM dissections revealed that only 26% of all mortalities had lip or mouth injuries (Table 9).

Table 9. Hooking location at capture and hooking injury validation by post-mortem.

Hooking location at capture and by PM	Percentage of fish hooked at each location		
	Lip/mouth	Throat/gill	Esophagus/gut
Deep-hooked fish with the hook not removed			
Hooking location recorded at capture	NA	63%	37%
Hooking location determined at PM	NA	0%	100%
Injuries			
Hooking location recorded at capture for mortalities	34%	50%	16%
Injury to area in mortalities determined at PM	26%	42%	32%
Hooking location in survivors recorded at capture	72%	20%	8%
Injury to area in survivors determined at PM	75%	4%	21%

Hooking location validation was not possible for shallow-hooked fish or fish that were deep-hooked and had the hook removed. NA means that the estimate was not applicable. PM = post-mortem

Applying post release survival and mortality rates to recreational fisheries

Released black bream in Gippsland Lakes fishery

Effect of fish length and hook type on shallow-hooking rates

Anglers participating in a fishing diary program and fish survival capture experiments provided a total of 2,859 records for under-size black bream that contained hook location. Simple logistic regression analysis indicated that shallow/deep-hooking rates of black bream were dependent ($P<0.0001$) on the size composition of the stock (fish length) and the hook sizes used by the anglers (hook size category). Of the total number of fish caught, shallow-hooking rates were significantly lower for the small hook size category (66 ±4%) than the medium (79 ±2%) and large (79 ±3%) hook categories (df 2, G^2 =37.7, $P<0.0001$). Scatterplots of the average rate of shallow-hooking fish in each under-size black bream size-classes for the hook size categories (medium and large were combined) showed evidence of a linear relationship (Appendix 5, Figure 20). The results of the linear regression model indicated that there was no difference in shallow-hooking rates for medium and large hook size categories ($P>0.05$) and that total fish lengths were negatively correlated for the hook size categories (Table 10).

Table 10. Linear regression model parameters for shallow-hooking rate against total length for under-size black bream caught by hook size categories (small- No.6 and smaller, medium- No.4 and large- No.2 and larger) for fishing diary anglers from 1997 to 2005.

Hook category	Slope	Intercept	Correlation coefficient (R^2)	No. of captures
Small	-0.0531	1.6837	0.8302	565
Medium & Large	-0.0233	1.278	0.8891	2,294

Size composition of the black bream stock

Anglers participating in the fishing diary program and fish survival capture experiments provided length measurements and hook sizes for 13,965 black bream from which the size-selectivity curves were estimated for the three hook sizes categories (Figure 6).

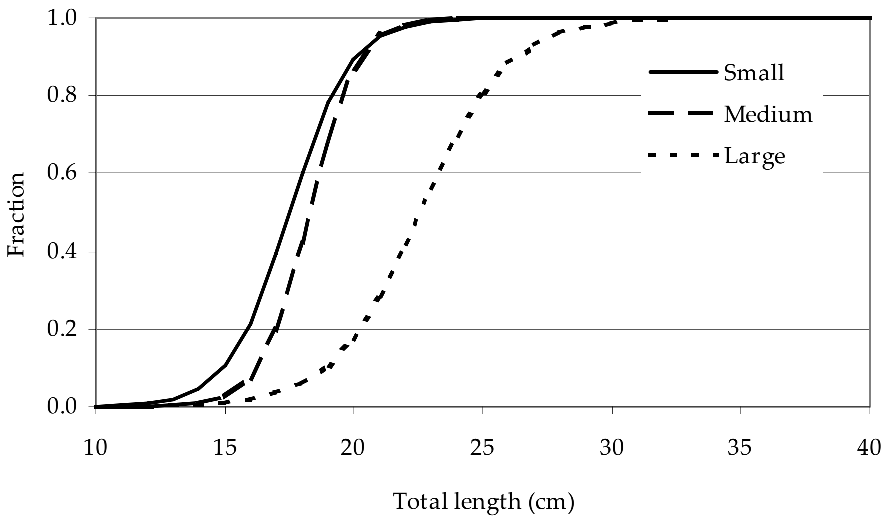


Figure 6. Estimated size selectivity curves for black bream caught by anglers fishing with three hook-size categories (small-No.8- No.6, medium- No.4, large- No.2- No.1/O) in Victorian estuaries between 2001 and 2005.

Anglers participating in the fishing diary from 2003 to 2005 recorded 1,901 hours of fishing effort in the Gippsland Lakes for a catch of 1,800 black bream. About 60% of this catch (between 15 and 40 cm TL) was below the LML of 28 cm. When the length-frequency distribution of the catch was adjusted for hook selectivity, about 90% of the sampled black bream population (15-40 cm TL) in the Gippsland Lakes was estimated to be under-size (Figure 7).

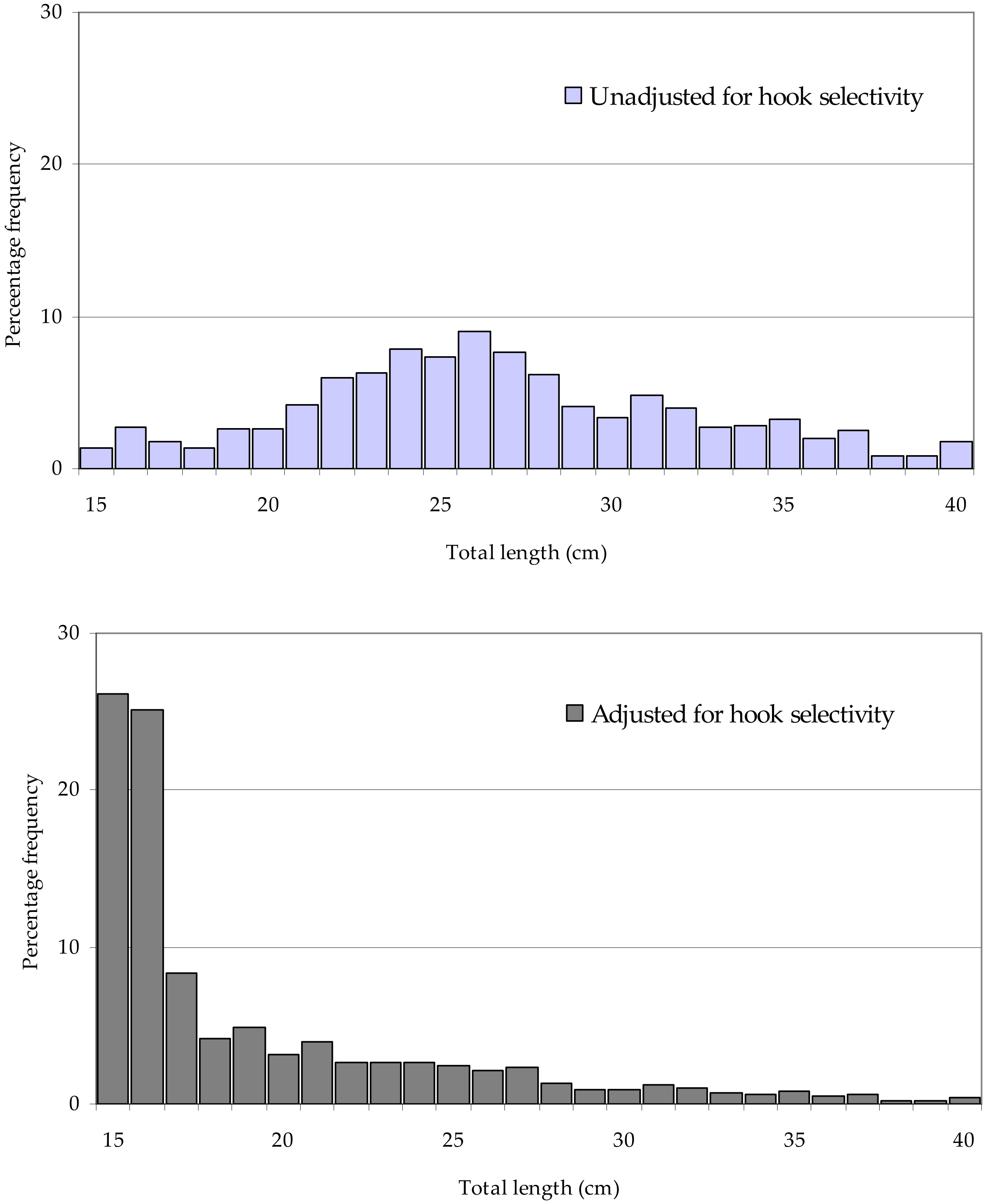


Figure 7. Estimated relative size composition of black bream in the Gippsland Lakes derived from anglers participating in fishing diary program from 2003 to 2005.

Hook sizes used by anglers

The on-site survey identified 1,518 fishing parties (from 454 boat-based and 1,064 shore-based parties) who reported catching and releasing under-size black bream between 2003 and 2005. Shore-based anglers were observed to fish more with smaller size hooks and less with the larger hook sizes than boat-based anglers ($P<0.05$), while the proportion of medium size hooks used were similar (Figure 8).

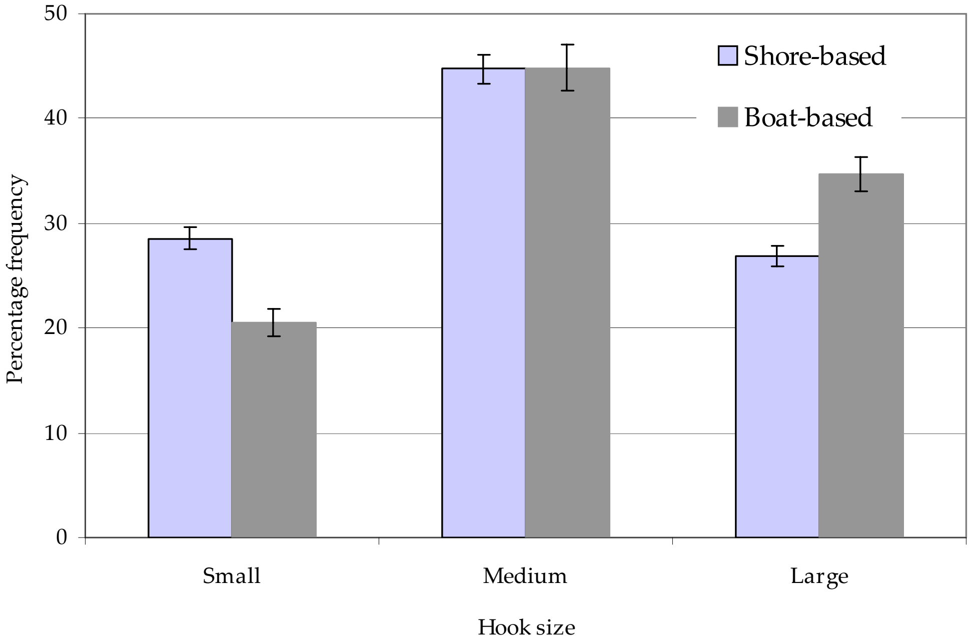


Figure 8. Distribution of hook-size categories (small-No.8 - No.6, medium- No.4, large- No.2 –No.1/O) and 95% confidence intervals by fishing platform for anglers fishing in the Gippsland Lakes from 2003 to 2005.

Estimating the size composition of the released black bream catch

The selectivity characteristics of the large hook-size category resulted in size composition catch estimates with a greater proportion of the larger fish (>24 cm) than smaller fish (<20 cm), while the catches with the small and medium hooks were less selective across the ranged of fish lengths (Figure 9). Hooks in the large hook-size category were more common in the boat-based fishery compared with the shore-based fishery resulting in a minor difference (highlighted by the arrows) in the estimated size-composition of the catch. The size composition of fish released by shore-based had more small (<20 cm) and less large (>24 cm) fish compared to the catch released by boat-based anglers (Figure 10) however a Kolmogorov-Smirnov test confirmed that these differences were not significant ($P>0.05$).

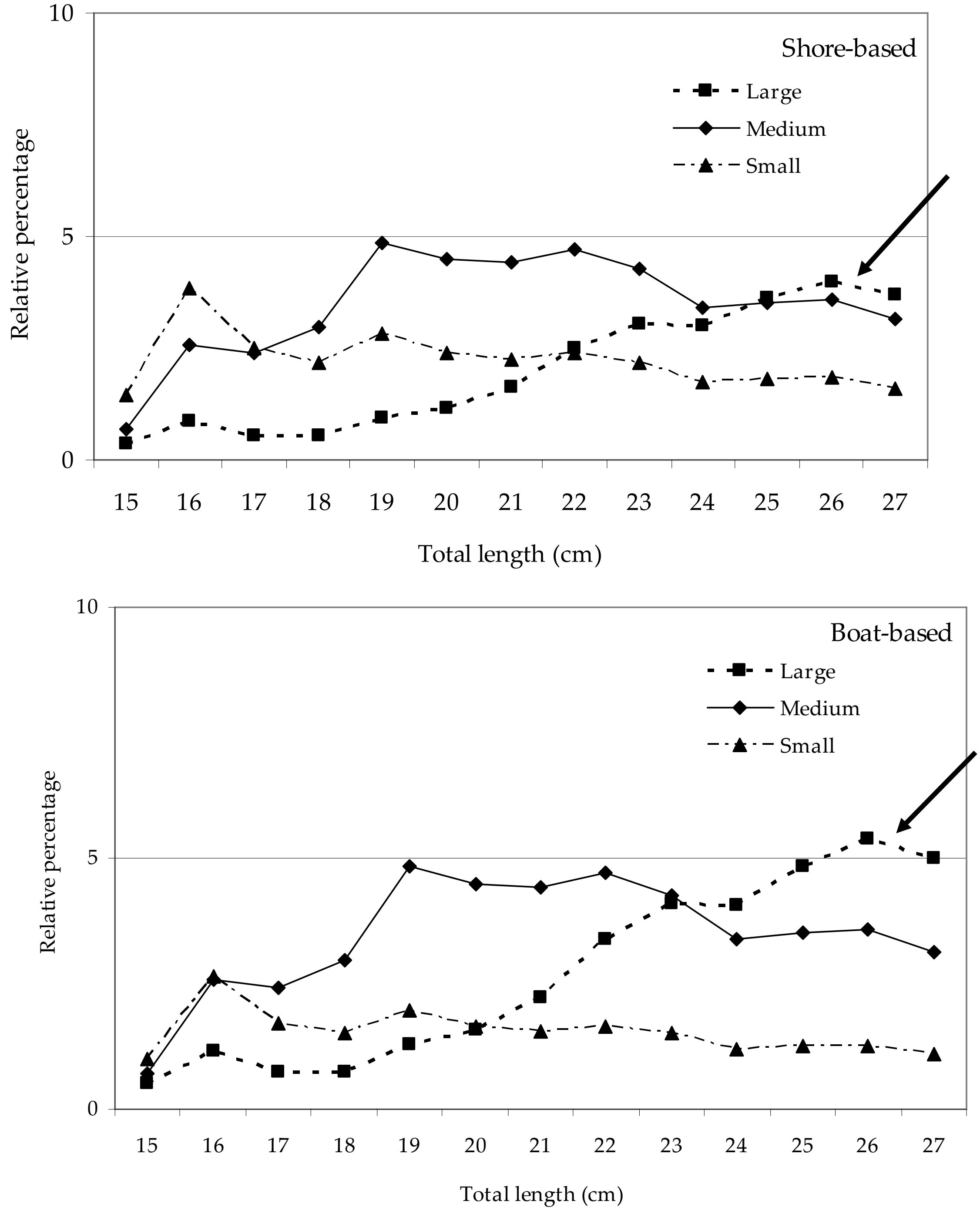


Figure 9. Estimated percentage of under-sized black bream released by number by hook-size category (small-No.8 - No.6, medium- No.4, large- No.2 –No.1/0) for shore and boat-based fisheries in the Gippsland

Lakes from 2003 to 2005. Arrows highlight the difference in percentage of black bream released between fisheries for large hooks.

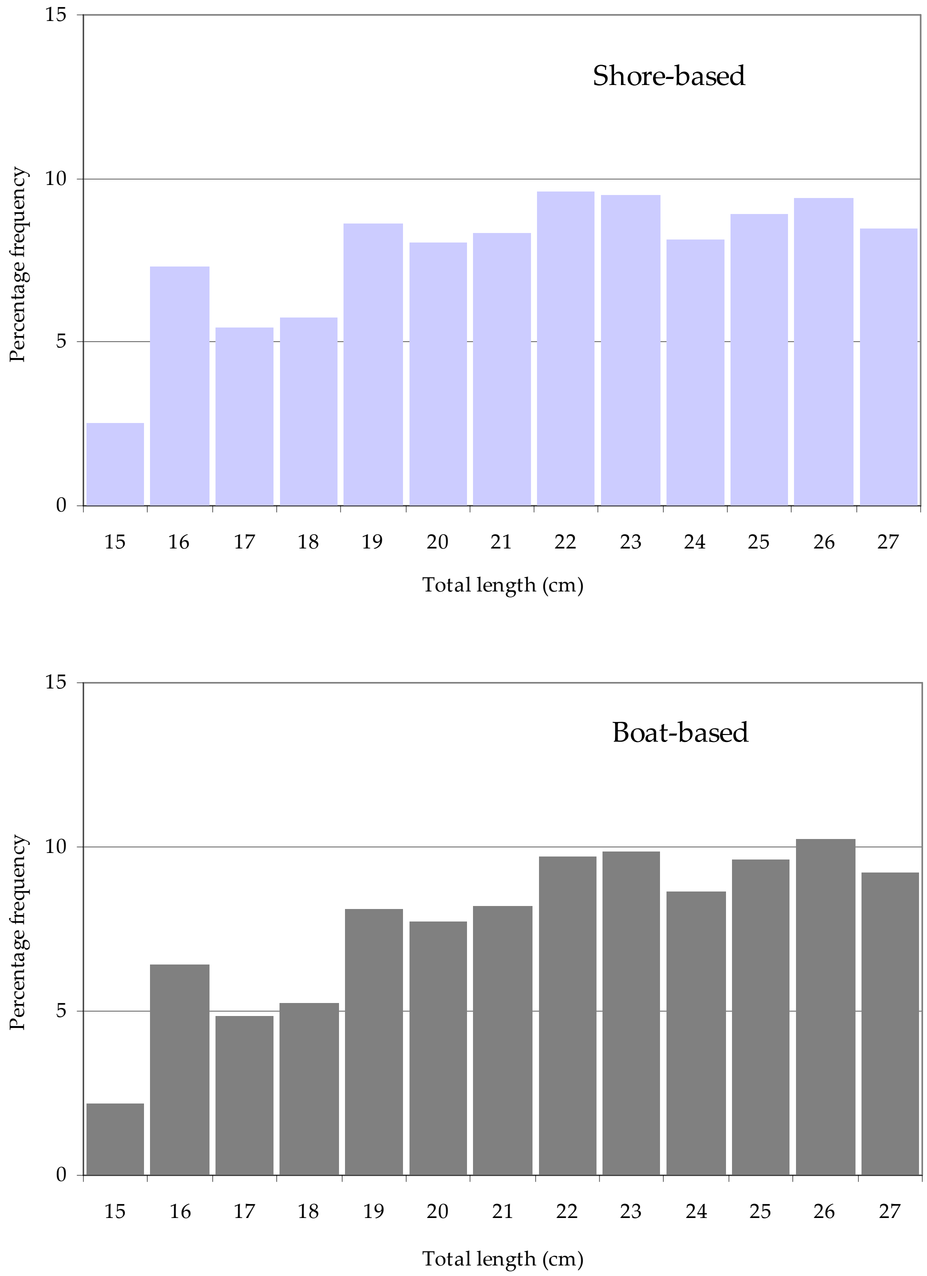


Figure 10. Relative size composition by number of under-sized black bream released for shore and boat-based fisheries in the Gippsland Lakes from 2003 to 2005.

Estimating the survival rate of the released black bream catch

When standardised by shallow/deep-hooking rates for each hook category (Table 10) shallow-hooking rates declined as fish length increased for both the shore- and boat-based fishery (Figure 11). When standardised by survival rates (initial and delayed) 89 (±6)% of released black bream survived. Estimates of survival were the same from shore- and boat-based anglers in the Gippsland Lakes.

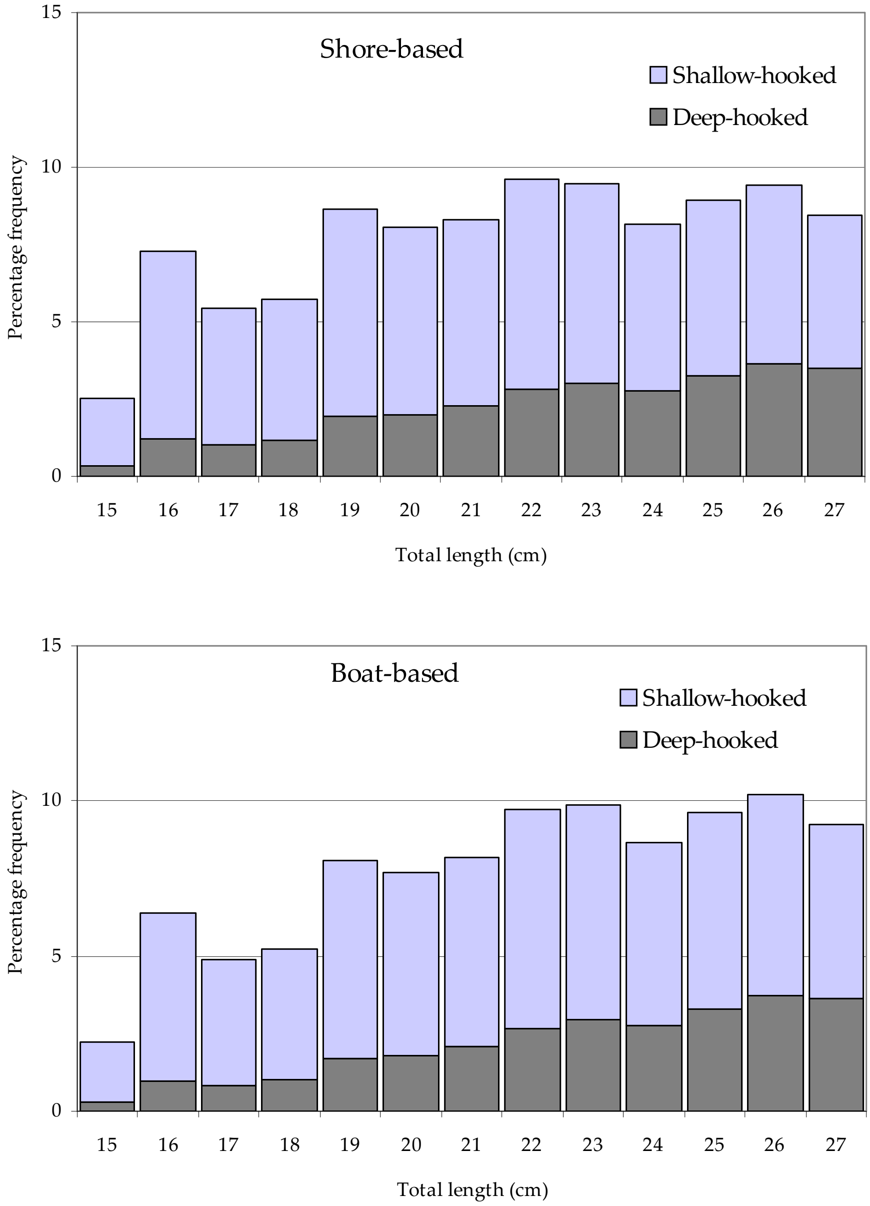


Figure 11. Relative size composition by hooking location for under-sized black bream released for shore and boat-based fisheries in the Gippsland Lakes from 2003 to 2005.

Fishing party catch rates from surveys undertaken between 2003 and 2005 indicated similar average released rates of black bream from both shore- and boat-based anglers (about 0.6 fish per angler hour). The average retained catch rates for both groups were lower (shore -0.06 fish per angler hour, boat-0.1 fish per angler hour) (Appendix 5, Figure 21).

Applying the estimated PRS of 89% to the average release rate allows the catch rate to be split between fish that survived or died. Figure 12 shows for both fisheries the proportion of the catch retained was similar to the proportion that was released and died. The higher retained catch by boat anglers was reflected in the marginally better proportion of retained to released and died compared with the shore-based fishery.

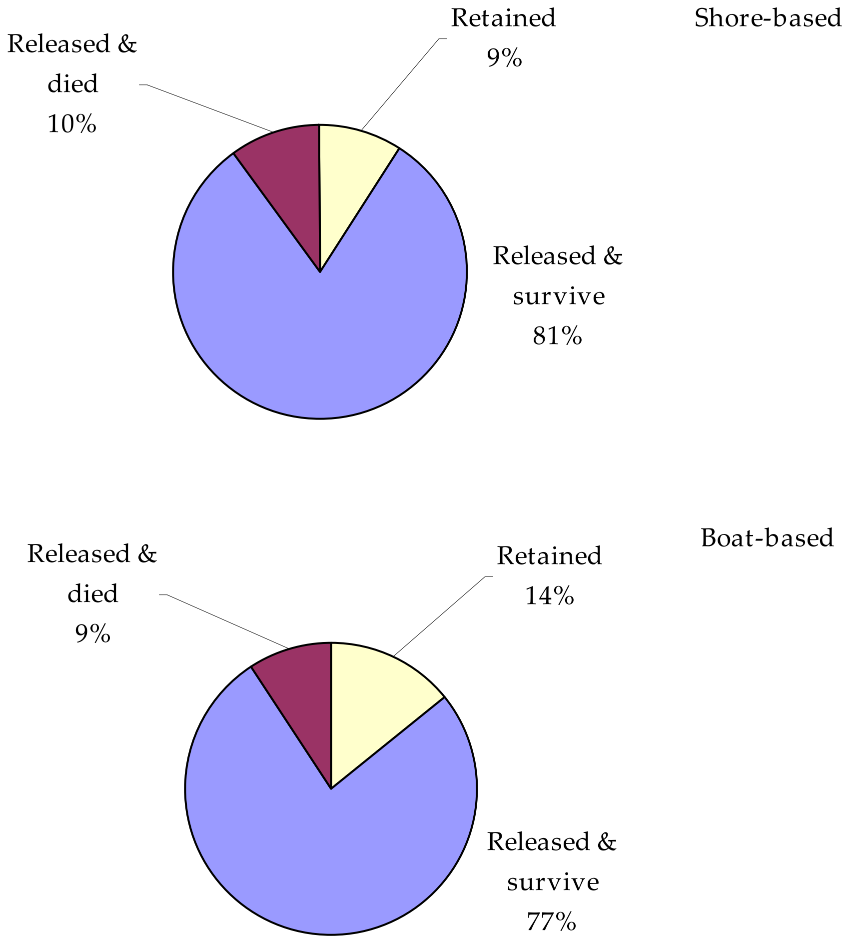


Figure 12. A comparison of percentage of the black bream catch (retained, released and survive and released and died) by number for shore-based and boat-based black bream fisheries in the Gippsland Lakes from 2003 to 2005.

Released snapper in the King George whiting fishery of Port Phillip Bay

Effect of fish length and hook type on shallow-hooking rates

Anglers participating in a fishing diary program and fish survival capture experiments provided a total of 3,698 under-size snapper hooking location capture details between 2003 and 2005. Shallow-hooking rates for under-size snapper (92 ± 2%) were significantly higher ($P<0.05$) than for under-size black bream. Regression analysis indicated that shallow/deep-hooking rates of snapper were not dependant on fish length ($P=0.4860$) or hook size (df 2, $G^2 = 1.07$, $P=0.5841$).

Estimating the survival rate of the released snapper catch

Standardised by total survival rate for hooking locations (obtained from the capture and holding experiments) 94 ± 3% of snapper released from boat-based anglers in Port Phillip Bay survived.

Mean catch rates by boat-based anglers targeting King George whiting in Port Phillip Bay between 2003 and 2005 were similar for under-size released snapper (0.7 ± 0.5 fish per angler hour) and retained King George whiting (0.6 ± 0.4 fish per angler hour). Mean release rates for under-size whiting were 0.2 ± 0.4 fish per angler hour), while snapper were retained at a rate less than 0.1 fish per angler hour over the 3 year monitoring period (Appendix 5, Figure 22).

For the King George whiting fishery, the percentage of the snapper catch that was under-size and released and died was very small (6%) compared to those that were released and survived (89 %) (Figure 13). The fate of the under-size component of King George whiting released catch was outside of the scope of the study.

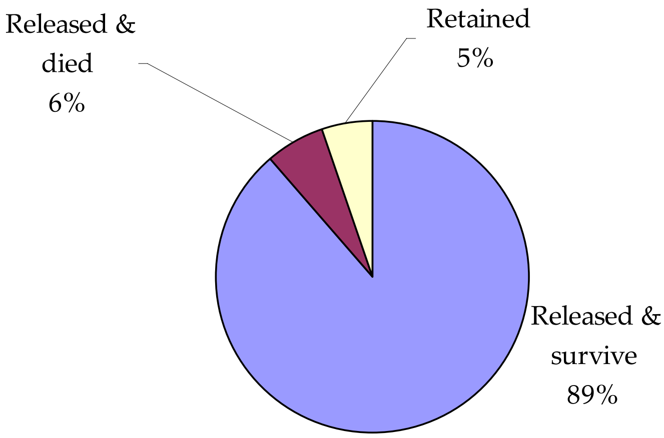


Figure 13. A comparison of relative percentage of snapper catches (retained, released and survive and released and died) averaged by number for the boat-based King George whiting fishery in Port Phillip Bay from 2003 to 2005.

Discussion

The results of this study indicate that PRS rates are high (>80 %) for under-size black bream and snapper in some important Victorian hook-and-line fisheries. These findings support the use of LMLs as a tool for protecting these fish stocks from some undesirable impacts of hook-and-line fishing. The integration of PRS rates with catch information from the fisheries provided a more comprehensive assessment of the overall efficiency of the LML management tool. Release rates of under-size snapper were similar to retained King George whiting catch rates in the boat-based King George whiting fishery in Port Phillip Bay. The post-release mortality component was only a small percentage of the released snapper. For black bream in the Gippsland Lakes, recreational shore-based and boat-based release rates of under-size fish were many times higher than retained catch rates. The post-release mortality component was therefore as large as the harvested catch, despite the high PRS rates.

The present study demonstrated how repeated field experiments, designed to reflect common fishing conditions and practices, can be used to determine the rates and key factors for both PRS and the catch of under-size black bream and snapper. This approach overcame potential problems from laboratory-based experiments in which fish have already been subject to capture stress and have had to become adapted to the artificial conditions in which they are held; the results from such experiments are therefore not necessarily representative of the wild fishery.

The capture and holding experiments showed that hooking location was the key factor that determines PRS for under-size black bream and snapper. Total survival was considerably higher for shallow-hooked (95% for black bream, 97% for snapper) than deep-hooked (74 % for black bream, 48% for snapper) fish. Compared with survival rates for other Australian temperate water species the shallow-hooking rates are similar, but the deep-hooking rates show substantial differences, with bream and snapper at the upper and lower ranges of values reported for such species as dusky flathead (73% [deep] and 96%[shallow] respectively; Lyle *et al.* 2006), sand flathead (64%[deep] and 100%[shallow] respectively; Lyle *et al.* 2007), and yellowfin bream (<55%[deep} and 97%[shallow] respectively; Broadhurst *et al.* 2005). When the estimates of shallow-hooking in the fisheries (black bream, from 30-90% depending on fish length and hook size; snapper, 92% ± 2%) were combined with the corresponding survival estimates, the PRS rates were 89% ± 6% for black bream and 94% ± 3% for snapper.

Black bream length strongly influenced the rate of shallow-hooking, with shallow-hooking decreasing as fish length increased. Similar trends were noted for black sea bass (Bugley & Shepard 1991), brook trout (Nuhfer & Alexander 1992) and flathead (Lyle *et al*. 2006). For snapper, the shallow-hooking rate in the present study was not found to be related to fish length. This may be because under-size snapper are a by-catch in the Port Phillip Bay King George whiting fishery. The hook size used by anglers to target King George whiting would be considered a small hook for targeting legal sized snapper (even just legal size fish of 28 cm). It is therefore possible that fish length did not influence shallow-hooking because the hook size was too small relative to the fish's length (and mouth size) and feeding behaviour to be influential.

In the present study, post mortem examinations of snapper and black bream revealed that survival rates were lowest for fish with throat, gill and heart hooking injuries. These types of injuries where present in 40–50% of deep-hooked fish. The examinations also showed that removing deeply swallowed hooks increased the severity of throat and gill injuries. Oesophagus/gut-hooked fish typically retained the hook and on most occasions had a pierced liver (often including the septum transversum and less regularly the heart). These fish had a high survival probability within 72 hours post-capture. Nuhfer & Alexander (1992) observed that the probability of survival in deep-hooked brook trout (*Salvelinus fontinalis*) decreased considerably if fish were hooked in the throat or gills and that hook removal exacerbated these injuries. Similar results were reported for striped bass (*Morone saxatilis*) (Nelson 1998), blue cod (*Parapercis colias*) (Carbines 1999) and flathead (*Platycephalus bassensis*) (Lyle *et al*. 2006; Lyle *et al*. 2007).

Anglers removed deeply embedded hooks for both species based on the most common practices in their fishery. Hooks were either removed by hand if anglers could reach the hook's eye with their fingertips (≤1 cm inside the fish's mouth) or not removed if they were unreachable. This removal protocol was shown to be consistent with angler responses from an on-site survey and also indicated that hooks were less likely to be removed as fish length increases. Removing hooks from deep-hooked fish increased the risk of bleeding. Deep-hooked fish that did not bleed had significantly higher survival rates than deep-hooked fish that bled. Total survival for deep-hooked black bream was higher (20%) when hooks were not removed than when removed. However, for snapper total survival for deep-hooked fish was similar regardless of whether the hook was removed (42%) or not removed (45%). It is possible that some recording errors at capture may have masked the effect of bleeding. Hook removal and bleeding have previously been linked to lower survival rates for flathead (Lyle *et al.* 2007), striped bass (Nelson 1998) and blue cod (Carbines 1999). Mason & Hunt (1967) reported survival for deep-hooked rainbow trout caught on natural baits to be 5% when hooks were removed by hand, 18% when hook extractors were used and 66% when hooks were not removed. Black sea bass (*Centropristis striata*) that swallowed a hook deeply had 100% survival if the hook was not removed, but this figure decreased to 40% when the hook was removed (Bugley & Shepherd 1991).

Only a small percent of deep-hooked snapper and black bream shed their retained hooks before death or within the 72-hour holding period and minimal hook degradation was observed for retained hooks. Implications of a pierced liver, in conjunction with possible longer-term retention of the hook, may not have been seen within 72 hours. Potential longer-term effects, such as interrupted hormone production (e.g. insulin), infections and impacts on feeding and digestion may lead to longer-term mortality (>72 hrs) or other sub-lethal effects such as weight loss or reduced reproductive success. Muoneke & Childress (1994) reported that provided there was no major tissue damage to the vital organs, some fish could either shed a hook, survive until the hook dissolved or grow new tissue around the hook. Jordan & Woodward (1992) determined that hooks required between 2 and 28 days to either deteriorate or dislodge for red drum (*Sciaenops ocellatus*). Schisler & Bergersen (1996) found that 18% of rainbow trout had shed retained hooks after three weeks. The probability of hooks being uncorroded and remaining in a charr (*Salvelinus leucomaenis*) gut decreased with time, while the estimated average time before hooks started to corrode was 22.1 ± 22.7 days after cutting the line and the average time for hook shedding was 53.3 ± 36.3 days (Tsuboi *et al*. 2006). Roennfeldt *et al.* (unpublished) found that after the first 24 hours, all deep-hooked black bream, including those with pierced livers, survived for four weeks in a study of hook retention times. No hooks were dislodged and hook degradation was minimal at the end of that study.

Previous studies have defined initial survival times ranging from <20 minutes (Jordan & Woodward 1992) to 24 hours (Plezman 1978). The primary objective of an initial survival period in the present study was to avoid putting dead fish into holding tanks, however this initial period also reflects the time that anglers might observe PRS. If many fish observably die, then anglers will perceive PRS to be low and the management to be ineffective. Initial survival was 97% and 98% for shallow- and 86% and 54% for deep-hooked black bream and snapper respectively. Most fish that subsequently died within the initial holding period (<20 minutes), swam briefly at first. These fish were generally disorientated and upside down at the water surface before eventually coming to rest on the cage bottom. The combination of high initial survival (because most fish are shallow-hooked) and dead fish sinking suggests that anglers might perceive PRS to be high.

Monitoring wild fish in holding tanks has limitations when trying to estimate PRS. These limitations include: altered physio-chemical conditions (e.g. flow), disrupted fish behaviour, decreased predation risk, increased stress and physical damage from transport, the holding tanks or other fish. Despite the limitations, monitoring wild fish in holding tanks is by far the most common method for studying PRS (Muoneke & Childress 1994) and is generally considered an acceptable methodology provided the limitations of results are realised. In the capture holding experiments only one of the 266 control black bream died and none of the snapper controls died, so recreationally caught mortalities were assumed to be from the angling activity.

Part 2 - Improving post release survival and mortality rates in recreational fisheries

Background

The results of the study reported in Part 1 indicated that under-size black bream and snapper are generally caught on hooks with natural baits and that PRS rates in the fisheries for these species would principally be determined by the hooking location. The present and previous studies (Conron *et al.* 2004; Grixti *et al.* 2007) have also shown that for under-size fish, shallow/deep hooking rates can be dependent on fish length and hook size. Those findings guided the process for estimating PRS rates in recreational fisheries.

Average retained and released catch rates from on-site angler catch surveys were used to estimate the ratio of the number of retained fish to the released under-size components of the catch that survived or died.

Need

The combination of high PRS rates and low catch rates of under-size snapper was considered not to warrant investigation of improvements. The combination of high PRS rates and high catch rates of under-size black bream was considered to warrant investigation of improvements into the impact of PRS of released fish on fish stocks.

Objective

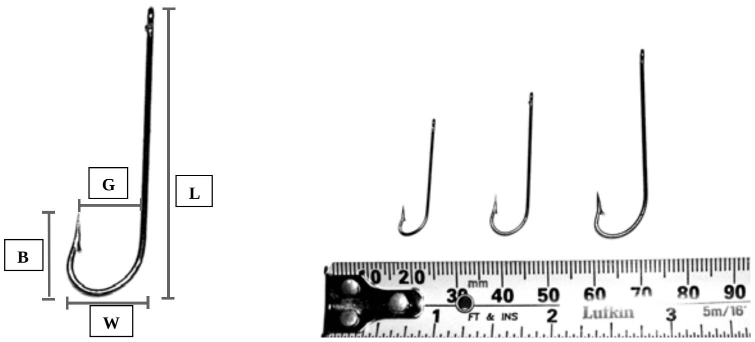
To determine the extent to which alternative fishing gears and angling methods could increase PRS rates for black bream.

Materials and Methods

Experiments to test measures for improving survival.

Fishing experiments were conducted on five Victorian estuaries: Sydenham Inlet (29 & 30 November 2004), Gippsland Lakes (1 & 2 December 2004), Mallacoota Inlet (6 & 7 December 2004), Hopkins River (31 January & 1 February 2005) and Glenelg River (8 & 9 February 2005).

Black bream were captured by the most common fishing techniques used in the Gippsland Lakes (as outlined in part 1 in this study). Experienced anglers used one or two 2–4 kg rod and reel arrangements, a running sinker rig (standardised 60 cm, 5.4 kg monofilament leader) and pod/sand-worm bait (local species, *Australonereis sp*.). Size 4 hooks were most commonly used to catch black bream in the Gippsland Lakes, so sizes 8, 4 and 1 (size 8 and 1 are, respectively two sizes below and above size 4) barbed, offset, longshank hooks (Dynatec Red-Line) were used to compare the effect of hook size (**Figure 14**). Hook length, width, gape, bill and absolute size (hook length x hook width) were quantified to the nearest 0.1 mm by measuring three randomly chosen hooks of each size from a packet of 50 hooks (Appendix 6 Table 17). Each hook was baited with pod/sand-worm until the entire hook shank and barb were covered. This meant that hook size and bait size could be differentiated, so from here on hook sizes 8, 4, and 1 are referred to as hook and bait size small, medium and large respectively (see Grixti *et al.* (2007) for discussion on this method). Anglers switched their angling technique, either holding the rod in hand while keeping a tight line or resting rod/s in a rod holder to allow a slack line. With a tight line, the angler sets the hook immediately after feeling a bite, while with the slack line a fish takes up the slack before the hook is set. These two techniques of passive bait fishing are commonly used by anglers of all experience levels when targeting black bream (numerous anglers, personal communication).



a b

Figure 14. (a) The dimensions of a hook: L = length, W = width, G = gape and B = bill. (b) Size 8, 4 & 1 longshank hooks (from left to right respectively).

Fishing experiments were repeated over two consecutive mornings at each estuary, starting between 08:00 and 09:00. The mornings were broken into three one-hour fishing sessions with each session at a different randomly chosen fishing site in the estuary. Six anglers fished from three boats (two anglers aboard each boat) each morning. Each boat used all sizes of the hook and bait during one of the three one-hour fishing sessions each morning. The anglers in each boat used a slack line for half of each one-hour session and a tight line for the other. Therefore the study had one one-hour fishing session per hook and bait size, per angler technique, per boat, per morning, per estuary (Figure 15). A severe storm resulted in the cancellation of the last one-hour fishing session on the second fishing morning at Mallacoota. All other sampling was successfully completed.

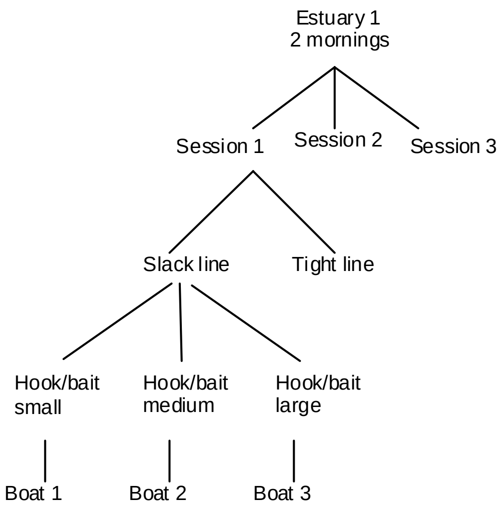


Figure 15. Experimental design for fishing experiments carried out in Victorian estuaries targeting consecutive mornings. Two line techniques and three hook-bait sizes were examined for black bream. At each of five estuaries three fishing sessions of 1hour were carried out on two mornings

The hook and bait size used by each boat was chosen at random for each fishing session and the three boats always had different hook and bait sizes from each other. Time spent moving, anchoring, and preparing new rigs was not included in the one-hour fishing sessions. The fishing session, hook and bait size, hooking location (shallow- [lip/mouth]; throat/gills-; oesophagus/gut-; foul-; eye-hooked), angling technique (slack line, tight line), hook removal (removed, not removed), external bleeding (blood, no blood) and fish length (TL, rounded down) were recorded for all captured black bream. Hooking locations throat/gills and oesophagus/gut were later combined to the one deep-hooked category because post-mortem (PM) examinations identified confusion between these categories in the records (see Results, section PM examination). The hooks in all shallow-hooked fish were removed. The hooks in deep-hooked fish were removed or the line was cut depending on the hook position. A hook was removed by fingers if the hook eye was swallowed approximately <1 cm from the tip of the lips, but the line was cut as close to the hook as possible when >1 cm. This method was used because the anglers said that hooks were usually removed from black bream when reachable with fingers. The number of baits used by each angler was noted for each hook and bait size, angling technique and fishing session. When a species other than black bream was captured, that bait was not counted. Fin clipping was used to identify individual fish according to hooking location (shallow- or deep-hooked), hook removal and external bleeding.

The first five shallow-hooked and all deep-hooked black bream captured during each one-hour fishing session were held in cages (0.25-cm diameter soft mesh cages measuring 70 cm deep x 62 cm long x 62 cm wide) beside anglers' boats for the duration of session to monitor 'initial' PRS (survival for first hour). All deep-hooked fish were kept because they have the greatest mortality rate and are a rarer occurrence than shallow-hooked fish (Grixti *et al*. 2008). Holding cages were empty at the start of each session, and then fish were assessed and cleared at the end of the one hour. To minimise potential fish size-related effects of confinement such as aggressive behaviour, fish smaller than 15 cm in total length were not held or monitored and neither were foul- and eye-hooked fish, because previous experience showed that these hooking locations are rare. Fish were categorised as 'initial mortalities' if they lacked or had very slow operculum movement and lay at the cage bottom or floated at the cage surface motionless. After each one-hour fishing session, surviving fish in the holding cages were euthanased in an iced water bath and then both they and the dead fish were dissected according to the PM procedure documented by Grixti *et al*. (2008). The PM dissection generally took between 3–5 minutes per fish and variables recorded were scale loss, hooking location, shed or retained hook, injuries and sex.

Statistical procedures

All statistics were analysed using SAS 9.1.2. for a three 3-way factorial ANOVA (details in Appendix 6). The numbers of captured fish ≥28 cm were insufficient for statistical analysis. Control fish that account for experimental effects on survival were not used in this study, so the results were used to compare survival rates between variables and not to provide a reliable survival estimate. Results are reported as means ± SE.

Results

Effects of hook and bait sizes, fishing techniques and estuaries

A total of 2,618 baits were used, averaging 15 ± 0.48 (SE) per boat hour (Table 11). The mean number of baits used per boat h^{-1} differed significantly across estuaries (ANOVA, df 4, F 16.60, P = <0.001), but not across hook and bait sizes, angling techniques or interactions between them (Table 11). The mean number of baits used per boat hr–1 in each estuary ranged between 10.7 ± 0.72 in Sydenham Inlet to 20.9 ± 0.78 (SE) in Mallacoota Inlet.

A total of 802 fish <28 cm were caught, averaging 4.6 ± 0.31 captures per boat hour (Table 11). Significantly more fish <28 cm were caught per boat hour fishing with a tight line than a slack line (ANOVA, df 2, F 4.89, P = <0.029) and a small hook and bait compared to a large hook and bait (ANOVA, df 2, F 3.19, P = 0.044) (Table 11). More legal-sized fish (≥28 cm) were caught on a tight line than a slack line and more on the medium hook and bait size than on the small or large size (Table 11).

The lengths of captured fish were more evenly distributed for the small and medium hook and bait sizes than the large hook and bait size (Table 11, Appendix 7 Figure 23). Mean lengths were significantly different, with a range of 2.6 cm across hook and bait sizes (ANOVA, df 2, F 13.71, P <0.001) and a range of 6 cm across estuaries (ANOVA, df 4, F 48.34, P <0.001) (Table 11). *Post hoc* comparisons revealed that the small hook and bait size caught significantly smaller fish than the medium and large hook and bait sizes. The mean length of fish captured with medium and large hook and bait sizes were not different (Table 11). Angling technique and interactions did not significantly (P >0.05) affect the mean length.

Survival experiments

There were 841 fish captured, 528 monitored for initial survival and 459 (87%) survivors. The initial survival, shallow-hooking and hook removal percentages for hook and bait sizes are summarised in Table 12. Significantly higher survival rates were observed (i) in shallow-hooked fish compared with deep-hooked fish (ii) as fish length increased and (iii) in deep-hooked fish when the hook was not removed compared with when the hook was removed (Appendix 7 Table 18). Logistic regression odds ratio (Appendix 7 Table 18) indicated 1.11 more chance of survival for every 1 cm increase in fish length. Hook size did not significantly affect the probability of survival (Appendix 7 Table 18). Of the 528 fish monitored for initial survival, 427 did not bleed. Deep-hooked fish accounted for 85% of bleeding fish and 41% of those fish survived. Survival was 82% for shallow-hooked fish that bled.

In total, 572 fish were shallow-hooked, 247 deep-hooked, 18 foul-hooked and 4 eye-hooked. Shallow-hooking rates were significantly affected by hook and bait size, angling technique, fish length and estuary (Table 11). Shallow-hooking rates increased as hook and bait size increased and were higher for tight than slack line fishing. Tight line fishing seemed to reduce the shallow-hooking effect of hook and bait size (Table 12). Logistic regression odds ratio (Appendix 7 Table 18) indicated 0.86 less chance of shallow-hooking for every 1 cm increase in fish length. Larger hooks were significantly more likely to be removed from deep-hooked fish than smaller hooks (Table 12, Appendix 7 Table 18). Fish length was significantly related to hook removal, with logistic regression odds ratio indicating 0.74 less chance of a hook being removed for every 1 cm increase in fish length (Appendix 7 Table 18).

Table 11. Summary of bait used, number of black bream caught and fish length. The means shown are per boat h^{-1} (± 1 SE). Factorial ANOVA and Tukey post-hoc tests were performed for each response variable except for number of fish caught ≥ 28 cm.

Independent variables	**Response variables**						
	No. baits used		No. fish caught ≤27 cm		No. fish caught >28 cm		Fish length
	Total no.	Mean (SE)	Total no.	Mean (SE)	Total no.	Mean (SE)	Mean (SE)
Hook and bait size							
Small	882	**a** 15.21 (0.89)	302	**a** 5.39 (0.63)	9	0.16 (0.07)	17.6 (0.26)
Medium	907	**a** 15.63 (0.85)	292	**a, b** 4.87 (0.51)	20	0.33 (0.7)	**a** 19.71 (0.28)
Large	829	**a** 14.29 (0.72)	208	**b** 3.59 (0.42)	10	0.17 (0.05)	**a** 20.26 (0.32)
Angling technique							
Slack line	1257	**d** 14.44 (0.66)	352	4.05 (0.41)	16	0.18 (0.05)	**d** 18.93 (0.24)
Tight line	1361	**d** 15.63 (0.68)	450	5.17 (0.44)	23	0.26 (0.06)	**d** 19.18 (0.23)
Estuary							
Sydenham Inlet	388	**e** 10.78 (0.72)	61	1.69 (0.28)	10	0.27 (0.09)	**e** 22.63 (0.59)
Gippsland Lakes	561	**f** 15.58 (1.18)	149	**e** 4.14 (0.53)	3	0.08 (0.05)	**f, g** 20.16 (0.32)
Glenelg River	753	20.92 (0.78)	328	9.11 (0.68	6	0.17 (0.07)	16.61 (0.23)
Hopkins River	545	**f** 15.14 (0.86)	134	**e** 3.72 (0.56)	8	0.22 (0.08)	**g** 19.60 (0.41)
Mallacoota inlet	371	**e, f** 12.37 (0.79)	130	**e** 4.33 (0.59)	12	0.40 (0.12)	**e, f** 21.37 (0.37)

Letters that are the same before the means of each response variable show that differences between independent variable groups were not significant. No letter indicates that the mean was different to all others in the group.

Table 12. Percentage of black bream caught by small, medium and large hooks that survived, that were shallow-hooked for slack or tight line and that had the hook removed

Response Variable	Size of hook/bait		
	Medium (n caught)	Medium (n caught)	Large (n caught)
% of surviving fish			
Shallow-hooked; hook removed	97 (85)	100 (102)	97 (102)
Deep-hooked; hook removed	36 (11)	24 (21)	15 (11)
Deep-hooked; hook not removed	91 (95)	83 (71)	84 (19)
% of fish shallow-hooked			
Slack line	54 (140)	66 (129)	76 (91)
Tight line	73 (168)	71 (176)	82 (115)
% of hooks removed			
Shallow-hooked	100 (197)	100 (211)	100 (164)
Deep-hooked	19 (111)	27 (94)	55 (42)

Estuaries combined in this table

Post-mortem examination

In all, 67% of deep-hooked mortalities had throat or gill injuries (Table 13). Removing hooks from deep-hooked fish increased the frequency and severity of throat and gill injuries compared with fish where hooks were not removed. Survival of deep-hooked fish was highest when hooks were not removed from the stomach, liver or septum transversum. When hooks were not removed from deep-hooked fish, the hook point was noted to always face down toward the ventral area. When a hook penetrated the septum transversum, the hook point remained in the pericardial cavity very close to or piercing the heart. Initial survival was not significantly different between males (86%) and females (88%) (Appendix 6 Table 18). No fish had lost scales or were able to shed a retained hook within the holding period.

In all, 29% of deep-hooked fish where the hook was not removed were called 'throat/gill-hooked at capture', but PM examination found just 2% were actually hooked in the throat or gills. Most of these fish had been hooked in the oesophagus/gut region (Table 14).

In all, 7% of mortalities had been reported as shallow-hooked (lip/mouth), however PM examination showed 3% of this group were deep-hooked having throat or gill injuries (Table 14). Deep-hooking survival rates had been overestimated. At the time of capture, 36% and 64% of deep-hooked fish that survived were recorded as throat/gill- and oesophagus/gut-hooked respectively, but post-mortems showed that 6% and 94% of these fish had throat/gill and oesophagus/gut injuries respectively. This meant that fish with throat/gill injuries had less chance of survival than suggested by the records made at the time of capture.

Table 13. Shallow- and deep-hooking injuries observed during post-mortem examinations. As only a sample of shallow-hooked survivors was examined by PM, the percent of survivors could not be calculated accurately.

Injury categories	Died	Survived	Total	% Survival for injury	% in Injury category
None	0	44	44	NA	100
Shallow-hooking injuries					
Slight maxillary	2	85	87	NA	32
Moderate maxillary	2	139	141	NA	51
Major maxillary	0	11	11	NA	4
Roof of mouth	1	34	35	NA	13
Deep injuries					
Slight perforation of throat	1	4	5	80	3
Extensive perforation of throat	10	2	12	17	6
Punctured gills	1	3	4	75	2
Broken gills	4	0	4	0	2
Broken gills and perforated throat	28	1	29	3	15
Pierced liver	0	1	1	100	1
Pierced liver and septum transversum	5	99	104	95	55
Pierced liver, septum transversum and heart	12	4	16	25	8
Pierced heart	1	1	2	50	1
Pierced stomach wall	0	13	13	100	7

Note: NA means that the estimate was not applicable (all dead shallow-hooked fish examined but only a sample of shallow-hooked survivors had a post mortem examination conducted so % survival could not be calculated correctly)

Table 14. Hooking location and hooking injury validation by post-mortem examination.

Validating hooking location	Percent of fish determined at each hooking location		
	Lip/mouth	Throat/gill	Oesophagus/gut
Deep-hooked fish with the hook not removed			
Hooking location recorded at capture	NA	29	71
Hooking location determined at PM	NA	2	98
Injuries			
Hooking location recorded at capture for mortalities	7	67	26
Injury to area determined at PM for mortalities	4	64	32
Hooking location recorded at capture for survivors	64	13	23
Injury to area determined at PM for survivors	65	2	33

Hooking location validation was not possible for shallow-hooked fish or fish that were deep-hooked and had the hook removed. All mortalities had an injury found during PM examination, but 10% of survivors had no noticeable injuries. Surviving fish with no post-mortem determined injuries were not compared in this table. NA means that the estimate was not applicable.

Discussion

The results of the present study suggest that legal-minimum length protection of black bream stocks can be improved through higher PRS rates and lower release rates of under-size fish if anglers use a hook size number 1 or larger. It is crucial that anglers do not remove deeply swallowed hooks, as removal appears to offset the benefit of larger hooks. Large hook and bait sizes will be most useful for anglers specifically targeting bream or for anglers who are catching numerous under-size fish. Fishing with a tight line increased shallow-hooking, but this survival benefit was somewhat offset (especially for the medium and large hook and bait size) by the increased catch of under-size fish.

Shallow-hooking rates increased as hook and bait size increased. The large hook and bait size caught fewer under-size black bream than the small hook and bait size. Studies by McCracken (1963), Ralston (1990), Otway & Craig (1993) and Grixti *et al*. (2007) reported that hook-size selectivity affected the length of fish captured. Capture success rates for hooks lodging in fish are perceived to increase if hooks are further down the fish's digestive tract at the time an angler 'sets' the hook (anglers, personal communication). As black bream have a small- to medium-size mouth relative to its body size, it is probable that the large hook and bait size would not be generally taken as far down the digestive tract as the smaller hook and bait sizes for fish of similar length. This would explain the higher shallow-hooking rates, fewer under-size fish caught and larger mean fish length for the biggest hook and bait size. The present study also shows that shallow-hooking decreases as fish length (mouth-size) increases. Examples of increasing fish length and decreasing shallow-hooking associations have been also found for black bream (Grixti *et al*. 2007, this study), largemouth bass (*Micropterus salmoides*) (Meals & Miranda 1994), brook trout (Nuhfer & Alexander 1992) and black sea bass (Bugley & Shepherd 1991).

While the mean fish length was largest for the large hook and bait size (mean 20.3 cm), this mean was still nearly eight centimetres less than the legal-size limit for bream in the Gippsland lakes. Larger hook and bait sizes than the range tested in the present study would probably further increase the mean length and reduce the number of under-size fish captured. However, hook sizes larger than the size 1 are less likely to be voluntarily adopted by anglers in the short-term due to perceived catch efficiency reductions for legal-sized fish (anglers, personal communication). Insufficient numbers of fish ≥28 cm were captured to analyse catch efficiency of legal-sized fish, but a trend for the medium hooks to catch more legal-sized fish was detected.

Hook selectivity analyses, including hooks sizes that select the legal-sized proportion of the black bream population, would complement the present study and help resolve catchability issues.

Slack-line fishing had a lower shallow-hooking rate and caught 1.2 fewer under-size black bream per boat per h than tight-line fishing, confirming previous findings (Grixti *et al*. 2007). This variation in angling technique may have affected shallow-hooking and the number of under-size fish captured because bream can remove worm baits from hooks quickly (anglers, personal communication). With a slack line the bait may be removed before setting the hook can be achieved. Lyle *et al.* (2007) also found that anglers using conventional hook types (e.g. J or octopus types) may increase shallow-hooking by maintaining a tight line while fishing.

Grixti *et al*. (2007) suggested that injury severity, particularly deep-hooking injuries, may potentially increase as hook size increases, because of the increasing length and gauge of the hook that penetrates the tissue. The present study found no significant survival difference between hook sizes, however, survival did decrease as hook size increased if hooks were removed from deep-hooked fish. This finding highlights the survival benefits of not removing hooks that have been deeply engulfed; similar findings have been reported for flathead (Lyle *et al*. 2007), striped bass (Nelson 1998) and blue cod (Carbines 1999). Australian anglers have been encouraged not to remove deeply embedded hooks (Recfish Australia, code of practice) because of suspected PRS benefits. While angler attitudes and behaviours are anecdotally changing, most black bream anglers still believe in removing hooks they can reach (Conron unpublished, Department of Primary Industries, creel survey data). The reasons anglers have continued to remove deeply embedded hooks could include:

- ineffective communication about not removing deeply engulfed hooks,
- time lost tying a new hook,
- expense of losing hooks and
- the low value some anglers place on under-size black bream during their fishing experience.

A crucial step in reducing the impacts of PRS on black bream stocks in the Gippsland Lakes will be the extension of information to anglers relating to:

- the impact of the current fishing practices identified in this study of PRS of black bream
- the benefits of switching to larger hook and bait size as well fishing with a tight line.

Further Development

An important area for further development relates to the need to regularly assess the fishing factors that influence PRS of fish in key fisheries. In recent years, Australian anglers have been targeted by a number extension programs outlining ways to improve the PRS of fish. As further advances in PRS research and extension to stakeholders are made, the regular assessment of the awareness of PRS issues amongst anglers and their fishing practices will provide an important indicator to the success of the National Strategy for the Survival of Released Line-caught Fish.

For Victorian fisheries, another important area for further development relates to how different hooks shapes (e.g. circle hooks) may reduce PRS for under-size fish caught in black bream and King George whiting fisheries.

Planned Outcomes

The outcome for this work is an improved understanding about the survival of snapper and black bream released after capture by hook-and-line fishing in sheltered temperate ecosystems. This has reduced the level of unaccounted mortality in these fisheries and therefore contributes to their ecological sustainable management plans. An additional outcome has been improvement to stock assessments which now incorporate the survival data. These findings support the current use of LMLs as a tool for protecting these fish stocks. In recent years the LML for black bream and snapper caught in Victorian waters has been increased.

Fishing methods that maximise the survival of under-size released black bream were outlined in information products and extended to the fishing community through a "Gently Does It Releasing Snapper and Bream" pamphlet and segment on the "Gently Does It #2" DVD. It is difficult to put an exact dollar value on the benefits of this project, but any improvement in the PRS of released fish will have significant long-term benefits to all users of these resources.

Conclusion

Post release survival rates for under-size black bream and snapper in some important Victorian hook-and-line fisheries is high (>80 %). These findings support the use of LML management regulations but high release rates can substantially reduce the benefits from a high PRS rate. The results of this study showed that the integration of PRS rates, fishery hooking location rates and fishery catch rates can provide comparisons between the under-size catch that is released by anglers and dies or survives and the harvested catch. For the boat-based King George whiting fishery in Port Phillip Bay where release catch rates of under-size snapper were similar to retained King George whiting catch rates, the mortality component of the released catch was shown to be only a fraction of the retained catch. For the Gippsland Lakes black bream recreational shore-based and boat-based fisheries, where released catch rates for under-size fish are many times higher than retained catch rates, even with very high PRS rates, the mortality component of the released catch was of the same magnitude as the retained catch.

Legal-minimum length protection of black bream stocks can be enhanced through higher shallow-hooking rates and reduced release rates of under-sized fish if anglers use a hook size number 1 or larger. It is critical that anglers do not remove deeply swallowed hooks, as removal appears to offset the benefit of larger hooks. Large hook and bait sizes will be most useful for anglers specifically targeting bream or anglers who are catching numerous under-sized fish. Fishing with a tight line increased shallow-hooking, but this survival benefit was somewhat offset (especially for the medium and large hook and bait size) by the increased catch of under-sized fish. Increasing the hook and bait size used by anglers fishing for black bream is a practical option for addressing the PRS management issue.

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Appendix 1: Intellectual Property

The intellectual property derived from this project is shared equally between Fisheries Research and Development Corporation and Fisheries Victoria .

Appendix 2: Staff

Primary Industries Research Victoria (PIRVic) Queenscliff (formerly Marine and Freshwater Resources Institute)

Sandy Morison - Principal Investigator

Simon Conron - Scientist

Daniel Gritxi - Scientist

Appendix 3: Part 1 Materials and Methods - Post mortem procedure

Step 1: Record scale loss % and signs of predation. Looking at the fish from different angles and touching fish with forceps help assess scale loss. Record the hooking location and whether the hook was removed as noted at the time of capture (only applicable if fin clipping or tagging at time of capture provides this information).

Step 2: Place fish on its right side, ventral area facing towards you. Use blunt tip scissors to cut from the operculum to the side of mouth. *NOTE*: Look down the fish's mouth and under the operculum to make sure the hooking injury is not in the area to be cut.

Step 3: Then peel back and cut away the operculum gill cover. During this step be careful not to cause new damage to the throat or gills. Using blunt forceps carefully assess the gill arches and throat for damage. Record lip, mouth, throat or gill injuries and hooking location if visible (if the hook was left in fish).

Step 4: Insert blunt edge of scissors into the fish's anus, holding fish with the ventral area facing upwards to avoid damaging the internal organs. Cut towards operculum, until the gills are reached. For fish with a retained hook, use the blunt forceps to see if the hook is visible in the pericardial or peritoneal cavity.

Step 5: Carefully remove the fish's left side using scissors and scalpel. During this cut, avoid piercing or pulling at the air bladder, gills and esophagus region. For fish with a retained hook, note if the hook has penetrated the heart, liver or other organs. *NOTE*: if the fish was foul-, eye-, shallow- (lip, mouth) throat- or gill-hooked then the gill and esophagus dissections in step 6 are not required.

Step 6: Remove the left gill arches using blunt scissors. Insert scissors down the esophagus tract and cut open the tissue. For fish with a retained hook, carefully follow the hook around recording the hooking location and organs that have been pierced (injuries).

Note hook loss, hook degradation, fish sex, and sexual conditions.

Figure 16. Post mortem examination procedure

Appendix 4: Part 1 Material Methods - Applying post release survival and mortality rates to recreational fisheries

Information sources

The results reported in the PRS studies and related sections showed that under-size black bream and snapper are generally caught on hooks with natural baits and that PRS rates in the fisheries for these species would principally be determined by the hooking location. Those findings guided the process for estimating PRS rates in recreational fisheries. The present and previous studies (Conron *et al.* 2004; Grixti *et al.* 2007) have also shown that for under-size black bream and snapper, shallow/deep hooking rates can be dependent on fish length and hook size.

Average retained and released catch rates from on-site angler catch surveys were used to estimate the ratio of the number of retained fish to the released under-size components of the catch that survived and died. The on-site angler catch surveys were undertaken for the shore and boat-based black bream fisheries in the Gippsland Lakes and the King George whiting boat-based fishery (under-size released snapper) in Port Phillip Bay from 2003 to 2005. The proportions of the released catch that were likely to survive were calculated using the shallow-hooking rates estimated from the fisheries in combination with the hooking location specific PRS rates estimated from the capture and holding experiments.

During on-site surveys, information on target species, fishing location, fishing effort, bait/hook size and type, number of species of fish kept and released, length measurements of retained fish (and handling techniques for the shore-based black bream fishery) was collected. However, hooking location for under-size fish could not be collected during on-site surveys because these fish had generally been released prior to the interview, making it difficult for anglers to accurately recall this information. The hooking location and fish length data required were provided by anglers participating in a Fishing Diary Program (Conron and Bridge 2004, Bridge and Conron inprep.) from 2003 to 2005. This program recorded trip date, target species, fishing location, fishing effort, hook size and type, number of species of fish kept and released and length for both retained and released fish. Anglers catching black bream and snapper also recorded hooking locations (as per the capture and holding experiments).

Simple logistic regression and frequency G-test analysis were used to compare hooking location of under-size black bream and snapper across fish length and hook and bait size one at a time. Where possible the range of hook sizes was grouped (small, medium, large) during analysis to increase statistical power. The results of this analysis directed the calculation steps to estimate the shallow-hooking rate for the fisheries. For example where hooking location was dependent (p<0.05) on both fish length and hook size, then the mean catch rate for the under-size component of the fish stock (CR_l) for each length class (l) was calculated using the equation

$$CR_l = \frac{\sum_{h=1}^{3} f / sel_{lh}}{\sum_{h=1}^{3} E_h}$$

Where f is the number fish caught by the diary anglers for each of the three hook size categories (h), sel_{lh} is the selectivity for fishing and E_h is the total hook effort for each of the three hook size categories (h). The mean relative catch rate (CR_{slh}) for each length class (l), hook size (h) and fishery(s), for the under-size component of the released catch was calculated using the equation

$$CR_{slh} = \frac{P_{sh} * CR_l * Sel_{lh}}{\sum_{l=15}^{27} CR_l * Sel_{lh}}$$

Where P_{sh} is the proportion of each hook category used by surveyed anglers who had reported releasing the under-size fish, CR_l is the average catch rate for the under-size component of the fish stock and sel_{lh} is the selectivity of fishing.

The relative percentage of the catch by number (N_{slh}) for each length class (l), hook size (h) and fishery(s) was calculated using the equation

$$N_{slh} = \frac{CR_{slh} * 100}{\sum_{l=15,h=1}^{l=27 h=3} CR_{slh}}$$

where CR_{slh} is the mean relative catch rate for each length class (l), hook size (h) and fishery(s).

The catch rate CR_{xslh} by hook location (x) for the fishery for each length class and hook category was calculated using the equation

$$CR_{xslh} = CR_{slh} * R_{lh}$$

where R_{lh} is the hook location (shallow/deep) rate estimated from regression analysis of the hooking location data recorded by the diary anglers and CR_{slh} is the mean relative catch rate for each length class (l), hook size (h) and fishery(s).

The relative size composition of under-sized fish released in the fishery N_{sxl} by hook location and length (N_{sxl}) was calculated using the equation

$$N_{sxl} = \frac{T_{sxl} * 100}{t_{sl}}$$

where t_{sl} is the total (shallow and deep-hooked) catch rate of under-size fish for the fishery and T_{sxl} is the catch rate by hook location for each length class calculated as

$$T_{sxl} = \sum_{h=1}^{3} CR_{sxl}$$

The post release survival rate for the fishery by length (PRS_{sl}) was then estimated given

$$PRS_{sl} = (T_{lsshallow} * S_{shallow} + T_{lsdeep} * .S_{deep}) * 100$$

Where $S_{shallow}$ and S_{deep} are the PRS total survival rates estimated from the capture and holding experiments

Estimating selectivity for fishing.

The selectivity for hook size categories was estimated using a modified 'direct' estimator. This estimator employed a Bayesian decomposition of the size-distribution in the sample (Troynikov in prep). The selectivity functions varied among hook sizes used in the recreational fishery. The logistic function commonly used in trawl size-selectivity studies (Cadigan and Miller 1992) was used to represent the selectivity for fishing Sel_{lh} each hook category and length class of fish.

$$Sel_{lh} = \frac{e^{(a+b-1)}}{1+e^{(a+b-1)}}$$

where *a* and *b* are constants (*a*>0, *b*<0).

The selectivity functions were estimated from catch data provided by anglers participating in a fishing diary program and from fish survival experiments, which covered a range of Victorian bays and inlets between 1998 and 2005 and was pooled across years. The size composition of the fish stock of interest was estimated as the average catch rate by length class using the ratio of the means method (Jones *et al.* 1995) using catch data only from between 2003 and 2005.

Shallow- and deep-hooking rates by fish length and hook size category

Anglers participating in the fishing diary program and the capture and holding experiments recorded both fish length and the anatomical hooking location for under-size black bream and snapper caught with a range of fishing gears across Victorian estuaries between 1998 and 2005. Simple regressions tested for relationships between shallow/deep-hooking and fish length and for each hook size category where required.

Appendix 5: Part 1 Results

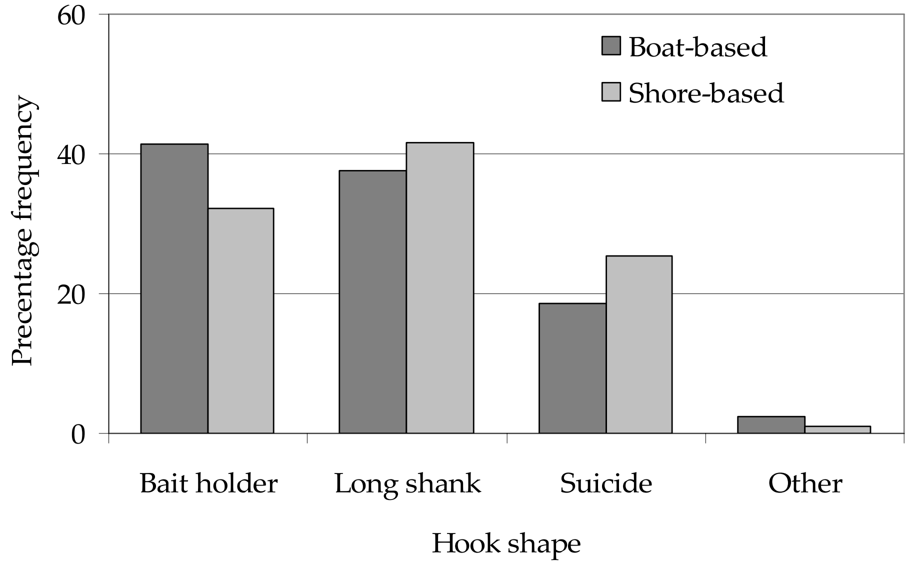


Figure 17. A comparison of hook shape for boat and shore-based anglers who reported releasing under-size black bream in the Gippsland Lakes during 2003-05 (number of hooks described = 2,542).

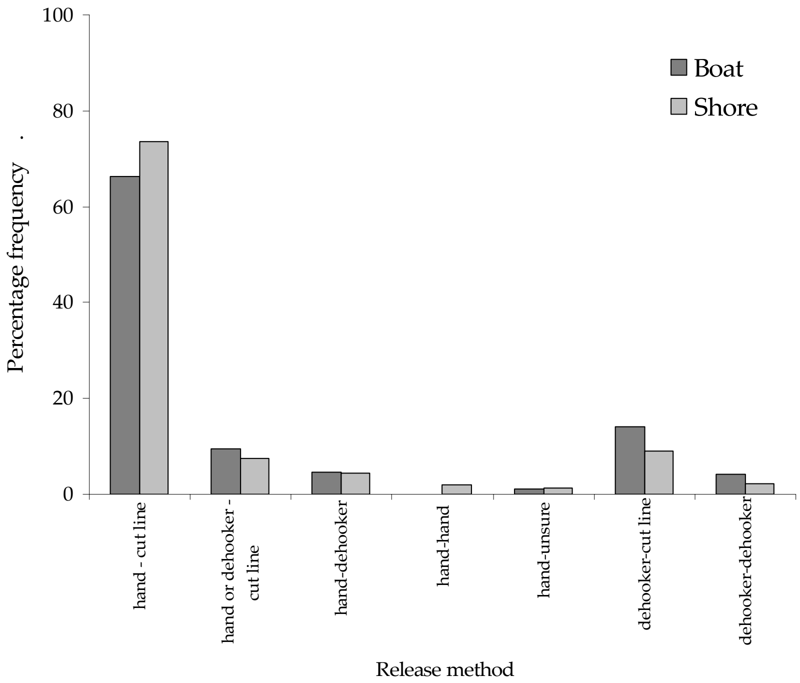


Figure 18. A comparison of commonly used handling practices for releasing shallow and deep-hooked black bream reported by boat- and shore-based anglers surveyed while fishing in the Gippsland Lakes during 2003-05.

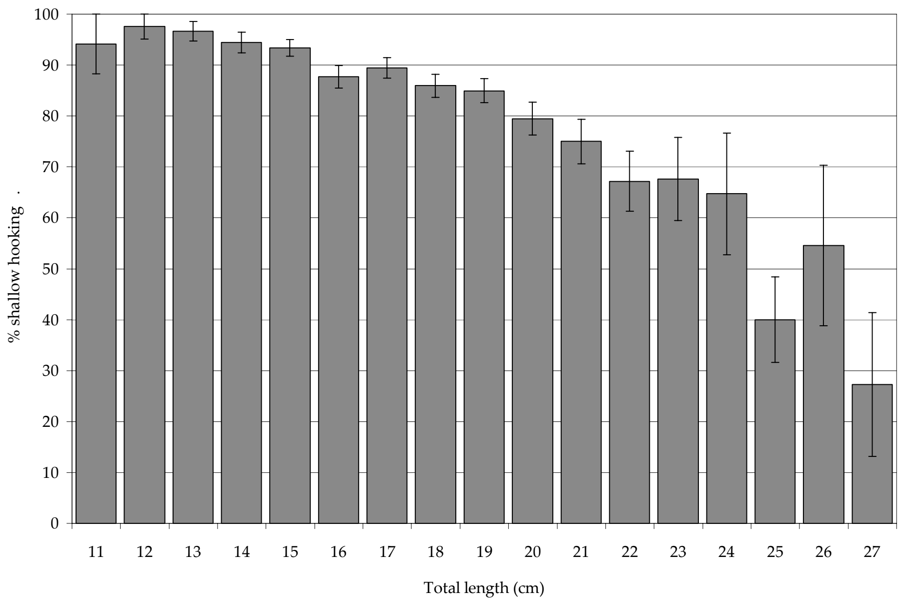


Figure 19. Percentage (± 1 SE) of shallow-hooking of black bream at various total lengths. Only fish lengths that had five or more fish were included in this figure.

Table 15. Summary of independent variable and survival analysis for black bream experiments. Variables in bold type are the response and those in normal type are the independent variables.

Variables	Test	Test statistic	df	*P*-value	Odds ratio[a]	95% CI
Shallow-hooking						
Fish Length	Logistic reg.	Wald 130.54	1	< 0.001	0.78	0.73-0.89
Water temperature	G-test	G2 13.31	1	< 0.001		
Hook removed (*deep-hooked only*)						
Fish length	Logistic reg.	Wald 12.04	1	< 0.001	0.8	0.71-0.91
Bleeding	G-test	G2 4.35	1	0.037		
Initial survival						
Hooking location	G-test	G2 42.55	1	< 0.001		
Fish Length	Logistic reg.	Wald 33.43	1	< 0.001	0.76	0.71-0.85
Water temperature	G-test	G2 4.86	1	0.028		
Sex	G-test	G2 1.70	1	0.132		
deep-hooked only						
Hook removal	G-test	G2 0.35	1	0.851		
Bleeding	G-test	G2 6.09	1	0.014		
Delayed survival						
Hooking location	G-test	G2 44.76	1	< 0.001		
Fish Length	Logistic reg.	Wald 3.57	1	0.059	0.89	0.78-1.00
Water temperature	G-test	G2 21.93	1	< 0.001		
Sex	G-test	G2 0.39	2	0.819		
deep-hooked only						
Hook removal	G-test	G2 18.42	1	< 0.001		
Bleeding	G-test	G2 2.791	2	0.024		

* Significant = *P*-value <0.05

[a] the odds ratio in the table above is ratio of the odds of an outcome of a response variable to the odds of the same outcome given a change in the independent variable. For example the measure of association of shallow hooking with fish length shows an odds ratio of less than 1 (0.76) which indicates a decrease the in the odds of shallow hooking fish with each centimetre increase in fish length. Confidence intervals for the odds ratio are calculated on the log odds ratio and then back-transformed.

Table 16. Summary of independent variable and survival analysis for snapper experiments. Variables in bold type are the responses and those in normal type are the independent variables.

Independent variables	Test	Test statistic	df	P-value	Odds ratio	95% CI
Initial survival						
Hooking location	Logistic reg.	Wald 10.18	1	<0.001		
Fish length	Logistic reg.	Wald 2.55	1	0.111	0.11	0.02–2.23
deep-hooked only						
Hook removal	Logistic reg.	Wald 4.14	1	0.042		
Bleeding	G-test	G2 19.41	1	<0.001		
Delayed survival						
Hooking location	Logistic reg.	Wald 1.55	1	0.213		
Fish length	Logistic reg.	Wald 5.19	1	0.023	1.24	1.10–1.39
deep-hooked only						
Hook removal	Logistic reg.	Wald 0.35	1	0.569		
Bleeding	G-test	G2 0.03	1	0.846		
Shallow-hooking						
Fish length	Logistic reg.	Wald 3.35	1	0.067	0.94	0.88–1.01
Hook removed (*deep-hooked only*)						
Fish length	Logistic reg.	Wald 2.77		0.096	0.89	0.79–1.02
Bleeding	G-test	G2 4.17	1	0.026		

Significant = *P*-value <0.05

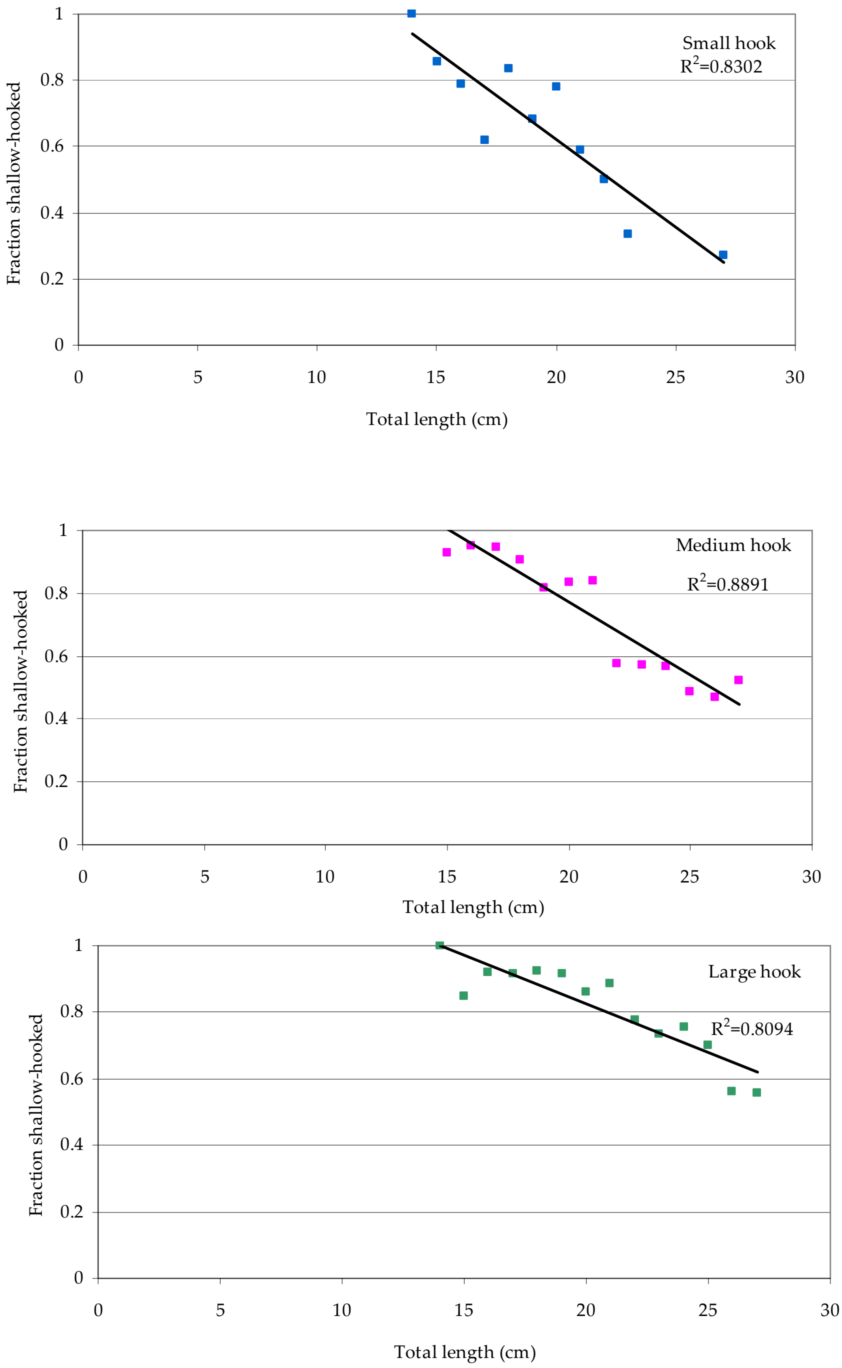


Figure 20. A comparison of shallow-hooking rate against total length for under-size black bream caught by hook size categories (small- No.6 and smaller, medium- No.4 and large- No.2 and larger) reported by fishing diary anglers from 1997 to 2005.

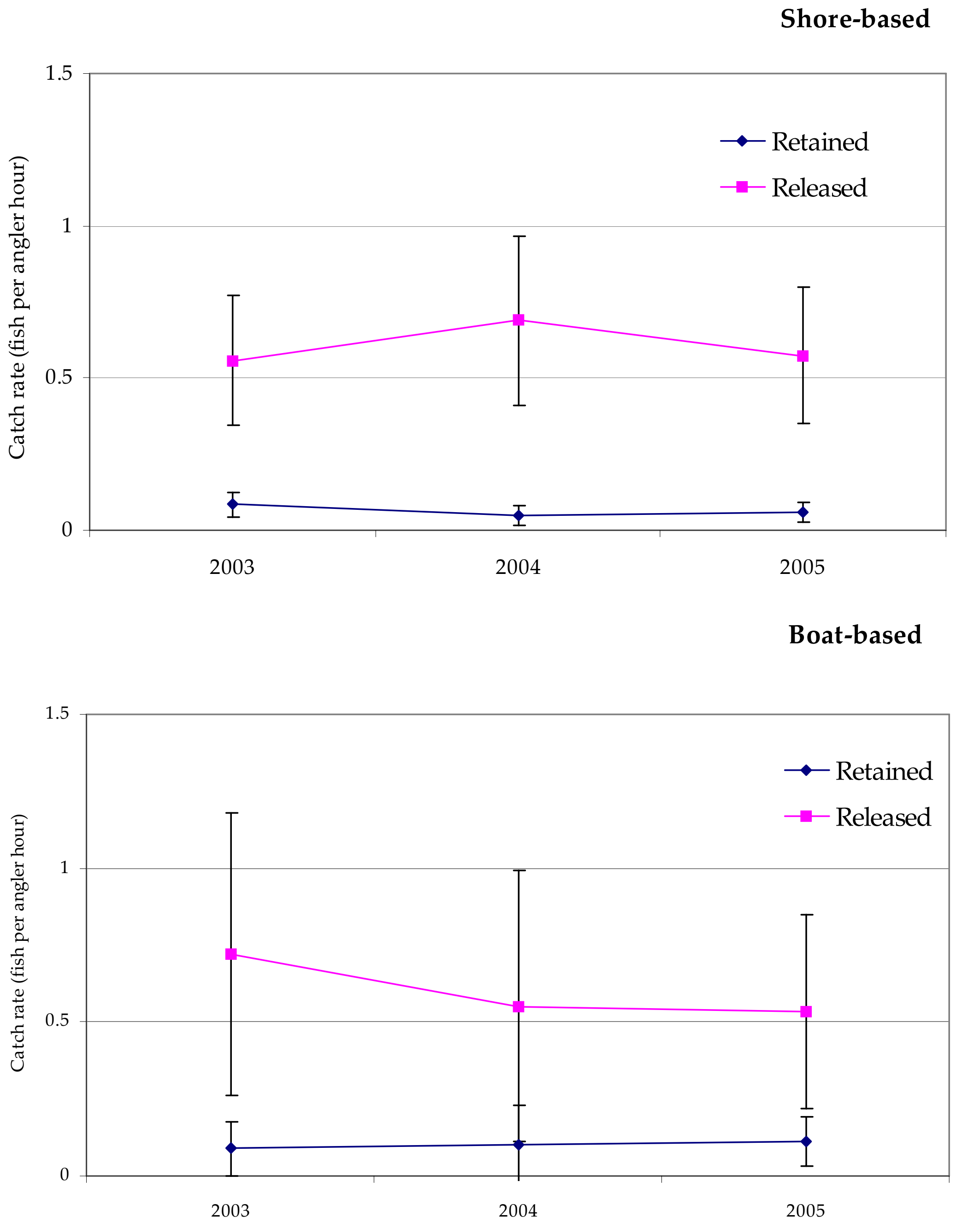


Figure 21. Black bream catch rates (2 SE) for shore- and boat-based anglers fishing in the Mitchell, Nicholson and Tambo river regions of the Gippsland Lakes from 2003 to 2005.

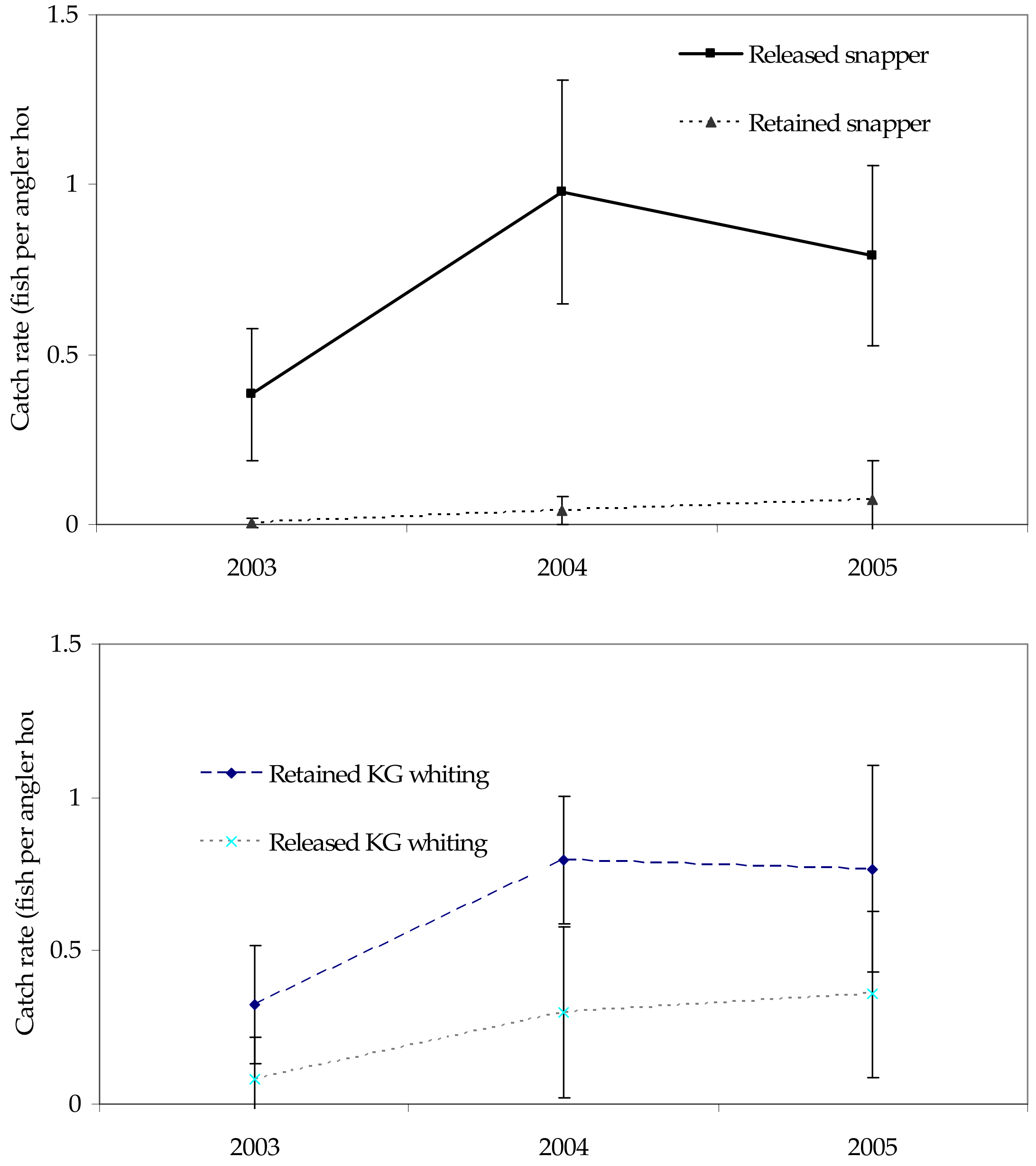


Figure 22. Snapper catch rates (2 SE) for boat-based anglers targeting King George whiting in Port Phillip Bay from 2003 to 2005.

Appendix 6: Part2 Methods and Materials

Field experiments to test measures for improving black bream survival.

Table 17. Hook dimensions in mm.

Hook dimensions	Size 8	Size 4	Size 1
Total length	30.1	37.8	44.7
Shank	23.7	30.7	33.7
Width	7	9	11.5
Gape	5.4	7.1	9.3
Bill	7.7	9.7	11.9
Absolute size*	210.7	340.2	514.1

*absolute size = hook length x hook width

Statistical procedures

Mean number of baits used, number of fish caught and fish length

All statistics were analysed using SAS 9.1.2. Three 3-way factorial ANOVA, including all interactions, tested differences in the mean number of baits used per boat h^{-1}, number of fish less than 28 cm TL caught per boat h^{-1} and fish length caught per boat h^{-1} across hook and baitsizes, angling technique and estuaries (fixed factors). ANOVA assumptions were tested through inspection of the response variables against predictor variables using box and whisker plots, Kolmogorov-Smirnov normality tests and Levenes variance homogeneity tests. Post hoc multiple comparisons (Tukey/HSD test) identified specific differences between independent variables. The numbers of captured fish ≥28 cm were insufficient to perform statistical analysis.

Survival (including PM fish)

Multiple logistic regression analysis was undertaken to examine relationships between independent variables hook and bait size, hooking location (shallow- and deep-hooked), estuary, fish length, hook removal and bleeding and the response variable initial survival (binary response; alive or dead, day is replication level). Where hook removal (hook removed or not removed) varied for deep-hooked fish, additional multiple logistic regressions, excluding shallow-hooked fish, were used explored the initial survival relationship of deep-hooked fish between hook removal method and level of bleeding.

ANOVA (fish length against hook size, fish length against estuary), simple logistic regression (hooking location against fish length, hook removal against fish length) and contingency table (G-test) analysis (hooking location against estuary, hooking location against hook size, bleeding and hook removal (for deep-hooked fish only)) tested the multiple logistic regression assumption of no collinearity between independent variables while also exploring trends between hooking location and hook removal and the possible influences on them for hook size, fish length and estuary (estuary not tested as an influence for hook removal). Simple logistic regression and contingency table (G-test) analysis compared initial survival across independent variables one at a time when multiple regression assumptions were not met. Contingency table (G-test) analysis also tested for associations for angling technique against hooking location and sex against initial survival. Assumptions of ANOVA and G-tests were checked by inspecting box and whisker plots, Kolmogorov-Smirnov normality tests, Levenes homogeneity test and counts of cell frequencies.

Appendix 7: Part 2 Results

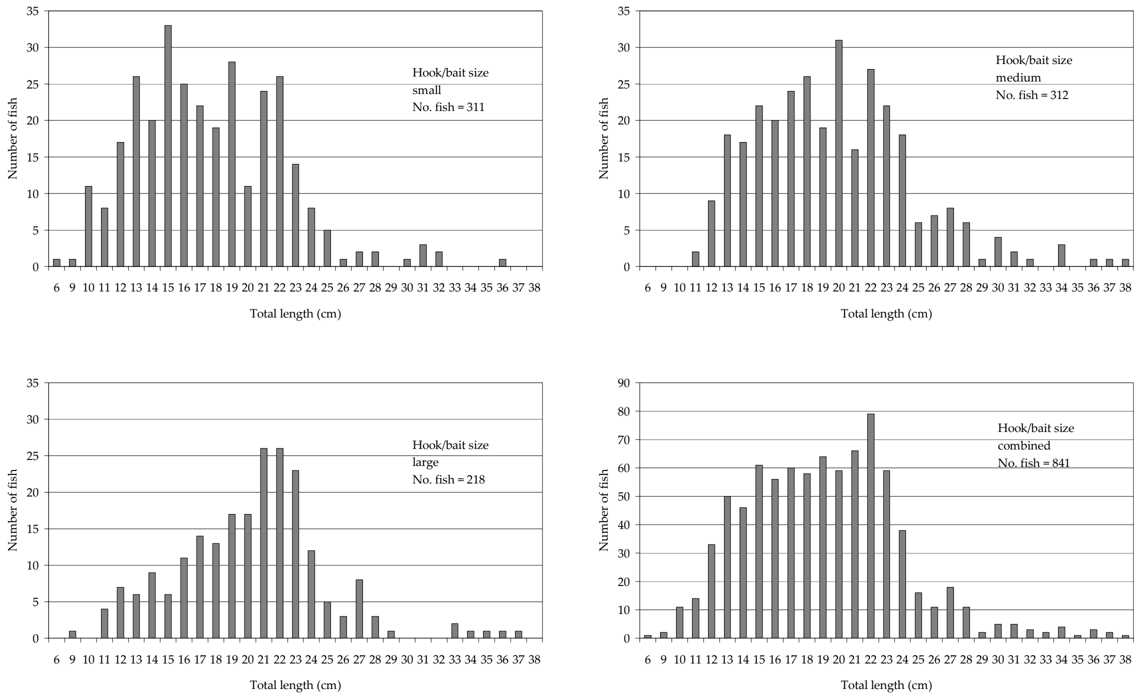


Figure 23. Length-frequency distribution of black bream for each hook and bait size and for all hook and bait sizes (estuaries combined).

Table 18. Summary of initial survival, shallow-hooking and hook-removal analysis for improving black bream experiments. Variables in bold type are the responses in the analysis; independent variables are in plain type.

Variables	Test	Test statistic	df	P-value	Odds ratio	95% CI
Initial survival						
Hooking location	G-test	G2 85.37	1	< 0.001		
Hook size	G-test	G2 4.07	2	0.131		
Fish length (1 cm between each length)	Logistic reg.	Wald 8.11	1	0.004	1.11	1.03-1.19
Sex	G-test	G2 1.21	1	0.546		
Estuary	G-test	G2 6.75	4	0.151		
Shallow-hooked fish removed from analysis						
Hook removed	G-test	G2 61.82	2	< 0.001		
Bleeding	G-test	G2 63.41	1	< 0.001		
Shallow-hooking						
Hook size	G-test	G2 15.01	2	<0.001		
Angling technique	G-test	G2 11.78	1	<0.001		
Fish length (1 cm between each length)	Logistic reg.	Wald 68.82	1	<0.001	0.86	0.83-0.89
Estuary	G-test	G2 49.94	4	<0.001		
Hook removed (*Shallow-hooked removed from analysis*)						
Hook size	G-test	G2 18.20	2	<0.001		
Bleeding	G-test	G2 79.40	2	< 0.001		
Fish length (1 cm between each length)	Logistic reg.	Wald 37.28	1	<0.001	0.743	0.68-0.82

When *P*-value is <0.05 there was a significant effect on the response variable

Appendix 8: Extension products

RELEASED FISH SURVIVAL FACT SHEET

SPECIES

Snapper or Pink Snapper
(*Pagrus auratus*)

KNOWLEDGE RATING

☑☑☑☑

5 ticks if there is sufficient knowledge of fish released, survival rates and best practices for the species

BEST PRACTICES IN RELEASING SNAPPER

Recommended practices for Snapper being released:

- For bait fishing use hooks that reduce deep hooking (1)
- Use single barbless hooks or barbless trebles on lures (1)
- When boat fishing use a knotless landing net to land larger fish
- Use wet hands or a wet cloth when handling fish
- Use a hookout or long nosed pliers to remove hooks
- Cut the line 10cm outside the mouth for deep hooked fish
- Hold the fish horizontally when taking photographs
- Fish from depths over 20m may need to be treated for barotrauma by venting or use of release weight (2)

Go to reference material in brackets for access to more information on any particular aspect of best practices

Other tips

- Avoid releasing Snapper if there are Sharks or other predatory species in the vicinity.

KEY SURVIVAL ISSUES

The following are the most likely survival issues for Snapper:

- Deep hooking
- Barotrauma in fish from deep water
- Handling of fish

SURVIVAL RATES

Research has shown the following survival rates for Snapper:

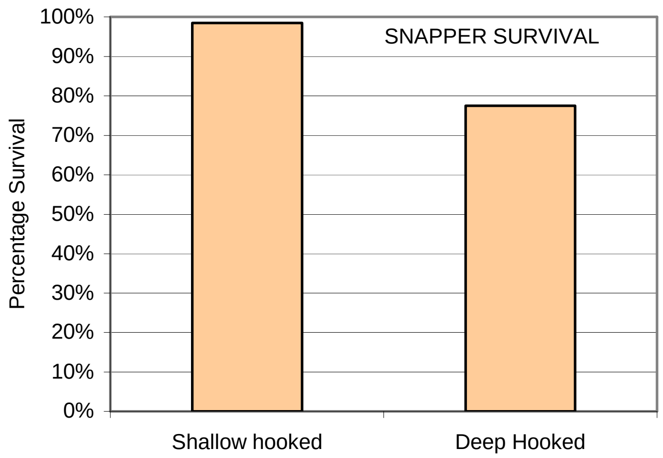
Victoria – Survival rate for Snapper of 95% (3)

NSW – Survival rate for Snapper of 66.5% (4)

WA – research currently underway (5)

Last Updated 11 April 2005

Australian Government
Fisheries Research and Development Corporation



Preliminary estimates of survival of undersized Snapper from Victoria based on hooking location.

RECREATIONAL CATCH

LOCATION	YEAR	HARVEST	RELEASED	CATCH	% REL	REF
NATIONAL	2000	1.7 million	0.8 million	2.6 million	33.7%	(6)
QUEENSLAND	1999	0.5 million	0.75 million	1.3 million	59%	(7)

Numbers of fish harvested and released in key fisheries with available data

HOOKING LOCATIONS

In the Victorian study 15% of Snapper were deep hooked in the throat or gut (3). In the NSW study 8% of Snapper were deep hooked (4).

It is recommended that gear that reduces deep hooking of Snapper be used.

REFERENCE MATERIAL

The following reference material has been used in the compilation of this fact sheet and can be used to obtain more detailed information.

(1) Released Fish Survival Fact Sheet on Hooking
(2) Released Fish Survival Fact Sheet on Barotrauma
(3) Conron S, Grixti D, Morison A (2004): Assessment of mortality of under-size snapper and black bream caught and released by recreational anglers: PIRVic report
(4) Broadhurst M et al (2005): Mortality of key species released by recreational fishers in an Australian estuary: Journal of Experimental Marine Biology and Ecology (in press)
(5) WA Fisheries (in progress 2000-2005): Maximising survival of released undersized west coast reef fish: FRDC project 2000/194
(6) Henry G and Lyle J (ed) (2003): The National Recreational and indigenous Fishing Survey: available at www.affa.gov.au/recfishsurvey
(7) Higgs J (2001): Recreational Catch Estimates for Queensland Residents: RFISH Technical Report #3 Results from the 1999 Diary Round available from Qld Dept of Primary Industries & Fisheries

This fact sheet is based on the latest available data and will be updated when new information becomes available

Released Fish SURVIVAL
Australian Government
Fisheries Research and Development Corporation
ANSA Australian National Sportfishing Association
infofish

RELEASED FISH SURVIVAL FACT SHEET

SPECIES

Bream (Family Sparidae)
(*Acanthopagrus spp*)
Tarwhine (*Rhabdosargus sarba*)

KNOWLEDGE RATING

☑☑☑☑☑

5 ticks if there is sufficient knowledge of fish released, survival rates and best practices for the species

BEST PRACTICES IN RELEASING BREAM

Recommended practices for Bream being released:

- Use barbless trebles on lures (1)
- For bait fishing use larger hooks than normal or circle hooks to reduce gut hooking (1) (4) (14)
- When bait fishing, rather than using high-carbon steel or stainless-steel hooks, use bronzed or nickel coated hooks as they are significantly quicker to degrade and are more likely to be ejected by deep hooked fish (15)
- Fishing with a tight line/active baits when bait fishing with conventional hooks will improve shallow hooking rates for under-sized Bream (16)
- Use a knotless landing net to land fish
- Use wet hands or a wet cloth to hold fish and minimise handling time as much as possible
- Lay the fish on a cool wet surface to remove hooks or to measure
- Use a hookout or long-nosed pliers to remove mouth hooks only (7) (8) (11)
- Cut the line outside the mouth for deep hooked fish and do not try to remove the hook (9) (13)
- When photographing your fish, support its body from underneath rather than suspending it by the line or holding it vertically
- Use a cradle to support the body of a fish for weighing
- Avoid releasing fish during very high summer temperatures

Go to reference material in brackets for access to more information on any particular aspect of best practices

Other tips

- When handling fish, be careful of the sharp dorsal and anal spines
- Do not place fingers inside the gill cover as this may damage the gills

KEY SURVIVAL ISSUES

The following are the most likely survival issues for Bream:

- Deep hooking (5) (8) (9) (10) (11) (13) (14)
- Handling (12)

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RECREATIONAL CATCH

Location	Year	Harvest	Released	Catch	%Rel	Ref
National	2000	4.8 million	8.2 million	13.0 million	62.9%	(2)
Queensland	1999	2.6 million	4.0 million	6.6 million	60.1%	(3)

Catch of Bream (all species) and Tarwhine
Numbers of fish harvested and released in key fisheries with available data

SURVIVAL RATES

Research has shown the following survival rates for Bream:

State	Species	Overall	Shallow hooked	Deep Hooked	Ref
Vic	Black Bream	93%	94%	74%	(4)
NSW	Yellowfin Bream	96%	97%	72%	(5, 10)
NSW	Yellowfin bream	100%	na	na	(7)
NSW	Yellowfin bream	95%			(8, 11)
NSW	Yellowfin bream	89%			(8, 11)
NSW	Yellowfin bream	85%	na	85%	(9, 13)
NSW	Yellowfin bream	97%	97%	na	12

HOOKING LOCATIONS

Hooking locations have been collected by researchers and by recreational fishers through the Austag program.

State	Species	Fishing Method	Shallow hooked	Deep hooked	Ref
Vic	Black Bream	Bait	56.1%	43.9%	(4)
NSW	Yellowfin Bream	Bait	96.7%	3.3%	(5, 10)
Qld	Yellowfin Bream	Bait	89.4%	10.6%	(6)
Qld	Pikey Bream	Bait	89.0%	11.0%	(6)
NSW	Yellowfin bream	Bait	75%	25%	(7)
NSW	Yellowfin bream	Bait	85%	15%	(8, 11)
NSW	Yellowfin bream	Bait	47%	53%	(8, 11)
NSW	Yellowfin bream	Bait	na	100%	(9, 13)
NSW	Yellowfin bream	Bait	85%	13%	14

These data are provided as a guide to selecting gear that will reduce rhe deep hooking of fish. It is recommended that, when fishing with bait, gear that reduces deep hooking of Bream is used.

REFERENCE MATERIAL

The following reference material has been used in the compilation of this fact sheet and can provide more detailed information.

(1) Released Fish Survival Fact Sheet on Hooking www.info-fish.net/releasefish
(2) Henry G and Lyle J (ed) (2003): The National Recreational and indigenous Fishing Survey: available at www.affa.gov.au/recfishsurvey
(3) Higgs J (2001): Recreational Catch Estimates for Queensland Residents: RFISH Technical Report #3 Results from the 1999 Diary Round: available from Qld Dept of Primary Industries & Fisheries
(4) Conron S, Grixti D and Morison A (2004): Assessment of mortality of under-size snapper and black bream caught and released by recreational anglers: PIRVic report
(5) 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. J. Exp. Mar. Biol. Ecol. 321: 171-179

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(6) Suntag (2006): Fish Survival from Hooking and Tagging: unpublished data
(7) Broadhurst, M.K., Barker, D.T. and Kennelly, S.J. (1999): Scale-loss and survival of juvenile bream (*Acanthopagrus australis*) after simulated escape from a Nordmøre-grid guiding panel and release from capture by hook and line. Bull. Mar. Sci. 64(2): 255-268
(8) Butcher, P.A., Broadhurst, M.K., Reynolds, D., Reid, D.D. and Gray, C.A. (2007): Release method and anatomical hook location: effects on short-term mortality of angler-caught *Acanthopagrus australis* and *Argyrosomus japonicus*. Dis. Aqu. Org. 74: 17-26
(9) Broadhurst, M.K., Butcher, P.A., Brand, C. and Porter, M. (2007): Ingestion and ejection of hooks: effects on long-term health and mortality of angler-caught yellowfin bream, *Acanthopagrus australis*. Dis. Aqu. Org. 74: 27 – 36
(10) Broadhurst, M (2005): The science of releasing fish. Fishing World, February 2005, p 52-53
(11) Butcher, P., Broadhurst, M and Reynolds, D (2005): Keeping Bream alive, Fishing World, April 2005, p 53-53
(12) Reynolds, D., Butcher, P. and Broadhurst, M. 2006. Tough bream! Fishing World, June 2006, p 38
(13) Broadhurst, M., Butcher, P. and Brand, C. 2006. Bream: the survivor. Fishing World, July 2006, p 62
(14) Butcher, P., Broadhurst, M., Reynolds, D. and Cairns, S (2007): Bream Survival, Modern Fishing, February 2007, p 84-86
(15) Roennfeldt R, Jones PL and Conron S (In prep). Hook composition effects on deep hook retention by black bream *Acanthopagrus butcheri* (Munro, 1949). Primary Industries Research Victoria, Queenscliff
(16) Grixti D, Conron S and Jones PL (2007): The effect of hook/bait size and angling technique on the hooking location and the catch or recreationally caught black bream Acanthopagrus butcheri, Fisheries Research, doi:10.1016/j.fishres.2006.11.039

This fact sheet is based on the latest available data and will be updated when new information becomes available

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Reproduction

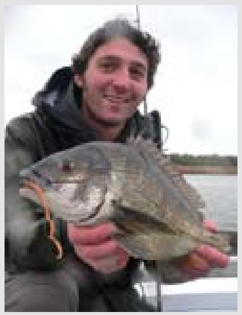
Fish become sexually mature over a range of sizes. The smallest black bream recorded as mature is at a total length of 23cm with males maturing at a slightly smaller length than females.

Total Length (cm)	Number of eggs*
22	632,000
26	801,000
30	1,002,000
34	1,353,000
38	1,813,000
44	2,740,000

* approximate number of eggs produced at various bream lengths.

Studies on North American species have indicated that in general larger fish contribute more eggs and the eggs from larger fish are more likely to hatch and the larvae are more likely to survive.

Catch



In 2000/01 the National Recreational and Indigenous Fishing survey was carried out. This survey was the largest of its type in Australian history and provided estimates of recreational fishing catch, effort and expenditure. Over a year it was estimated that 80,000 anglers made 350,000 bream fishing trips in Victoria.

On average individual bream kept by anglers weighed 0.4kg. An estimated 505,000 bream (around 200,000kg of fish) were kept annually. About half of the bream kept came from the Gippsland Lakes. It was estimated in that year, a further 840,000 bream were released, mostly undersized.

Fishing Methods

Bream can be caught at any time of the day or night and in a variety of habitats within estuaries. Experienced anglers pay attention to submerged structures, tides and changes in fish behaviour during the year when targeting bream. The varied diet of worms, bivalves, crustaceans and fish provides anglers with many options to catch bream. Sandworms and crabs are two of the dominant natural baits used and these are usually baited onto a size 4 or 2 long-shank or bait-holder hook. More recently, anglers have found lures and soft plastics to be highly effective at catching bream.

Post Release Survival

Research shows that for undersize bream, 94% of lip or mouth-hooked and 74% of deep-hooked undersize bream (hooked in the throat, gill or gut) survived more than 72 hours after release (maximum time held in containment tanks). Deep-hooking rates occur 15–30% of the time when common fishing methods are used. Estuaries are bream nursery areas and have large numbers of undersize bream so deep-hooking is an important issue.

How can you help?

Anglers fishing for bream with hook sizes 1–1/O and larger have been found to catch fewer undersize fish and have lower deep-hooking rates than anglers using smaller hooks (size 4 or smaller). Anglers report catching more larger fish by switching from soft to hard baits like crabs when undersize bream are present. Keeping a tight line between the rod tip and the hook, or fishing with a moving lure or soft plastic can also reduce deep-hooking significantly. When fish are deep-hooked, research suggests increased survival when anglers do not remove the hook, but instead cut the line as close to the hook as possible. Go to http://www.info-fish.net/releasefish/ for more information on this topic. Anglers can further assist survival rates by handling fish with wet hands or wet rags and avoid suspending fish on the hook.

ONE ANGLER CAN HELP, MANY ANGLERS CAN MAKE A DIFFERENCE.

www.fishcare.org.au

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This information is a guide only. Produced February 2008.
Photographs courtesy of Dr. Jeremy Hindell & Scott Gray.

dezigned by adz@work (03) 5562 0155

know your catch...

BLACK BREAM

Fishcare

Australian Government
Department of Agriculture, Fisheries and Forestry
Recreational Fishing Community Grants Programme

VIC TAG

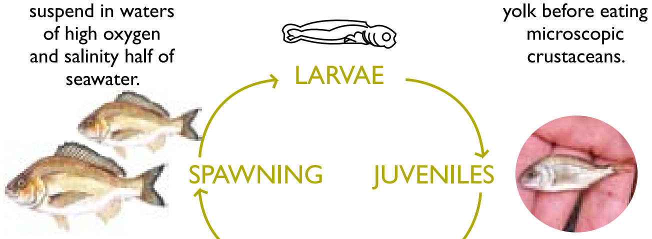
Victoria
The Place To Be

Lifecycle

Success of fertilised eggs hatching to larvae may be reduced during drought.

Spawned eggs suspend in waters of high oxygen and salinity half of seawater.

Larvae survive on yolk before eating microscopic crustaceans.



During Sep–Oct mature bream form tight schools in deep waters before spawning.

Adults travel throughout estuary in search of food, rarely staying in one location.

Juveniles school and use habitats with heavy cover. Their diet broadens as they grow.

- Black bream can complete their entire lifecycle within one estuary.
- In late winter, bream form tight schools in deeper estuary waters and just before spawning appear to form single sex schools. Spawning peaks in October and November, when water temperatures are 15–26˚C.
- Hatching of eggs and survival of larvae are linked to salinities around 20 parts per thousand (ppt), the amount of available habitat and food availability.

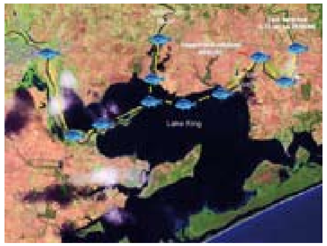
Migration

- Most black bream rarely leave their home estuary, however they can move into open coastal waters, especially when flushed out of the estuary by heavy floods.
- Black bream movement has been studied using visible tags, genetics and acoustic telemetry. In the Gippsland Lakes, acoustic transmitters are surgically implanted in fish and their movements are recorded when these fish swim within 400m of an acoustic receiver (listening station).

- Acoustic telemetry results from the Gippsland Lakes indicate that adult black bream:
  - Rarely remain in the one place for more than days or weeks.
  - Move large distances in a day. One bream travelled from Lakes Entrance to Swan Reach on the Tambo River in 24 hours. Others travelled over 3,000km in a single year!
  - Bream move between rivers and lakes with the highest lake occupation during winter and at night. Bream appear to use structures such as jetties and large woody debris as refuges and temporary accommodation along their travels.
- You can track the movements of bream and review more telemetry information at: http://www.dpi.vic.gov.au/vro/fishtrack

Acoustic transmitters

Listening station

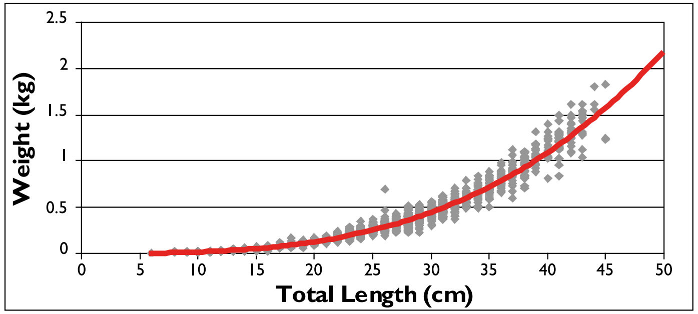


Bream movement

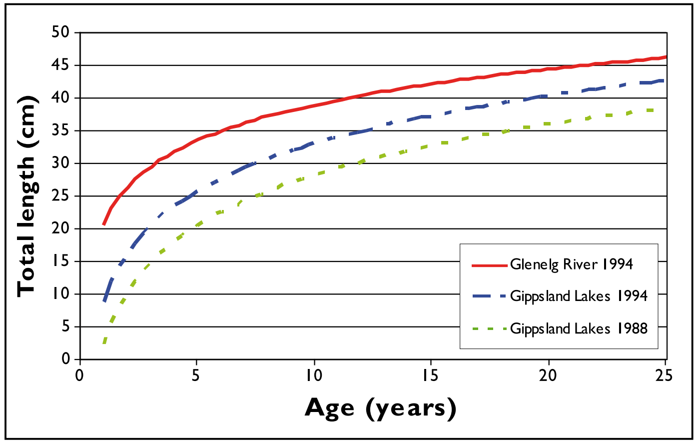
Age & Growth

Black Bream are a relatively long lived species.

The oldest bream recorded in Victoria is estimated to be 37 years of age and was captured from the Bemm River, East Gippsland. In the Gippsland Lakes, bream from an abundant year-class spawned in 1988 took about 10 years to reach 26cm, whereas a year-class spawned in 1994 reached the same size in about half that time. The fastest growing bream were observed in the Glenelg River, southwest Victoria, and took just three years to grow to 26cm. Bream commonly grow to 35–40cm, but have been known to reach 45–50cm.



Average bream weight at various total lengths.



Growth rates of bream spawning 1988 and 1994 in two different Victorian estuaries (actual data graphs extended with predicted growth rates).