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Maximising survival of released undersize west coast reef fish

Final FRDC Report – Project 2000/194

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Fish for the future

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For line-caught demersal fish, depth of capture is the most important factor affecting survival after release, indicating that barotrauma is a significant cause of mortality. Barotrauma symptoms vary among species and appear to have varying effects on post-release survival. Consequently, the degree of post-release mortality and the relationship with depth varies between species. The condition of the fish when landed and returned to the water provides an indication of the subsequent ability to survive.

This study compliments a recently published report on the survival of released tropical reef species (FRDC Project 2003/019, Brown *et al*., 2008), which similarly found that post-release survival rates and the usefulness of release methods to increase survival vary considerably between species.

The shotline release method improved recapture rates for WA dhufish whereas the use of venting did not generate any improvement compared to the simple release method. The proportion of undersize and legal size dhufish was uniform at every depth up to 100 m.

The shotline method appears to improve survival of snapper from deeper waters. The spatial size distribution of snapper varied depending on the topography of the coastline. Juvenile and large mature spawning snapper were found in the shallow bays and sounds of WA whereas in deeper offshore waters captured snapper were mostly undersize individuals.

The effects of depth and the shotline release method for breaksea cod were most similar to those for dhufish.

Very poor survivorship and the relatively low numbers tagged and released probably contributed to the absence of baldchin groper recaptures.

The results of this study provide several recommendations for fish handling.

The shotline release method should be used on suitable benthic species such as WA dhufish and breaksea cod but venting should not be used.

Circle hooks should be used in preference to J hooks to reduce mortality from gut-hooking, and

Careful capture and onboard handling can improve survival.

The critical need to consider mortality rates of released fish is now widely recognized through the fishing community in WA, as are techniques to improve survival of released fish.

In Australia, most fishery managers regulate the catch of recreational fishes using size and bag limits. The effectiveness of these regulations depends on the fish surviving capture and then release back into the water. Effective management of fishing using size or bag limits therefore requires an understanding of the rates of mortality of released fish and what factors are causing mortality so that these might be alleviated. The rates and likely causes of mortality of released WA dhufish (*Glaucosoma hebraicum*) and snapper (*Pagrus auratus*), breaksea cod (*Epinephelides armatus*) and baldchin groper (*Choerodon rubescens*) off south-western Australia were assessed in this study using (i) caging experiments (dhufish and snapper only) and (ii) a tag and recapture experiment for all four species.

The caging experiment involved replicating recreational catch and release fishing activities for dhufish and snapper, with fish returned to their depth of capture in a cage for 1 to 5 days following capture.

The mortality rate of dhufish increased with depth of capture from 21% at < 14 m to 86% at 45-59 m. Overall, 49% of the caged dhufish survived: barotrauma accounted for 38.4% of deaths, with hook-injuries contributing a further 13.2% mortality of caged dhufish. Post-release mortality of *G. hebraicum* at any given depth was high compared to other demersal fishes, indicating that dhufish are particularly susceptible to barotrauma.

Overall, 65.4% of the caged snapper survived. The most important factor affecting release mortality in snapper was depth of capture, i.e. the cause of death was barotrauma. Post-release mortality of snapper from < 30 m depth was low (3.4%), with an increase to a high rate of mortality (69%) at 45 m and 65 m. Mortality due to hook-injuries was low because < 2% of snapper swallowed the hook, with circle hooks swallowed less often than J-hooks. Venting did not improve survival of snapper.

The tagging study also revealed decreased survival with depth of capture, again with variation between species. The data clearly indicated that the use of the shotline release method (a weighted device to return fish to the bottom) improved the survival of dhufish and snapper. Elevated survival of tagged snapper released in deeper water is believed to be related to the heavy targeting of snapper in those depths by the charter sector - crew on charter vessels are well practiced at handling and releasing fish so this "expert" handling helped the survival or released fish.

The effects of depth and the shotline release method for breaksea cod were most similar to those for dhufish.

Baldchin groper taken from boats suffer very high rates of severe barotrauma (stomach protruding through mouth). Very poor survival and the relatively low numbers tagged and released probably contributed to the absence of baldchin groper recaptures.

In addition to estimating release mortality of demersal fish, information on the sizes of dhufish and snapper in relation to depth was collected to determine the proportion of undersize fish at different depths. Size data for dhufish and snapper from various depths was collated from the commercial, recreational and charter fishing records. Each data set has various biases and comes from different locations, but together provide information about the distribution of undersize and legal size demersal fish along the lower west coast of WA.

Examination of available fishing data showed that both WA dhufish and pink snapper have peaks in catch at depths of 20-59 m and 80-99 m, which may reflect a discontinuity in available habitat at depths of 60-79 m. The highest proportion of dhufish was caught at 40-59 m. Most snapper are caught between 20 and 59 m.

The relative depth-distribution of undersize and legal sized WA dhufish are similar across all depth ranges. Recreational fishers target shallow (20-39 m) dhufish, commercial fishers target deeper dhufish, while the charter boats target the most common depth distribution (40-59 m). In contrast, proportions of undersize and legal sized snapper vary in depth depending on location and method of fishing. In the West Coast Bioregion legal size fish are caught shallower (40-59 m) than undersize fish (80-99 m). The depths of undersize and legal snapper caught by charter boat fishing along the West Coast, however, varied spatially.

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Key Words

Pink snapper, snapper, *Pagrus auratus,* West Australian dhufish *Glaucosoma hebraicum,* breaksea cod *Epinephelides armatus*, baldchin groper *Choerodon rubescens*, tagging, catch and release, venting, shotline

1.0 General introduction

1.1 Background

The main West Coast demersal scalefish species such as dhufish, snapper (known locally as pink snapper), breaksea cod (*Epinephelides armatus*) and baldchin groper (*Choerodon rubescens*) are targeted by the West Coast Demersal Scalefish (Interim) Managed Fishery (Crowe *et al*., 1999; Wise *et al*., 2007), recreational anglers (Sumner & Williamson, 1999, Sumner *et al*, 2008), and the charter sector (Wise *et al*, 2007). These species are also caught by the West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery (McAuley, 2007). This commercial catch of demersal scalefish in 2005/06 was 975 tonnes with a value of $6.4 million. The recreational catch was approximately 300 tonnes, and the charter catch approximately 70 tonnes (St John & Johnson, 2007).

A survey of recreational boat angling in the West Coast Bioregion indicated that around 50% of the common target species, such as snapper (*Pagrus auratus*) and dhufish (*Glaucosoma hebraicum*), are released by anglers, usually because they are under the legal minimum size and far less commonly because they are in excess of the bag limit (Sumner & Williamson, 1999; Sumner *et al*., 2008). It is not known what proportion of the commercial catch is released as undersize.

If some undersize fish die following capture and release, the fishing mortality is higher and the mean size at first capture lower than would be expected on the basis of the retained catches. This affects the abundance of spawning stocks, and the sustainable yield which can be taken by the fishery. Increasing the survival of released fish is likely to be one of the most effective measures available to conserve reef fish stocks. This can only be done with an understanding of the sources of release mortality and estimation of the effectiveness of techniques to reduce that mortality.

Two factors that contribute to release mortality include damage to vital organs due to fish being hooked in the viscera rather than the mouth, and barotrauma due to gases in the fishes' bodies expanding with the reduction in pressure as the fish are brought to the surface from deep water. Barotrauma can include stomachs to be everted from the mouth, intestines everted from the anus and eyes to pop from their sockets. Also, there may be damage to internal organs and bleeding which is not externally apparent. It is suspected that the majority of fish that display external signs of barotrauma suffer mortality after release.

As the main management measures for recreational fishers currently in place for west coast demersal scalefish are minimum legal size and bag limits, it is important to understand the rates and causes of release mortality, and to find ways of minimising it, possibly through improving methods of handling the fish. In order to develop effective management measures, fisheries managers need to know whether release mortality is high enough to significantly contribute to fishing mortality of a stock and if improved handling methods may adequately address the problem (i.e. reduce post release survival.

This project proposes to estimate the level of release mortality for west coast reef fish, investigate the effect on mortality of fishing gear type, depth, and methods of handling the released fish; and to produce for fishers an educational package on how to minimise release mortality. Studies elsewhere, mainly the USA, indicate that there is a great deal of difference between species both in the susceptibility to release mortality and in the effectiveness of handling and fishing methods to reduce that mortality.

The main species to be studied in this project were WA dhufish and pink snapper and the following aspects were to be investigated:

- Distribution of sizes of fish in relation to depth in both recreational and commercial catches, i.e. percent of undersize at various depths
- Incidence of mouth-hooking and gut-hooking with standard hooks and circle hooks
- Mortality of gut-hooked fish when the line is cut and hook left in place
- Mortality of released fish in relation to fish size, depth and methods of handling

The two techniques used to investigate release mortality were returning fish to the seabed in a cage for several days to observe short-term mortality directly, and to tag and release fish and then rely on recaptures to compare relative survival following different handling methods. This study compares results from both methods.

The earliest work on release mortality research, which was funded by the Department of Fisheries, through the Recreational Fishing Advisory Committee, was a student project on decompression sickness in dhufish in association with Fremantle Maritime Centre (TAFE) (FRDC 95/095). That pathology-based project identified types of tissue damage due to decompression but did not measure mortality rates.

Since depth is expected to be a major determinant of release mortality, in order to assist the management process, the project will also use commercial and recreational fishing databases to report the distribution of catches, particularly in relation to depth, and will gather new data on size-frequency of catches in relation to depth.

By 2000, the Australian National Sportfishing Association, WA Branch (ANSA WA), with support from Department of Fisheries, had already begun a tag and release program. This current project built on ANSA's existing tagging program. Increased funding for more promotion has led to greater angler involvement and numbers of fish released, enabling this programme to comprise the tag and release component of the overall project.

In the later years of the project, an extensive education program of publications and talks coordinated by ANSA WA informed fishers of the outcomes of the project and the optimal fishing, handling and release methods to maximise the survival of reef fish.

1.2 Need

The effectiveness of current conservation measures, the minimum legal length and bag limit for legal sized fish, on demersal scalefish populations off the west coast, is currently unknown, largely due to an undetermined level of mortality in released fish. There is an urgent need to measure the discard mortality for this key suite of reef fish species and to educate fishers in techniques that minimise this mortality.

1.3 Objectives

The three main objectives of this study are to:

- Estimate mortality of hook and line caught west coast reef fish released back to the sea, taking account of hook type, depth of capture and on-board handling techniques.

Collect information on the size of west coast reef fish in relation to depth, to assess the proportion of undersize fish at different depths.

Educate fishers in optimal catching and handling techniques to minimise the mortality of released fish.

1.4 Structure of report

The report has eight chapters, five of which address the three objectives of the study. Objective 1 is addressed in Chapters 2, 3 and 4. Chapters 2 and 3 are a paper and a manuscript prepared for scientific journals estimating release mortality of WA dhufish and pink snapper in caging experiments. These two chapters have separate abstracts and introductions. Chapter 4 discusses rates of recaptures in a tagging study due to different methods of release. Chapter 5 addresses Objective 2 and Chapter 6 examines Objective 3. The project summary (Benefits and Adoptions, Further Development, Planned Outcomes and Conclusions) is provided in Chapter 7.

2.0 Post-release mortality of the demersal West Australian dhufish, *Glaucosoma hebraicum* (Richardson) following catch and release: the influence of depth of capture, venting and hook type

Jill St John and Clinton Syers

This chapter comprises a transcript of the following journal publication. However, please note that Figure 2.4 has been updated, so replaces the figure showing cumulative mortality that appeared in the journal publication. This has required a change to the text that refers to this figure, but has not required any change to the discussion of the results. St John, J., Syers C.J., 2005. Mortality of the demersal West Australian dhufish, *Glaucosoma hebraicum* (Richardson 1845) following catch and release: the influence of capture depth, venting and hook type. Fisheries Research. 76:106-116.

2.1 Abstract

Cages were used to investigate the mortality after catch and release angling of the demersal scalefish *Glaucosoma hebraicum* (Family *Glaucosomatidae*), a recreationally and commercially important species in south-western Australia. The effects of capture depth, venting the swim bladder, two types of hooks and anatomical hooking location, on mortality of *G. hebraicum* were examined by simulating actual catch and release fishing by recreational anglers. Additional factors (length of fish, duration of caging and the ability of released fish to swim) were included in a logistic regression. Only depth ($p < 0.01$), duration of caging ($p = 0.01$) and hook location ($p = 0.01$) were significant factors in predicting whether or not a fish died after release. Mortality of *G. hebraicum* increased with depth of capture from 21% at 0-14 m to 86% at 45-59 m. Overall, 51% of all *G. hebraicum* caught in the experiment died. Most deaths (38.4%) were attributed to barotraumas while the remainder (13.2%) was caused by damage by hooks. The high post-release mortality of *G. hebraicum* at any given depth compared to other demersal species is best explained by their susceptibility to barotrauma. Traditional management strategies that assume the survival of undersize or fish in excess of the bag limit that are returned to the water are not appropriate for *G. hebraicum*, particularly in deeper waters. Alternative management options must be developed to protect this slow growing, long-lived species.

2.2 Introduction

Post-capture release of catch and release angling fish is at its highest level ever in Australia due to increases in numbers of recreational and charter anglers and by shifts to rod and reel by commercial anglers (McLeay *et al*., 2002). The popularity of catch-and-release angling in the recreational sector has been promoted by media and government and supported by sport fishing associations (Barnhart, 1989) and charter fishing industries. Promotion of catch-and-release angling is often viewed as a means of maintaining fish populations in the face of increasing levels of angler participation. In a recent review of recreational fisheries in Australia between 2000 and 2001, recreational anglers caught and kept an estimated 60.4 million fish and caught and released a further 30-40% (Henry & Lyle, 2003). Catch-and-release angling poses special problems to fisheries management and stock assessment as post-release mortality can exceed 80% in some species (Muoneke & Childress, 1994) and will reduce the effectiveness of regulations such as size and bag limits designed to help manage the impact of conventional angling. This additional mortality needs to be included in fishing mortality estimates used in assessing the status of stocks.

Mortality following catch-and-release angling is expected to depend on both the physical damage and physiological response of each species to angling related stressors and their ability to recover from such events. These responses can be altered by other environmental factors such as depth of capture (Cooke & Suski, 2005). Post-release mortality studies often focus on the physical effects of capture. Injuries to the fish from angling include damage from hooking, on-board handling (e.g. air exposure, dehydration, loss of scales and other damage) and the effects of decompression.

Of the physical hooking and handling injuries, hook size, type and anatomical location of hook injuries influence mortality levels. Hooking mortality has been reported to range from 5% to 50% among demersal species (Bugley & Shepherd, 1991) with most mortality associated with gut- or deep- hooking (McLeay *et al*., 2002). Other on-board handling methods appear to have received little specific attention in post-release mortality studies.

Decompression injuries (i.e. barotraumas) occur from the physical effects of rapid and/or extensive reduction in barometric pressure on both the cryptic (inert) gas bubble formation in the bloodstream and tissue cells and the more visible (inert) gases in the swim bladder. This formation of gas bubbles can cause gas embolism, haemorrhaging and clotting as well as other haematological changes (Kulshrestha & Mandal, 1982; Ashby, 1996). Expansion of the swim bladder can weaken or rupture the walls of the swim bladder, and displace and injure other organs. As over-inflated swim bladders make fish positively buoyant, handling and release methods have been developed to enable the fish to swim away and/or return to its depth of capture. One of these treatments is venting, or piercing, the over-inflated swim bladder to release the air inside. The effectiveness of venting on the survival of released fish, however, depends on the methods used (Childress, 1988; Shasteen & Sheehan, 1997) and varies among species (McLeay *et al*., 2002). Another treatment for demersal species gaining popularity in Western Australia is to use a weighted device (release weight) to return the fish to its depth of capture (www.recfishwest.org.au).

The West Australian dhufish *Glaucosoma hebraicum* (Richardson) is endemic to the coastal waters of western and south-western Australia. An icon species targeted both commercially and recreationally, *G. hebraicum* is an excellent table fish commanding a high market value. Improvements in fishing technology over the last decade have increased their rates of exploitation, however, there have been recent declines in the abundance of *G. hebraicum* in the metropolitan waters off Perth (Hesp *et al*., 2002). As *G. hebraicum* is managed by a size limits, and a recreational bag limit of two fish per angler per day, all anglers are legally required to release all undersize fish. Recreational anglers caught an estimated 43 000 *G. hebraicum* in 1996/7 and released 35% (or 15 050 fish, Sumner & Williamson, 1999). Five years later, this recreational catch has increased substantially (Henry & Lyle, 2003). Post-release mortality is of concern to the management of both recreational and commercial fisheries as commercial boats generally fish deeper than recreational boats (St John, unpubl. data).

Glaucosoma hebraicum appear to be susceptible to post-release mortality and barotrauma. Many *G. hebraicum* caught from depths > 20 m float when released. In a study of "decompression sickness" in dhufish (Ashby, 1996), all 30 *G. hebraicum* collected at two depths (> and < 20 m) and examined for barotraumas had sustained internal damage. Adult *G. hebraicum* collected for brood stock in an aquaculture research trial suffered significant mortality when caught at depths greater than 20 m and held in surface tanks (Cleary & Jenkins, 2003).

As *Glaucosoma hebraicum* are regarded as a sedentary, 'sit and wait' predator, that commonly linger under overhangs, and like many large predatory piscivores (St John, 1999), do not feed daily (St John, pers. obs. of aquacultured fish), this species appeared well suited to cage experiments. Experimental cages were chosen to monitor survival up to five days after capture to examine the effect of capture depth, venting, hook type and anatomical hooking location of hooking injuries on the short-term post-release mortality of *G. hebraicum*.

The aim of this study (see Objective 1, Section 1.3) was to examine the effect of capture depth, venting, hook type and anatomical location of hooking injuries on the short-term post-release mortality of the dhufish using experimental cages to monitor survival up to four days after capture.

2.3 Methods

Study sites

Experiments were undertaken at three locations along the lower south-western Australian coast within the latitudes of 30º 00' S and 31º 30' S, during the Austral summers of, 2000/01 and, 2001/02. Locations were chosen on the basis of suitable habitat for *G. hebraicum* at the depth range required (0 to 60 m) for the experiment. Data was pooled among sites for analyses.

Cage design and pilot studies

Sea trials identified the most appropriate cage design to be a circular steel framed cage approx. 75 cm in diameter with a hinged door. The floor of the cage was metal mesh and the rest of the cage was covered in plastic (50 mm square) mesh lined with shade cloth to provide protection from the strong surge common in southwest Australian coastal waters. Cages were weighted with lead strapped to the mesh bottom and attached to anchored ropes. Cage retrieval was done either by hand or using a pot winch on a slow speed. Two preliminary caging and video trials in shallow water (< 20 m) showed that there was no effect of cage retrieval on either the physical condition of *G. hebraicum* (n = 7) before and after ascent, or the behaviour of the fish during ascent.

Experimental protocol

Glaucosoma hebraicum were caught using typical recreational fishing methods while drift fishing. To test the effects of hook type, anglers were required to use a two-hook rig with a circle hook (Tainawa, size 18) and a J hook (Mustad size 5, Fig. 2.1) on a line. No landing nets were used. After landing, the hook was removed from each fish and its type and anatomical location (gut or other) was noted. If the hook was swallowed, the line was cut with no attempt to remove it as hook removal has been found to increase mortality in commercial fishing (Kaimmer, 1994). Damage by the other hook (termed foul hooking) was also recorded. Hook wounds were classified either as "minor" where the skin was punctured and bleeding, if any, was minimal (e.g. lip) or "severe" where the blood was dark and formed clots (e.g. from damaged gills). Each *G. hebraicum* was examined for any external evidence of barotraumas (Table 2.1, Fig. 2.2). Total length (TL) of every *G. hebraicum* was measured to the nearest mm, and their depth of capture was recorded.

Table 2.1. Injuries, listed from mild to severe, sustained by *Glaucosoma hebraicum* after capture and caging and their likely cause.

	Label	Description	Likely cause
After capture	LS = Large Stomach	Enlarged swim bladder	air expanding rapidly in swim bladder as pressure decreases during capture
	SM = Stomach in Mouth	Stomach everted and visible in mouth	expansion of swim bladder forces stomach out of peritoneal cavity
	EX = Exophthalmia	Eyes protruding from orbits or popeye (see Fig. 2.2)	pressure from within or behind the eyeball caused by gas bubbles rupturing the capillaries in the chloroid body in the eyeball (Stephens, 2001)
	BE = Bubbles in Eyes	Gas bubbles visible to the naked eye (Stephens *et al*., 2001)	rapid decompression during capture by hand-line (Ashby, 1996)
After caging	FF = Frayed Fins	Extremities of caudal and ventral fins frayed	Contact with side of cage
	KE = Keratitis	Retina of eye clouded due to inflammation of the outer layer of the cornea	Contact with side of cage (McLaughlin *et al*., 1997)

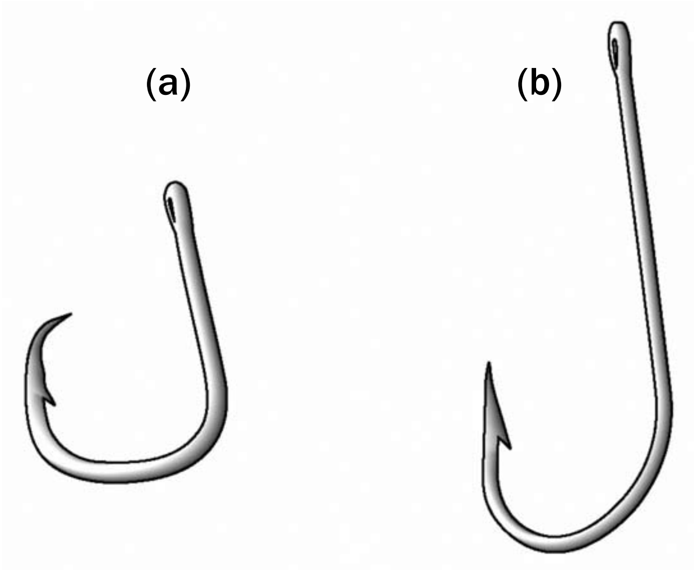

Figure 2.1. The two types of hooks used in the experiment. (a) a circle hook, Tainawa, size 18 and (b) a J hook, Mustad, size 5 (b).

The swim bladder of alternate captured fish was vented using a hypodermic needle (1.5” x 22 g). The needle was inserted at a 45° angle under a scale on the left side of the fish below the lateral line, near the tip of the pectoral fin until the swim bladder was punctured. The sound of gas escaping through the needle was an indication that it was inserted correctly. After the initial release of air, gentle pressure was applied to the ventral surface of the fish to expel the remaining air. The needle was removed, cleared (unblocked) and rinsed before re-use.

Figure 2.2. Exophthalmia in a dhufish captured by a recreational angler from approximately 40m in depth.

Following measurements and procedures, each fish was placed into a partly submerged cage alongside the boat and classified as either 'floating' or 'swimming'. When more than one *G. hebraicum* was caught during a drift, cages were hung 3-4 metres below the boat. At the end of every successful drift, that was generally conducted at relatively constant depths, the cage(s) were attached to an anchored line and set on the sea floor at approximately the depth of capture. Most fishing drifts were approximately 30 minutes in duration and all were terminated within the hour. Cages were usually pulled 1 or 3 days after setting, however weather conditions delayed some cage retrieval (up to 5 days after setting). After retrieval, the injuries of each fish were recorded (Table 2.1) and live fish were released.

Ideally, cage controls would be required at every caging location and time because of the varying topography, depth, seas and weather conditions. Cage controls, however, were impractical for *G. hebraicum* because their distribution made them difficult to trap in sufficient numbers to do controls. To compensate, we recorded all sea conditions affecting experimental caged fish and disregarded all results that were impacted by adverse weather conditions (including swells > 2 m and calm conditions when dead, decomposing sea grasses covered the cages and physically reduced the water flow). Twenty percent of the caged fish were excluded from the experiment.

Data Analysis

A logistic regression model tested the effect of seven factors (total length, depth of capture, days caged, venting the swim bladder, location of hook, hook type and the ability of fish to swim after release) on post-release mortality according to the following logistic equation:

$$Y_i = \frac{\exp\begin{pmatrix} a + b\,\mathrm{TL}_i + c\,\mathrm{Depth}_i + f\mathrm{Days}_i + g\,\mathrm{Vented}_i + h\,\mathrm{Hook.Location}_i \\ + j\,\mathrm{Hook.Type}_i + k\,\mathrm{Swimming}_i \end{pmatrix}}{1 + \exp\begin{pmatrix} a + b\,\mathrm{TL}_i + c\,\mathrm{Depth}_i + f\mathrm{Days}_i + g\,\mathrm{Vented}_i + h\,\mathrm{Hook.Location}_i \\ + j\,\mathrm{Hook.Type}_i + k\,\mathrm{Swimming}_i \end{pmatrix}} + \varepsilon_i$$

Where: Y_i is a binary variable measuring if fish *i* was dead (1) or alive (0) when inspected; TL_i is the total length (in mm) of fish *i* at capture; $Depth_i$ is the depth (in m) that fish *i* was first captured at and then returned to in a cage (0-14 m, 15-29 m, 30-44 m and 45-59 m, the depth 60-75 m was omitted as n = 1); $Days_i$ is the number of days, either (0) if fish died on deck or (1 to 5), after setting in the cage that fish *i* was inspected for its state (alive or dead); $Vented_i$ is a binary variable recording if fish *i* was vented (1) or not (0) at capture; $Hook.Location_i$ is a binary variable recording how fish *i* took the bait, whether the hook lodged in the gut (0) or otherwise (1); $Hook.Type_i$ is a binary variable recording if fish *i* was caught by a 'C' hook (1) or 'J' hook (0); and $Swimming_i$ is a binary variable measuring if fish *i* was swimming (1) or not (0) when placed in the cage; *a-k* are constants and ε_i is the error term.

The model was calculated using S-PLUS Version 6.1. The significance of each variable was assessed using t-tests. The power of the test for each parameter (i.e. the probability of accepting an incorrect H_0 (coefficient is 0) when H_1 (coefficient is the estimated value) is true) was calculated at $\alpha = 0.05$.

Pearson χ^2 tests were used to examine whether venting significantly increased the ability for dhufish to swim rather than float when returned to the water.

2.4 Results

Ninety-one *G. hebraicum,* ranging in size from 270-670 mm (TL), were captured by line. Four (4.4% of the sample) died immediately after capture and the remainder were caged for further assessment of post-release mortality. During the caging experiment 42 fish were examined after Day 1, one fish on Day 2, 12 fish on Day 3, 26 fish on Day 4 and six fish on Day 5.

The full logistic regression model contained seven parameters. Non-significant ($p > 0.05$, Table 2.2) parameters (Model I, Table 2.2) were removed using backward deletion. A likelihood ratio test of the reduced model (Model II) showed that both models are an adequate fit ($p < 0.001$) of the response variable. The ability of the reduced model (Model II) to correctly predict Y_i (whether the fish was alive or dead) was 63%, with 16% of fish recorded as alive that were incorrectly predicted to be dead while 21% of fish that died were incorrectly predicted as alive.

Table 2.2. Parameter estimates for the logistic regression to describe if the fish was alive or dead for various explanatory variables. Significance was tested using t-tests. Model I is the full model and Model II is the fully reduced model. Power refers to the probability (at α = 0.05 level) of incorrectly accepting H_0 (when H_1 is true). The non-significant parameters with low power (p < 0.40) are underlined.

Coefficient		Value	s.e.	t	p-value	Power
Model I						
a		-2.75	1.99	-1.39	0.17	0.65
b	TL	0.0024	0.0035	0.69	0.49	0.10*
c	Depth	0.128	0.035	3.70	< 0.01	0.95
f	Days	0.535	0.246	2.18	0.03	0.57
g	Vented	-0.69	0.68	-1.02	0.31	0.16*
h	Hook-location	-3.08	1.10	-2.81	< 0.01	0.79
J	Hook-type	0.55	1.04	0.52	0.60	0.07*
k	Swimming	-0.69	0.68	1.02	0.31	0.16*
Model II						

a		-2.20	0.94	-3.228	0.02
c	Depth	0.119	0.029	4.05	< 0.01
f	Days	0.55	0.22	2.49	0.01
h	Hook-location	-2.66	0.95	-2.80	0.01

Depth

Overall, 51.4% of captured *G. hebraicum* did not survive the caging experiment. The most important factor affecting release mortality of *G. hebraicum* was the depth of capture (Model II, $p < 0.01$, Table 2.2). Mortality of *G. hebraicum* increased from 21% at depths of 0-14 m to 86% at depths of 45-59 m (Fig. 2.3).

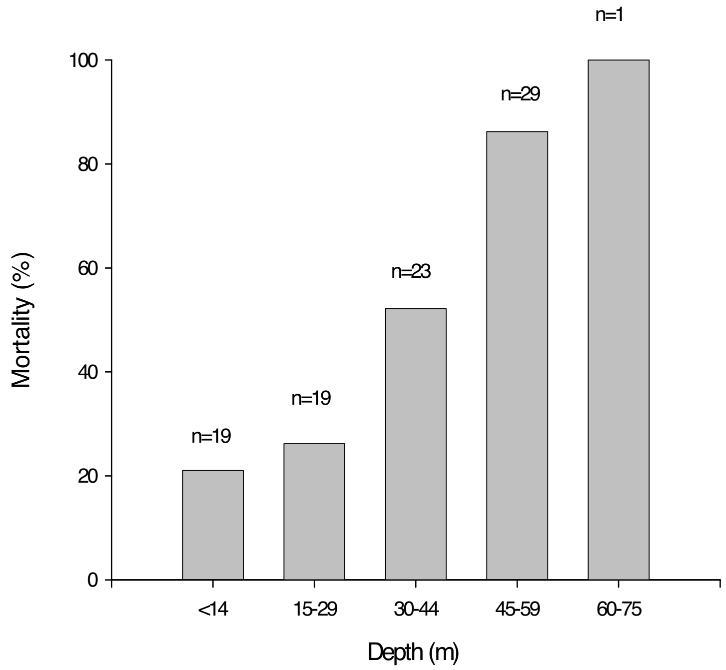

Figure 2.3. Mortality of *Glaucosoma hebraicum* caught at six depths of capture. Note that the single fish caught in the 60-75 m depth range did not survive.

Days

Duration of caging significantly affected mortality of *G. hebraicum* (Model II, $p = 0.01$, Table 2.2). Notwithstanding the gaps in the data for day 2 and low (or no) sample numbers for some day-depth combinations, there appears to be a slow rate of cumulative mortality at the shallower depths, and more obvious increases in mortality with time at the two deeper depths (Fig. 2.4). These results indicate that mortality may take up to five days to manifest following release.

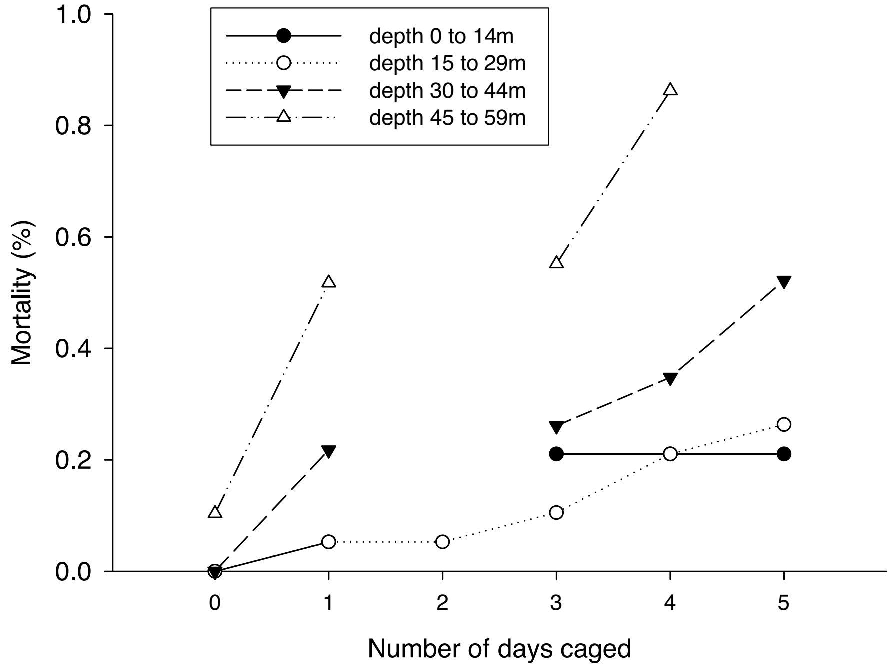

Figure 2.4. Cumulative percentage mortality (including swallowed hooked etc.) of *Glaucosoma hebraicum* expressed as percent mortality caged from 0 to 5 days.

Venting

Venting the swim bladder of *G. hebraicum* did not appear to increase mortality (Logistic regression, p = 0.31, power = 0.16 Table 2.2, Fig. 2.5a).

Swimming

Swimming after release did not appear to be related to survival of *G. hebraicum* (Logistic regression, p = 0.31, power = 0.16, Table 2.2). Swimming in released *G. hebraicum* significantly increased after venting when depths were pooled ($x^2_{[1]} = 5.09$, p = 0.02). When released into the cage after capture, 60% of vented *G. hebraicum* swam while 65% of unvented *G. hebraicum* floated. At every depth category, a higher percentage of vented fish swam compared to unvented fish and this difference was highest at the greatest depth of capture (Fig. 2.5b). By contrast, when the swim bladder was not vented, the proportion of floating *G. hebraicum* increased with depth of capture due to swim bladder expansion (Fig 2.5b).

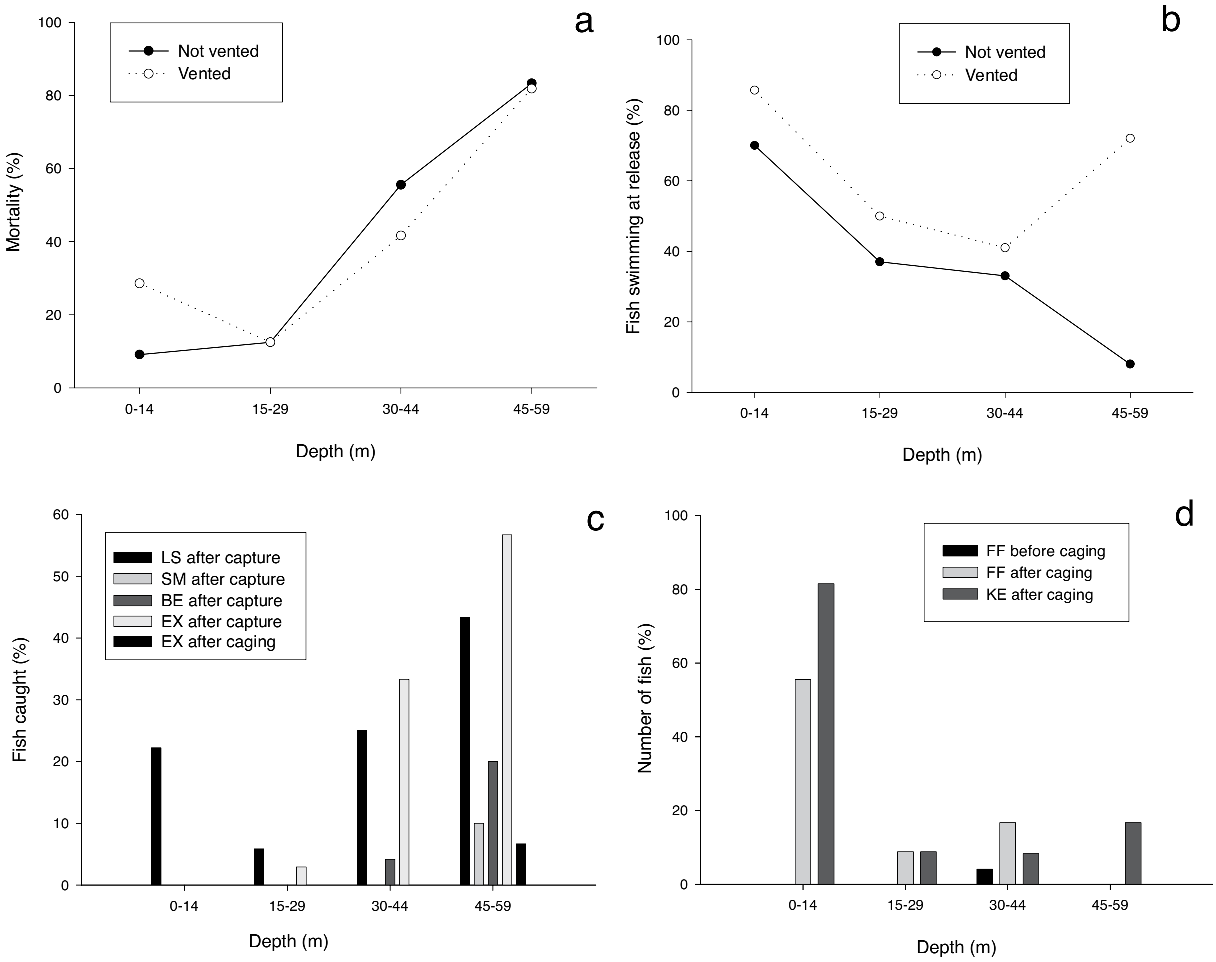

Figure 2.5. a, b, c & d. The effect on mortality of (a) venting and (b) swimming ability after release of *Glaucosoma hebraicum* captured from four depths: 0-14 m (n = 18), 15-29 m (n = 16), 40-44 m (n = 21) and 45-59 (n = 23). The proportion of caught and released *Glaucosoma hebraicum* with (c) barotraumas injuries and (d) cage-related injuries before (immediately after capture) and after caging 1 to 5 days from the four depth categories: 0-14 m (n = 27), 15-29 m (n = 44), 40-44 m (n = 24) and 45-59 m (n = 40). These data include caged fish that were omitted from the mortality study (n = 135). Barotrauma injuries are, from mild to severe LS = enlarged stomach, EX = Exophthalmia, SM = Stomach in mouth or everted stomach and BE = bubbles in eyes (see Table 2.1). Cage-related injuries are FF = frayed fins and KE = keratitis (see Table 2.1).

Hook Type

Most of the catch (82%) was hooked by standard J hooks (Table 2.3). The test to determine any links between hook type and location of the hook in the fish was inconclusive due to low power because so few *G. hebraicum* were caught on circle hooks (Logistic Regression, p = 0.60, Model I, Table 2.2).

Hook Location

All *G. hebraicum* caught by circle hooks and most fish caught by J hooks were hooked in the jaw. Ten fish (11%) swallowed J hooks. Gut hooking occurred in fish caught from both shallow and deep waters (Table 2.3). Seven of the ten *G. hebraicum* that swallowed a hook died after caging (Table 2.3), however, one of the survivors had dislodged its hook by the next day. Although mortality in gut-hooked *G. hebraicum* was high (70%), these fish were a relatively small proportion (7.8%) of the total catch. Bleeding was severe in four fish caught by J hooks and one caught by a circle hook, although it was often the second, unbaited hook that caused the damage to the gills or throat (foul hooking). All five *G. hebraicum* with severe bleeding died, two on deck just minutes after capture (Table 2.3). Thus if this small sample size is assumed to be representative, then hook damage that induces severe bleeding is likely to be fatal. In this experiment it accounted for 5.5% mortality of the total catch of *G. hebraicum*.

Table 2.3. Number of *Glaucosoma hebraicum* at each depth that remained alive or died during the experiment caught by Tainawa circle hooks and standard "J" hooks including the location of the hook in the fish, Gut or Other (jaw, lip and mouth). Numbers of fish that bled severely are in brackets.

	Hook type							
	Tainawa Circle				Standard J			
	Gut		Other		Gut		Other	
Capture Depth (m)	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**
0-14			1		1	1	13	3
15-29					2	3(1)	12	2
30-44			1	1		1	10	10(2)
45-59			1	12 (1)		2	3	11(1)
60-75				0				1
TOTAL			3	13(1)	3	7(1)	38	27(3)
GRAND TOTAL	**16**				**75**			

Effects of barotraumas

Although enlarged swim bladders occurred in *G. hebraicum* captured from all depths, exophthalmia occurred in *G. hebraicum* captured from depths greater than 15 m, bubbles in eyes occurred at depths greater than 30 m and everted stomachs (assumed to be the result of a severely enlarged swim bladder), occurred deeper than 45m (Fig. 2.5c). Except for enlarged stomachs at the shallowest depth, all barotraumas increased in frequency and severity with depth (Fig. 2.5c). Except for exophthalmia, the barotraumas that were observed at capture were generally not present after one day of caging (Fig. 2.5c).

The proportion of fish with torn fins and keratitis increased after caging and were most frequent in *G. hebraicum* caught and caged in shallower water (Table 2.1, Fig. 2.5d).

2.5 Discussion

Post-release mortality of *G. hebraicum* is at the higher end of the range recorded for demersal fish species examined in similar caging experiments at comparable depth ranges (Render & Wilson, 1994; Gitschlag & Renaud, 1994; Wilson & Burns, 1996). Even though rates of post-release mortality vary among species (Cooke & Suski in press), rates over 20% as found in this study are considered to be high (Muoneke & Childress, 1994).

The prevalence and severity of barotraumas in *G. hebraicum* increased with depth of capture. Enlarged swim bladders were observed at all depths of capture, while the more severe barotraumas, such as everted stomachs, were mostly restricted to depths > 30 m. Internal barotraumas, including haemorrhaging and/or bubble formation in the eyes, skin, opercula, gills, peritoneal lining (gut flaps), liver, spleen, heart, kidney and swim bladder, in *G. hebraicum* follow the same trend (Ashby, 1996). The presence of external bubbles corresponded to internal bubbles throughout all the major organs in *G. hebraicum* (Ashby, 1996). Clotting and haemorrhaging were present in all 30 *G. hebraicum* caught from shallow (9 m) to deep (73 m) depths suggesting that this species suffers some degree of barotrauma, signified by the presence of bubbles (Shilling *et al*., 1976), at all depths of capture (Ashby, 1996).

The severity of barotrauma appears to affect the timing of mortality after capture. Mortality of *G. hebraicum* occurred over the duration of caging in the shallow depths but was rapid at the deepest depth 45 m to 59 m. A similar effect was observed in other studies where death occurs rapidly in fish caught from relatively deep depths, but was slower in fish caught from shallow depths (Feathers & Knable, 1983; Gitschlag & Renaud, 1994; Pálsson *et al*., 2003).

Delayed or no repressurisation after capture, which prolongs decompression sickness, is another factor in depth-related mortality. The only study that reported higher mortality than *G. hebraicum* for any given depth did not repressurise two size classes of largemouth bass *Micropterus salmoides* in hyperbaric chamber experiments (Feathers & Knable, 1983). Similarly, a lack of repressurisation caused high post-capture mortality of brood stock *G. hebraicum* caught from depths greater than 20 m and kept in shallow tanks (Cleary & Jenkins, 2003). Repressurisation, by returning the caged fish to its depth of capture, alleviated some external barotraumas. Swim bladders had returned to normal after one day of caging suggesting that, similar to other species (Feathers & Knable, 1983, pers. obs. on coral trout, *Plectropomus leopardus*), swim bladders of *G. hebraicum* diffuse excess gas in about 24 hours. It is not clear why the second depressurization of *G. hebraicum* during cage retrieval did not cause barotraumas to reoccur. Cage retrieval was slower than line-capture and was assumed to be less stressful. Barotraumas are less prevalent in fish when their ascent is slower (Rogers *et al*., 1986).

The high to very high levels of post-release mortality in *G. hebraicum* captured from all depths is due to their susceptibility to barotraumas. Susceptibility to barotraumas is caused by a number of factors, including natural habit, blood physiology (Stephens, 2001), environmental conditions (Muoneke & Childress, 1994) and relative volume of swim bladder (Rogers *et al*., 1986), affecting *G. hebraicum* either independently or synergistically. The blood chemistry of *G. hebraicum* suggests that they are physiologically adapted to inactivity (Stephens, 2001). Thus, *G. hebraicum* are not expected to cope with, nor recover quickly from, periods of high levels of activity during capture. Stephens (2001) concluded that the optimum habitat of *G. hebraicum* is around depths of 40 m and in captivity this species cannot adapt to long-term life at shallow depths because healthy brood stock eventually develop exophthalmia or succumb to infectious diseases in aquaculture tanks. In the wild, however, juveniles and adults of this species are caught occasionally in shallow water (> 10 m). *Glaucosoma hebraicum* are not well adapted to handle rapid reductions in pressure when pulled to the water surface during capture because they have unusual blood oxygen properties for marine teleosts (Stephens, 2001). The blood of *G. hebraicum* has a large 'Root effect' and a "single" haemoglobin, compared to three haemoglobins in snapper *Pagrus auratus* (Stephens, 2001). With only one haemoglobin, haemoglobin oxygenation is restricted to a narrow range of blood pH and when *G. hebraicum* are stressed, the pH of blood falls. As blood haemoglobins allow the fish to adapt to a changing physical and physiological environment (Weber & Jensen, 1988), *G. hebraicum* is poorly adapted to hypoxic conditions (Stephens *et al*., 2002). Their relatively large, thick-skinned swim bladders make *G. hebraicum* more susceptible to barotraumas (Rogers *et al*., 1986). *Glaucosoma hebraicum* are noted for their buoyancy among local anglers. During these experiments several fish detached from the hook during the ascent and floated to the surface in a moribund state. This phenomenon in *G. hebraicum* can be explained by their large swim bladder and their physiological response to lactic acidosis (when blood pH falls) as a result of exercise during capture (Kieffer, 2000).

Separating the effects of caging from capture on the mortality of *G. hebraicum* was not possible to assess. We have assumed, however, that it was relatively small compared to the 'treatments', particularly depth of capture. Firstly, *G. hebraicum* are known to survive caging. Rock lobster fishers report that *G. hebraicum* are very occasionally trapped in their pots that have been set for one to three days and are alive when brought up from depths of up to 80 m. (E. Barker pers. comm.). Secondly, the only detectable effects of caging were frayed fins and keratitis and were probably caused by the fish touching the sides of the cage in surging seas. These two types of superficial injuries were not considered to confound the results of the trials because they occurred most frequently at shallow depths, where mortality of *G. hebraicum* was lowest. *Glaucosoma hebraicum* are susceptible to keratitis when held in confined conditions because they have relatively large protruding eyes, however this damage is not permanent because the outer layer of the cornea is thick (Stephens, 2001).

Venting did not appear to increase short-term mortality of *G. hebraicum,* which is consistent with other demersal fishes (Lee, 1992; Render & Wilson, 1994 and Keniry *et al*., 1996). The converse of this result is that swim bladder deflation may increase short-term survival in *G. hebraicum*, particularly at shallow depths where barotraumas are less severe, because it improves their ability to swim back down to the bottom and repressurise. Yet, swimming ability at release is probably not a good predictor of survival of *G. hebraicum* as seen in other species (Bettoli & Osborne, 1998). In general, although venting increases the immediate survival of some species (Burns & Restrepo, 2002) and the benefits of deflation increased with capture depth in others (Collins *et al*., 1999), venting did not affect long-term growth in largemouth bass (Shasteen & Sheehan, 1997). Furthermore, over the longer term Burns and Restrepo (2002) found that other factors related to environment (depth of capture, habitat), capture (hook type), physiology and anatomy, were more important in the survival of released fish.

In contrast, nothing is known about the benefits of venting ruptured swim bladders, which can heal in one to four days in some demersal species (Burns & Restrepo, 2002). Ruptured swim bladders are common to *G. hebraicum* (80% of fish caught from depths of < 20m, Ashby, 1996). The healed scars on swim bladders of *G. hebraicum* found in post-mortems on several wild-caught brood stock held for extended periods suggested that *G. hebraicum* survive ruptured swim bladders (Stephens, 2001). Each thin fibrous scar tissue was located at a similar position on the swim bladder suggesting that the swim bladder has a natural weak area and healed scars may rupture more easily during subsequent decompression events (Stephens, 2001). The benefits of venting ruptured swim bladders, however, has not been studied.

The other source of mortality found in *G. hebraicum* during the experiment was damage by the hooks themselves. Hooking mortality of *G. hebraicum,* estimated at 13.2% in this study, is at the lower end of the range of other demersal fish species (5 to 50%, Bugley & Shepherd, 1991). Generally, the major factor affecting hooking mortality in many fish species is the anatomical location of hook wounds (Muoneke & Childress, 1994). Hook wounds in vulnerable locations, such as gills and stomach, were the major source of mortality in *G. hebraicum,* as in other studies (Carbines, 1999; Malchoff *et al*., 1995). Occasionally, the second free hook of the terminal rigs was observed to wound *G. hebraicum* in a vulnerable location (termed foul hooking). Thus, the design of the terminal rig used in this experiment may have increased the incidence of foul hooking and its associated mortality.

The effect of hook type on location of the hook in *G. hebraicum* was inconclusive in our study due to low power of the test because too few fish were caught by circle hook. Our volunteer anglers typically used 'J' hooks and were inexperienced in using circle hooks that require a different fishing technique. Although our study did not examine fishing efficiency between the two hook types, 82% of the catch was caught on standard 'J' hooks. In contrast, circle hooks are the standard tackle used on most charter boats that target *G. hebraicum*. As the value of using circle hooks is species-specific (see review by Cooke & Suski, 2004), more research into the effects of hook type on both hooking injury and onboard handling time in *G. hebraicum* is required to minimize post-release mortality. In general, the effectiveness of circle hooks depends on hook size, fishing style, fish feeding mode and mouth morphology (Cooke & Suski, 2004).

Optimally, post release mortality of a species should be measured by more than one method as every method used to assess post-release mortality measures a different component of this mortality and has some associated biases. Tank experiments using hyperbaric chambers measure the effects of decompression only, without the stress of capture (e.g. Feathers and Knable, 1983; Wilson and Burns, 1996). Surface release studies measure initial mortality only and any immediate mortality due to predation (Gitschlag and Renaud, 1994). Any delayed mortality caused by minor injuries or barotrauma (Feathers and Knable, 1983; Pàlsson *et al*., 2003) is ignored. Caging experiments in the field (Bugley and Shepherd, 1991; Render and Wilson, 1994; Carbines, 1999) measure the initial mortality of capture and mortality due to barotrauma over the caging period excluding any mortality associated with the return to and resettlement into their habitat. Tagging studies (Wilson and Burns, 1996; Bettoli and Osborne, 1998 –ultra sonic transmitters) allow useful comparisons of longer-term mortality among treatments (e.g. depth, release methods, species etc.) but do not provide actual rates of post-release mortality because only a proportion of the survivors are recaptured. Estimates of mortality are confounded by tag shedding, non-reporting and tagging-induced mortality.

Implications for management

As rates of post-release mortality over 20% are generally considered to be deserving of management action (Muoneke and Childress, 1994), release mortality rates of *G. hebraicum* are a major management issue for both commercial and recreational fisheries due to the high proportion of undersize fish caught in the fishery (33% Sumner and Williamson, 1999, 54% Henry and Lyle, 2003). Rates of post-release mortality need to be factored into estimates of total fishing mortality. Using recreational catch and release data from two depths, shallow (< 20 m) and deep (> 20 m, Sumner and Williamson, 1999), and estimates of post-release mortality from this study, a multiplier for each depth was calculated (see Table 2.4). To determine total fishing mortality of recreationally caught *G. hebraicum,* catches should be multiplied by a factor of 1.13 for shallow caught fish and 1.27 for *G. hebraicum* caught deeper (Table 2.4). Although minor in comparison to the effects of barotraumas, other sources of mortality discussed in this study provide some management options. Neither standard J hooks nor circle hooks can be recommended to reduce post-release mortality, however, either a terminal rig of one hook or possibly wider spacing of multiple hooks may prevent foul hooking and reduce mortality by about 5%.

Table 2.4. Calculating a multiplier factor for recreational catches of *Glaucosoma hebraicum* caught from shallow (< 20 m) and deep (> 20 m) waters caught using recreational catch and release data from two depths (Sumner and Williamson, 1999) and estimates of post-release mortality from this study.

	Catch of dhufish	Calculations	Depth	
			< 20 m	> 20 m
a	Number retained		280	755
b	Number released		184	373
c	Estimated % release mortality		0.2	0.55
d	Mortality of released fish	b x c	37	205
	Multiplier factor on catch	1 + (d/a)	1.13	1.27

In general, bag limits that are rarely achieved are ineffectual as a management measure and become less effective as abundance declines (Sumner & Williamson, 1999). In 1996, Sumner and Williamson (1999) found that only 0.2% of boat owners interviewed captured the daily bag limit of four *G. hebraicum* per person and the mean catch rate for anglers targeting this species was 0.42 fish per angler per day. In November 2003, management halved the bag limits for *G. hebraicum* to two fish per person per day but current data on the daily recreational catch of dhufish is required to determine its usefulness in reducing fishing effort. Due to the high post-release morality in *G. hebraicum*, the reduction in fishing mortality offered by bag limits will, in part, be negated by the mortality of fish caught in excess of the bag limit and released. Similarly, the high release mortality reduces the effectiveness of legal minimum sizes. Modeling has shown that the optimum LML of a fish species decreases significantly when release mortality increases (Walters & Huntsman, 1986). A reduction in survival of released fish from 100% to 60% may reduce the optimum minimum size by 36% (Walters & Huntsman, 1986).

In general, future management of *G. hebraicum* will need to consider strategies that do not focus solely on the return of either undersize fish or fish in excess of the bag limit, particularly those caught from deeper waters. A greater understanding of their size distribution relative to depth will assist in the development of additional management strategies. As this species has high site fidelity (Chapter 5), spatial closures, that ban all demersal angling in areas where undersize fish dominate the population, may be a useful management tool.

The biology of *G. hebraicum* suggests that this species is vulnerable to overexploitation because they are long-lived, slow growing and endemic to a relatively small area of the coastline (Hesp *et al*., 2002). Also, *G. hebraicum* are likely to be vulnerable to localized depletion due to their site fidelity. The high level of post-release mortality in *G. hebraicum* needs to be considered in the management process for conserving this recreationally and commercially important, iconic species of Western Australia.

3.0 The influence of depth, venting and hook type on catch and release angling mortality of snapper, *Pagrus auratus* (sparidae): implications for management

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This chapter comprises a transcript of a manuscript submitted for journal publication.

3.1 Abstract

Cages were used to investigate the mortality after catch and release angling of snapper *Pagrus auratus* (Family *Sparidae*), a recreationally and commercially important demersal species found throughout temperate coastal and shelf waters of Australia. Overall, 65.4% of the 604 snapper caged in the experiment survived release. Depth of capture was by far the most important factor affecting release mortality. Mortality increased from an average of 3.42% of fish caught in the shallows (5, 15 and 30 m) to 69.0% of fish from the deeper waters (45 and 65 m). Due to the practicalities of catching and caging fish while working at sea it was necessary to mix fish of different sizes in cages and to have different quantities of fish in cages. However, while there was increased mortality associated with increased quantities of fish in cages, this did not affect the result of increased mortality with depth. Venting, hook pattern, hook location, number of days caged, size of fish (TL in cm) and swimming at release did not affect mortality significantly. Although mortality in gut-hooked fish was almost three times (91.7%) that of mouth-hooked fish (33.6%), the proportion of gut-hooked fish in the total catch was small (1% of circle hooks and 3% of J hooks).

The clear depth stratification in rates of mortality of snapper indicates that Legal Minimum Length (LML) and or bag limits are suitable management regulations for shallow coastal areas, but that their usefulness decreases at deeper offshore locations. This bodes well for the management of snapper dwelling in the numerous shallow bays, sounds and gulfs around Australia that have well defined boundaries suitable for defining separate management zones. In contrast, deeper offshore fisheries need to consider management strategies that include alternatives to size and bag limits, and would certainly need to include estimates of post-release mortality when attempting to manage a fishery through controlling total fishing mortality.

3.2 Introduction

The sparid, *Pagrus auratus* (Bloch & Schneider, 1801) is widely distributed in the warm temperate and sub-tropical waters of the Indo–Pacific region including New Zealand, Japan and Australia (Kailola *et al*., 1993). Commonly known as snapper, *P. auratus* have a continuous distribution around the southern coastline of mainland Australia, from Gladstone in Queensland to Barrow Island in Western Australia, inhabiting the coastal marine waters from 0 m to 200 m. Juvenile snapper are generally found in sheltered, shallow, nearshore habitats, including marine embayments and estuaries while sub-adults and adults inhabit marine embayments and coastal reefs as well as other habitats over the continental shelf (Kailola *et al*., 1993, Gillanders *et al*., 2003). The life history characteristics and movement of adult snapper vary greatly among regions (Johnson *et al*., 1986; Edmonds *et al*., 1999; Fowler & Jennings, 2003; Sumpton *et al*., 2003). In coastal waters near Perth (32° S), sub-adults leave juvenile nursery areas in Cockburn

Sound (Lenanton, 1974) and move outside the sound to waters of depths of up to 200 m. When mature, these snapper appear to return to the nursery areas during spring and early summer to spawn in aggregations (Wakefield, 2008). Further north, oceanic snapper distributed across shelf waters off Shark Bay (24° S) migrate inshore in winter to spawn in large aggregations.

Snapper are an important commercial and recreational fishery in most states of Australia. Recent commercial catches (e.g. 1625 tonnes in 2003-04) are much lower than the national peak of 2500 tonnes recorded in the early 1980s (Kailola *et al*., 1993). In contrast, the recreational catch is increasing. In 2000-01 a national recreational fishing survey ranked snapper fourth by weight of all species caught, with an estimated catch of 1422 tonnes (Henry & Lyle, 2003). Although many commercial snapper are caught by hand line in Australia, nets, trap and longlines are also used in the commercial fishery, whereas recreational fishers use hand lines exclusively. Recent changes in the proportions of snapper catch by the two fishing sectors suggest two emerging trends in the Australian snapper fishery; that a higher proportion of snapper are caught by hook and line and a higher proportion of undersize snapper are caught and released.

Recreational snapper fisheries in mainland Australian states are managed mostly by Legal Minimum Lengths (LML) and bag limits, both of which vary throughout Australia. As juveniles prefer sheltered inshore habitats and are easily caught by hook and line, undersize snapper are vulnerable to incidental capture. Australian recreational fishers discard over 2.5 million snapper each year, or 66% of the catch (Henry & Lyle, 2003).

In general, rates of post-release mortality must be estimated for each species because survival after release varies among species (Muoneke & Childress, 1994). Given the high rates of release of snapper in the recreational fishery in Australia, managers need to understand variables affecting post-release mortality of snapper as well as the fishing methods (gear or handling techniques) that will optimize their survival. This information can be obtained by effective experiments estimating post-release mortality that:

- simulate actual catch and release methods;
- account for all possible variables influencing mortality; and
- run for a sufficient period of time to measure mortality.

Post-release mortality following angling is influenced by fishery related (anthropogenic) and environmental variables. Fatalities may be caused by one primary source or the cumulative effects of sublethal variables (Kwak & Henry, 1995). The main variables in recreational and commercial angling of coastal demersal fish species within Australia include hook injuries, onboard handling methods and barotrauma or decompression injuries (St John & Syers, 2005).

In general, hooking mortality ranges from 5% to 50% in demersal species (Bugley & Shepherd, 1991) and high mortality is associated with gut- or deep-hooking (Muoneke & Childress, 1994; McLeay *et al*., 2002). Circle hooks are considered to reduce gut hooking (Beckwith & Rand, 2005) and some sectors of the hook and line fishery (i.e. Shark Bay commercial snapper fishery and the charter boat industry in Western Australia) have changed to using circle hooks to catch snapper. Yet the effectiveness of circle hooks to reduce mortality is highly species-specific as it depends on hook size, fishing style, fish feeding mode and mouth morphology (Cooke & Suski, 2004). The two studies focusing on the selectivity of hook size and the effects of modifications of circle hooks on mortality of snapper have used demersal longlines (Otway & Craig, 1993; Willis & Millar, 2001). Although the incidence of gut-hooking and therefore mortality is considered to be higher in longlines than in hand lines recreational fishing (Barnes *et al*. in press), mortality associated with circle hooks used on hand lines has not yet been determined for snapper.

A popular treatment considered to promote the survival of released fish is venting, or piercing, the over-inflated swim bladder to release the air inside. Venting reduces the buoyancy of the released fish, assisting the fish to swim away from the surface and return more quickly to its depth of capture. The usefulness of venting on the survival of released fish, however, depends on the methods used (Childress, 1988; Shasteen & Sheehan, 1997) and varies among species (McLeay *et al*., 2002). In other studies on demersal fish, depth of capture was shown to be an important variable affecting post-release mortality (St John and Syers, 2005). Of the 1.28 million snapper caught and kept by Australian recreational anglers, 30% were from shallow estuaries, 43.5% from coastal waters and 26.5% from the deeper waters offshore (Henry & Lyle, 2003). Understanding the relationship between depth of capture and post-release mortality is important for the management of these fisheries. Previously, depth of capture has been overlooked as a variable contributing to release mortality in investigations simulating optimal LML for snapper fisheries (e.g. Shark Bay, Moran, 1990; New Zealand, Harley *et al*., 2000) and estimating unaccounted fishing mortality (New Zealand, Harley *et al*., 2000).

The specific aim of this study (see Objective 1, Section 1.3) was to examine the effect of capture depth, venting, hook type and anatomical location of hooking injuries on the short-term post-release mortality of the snapper using experimental cages to monitor survival up to four days after capture.

3.3 Methods

The study was undertaken in Shark Bay (25°S 20' S, 113° 00' E), on the mid-west Australian coast during three periods, 30/5/2001 to 7/6/2001, 24-27/7/2001 and 2-8/7/2002. Schools of fish were targeted at five sites of different depths: 5, 15, 30, 45 and 65 m.

Cage design and pilot study

Sea trials identified the most appropriate cage design to be a circular steel framed cage of approx. 75 cm in diameter with a hinged door. The floor of the cage was metal mesh and the rest of the cage was covered in plastic (50 mm square) mesh lined with shade cloth. Cages were weighted with lead strapped to the mesh bottom and attached to anchored ropes. They were retrieved using a pot winch on a slow speed. A small pilot study (n = 9) found 100% survival of snapper caged in different densities (1, 3 and 5 fish per cage) after three days at 10 m depth.

Experimental protocol

Pagrus auratus were caught using either typical recreational or commercial line-fishing methods. To test the effects of hook type, recreational anglers used a two-hook rig, with a circle hook (Tainawa, size 18) and a J hook (Mustad, size 5) (Figure 3.1) attached to a line on a rod or winch. Tainawa, size 18 hooks are the preferred circle hook used by the commercial fishers in Shark Bay and New Zealand. Commercial fishers used hand operated or electric winches with approximately 6 to 10 hooks per line using equal numbers of both types of hooks. Commercial-style fishing was done at the 30 and 65 m sites only.

After landing (without landing nets), the hook was removed from each fish and its type and anatomical location (gut or other) was noted. If the hook was swallowed, the line was cut with no attempt to remove it as careless hook removal has been found to increase mortality in commercial fishing (Kaimmer, 1994). The condition of each fish, including external evidence of barotraumas (such as distended anus) and the location of any hook injuries by the other hook (termed foul hooking), and specific handling conditions were noted and total length (TL) was measured to the nearest mm.

The swim bladder of alternate captured fish was vented using a hypodermic needle (1.5" x 22 g). The needle was inserted at a 45° angle under a scale on the left side of the fish below the lateral line, near the tip of the pectoral fin until the swim bladder was punctured. When inserted properly, gas could be heard escaping through the needle. After the initial release of air, gentle pressure was applied to the ventral surface of the fish to expel the remaining air. The needle was removed, cleared (unblocked) and rinsed before re-use. Following measurements and procedures, each *P. auratus* was tagged for individual identification before release into a numbered cage in a deck tank with circulating water. The ability to swim after placement in the water was recorded as either 'floating' or 'swimming'. Depending on size of the snapper one to six fish were placed in each cage and the door was secured with two plastic cable ties. The boat motored away from the school to drop the cages overboard at the same depth of capture using anchored lines with numbered buoys. The first cage was lowered with the anchor, and up to four subsequent cages were added onto each line as each cage was filled. Fish spent on average approximately 20 minutes in a cage in the deck tanks before being returned to the sea.

In the experimental design random cages were to be pulled one or three days after setting. Weather sometimes delayed retrieval by one day and so cages were pulled after 1, 2, 3 and 4 days. Live fish were released.

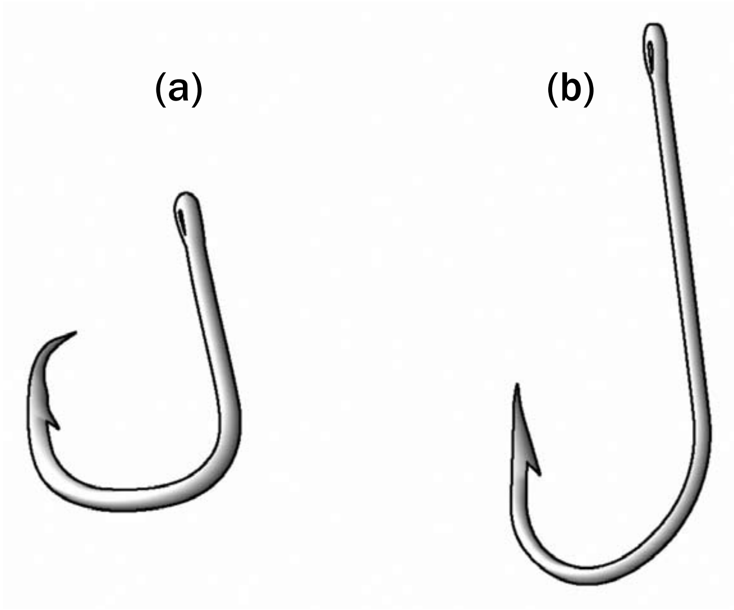


Figure 3.1. The two hook patterns used in the experiment: a circle hook, Tainawa, size 18 (a) and a J hook, Mustad, size 5 (b).

Controls

In an attempt to test the effect of caging on survival of snapper without the effects of line capture, four cages were converted into traps by baiting the trap and securing the door open with a spring-release close activated by a time-elapse solenoid. These traps were set near a school of snapper at 15 m and retrieved after three days. Three traps were empty and the other contained a *Lutjanus hutchinsi* that was alive and in perfect condition.

Data Analysis

Due to differing size of fish in schools, neither the size of snapper nor the number of fish in each cage was standardized in the experiment. To measure the effect of the variable number and weight of fish in the cage, two additional variables ("relative (%) cage biomass" = %(individual fish biomass/total cage biomass)) and "cage crowding" ((cage biomass – smallest cage biomass)/(largest cage biomass – smallest cage biomass)) expressed as a percentage were calculated and examined in the model. [Measured TL was converted to weights using the following equations (where W = weight in grams, L = LCF in cm, a = 0.0467727 and B = 2.781 and LCF = 0.3 + 0. 8460 TL; Moran & Burton, 1990).]

Cage crowding was highly correlated to size (TL) of snapper (r = 0.84) and including both these variables (i.e. cage crowding and TL) would violate the model's assumption of independence, consequently the effect of both variables was assessed in separate runs of the model (Model a and b) to determine which variables were most relevant to the effect of cages on the snapper.

A logistic regression model tested the effect of variables on the post-release mortality of individual *P. auratus* according to the following models:

Model a (including Length, but not %Crowding)

$$Y_i = \frac{\exp\begin{pmatrix} a + b\%\text{Biomass}_i + c\text{Length}_i + f\ \text{Depth}_i + g\text{Days}_i + h\,\text{Vented}_i + j\,\text{Hook.Location}_i \\ + k\ \text{Hook.Type}_i + l\,\text{Swimming}_i + t_1 date_{1i} + t_2 date_{2i} \end{pmatrix}}{1 + \exp\begin{pmatrix} a + b\%\text{Biomass}_i + c\text{Length}_i + f\ \text{Depth}_i + g\text{Days}_i + h\,\text{Vented}_i + j\,\text{Hook.Location}_i \\ + k\ \text{Hook.Type}_i + l\,\text{Swimming}_i + t_1 date_{1i} + t_2 date_{2i} \end{pmatrix}} + \varepsilon_i$$

Model b (including %Crowding, but not Length)

$$Y_i = \frac{\exp\begin{pmatrix} a + b\%\text{Biomass}_i + f\ \text{Depth}_i + g\text{Days}_i + h\,\text{Vented}_i + j\,\text{Hook.Location}_i \\ + k\ \text{Hook.Type}_i + l\,\text{Swimming}_i + m\%\text{Crowding}_i + t_1 date_{1i} + t_2 date_{2i} \end{pmatrix}}{1 + \exp\begin{pmatrix} a + b\%\text{Biomass}_i + f\ \text{Depth}_i + g\text{Days}_i + h\,\text{Vented}_i + j\,\text{Hook.Location}_i \\ + k\ \text{Hook.Type}_i + l\,\text{Swimming}_i + m\%\text{Crowding}_i + t_1 date_{1i} + t_2 date_{2i} \end{pmatrix}} + \varepsilon_i$$

Where:

Y_i is a binary variable measuring if fish i was dead (1) or alive (0) when inspected;

$\%\text{Biomass}_i$ is the estimated weight of fish i expressed as a percentage of the total biomass of the fish in its cage;

L_i is the total length of fish i; Depth_i is the depth (in m) that fish i was captured and caged (5 m, 15 m, 30 m, 45 m and 65 m);

Days_i is the number of days in the cage (0 if fish died at capture or 1 to 4);

Vented_i is a binary variable recording if fish i was vented (1) or not (0) at capture;

Hook location_i is a binary variable recording how fish i took the bait, whether the hook lodged in the gut (0) or otherwise (1);

Hook type_i is a binary variable recording if fish i was caught by a 'C' hook (1) or 'J' hook (0);

Swimming_i is a binary variable measuring if fish i was swimming (1) or not (0) when placed in the cage; $\%Crowding_i$ is the estimated biomass of the total fish in cage i expressed as a percentage of the largest cage biomass;

a-k are constants; and

ε_i is the error term.

Date is a binary variable identifying the period when fish i was placed in the cage. $Date_{1i}$ is 1 if fish i was placed in the cage between 24 and 25 July 2001, else it is 0. $Date_{2i}$ is 1 if fish i was placed in the cage between 2-4 July 2002, else it is 0.

The models were calculated using S-PLUS Version 6.1 (Insightful Corp, 2001) and assumes that, if depth of capture and days in the cage are statistically significant, their effects either increase or decrease as depth or time increases. The significance of each variable was assessed using t-tests. The power of the test for each variable (i.e. the probability of accepting an incorrect H0 (coefficient is 0) when H1 (coefficient is the estimated value) is true) was calculated at $\alpha = 0.05$.

In the full logistic regression models (a and b) a number of variables were not significant ($p > 0.05$). The non-significant variables were removed from the model using backward deletion and the model was refitted. This process was repeated until all remaining variables were significant. The models are designated as follows:

Model Ia - full model with variable Length, but not %Crowding
Model Ib – full model with variable %Crowding, but not Length
Model IIa - reduced model with variable Length, but not %Crowding
Model IIb - reduced model with variable %Crowding, but not Length

3.4 Results

A total of 699 *Pagrus auratus* were captured by line and caged but 74 escaped from cages that were damaged by strong swells or occasional shark attack (n = 625). Nine snapper used in the pilot study were excluded from the analyses (n = 616). A further 12 snapper were also removed from the modelling because there was no information on hook type and/or hook location (n = 604). Thus, while gut-hooked fish (n = 12) were included in the model analyses they were excluded from other analyses investigating effect of depth, venting and fish length (592 snapper were used in the latter analyses – see Table 3.5).

In the reduced Model IIa three variables, depth of capture ($p < 0.01$), %Biomass ($p < 0.01$) and Length ($p = 0.02$) remained significant in predicting the mortality of *P. auratus* (Model IIa, Table 3.1). The reduced alternative model was the following:

$$Y_i = \frac{\exp\left(a + b\%Biomass_i + cLength_i + f\ \mathrm{Depth}_i\right)}{1 + \exp\left(a + b\%Biomass_i + cLength_i + f\ \mathrm{Depth}_i\right)} + \varepsilon_i$$

In the reduced Model IIb two variables depth of capture ($p < 0.01$) and cage crowding ($p < 0.01$), remained significant in predicting the mortality of P. auratus (Model IIb, Table 3.1). The reduced alternative model was the following:

$$Y_i = \frac{\exp(a + f\ \text{Depth}_i + m\%\text{Crowding}_i)}{1 + \exp(a + f\ \text{Depth}_i + m\%\text{Crowding}_i)} + \varepsilon_i$$

A likelihood ratio test of the most reduced models (Model IIa and Model IIb) showed that the model was an adequate fit ($p < 0.001$) of the response variable, explaining 52% of the variation. The ability of the reduced models (Model IIa and Model IIb) to correctly predict Y_i (whether the fish was alive or dead) was 84% (i.e. 21% of live fish predicted to be dead while 5% of dead fish were predicted as alive, Table 3.2, n = 604).

Table 3.1. Parameter estimates for the logistic regression to describe if the fish was alive or dead for various explanatory variables. Significance was tested using t-tests. Model Ia is the full model and Model IIa is the reduced model. Similarly Model Ib is the full model and Model IIb is the fully reduced model. Power refers to the probability (at α = 0.05 level) of incorrectly accepting Ho (when H_1 is true).

	Variable	Parameter estimate	s.e.	T	p-value	Power
MODEL Ia						
a		-3.06	1.81	-1.69	0.09	0.95
b	**%Biomass**	-0.08	0.029	-2.81	**< 0.01**	0.98
c	**Length**	0.0094	0.0041	2.31	**0.02**	0.98
f	**Depth**	3.81	0.96	3.97	**< 0.01**	0.98
g	Days	0.13	0.26	0.52	0.60	0.20
h	Vented	0.41	0.20	2.07	0.04	0.99
j	Hook location	-2.40	1.34	-1.80	0.07	0.97
k	Hook type	-0.31	0.20	-1.52	0.13	0.88
l	Swimming	-0.21	0.22	-0.95	0.34	0.50
T_1	Date_1	-0.034	0.45	-0.07	0.94	0.06
T_2	Date_2	0.052	0.69	0.07	0.94	0.06
MODEL IIa						
a		-4.97	0.81	-6.14	< 0.01	0.98
b	%Biomass	-0.070	0.022	-3.20	< 0.01	0.98
c	Length	0.0091	0.0022	4.14	< 0.01	0.98
f	Depth	3.57	0.70	5.09	< 0.01	0.98
MODEL Ib						
a		-1.73	1.53	-1.13	0.26	0.64
b	%Biomass	-0.024	0.016	-1.54	0.12	0.89
f	**Depth**	3.80	0.86	4.42	**< 0.01**	0.98
g	Days	0.12	0.26	0.60	0.64	0.08
h	Vented	0.41	0.20	2.07	0.04	0.99
j	Hook location	-2.23	1.20	-1.86	0.06	0.99
k	Hook type	-0.30	0.20	-1.48	0.13	0.86
l	Swimming	-0.21	0.22	-0.96	0.36	0.51
m	**%Crowding**	3.58	1.61	2.22	**0.03**	0.98
T_1	Date_1	-0.09	0.44	-0.21	0.83	0.09
T_2	Date_2	-0.14	0.74	-0.18	0.86	0.08
MODEL IIb						
a		-3.92	0.61	-6.46	< 0.01	0.98
f	Depth	3.57	0.61	5.87	< 0.01	0.98
m	%Crowding	3.27	0.80	4.07	< 0.01	0.98

Table 3.2. A "Conditional Probability Table" presenting the apparent percentage error for both reduced models (Model IIa and IIb) predicting whether the fish was alive or dead (n = 604).

	Predicted Alive	Predicted Dead	Error (%)
Observed Alive n = 393	311	82	21
Observed Dead N = 208	11	197	5

Depth

Model I began with five levels (5, 15, 30, 45, 65 m) in the depth factor but pre-analysis using a logistic model [with intercept and four independent cage depth variables (control = 5 m)] showed that mortality of snapper fell into two significantly different depth groups: shallow (5, 15, 30 m) and deep (45, 65 m, Table 3.3). Hence, models were run with two levels in factor depth.

Of the 604 *P. auratus* caged in the experiment, 65.4% survived caged release, however, the most important factor affecting post-release mortality of *P. auratus* was the depth of capture (Model IIa and Model IIb, Table 3.1). If the range of mortality experienced in traps set at each of the 5 depths is presented independently (Figure 3.2), it is clear that mortality at depths up to and including 30 m was lower, with a trend of increasing proportion of traps experiencing higher mortality with increasing depth, resulting in a marked increase in overall mortality between 30 and 45m depth. There was a further increase in mortality between the intermediate depth (45 m) to the deepest site (65 m). This indicates relatively low mortality at the shallow depths, then rapidly increasing rates of mortality at depths greater than 30 m.

Length

Pagrus auratus ranged in size from 190 – 670 mm TL in the experiment. Length of fish affected post-release mortality of *P. auratus* significantly (Model IIa, Table 3.1, Figures 3.3a and b). The size distribution of fish caught from the shallows (5, 15 and 30 m) (n = 321) varied significantly (two-sided Kolmogorov-Smirnov statistic = 0.5614, p-value < 0.001) from the deeper sites (45 & 65 m) (n = 271) because the two smallest size classes (200 & 250 mm size class, Figure 3.3 a & b) were not caught at the deeper sites.

While there were no significant changes in mortality with fish size at the shallow sites, there was a marked increasing trend in mortality at the deep sites (Figure 3.3 a and b).

% Biomass and Cage crowding

The comparison between the outputs of the two models revealed that both the total variation and level of mortality correctly predicted by the reduced models was similar. Thus the variables cage crowding (Model IIa) and %biomass plus total length (Model IIb) are equally effective at measuring the effect of variable numbers and weight of fish in each cage.

Individual snapper ranged in weight from 137 - 4985 g and the total biomass of fish in cages ranged from 489 - 16472 g. Relative (%) cage biomass only was only significant when %crowding was excluded (Model IIa, Table 3.1).

A total of 144 cages were retrieved in the experiment and cage crowding ranged from 0 - 10% up to 51 - 60% at the shallow sites and up to 91 - 100% at the deep sites (Figures 3.4a and b). Cage crowding affected post-release mortality of *P. auratus* significantly (Model IIb, Table

3.1). However, there was no relationship between crowding and mortality within either of the two depth groups (Shallow (5, 15 and 30 m deep): F regression stat = 0.05, p = 0.83; Deep (45 and 65 m): F regression stat = 1.43, p = 0.27, Figures 3.4a and b).

Venting

Of a total of 604 snapper captured across the five depths, the swim bladders of 306 fish were vented and 298 were not vented. Venting the swim bladder of *P. auratus* does not increase mortality (Model Ia and Ib, Table 3.1, Figure 3.5a).

Swimming

When released into the tank or cage after capture, 75.8% of vented fish swam compared to 64.4% of unvented fish. The percentage of vented fish that swam was higher than unvented fish for all depth categories except 5 m (Figure 3.5b). Swimming in cages after release, however, did not increase survival (Model Ia and Ib, Table 3.1).

Hook Type

Hook type did not affect mortality of snapper (Model Ia and Ib, Table 3.1). Circle hooks were responsible for hooking 54.3% of the catch (Table 3.4) and 35.8% of fish caught by circle hooks died compared to 33.3% caught by standard J hooks.

Anatomical Hook Location

The anatomical location of the hook did not affect mortality of snapper (Model Ia and Model Ib, Table 3.1). However, most *P. auratus* (98%) did not swallow the hook (Table 3.4). 1.2% of circle hooks and 3% of J hooks were swallowed. Mortality from swallowed hooks was almost three times as high (91.7%) as hooks lodged in the jaw or lip (other, 33.6%).

Days

During the caging experiment the post-release mortality was assessed for 24 fish caged for one day, 140 fish caged for two days, 288 fish caged for three days and 152 fish caged for four days. Duration of caging did not significantly affect mortality (Model Ia and Ib, Table 3.1). Therefore mortality can be summed over the duration of the experiment.

Date

The date of placement of fish in the cage did not affect mortality of snapper (Model Ia and Ib, Table 3.1).

Effects of hook injuries, barotraumas and extended onboard handling time

The condition of each fish was monitored after capture and caging. Relatively few *P. auratus* incurred major hook injuries hook and all of these fish were captured from shallow depths. Of the 11 snapper wounded by hooks in the body (n = 7), eye (n = 1) and gills (n = 2) only one hooked in the gills died. The main visible barotrauma injury was bleeding from the anus, which occurred in 12 fish and all fish with this injury caught from the deeper areas died (n = 4). One snapper caught from the shallows was recorded as having an extended onboard handling time and subsequently died.

Table 3.3. Parameter estimates for the logistic regression to compare depth 5m with the rest.

Parameter	Coefficient	Std. error	t-value	p-value
Intercept	-3.22	0.90	-3.57	< 0.01
Cage depth = 15m	-0.26	1.48	-0.17	0.86
Cage depth = 30m	-0.12	1.31	-0.09	0.93
Cage depth = 45m	4.21	0.92	4.58	< 0.01
Cage depth = 65m	4.02	0.91	4.42	< 0.01

Table 3.4. Number of *Pagrus auratus* at each depth that remained alive or died during the experiment for each hook type (circle hooks and J hook) and location of the hook in the fish (gut or mouth). NA = fish were hook type and/or anatomical location is unknown.

Capture Depth (m)	Type of hook									
	Circle				Standard J				Both	
	Gut		Mouth		Gut		Mouth		Other	NA
	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	
5			48	2	1		51	2		3
15			40	1			57	2		3
30			81	4			32			
45		4	11	32		4	15	30	2	1
65			35	77		3	22	48		5
Total		**4**	**215**	**116**	**1**	**7**	**177**	**82**	**2**	**12**
Grand Total	**335**				**267**				**2**	**12**

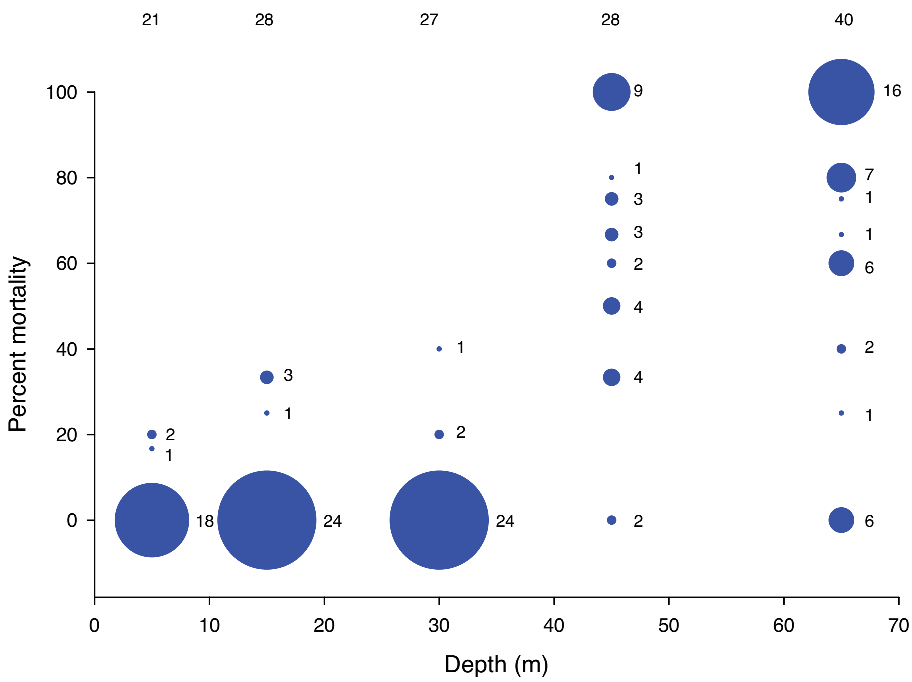


Figure 3.2. Mortality of *Pagrus auratus* caught at five depths of capture 5 m (n = 102 fish), 15 m (n = 102 fish), 30 m (n = 117 fish), 45 m (n = 89 fish) and 65 m (n = 182 fish). Number of cages at each depth is presented beside each bubble.

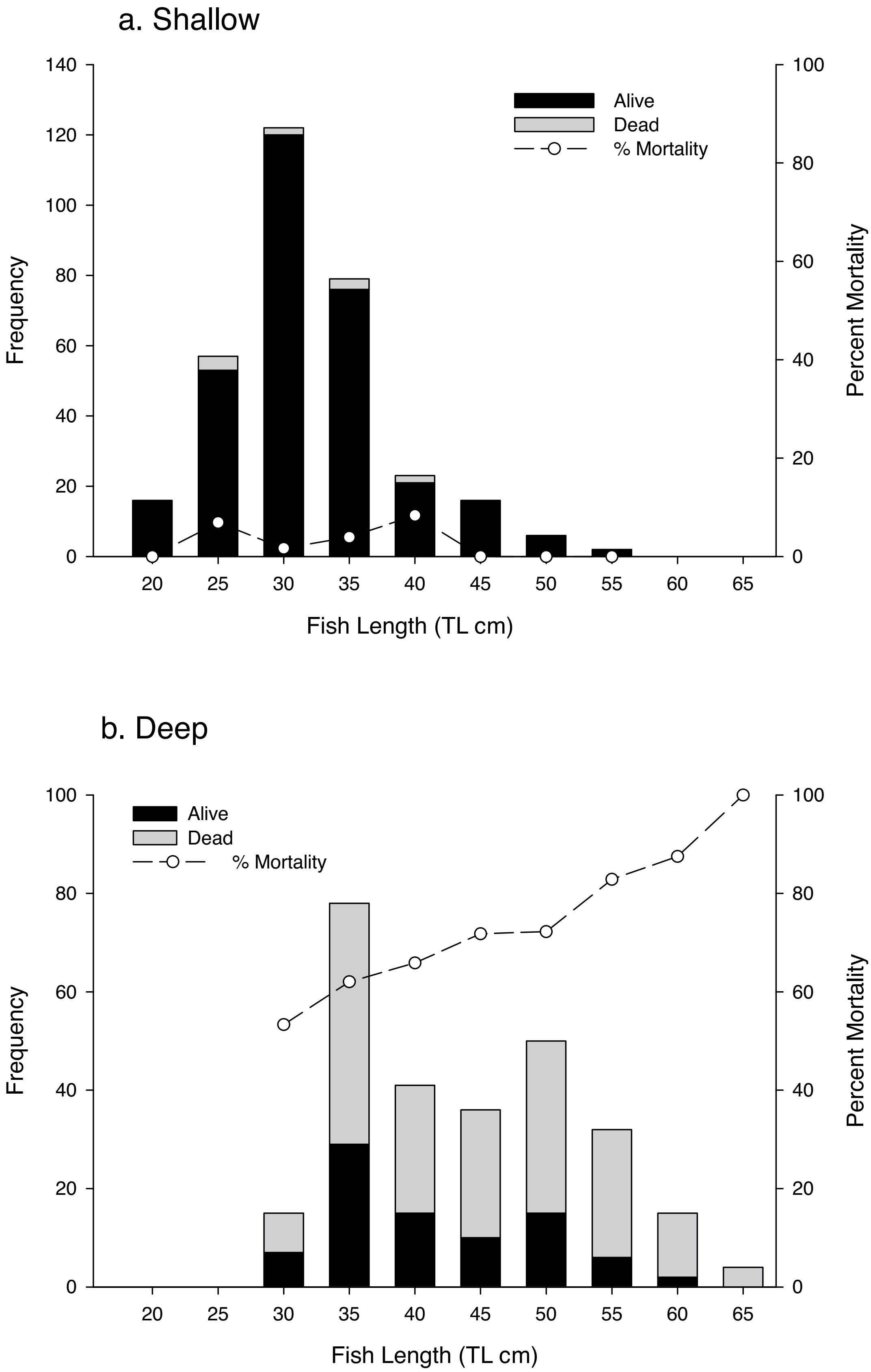


Figure 3.3. a & b. The effect of length on mortality of *Pagrus auratus* caught at the (a) shallow (5, 15 and 30 m) (n = 321) and (b) deep (45 and 65 m) (n = 271) sites.

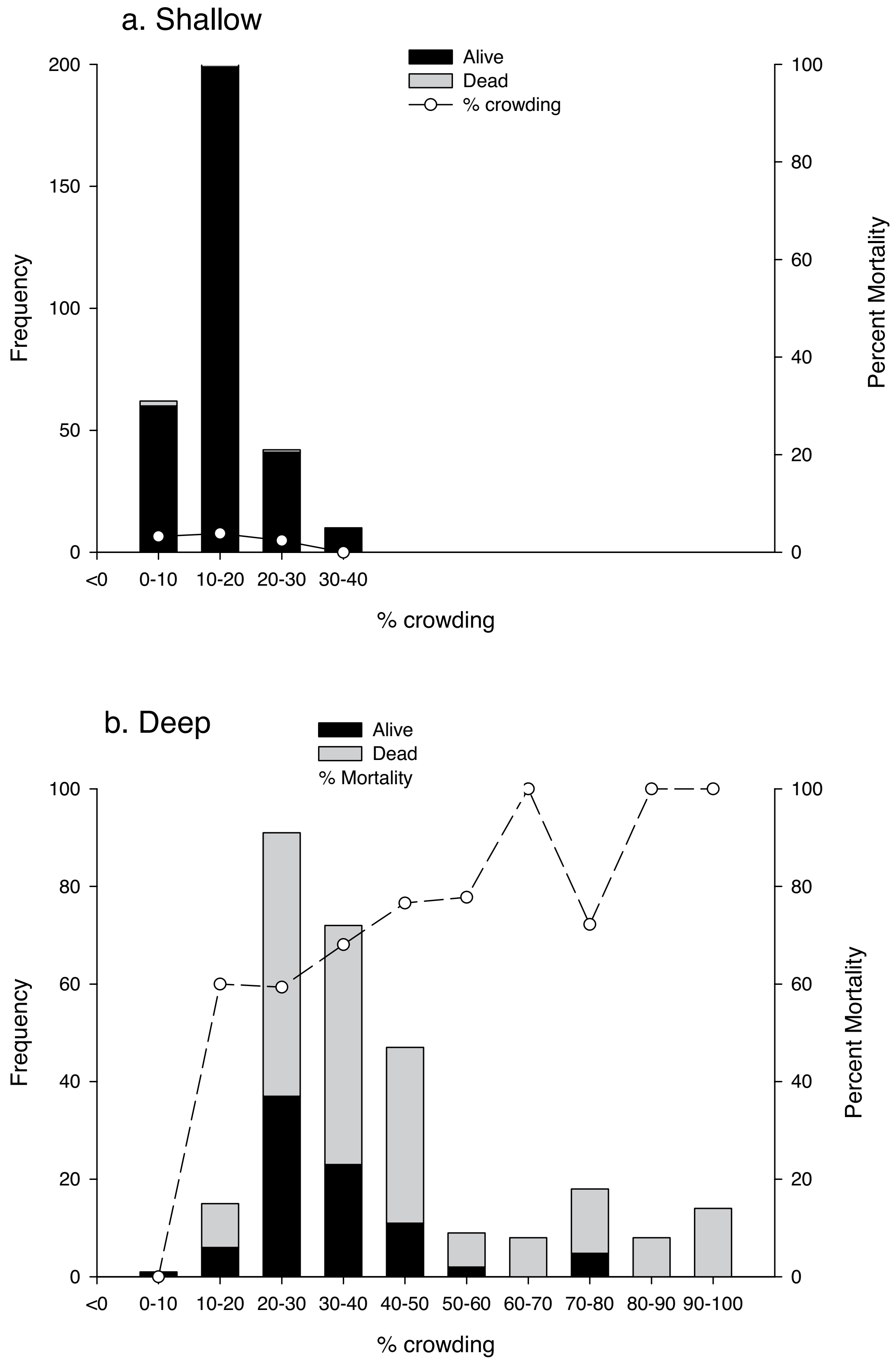


Figure 3.4. a & b. The effect of percent cage biomass on mortality of *Pagrus auratus* caught at the (a) shallow (5, 15 and 30 m) (n = 321) and (b) deep (45 and 65 m) (n = 271) sites.

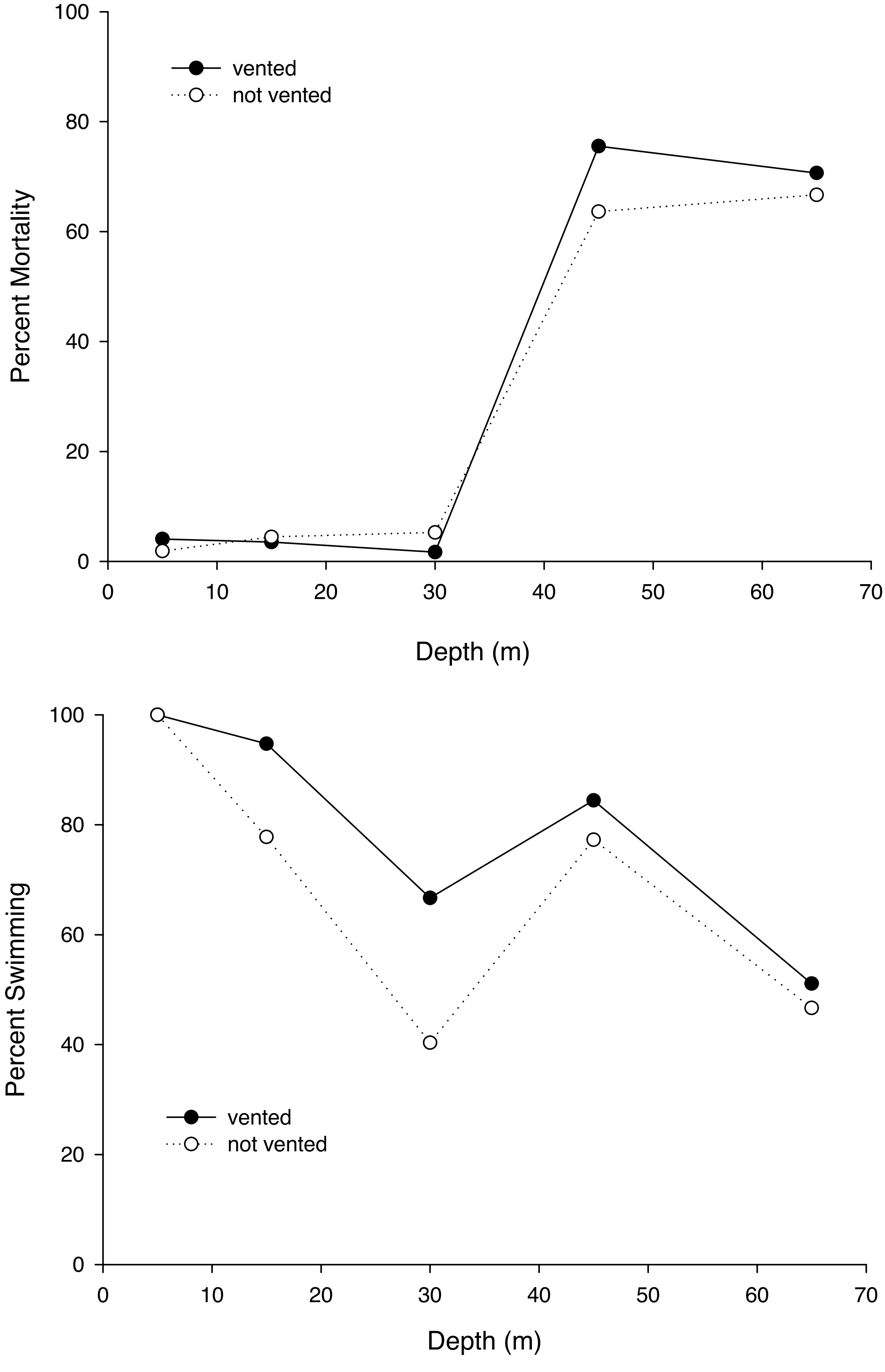


Figure 3.5. a & b. The effect of venting on the (a) mortality and (b) swimming ability after release of *Pagrus auratus* captured from five depths: 5 m (n = 102), 15 m (n = 102), 30 m (n = 117), 45 m (n = 89) and 65 m (n = 182).

3.5 Discussion

Based on the review by Muoneke and Childress (1994), where rates of post-release mortality > 20% were considered to be high, mortality of snapper in our study at depths of < 30 m was consistently low, but high at depths of > 30 m. A similar study conducted in NSW (Stewart 2008) investigated the mortality of juvenile and sub-adult snapper (170-400 mm TL) caught in commercial fish traps at depths ranging from < 10 m to 56 m, pulled to the surface then returned in cages to the depth of capture: depth was shown to have the greatest effect on short-term survival, with only ~2% mortality at < 30 m, increasing to ~39% at 30 to 44 m, and ~55% at 45 to 59 m. There have been two other studies examining mortality of juvenile and sub-adult *P. auratus* in Australia, one in NSW (Broadhurst *et al*., 2005), and another in Victoria (Grixti *et al*., in review). Fish were caught and kept in holding tanks/cages before being transported to sea cages, where their mortality was assessed over a number of days. The mortality of the fish assessed in the current WA study (approximately 2-4%) was far less than the mortality reported in the NSW study (26%), but comparable to the mortality reported for shallow-hooked fish in the Victorian study (3%), noting that a much higher mortality was experienced by the gut-hooked fish (52%) in the latter study. The high survival of juvenile and sub-adult snapper caught in shallow waters was confirmed by an additional study conducted between 2003 and 2005 in the shallow (< 10 m) waters of Port Phillip Bay, Victoria (Grixti *et al*., in review). Here, the post–release survival of recreationally caught juvenile snapper varied from 97% for mouth-hooked (referred to as "shallow-hooked"), to 48% for gut-hooked (referred to as "deep-hooked") fish. The consistent results from these studies thus clearly indicate that snapper that have not swallowed the hook can survive release following capture from shallow waters, while a high rate of mortality will be experienced by snapper caught at depths > 30 m.

A number of other studies that examined the effect of depth on post-release mortality in demersal species found similar rates of mortality. St John and Syers (2005, Chapter 2) found that mortality of *Glaucosoma hebraicum*, increased with depth of capture from 21% at 0-14 m to 86% at 45-59 m. Similarly, surface release experiments on *Lutjanus campechanus* (*Lutjanidae*) found that mortality ranged from 1% at 21-24 m, 10% at 27-30 m to 44% at 37-40 m (Gitschlag & Renaud, 1994). In contrast to the marked increase in mortality of snapper once depth exceeded 30 m, mortality in these other species increased uniformly with depth. Low mortality of snapper in shallow depths may be due to them having a relatively robust body and physiology. Compared to *G. hebraicum*, both frequency and the number of types of visible barotrauma were lower in snapper and the incidence of external evidence of barotrauma was lower at all depths (St John & Syers, 2005; Chapter 2). The most common evidence of barotrauma was bleeding from the anus caused by distended intestines and was only fatal at the deeper sites.

Even though the sample size was small, the very high rate of mortality from the gut hooked fish (which has been confirmed with studies by Grixti *et al*., in review), means that this can be a source of capture induced mortality. If however, less than 2% of the catch is gut hooked, the overall effect on population dynamics would be small.

The only onboard handling technique tested, venting, did not increase short-term (i.e. over several days) mortality of snapper and this result was consistent with other demersal fishes (Lee, 1992; Render & Wilson, 1994 and Keniry *et al*., 1996). Our caging experiments, however, did not examine whether venting benefits fish released on the surface because fish were returned to the sea floor in cages. As with other demersal species (Bettoli & Osborne, 1998: St John and Syers, 2005), swimming ability at release is not a good predictor of short-term survival in snapper.

The main result of this study, i.e. low post-release mortality at depths < 30 m and the high mortality for depths > 30 m, has important implications for management of snapper fisheries. Juveniles and sub-adult snapper often live in nursery habitats within sheltered, nearshore embayments. In Australia, most large cities are coastal and many, including mainland state capitals, are situated near important recreational snapper fisheries in bays (Moreton Bay, Queensland; Botany Bay, New South Wales; and Port Phillip Bay, Victoria), gulfs (Spencer Gulf, SA) and sounds (Cockburn Sound, WA). These fisheries are subject to intense and increasing fishing pressure as populations increase because Australian recreational fisheries do not generally limit entry. The consistently low rates of post-release mortality for snapper in shallower waters supports the use of size and bag limit regulations to restrict recreational catch in such waters.

Snapper fisheries in deeper waters, however, will not benefit from size and bag limits to the same degree because the usefulness of returning undersized or excess snapper decreases at depths greater than 30 m due to high rates of post-release mortality. The results of this study have already been incorporated into the management of the Shark Bay Snapper Managed Fishery (SBSF, Jackson *et al*. 2007). This commercial line-fishery targets the oceanic snapper stock off Shark Bay and uses a quota-based system with an annual Total Allowable Commercial Catch (TACC). Licensed SBSF vessels take their individual snapper quota as well as other demersal species, e.g. lethrinids and cods, as bycatch. Until recently, commercial vessels without SBSF quota were able to fish for species other than snapper in the same waters. In the deeper waters of the fishery this resulted in high levels of depth-related mortality of snapper because these vessels were releasing large numbers of snapper that they were unable to legally land. Therefore, based on information from this study in 2004 the regulations were changed so that all commercial vessels fishing in these waters required a minimum holding of snapper quota, in an attempt to reduce the discarding and associated post-release mortality of snapper at deep sites.

Information on whether variables, other than depth, affect post release mortality in snapper is also useful for management. Although the results of this study provide no evidence to recommend the use of circle hooks in the recreational fishery, it showed circle hooks to have some benefit to the commercial Shark Bay Snapper Fishery because they caught higher numbers of fish and were not swallowed. Although venting did not increase mortality of caged fish, it may increase survival by enabling released fish to swim back down to the bottom and avoid surface predation. Also, efficient methods to handle the fish once on-board can prevent mortality from air exposure (Ferguson and Tufts, 1992). Post-release mortality of snapper caught from shallows can always be improved by angler education about care of fish. Recently, education of recreational fishers to handle fish gently has been encouraged through national and state campaigns (See RecFishWest website: http://www.recfishwest.org.au). There is also currently no specific handling protocol to improve survival in the commercial sector, which needs to be addressed at the behavioural level.

4.0 Effects of onboard handling techniques and methods of release on recapture rates of temperate demersal species in Western Australia

Jill St John, Ian Keay and Ian Wright

4.1 Introduction

Demersal reef fishes are targeted by recreational and commercial fishers using boats; recreational fishers use privately owned boats or charter boats. Demersal reef fishes commonly caught off south-western Western Australia include three endemic species, West Australian dhufish *Glaucosoma hebraicum*, the breaksea cod, *Epinephelides armatus,* and the baldchin groper *Choerodon rubescens*. The snapper *Pagrus auratus*, has a widespread distribution throughout temperate Australia. In recent years the rates of exploitation of these demersal species have increased due to increases in numbers and size of recreational fishing boats in WA. Also, improvements in, and more affordable, fishing technology have increased fishing efficiency in both the recreational and commercial fleets. As most of the population of WA lives in metropolitan Perth, increased exploitation is particularly evident in the metropolitan waters off Perth (Wise *et al*. 2007).

Both commercial and recreational fishers are legally required to release all undersize fish. In a recreational line fishing survey conducted in 1996-7, Sumner and Williamson (1999) estimated that nearly 43,000 WA dhufish were captured over a 12 month period and 35% of these (or 15 050 fish) were released. Since that survey, recreational fishing effort has further increased in WA (Henry & Lyle 2003; Wise *et al*. 2007, Sumner *et al*. 2008). A creel survey for the West Coast Bioregion in 2005/06 estimated that 58% of the recreational catch of demersal scalefish were released.

In addition to the caging experiments described in Chapters 2 and 3, a research-tagging programme commenced in 2000 to further investigate how to maximise release-survival of demersal line-caught fish. The research-tagging programme was undertaken by the Australian National Sportsfishing Association (ANSA) - WA and RecFishWest, with analysis of data by the Department of Fisheries. The broad aim of the tagging programme was to understand more about release mortality of the suite of temperate demersal species in the West Coast Bioregion.

More specifically, the objectives of the tagging study were to examine whether different release methods affect the recapture rates of demersal fish species. Two of the three different release methods (shotline and venting) were designed to enable the fish to return to the ocean floor quickly while the third method (simple) was a control.

4.2. Methods

Taggers and training

In October 2000 ANSA-WA appointed their member Peter Anderton, who ran Edfish (a company providing recreational fishing education and training), to be their endorsed tag trainer. All requests for training were forwarded through the ANSA-WA president, Stephen Gilders to Mr Anderton, who ran classes when there were sufficient numbers of participants. To participate in the programme, all taggers were required to join ANSA-WA, either as a club member associated with one of several clubs or as an ‘antagger’, an individual member. A number of Perth-based charter boat companies were recruited to the tagging programme and began tagging fish in January 2001.

In November 2002 a tagging facilitator, Andrew Rowland, based at RecFishWest, was employed to increase the numbers of fish tagged in the tagging programme by recruiting and training more taggers. In addition, the tagging facilitator assisted in the co-ordination of tag distribution, collection of data sheets, data entry and provision of certificates for anglers recapturing tagged fish. Tagging became open to all interested anglers and the requirement to join ANSA was dropped.

Tagging procedure

Taggers involved were asked to release tagged fish using one of three release methods:

Simple, where the fish is simply placed back in the water;

Vented, where the swim bladder of the fish is punctured with a clean, hollow needle and the air released; and

Shotline, where a weighted barbless hook (release weight) is connected to the fishing line and attached to the jaw of the fish and the fish is dropped back down to the bottom. When the weight touches the sea floor, a gentle tug on the line releases the fish.

A shotline, designed by one of the ANSA members, was produced at low cost and provided to taggers participating in the programme (see flier for explanation, Appendix 1.1).

The new WESTAG sportfish tagging sheet included three sections (Appendix 1.2). Taggers recorded tag number, date, angler ID, location, species, total length, caudal fork length and depth (m) in the first section. The second section listed a range of options that taggers ticked: hook type (normal hook, circle hook), location of hook in fish (gut-hooked, lip-hooked, jaw-hooked) method of release (simple release, vented release, shotline release), onboard activity of fish (body movement, fin movement, no movement) and five common, visible symptoms of barotraumas (scales raised, eyes out of sockets, bubbles in eyes, large swim bladder, stomach in mouth). Anal prolapse was thought to be a less common symptom overall, and was therefore not include as one of the five common symptoms. Definite symptoms of barotraumas and descriptions of onboard activity (movement) were deliberately used to avoid vague or subjective judgments of condition such as poor, good etc. The last section was a comments section where taggers could add extra information.

This information was only recorded for the tagged fish on initial release. Recapture information provided by the angler who caught a tagged fish included: tag number, species, date, total length (TL), location and information about themselves, such as name and contact details.

Tagging database

The original database "Infotag" written for ANSA- Australia was adapted to include the extra information on release methods and fish condition required by this project. The data was entered by ANSA-WA tag co-ordinators or by the RecFishWest tag facilitator.

Data on initial tag and releases and subsequent recaptures between January 2001 and December 2006 was referred to as the "analysis database" and analysis of release methods using recapture rates was restricted to this database only. Although fish tagged prior to the beginning of this study were released simply, and contained no information about the condition of the fish, they provided useful additional information about location, migration or movement, fish length and days at liberty and thus were included in analyses of this information. The database housing all of the data (i.e. from 1996 onwards) up to and including some of the 2006 data is referred to as the 'extended database'; the "analysis database" (data from 2001 to 2006) was a subset of this larger database.

Database validation was undertaken to remove obvious errors. They included:

Duplicate tag numbers (same tag number with different information eg species or dates);

Duplicate entries (same tag number with identical information);

No tag numbers (47 entries);

No information on the Tag numbers of recaptured fish (35 entries);

Length data outside their expected range (i.e. < 100 mm (but probably recorded in cms) and > 1 m (e.g. Dhufish 4555 mm breaksea cod 1190 and 1200 mm)); and

Dates where fish were recaptured before they were tagged (4 entries).

Recapture records for which there was no record of initial fish tagging (some fish for 2006 and all those for 2007).

Core assumptions of tagging data

Hilborn and Walters (1992) review a number of important considerations in tagging studies. These are the assumptions of tagging studies that need to be addressed to be able to assume that recapture rates reflect rates of survival of tagged fish, and include:

Numbers tagged and fishing effort. Our study has records of all fish tagged but assumes that fishing effort expended to capture the fish to tag is similar throughout the study;

Release mortality of tagged fish. We assume that the survival of tagged fish does not vary from the survival of untagged fish;

Tagged fish behaviour. We assume the behaviour of fish does not change due to tagging;

Tag loss. This study did not examine tag loss and thus assumes the type of release method used did not affect tag loss;

Natural mortality. Natural mortality has been estimated for these species (Wise *et al*, 2007);

Tag reporting rate. Tag reporting rate was not investigated and was assumed to be similar for all types of anglers and fish species; and

Number recaptures and fishing effort. The effort expended to catch fish is assumed to be similar throughout the study.

Tagging analyses

Locations on tag data sheets were recorded as either latitude and longitude co-ordinates or local place names. If neither location nor co-ordinate was reported or the location could not be allocated a co-ordinate (i.e. not a name generally used), then the data was not included in the map. Locations with directional distances from recognisable location names were assigned a co-ordinate. Less accurate co-ordinates from less specific locations were flagged in the analysis. General locations (e.g. Rottnest) were allocated the closest and most reasonable marine co-ordinate and flagged as less accurate in the database.

A 5 by 5 nm block spatial system used by the Department of Fisheries for recording catch and effort data for creel surveys and charter boat operators was used to plot maps of tag and recapture locations for the three most commonly tagged species (dhufish, snapper, and breaksea cod). All blocks were assigned visually using maps of the block system along the coastline. This was straightforward for latitude and longitude co-ordinates and directional distances from recognisable location names. If only a place name was recorded, then the sea block closest to the location was used.

Maps were produced using ArcGIS, employing a colour scale to show categories of numbers of fish tagged and recaptured. This scale was calculated for each species from the range of fish numbers in each block.

4.3 Results

Data sets

The number of fish tagged and recaptured by species and year in the extended database and the "analysis" database, a subset of the "extended" database, is shown in Table 4.1. As well as the different types of release methods, this more restricted database includes new information about methods and condition of captured fish, release, and condition of released fish (see Table 4.2).

In the extended database containing all tagging information, a total 3332 individuals of four temperate demersal reef species were tagged and 261 were recaptured (Table 4.1). Tagged fish include 1509 WA dhufish, 1381 snapper, 364 breaksea cod and 78 baldchin groper (Table 4.1). In the analysis database, a total 2781 temperate demersal reef species were tagged and 195 were recaptured between 2001 and 2006 (Table 4.1). Tagged fish include 1206 WA dhufish, 1181 snapper, 323 breaksea cod and 71 baldchin groper.

Table 4.1. The number of fish tagged and recaptured by species and year in the extended database showing the analysis database (shaded) as a subset. *The low numbers in 2006 were due to the few datasheets entered into the database, as there was no tag information on many of recaptures reported.

Year	Dhufish	Pink snapper	Breaksea cod	Baldchin groper	Total	
					Tags	Recaptures
1996	8	3	6		17	5
1997	78	33	7		118	13
1998	112	91	6	4	213	18
1999	55	35	7	2	99	10
2000	50	38	15	1	104	20
2001	259	324	74	14	671	60
2002	258	174	66	31	529	39
2003	199	185	32	11	427	24
2004	259	256	78	5	598	44
2005	169	158	56	9	392	25
2006	18	37	4	1	60	3
Unknown	44	47	13	0	104	0
Res Total	1206	1181	323	71	2781	
Recaptures	89	96	10	0		195
Ext Total	1509	1381	364	78	3332	261

Information recorded by taggers

Generally capture information was well reported with a low rate of non-reporting for depth and release method (average of < 4%) and a low rate of non-reporting for location of capture (< 20% for all species except dhufish, Table 4.3). Non-reporting of locations included place names that could not be identified. Hook type and anatomical location in the fish was well reported as 87% of all tag records included both hook type and anatomical location (Table 4.4). The level of reporting information about the condition of the fish, however, was lower. Fish activity onboard was not reported in 44% of records and barotraumas symptoms were not reported in 78% of records (Table 4.3). There was no separate category for no barotrauma symptoms, thus, non-reporting could not be distinguished from healthy fish with no obvious symptoms.

Table 4.2. The information requested by the tag data sheet about the tagged and released fish.

Standard Information Requested					
Tag	Tag Number	Tag Type, Double Tag Retag Retag Type	Date	Location, Latitude Longitude	Depth
Tagger	Tagger name	Tagger type	Club	Time Spent Fishing	Tag Issue
Fish	Species	Total Length Fork Length	Recaptured	Rel. Condition	Swim Bladder
Research information requested					
Hook type	Normal J	Circle	Treble	Barbless	
Hook location	Gut	Lip	Jaw	Other	
Fish Activity on board	Fins	Body	None		
Effects of depth	Scales Raised	Eyes_ Sockets	Eyes_ Bubbles	Swim_ Bladder	Large Stomach
Release method	Simple	Vented	Shot		

Table 4.3. Percentage of taggers recording information about the fish they have tagged and released. The information is depth of capture, onboard activity by the fish, barotrauma symptoms and location.

Percentage of taggers recording information on	**Dhufish**	**Pink snapper**	**Breaksea cod**	**Baldchin groper**	**All species**
Depth of Capture	98.8	93.3	99.1	95.8	96.3
Onboard activity	56	55.3	67.2	33.8	56.4
Barotrauma symptoms	27.3	11.8	35.9	31	21.8
Location of capture	74.4	81.6	100	85.9	80.4

Table 4.4. Percentage of taggers recording information about hook type used and anatomical location of hook in fish.

Information on hooks	Dhufish	Pink snapper	Breaksea cod	Baldchin groper	All species
no info	2.5	9.4	1.5	5.6	5.4
hook type only	6.7	5.2	3.1	9.9	5.7
hook location only	2.2	0.9	0.6	1.4	1.4
both hook type and location	88.6	84.5	95.0	83.1	87.3

Description of the taggers and recapturers, and where they fished

Between 60 and 671 demersal scalefish were tagged each year of the "analysis" programme (Table 4.1, Figure 4.1a). The low numbers in 2006 are not an accurate representation of the number of fish tagged, but reflect difficulties at that time with data entry into the database. Taggers were mostly charter boat anglers or ANSA-WA trained anglers and the proportion of fish each group tagged varied among the years (Figure 4.1a). Fish tagged by research anglers in 2001 were released during the caging experiments. Tagged fish were recaptured by a wide variety of angler types including charter boat anglers, ANSA-WA members, public anglers, commercial wetliners, research anglers or unknown (Figure 4.1b).

Although fish were caught from depths up to 120 m, across all four species most fish were caught between 10 and 50 m (Figure 4.2a-d). Charter boat operators generally fished and tagged in deeper waters compared to recreational fishers (Figure 4.2 a-d). Generally, the patterns of the depth of capture were similar for dhufish, breaksea cod and baldchin groper, but a higher proportion of snapper were caught in < 10 m and in -100 m of water. The deep-water captures of snapper at around 75 and 95 metres reveals patterns of fishing by metropolitan charter boat operators that fish at these depths offshore from Rottnest Island.

Notwithstanding the higher variability due to low numbers, the patterns of depth of recaptures are similar to the patterns of tagging, particularly in breaksea cod (Figure 4.3). The relatively higher numbers of breaksea cod caught at deep sites reflects the consistent effort of the charter boats in that area (Figure 4.3).

Fish were tagged and recaptured by recreational anglers from Shark Bay to Albany (Figure 4.4). The majority of fishing by recreational anglers, however, was done in the Metropolitan region (Figure 4.4). Fish tagged and recaptured by other types of anglers (predominantly charter boats) showed a focus in the Metropolitan region an additional area of focus off Albany (Figure 4.5).

Locations and lengths of fish

Locations of 1120 tagged dhufish with location information recorded were plotted in a 5 by 5 nm grid from Kalbarri to Albany show most fish tagged in areas around Rottnest Island and other metropolitan locations from Mandurah to Two Rocks (Figure 4.6). Outside the metropolitan area, areas near Leeman and Port Gregory were popular tagging areas. Overall, 93 dhufish recaptured with location information were mapped, most occurred in the Metropolitan area, particularly around Rottnest Island (Figure 4.7).

The 1128 tagged snapper with known locations ranged from Shark Bay to Albany. Although most snapper were tagged in the Metropolitan region, similar to the situation for dhufish, other popular tagging areas included Kalbarri and outer Geographe Bay (Figure 4.8). Most of the recaptures with known locations (n = 94) were caught in the metropolitan area (Figure 4.9).

All locations of tagged Breaksea cod were reported (n = 364). While breaksea cod extend from Kalbarri to Albany, most were caught in waters off the Metropolitan region (Figure 4.10). All of the recaptures with known location (n = 8) occurred in the Metropolitan region (Figure 4.11).

Although the spatial distribution of tagging for baldchin groper ranged from Kalbarri to Bunbury (n = 71, Figure 4.12), most fish were captured in the Metropolitan region. There were no reported recaptures of this species.

The length of fish tagged and recaptured varied among the four species due to differences in both the size attained by each species and their Legal Minimum Lengths (LML): 50 cm for dhufish, 41 cm for snapper, 40 cm for baldchin groper and 30 cm (TL) cm for breaksea cod (Figure 4.13). Although tagged dhufish ranged in size from 15 to 90 cm TL, the dominant size class tagged was between 30 and 50 cm TL (Figure 4.13a). The size range of tagged snapper was similar to dhufish but the majority of tagged snapper were between 25 and 45 cm TL reflecting a LML 9 cm lower than dhufish (Figure 4.13b). The size range of breaksea cod was 15 to 50 cm TL with the majority of fish tagged between 20 and 35 cm TL (Figure 4.13c). The size range of baldchin groper was smallest, 25 to 55 cm TL with the majority of fish tagged between 30 and 40 cm TL (Figure 4.13d).

The size structure of the released dhufish and snapper was smaller than that of recaptured fish, but was similar for breaksea cod (Figure 4.13).

Capture method, fish condition and release method

Four hook types were reported to have caught demersal fish (Table 4.5). Overall, most fish were caught with J hooks, followed by circle hooks. Treble gangs and barbless hooks caught less than 0.5% of the total fish tagged (Table 4.5). On the charter boats, however, circle hooks caught most dhufish and baldchin groper, whereas J hooks caught most snapper and breaksea cod (Figure 4.14).

Table 4.5. Percentage of fish caught using various hook types.

Type of hook	Dhufish	Pink snapper	Breaksea cod	Baldchin groper	Total number
Circle	43.3	25.8	22.7	26.6	33.6
J	56.6	73.1	77.3	73.1	65.9
Treble/gang	0.0	0.9	0.0	0.0	0.4
Barbless	0.1	0.1	0.0	0.3	0.1

Of the two most common hook types, J hooks were swallowed more than circle hooks and dhufish were more likely to swallow hooks than snapper. 3.2% of J hooks and 1.0% of circles hooks were swallowed by dhufish, whereas 1.2% of J hooks and no circle hooks were swallowed by snapper (Table 4.6). No gut-hooked fish were ever recaptured, although release numbers were very low. In dhufish, recapture rates of fish hooked by J hooks (2.8%) was double the rate of circle hooks (1.4%), however, the opposite occurred in snapper as the recapture rates of circle hooks (6.2%) were higher than in J hooks (4.4%, Table 4.6).

Table 4.6. The number of dhufish and snapper caught by the two most common hook types, J and circle, and the anatomical location of the hook in the fish.

Type of hook	J		Circle	
	# Caught	% Recapture	# Caught	% Recapture
Dhufish				
Gut-hooked	21 (3.2%)	0%	5 (1%)	0%
Not gut-hooked	629 (96.8%)	2.8%	492 (99%)	1.4%
Snapper				
Gut-hooked	10 (1.2%)	0%	0	0%
Not gut-hooked	765 (98.8%)	4.4%	274 (100%)	6.2%

Most fish (78%) were reported as having no barotraumas symptoms, however, this value confounds healthy fish with non-reporting because the tag sheets lacked a category for 'No Barotrauma symptoms' (Table 4.7). Overall 609 fish (21.9% of the total number tagged) were reported to have barotrauma symptoms (Table 4.7). This indicates that, at a minimum, 21.9% of tagged fish had incurred some barotrauma. The percentage of barotrauma for individual species is shown in Table 4.7.

Table 4.7. The number and percentage of fish recorded to have barotrauma symptoms.

	Total fish	Not reported	Total fish with barotrauma	% Of total reported to have barotrauma
Dhufish	1206	875	331	27.4
Snapper	1181	1041	140	11.8
Breaksea cod	323	207	116	35.9
Baldchin groper	71	49	22	31.0
Total	2781	2172	609	21.9

Captured fish often displayed > 1 type of barotrauma symptom, hence the 609 fish with barotrauma displayed a total of 789 barotrauma symptoms (Table 4.8). Three barotrauma symptoms, Stomach in mouth, Eyes out of sockets and Large swim bladders comprised around 90% of all barotrauma symptoms reported (Table 4.8). By comparison, Bubbles in Eyes and Raised scales were much less common. The proportions of these barotrauma symptoms varied among species and are most likely related to the morphology of the species. For example, Eyes out of sockets was less common in snapper and baldchin groper compared to dhufish and breaksea cod (Table 4.8).

Table 4.8. The types of barotrauma symptoms recorded in each species of released fish by taggers.

	Dhufish		Snapper		Breaksea cod		Baldchin groper		Total	
	#	%	#	%	#	%	#	%	#	%
Scales raised	16	4.8	2	1.4	6	5.2	0	0.0	24	3.0
Stomach in mouth	106	32.0	101	72.1	66	56.9	19	86.4	292	37.0
Eyes out of sockets	162	48.9	14	10.0	54	46.6	3	13.6	233	29.5
Bubbles in eyes	39	11.8	4	2.9	15	12.9	0	0.0	58	7.4
Large swim bladder	121	36.6	31	22.1	29	25.0	1	4.5	182	23.1
Total # of barotrauma	444		152		170		23		789	
Total # of fish	331		140		116		22		609	

The combinations of barotrauma symptoms varied among species (Figure 4.15a-d). Breaksea cod had the greatest number of combinations of barotrauma symptoms (Figure 4.15c). Most breaksea cod had either Stomach in mouth, Eyes out of sockets or both symptoms combined (Figure 4.15c). Barotrauma symptoms in dhufish, however, were split between the three most common symptoms, Stomach in mouth, Eyes out of sockets and Large swim bladders (Figure 4.15a). The most common barotrauma symptoms in snapper and baldchin groper was Stomach in mouth (Figure 4.15b & d) and this was followed by Large swim bladder in snapper (Figure 4.15b).

The release method was not recorded for 4.5 % of fish (Table 4.9). Some taggers used more than one release method on the same fish, presumably because the first method was unsuccessful. For the analyses of numbers released by method, ‘simple and shotline’ was grouped with shotline and ‘simple and vented’ was grouped with vented. The category ‘vented and shotline’ was omitted from the analyses. Excluding fish with no release information, the proportion of fish released by the different methods varied among species. Dhufish and baldchin groper were released by all three methods: simple (dhufish = 42.7%, baldchin = 31%), vented (dhufish = 19.8%, baldchin = 16.9%) and shotline (dhufish = 33.4%, baldchin = 42.2%). Breaksea cod were released mostly by shotline (44.9%) or simple (36.5%), whereas snapper were mostly released by the simple method (78.4%). Generally pink snapper are difficult to attach to a release weight because they are very active in the boat and will swim down strongly when released at the surface. Thus, as indicated above, the majority of pink snapper released in depths greater than 80 metres were done so by the simple method.

Table 4.9. Number of fish recorded by each release method.

Release method	Dhufish	Pink snapper	Breaksea cod	Baldchin groper	Total
Not recorded (neither simple, vented, or shotline)	22	94	5	4	125
Simple	515	926	118	22	1581
Simple and vented	50	13	17	5	85
Vented	189	83	36	7	315
Simple and shotline	2	0	0	0	2
Shotline	403	62	145	30	640
Vented and shotline	25	3	2	3	33
Total	1206	1181	323	71	2781

The condition of the fish indicated by the number of barotraumas that were recorded by the taggers appeared to affect the method of release chosen by the tagger (Table 4.10). Less than 5% of fish recorded with one, two or three barotrauma symptoms were released by venting (Table 4.10). Simple and shotline release were used in preference to venting when fish had one barotrauma symptom. However the proportion of shotline releases increased with increasing numbers of barotraumas symptoms (Table 4.10).

Table 4.10. The total number of fish released by release method exhibiting one or more barotraumas, categorised by the number of barotrauma symptoms recorded.

Number of fish	Release method			
	No information	Simple	Vented	Shotline
No barotrauma or none recorded	125	1321	287	339
1 barotrauma symptom		233	20	191
2 barotrauma symptoms		25	7	90
3 barotrauma symptoms		2	1	15
4 barotrauma symptoms		0	0	5

Days at liberty and recapture rates by release methods

The general pattern of highest number of recaptures during the first 100 days after release was consistent for all species irrespective of sample size, but most prominent in snapper (Figure 4.16). Although most snapper were recaptured within 200 days, one snapper was recaptured after nearly 7 years, almost two years longer than any other tagged fish (Figure 4.16). While most dhufish were recaptured within the first year, some were recaptured up to three years after tagging, and occasional recaptures occurred up to nearly 6 years after tagging (Figure 4.16). The pattern of days at liberty for breaksea cod is less clear due to the small number recaptured but there appear to be some similarities with the pattern revealed for dhufish (Figure 4.16).

There is no obvious influence of release methods used by the taggers on days at liberty because the proportion of recaptures from the three release methods does not appear to vary consistently with time at liberty (Figure 4.16). As expected the ‘not reported’ category of release methods is more common as the number of days at liberty increases because although tagging commenced in 1996 (Table 4.1) release methods (which include not reported) were only reported after 2000 (Figure 4.16).

Rates of recapture varied among species and release methods (Figure 4.17). For dhufish the shotline release method improved recapture rates, while recapture rates of vented fish were lowest (Figure 4.17) This pattern was not evident for breaksea cod and snapper (Figure 4.17).

Effects of depth

As the short-term caging experiments found that the depth of capture was the most important factor affecting the survival of caged dhufish and snapper (see Chapter 2), the influence of depth of capture of tagged fish was examined separately.

The majority of fish were recorded to have only one or two barotrauma symptoms. In dhufish the proportion of fish with three or more barotraumas increased with depth (Figure 4.18a). For snapper, however, there was no pattern of increasing barotraumas symptoms with depth (Figure 4.18b), despite adequate sample sizes from deeper water (Figure 4.19). Breaksea cod showed a depth related pattern of decreasing single barotrauma symptoms and increasing two barotraumas with depth (Figure 4.18c).

Rates of recaptures varied with depth (Figure 4.19a-c). For dhufish there was a gradual reduction in percent recaptured (observed) at depths > 30 m (Figure 4.19a). Recapture rates (observed) of tagged snapper also showed a trend of decreasing recaptures at depths > 30 m (Figure 4.19b). The pattern for breaksea cod was less clear due to the low number of recaptures; recaptures fell at > 20 m depth, except for the fish caught by charter boats at these greater depths (Figure 4.19c).

Recapture data was modelled using a linear regression model with a logistic link using capture depth as an explanatory variable with dummy variables for release method and species. The model found significant effect of depth for snapper (P = 0.008,Table 4.11) and dhufish (P = 0.021, Table 4.11 (Figure 4.19a, b). For dhufish, recapture rates of those subject to simple release and venting were combined because they did not differ significantly from each other (t = -0.63, P = 0.545), due to the low sample sizes (n = 7, Table 4.12) for vented dhufish. These two release methods significantly differed from the shotline release methods (P = 0.0375, one-sided t-test). The effect of depth on snapper recapture rate however was less than that for dhufish (B [slope] = -0.319 compared with B [slope] = -0.194, Table 4.11, Fitted rates, Figure 4.19 a & b), although the difference was not statistically significant (P = 0.17). Thus the major statistical conclusion from the tagging study is that:

The recapture rates of dhufish were affected by depth and the shotline release method;

But recapture rates of snapper were not significantly affected by release method and less affected by depth than dhufish; and

The recapture rates of the simple and venting release methods did not vary significantly for either species.

Table 4.11. Linear regression model with a logistic link for recapture proportion against excess depth using dummy variables for species.

	Coefficients		t	Significance
	B	SE		P
Model – Dhufish				
Constant	-2.227	0.182	-12.207	0.007
Excess Depth	-0.319	0.136	-2.356	0.021
Model – Pink snapper				
Constant	-2.212	0.073	-30.314	7.89E-05
Excess Depth	-0.194	0.039	-4.949	0.008

Further depth related patterns were elucidated when the releases and recaptures from the same depth category were split by the release method used (Table 12, Figure 4.20a-c). The low numbers of fish tagged and recaptured by the least common methods for each species (e.g. venting (n = 7) in dhufish, shotline (n = 5) and venting (n = 7) in snapper, and all methods in breaksea cod (n = 9)) resulted in an absence of recaptures at some depths and biased results at other depths. Therefore while presented; only release methods with higher sample sizes are discussed. Recapture rates of dhufish released using shotline were higher on average than recaptures rates of dhufish released simply despite spanning greater depths (Figure 4.20a). In contrast, recapture rates were relatively similar across depth for snapper released simply (Figure 4.20b).

When the two release methods, simple and venting, for dhufish were combined and compared to the shotline, recapture rates of shotline were more than for the non-shotline release methods at both < 40 and > 40 m (Figure 4.21). As expected, recapture rates were higher in the shallower depths for both methods.

Table 4.12. The number of dhufish, snapper and breaksea cod released and recaptured by the three methods, simple, vented and shotline by depth of initial capture; where tagged and recaptured within the same depth category.

		Depth (m)	No depth info	0-19	20-39	40-59	60-79	80-99	100-119	120-139	Total
Dhufish	Simple	Tagged	6	21	229	202	32	8	17		515
	only	Recaptured	0	2	24	11	2	0	0		39
	Vented	Tagged	3	0	37	121	26	2	0		189
	only	Recaptured	0	0	2	5	0	0	0		7
	Shotline	Tagged	3	1	157	197	17	25	3		403
	only	Recaptured	0	0	23	14	1	4	0		42
Pink snapper	Simple	Tagged	5	121	230	237	51	115	164	3	926
	only	Recaptured	2	11	22	20	6	10	5	0	76
	Vented	Tagged	0	52	3	23	2	2	1		83
	only	Recaptured	0	7	0	0	0	0	0		7
	Shotline	Tagged	0	1	24	12	1	7	17		62
	only	Recaptured	0	0	5	0	0	0	0		5
Breaksea cod	Simple	Tagged	2	13	62	24	1	11	5		118
	only	Recaptured	0	2	2	0	0	0	0		4
	Vented	Tagged	1	0	4	18	12	1			36
	only	Recaptured	0	0	0	0	0	0			0
	Shotline	Tagged	0	4	49	46	7	28	11		145
	only	Recaptured	0	1	0	0	0	2	2		5

Movement of individuals

Movement of individual dhufish and snapper were mapped when specific locations or latitude and longitude co-ordinates were provided by both the anglers who tagged and recaptured the fish.

As most tagged dhufish (93%) were recaptured near (< 5 nm) their point of capture, and only 2 fish (1.5%) moved more than 30 nm, this study suggests that dhufish are a sedentary species (Table 4.13a, Figures 4.22 and 4.23). Patterns of movement appeared to be mostly cross shelf in dhufish.

75% of tagged snapper were recaptured near their point of capture, and only 2 fish (6%) moved more than 30 nm (Table 4.13 b, Figure 4.24). Snapper exhibited both longshore and cross shelf patterns of movement. Although there was considerable movement within the Metropolitan Zone where most of the fish were tagged, there was only one recorded movement outside that zone (Figure 4.25).

Table 4.13 **a.** Distance of movement of recaptured dhufish in the tagging programme.

Movement	Undersize	Legal	Unknown	Total
Large (> 30 nm)	2	0	0	2
Moderate (5 to 30 nm)	8	0	0	8
Slight (< 5 nm)	4	0	0	4
Same Area	102	11	4	117
Unknown	24	0	0	24
Total	140	11	4	155

Table 4.13 **b.** Distance of movement of recaptured snapper in the tagging programme in the West Coast Bioregion (excluding Shark Bay).

Movement	Undersize	Legal	Unknown	Total
Large (> 30 nm)	1	1		2
Moderate (5 to 30 nm)	11	6		17
Slight (< 5 nm)	11	0	1	12
Same Area	9	2	1	12
Unknown	51	6	26	83
Total	83	15	28	126

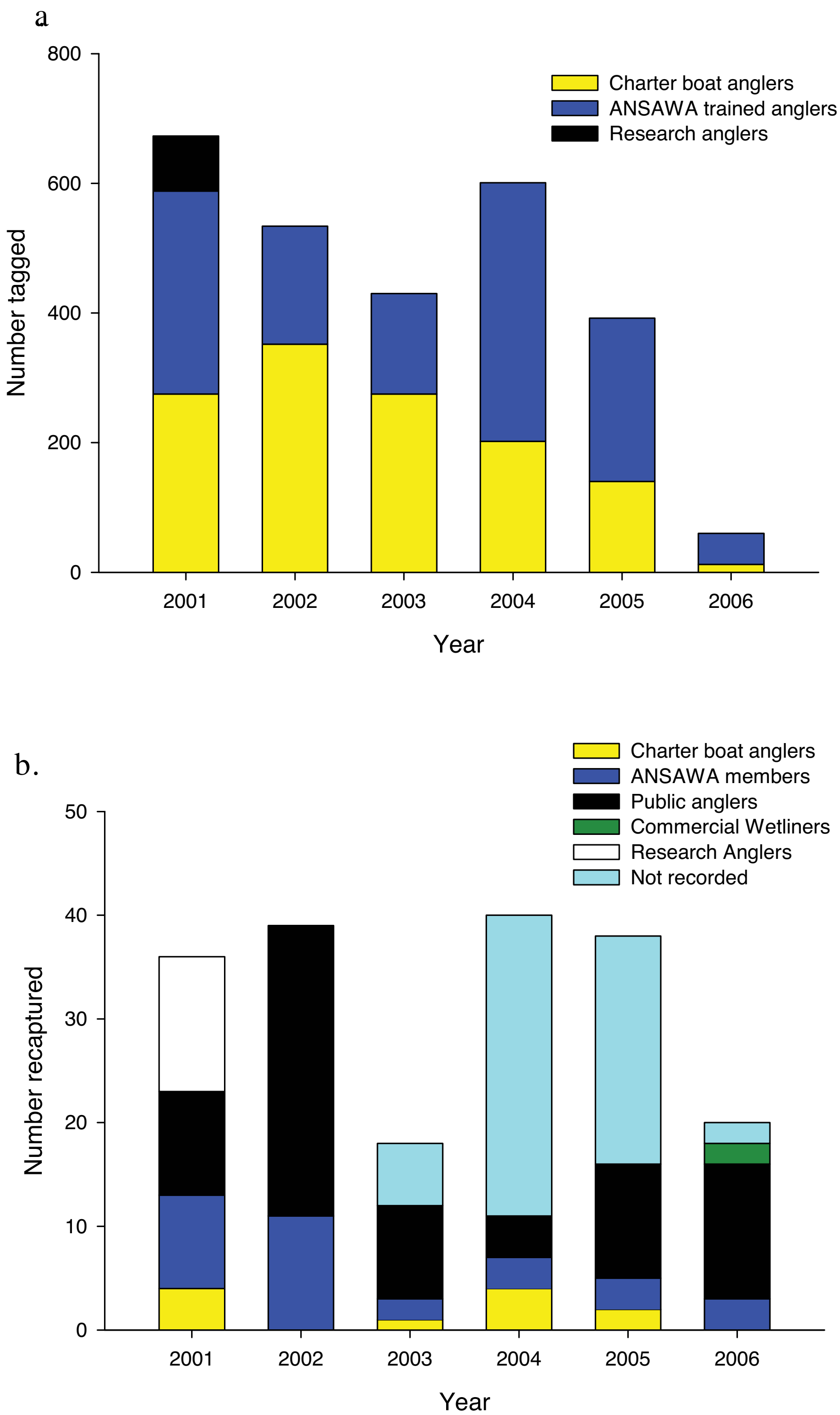


Figure 4.1. The number of demersal fish species (a) tagged and (b) recaptured during the FRDC tagging project categorised by angler type. Taggers were either charter boat anglers, ANSWA trained anglers or Research anglers whereas recaptures were caught by charter boat anglers, ANSWA members, public anglers, commercial wetliners, research anglers or not recorded.

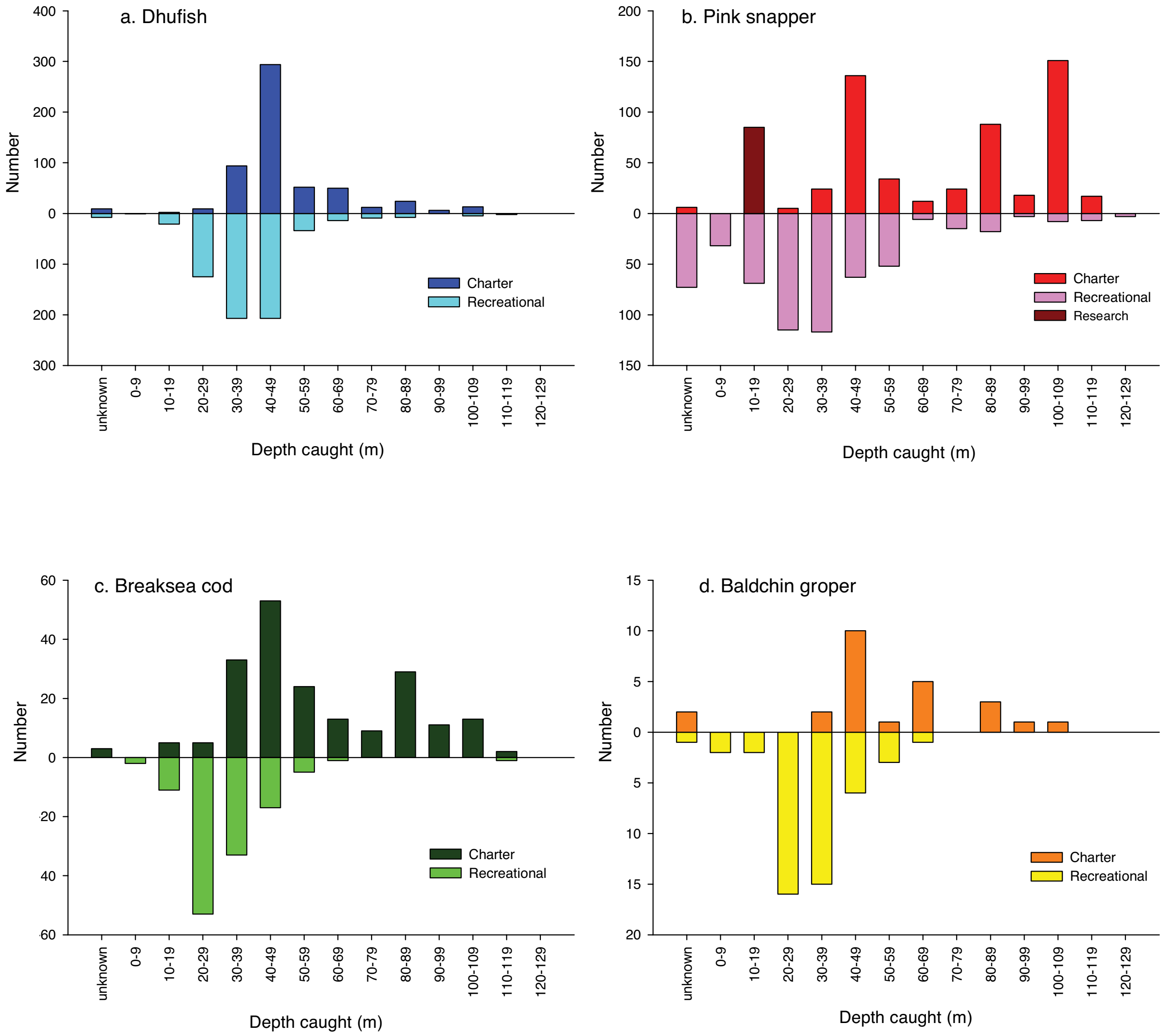


Figure 4.2. The depth of (a) dhufish (n = 1206), (b) snapper (n = 1181), (c) breaksea cod (n = 323) and (d) baldchin groper (n = 71) caught and tagged by charter and recreational anglers between 2001 and 2006.

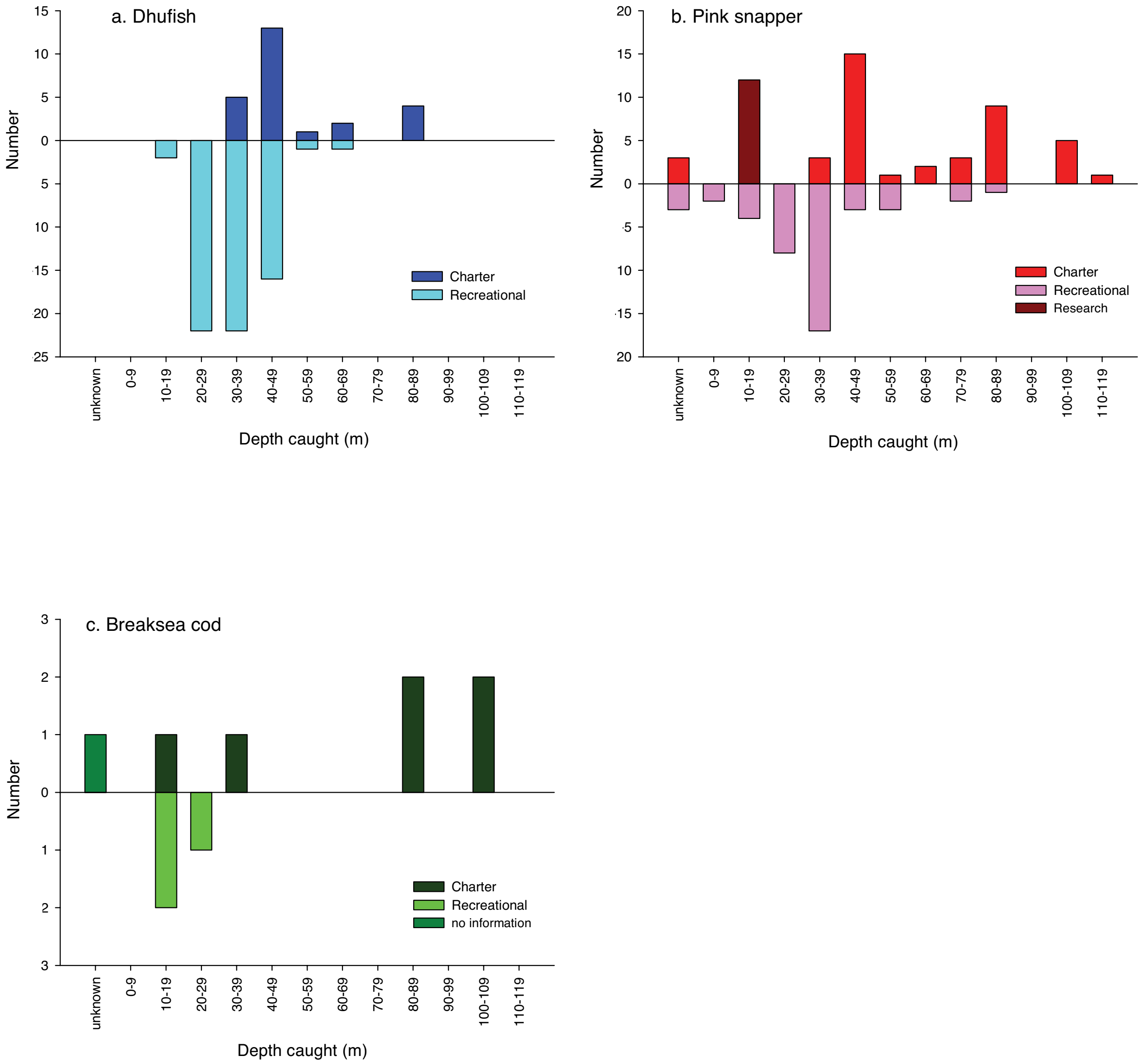


Figure 4.3. The depth of tagged (a) dhufish (n = 89), (b) snapper (n = 96) and (c) breaksea cod (n = 10) recaptured by charter and recreational anglers.

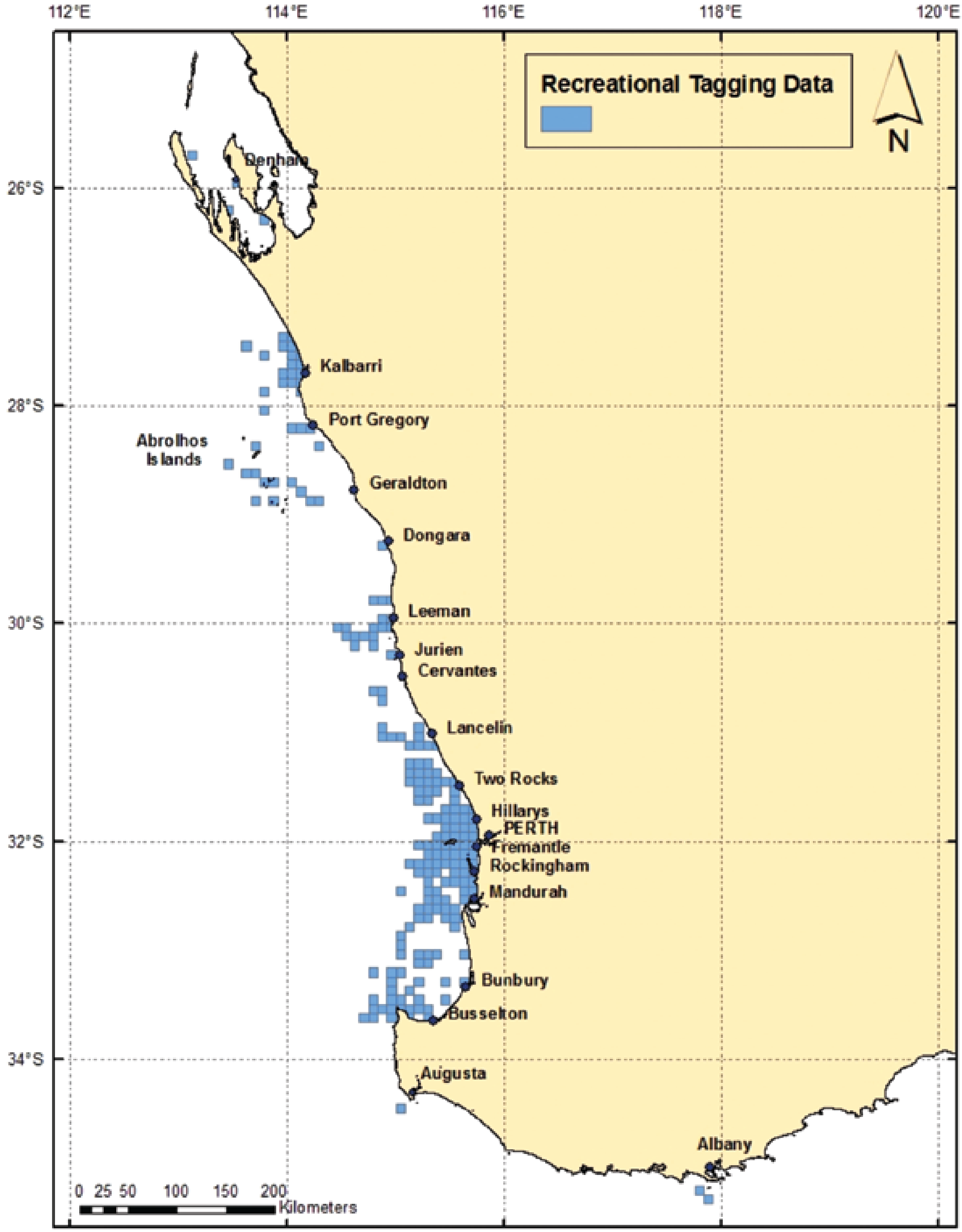


Figure 4.4. Location of all species of fish tagged or recaptured by all recreational fishers including ANSA WA members throughout the tagging programme.

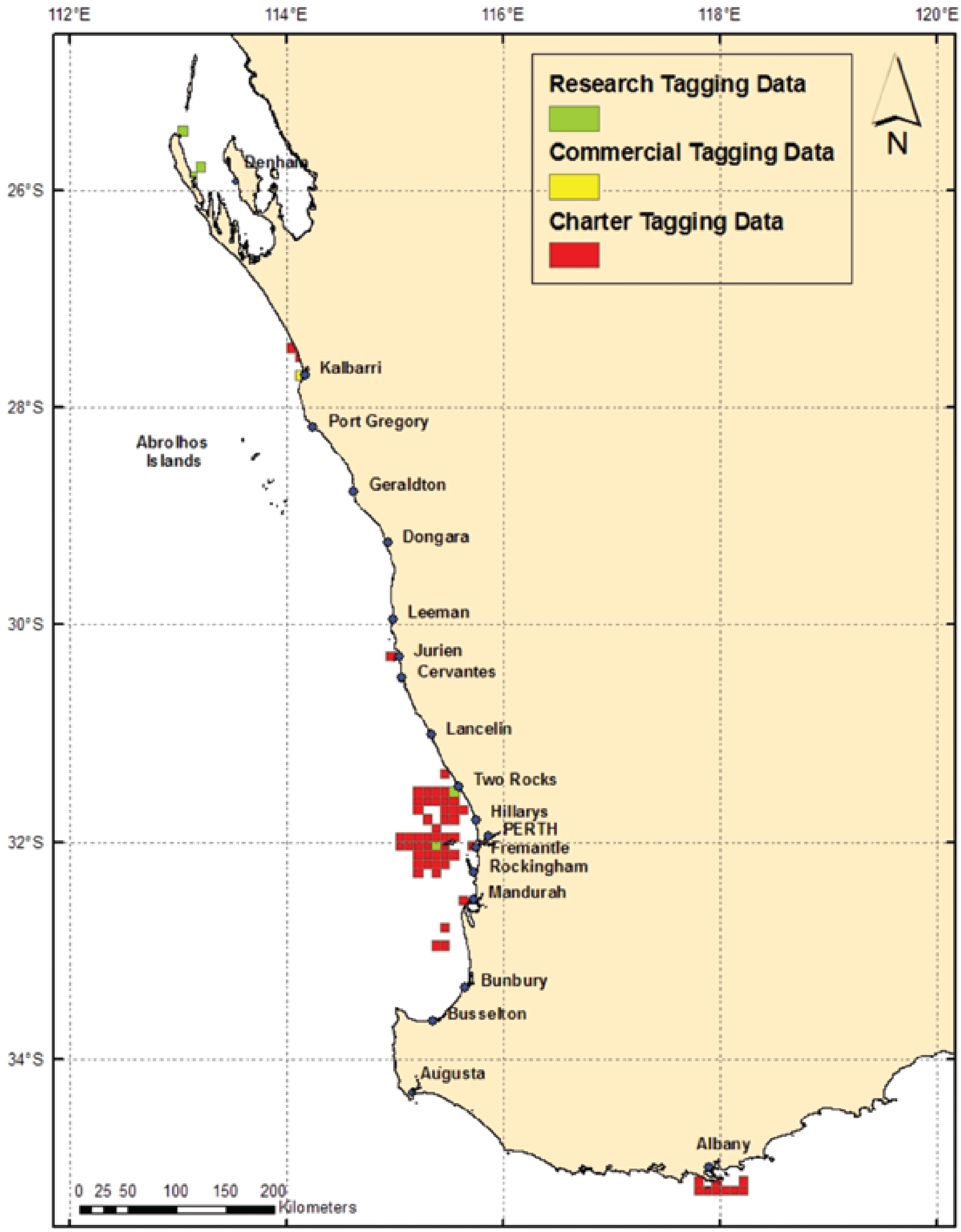


Figure 4.5. Location of all species of fish tagged or recaptured by charter boat anglers, research anglers and commercial fishers throughout the tagging programme.

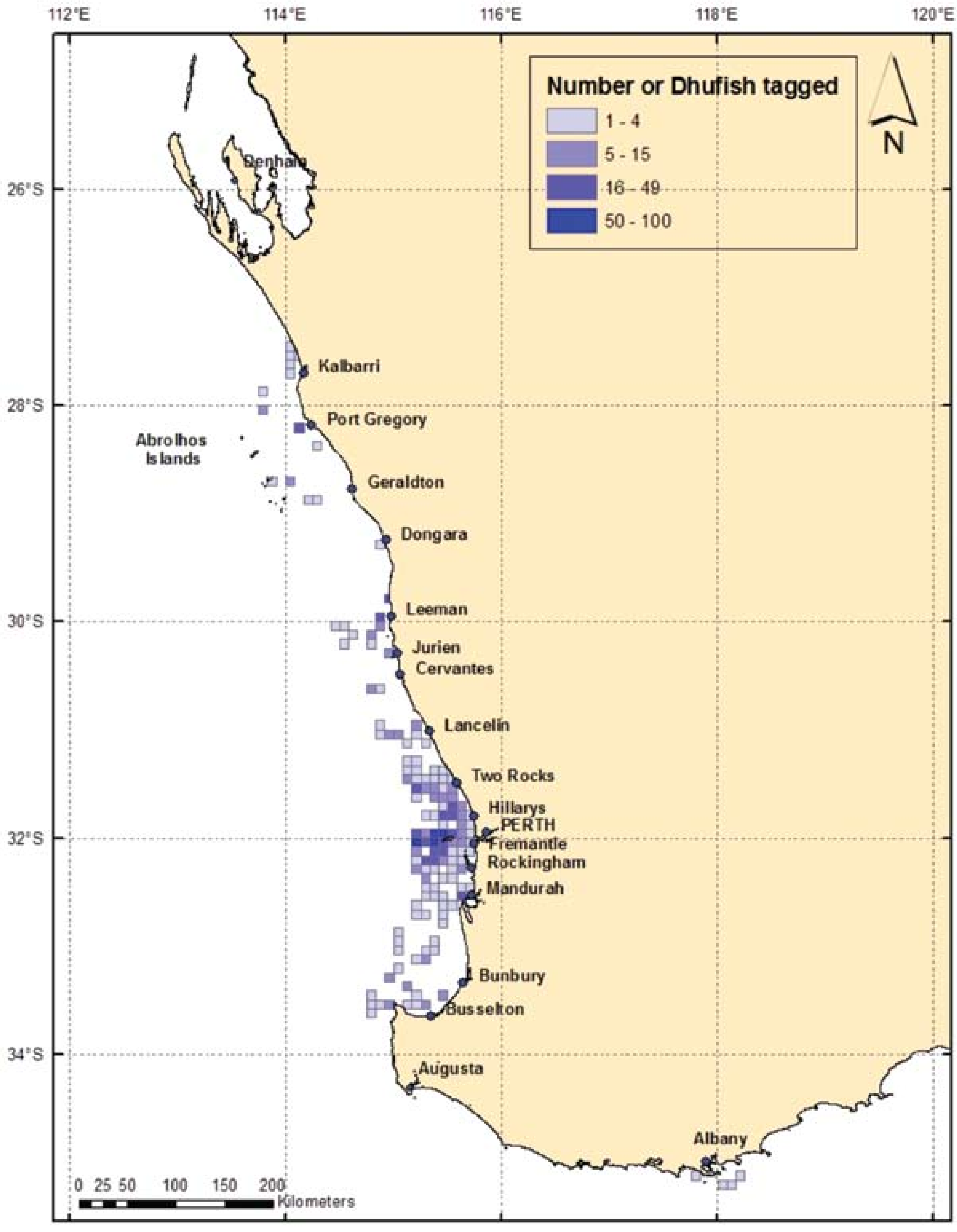


Figure 4.6. Location of dhufish caught and tagged throughout the tagging programme.

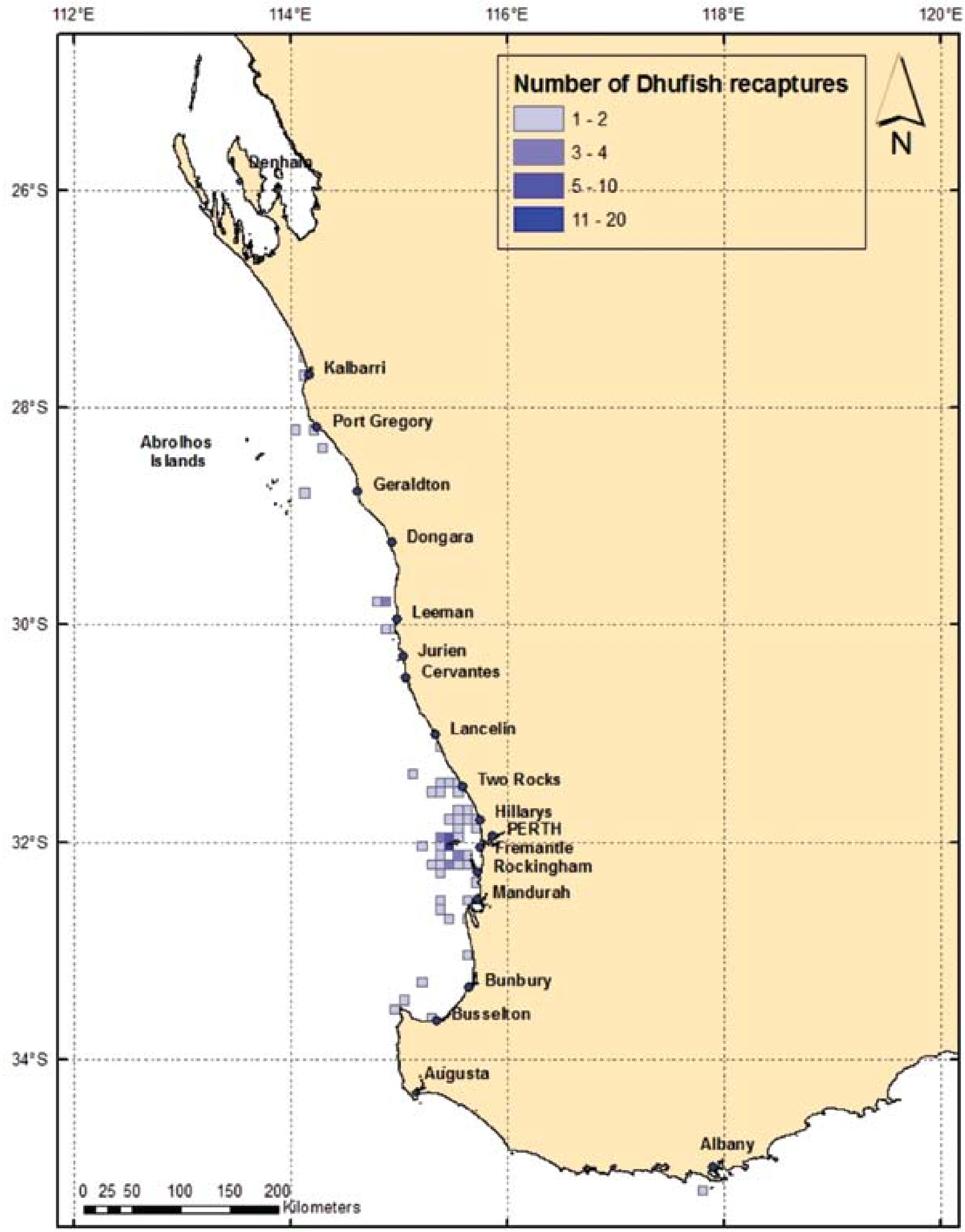


Figure 4.7. Location of dhufish recaptured throughout the tagging programme.

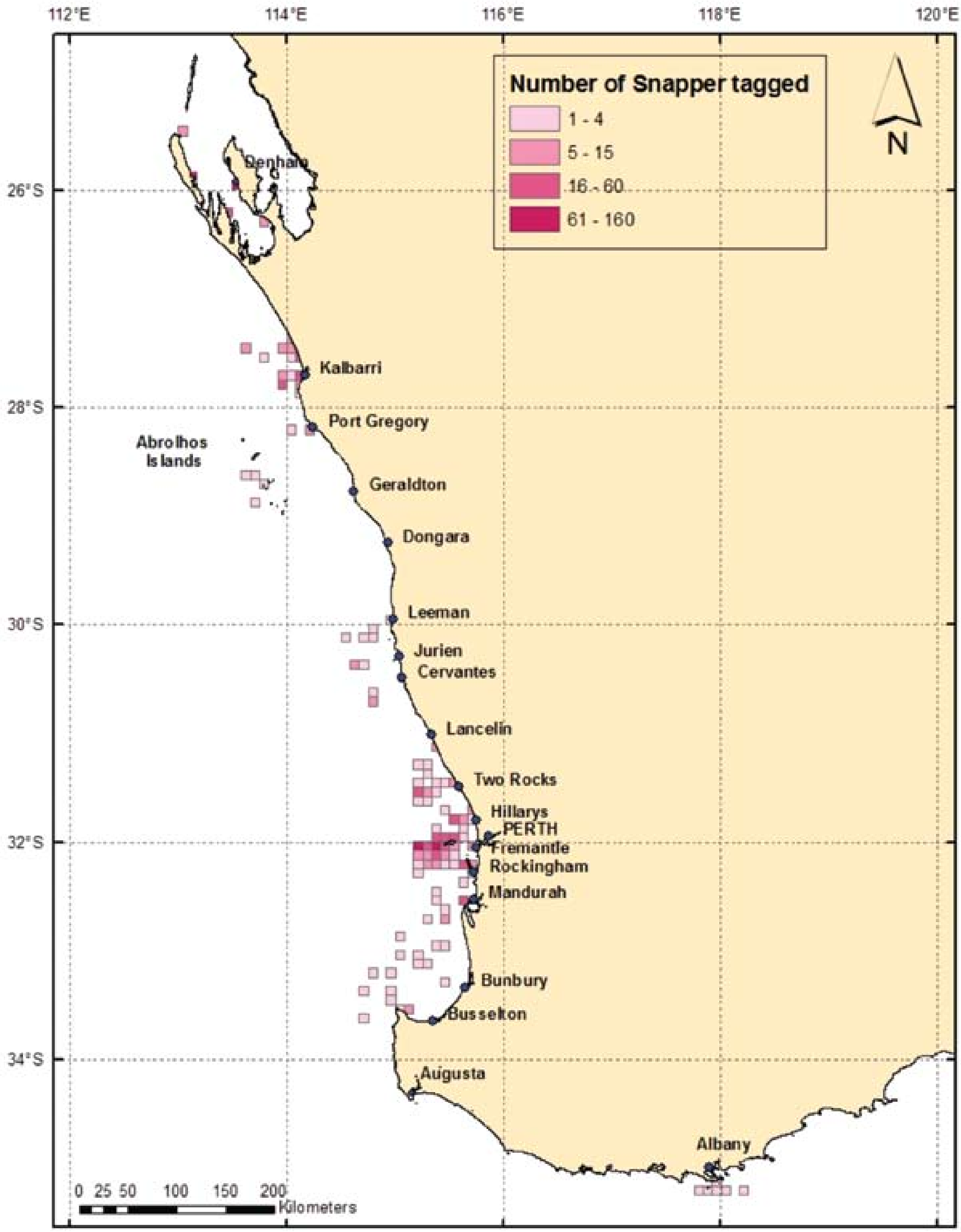


Figure 4.8. Location of snapper caught and tagged throughout the tagging programme.

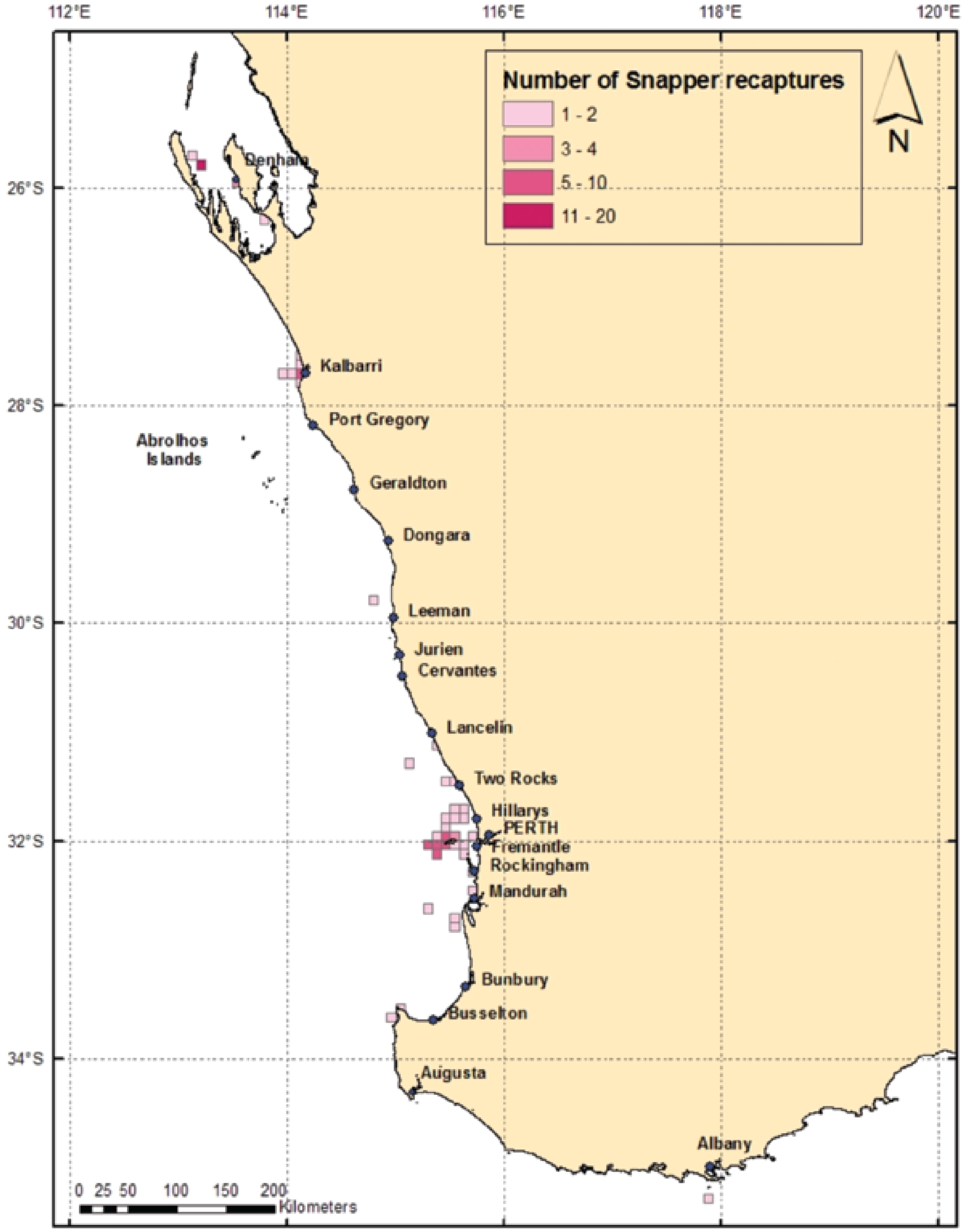


Figure 4.9. Location of recaptured snapper throughout the tagging programme.

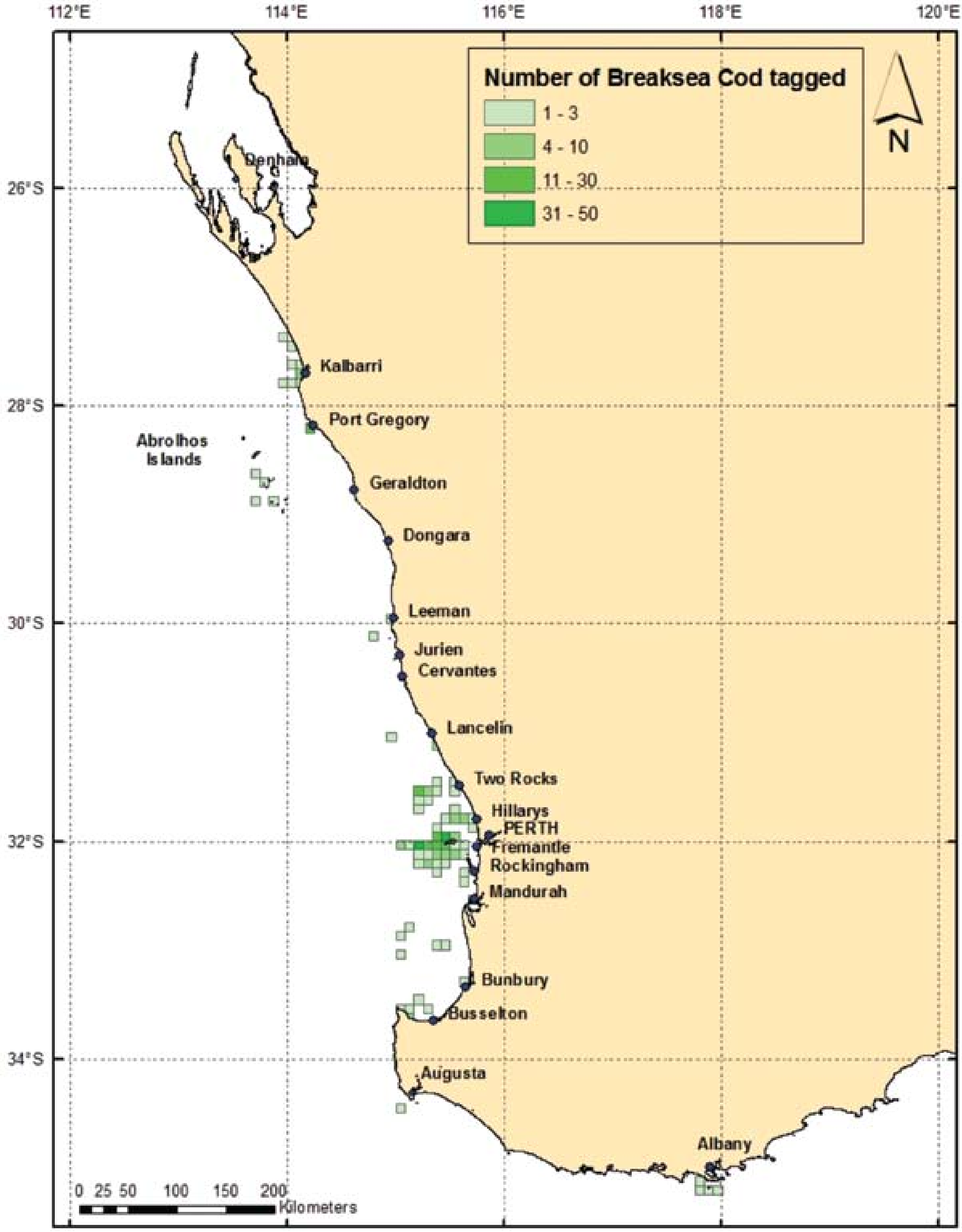


Figure 4.10. Location of breaksea cod caught and tagged throughout the tagging programme.

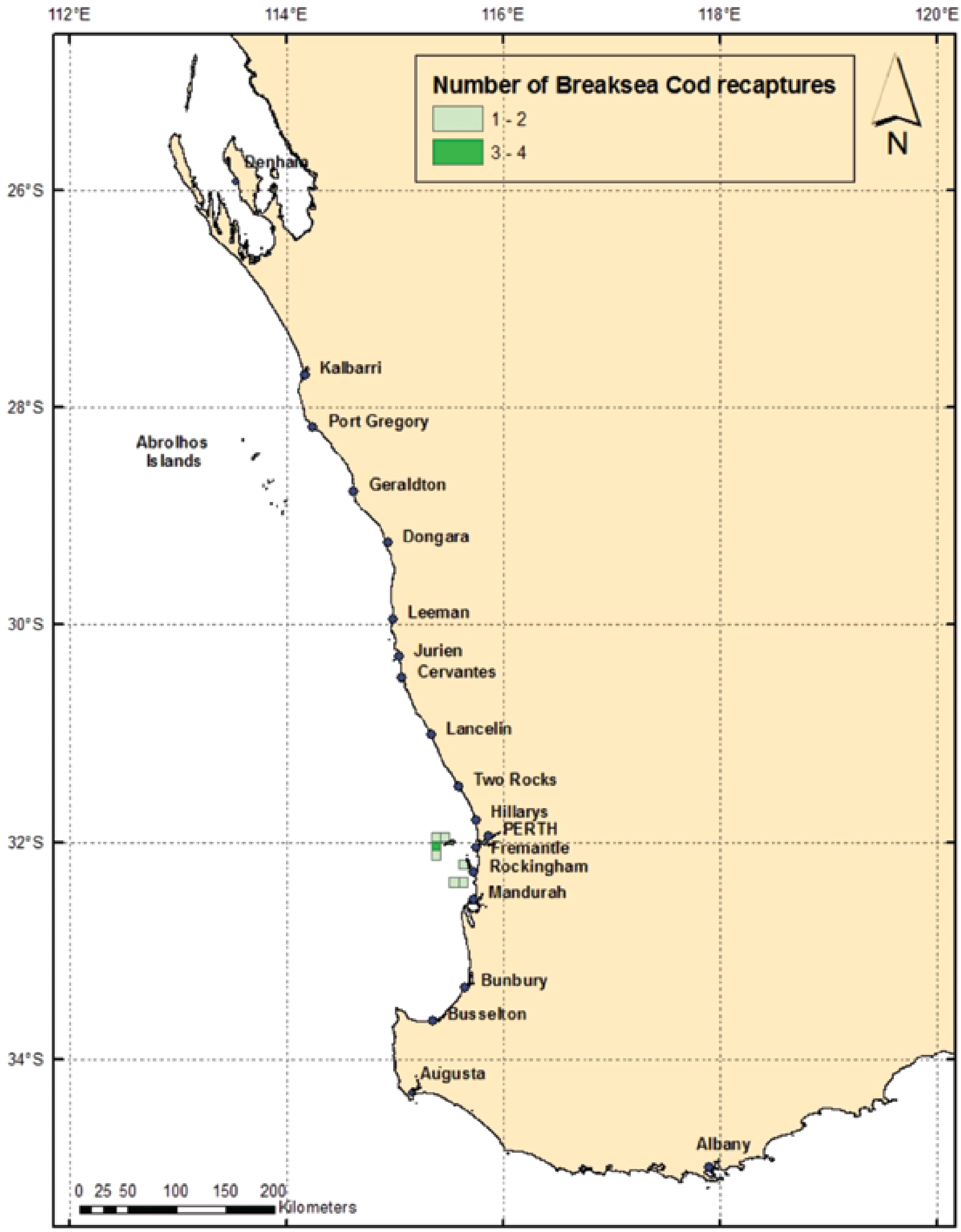


Figure 4.11. Location of breaksea cod recaptured throughout the tagging programme.

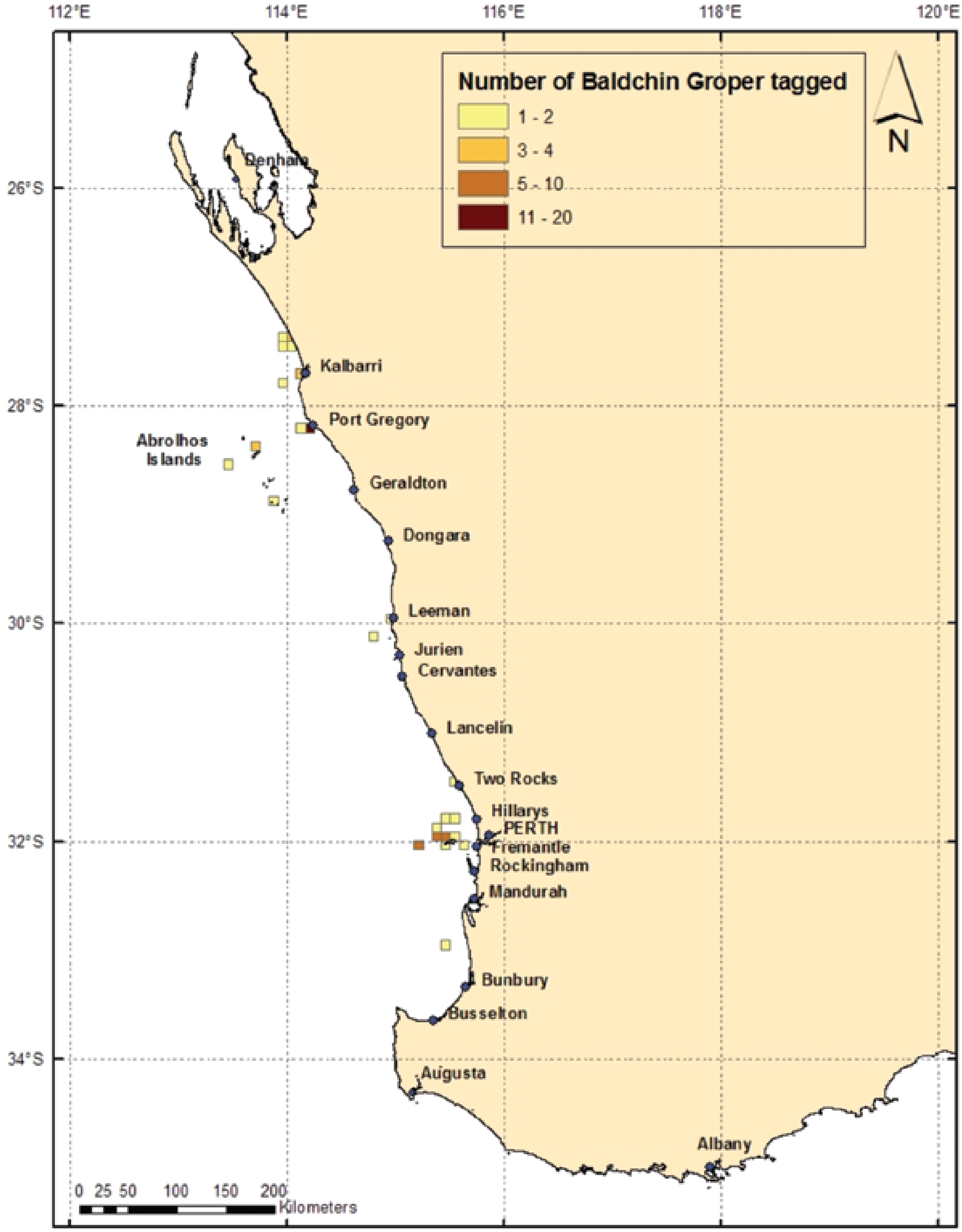


Figure 4.12. Location of baldchin groper caught and tagged throughout the tagging programme.

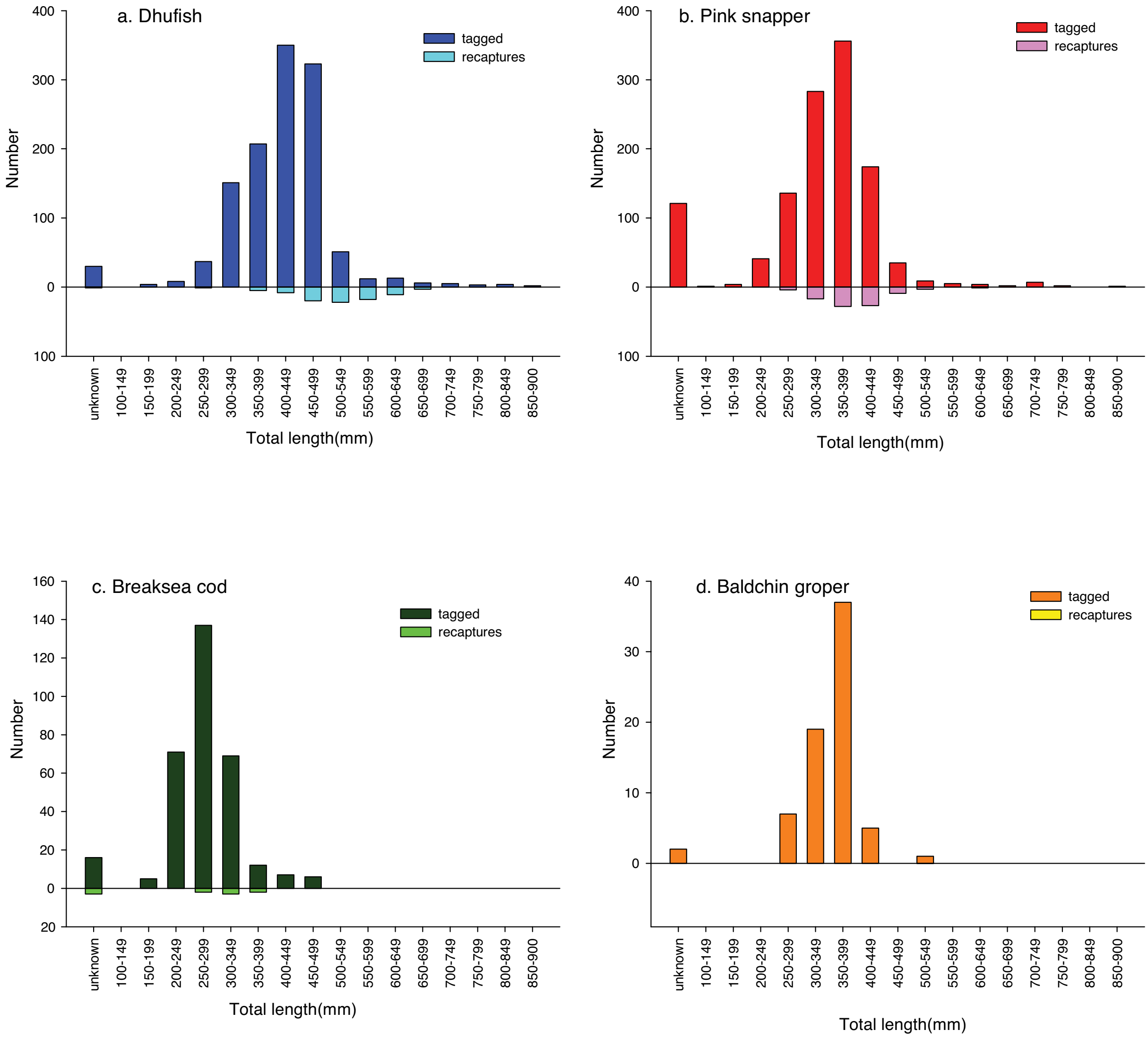


Figure 4.13. The length of (a) dhufish, (b) snapper, (c) breaksea cod and (d) baldchin groper tagged and recaptured.

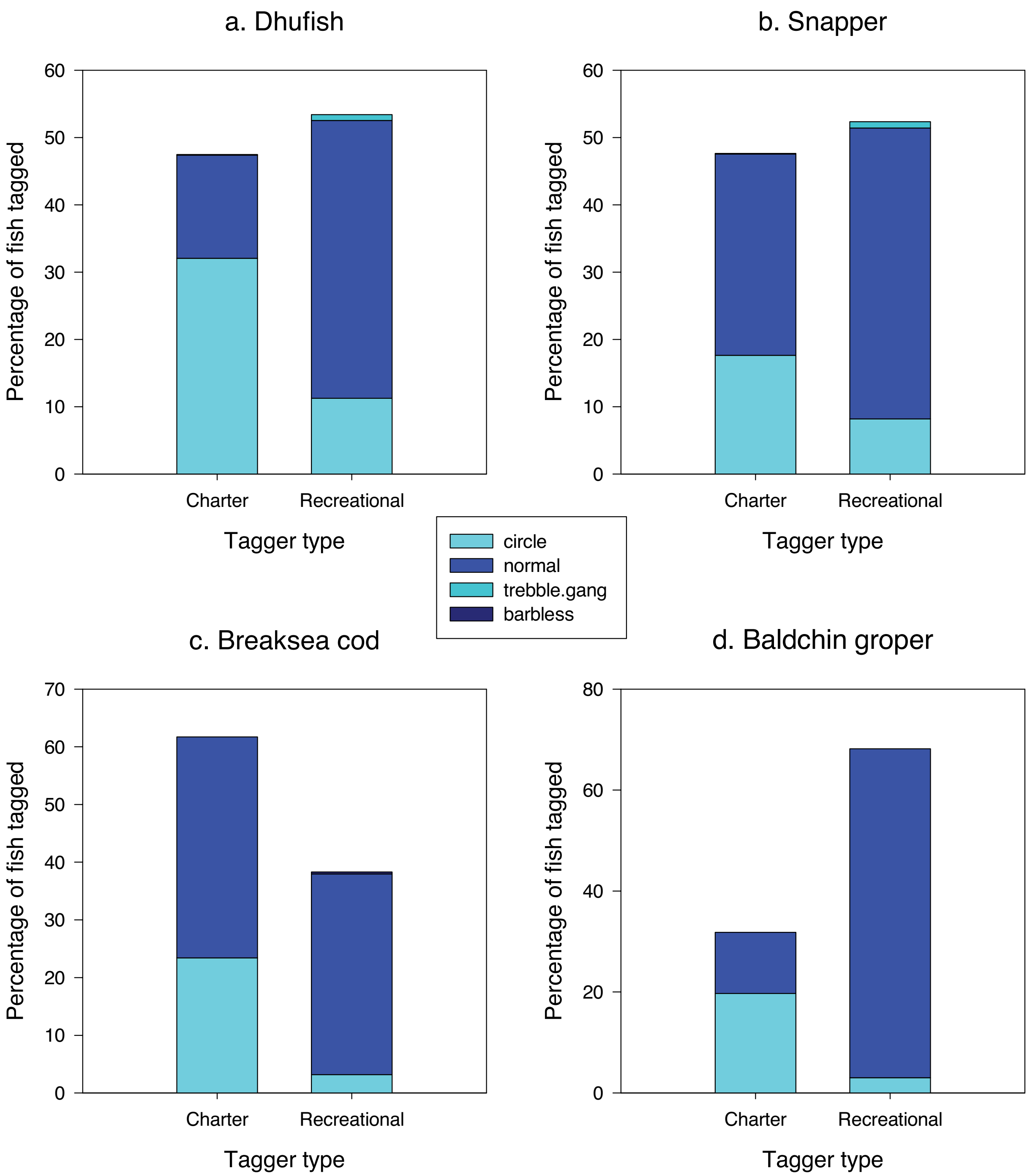


Figure 4.14. The proportion of (a) dhufish, (b) snapper, (c) breaksea cod and (d) baldchin groper caught, tagged and released by angler and hook type.

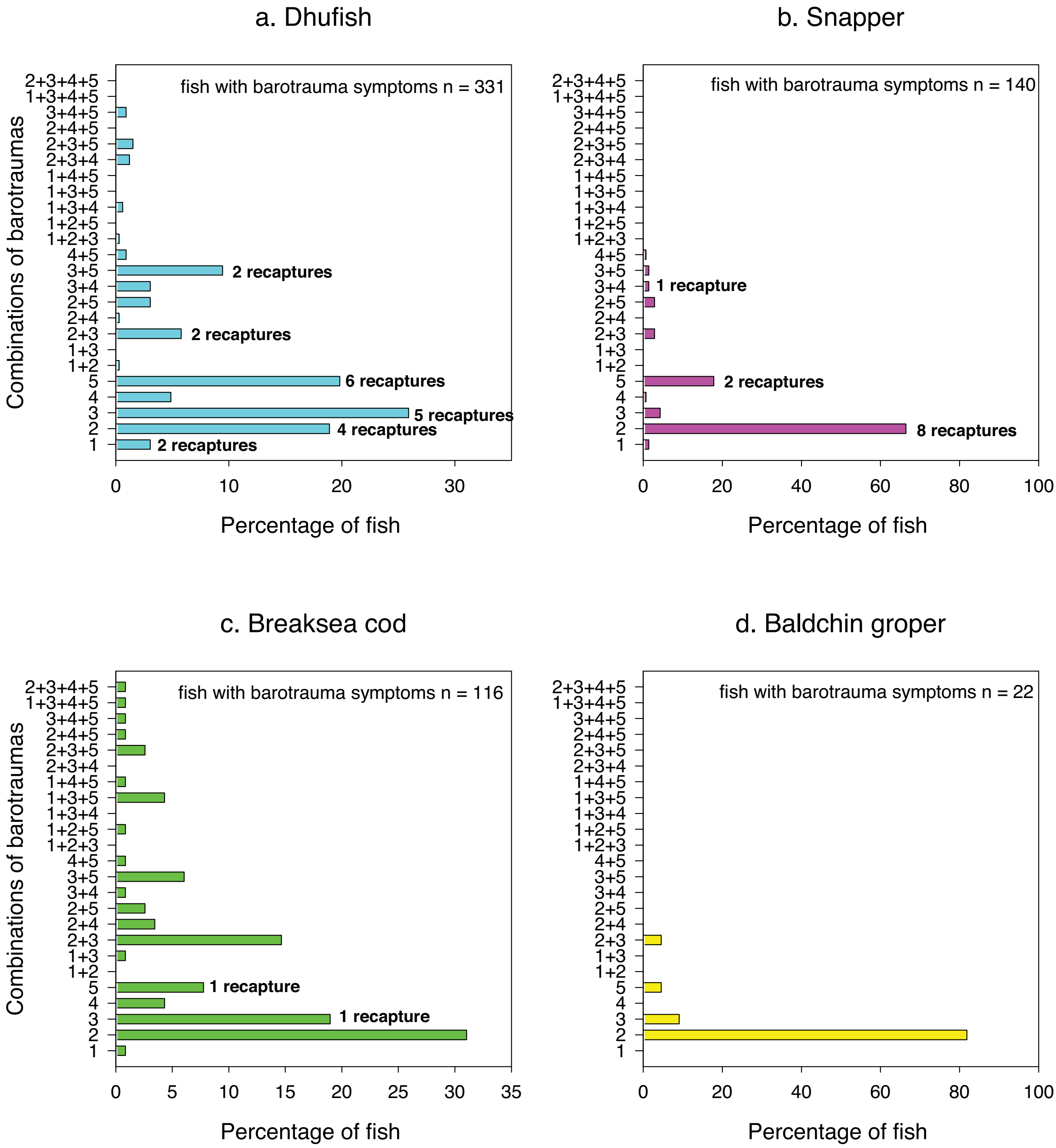


Figure 4.15. The proportion of tagged and released (a) dhufish, (b) snapper, (c) breaksea cod and (d) baldchin groper (d) that were recorded to have at least one barotrauma categorised by the barotraumas recorded. 1 = raised scales, 2 = stomach in mouth, 3 = eyes out of sockets, 4 = bubbles in eyes and 5 = large swim bladder. The number of recaptures are written alongside each group of barotraumas symptoms.

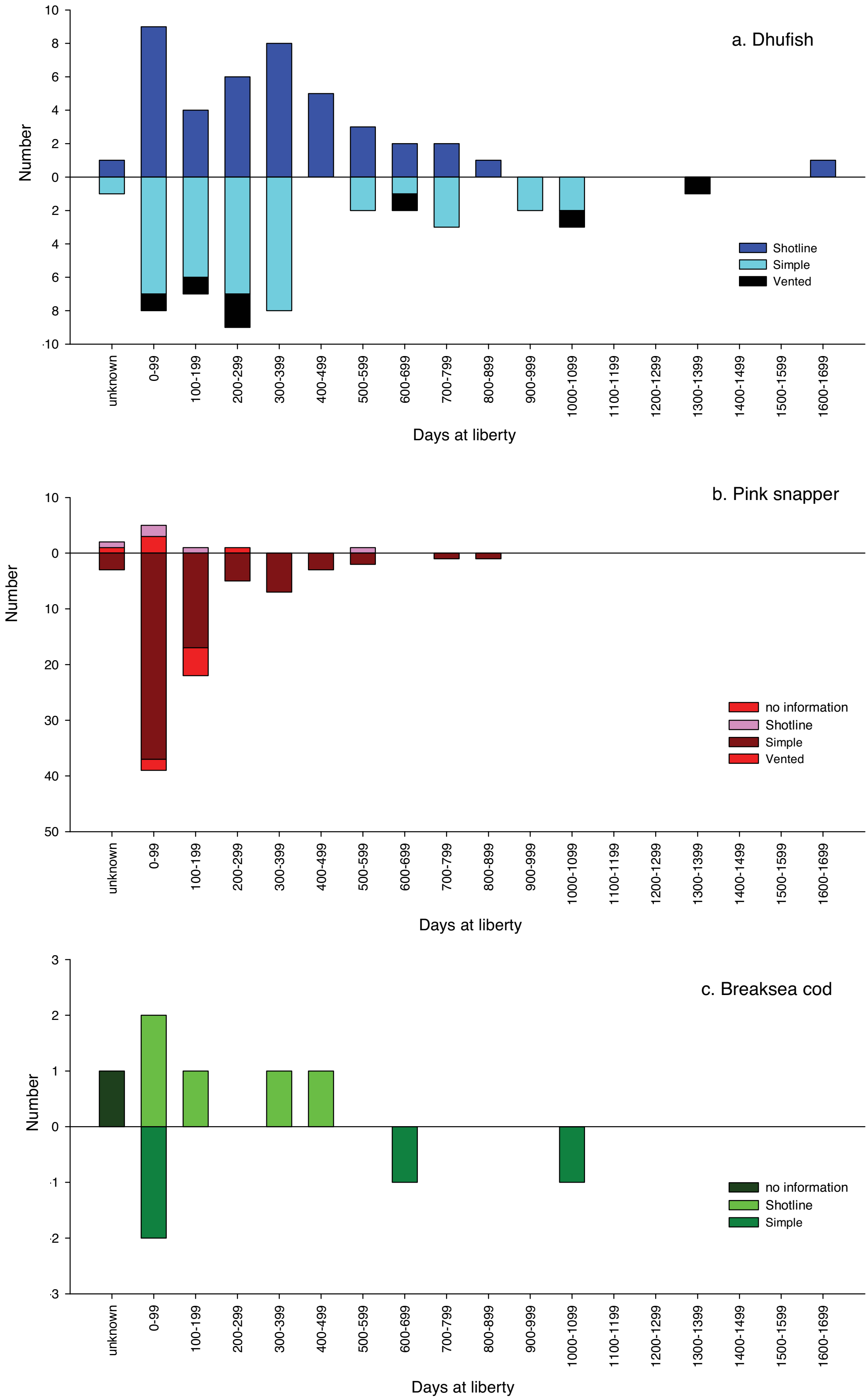


Figure 4.16. Days at liberty for the three demersal species tagged and recaptured during the tagging project; (a) dhufish (n = 89), (b) snapper (n = 96), and (c) breaksea cod (n = 10).

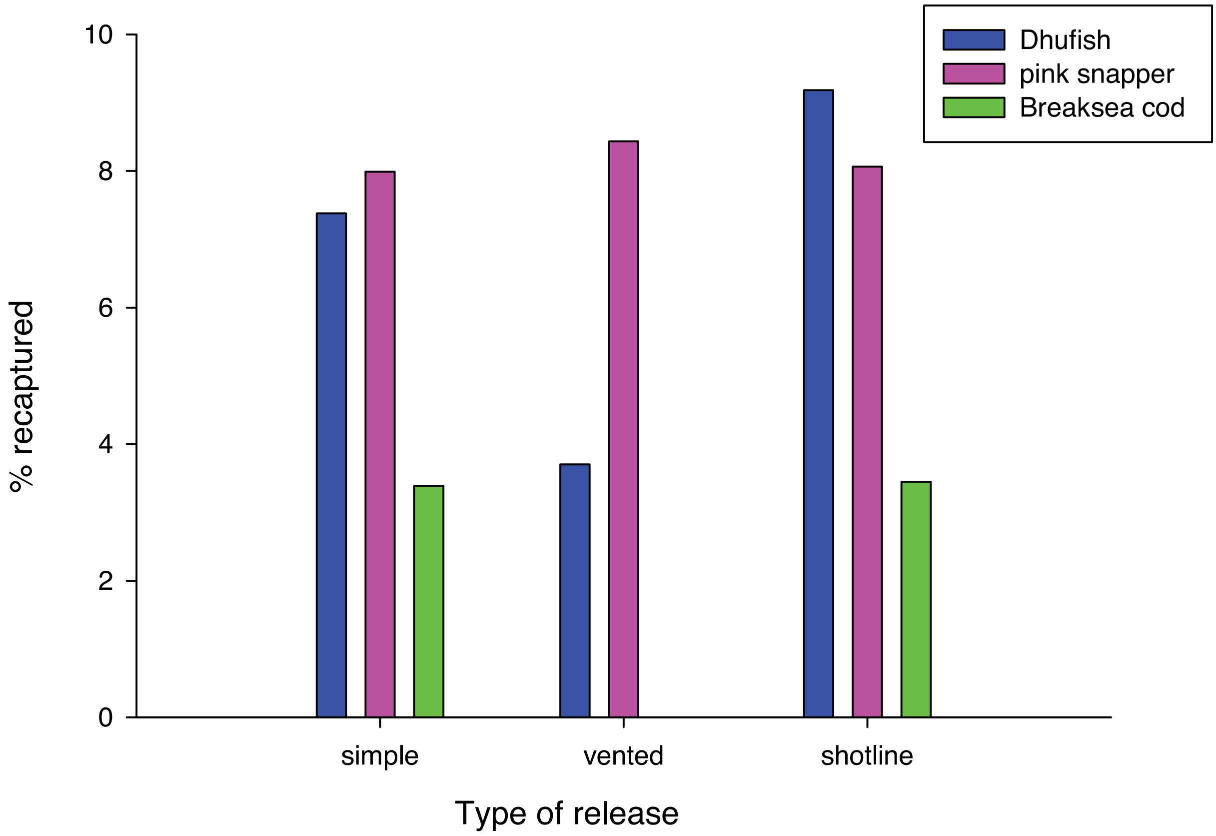


Figure 4.17. Recapture rates of the three methods, simple, vented and shotline for three species, dhufish, snapper and breaksea cod.

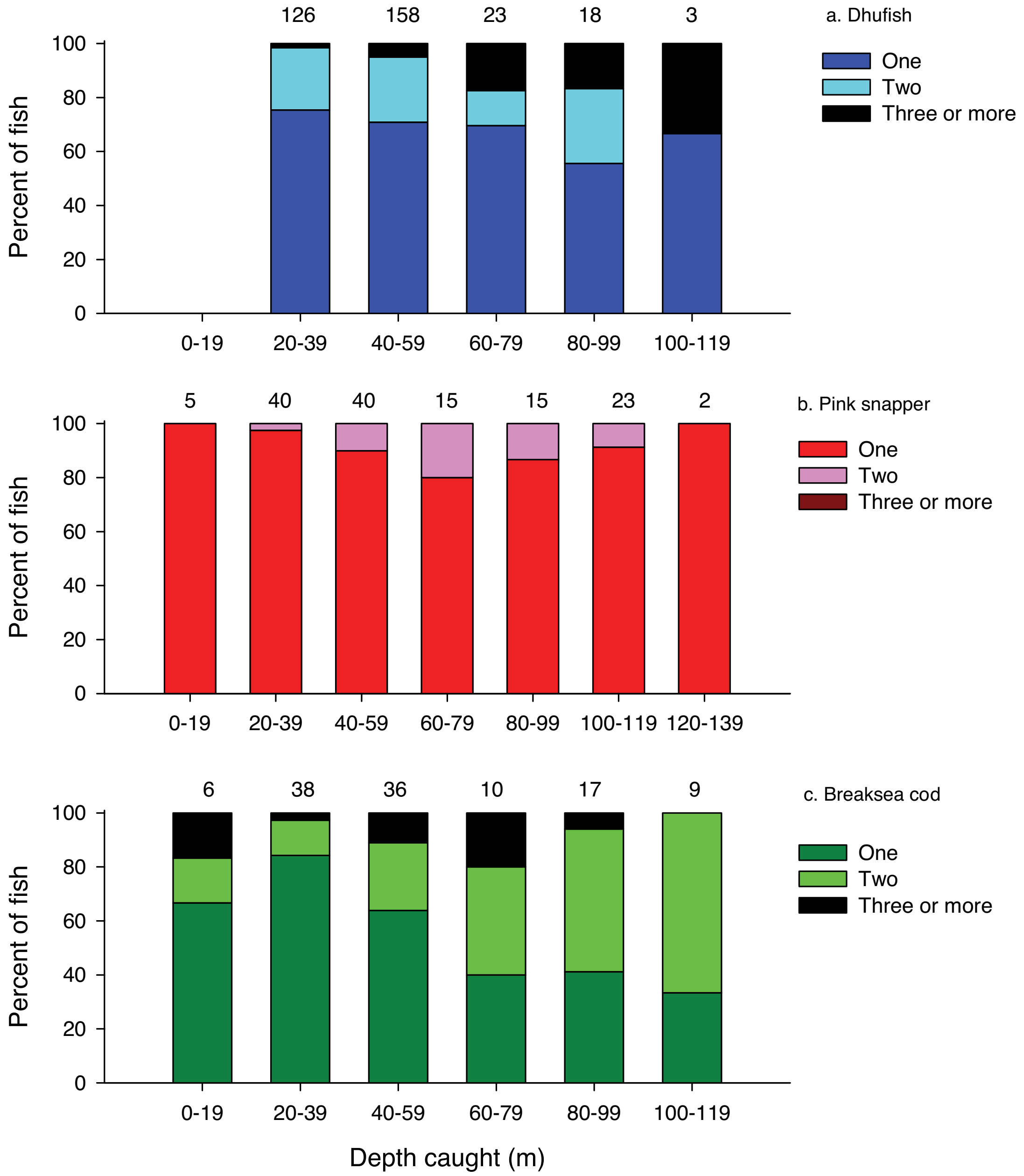


Figure 4.18. The proportion of (a) dhufish (n = 328), (b) snapper (n = 140), and (c) breaksea cod (n = 116) with different numbers of barotrauma symptoms (1, 2 and 3 or more) caught at each depth of capture. Note that unreported barotrauma symptoms including fish that did not have any symptoms are not included.

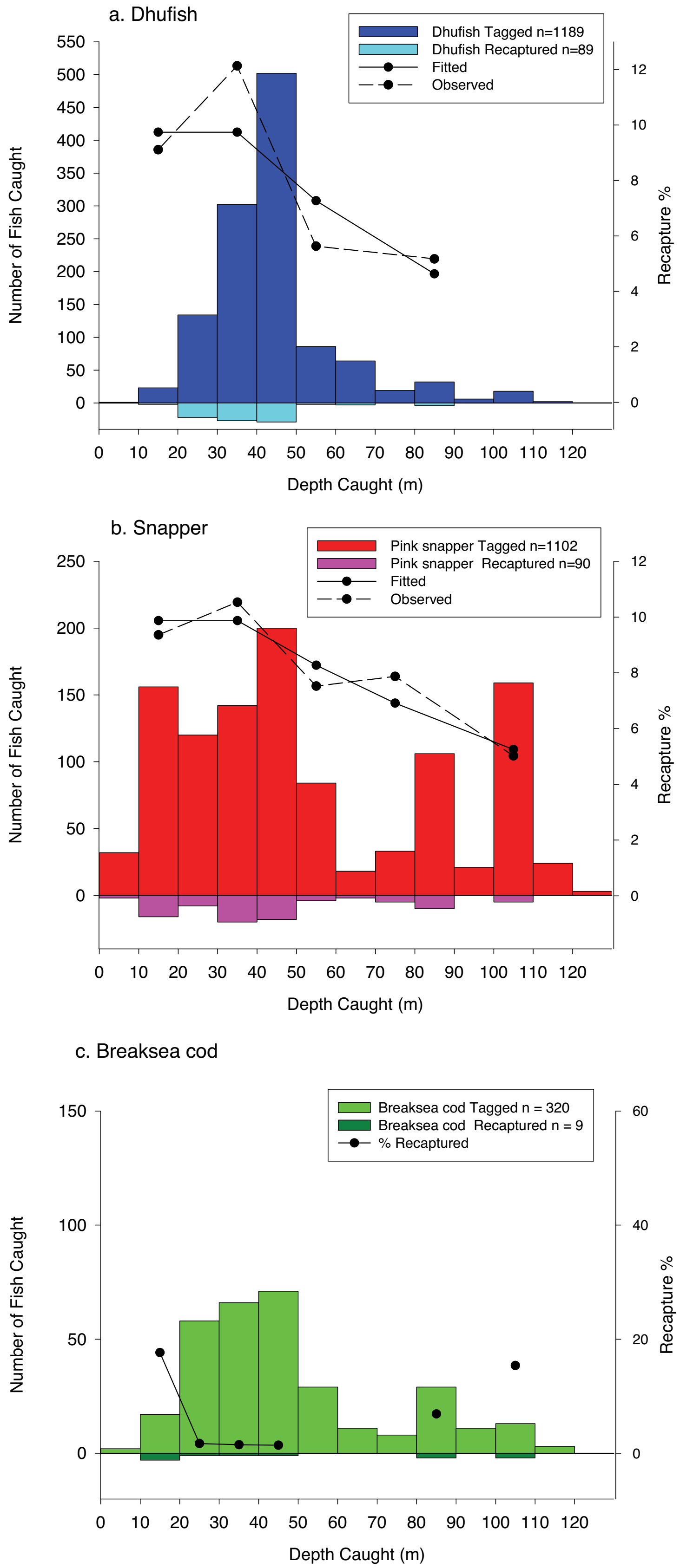


Figure 4.19. Number of (a) dhufish, (b) snapper and (c) breaksea cod tagged and recaptured since 1996 by depth. The % of snapper recaptured by depth for all types of fisher were calculated when more than 50 snapper have been tagged. See the text under Effects of Depth for explanation of the fitted lines for dhufish and snapper.

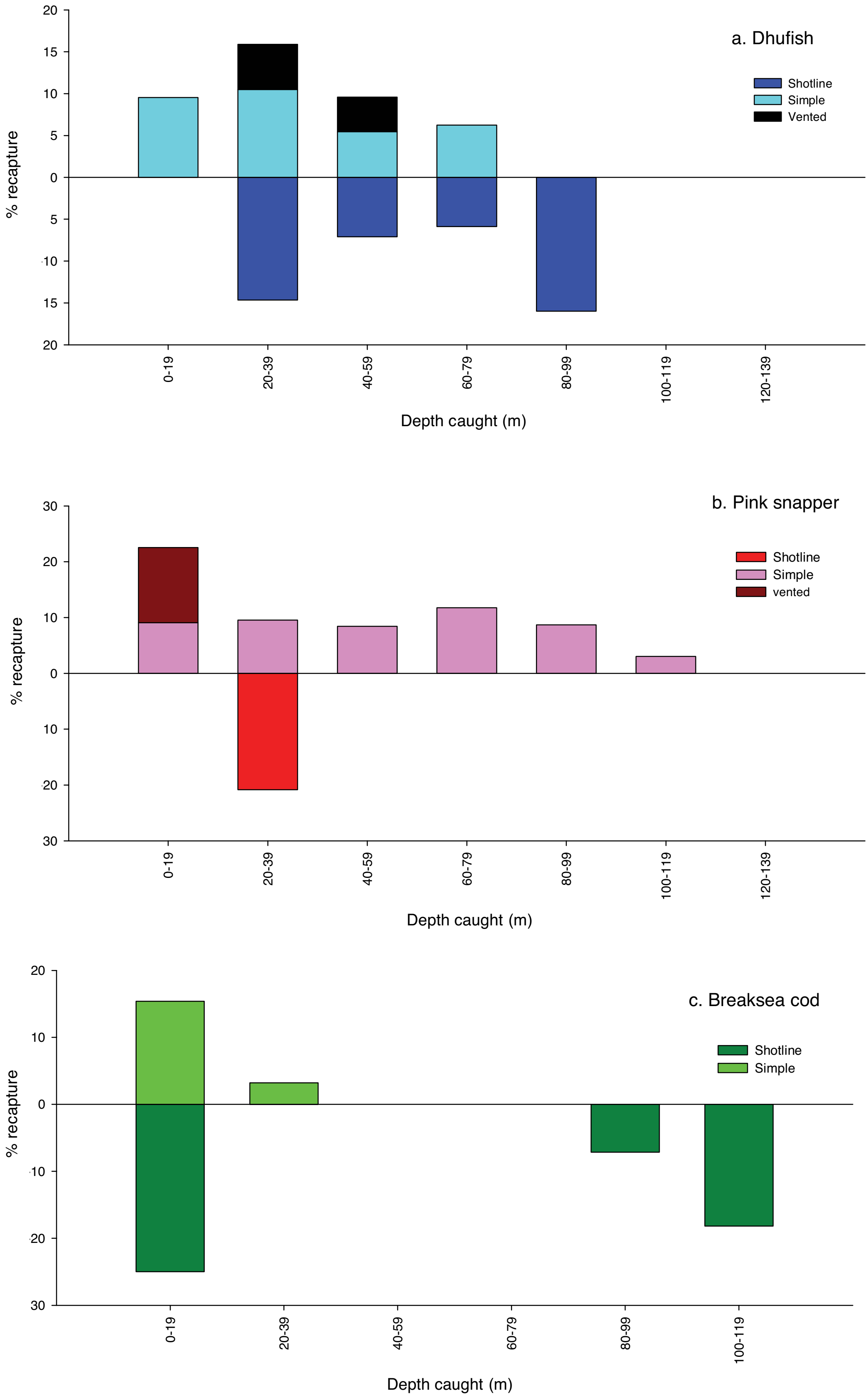


Figure 4.20. Percent recapture of (a) dhufish (b), snapper and (c) breaksea cod released by the three methods, simple, vented and shotline by depth of initial capture; where tagged and recaptured within the same depth category.

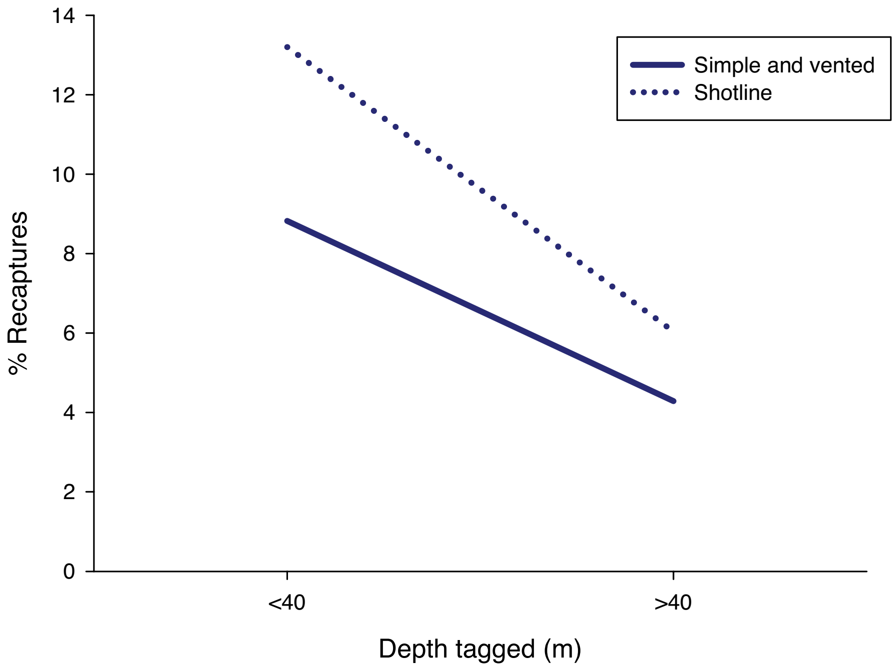


Figure 4.21. The percentage of recaptures of dhufish released using either the shotline release method (n = 40) or non-shotline release methods (simple and vented, n = 48) for two depth categories: < 40 m and > 40 m.

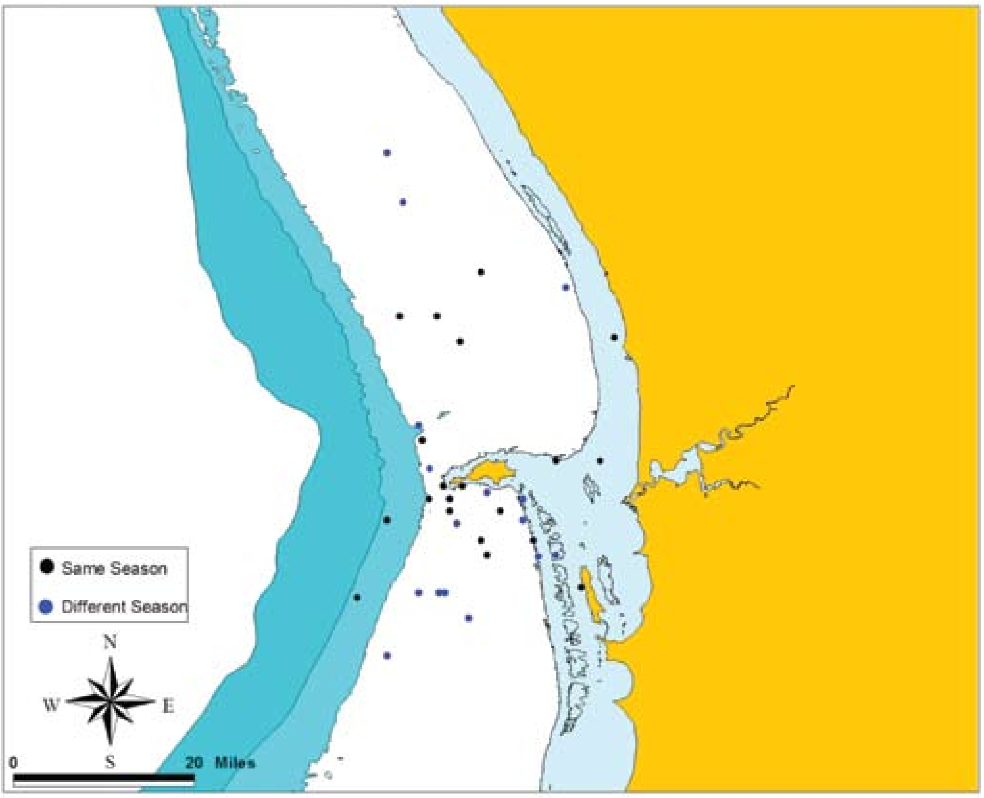


Figure 4.22. Locations where dhufish have been recaptured in those cases where they moved < 5 nautical miles (i.e. release and recapture locations are similar). Each point represents an individual dhufish.

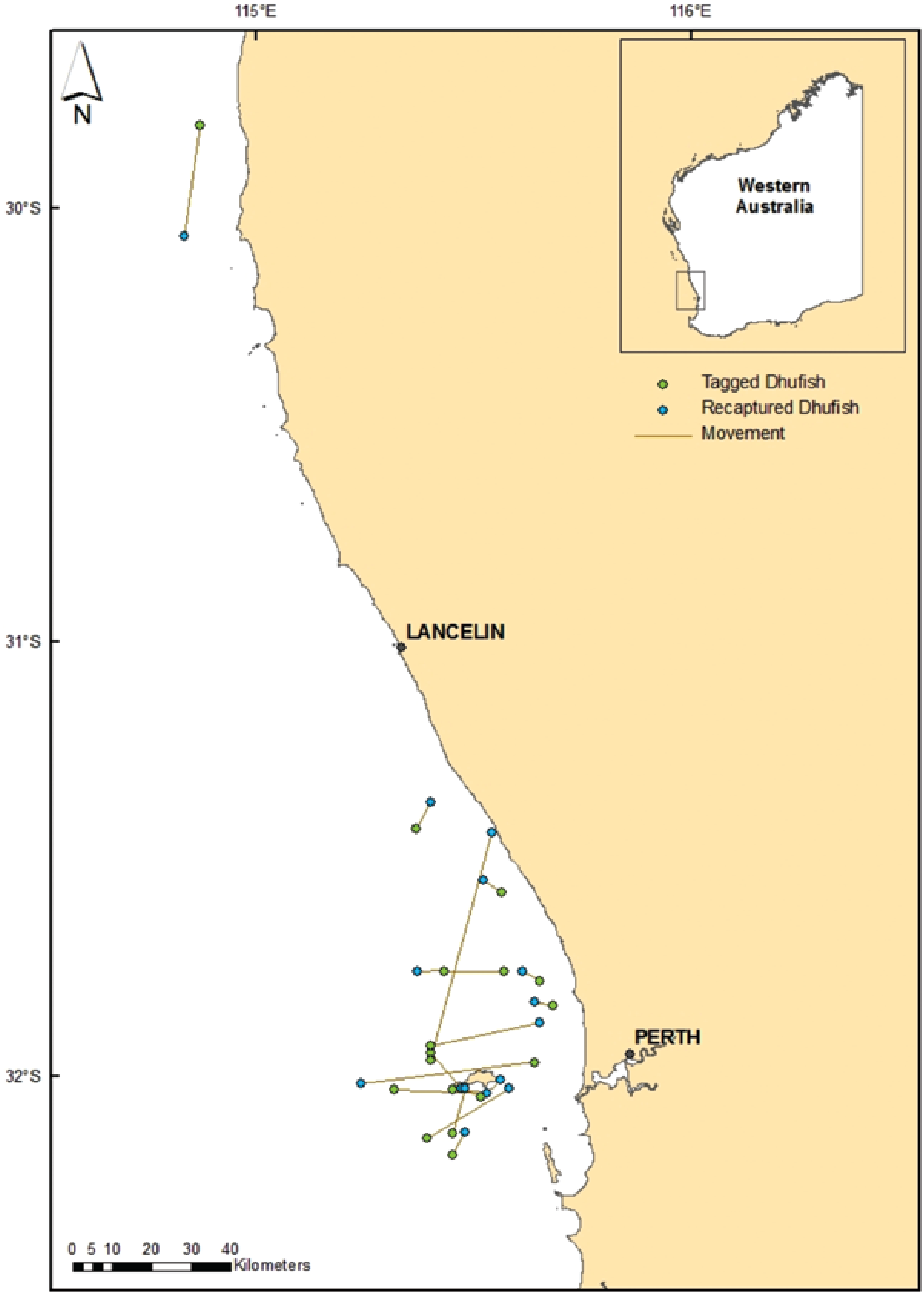


Figure 4.23. Movement patterns of dhufish that have moved > 5 nautical miles since being tagged.

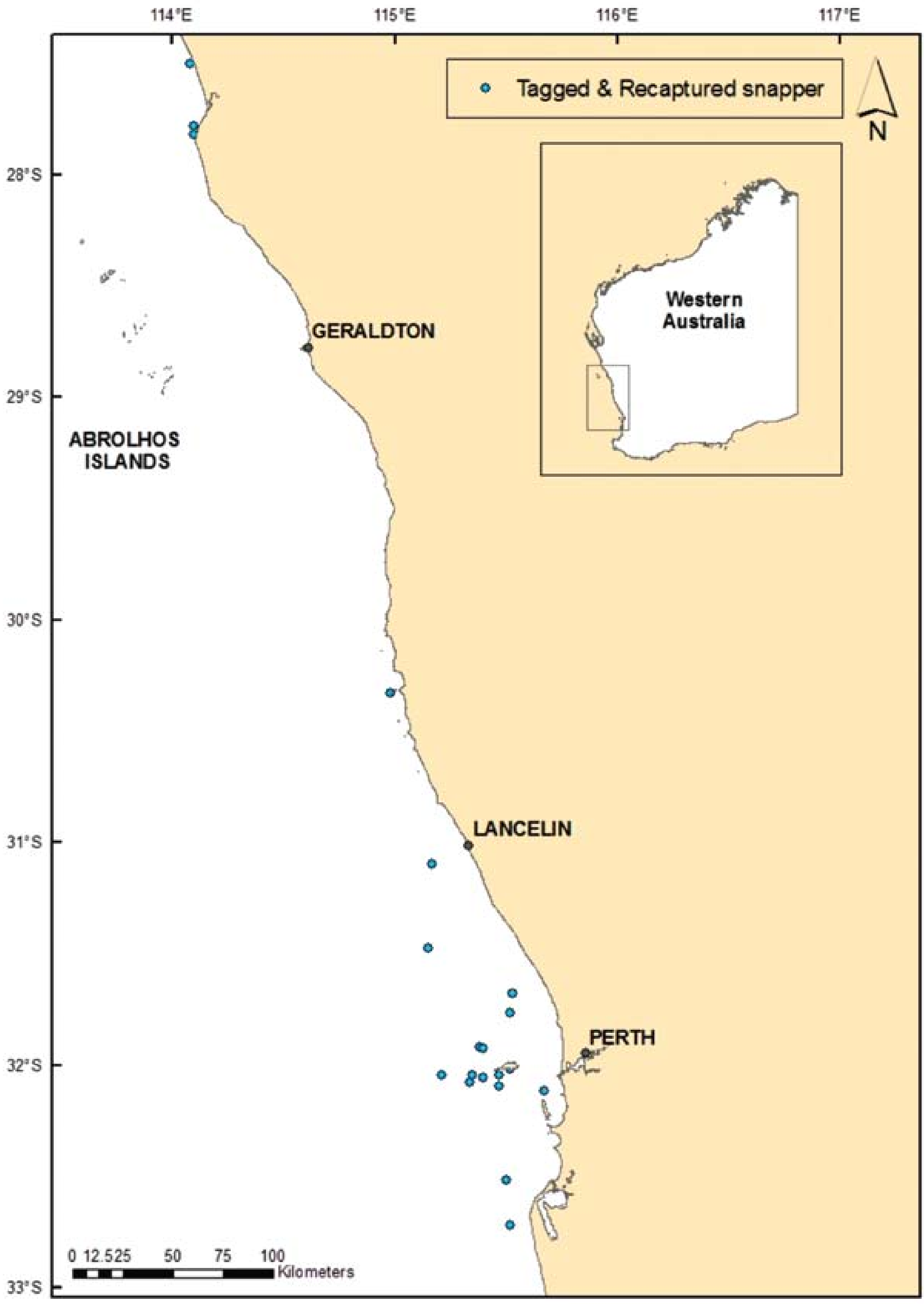


Figure 4.24. Locations where snapper have been recaptured in those cases where they moved < 5 nautical miles (i.e. release and recapture locations are similar). Each point represents an individual snapper.

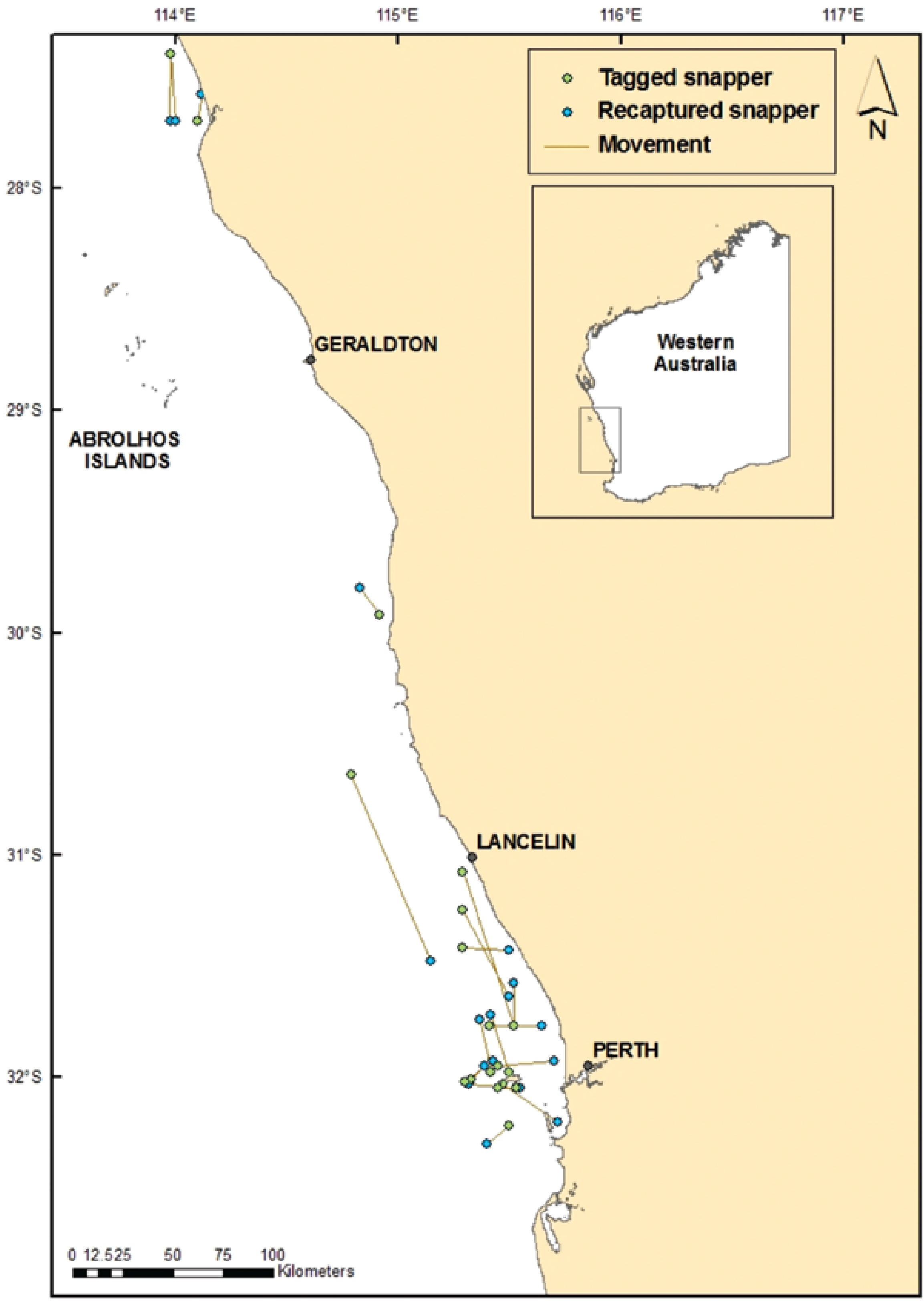


Figure 4.25. Movement patterns of pink snapper that have moved > 5 nautical miles since being tagged.

4.4 Discussion

Variability in the effects of catch and release among species was evident among the demersal fish species (dhufish, snapper, breaksea cod and baldchin groper) examined in this tagging study. The three fish species varied in response to the release methods, depth-of-capture as well as in the incidence and type of barotrauma symptoms. Recapture rates varied from 0% for all baldchin groper (with low numbers tagged, a possible contributing factor) up to 9% for dhufish released by the shotline (across all depths). The varying numbers of fish tagged and released and subsequent recaptures dictated the amount of information collected for each species. The numbers of recaptures of dhufish and snapper were sufficiently large to allow statistical analyses of the data collected for these species. The effects of the three release methods on recapture rates varied among the four fish species examined. However there was some confounding of results because all release methods were not uniformly used across all depths. Nevertheless, a major conclusion was that venting did not significantly improve survival over the simple release method, whereas shotline improved recapture rates in some species.

The effect of depth and the improvement in recapture rates using the shotline method of release was most evident in dhufish. Most dhufish were caught and tagged at depths between 40 to 50 m but recapture rates were higher at 20-40 m. Overall, recapture rates were generally higher when the shotline release method was used even though it was used at greater depths in preference to simple or vented release methods. Unfortunately, this change in the use of release method with increasing depth confounded the results of the recapture rates for each release methods because post-release mortality increases with depth.

Although most dhufish caught at all depths suffered only one barotrauma symptom, the proportion of fish with two or more barotrauma symptoms increased with depth. Unlike the other three species, three types of barotraumas symptoms (large stomach, eyes out of sockets and stomach in mouth) were the most common single or paired barotraumas seen in dhufish. Of these symptoms, “stomach in mouth” was considered more severe than “large swim bladder” because it was a symptom of greater pressure imbalance. “Eyes out of sockets” was a symptom mostly found in dhufish.

If there was tendency for taggers to release fish using a shotline when the fish displayed more symptoms of barotraumas, suggesting that these shotlined dhufish were most likely to be the most injured and thus have the least chance of survival, then this tagging study may have to some extent inadvertently masked the success of the shotline as a useful release method. That is, the benefits of the shotline release method were likely to have been greater than our results indicate.

Longer days at liberty for dhufish compared to snapper suggest that snapper is more heavily fished than dhufish. As most dhufish (93%) were recaptured near their point of capture and only 1.5% moved more than 30 nm, this study suggests that dhufish are a sedentary species. By contrast, although snapper were shown to be less sedentary, with a greater proportion of the population displaying some movement, there was virtually no recorded movement between management zones, supporting the current choice of spatial fisheries management arrangements.

Snapper recapture rates in this study are similar to snapper recapture rates in other tagging programmes in WA, and higher than recapture rates of snapper tagged elsewhere in Australia (St John *et al*. 2002). Compared with dhufish, snapper showed less depth related changes in recapture rates and the number of symptoms of barotraumas showed less depth related patterns. Overall, snapper had less than half the barotraumas symptoms of dhufish despite a larger sample size tagged. These results suggest that snapper are a more robust species than the other demersal species studied.

Relatively fewer snapper were released using shotline, as this species was not well suited to shotline release because it was highly active onboard and difficult to attach to the shotline. Nevertheless the recapture rate of those recovered was encouraging.

Because the sample size for breaksea cod was small, results of this species can only be considered as preliminary. Except for some deep recaptures, breaksea cod generally appeared most similar to dhufish in their response to capture and release because of the higher recapture rates in fish released by shotline compared to the simple method and the high number and similarity of common barotraumas symptoms. Similar to dhufish, the two most common barotraumas symptoms were "stomach in mouth" followed by "eyes out of sockets" and then both symptoms simultaneously. Breaksea had the highest proportions of two or more barotraumas and, unlike the other three species; far fewer breaksea cod were released by simple method than either shotline or vented. Also, breaksea cod was the only species tagged more by the charter boat operators than by recreational fishers.

Baldchin groper appears to have a much higher release mortality than the other three species as no tagged fish have been recaptured. Although few fish were tagged, we calculated that nearly eight baldchin groper should have been recaptured throughout the tagging programme using the average annual recapture rate for all demersal species over the 12 years (11%). Aside from low survival and variability due to low numbers, another reason that could explain this apparent lack of recaptures is non-reporting. However there was no evidence of this during the operations of this programme. This species appears to be highly susceptible to the effects of barotrauma, with considerable anecdotal reports of their poor survival. The most prevalent symptom of barotraumas recorded for baldchin groper was "stomach in mouth" (> 80%). In this species an inverted stomach protrudes from the mouth, where it is very susceptible to damage by the fish's large teeth during capture.

In this experiment, despite the high usage of J hooks in fishing for demersal fish species, circle hooks contributed less to mortality than J hooks. First, compared to J hooks, less circle hooks were swallowed by dhufish and none were swallowed by snapper. Second, none of the tagged fish that swallowed hooks were recaptured. Results from investigations into the impact of hook types and anatomical location of hooks are similar for both the caging experiments and the tagging programme. Dhufish were more susceptible to gut hooking than snapper. Mortality of gut-hooked fish in the caging experiments, however, was similar between species at 70% and 60% for dhufish and snapper respectively. In conclusion, both studies suggest that gut hooking increases mortality and circle hooks should be used in preference to J hooks to reduce gut-hooking in demersal fishes.

As the distribution of tagging and recaptures of all demersal species were reasonably consistent with spatial distribution of fishing on recreational private and charter boats (Wise *et al*. 2007), taggers in this programme appeared to fish in representative areas for the two sectors. The occurrence of the majority of releases and recaptures in the metropolitan area would appear to be a function of the level of effort expended in this area.

As most of the core assumptions in the tagging study were not satisfied, in particular the lack of quantification of the amount of effort expended to recapture tagged fish, the recapture rates in this tagging programme cannot be equated to rates of mortality. Although recapture rates do provide some indication of survival, no direct relationship can be inferred. This means that great care needs to be exercised when considering if the comparative increases in recapture rates of the fish released by the shotline and simple method can be interpreted as improvements in their survival.

In general, anglers were good at providing the information that they understood clearly, (i.e. information on capture such as location, depth, hook type, anatomical location of hook in the fish and release method) but less well on information about the condition of the fish (i.e. symptoms of barotraumas, fish movement onboard) suggesting that they were not as confident about assessing fish condition. Also, this latter information was in a different location on the original form. Thus it may have been less obvious or have given the impression that the data were less important.

The original objective of the research programme required participating taggers to alternate the release of fish across the three different methods. This did not happen in practice, as either taggers had a preferred release method, or they chose the release method they believed would best maximise the survival of the fish. As such, release methods could not be tested for all depths and symptoms of barotrauma because there was not a uniform distribution of fish caught, tagged and released by every method across all depths.

Depth of capture was an important factor affecting recapture rates. Depth of capture of demersal species on the lower west coast is related distribution of the fish (e.g. relative to available benthic habitat) and distribution of fishing effort. In < 40 m depth the most common species, dhufish and baldchin groper, are caught mostly by private recreational fishers. Depths between 40 and 70 m appear to have less habitat for demersal species and demersal fishes in > 80 m of water are caught mostly by charter boats. This meant that depth of capture and type of angler were confounded and could not be compared.

Compared to private boats, the available evidence suggests charter boats fished specific areas off metropolitan Perth more regularly and more intensively than other recreational fishers; thereby increasing their chances of recapturing tagged fish. Further, tagging was undertaken on charter boats by experienced deckhands who can apparently tag and release fish faster than anglers who tag fish less frequently. The resultant more efficient on-board handling of tagged fish by this sector may have resulted in improved survivorship. Unfortunately, a comparison of recapture rates across all sectors could not be examined because there was not a uniform distribution of data for each sector across all depths.

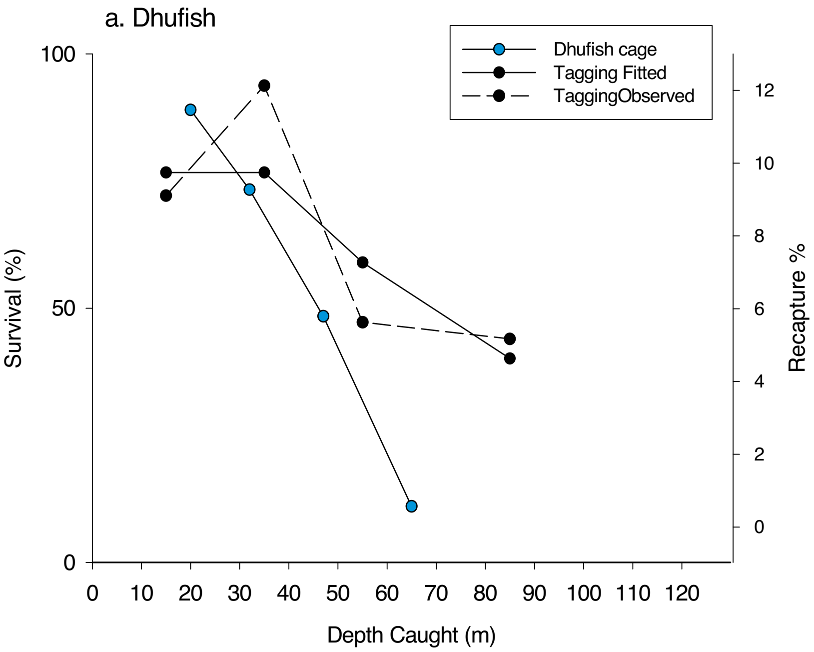
Comparison with results from caging experiments

A direct comparison between the results of the caging experiments with those from the tagging study for the two primary target species, dhufish and snapper, provides a good overall summary of the key results of the project.

The mortality rates determined from the caging experiments were expressed in terms of survival and compared to the tag recapture rates, noting that the tag-recapture data were unable to be adjusted by the fishing effort expended to recover the tags, and thus only represent a proxy for relative survival. Both experiments showed decreasing survival with depth of capture (Figure 4.26). For dhufish, the tag recapture results for waters up to 60 m depth are consistent with the results from the caging experiments, i.e. a consistent decrease in survival with depth. However the higher than anticipated recapture rates from waters in the 80 to 90 m depth range was a consequence of fish being released using the shot-line method. For snapper, the tag recapture results from waters up to 30 m depth were relatively consistent with the results from the caging experiments (i.e. high rates of survival). However higher recapture rates for waters

> 40 m deep are believed to be mostly a consequence of the greater effort spent by the charter sector targeting schooling snapper in deeper waters of the Metropolitan region combined with the efficient handling and release of fish by the crew of these vessels.

The limitations imposed by the inability to adjust the tag recapture data by the effort expended to recapture the tags highlights the need in the future for more rigorous experimental approach in the design and application of the recreational tagging methodology. Specific tagging studies need to have clear objectives and these need to be clearly explained to the participating taggers. Furthermore, for projects in which a relatively long-term tagging component is required to meet the objectives of the project, a dedicated tag co-ordinator will be critical to ensure the quality and consistency of the data.



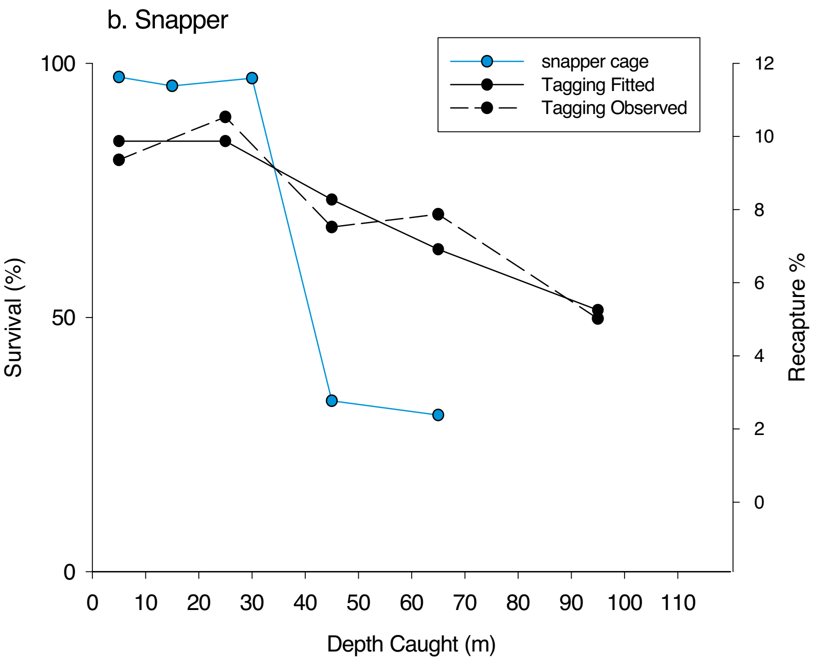


Figure 4.26. Comparisons between the results of the caging experiments (expressed as % survival), with those from the tagging study (expressed as % recapture) for dhufish and snapper.

Future recommendations

To our knowledge, along with the study conducted in Queensland by Brown *et al*, (2008) these are the first tagging studies used to document release methodology, and to assess the impact of this methodology on the survival of demersal reef fishes.

To be most successful, the experimental design for this tagging programme needed to be more robustly applied, as also found for a similar tagging study in Queensland (Brown *et al*., 2008): to ensure that each release method is uniformly applied to each species across all depths of capture, and the effort expended to recover tagged fish was recorded. In practise, however, uniform release across depths was difficult to achieve because it was difficult to catch and release similar numbers of each species at every depth. Some additional improvements in experimental design are also warranted. They include improvements of the tag sheet design, such as:

A ‘no barotraumas’ field;

Instructions to rotate release methods to ensure that every release method is done in turn;

Clear photos showing the different barotrauma symptoms experienced by fish; and

Stricter protocols must be associated with tag distribution and datasheet collection, to ensure that completed tag sheets are returned before more tags are distributed. Importantly, there also needs to provide feedback on performance to each tagger, especially if some non-reporting is occurring. Reiterating from above, for projects in which a tagging component is required to meet the objectives of the project, a dedicated tag co-ordinator will be critical to ensure the quality and consistency of the data. In addition, for long-term tagging studies in particular, ongoing extension to fishers likely to encounter tagged fish is required to maintain dissemination of information from the project and to reinforce, as required, the objectives of the tagging program.

Main conclusions

The main conclusions of this tagging study are:

Recapture-rates vary among species, release methods and depth.

Brown *et al*. (2008) examined the post-release survival rates of five reef fish species in Queensland and also found that survival rates and the usefulness of release methods to increase survival varied considerably between species.

To maximise survivorship of released demersal fishes release methods will vary depending on the species, depth of capture and condition of the fish. In dhufish, recapture rates declined with depth and the shotline method improved recapture rates compared to vented and simple release, both of which were associated with similar recapture rates. Recapture rates of snapper declined with depth and while the shotline method of release improved recapture rates, the available data was only from shallower waters. Although breaksea cod had a much lower recapture rate than dhufish and snapper, the effects of depth and the shotline release methods appeared to be most similar to dhufish. No baldchin groper were recaptured.

Barotrauma symptoms varied with species and had varying effects on recapture rate depending on their severity. Some barotraumas were more prevalent at depth, but not for all species; and

Circle hooks should be used in preference to J hooks to reduce gut hooking, and therefore mortality of these demersal fishes. Survival of released fish, particularly in intermediate depths, will depend on how well fish are caught, handled and released.

5.0 The distribution of sizes of demersal fish in relation to depth: does the proportion of undersize fish vary across depths?

Jill St John

5.1 Introduction

This chapter deals with the second objective of the project:

"Collect information on the size of west coast reef fish in relation to depth, to assess the proportion of undersize fish at different depths."

If some undersize fish die following capture and release, the fishing mortality is higher and the mean size at first capture lower than would be expected on the basis of the retained catches. This affects the abundance of spawning stocks, and the sustainable yield which can be taken by the fishery. Increasing the survival of released fish is likely to be one of the most effective measures available to conserve reef fish stocks. This can only be done with an understanding of the sources of release mortality and estimation of the effectiveness of techniques to reduce that mortality, which have been investigated in Chapters 2 to 4.

However, besides improving the survival of released fish, an additional option to conserve fish may be to reduce the actual capture rate of undersize fish. In this Chapter the relative distribution of undersize and legal size dhufish and snapper caught by the different fishing sectors are examined to determine if there are any spatial patterns that might be informative for reducing the likelihood of catching undersize fish, for example, through modification of fisher behaviour.

5.2 Methods

Size composition data for dhufish and snapper caught from various depths using gillnet and line was collated. The material contributing to each data set comes from different geographic locations. In this section the West Coast refers to the lower west coast from 26° S to 116° E.

Gillnet fishing

Information about dhufish and snapper caught by demersal gillnets was collected from the commercial gillnet fisheries in temperate WA. This fishery is described in detail by McAuley and Simpendorfer (2003). Although the fishery primarily targets sharks, teleost fish (or scalefish) represented approximately 17 to 20% of their annual finfish catch of up to 925 tonnes. Dhufish and snapper comprised 16.2 and 11.2% respectively of the scalefish catch. Between 1994/95 and 1998/99, observers working for the Research Division of the Department of Fisheries collected information about the gillnet catches, including the size composition of dhufish and snapper caught at different depths.

Size selectivity: As these gillnets were set primarily to catch sharks, they have a large mesh size (ranging between 165 mm to 178 mm) that does not normally retain smaller dhufish and snapper (McAuley unpubl. data). Commercial gillnet predominantly select for WA dhufish between 700-850 mm TL. At 550 mm TL relative selectivity of the gillnets falls to 0.5 and dhufish of size 300-350 mm TL are not caught at all (McAuley unpubl. data). Commercial gillnet select mainly for snapper was between 900-1000 mm TL (McAuley unpubl. data). Modelled relative selectivity falls to less than 0.1 for snapper just over legal size (400-500 mm TL) and is less than 0.01 for the next smaller size class (300-400 mm, McAuley unpubl. data). Thus, comparisons need to be confined to the use of data from similar gears.

Gillnets are set on habitat that will maximise the catch of sharks, but may not necessarily be representative of the real teleost abundance and size composition in the area. Also, the depth at which gillnets are set may influence results because greater catches would be taken at the most common depth of setting (i.e. where most effort was expended). Representative catches across depths would result from gillnets being set randomly across all depths.

As gillnets do catch some undersize fish (2.4% of snapper and 6.8% of dhufish), the proportion of undersize and legal sized catch at each depth range can be independently compared to determine whether the depth distribution of each of the two size categories varies.

Line fishing

Specific demersal species are targeted with baited hooks on a line. Information about dhufish and snapper caught by line was collected from several data sources.

Charter boat data set
Reporting by the charter boat fishery requires information on fish size and depth of capture. The size and depth-based dhufish and snapper catches of charter boats from the West Coast for 2002/03 have been used in these analyses. The precision and quality of the data provided on the size of fish and depth of capture varies between charter boat operators. Some operators round fish lengths to 5 cm size classes. All charter boat operators record the average depth for the entire days fishing, not individual depths at which each fish is caught. Although some charter boats may stay in the one spot for the entire day, others do not and there is no way of assigning catch to different depths fished during the day. Charter boat operators record the lengths of legal sized fish retained and the number of undersize fish that are released. The charter boat data set is large (contains records of nearly 2000 dhufish, and 3500 snapper) and provides useful information about where and how deep this sector fishes. The proportion of both undersize and legal size fish caught at different depths can be compared.

Information from fish frames
The demersal finfish group in the Research Division of the Department of Fisheries has been collecting information on demersal finfish on the west coast since, 2001. This data set contains depth information supplied by fishers and size information measured by researchers from fish caught by commercial, recreational and by research fishers. (Note that depth of capture was not available for every recreationally or commercially caught fish, especially when frames caught commercially were sampled through processors).

Recreational catches
Some recreational fishers were allocated permits for collecting undersize snapper and dhufish, however, there were relatively few undersize fish collected compared to legal size fish. Although the sample of dhufish is relatively small, the proportion of undersize fish across depths can be compared to the proportion of legal size fish. Most of the recreational samples of dhufish come from waters off the Perth Metropolitan Area (Two Rocks to Mandurah). To date we have only 32 snapper caught recreationally with depth information.

Commercial catches
One commercial fisher in the northern part of the west coast provided considerable information

about depth of capture for his retained catch, and for every undersize dhufish he caught. Thus the proportion of undersize fish across depths are compared to the proportion of legal size fish.

Selectivity of line fishing

As line fishing actively targets individual species, it is not a method that provides an unbiased estimate of abundance. Unlike gillnet fishing in the commercial shark fishery, where the nets are laid to maximise shark catches, the location of line fishing is decided by the catch rates of the target species. Line fishers will alter their fishing location when fish are not biting. Thus, the fishing location is determined by the abundance of the fish, however, boat size and time restrictions may also affect the choice of fishing sites.

Small dhufish (< 300 mm TL) are rarely caught by baited hook and line, but snapper > 150 mm TL are easily caught. Smaller hooks and bait catch smaller fish. In all of the samples collected using line fishing, hook sizes were chosen to target legal size fish. It is commonly believed that recreational fishers target larger fish. High grading, when a smaller fish is replaced with a larger fish caught subsequently, can be a problem in the recreational sector when the bag limit for a species or group of fishes can be easily achieved. High grading is unlikely to be a problem for dhufish. Between 1996-1997 recreational anglers on the west coast targeting dhufish averaged 0.42 dhufish per angler (Sumner & Williamson, 1999). At that time, the bag limit for dhufish (four fish per person) was rarely reached. Only one of the 501 boat owners interviewed that had caught dhufish had achieved the bag limit. At present the bag limit for dhufish is two per person, which is still well above the average catch of recreational fishers. High grading may be a problem for snapper because they are very catchable by line when forming their annual spawning aggregations.

Location of fishing:

The bathymetry, bottom topography and availability of suitable habitat, as well as the timing of sampling relative to feeding behaviour may affect the depth related size structure of fish species. For example, the behaviour and movement of snapper is very site dependent. In the waters off the Perth Metropolitan Area, large snapper (> 700 mm TL) migrate to shallow Cockburn Sound to spawn in aggregations during late spring early summer. Thus, the results of investigations into size structure across depths of snapper, in particular, is likely to be very site-specific, and therefore not able to be applied more broadly to other locations.

5.3 Results and Discussion

5.3.1 Dhufish

Gillnet vs. Line fishing

The gillnet sample includes measurements (TL in mm) of 2716 fish collected from nets between 1994/95 and 1998/99 (raw data, McAuley & Simpendorfer, 2003). The sample of line-caught fish included 1861 fish from log books recording the retained charter boat catch of 2002/2003, and 1120 fish collected for biological information from recreational, commercial and charter boat fishers (Table 5.1). Line fishing data were pooled even though the depths at which dhufish were caught varied significantly between charter boat and the other sectors (Kolmogorov-Smirnoff statistic = 0.2461, p-value < 0.01).

Table 5.1. The number of West Australian dhufish caught at, 20 m depth intervals by gillnet and line fishing. Line fishing included 1861 dhufish caught by charter boats fish and 1120 fish collected for biological information from recreational, commercial and charter boat fishers.

Depth	Gillnet	Line fishing
0-19	88	118
20-39	912	656
40-59	1254	1102
60-79	71	305
80-99	385	731
100-119	6	56
120-139		5
140-159		8
n	2716	2981

More than half of the dhufish were caught between 20 to 59 m (59% of line-caught and 80% of the gillnet catch, Fig. 5.1). Although both line and gillnet fishing followed a similar bimodal pattern of relative abundance with two peaks in abundance (20 to 59 m and 80-99 m) and a drop in the proportion of the dhufish catch between 60-79 m, the proportions of dhufish caught at various depths varied significantly between the two methods (Kolmogorov-Smirnoff statistic = 0.1978 p-value < 0.01, Fig. 5.1).

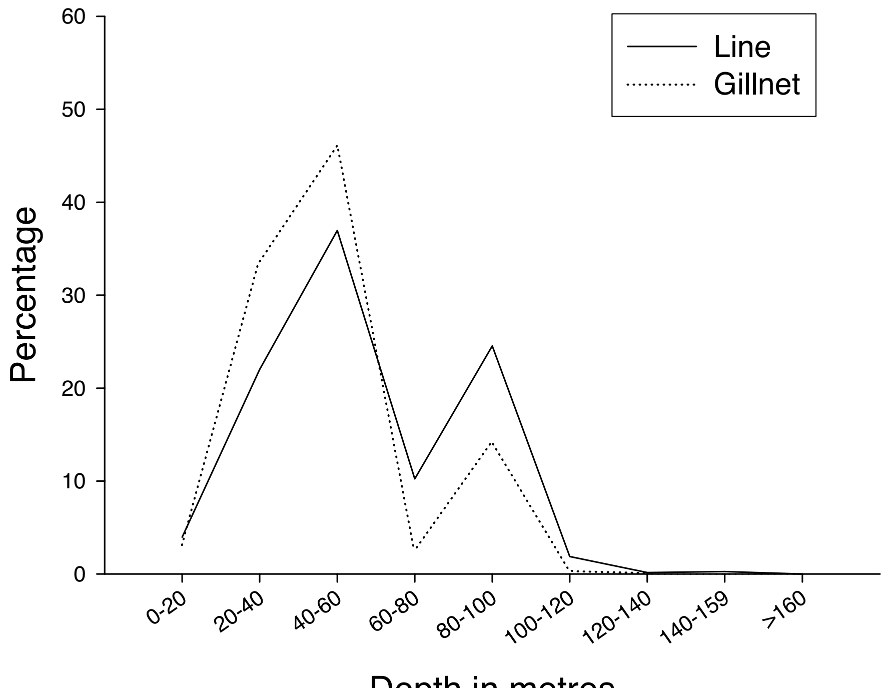


Figure 5.1. The proportion of West Australian dhufish caught at 20 m depth intervals by two fishing methods gillnet and line fishing. Line fishing included 1861 dhufish caught by charter boat fish and 1120 fish caught by line for biological information from recreational, commercial and charter boat fishers.

Line fishing sector – charter boat, recreational and commercial

The depths at which the highest proportion of the catch samples were taken by each sector became progressively deeper for recreational fishers (20-39 m), charter boat operators (40-59 m) and commercial fishers (80-99 m). This is likely to be a reflection of the spatial distribution of fishing effort. This pattern is most likely explained by size of boats and time constraints (Table 5.2). Most recreational fishers have smaller boats that are less able to travel to the deeper sites further off shore. Although experienced recreational fishers with larger boats would have no difficulties reaching deep waters, they are nonetheless more likely to avoid fishing on rough days. Charter and commercial operators, however, have larger and more seaworthy boats. Charter boats would be constrained by duration of trips, however, because most charter operators on the west coast run day trips (C. Johnson, pers. comm.). Thus, deeper, offshore fishing sites are not easily reached in a day-trip from populated areas, i.e. offshore sites are less accessible. Also, deeper fishing sites could be more exposed to weather and seas, making fishing condition less comfortable for clients on charter boats. In contrast, commercial operators, who have different incentives to fish, operate from several days up to more than a week at a time, and can cover a much larger area.

Table 5.2. The proportion of the sample of West Australian dhufish caught by different sectors within line fishing. Sample sizes for each sample are recorded.

Depth	Commercial %	Charter boat %	Recreational %
0-19	0.0	5.7	13.0
20-39	3.1	26.5	43.5
40-59	23.2	37.7	34.8
60-79	27.7	12.6	0
80-99	44.1	14.9	8.7
100-119	1.9	2.3	0
120-139	-	0.3	-
n =	1182	1861	188

Four separate line-fishing data sets and one gillnet data set were divided into legal and undersize dhufish: the proportion of the catch at each depth was calculated (Table 5.3). Assuming that bag limits were not reached, the depth with the highest proportion of dhufish appeared to be similar between undersize and legal size fish, suggesting that undersize fish live in similar depths as legal fish.

Table 5.3. The percentage of the sample of undersize and legal sized dhufish caught by two fishing methods and by different fishing sectors. Sample sizes for each sample are recorded. Charter boat catch is summed across all zones of the WC Bioregion where both depth and block is recorded.

Depth	Line fishing								Gillnet	
	Charter boat		Commercial		Recreational		Research			
	Under	Legal	Under	Legal	Under	Legal	Under	Legal	Under	Legal
0-19	5.1	7.5	0.0	0.0	3.2	3.6	26.3	42.9	2.9	3.3
20-39	25.3	23.2	1.4	3.7	43.5	58.8	2.6	7.1	31.8	33.7
40-59	31.5	34.8	23.8	23.0	34.8	31.0	65.8	42.9	31.2	47.2
60-79	14.8	15.6	33.0	26.0	0.0	1.8	5.3	7.1	4.6	2.5
80-99	21.3	16.7	40.8	45.1	8.7	6.7	-	-	29.5	13.1
100-119	1.9	2.2	1.1	2.2	0.0	0.0	-	-	0	0.2
120-139	0.1	0	-	-	-	-	-	-		
140-159	0.1	0								
n	1274	2173	282	900	23	165	38	56	173	2543

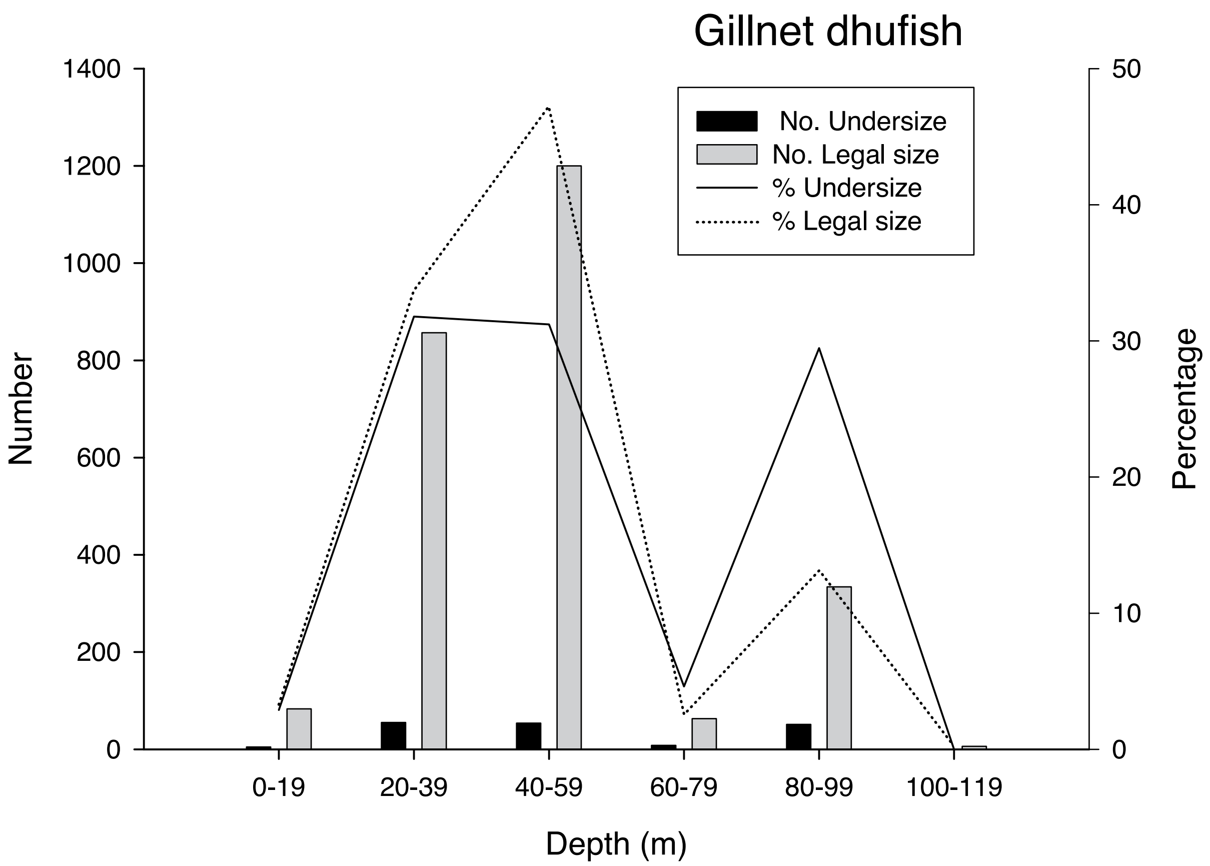


Figure 5.2. The number and percentage of undersized and legal sized dhufish caught by gillnet (n = 2716) at 20 m depth intervals up to 120 m.

Similar proportions of undersize dhufish were caught by gillnets at three depths, 20-39 m, 40-59 m and 80-99 m (Table 5.3, Fig. 5.2). Nearly 50% of the legal size dhufish were caught at 40-59 m and 30% at 20-39 m. In contrast to undersize fish, only 13% of legal fish were caught in gillnets at 80-99 m (Table 5.3, Fig. 5.2). Despite the small sample size of undersize dhufish, these results clearly demonstrate that small fish live in similar depths as large fish.

Depths were pooled into three categories: shallow (0-39 m), medium (40-79 m) and deep (80 m+) for statistical comparisons (Table 5.4 and Table 5.5 for graphical summary). The depth-related patterns of size distribution of dhufish varied among the three line-fishing sectors. The proportion of undersize and legal size fish varied significantly among the three depths for the commercial fishery and between the two shallower depths for the research data (Table 5.4 & 5.5). In the recreational data, there was no significant difference between shallow, mid depths and deep (Table 5.5).

Table 5.4. Binomial tests of line-caught undersize and legal size dhufish at various depths. Depths were pooled into three categories: shallow (0-39 m), medium (40-79 m) and deep (> 80 m). Normal approximations to the assumed binomial distributions were made where *np > 5 and n(1-p) > 5* and the p-values are displayed. Where normal approximations are adequate, a standard *t*-test with pooled variance is used. If *np ≤ 5* for either sample, the binomial distribution is compared and the *p*-values are underlined.

	Sample 1 (undersize)			Sample 2 (legal size)			
	N	**np**	**n(1-p)**	**n**	**np**	**N(1-p)**	**p-value**
Rec							
Shallow v. mid-depth	113	13	100	62	8	54	0.69
Shallow v. deep	113	13	100	13	2	11	<u>0.45</u>
Mid-depth v. deep	62	8	54	13	2	11	<u>0.51</u>
Com							
Shallow v. mid-depth	37	4	33	601	160	441	< 0.001
Shallow v. deep	37	4	33	544	118	426	< 0.001
Mid-depth v. deep	601	160	441	544	118	426	0.006
Research							
Shallow v. mid-depth	39	11	28	55	27	28	0.003
Rec v. com							
Shallow	113	13	100	33	4	44	<u>0.89</u>
Mid-depth	62	8	54	601	160	441	< 0.001
Deep	13	2	11	554	118	426	<u>0.35</u>

Table 5.5. Summary of statistical results from above Table 5.4.

	SHALLOW	MID DEPTH	DEEP
Recreational	n.s.	n.s	n.s.
Commercial	sig.	sig.	sig.
Research	sig.	sig.	Not sampled

Because of the sampling biases outlined earlier in this report, proportions, rather than numbers, of legal and under-size fish were used to compare the relative abundance of undersize and legal dhufish caught by different methods/sectors within the 20 m depth intervals. The proportions of undersize and legal size fish at each, 20 m depth were similar within each line fishing method, however, the pattern of depth distribution of dhufish varied among fishing sectors (Charter boat Fig. 5.3a, Commercial Fig. 5.3b, Recreational Fig. 5.3c). When the proportions of the two size groups of dhufish were averaged across every data set, the proportions were close at each depths and followed the same trends (Fig. 5.4) indicating that the proportion of undersize and legal sized WA dhufish are relatively evenly distributed among all depth ranges.

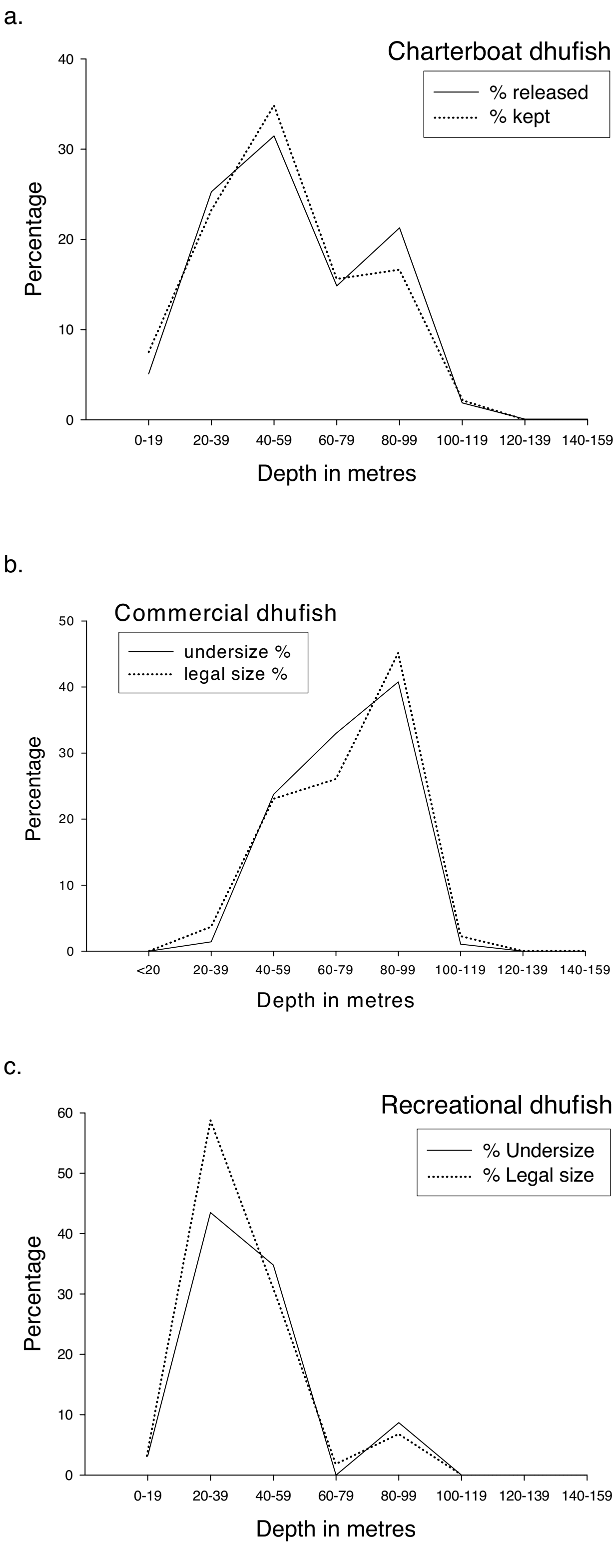


Figure 5.3. The proportion of the sample of undersize and legal sized West Australian dhufish caught by different sectors within wetline fishing a charter boat n = 861, b commercial n = 1182 and c recreational n = 188. Proportions were used because the methods

biased the undersize or legal size catch.

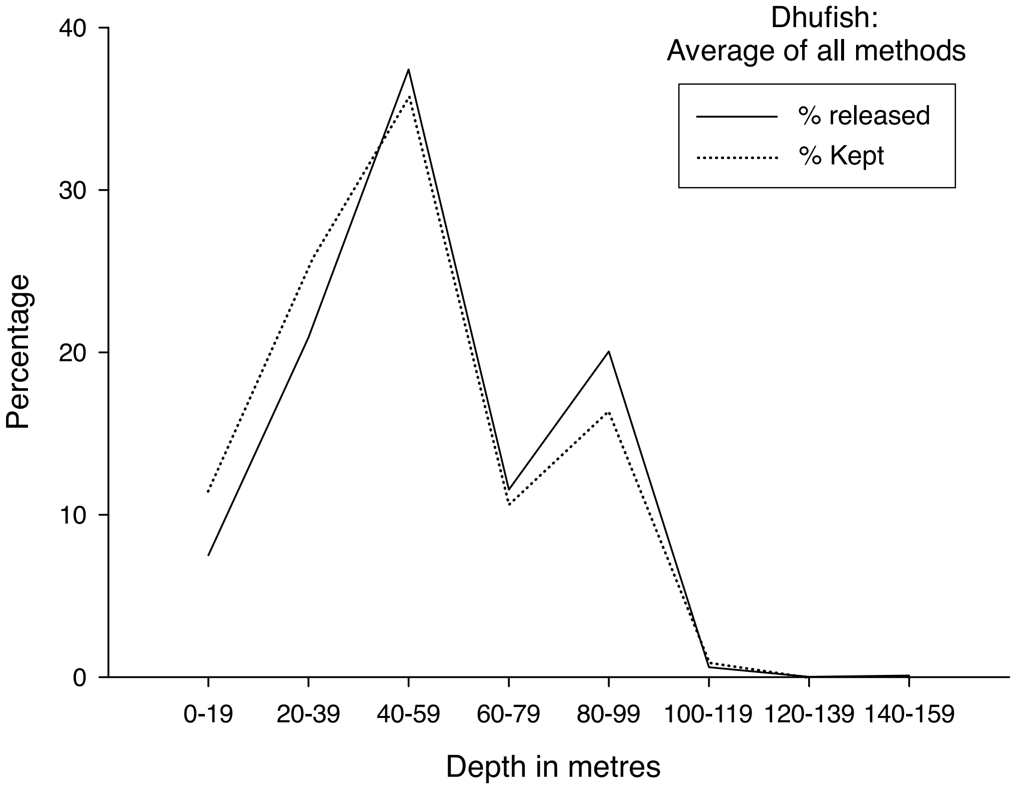


Figure 5.4. The average proportion of the sample of undersize and legal sized West Australian dhufish caught by different line sectors: charter boat, commercial and recreational.

Proportion of WA dhufish released by the various sectors

The proportion of WA dhufish released after capture, presumably due to legal size requirements, ranges from 24% to 54 % (Table 5.6). The commercial fisher had the lowest rate of release at 24%. Commercial fishers are unlikely to stay in areas where they are catching undersize fish. Rates of release of charter boat fishers was 35%. Rates of release of recreational fishers varied from 32% estimated through a creel survey in 2005/06, to 54% estimated by a national phone survey in 2000/01 (see Table 5.5 for details).

Table 5.6. The proportion of West Australian dhufish kept and released: data from different sectors.

Data set	Date	Number kept	Number released	Percentage released	Source
Creel Survey	1996/97	23,982 (125 t)	11,801	33%	Sumner and Williamson, 1999
Creel survey	2005/06	35,222 (186 t)	16,766	32%	Sumner et al, 2008
National Survey	2000/01	102,800 (578 t)	55,000	54%	Henry and Lyle, 2003
Charter Boat	2002/03	4,462 (24 t)	2,385	35%	Dept Fisheries WA unpubl. Data
Commercial Logbook	2002/03	900	282	24%	Dept Fisheries WA unpubl. Data

5.3.2 Snapper

Gillnet vs. Line fishing

The gillnet sample includes measurements (TL in mm) of 2055 fish from between 1994/95 and 1998/99 (McAuley & Simpendorfer, 2003). The line-fishing sample included 3513 snapper caught from charter boats and 304 snapper collected by line for biological samples (Table 5.7). Most snapper were caught at depths between 20 and 120 m (92.4% of line caught and 94.3% of the gillnet catch, Fig. 5.5) and both line and gillnet fishing followed a similar bimodal pattern with peaks in catch at 20-59 m and 80-99 m (Fig. 5.5). The proportions of snapper caught at 20 m depth intervals differed significantly between line and gillnet fishing ((Kolmogorov-Smirnoff statistic = 0.081 p-value < 0.01, Fig. 5.5). The highest proportion of snapper caught in gillnets was at 40-59 m and by line from 20-39 m (Fig. 5.5).

Table 5.7. The number of snapper caught from depths of, 20 m intervals by two fishing methods gillnet and line fishing. Line fishing included lengths of 3513 snapper caught from charter boats, and lengths of 304 snapper collected for biological information from recreational (n = 32), commercial (n = 197) and charter boat (n = 75) fishers.

Depth	Gillnet	Line fishing
0-19	117	121
20-39	405	1102
40-59	699	903
60-79	168	504
80-99	459	709
100-119	206	310
120-139	1	19
140-159		56
160-179		80
180-199		13
n	2055	3817

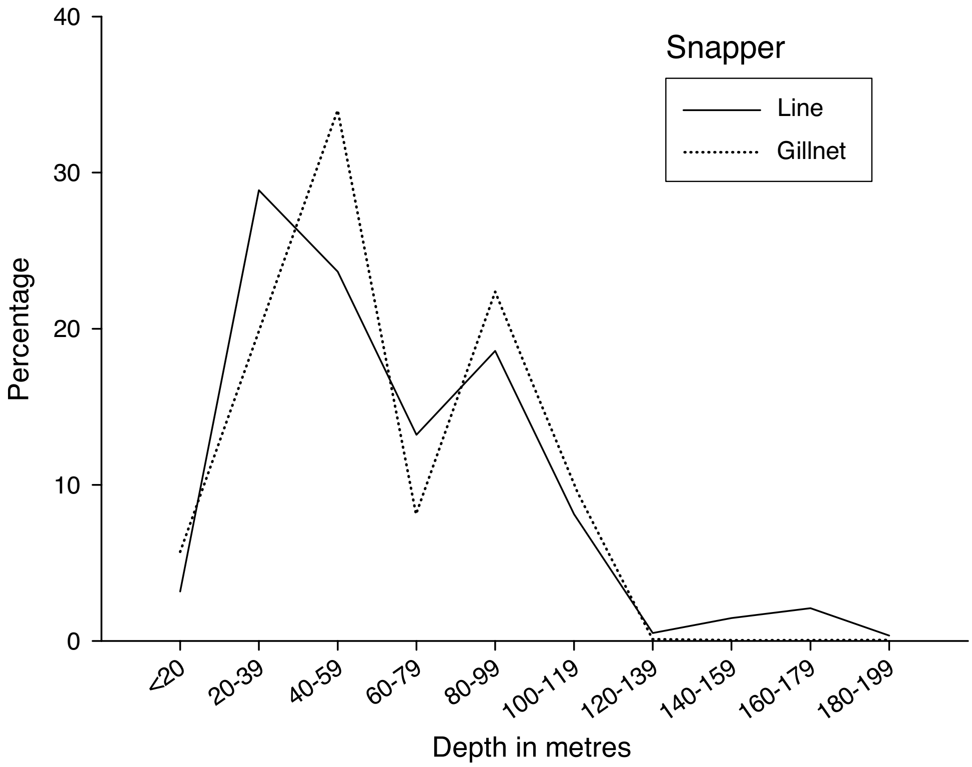


Figure 5.5. The percentage of snapper caught at 20 m depth intervals by two gillnet and line fishing. Line fishing included 3513 snapper caught by charter boats and 304 fish caught by line for biological information from recreational, commercial and charter boat fishers.

The similarity in the bimodal pattern in the depth structure of the snapper and dhufish catch suggests that either relatively little effort was expended in the 60 to 80 m depth range or these species were less abundant at these depths, possibly due to the lower availability of suitable habitat.

Line fishing sector – charter boat vs. commercial

The proportion of the samples caught by line fishing at 20 m interval depths were compared between charter boats and commercial fishers (Table 5.8). The catch sample from recreational fishers is not included as the sample size was considered too low (n = 32). The highest proportion of snapper caught by charter boat operators was at 20-59 m and the highest proportion of the commercial catch of snapper caught was at 40-59 m (Table 5.8).

Table 5.8. The proportion of the sample of snapper caught by commercial and charter boat line-fishing sectors. Recreational catch is not included as the sample size was too low (n = 32).

Depth	Commercial %	Charter boat %
0-19	0	3.4
20-39	3.6	29.6
40-59	53.8	25.0
60-79	7.1	10.7
80-99	16.8	19.8
100-119	0.5	7.8
120-139	18.3	0.5
140-159	0	0.6
160-179	0	2.3
180-199	-	0.4
n	197	3513

Size differences at various depths

Three data sets from different methods (gillnet and line fishing) and sectors (Line fishing: commercial and charter boat) provided information on legal and undersize snapper (Table 5.9). Similar to the presentation of the dhufish data, proportions, rather than numbers, of legal and under-size fish were used to compare depths (when samples were **not** representative). Numbers were used when the samples included **all** undersize and legal size fish that were caught, however, the selectivity of the gill nets towards larger fish (McAuley unpubl. data) meant that undersize snapper were under-represented in the gillnet fishery (2.4% Fig. 5.7).

For each method at each 20 m depth interval the catch that was undersize was compared with the proportion of the catch that was legal size. The depth structure of the undersize snapper was not similar to the depth structure of the legal size fish in any of the four data sets (but see charter boat data set when divided by region). The highest proportion of the undersize snapper was caught at either the most shallow depth < 20 m (charter boat Fig.5.8a) or deep at 80-99 m (gillnet Fig. 5.7 and commercial line fishing Fig. 5.8b, Table 5.9). The highest proportions of legal size snapper were caught deeper in depths of 40-59 m (gillnet Fig. 5.7, commercial line fishing Fig. 5.8b), and 80-99 m (charter boat Fig.5.8a, Table 5.9). Although the commercial line fishing sample was similar to the gillnet, with most undersize fish caught at 80-99 m and most legal size fish caught at 40-59 m (Fig.5.7 and Fig.5.8b), the trend of undersize fish at deeper depths reversed in the other line fishing data sets (Fig.5.8a and 5.9, Table 5.9). The commercial data and gillnet data sets are considered to reflect the actual depth distribution of the two size classes. Reasons for the two opposing trends in the other two data sets are explained below.

Table 5.9. The proportion of the sample of undersize and legal sized snapper caught by gillnet and line, and by commercial and charter sectors. Charter boat catch is summed across all zones of the WC Bioregion where both depth and block is recorded. Sample sizes for each sector are presented.

Depth	Gillnet		Line Fishing Commercial		Line Fishing Charter boat	
	Under	Legal	Under[1]	Legal[1]	Released	Kept
0-19	4.1	5.7	0	0	26.1	10.1
20-39	10.2	19.9	0	4.3	19.9	12.7
40-59	30.6	34.1	38.2	57.1	14.3	13.5
60-79	8.2	8.2	0	8.6	11.3	20.7
80-99	38.8	21.9	61.8	7.4	19.6	28.7
100-119	8.2	10.1	0	0.6	5.5	5.6
120-139	0.0	0	0	22.1	0.4	1.4
140-159					0.3	1.6
160-179					2.6	5.5
180-199					0.0	0.1
n	49	2006	34	163	3501	6125

[1] legal minimum length was 420 mm TL so < 400 mm TL was classified as undersize.

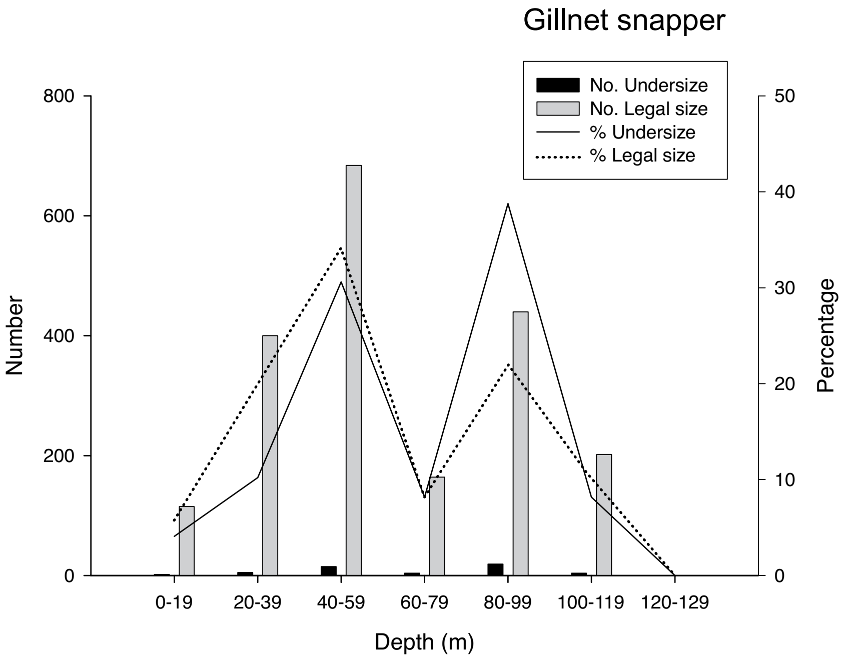
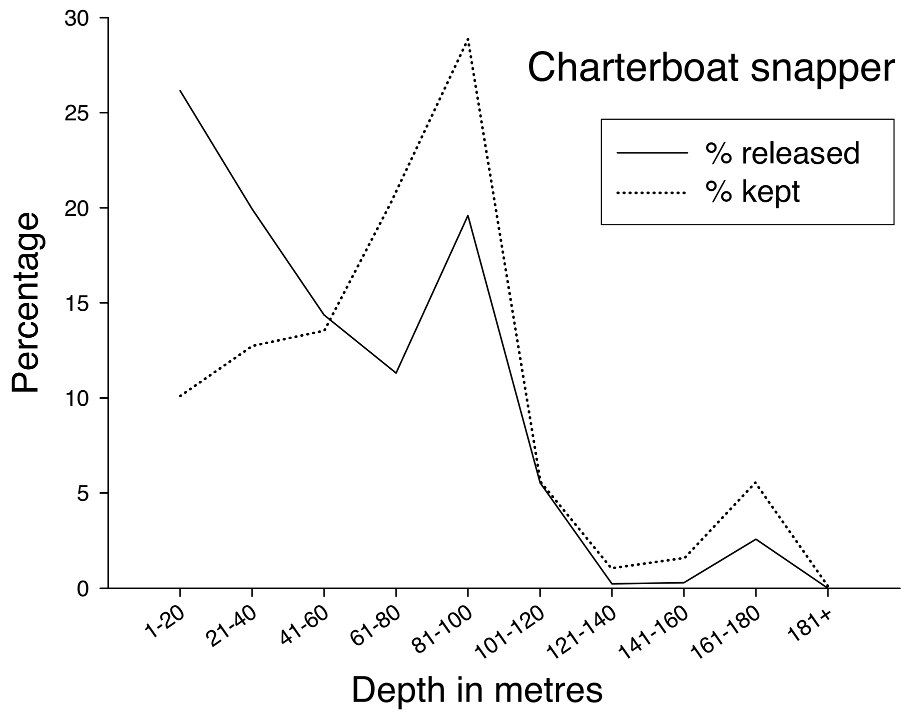


Figure 5.7. The number and percentage of undersize and legal sized snapper caught by gillnets at 20 m depth intervals (n = 2055).

a.



b.

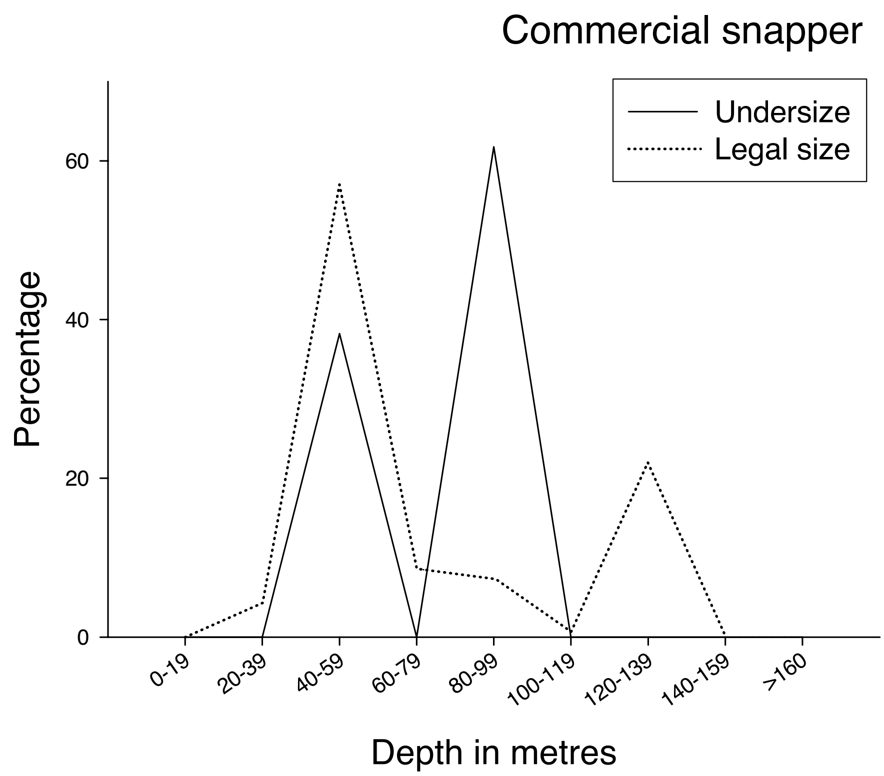


Figure 5.8. The proportion of the sample of undersize and legal sized snapper caught by different sectors by line fishing by (a) charter boat (n = 2055) and (b) commercial fishers (n = 197).

In the West Coast Bioregion the depths of capture of undersize snapper by charter boats differs with the patterns apparent in the commercial line fishing and gillnet samples. However there are marked variations in the proportion of undersize snapper caught at different depths by the charter boats operating in the 4 zones of the West Coast Bioregion. The charter boat sample was divided into 4 zones: Kalbarri (27' S to 28' S), Mid West (28' S to 31' S) Metropolitan (31' S to 33' S) and South West (33' S to 115.30' E, Table 5.11, Fig. 5.9). Most of the snapper catch from charter boats (52%) is from the metro area where both size categories are fished predominately from depths of 60 to 99 m (Table 5.11). The majority of the remaining snapper are caught in the north (Midwest: 23% and Kalbarri: 22%), where they are fished from more shallow depths (Midwest: 20-39 m and Kalbarri: < 20 m). Most undersize fish caught by charter boats from < 20 m came from Kalbarri.

Table 5.11. The proportion of the sample of undersize and legal sized snapper caught by at various depths by charter boats divided into four zones in the West Coast Bioregion. The four zones are Kalbarri (27' S to 28' S), Mid West (28' S to 31' S) Metropolitan (31' S to 33' S) and South West (33' S to 115.30' E). Average depth of fishing and sample sizes for each region are presented.

Depth	Kalbarri		Mid west		Metro		South West	
Average depth	30 m		47 m		85 m		54 m	
	Kept	Released	Kept	Released	Kept	Released	Kept	Released
< , 20 m	62.6	69.7	5.0	12.2	0.2	0.1	0.3	1.6
20 to 39 m	15.9	14.7	34.7	53.1	3.8	8.2	11.6	47.5
40 to 59 m	20.3	15.5	14.8	14.4	7.9	13.0	57.0	27.9
60 to 79 m	1.1	0.1	21.5	7.4	25.1	21.6	21.8	11.5
80 to 99 m	0.0	0.0	24.0	12.9	39.2	37.8	0.0	0.0
100 to 119 m	0.0	0.0	0.0	0.0	9.6	12.4	0.0	0.0
120 to 139 m	0.0	0.0	0.0	0.0	1.7	0.5	0.0	0.0
140 to 159 m	0.0	0.0	0.0	0.0	2.7	0.6	9.2	11.5
160 to 179 m	0.0	0.0	0.0	0.0	9.4	5.8	0.0	0.0
180 m +	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
N	870	1189	1351	689	3611	1562	293	61
% of catch	22.0		22.8		52.5		2.7	

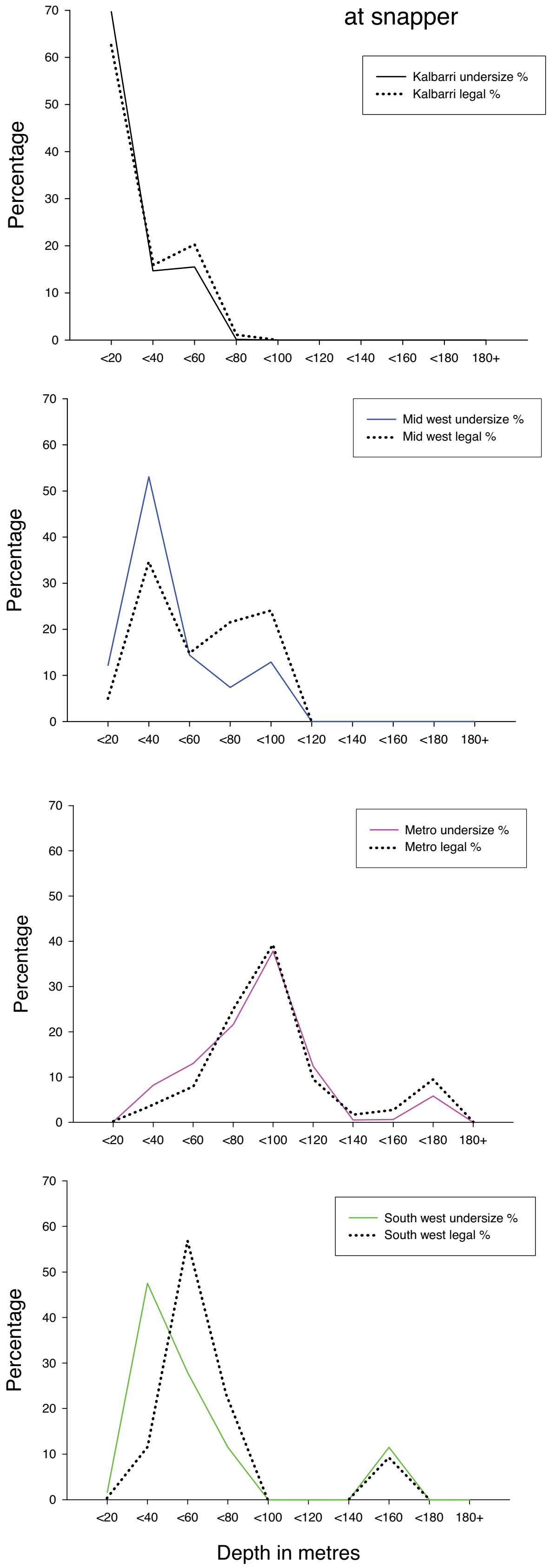


Figure 5.10. The proportion of the sample of undersize and legal sized snapper caught by charter boat divided into four zones within the West Coast Bioregion. The four zones are Kalbarri (27' S to 28' S, n = 2059), Mid West (28' S to 31' S, n = 2040), Metropolitan (31' S to 33' S, n = 5173) and South West (33' S to 115.30' E, n = 354).

Proportion of snapper released by the various sectors

The proportion of snapper released in the West Coast Bioregion varies from 57% in the Kalbarri zone to 16% in the South West. At 34% the proportion of undersize snapper released after capture estimated for recreational fishers in the West Coast Bioregion almost 10 years ago is similar to the overall release rates for charter boats in 2002-03 (Table 5.12). These recreational WA figures for snapper are approximately half of the national average of recreational fishing in 2000-01 (Table 5.12).

Table 5.12. The proportion of snapper kept and released: data from different sectors.

Data set		Date	Number kept	Number released	Percentage released	Source
Creel Survey	West Coast Bioregion	1996/97	15,546 (25 t.)	8,294	34%	Sumner & Williamson, 1999
Creel Survey	West Coast Bioregion	2005/06	17 808 (40 t.)	13,693	43%	Sumner et al, 2008
National Survey	Australia	2000/01	1287,826 (578 t.)	2,535,955	66.3%	Henry & Lyle, 2003
Charter Boat	West Coast Bioregion	2002/03	10,660	5,829	35%	Dept Fisheries WA unpubl. Data
"	Kalbarri	"	1368	1794	57%	"
"	Midwest	"	2170	1105	34%	"
"	Metro	"	5352	2204	29%	"
"	South West	"	327	61	16%	"

5.4 Conclusions

5.4.1 WA dhufish

Both passive and targeted fishing methods indicated that the catch of WA dhufish has a bimodal depth distribution with peaks at 40 to 59 m and 80-99 m. The highest proportion of dhufish were caught at 40-59 m.

Undersize and legal sized WA dhufish are relatively evenly distributed among all depth ranges.

The three line-fishing sectors target dhufish at different depths. Recreational fishers target dhufish in the shallows (20-39 m), commercial fishers target dhufish in deeper waters, while the charter boats target the depth range (40-59 m), where the majority of dhufish were caught.

The proportions of the dhufish catch discarded vary among sectors (recreational average 43.5 %, charter boat 35% and commercial 24%). The proportion of commercial dhufish discarded was almost half that of the recreational fishers, and is perhaps related to the experienced commercial operators ability to avoid areas where small fish are abundant.

Localised depletion around the Perth metropolitan area (Hesp *et al*., 2002) means that some fishers now travel further to catch WA dhufish. The results of this study (and from discussions with recreational fishers) suggest that recreational fishers drive further north or south to fish for dhufish in shallow depths, rather than travelling to deeper offshore waters. Charter boat and commercial fishers, however, may fish deeper sites to catch this species and if so, discard mortality will likely increase with a shift to the deeper sites.

5.4.2 Snapper

Both passive and targeted fishing methods indicated that although snapper are caught at depths of up to 200 m in WA, the catches have a bimodal depth distribution with two peaks, one at 20 to 59 m and another at 80-99 m. Most snapper are caught between 20 and 59 m.

The patterns of distribution of undersize and legal sized snapper vary amongst the data depending on location and method of fishing. Most legal size fish are caught shallower (40–59 m) than most undersize fish (80-99 m) in two commercial methods, gillnets and lines, on the West Coast Bioregion. The depths of capture of undersize and legal snapper by charter boat fishing along the West Coast varied according to the particular area fished and differed to every other dataset because the proportion of undersize and legal size fish was relatively similar among depths. This may be explained either by the diverse nature of this industry, where boats in each port may fish differently; or is related to different spatial distribution of the stock in each zone, perhaps as a consequence of the availability of suitable habitat.

In WA the overall proportions of the recreational snapper catch discarded was about half the rate of recreational fishers releasing snapper nationally, perhaps as a consequence of the status of different stock distributed around the Australian coastline and the behaviours of spatial behaviour of fishers.

6.0 Community education of best methods to release demersal reef fishes

6.1 Background

This chapter deals with the last objective of the project: Objective 3: "Educate fishers in optimal catching and handling techniques to minimise the mortality of released fish".

The intent of this objective was to educate fishers once optimal catching and handling techniques were developed. The caging experiments were completed within two years of the commencement of the study and provided information about the effect of depth, barotrauma and hooks on release mortality of snapper and dhufish. The caging experiments, however, did not address optimal catch and handling methods that were addressed by the tagging study.

The National Strategy for the Survival of Released Line Caught Fish commenced in 2001/02 with the aim to improve the survival of released fish. The National Strategy began with a review of the current knowledge and priority issues for the State fisheries agencies. In 2003 the National Strategy for the Survival of Released Line Caught Fish began an Australian-wide programme promoting best practices. Due to differences in the timing of the commencement of the National Strategy and our project, FRDC 2000/194 was the only research project that began before the education programme of the National Strategy for the Survival of Released Line Caught Fish. Thus, in addition to the programme run by the National Strategy for the Survival of Released Line Caught Fish, the education of WA fishers in optimal catching and handling techniques was provided by ANSA-WA, RecFishWest and the Department of Fisheries.

FRDC Project 2004/051 'Management and monitoring of fish spawning aggregations within the West Coast Bioregion of WA' commenced in mid 2004. The project involved a high level of community involvement through the 'Samson Science' project and an extensive series of public workshops and seminars were provided through 2004 and 2005 to train and liaise with project participants. A newsletter, internet forum (on the *Western Angler* website) and print/radio/TV media were used to promote the project and disseminate results.

The Australian National Sportfishing Association is the umbrella organization for the state ANSA's. Tagging programmes run by ANSA have separate names reflecting their affiliations. For example Austag is the national programme run by ANSA and Westag is the tagging programme run by ANSA-WA.

The "education of fishers" includes promotion of the tagging programme, which was imperative for its ultimate success and was done throughout the entire project. As well as increasing participation, a greater awareness of the tagging programme focuses fishers on the underlying reasons for releasing fish. Thus, "education of the fishers of optimal catch and handling techniques" comprised two parts, awareness of the tagging programme and providing information on the optimal catch and handling techniques to minimise the mortality of released fish. Both parts of this objective were achieved through different types of communication:

Verbal: including radio discussion and formal talks at public forums and fishing clubs;

Visual demonstrations both live and recorded (TV and DVD);

Printed reading material; and

Internet including websites of participating organisations and the National Strategy for the

Survival of Released Line Caught Fish as well as internet discussion forums.

Accordingly, this chapter is divided into four sections.

6.2. Verbal communication

Verbal communication including radio discussion and formal talks at public forums and fishing clubs.

RADIO: In 2001 a weekly radio programme ‘Hook Line and Sinker’, co-hosted by RecFishWest Frank Prokop, regularly discussed ANSA-WA’s tagging programme. Interesting recaptures were discussed on the show and ANSA-WA members, such as Steven Wiseman, were interviewed by phone or in person. Another radio programme, ‘Talking Fishing’ also promoted the programme. Unfortunately for the tagging programme, these radio programmes were discontinued by mid 2002.

Excerpts of radio shows

720 ABC Perth, Hook line and sinker - 23/12/01

Interview about Dhufish tagging with Steve Wiseman, Secretary of ANSA-WA

RI “tell us about this wonderful co-operative tagging programme that you have got running now with Fisheries”

Steve “…it an exciting program that’s been running for a few years (and its) gone into its latter stages and hope to have a full promotion out to the public so the awareness is there. There are a lot of tagged fish off Perth’s waters , Dhuies, and we are getting quite a number of recaptures

RI “..I understand ANSA has been working very hard at exploding some of these myths (that fish die after release)

Steve “… (and their) growth rates are still very good….A lot of work has been done on the release of Dhufish using shotline.. Garry Lily has a very successful method of releasing the Dhuies which we hope to have out in brochure form.

Find us through the Fishery website, ANSA website..”

RI “And you’ve got a fair bit of money out of FWA for a dedicated research programme now I understand?

Steve “.. enough to do a worthwhile job.. we are looking at gaining info on a valued species (such as) Dhufish, snapper, baldchin, they are all species of fish that are depleting in quantity around Perth”….

“This is talking tagging with Judy and Frank”

720 ABC Perth, Hook line and sinker with Jody Hoffman - 27/01/01

Steve "I have rounded up some information on the tagging program that ANSA and WA Fisheries are running with our demersal fish off the coast….theres been a lot of debate about the Dhufish released (that are caught) from 30-40 m off Perth… in excess of 300 dhufish tagged and in excess of 35 recaptured so they are surviving…its out there feeding again even though they have been tagged and released and they are growing quite well…

6PR Perth, Talking Fishing - 02/02/01

Steve "Id like to report a recaptured Dhufish through our tagging program with ANSA and Fisheries…results are going out, with have over 350 tagged Dhufish out there… recaptures now are over 50…..fisheries are now gleaning a bit of information from the recaptures and we have growth rates… (example of one fish)…"

RI " I got some information during the week from Peter Anderton and he was saying that your recapture rate is a just bit under 10% which is a fairly high percentage. What sort of interpretation do you put on that?"

Steve " Well its hard to say, we're a bit bemused. If we have such a high recapture, are there so few fish out there? And the other thing is with such a high recapture, are we now hitting on a way of getting them back that they are now surviving? ... there are two ways of looking at it and we really haven't got enough information to go into any great depth ..its still an undefined area and were still learning and we gotta learn to save the fish. "

RI "…Have you had someone just throw a fish back and not do the punch or the (shotline) method ... not going to the trouble you guys do?"

Steve " We have got it on our sheets to put down what hook type,…., we have got three different methods of release, the venting, or (simple) and of course the shotline so we are trying all methods of release although Joe Blow public would just toss it over the side.

Talks

There were many talks given to fishers throughout the years of the project. Talks about the tagging study were organised by Department of Fisheries, RecFishWest, Fishing clubs or groups and tackle shops. A two-year period was chosen to demonstrate the forum and location of presentations (Table 6.1). Of the 20 talks given during 2003 and 2004, 13 were given in the metropolitan area and seven were given in regional areas in the lower west coast (Table 6.1).

Table 6.1. Presentations to fishers in public or club meetings about the tagging program and results by location, group and date during 2003 and 2004 Information about the addressed given by either the tag facilitator or the PI of the project (research scientist).

Location	Group	Date
REGIONAL		
	Busselton	
	South-west Regional Recreational Fishing Advisory Committee	27th January 2003
	Naturaliste Gamefishing Club	3rd March 2003
	DoF Research Division's Dhufish and Snapper Research Seminar.	30th June 2003
	DoF Research Division's Dhufish and Snapper Research Seminar.	7th December 2003
	Geraldton	
	DoF Research Division's Dhufish and Snapper Research Seminar.	7th July 2003
	DoF Research Division's Dhufish and Snapper Research Seminar.	13th December 2003
	Lancelin	
	Lancelin Fishing Club	7th August 2003
METROPOLITIAN AREA AND FREMANTLE		
	Cockburn Sound	
	Cockburn Powerboat Association	19th March 2003
	Cockburn Powerboat Association	26th October 2003
	East Fremantle	
	Swan Yacht Club	8th December 2003
	Fremantle	
	Metropolitan VFLOs meeting, Dept of Fisheries Office	20th July 2003
	Volunteer Fisheries Liaison Officers (VFLO's)	7th September 2003
	Perth Game Fishing Club	15th December 2003
	Hillarys	
	Australian Anglers Association fishing clinic, Hillarys Yacht Club	12th July 2003
	DoF Research Division's Dhufish and Snapper Research Seminar	14th July 2003
	Fishing clinic, Hillarys Yacht Club	11th July 2004
	North Beach	
	Marmion Angling and Aquatic Club	10th November 2003
	Murdoch	
	Information and briefing day for large scale samson fish tagging project, Murdoch University	8th January 2004
	Presentation day for samson fish tagging project, Murdoch Univ.	19th March 2004
	Woodvale	
	Got One Tackle Store	18th December 2003

Since 2001, international and national communication of results of the project was delivered to fishery scientists, managers and fishers at the World Recreational Fishing Congress in Norway, The 3rd World Recreational Fishing Conference in Darwin, Australian Society of Fish Biology annual conferences (Bunbury and Canberra) as well as to the Released Fish Survival Committee at Brisbane (Table 6.2).

Table 6.2. Presentations to fishers, fishery scientists and managers about the results of FRDC 2000/194 since 2001.

Conference/workshop	Location and year	Presenter
World Recreational Fishing Congress	Norway, 2006	Frank Prokop
Release fish survival committee workshop	Brisbane, 2006	Gary Jackson for Jill St John
The 3rd world recreational fishing conference	Northern Territory, Australia 2002	St John J, Jackson, G and P Coutin
Australian Society of Fish Biology	Bunbury WA, 2001 Canberra, ACT, 2003	St John J and Moran M. St John J

Dhufish Workshop

The West Australian Dhufish workshop (Pagano & Fuller, 2006) held on June 12, 2004 was funded by Fishcare WA and jointly hosted by Recfishwest and DOFWA.

Over 100 people attended the workshop and had the opportunity to partake in discussions throughout the day. The workshop was divided into three sessions. In the first session entitled 'Current Knowledge', the information from research on the biology and physiology of dhufish was presented. The results of the mortality experiments and tagging studies for dhufish were discussed in Section 1.4 entitled "Dhufish (*Glaucosoma hebraicum*) research by the Department of Fisheries. Of the 12 questions posed to the discussion Panel at the end of the first session, five were answered by Dr D Gaughan who presented the information on dhufish research.

6.3 Visual communication and demonstrations

For the purposes of this report, visual communication includes live demonstrations for tag training and TV and DVD mediums, except audio-visuals played on the net.

Demonstrations

For the first few years, tag training was handled by Peter Anderton and Steven Gilders. Andrew Rowland trained taggers when he joined the programme as a tag facilitator in late 2002. The release weight has been demonstrated during the fishing clinics since 2003.

TV

In 2001 the tagging programme received some TV coverage on Channel 31's 'Fishing Show' and 'Just Add Water'. In 2003 the National Strategy for the Survival of Released Line Caught Fish ran TV commercials showing important tips on maximising post-release survival of fish using the national football personality "ET" during the cricket season.

DVD

Recently, RecFishWest has been funded by Round 5 of the Recreational Fishing Community Grants Programme to produce a DVD about the release weight. The DVD will contain live action on how the Release Weight works and will provide important tips on maximising a fish's post-release survival. It is planned to have a locally recognisable fishing identity as the presenter for the Release Weight DVD (5,000 DVDs to be printed).

6.4 Printed material

Printed reading material includes posters, brochures, instructions, articles, newsletters and advertisements.

Posters

In 2000 and 2001 50,000 display posters with the message 'Tags Wanted' and 10,000 information sheets about the tagging programme were printed by ANSA-WA. Posters were distributed to ANSA clubs and tackle shops from Geographe Bay to Port Hedland, and the August Boat Show and The 4 Wheel Drive and Camping Show. The Department of Fisheries included posters in their mail-out to all charter boats operators (see Appendix 1.3).

Instructions and tag data sheets:

Tag data sheets were designed by ANSA-WA members and fisheries staff to ensure that the data about each fish was being collected. Instructions on how to tag a fish was written and given to all tag trainees (see Appendix 1.4).

Brochures

RecFishWest has produced three brochures. They are

How to use a Release Weight

What to do when you catch a tagged fish

Preliminary results

How to use a Release Weight

The first print run was 2000 brochures in 2003 followed by a second print run of 10,000. Of these 2000 were sent to Bill Sawynok, National Strategy on Released Fish Survival. This release weight brochures has had significant National and world-wide interest and has been sent all over Australia and to the USA, Japan and South Africa. All of the release weight brochures have been distributed (see Appendix 1.2).

In 2007, RecFishWest has been funded by Round 5 of the Recreational Fishing Community Grants Programme to re-design and reprint another 20,000 brochures.

What to do when you catch a tagged fish

"As many fishers want to help research but do not know what to do if they catch a tagged fish, I wrote and printed a flyer aimed to improve the information provided by recreational and commercial fishers when they catch a tagged fish" (Andrew Rowland 2004)

This is a waterproof flyer designed to be kept in tackle boxes or on boats. It provides general background information on the tagging project and, importantly, a place to record the information about the capture of the fish required for research (eg. total length, water depth etc.). The first print run of the flyer was 20,000 and has proved useful to the tagging programme because it is very popular among fishers. These flyers have been distributed to tackle shops and the Department of Fisheries. Staff from the Department of Fisheries and RecFishWest, particularly Andrew Rowland, hand out these flyers at fisher meetings and presentation nights. Also the Department of Fisheries Volunteer Fisheries Liaison Officers (VFLOs) give out brochures during their patrols of boat ramps and popular fishing spots (see Appendix 1.5: What to do when you catch a tagged fish).

Preliminary results

This brochure describes the preliminary results of the tagging study for dhufish and snapper. The initial print run was 1000 copies in 2005 (see Appendix 1.6: Preliminary results). This brochure is on the RecFishWest and the National Strategy for the Survival of Released Line Caught Fish websites.

The Department of Fisheries have discussed barotraumas and the release weight in several of their booklets and brochures, many of which are available on the fisheries website.

Each bioregion in the state has a guide to recreational fishing and the every booklet includes a section on releasing tips (see Appendix 1.7: Recreational Fishing guide – West Coast Bioregion)

Catch care - tips for recreational fishers

In the section on "Fish n tips" this booklet discusses releasing fish as well as hooking etc. (see Appendix 1.8: Catch care)

Fact Sheet 3 "Jewel in the Crown"

Fact sheet about the West Australian dhufish available on the web at http://www.fish.wa.gov.au/docs/pub/FactSheets/dhufish-download.php . This fact sheet includes a discussion box on barotraumas and the release weight. (see Appendix 1.9: Fact Sheet 3)

Articles

Since 2001 articles about the tagging study and its results have been published in general newspapers, including The West, Sunday Times, and local community papers. The West Australian newspaper has run articles with photos written by journalists and ANSA-WA member, Peter Anderton, on ANSA-WA in the Friday Fishing Section, Saturday's Boating and Camping Section and in the General News Section on a Wednesday.

Articles about survivorship of released fish and the tagging programme have appeared in specialist fishing magazines including Australian Boating and Fishing magazine, Western Angler, Hotbite and Fishing WA Magazine. Since 2000 articles about survivorship of released fish and the tagging programme have been published in Western Fisheries, the magazine of the Department of Fisheries.

In addition to articles written for general readership or fishers, several papers and abstracts have been published in scientific journals and conference proceedings. Due to the publicity of the programme, Jill St John was approached to write about survivorship of released fish and the tagging programme for two international specialised newsletters, *Live Reef Fish Information Bulletin* (no. 11), published by the Secretariat of the Pacific Community, and *Tagging News* (no. 18), published by the South African Association for Marine Biological Research, South Africa (see references).

Newsletters

When Tamlin Little was the tag co-ordinator for ANSA-WA, he provided monthly updates on the website.

A monthly Tagging newsletter entitled Westag Update Bulletin which was produced by Andrew and emailed out to all taggers to provide up to date tag information and necessary reminders (see examples attached).

Austag produces an annual report that includes tagging information from each state including Westag (http://www.ansa.com.au/Sportfishing.htm).

Advertisements

Throughout 2001 the 'Tags Wanted' poster was run as an advertisement in the fishing magazine "Western Angler". In 2007, RecFishWest ran a one-page advertisement on the release weight.

6.5 Websites

Several websites promoted the ANSA-WA tagging programme by either providing information on the tagging programme or results or links to these websites. These included the websites of ANSA-WA, ANSA national, RecFishWest, FRDC and National Strategy for the Survival of Released Line Caught Fish as well as the websites of West Australian fishing magazines.

The ANSA-WA website, http://www.ansawa.iinet.net.au/westag.html, promotes their tagging programme (Westag) and the national code of ethics. It has links to ANSA national website and tagging programme (Austag).

ANSA national website and tagging programme (Austag) http://www.ansa.com.au/ has a link to the Release Fish Survival website (http://www.info-fish.net/releasefish/default). The Recfishing Research website (http://www.recfishingresearch.org/reports) also provides a central site for information on maximising survival of released fish. The National Strategy for the Survival of Released Line Caught Fish website, is dedicated to the education of fishers on best practices of releasing fish and has information about the nations current research including information about the FRDC 2000/194 project. It has a copy of the preliminary results of the west coast tagging programme form the RecFishWest website (see Appendix 1.6).

The FRDC website http://www.frdc.com.au/recreational/catch/ has a link to the National Strategy for the Survival of Released Line Caught Fish. (See Below Excerpt from the Catch and Release sub-programme).

> The National Strategy for the Survival of Released Line Caught Fish is an initiative of the Fisheries Research and Development Corporation (FRDC) in conjunction with the Australian National Sportfishing Association (ANSA) and Recfish Australia. The strategy aims to improve the understanding of and increase the survival rates of released line caught fish.
>
> The National Strategy promotes best practices in releasing fish by recreational fishers and includes a number of research projects into aspects of fish survival. The National Strategy involves projects aimed at achieving the following outcomes.
>
> Improving the survival of released line caught fish through:
>
> A better understanding of the effects of fishing; and
>
> Increased adoption of best practices in handling fish.
>
> Improving fisheries management through:
>
> A reduction in the total mortality of released line caught fish; and
>
> Inclusion of recreational catch and fish survival data in fisheries stock assessment.
>
> More information visit the release fish survival website.

The Recfishwest website, at http://www.recfishwest.org.au/**,** lists research information including:

Release Weight to Improve the Survival of Released Reef Fish;

Tagging and Research Program - Survival of Released Fish;

Maximising the Survival of Released West Coast Reef Fish: - Preliminary Results up to early 2006; and

Proceedings of the Western Australian Dhufish Workshop 2004.

All of this research is about or discusses the results of the tagging programme. Also, the site regularly publishes electronic newsletters that provide update on the tagging programme and links to these research articles and brochures in the website. The articles on the RecFishWest website link to the Austag website and mention the National Strategy for the Survival of Released Line Caught Fish. The National Strategy for the Survival of Released Line Caught Fish has duplicated some of this information on their website.

The local website-based forums include *Western Angler*, *Fishwrecked*, *Hotbite*, *Fishing WA*, *Breammaster* and *The South Coast Fishing Forum*. Out of these forums, only two *Western Angler* and *Fishwrecked* discuss environmental issues and the *Western Angler* has the largest and busiest website-based forums where anglers can discuss fishing issues of interest (http://www.westernangler.com.au/forum/). Anglers must register with a distinct user name to participate (initiate a topic or reply to an issue raised). The forum is divided into discussion groups and each site is assigned a moderator to manage the discussion. The ANSA-WA tagging programme and subsequent recaptures were discussed in five of these forum topics since October 2003 (Table 6.3). These five topics had over 160 discussions, 1000 replies and 57,000 hits. It is important to note that these numbers represent only the initial interest in these subjects as the discussion may branch out from individual replies generating a new discussion with further replies and many more hits or discussions.

Table 6.3. The numbers of discussions initiated about tagging including replies and hits, categorized by fish species, over a given time period. Hits on topic are the number of times the topic was visited.

Forum	Topic	Tagging related			
		Discussions	Replies	Hits	Period
Fishing Reports	Sampson	5	7	n/a	22/11/03 - 8/6/06
	Snapper	3	41	2338	4/12/2004 - 23/8/07
	Other	11	77	5179	7/10/03 - 14/8/07
Samson Science	Recapture	11	148	9233	9/02/05 -10/10/07
	Other	16	211	12590	10/01/05 - 21/9/07
Tackle Talk	All	8	5	573	29/6/03 - 19/9/07
General Fishing Discussion	Snapper	1	3	n/a	20/12/06 - 5/1/07
	Dhufish	3	17	n/a	6/7/04 - 9/1/07
	Sampson	3	9	n/a	21/1/05 - 15/10/07
	Other	53	140	5967	25/6/03 - 11/9/07
Fisheries Management & Environmental Issues	Snapper	3	23	787	8/9/04 - 25/8/06
	Dhufish	8	135	6084	19/3/04 - 24/7/07
	Sampson	4	30	1391	28/6/04 - 9/9/05
	Other	33	247	12890	13/8/03 - 8/10/07

The website of the fisheries department has no link to the ANSA tagging programme apart from the Samson Science tagging project that was discussed in the section on research volunteers.

7.0 Project summary

7.1 Benefits and adoption

The results of the experimental component of the study explain the importance of depth on the release mortality of two important demersal reef fish on the West Coast, West Australian dhufish and snapper. Clearly the depth of the fishing habitat is a key factor to be considered when assessing management options for these demersal fisheries. Results from the tagging study showed that recapture rates varied between the four demersal species examined in relation to release method, depth of capture and condition of fish after capture. Also, the investigation into the depth distribution of legal and under size WA dhufish and snapper reveals that the average depth of habitat fished and behaviour by fishers varies among and within the various fishing sectors. Such information suggests that optimal management arrangements could differ between the fishing sectors.

One of the major outcomes of this project was the development of the shotline method of releasing fish: the shotline device was developed by Garry Lilley and ANSA-WA friends. This device was adopted and tested by the tagging programme and results show that the use of the shotline is extremely successful in alleviating the impacts of barotrauma by returning fish quickly to their depth of capture. In contrast, venting fish had little effect on recapture rates. The shotline release has been promoted throughout Australia and has had some exposure internationally. It has been well received by the fishing public of WA and its use should continue to be adopted as the results of this study are promoted.

Results of this study have already been incorporated into the management of the Shark Bay commercial snapper fishery that uses a catch quota system based on annual Total Allowable Catch (TAC). Line fishers in the managed fishery take their proportion of the snapper TAC as well as other demersal species, e.g. lethrinids, as bycatch. Until relatively recently, other commercial fishers, who were not in the managed snapper fishery, were able to line fish species other than snapper. Fishing deep waters outside the bay, these line fishers were releasing more than half of their catch because it was snapper that they were unable to land without a quota licence. The high rates of post-release mortality of snapper at deep sites found in this study dictated that these non-snapper fishers be excluded from within the boundaries of the Shark Bay managed commercial snapper fishery during the times of peak snapper catches.

The susceptibility to barotraumas, the lower recapture rate and decreased survivorship of dhufish with increasing depth has led to concerns about the usefulness of legal minimum lengths (and bag limits, but noting that most fishers do not attain their bag limit) as a management tool for this species. For this reason, seasonal and/or spatial closures were investigated as alternative, additional management tools in proposals for new management plans for all West Coast Bioregion demersal species. Results of the tagging study and the caging experiments have led to much discussion within the recreational fishing community and the industries that rely on recreational fishing about possible management measures and have paved the way for acceptance of the need to consider survival rates of released fish when developing new management strategies.

7.2 Further Developments

The shotline device should be used by all fishers of demersal species so should continue to be promoted.

The research found that circle hooks should be used in preference to standard hooks because the use of circle hooks results in less fish being gut-hooked. In the tagging study, only one third of fishers used circle hooks and only 0.1% of fishers used barbless hooks. Further study on the effects of barbless hooks is required to determine whether they reduce gut-hooking and other hook damage. Further information on the catch rates of various hooks (including types not tested here) and their impact on the fish caught is likely to be required before fishers are convinced to change their fishing habits.

Differences in depths fished varied between species and among fishing sectors

The synthesis of information about size of snapper and dhufish caught at different depths revealed that line fishers from the different sectors fish different depths. The highest proportion of dhufish samples caught by each sector became progressively deeper for recreational fishers (20-39 m), charter boat operators (40-59 m) and commercial fishers (80-99 m). In contrast, the highest proportion of snapper caught occurred across both shallow and medium depths (20-39 m and 40-59 m) for the charter boat operators and only at medium depths (40-59 m) for the commercial fishers. These results highlight the crucial need to assess the fishing behaviour of extractive stakeholders when considering the fisheries management implications of post-release mortality. Finer resolution spatial and effort information across all sectors would greatly assist with interpretation of current data and any new tagging data that becomes available, as well as allowing more considered conceptualization of what any “new” management tools will actually achieve.

7.3 Planned outcomes

This project has provided fishery managers with information on release mortality of four important commercial and recreational demersal finfish species. This project has also assessed the effects of the three methods used to release these species on their recapture rates as well as describing the size distribution of the catches of the two most important species of demersal scalefish along the lower west coast, snapper and WA dhufish. Lastly, public awareness of catch and release as well as the methods used to minimise mortality has increased throughout the seven-year study.

Promotion of optimal catching and handling methods by the Department of Fisheries WA in partnership with RecFishWest will be continued after the completion of this project as part of the agency’s ongoing “Fish for the Future” program of encouraging responsible fishing practices.

7.4 Conclusion

Objective 1

Objective 1 was to “Estimate mortality of hook and line caught west coast reef fish released back to the sea, taking account of hook type, depth of capture and on-board handling techniques”.

This was undertaken for the two most common demersal species, the snapper *Pagrus auratus* and the West Australian dhufish *Glaucosoma hebraicum*. Additional information on the recapture rate of two other demersal species, breaksea cod *Epinephelides armatus* and baldchin groper *Choerodon rubescens*, was obtained from the tagging study.

In this section, the effects specifically mentioned in the objective (depth of capture, on-board handling techniques such as venting the swim bladder, and two hook types) will be discussed even though additional factors in the analysis of the cage experiment (length of fish, duration of caging, the ability of released fish to swim and cage crowding) and tagging study (fish condition, barotraumas symptoms, days at liberty and movement) were also examined.

Hook types

Both the tagging and cage experiment found that the incidence of gut hooking varied between species and hook type. In the caging experiment hook type was found to have no effect on mortality. Although mortality in gut-hooked fish was high (70% in dhufish and 91.7% in snapper) it occurred in 11% of the total catch of dhufish but only in 2% of snapper. Overall 7.8 % of the total catch of dhufish died from gut-hooking but a further 5.5% of the total catch of dhufish died from severe bleeding caused by hook damage elsewhere (e.g. gills).

The tagging study found that more J hooks were swallowed than circle hooks and dhufish were more likely to swallow hooks than snapper. None of the released gut-hooked fish were recaptured. Results of this research suggest that circle hooks should be used in preference to J hooks to reduce gut hooking, and therefore mortality, in these demersal fishes.

Depth of capture

Depth of capture was the most important factor affecting mortality. Mortality of snapper at depths up to 30 m was very low, with a marked increase in mortality between 30 and 45 m, then a further increasing trend in mortality from these intermediate depths (45 m) to the deepest site (65 m). Mortality was higher in dhufish overall and gradually increased with depth from 21% at 0-14 m to 86% at 45-59 m.

The tagging study examined recapture rates that could not be translated directly into mortality because many of the assumptions of tagging studies were not addressed. Nevertheless, results of recapture rates found that, similar to the caging experiments, recapture rates of dhufish decreased with depth. The recapture rates of snapper also decreased with depth, albeit at a slightly slower rate.

Onboard handling methods (simple, vented and shotline release methods)

In both dhufish and snapper the tag recapture rates of the simple and venting release methods did not vary significantly. The shotline release method improved recapture rates of dhufish, particularly those caught in deeper water. Snapper recapture rates in deep water were enhanced by the shotline release method. Although breaksea cod had a much lower recapture rate than dhufish and snapper, the effects of depth and the shotline release methods appeared to be most similar to dhufish. No released baldchin groper were recaptured.

Objective 2

The second objective, "Collect information on the size of west coast reef fish in relation to depth, to assess the proportion of undersize fish at different depths", of the research project was met.

In WA, WA dhufish and pink snapper catches have a bimodal depth distribution with peaks in catches at 20-59 m and 80-99 m. Catches of both species appear to be greater in the shallow waters, but this may only reflect the concentration of effort by most fisheries at these depths (< 60m). These demersal fish species are not commonly caught between the depths of 60-79 m, and this may be related to lower levels of effort expended at these depths, possibly related to a lack of suitable habitat for both species. The highest proportion of dhufish were caught at 40-59 m and snapper at 20-59 m depth. In WA, snapper were caught at much deeper sites (up to depths of 200 m) than dhufish.

The patterns of the proportion of undersize and legal fish in catches from different depths varied between the two species. Catches of undersize and legal sized WA dhufish were relatively evenly distributed among all depth ranges, but the three line-fishing sectors caught dhufish at different depths. Recreational fishers caught dhufish at shallow (20-39 m) depths; commercial fishers caught dhufish at deeper locations (80-99 m), while the charter boats primarily caught dhufish at depths of 40-59 m. In contrast, proportions of undersize and legal sized snapper varied in depth depending on location and method of fishing. In the West Coast Bioregion, legal size fish were caught more commonly caught at shallow (40-59 m) sites than undersize fish (80-99 m). The depths of capture of undersize and legal snapper taken by charter boat fishing along the West Coast varied according to the particular area fished, and differed to the patterns revealed by other sectors.

The proportions of the dhufish catch discarded varied among sectors (recreational average 43.5%, charter boat 35% and commercial 24%) with recreational discards being almost double commercial discards. On the basis of the results of this study, discards by recreational fishers would be expected to cause overall lower rate mortality than commercial discards, because recreational fishers target dhufish at shallower depths. Overall, the proportions of the recreational snapper catch discarded was similar among recreational and charter boats (~40%). The discard rate for snapper, however, depends on the location fished.

Objective 3

The third objective is to “Educate fishers in optimal catching and handling techniques to minimise the mortality of released fish” and is ongoing, as the results of the tagging study are made public.

This objective formed two parts,

Awareness of the tagging programme and

Providing information on the optimal catch and handling techniques to minimise the mortality of released fish.

Since the tagging programme began over seven years ago there has been a huge increase in awareness about catch and release fishing and post-release mortality of demersal fishes.

Four different types of communication (verbal, visual demonstrations, printed reading material and the internet) were used to educate fishers in optimal catching and handling techniques.

Promotion of optimal catching and handling methods by Fisheries WA will be continued after the completion of this project as part of the agency’s ongoing “Fish for the Future” program of encouraging responsible fishing practices through brochures, TV advertising, fishing clinics, school visits etc.

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9.0 Appendices

Appendix 1 ANSA tag data sheet

WESTAG
SPORTFISH TAGGING SHEET
Phone:- 1800 682 002

Return sheets to:
Mail - ANSA WA TAGGING COORDINATOR
PO Box 366 Osborne Park W.A. 6917

Fish for the future

FISHERIES WESTERN AUSTRALIA
FISHERIES RESEARCH & DEVELOPMENT CORPORATION

Sheet No: Date Forwarded: Club:

TAG No.	DATE	ANGLER	LOCATION	SPECIES	TOTAL LENGTH (mm)	LENGTH CAUDAL FORK (mm)	DEPTH (m)	Normal Hook	Circle Hook	Gut Hooked	Lip Hooked	Jaw Hooked	Simple Release	Vented Release	Shotline Release	Body Movement	Fin Movement	No Movement	Scales Raised	Eyes out of sockets	Bubbles in Eyes	Large Swim Bladder	Stomach in Mouth	COMMENT RELEASE CONDITION

Appendix 2 Release Weight Brochure Recfishwest

Advantages

- Gets the fish back to its habitat fast.
- Re-pressurises the fish to lessen the effects of barotrauma.
- Reduces predation through decrease surface and mid water exposure time.
- Showing signs of increased recapture rates for several species.

Fish Handling

- Keep fish out of water for a minimum time possible.
- Work fast but without haste.
- Always use wet hands or a wet cloth.
- Place fish on a wet surface. Avoid hot dry surfaces.
- Avoid contact with gills and eyes of fish and try to keep shaded (particularly dhufish).
- Fully support the body of large fish at all times to avoid organ damage.

Some of the species for which the release weight can be used :

- ✓ West Australian Dhufish
- ✓ Pink Snapper
- ✓ Breaksea Cod
- ✓ Mulloway / Northern Jewfish
- ✓ Red Emperor / Coral Trout
- ✓ Baldchin Groper and other Tuskfish
- ✓ Various Cod Species
- ✓ Nor-west Snappers

It is the responsibility of every angler to maximise the chances of survival of fish that are released.

This information is provided as part of the National Strategy on the Survival of Released Fish.

Fish Today – For Tomorrow

Fish for the future

Australian Government Fisheries Research & Development Corporation

Released Fish Survival

Distributed by Hill Mako Tackle
Bellevue, Western Australia
(08) 9274 5255

THE RELEASE WEIGHT

TO IMPROVE THE SURVIVAL OF RELEASED REEF FISH

The release of marine fish has become increasingly important to recreational anglers. Fisheries regulations and management tools such as size limits, bag limits and closed seasons as well as a stronger conservation ethic has resulted in more fish being released.

Many reef species, such as dhufish and breaksea cod, are susceptible to pressure related injuries called barotrauma when raised to the surface from depths of around 20 metres or more.

Barotrauma results from the expansion of gases in the swim bladder and other organs when fish do not have time to adjust to the rapid changes in water pressure as they are pulled to the surface.

The physical effects of barotrauma can be seen in the form of inflated abdomen, bulging eyes, stomach pushed into the mouth and distended intestines.

Signs of barotrauma - Breaksea Cod (left) with stomach in mouth and bulging eye. Pink Snapper with distended intestines.

Undersize or unwanted fish that are returned to the water showing signs of barotrauma may often have difficulty swimming and returning to the bottom. Such fish may be unable to reach a depth where water pressure would allow their swim bladder to revert to the normal size and therefore may require special handling to improve survival. Many anglers have been concerned to see released fish drift away on the surface and wanted a simple method to help survival.

The Release Weight

This device essentially comprises of a weighted barb-less hook. The release weight can either be connected to an existing fishing rig via the clip or used on a rod and reel or hand-line specially set aside for releasing fish.

The Release weight is attached through the lip of a fish to be released, lowered into the water and dropped back to the reef. It is then easily detached from the fish by a tug on the line when it reaches the bottom leaving it back at the depth where it was captured. In many cases the fish recovers and gets off the barbless hook on the way down.

Using the Release Weight

The release weight is simple to use. The complete release procedure can be performed by one person for small fish while larger fish will need the co-operation of two people.

Single operator – small fish only

Attach the release weight through the jaw of the fish. Hold the fish in one hand and the rod or hand-line ready for free spool in the other. Place the fish into the water headfirst and let the attached line run free as the fish is released.

Two person approach

Whilst one person supports the body of the fish the other can fix the weight in place and then operate the rod or hand-line as the fish is released (cover photo).

It is important to get the fish as deep as possible before it gets off the weight. Beware of any sudden jerk on the line while the fish is descending as this may dislodge the weight from the fish before it has reached the bottom.

Appendix 3 Tags wanted poster - printed by ANSA-WA

Appendix 4 How to tag a fish instructions

Fish Tagging

Handling

Keep the fish out of the water for a minimum time possible.
Always use wet hands or a wet cloth.
Place fish on a wet surface. Avoid hot dry surfaces.
Work fast but without haste.
Avoid contact with gills and eyes of fish and try to keep shaded (particularly dhufish).
Fully support the body of large fish at all times to avoid organ damage.

Tagging Procedure:

1) Have tag applicator loaded and in a handy spot before you start fishing.
2) Lay the fish against a solid surface to tag and measure.
3) Insert the tag close to the dorsal fin.
4) The point of the tag should be inserted at a 45 degree angle towards the fish's head with the tag's barb up, pointing toward the tagger.
5) Inserted the tag so the streamer slants towards the tail of the fish and deep enough so that the barb passes between the bones of the dorsal fin spines.
6) Give the tag applicator a twist while in the fish to properly anchor the tag between the internal fin rays and remove.
7) Tug lightly on the streamer to ensure a secure fit.

Tagging Tips

Attempting to implant the tag into a fish not fully under control could result in poor tag placement.

Be sure to record **all information** on the data sheet provided (length, date, location, etc.). Also record any observations on the fish health, injuries or the general procedure.

Keep tagging equipment clean to ensure fast and easy tagging.

The less you handle the fish, the better the chances of the fish surviving. Fishers that adhere to proper handling techniques will ensure that tagging efforts produce useful information.

It is very important that the project receives precise data on each fish to maximize the value of each recapture. Please return completed data sheets and report recaptures without delay.

Thank you for lending a hand!

GOOD LUCK!!!!

Appendix 5 What to do when you catch a tagged fish - Recfishwest

Tagged Fish Information Sheet
Phone: 1800 682 002

TAG NO.	DATE	ANGLER'S NAME & CONTACT DETAILS	LOCATION (e.g. 2km NW of Carnac Island or GPS)	DEPTH

SPECIES	TOTAL LENGTH	CAUDAL FORK LENGTH	CONDITION AND COMMENTS (e.g. fish released, good condition)

Please release undersize tagged fish with tag intact. Tagged fish greater than minimum legal length can be kept, however we encourage the release of all tagged fish as multiple recaptures can greatly increase our knowledge and understanding of many fish species.

This project is proudly supported by:

Department of Fisheries
Government of Western Australia

Australian Government
Fisheries Research & Development Corporation

Appendix 6 Preliminary results - Recfishwest

MAXIMISING THE SURVIVAL OF RELEASED UNDERSIZE WEST COAST REEF FISH

(FRDC PROJECT 2000/194)

PRELIMINARY RESULTS

Project Background

Many anglers are keen to know the fate of released fish and how to best enhance their chances of survival. The information contained here details the preliminary findings of a collaborative WA project designed to study the post-release survival of released reef species. The results discussed here focus on the West Australian dhufish (*Glaucosoma hebraicum*) and pink snapper (*Pagrus auratus)*.

Barotrauma

Barotrauma results from the expansion of gases in the swim bladder and other organs when retrieved fish do not have time to adjust to the rapid changes in water pressure as they are pulled to the surface. Undersize or unwanted fish that are returned to the water showing signs of barotraumas may often have difficulty swimming and returning to the bottom. Such fish may be unable to reach a depth where water pressure would allow their swim bladder to revert to the normal size and therefore may require special handling to improve survival. Furthermore, barotrauma injuries may have longer term internal effects that may influence the survival of a released fish.

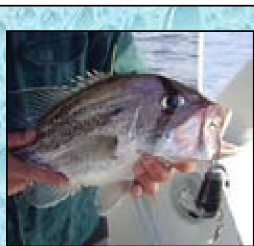
Various reef species, such as dhufish and breaksea cod, are susceptible to barotrauma when raised to the surface from depths of around 20 meters or more.

During this study tagged fish were released by one of three methods:

- ***Shotline*** -a release weight is used to return the fish to the bottom.
- ***Vented*** - excess gas is released from the swim bladder using a hollow spike.
- ***Simple*** - the fish is released at the surface with no other treatment.

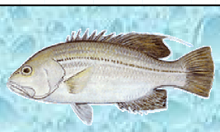
Information collected during this project is providing a better understanding of the post-release survival of some important reef species. The data can help anglers to mitigate the effects of barotrauma and enhance the survival of the released fish.

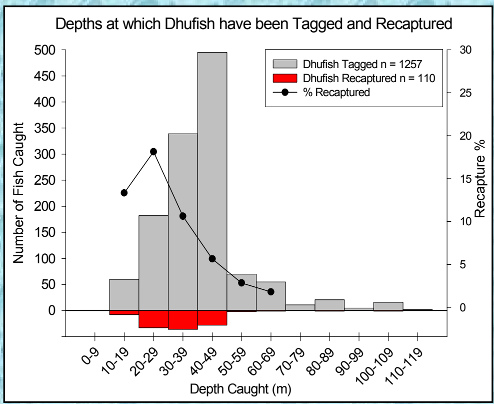
The Release Weight



Appendix 6 continued

West Australian Dhufish
(*Glaucosoma hebraicum*)

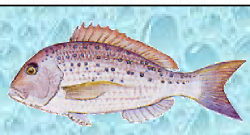


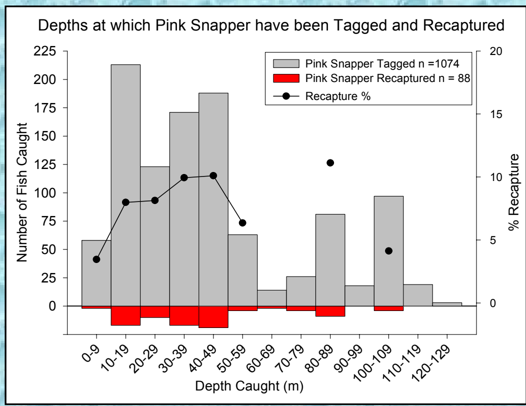


The recapture rates of dhufish fall dramatically from a high of up to 18% in shallow waters less than 30 m to below 2% at 60 to 69m.
Release by shotline is the best release method for the survival of Dhufish (10.1%), whereas venting has the lowest rate recapture rate (2.5%).

Release Method	Total Tagged	Total Recaptured	Percentage Recaptured
Simple	366	23	6.3
Vented	199	5	2.5
Shotline	318	32	**10.1**
Total	883	60	6.8

Pink Snapper
(*Pagrus auratus*)





The recapture rates of pink snapper are similar for all three release methods (close to 10%).
This rate is similar to pink snapper tagged in the shallower Shark Bay region (10.3%) and higher than recapture rates for this species tagged in Victoria (2.1%). Furthermore, the decreasing trend in recapture rates with depth is not evident in this species.

Release Method	Total Tagged	Total Recaptured	Percentage Recaptured
Simple	694	65	9.4
Vented	89	9	10.1
Shotline	37	4	10.8
Total	820	78	9.5

Preliminary Recapture Results Summery

Interesting Facts

- ✓ Survival rates differ between released reef fish that inhabit the West Coast region.
- ✓ Water depth and the choice of release method affect the post-release survival of these species.
- ✓ The deepest recapture for a pink snapper is 118m using simple release.
- ✓ The deepest recapture of a dhufish to date is 90m released using a release weight (shotline).
- ✓ Not one of the recaptured dhufish has shown any significant movement.

Best Handling Practice

- ✓ The release weight is recommended for dhufish that show signs of barotrauma.
- ✓ Venting is not recommended for dhufish.
- ✓ Undersize pink snapper respond well to simple release at depths up to 100m.
- ✓ Careful handling of fish also increases survival.

The survival of dhufish is affected by the depth at which they are caught. Dhufish caught in deepwater may require special handling to improve survival. When suffering from barotrauma many individual dhufish appear unable to reach a depth where the swim bladder can revert to normal size. The release weight dramatically increases the chances of survival of dhufish caught from any depths that show signs of barotrauma. Dhufish released in waters deeper than 40m should be returned to the bottom with a release weight to maximsie survival chances.

Pink snapper are a more robust species and are better adapted to tolerate capture and release in deeper water. The majority of pink snapper released in depths greater than 80m were done so by the simple method. Generally pink snapper are difficult to attach to a release weight because they are very active in the boat and will swim down strongly when released at the surface.

Some Notable Recaptures

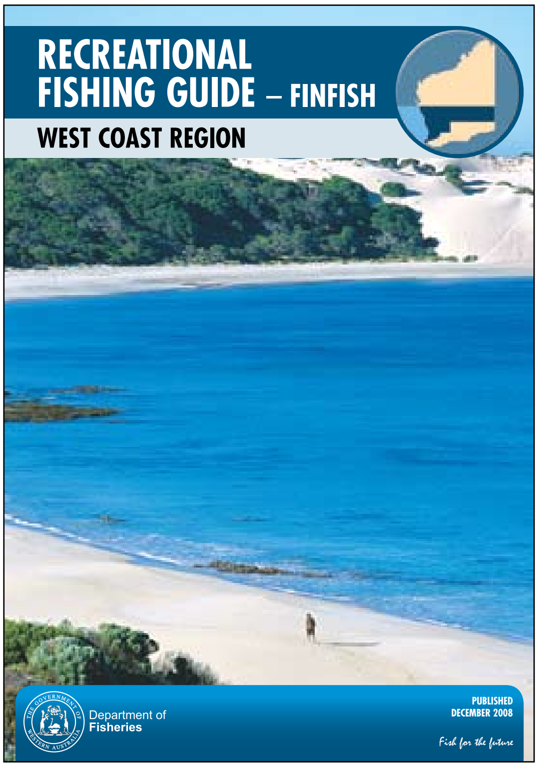
Tag 17525 - Pink Snapper (Nicknamed Yo-Yo)
Originally released by the **Simple method** in March 2003 in **80m**. Since being tagged this fish has been recaptured **5 times** in the same area and each time it has been released by the simple method, with depth recordings of between 80 and 86 metres.

Tag 18148 - West Australian Dhufish
Originally released by **Shotline** in **50m**, recaptured by the same fisherman in the same place **29 days** later. On capture this small dhufish had its stomach pushed into its mouth due to pressure injury but was otherwise in good condition and released with a release weight. This recapture demonstrates that small dhufish can survive barotrauma with the correct release treatment.

Tag 33759 - West Australian Dhufish
Originally released by **Shotline** in **86m**, recaptured in the same area in **90m** after **350 days** at liberty. This is one of the deepest dhufish recaptures to date. The fish originally showed little effects of being caught from deepwater and demonstrates that dhufish can survive deepwater capture and release when treated correctly.

This information is provided by Recfishwest, Westag and the Western Australian Department of Fisheries as part of the National Strategy on the Survival of Released Fish. This research project is funded by the Fisheries Research and Development Corporation.

Appendix 7 Recreational Fishing guide – West Coast Bioregion - DoF



Appendix 8 Catch care - tips for recreational fishers - DoF

FACT SHEET 3

JEWEL IN THE CROWN

Department of Fisheries

West Australian dhufish

Glaucosoma hebraicum

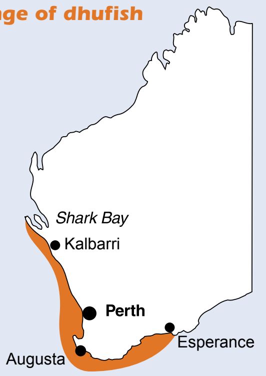
There are good reasons why the West Australian dhufish is a WA fishing icon: it grows to a great size and tastes superb. Most importantly, this fish is found nowhere else in the world.

Exclusive to WA waters

Dhufish are 'endemic' to Western Australia, which means they do not live anywhere else.

Dhufish have been found off the Recherche Archipelago near Esperance and as far north as Shark Bay. However they are most common along WA's lower west coast between Kalbarri and Augusta.

Range of dhufish



Dhufish, not jewfish

In the past, dhufish have also been called jewfish or 'jewies'. West Australian dhufish belong to the Glaucosomatidae family and are related to a number of fish commonly called pearl perch.

Home-lovers

Dhufish prefer to live around rocky outcrops and ledges. They can usually be found in water 20 to 50 metres deep, however sometimes they have surprised fishers by turning up in water just three metres deep.

Tagging studies have shown that they are generally sedentary – that is, they usually do not travel far from home.

An important characteristic of dhufish is they are 'demersal', which means they live near the seabed. As with other demersal fish, dhufish are inclined to suffer 'barotrauma' if caught in depths of 20 metres or more. This is an important issue for managing dhufish stocks as fishers must return undersize and unwanted dhufish to the water.

SEPTEMBER 2007

MarineDiscoveryWest

Appendix 10 Staff

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