Assessing the impacts of gillnetting in Tasmania: Implications for by-catch and biodiversity

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Abbreviations

AFMA	Australian Fisheries Management Authority
ANOSIM	Analysis of similarity
ANOVA	Analysis of variance
DM	Delayed mortality
DPIPWE	Department of Primary Industries, Parks, Water and Environment
ERAEF	Ecological risk assessment for the effects of fishing
FRDC	Fisheries Research and Development Corporation
GAM	Generalised additive model
GLM	Generalised linear model
IM	Initial mortality
IMAS	Institute of Marine and Antarctic Studies, University of Tasmania
IUCN	International Union for the Conservation of Nature
LML	Legal minimum length
PERMANOVA	Permutational multivariate analysis of variance
PRS	Post release survival
PSA	Productivity, Susceptibility Analysis
RFAC	Recreational Fishery Advisory Committee
SESSF	Southern and Eastern Scalefish and Shark fishery
SFAC	Scalefish Fishery Advisory Committee
SICA	Scale, Intensity and Consequence Analysis
SRA	Shark Refuge Area
TEPS	Threatened, endangered and protected species
TSF	Tasmanian Scalefish Fishery

Executive Summary

What the report is about

In Tasmania, both recreational and commercial gillnetting is permitted. This study, conducted by the Institute for Marine and Antarctic Studies between 2010 and 2013, represents the most comprehensive investigation into the Tasmanian gillnet fishery and its implications for by-catch and biodiversity. Gillnet catch composition (target, by-product, by-catch), post release survival, interactions with threatened, endangered and protected species, and implications of management changes on gillnetting practices were investigated. In addition, catch composition and abundances of key gillnet species over the past 20 years were examined using a range of historical data. This information was then used to inform an ecological risk assessment to identify the vulnerabilities of the species impacted by gillnetting.

Background

Recreational gillnet fishers target a wide variety of species with the main target species being Blue Warehou, Bastard Trumpeter, Atlantic Salmon (escapees from marine farms), Australian Salmon and Yelloweye Mullet. The commercial fishery is a dynamic multi-species fishery with fishers adapting to species availability, market preferences and opportunities. Commercial fishers target similar species to recreational fishers although in the early 1990s a fishery targeting Banded Morwong for the domestic live fish trade developed rapidly and the majority of the commercial effort is now directed at this species.

Over the past decade there have been a number of management initiatives, including a prohibition on overnight recreational netting (with the exception of Macquarie Harbour), introduction of attendance requirements for commercial night gillnetting, and more recently the introduction of maximum soak times for both the recreational and commercial fishery, which have been designed to improve fishing practices and reduce wastage and impacts on non-target species. Despite this, there have been conspicuous declines in the abundance of several key gillnet species along with increasing community concern about the ecological impacts of gillnetting. There is a need, therefore, to better understand how recent management initiatives have influenced netting practices and to objectively assess the risks and impacts on target and non-target species. Ultimately such an understanding will be pivotal in informing the on-going debate over the future management of gillnetting in Tasmania.

Aims/objectives

1. Synthesise available gillnetting information, with particular reference to links between operational parameters and catch composition
2. Determine catch composition and levels of by-catch associated with the main commercial gillnet fisheries
3. Assess implications of recent management changes on recreational netting practices
4. Assess the relationships between gillnet soak times, capture condition and by-catch survival
5. Evaluate the impacts of gillnetting on the biodiversity of key inshore ecosystems and potential strategies to mitigate these impacts

Methodology

In relation to Objective 1 available information based on previous research and commercial gillnet catch sampling studies were collated and assessed to examine for regional and temporal changes in target and non-target species abundance. For Objective 2 a variety of data sources were investigated, including commercial logbook data, previous recreational fishing survey data, on-board commercial catch sampling and results from research netting. Objective 3 was primarily addressed through a survey of recreational gillnet fishers and the synthesis of trends based on previous recreational fishing surveys. For Objective 4 research gillnetting trials involving post release survival experiments, along with on-board commercial catch sampling, provided information about operational relationships between soak times, catch condition and by-catch survival. Finally, Objective 5 involved the synthesis of information reported for the present study integrated with long-term biodiversity monitoring data based on underwater visual census surveys and a formal ecological risk assessment of the major Tasmanian gillnet fisheries.

Results/key findings

Gillnet fisheries target a range of habitats, including reef and non-reef areas, and land a wide diversity of fish species, with over 90 taxa reported in commercial catch returns. The recreational gillnet fishery targets much the same species as the commercial sector and there is considerable overlap between sectors in the areas fished. For both sectors comparatively few species account for the majority of the landings. Catches in the Banded Morwong fishery are dominated by the target species (>85%), only Bastard Trumpeter and Longsnout Boarfish are of any significance amongst the other species harvested. The general graball net fisheries target a range of species with Bastard Trumpeter, Blue Warehou and Australian Salmon key components of the catch. Bastard Trumpeter, Blue Warehou and Atlantic Salmon (escapees from fish farms) comprise the main species retained by the recreational gillnet sectors. Catches in the commercial small mesh and recreational mullet net fisheries although low, are dominated by Australian Salmon, ‘Pike’ (Snook and Longfin Pike) and Yelloweye Mullet. The difference in catch composition between graball and small mesh nets is due to mesh selectivity, along with the prohibition of setting recreational mullet nets over reef.

In each of the gillnet fisheries a component of the catch is not retained (by-catch), either because of regulation (size or catch limits, closed seasons for selected species, prohibited or protected species) or because of market and/or fisher preferences. The by-catch component, as a proportion of total catch numbers was found to be relatively high; 52% for Banded Morwong fishers, 49% for the general graball fishery, 66% for the small mesh fishery and 35% for the recreational gillnet fishery, although the latter may be an underestimate as it is based on self-reported information. A wide diversity of species that included target species comprised the by-catch component, but in terms of overall contribution to by-catch numbers relatively few species accounted for the bulk of the discards. The main non-target by-catch species included Draughtboard Shark, Marblefish, Bluethroat Wrasse, Leatherjackets and Skates/Rays. Discard rates for by-catch species tended to exceed 80%, whereas discard rates for species typically targeted or retained as by-product typically ranged between 10 – 20%.

Capture condition (based on an assessment of physical damage and responsiveness) and delayed mortality rates (based on tank survival trials) of gillnet caught fish varied between species and were influenced by operational factors including soak time and in some instances season. Several species were particularly resilient, suffering minimal physical damage and low rates of initial and delayed mortality, and experienced high overall post release survival (PRS) rates (>85%) irrespective of soak duration. Species in this category included Banded Morwong, Bastard Trumpeter, Marblefish, Draughtboard Shark, Purple Wrasse, Leatherjackets, Longsnout Boarfish and Skates/Rays. Species with moderately high PRS rates (70 – 85%) included Bluethroat Wrasse, Elephantfish, Whitespotted Dogfish and Bluestriped Goatfish. Southern Sand Flathead, Gummy Shark and Jackass Morwong had lower PRS rates (50 – 70%), while survival rates for a suite of other species including Blue Warehou, Australian Salmon and Atlantic Salmon were quite poor (< 50%).

A number of interactions with threatened, endangered and protected species (TEPS) were observed in this study. Fur Seals were commonly observed in the vicinity of gillnets and the majority of direct interactions with the nets involved provisioning (removal and consumption of entangled fish); there were no instances involving entanglement of seals. Entanglement and drowning of seabirds (Cormorants and Penguins) in gillnets was observed, though such incidences were rare making it difficult to identify contributing factors. In Macquarie Harbour, the endangered Maugean Skate was regularly caught in gillnets set in depths of between about 5-15 m. Although the majority of individuals captured were in excellent condition and lively when released, a small proportion of those captured in overnight deployments were either in poor condition or had died, confirming some by-catch mortality in these longer soak times.

Analyses of historic gillnetting data and underwater visual census data revealed that there have been some changes to species abundance and species composition over the past 20 years but, on the whole, this has been dominated by the decline in Banded Morwong abundance and inter-annual variability in the abundance of Bastard Trumpeter and Blue Warehou. Marblefish abundances have declined in most regions since the mid-1990s despite being rarely retained and having high post release survival. Previous fishing and poor handling practices may have resulted in higher than expected by-catch mortality.

Overnight netting was a common practice for recreational fishers prior to its prohibition in all areas apart from Macquarie Harbour. This ban appears to have had a significant impact on netting effort, not only has it achieved a marked reduction in the proportion of overnight sets but there has been a substantial reduction in overall recreational netting effort. Virtually all recreational gillnet fishers engage in other types of recreational fishing, only a small proportion identified gillnetting as their main recreational fishing activity or that they would consider giving up fishing altogether if they could not gillnet. There was general agreement amongst recreational fishers that recent management changes had been effective in improving fishing practices and in reducing wastage and by-catch.

A formal ecological risk assessment was conducted based on four sub-fisheries that make up the Tasmanian gillnet fishery. These are the large mesh graball (Banded Morwong) sub-fishery, the general graball net fishery, comprised of reef and non-reef sub-fishery components, the latter occurs predominately within shark refuge areas, and the small mesh fishery, which includes commercial small mesh and recreational mullet net components.

Level 1, Scale, Intensity and Consequence Analysis identified that target, by-catch/by-product and TEPS components had consequence scores above moderate for several hazards (principally ‘capture by fishing’, ‘fishing without capture’ and ‘external hazards’). By contrast habitats and communities were judged to be impacted with low consequence by each of the gillnet fisheries and thus were not considered in the Level 2 Productivity Susceptibility Analysis (PSA) assessment.

The PSA identified a number of species at high risk, each specific to a sub-fishery and a result that reflects differences in mesh selectivity as well as differences in the spatial coverage of the fisheries. Bastard Trumpeter was the only species ranked as high risk in the graball (reef) sub-fishery, largely because inshore reefs represent the core habitat for juveniles and sub-adults and the species is particularly susceptible to gillnet capture. None of the species that interacted with the graball (Banded Morwong) sub-fishery were ranked as high risk, predominantly due to the high level of selectivity achieved for the target species by the large mesh size. Atlantic Salmon and Rainbow Trout were ranked as having high vulnerability in the non-reef sub-fishery but, being introduced exotics, this represents a positive ranking, with fishing pressure contributing to their removal from the environment. Maugean Skate and Whitespotted Dogfish were also identified as high vulnerability species; the former has a highly restricted distributional range, presumed low population size and key biological attributes are unknown, and the latter on the other hand is amongst the least productive chondrichthyan species known. Within the small mesh fishery, the Great Cormorant, Rock Flathead and Snook were ranked as having high vulnerability, although low catches and wide distribution outside of Tasmania waters suggest the actual vulnerabilities for the fish at least may not be as high as implied by this analysis. Of the marine mammals, other seabirds and other chondrichthyans considered in the PSA most were ranked as medium vulnerability, mainly due to low productivity levels.

Implications for relevant stakeholders

This study has identified a number of issues that have particular relevance to the future management of gillnetting in Tasmania, noting that gillnet usage has emerged as an area of particular focus in the 2014 review of the Scalefish Management Plan and while it is beyond the scope of the present study to make recommendations on whether or not recreational gillnetting should be banned, this study does provide information that will assist in informing this debate.

There is little doubt that gillnetting has had demonstrable impacts on populations of the key target species, in particular Banded Morwong, Blue Warehou and Bastard Trumpeter. There are specific management measures now in place for Banded Morwong (quota management) and Blue Warehou (Commonwealth stock rebuilding strategy) to help sustain and rebuild populations. There is also a case for management intervention to reduce fishing pressure on Bastard Trumpeter, especially given its high vulnerability ranking; such measures could include expansion of no-netting areas, increase in legal minimum size and/or reduction of bag or trip limits.

This study has established that post release survival of many of the key by-catch species is likely to be high, a situation enhanced by improvements in fishing practices over the past few years. While there would be some benefit, albeit minor, for by-catch survival in reducing the maximum soak time to less than six hours, the prohibition on night netting and introduction of the soak time regulations appear to have been quite successful in reducing wastage and impacts on non-target species.

Interactions with seabirds appear to be an inevitable consequence of gillnetting in shallow coastal waters, though in the main they do tend to occur with low frequency. However, if gillnets are deployed near rookeries, or in corridors that seabirds use to access rookeries, there is potential for interactions involving greater numbers than occurred in the present study. In order to minimise this risk, consideration should be given to establishing no-netting areas around key rookeries. The development of a code of practice for gillnet usage that includes voluntary cessation of gillnet activities while flocks of seabirds (especially Short-tailed Shearwaters) are present in high net use areas would also help reduce the risk of interactions.

This study has established that the endangered Maugean Skate is particularly susceptible to capture in gillnets and although the vast majority are expected to survive, some mortalities, especially in overnight sets, are expected. As a listed species, options to reduce such interactions need to be considered. There are a number of strategies that would help miminise Maugean Skate by-catch and mortality, these include a ban on overnight netting (bringing Macquarie Harbour into line with the remainder of the state), an expansion of the areas closed to netting and/or restricting gillnet usage within Macquarie Harbour to shallow waters (< ~5 m). Implemention of a strategy based on fishing depth may be best achieved through a code of practice and education, noting that the main target species – Atlantic Salmon and Flounder – are commonly caught in the shallows. Deployment of gillnets in shallow waters would also have the benefit of reducing the by-catch of Whitespotted Dogfish, assessed along with the Maugean Skate as having high vulnerability.

Keywords

Gillnet, by-catch, post release survival, ecological risk assessment, fishing practices, fisher motivations and attitudes

Introduction

Tasmanian gillnet fisheries

Globally, gillnetting is the fifth most productive fishing method, in terms of landed mass (Kelleher, 2005). In Tasmania, the use of gillnets commenced in 1803, soon after European settlement (Harries and Croome, 1989), and has continued since with both commercial and recreational sectors remaining active. Gillnetting is managed as part of the Tasmanian Scalefish Fishery (TSF), a multi-species and multi-gear fishery in which fishers adapt rapidly to species availability, market requirements and opportunities (Hartmann and Lyle, 2011). Gillnetting is the most commonly utilised commercial scalefish fishing method and lands the third highest quantity of fish behind beach seine and purse seine, which target abundant, yet low value, pelagic species (Hartmann and Lyle, 2011).

The gillnet fishery is comprised of several sub-fisheries defined by gear characteristics (mesh size, mesh gauge, hanging ratios, etc.), fishing practices (set duration, orientation of nets, etc.), habitat fished and target species (Ziegler *et al.*, 2013). Excluding shark nets (managed by the Commonwealth as a component of the Southern and Eastern Scalefish and Shark Fishery - SESSF), there are three classes of gillnet (distinguished by mesh size) that can be used legally in Tasmanian waters; namely ‘graball’ (105 – 140 mm), ‘small mesh’ (75 – 100 mm) [1] and ‘mullet’ (60 – 70 mm) nets. Commercial operators are permitted to use graball and small mesh nets whereas recreational fishers have access to graball and mullet nets.

Commercial and recreational fishers have traditionally used graball nets on rocky reef habitats to target Bastard Trumpeter (*Latridopsis forsteri*) and Blue Warehou (*Seriolella brama*), with a variety of other species retained as by-product (Hartmann and Lyle, 2011; Lyle and Tracey, 2012). Gillnetting in coastal bays and inlets also has a long history with Flounder (principally Greenback Flounder *Rhombosolea tapirina*) being the main target species (Frijlink and Lyle, 2013). So-called ‘flounder nets’, which are large mesh (130 – 140 mm mesh size) graball nets, are used to target the species in overnight sets. On the north coast of Tasmania both commercial and recreational fishers tend to use smaller mesh sizes (small mesh and mullet nets, respectively) on soft sediment habitats, including seagrass, to target a wide variety of scalefish species.

During the early 1990s, a commercial fishery for Banded Morwong (*Cheilodactylus spectabilis*) developed rapidly to supply the domestic live fish market and this fishery has dominated commercial gillnet activity in terms of effort since that time (Murphy and Lyle, 1999). The nets used to target Banded Morwong are effectively modified flounder nets (large mesh and light gauge monofilament).

The introduction of sea cage aquaculture for Atlantic Salmon (*Salmo salar*) and Rainbow Trout (*Oncorhynchus mykiss*) during the 1980s has seen escapees from fish farms becoming a keenly sought after target species for recreational gillnetters, particularly in the D'Entrecasteaux Channel and Macquarie Harbour (Lyle and Tracey, 2012). There is also limited targeting of escapees by commercial gillnetters with aquaculture companies engaging commercial fishers to catch escapees following large escape events; much of this catch is not, however, marketed.

Management of gillnet fishing in Tasmania

Until the mid-1990s, regulations governing the use of gillnets remained virtually unchanged from when initial restrictions (mainly relating to minimum mesh sizes and some no netting areas) were introduced in the 1890s (Harries and Croome, 1989).

In 1998 the TSF Management Plan was implemented, recognising three categories of general Scalefish (commercial) licence, each with limits on the quantity of graball net that could be used (Table 1). In

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[1] There is an endorsement that allows the use of a ‘Special small-mesh gillnet’. This net has a mesh size of 70-100 mm, with only a couple of north coast operators endorsed for its use. For the purposes of this study, these nets are considered part of the small mesh fishery.

addition, a number of Small Mesh Net entitlements which are restricted to the north coast of Tasmania were issued under the management plan. All holders of Tasmanian commercial Rock Lobster licences who do not possess a general Scalefish licence are also entitled to use up to 150 m graball net. Since the management plan was introduced there has been a marked reduction in commercial gillnet effort and catch, with landings down from over 500 tonnes in 1998/99 to around 110 tonnes in 2011/12, coupled with a two thirds reduction in effort, down from around 5000 fisher-days to around 1700 fisher-days (André *et al.*, 2014). Management changes, changing market preferences as well as reduced availability of some key species have contributed to these declines.

Licensing of recreational gillnets was first introduced in 1995. Recreational gillnet licences are issued annually and initially fishers were permitted to license two 50 m graball nets and one 50 m mullet net. In 2002 this was reduced to one 50 m graball net and the maximum length of mullet nets was reduced to 25 m. Over the past decade there have been a number of major management changes in relation to recreational gillnet usage, largely designed to improve fishing practices, reduce wastage and decrease impacts on non-target species. From November 1998 recreational gillnets were required to be marked and fished as either day or night time sets to address the common practice of leaving gillnets unattended for excessively long periods (> 12 h) (Lyle, 2000). Overnight netting was subsequently prohibited in November 2004 in all waters apart from Macquarie Harbour on the west coast. Although night netting was a common and popular practice amongst recreational fishers (Lyle and Smith, 1998; Lyle, 2000), it is significant that the night netting ban has had little discernible impact on gillnet licence numbers, which have fluctuated between 9000 and 10000 since the mid-2000s (André *et al.*, 2014).

A key element of the most recent review of the TSF management plan has been the introduction of maximum soak times for gillnets, a measure specifically intended to improve fishing practices. The new arrangements took effect in November 2009 and specify that recreational gillnets may only be set for a maximum of two hours in Shark Refuge Areas (SRAs) or a maximum of six hours in all other waters excluding Macquarie Harbour where night netting is permitted. Soak time regulations were also introduced for commercial fishers, with a maximum soak time of six hours in all state waters, exceptions being fishers endorsed to take scalefish in Macquarie Harbour, attended night fishing and those endorsed for unattended night netting (north coast).

Both recreational and commercial gillnet fishers are subject to a variety of other regulations regarding where gillnets may be used (including spatial closures) and specifications on the type and quantity of gear that may be used in certain regions. Legal minimum lengths (LMLs), bag and possession limits apply for recreational fishers while trip and possession limits apply for certain gillnet target species for commercial fishers. Specific information relating to these restrictions is available on the Department of Primary Industry, Parks, Water and Environment (DPIPWE) website (http://www.dpipwe.tas.gov.au/).

Table 1: Tasmanian licence categories permitting gillnet usage, current licence numbers and gear limits.

Licence type	No. licences (2012)	Net type and max length	Mesh size
Commercial			
Scalefish A	65	1000 m of graball	105 – 140 mm
Scalefish B	158	500 m of graball	105 – 140 mm
Scalefish C	86	150 m graball	105 – 140 mm
Small Mesh	10	600 m (no one net >200 m)	75 – 100 mm
Rock Lobster		150 m graball	105 – 140 mm
Recreational			
Graball	8248	50 m graball	105 – 140 mm
Mullet Net	888	25 m Mullet net	60 – 70 mm

By-catch

In most fisheries, the impacts on target species are relatively well understood and fisheries are managed through a variety of input (gear restrictions, closed seasons) and output controls (size limits, quotas, possession limits) to ensure sustainable harvest of these species. An inevitable consequence of deploying any form of fishing gear is by-product and by-catch.

By-catch is defined as any organism that is caught in fishing gear and subsequently released or discarded. By-catch includes undersize (or oversize) target and/or non-target species, catch in excess of bag/possession limits or quota, species of low/no economic value, and protected species that cannot be legally retained. By-product, although not the target of the fishery, is retained and is generally managed in a similar fashion to target species.

By-catch is often poorly quantified (if at all) and frequently not accounted for when assessing fishery impacts. By-catch rates from major global gillnet fisheries range from 0 – 66% (Kelleher, 2005), the actual rates being influenced by a range of factors including selectivity characteristics of the gillnets (reviewed by Hamley (1975)) along with the diversity, behaviour and abundance of the fish community. Complicating matters, by-catch of one fishery may be the target for another. For example in Tasmania, Banded Morwong are targeted for the live-fish trade, however, only commercial fishers with a specific Banded Morwong licence are legally able to retain the species. Therefore, they are discarded by other fishing sectors and rarely retained by the recreational sector due to perceived poor eating qualities (Lyle and Tracey, 2012). Another example where fishers are required to discard species of value is shark. Tasmanian fishers without a Commonwealth shark licence are only permitted to retain a maximum of five shark bodies (all species) per trip, potentially having to discard individuals in excess of this limit even when dead or moribund. Recreational fishers are also subject to a combined possession limit of 2, a boat possession limit of 5 and size limits for sharks. Neither commercial nor recreational fishers are permitted to retain shark (other than Elephantfish) in designated SRAs, where a large proportion of recreational gillnet effort takes place targeting escapee salmonids. Sharks are an inevitable by-catch in these regions.

Gillnetting, along with other forms of fishing, is increasingly coming under the spotlight in terms of its impact on by-catch. Until recently, most fisheries have been managed, and researched, primarily with respect to the sustainability of the target species. Due to an increased interest in ecosystem based management and the implementation of ecological risk assessment methodologies that focus on a wide variety of fishery impacts (i.e. impacts on target, by-product, by-catch, threatened, endangered and protected species (TEPS), habitats, and communities) there has been greater effort to gather information on by-catch. Furthermore, management authorities have shown a willingness to manage fisheries for the sustainability of non-target as well as target species. For example, the Australian Fisheries Management Authority (AFMA) has implemented an Australian Sea Lion Management Strategy which has involved the closure of areas surrounding sea lion colonies to the shark gillnet sector of the SESSF along with provisions to close portions of the fishery following the incidental capture of specified numbers of sea lions (Anon, 2010). Similarly, a variety of restrictions have been imposed on trawl and longline fisheries in southern Australia to prevent the over-exploitation of low-productivity deep-sea Squalid sharks such as the endangered Harrison’s Dogfish, *Centrophorus harrissoni* (Anon, 2009).

Post release survival

The mortality of by-catch is one of the most significant issues facing fisheries management (Davis, 2002). Although, there has been considerable progress in the development of methods to reduce by-catch through technological development of fishing gears (see review by Werner *et al.* (2006)), in many cases there is a lack of knowledge relating to the survival of fish that either escape the gear before being landed or are caught and subsequently discarded (Davis, 2002).

This field of research has progressed over the years and there are now several techniques available to assess post release survival (PRS). These include sea cage/tank trials, laboratory experimentation, tag-release-recapture methods, acoustic and satellite tagging and physiological investigations.

Sea cage and tank trials are perhaps the most widely used approach for assessing PRS and involve holding wild caught fish in sea cages (Broadhurst *et al.*, 2005; Grixti *et al.*, 2007; Broadhurst *et al.*, 2008; Grixti *et al.*, 2008; Hall *et al.*, 2009; Grixti *et al.*, 2010) or in aquaria (Gingerich *et al.*, 2007; Lyle *et al.*, 2007;

Enever *et al.*, 2009). Laboratory based trials are also a common approach to estimating PRS and involves capturing fish already held in captivity and has the advantage that many variables can be controlled and the exact nature of the interaction with the fishing gear can be identified (Davis and Ottmar, 2006; Frick *et al.*, 2010a; Frick *et al.*, 2010b; Frick *et al.*, 2012). A disadvantage of laboratory experiments is that simulated capture and subsequent behaviour of the fish may not necessarily be representative of what happens in the wild.

Tag-release-recapture approaches, although less widely used, have an advantage over other methods in that they enable the recovery of fish under natural conditions. Assuming that the tagging procedure does not induce mortality, the survival rates should be representative of natural conditions. Unfortunately, due to the relatively low frequency of tag returns, most studies are only able to provide relative mortality rates that can be linked to the condition of the fish when released (Vander Haegen *et al.*, 2004; Hueter *et al.*, 2006; Sumpton *et al.*, 2010). Acoustic tracking has been used to estimate PRS and behavioural responses using acoustic arrays in either rivers or small embayments (Heupel and Simpfendorfer, 2002; Parkyn *et al.*, 2006; Donaldson *et al.*, 2011). In other cases this has been carried out by manually tracking released fish, however, this approach is subject to various biases (reviewed by Skomal (2007)) and is particularly labour intensive and expensive if animals are followed for any length of time. Pop-up satellite archival tags (PSAT) have become increasingly popular to assess the post release survival of large, pelagic fish and sharks (Domeier *et al.*, 2003; Kerstetter *et al.*, 2003; Moyes *et al.*, 2006) as these species are ill-suited to more traditional techniques such as tank trials. Due to the large size of PSAT tags their use is limited to large species to minimise the possibility of tag induced mortality.

Physiological indicators (e.g. cortisol, lactate, glucose, heat shock proteins) have also been used to identify impacts of capture and subsequent survival potential (Moyes *et al.*, 2006; Frick *et al.*, 2010a; Frick *et al.*, 2010b; Frick *et al.*, 2012). These studies typically require validation, usually through laboratory experimentation or PSAT tagging and links to mortality are often tedious and poorly understood (Barton *et al.*, 2002).

Need

Commercial and recreational fishers are permitted to use gillnets in Tasmania. There are several classes of gillnet distinguished by mesh size – commercial gillnets include, small mesh and graball, while recreational gillnets include mullet and graball nets. Since the mid-2000s around 100 commercial operators have reported gillnet use each year, for an average catch of over 150 tonnes of scalefish per annum (p.a.) Recent information for the recreational sector indicates that recreational netting remains popular, with 9000 – 10000 gillnet licences issued each year. Recreational fishers target many of the same species as commercial operators.

Over the past decade there have been several management initiatives, including a prohibition on recreational night netting and unattended commercial night netting for most areas and, more recently, the introduction of maximum soak times for both sectors designed to improve gillnetting practices, and reduce wastage and impacts on non-target species. Despite this, there have been conspicuous declines in the abundance of several key gillnet species along with increasing community concern about the ecological impacts of gillnetting. This concern has been particularly evident in the debate surrounding the introduction of marine protected areas, with gillnetting identified as a key threat to biodiversity. Furthermore, in the 2009 TSF management plan review (DPIPWE) identified the need to develop strategic policy in relation to no-netting areas to address issues including resource sharing, wildlife interactions and stock management.

In view of the above, there is an urgent need to better understand how recent management initiatives have influenced netting practices in Tasmania, and to objectively assess the risks and impacts on target and non-target species. All prior assessments have relied on self-reporting, either in commercial logbooks or recreational diary surveys, and as a result by-catch levels are likely to be understated (recreational surveys) or not reported (commercial logbook data). Ultimately such an understanding will be pivotal in informing the on-going debate over the future management of gillnetting in Tasmania.

Objectives

1. Synthesise available gillnetting information, with particular reference to links between operational parameters and catch composition,
2. Determine catch composition and levels of by-catch associated with the main gillnet fisheries,
3. Assess implications of recent management changes on recreational netting practices,
4. Assess the relationships between gillnet soak times, capture condition and by-catch survival,
5. Evaluate the impacts of gillnetting on the biodiversity of key inshore ecosystems and potential strategies to mitigate these impacts.

Methodology

Overview

This study is comprised of a number of components intended to address the study's objectives. In relation to Objective 1 (Synthesise available gillnetting information, with particular reference to links between operational parameters and catch composition) available information based on previous research and commercial gillnet catch sampling studies have been collated and assessed to examine for regional and temporal changes in target and non-target species abundance. For Objective 2 (Determine catch composition and levels of by-catch associated with the main gillnet fisheries) a variety of data sources were investigated, including commercial logbook data for the period that corresponded to this study, previous recreational fishing survey data, on-board commercial catch sampling and research fishing using recreational gillnets. Objective 3 (Assess implications of recent management changes on recreational netting practices) was primarily addressed through a survey of recreational gillnet fishers and synthesis of trends based on previous recreational fishing surveys. For Objective 4 (Assess the relationships between gillnet soak times, capture condition and by-catch survival) research gillnetting trials involving PRS experiments, along with on-board commercial catch sampling, provided information about operational relationships between soak time, catch condition and by-catch survival. Finally, Objective 5 (Evaluate the impacts of gillnetting on the biodiversity of key inshore ecosystems and potential strategies to mitigate these impacts) involved the synthesis of information reported for the present study integrated with long-term biodiversity monitoring data based on underwater visual census surveys and an ecological risk assessment of the major Tasmanian gillnet sub-fisheries.

Research fishing

To investigate catch composition, the effect of soak time on capture condition and to obtain fish for post release survival trials (as detailed later), researchers deployed both graball and mullet nets (with the same specifications as permitted for recreational use) throughout the state. Graball nets were 50 m in length, 33 meshes deep and had a stretched mesh size of 114 mm. Mullet nets were 25 m in length, 50 meshes deep and had a stretched mesh size of 64 mm. Nets were soaked for a variety of times depending on the recreational fishing regulations;

- 2 hours in SRAs,
- 2 to 6 hours in open waters,
- 2 hours to overnight in Macquarie Harbour. Overnight sets were deployed within two hours of dusk and hauled within two hours of dawn, with total soak time dictated by scotophase.

Sampling was designed to provide regional coverage of the major areas in which recreational gillnet fishers operate (principally off east and southeast Tasmania and in Macquarie Harbour, western Tasmania) (Figure 1) and to explore regional differences in catch composition. Operational parameters such as location, set and haul times, minimum and maximum depth, mesh size and water temperature were recorded. Catch data gathered included; species (Following the Australian Fish Names Standard (Anon, 2007)), fish length (measured to the fork of the tail if present, otherwise to the tip of the tail), capture condition stage (Table 2), how the fish was meshed (refer Table 3), release condition if relevant (fish swam away strongly, fish swam away lethargically or fish floated or sank without actively swimming), presence/absence of barotrauma and evidence of predation. If fish displayed symptoms of barotrauma, the swim bladder was deflated using a hypodermic needle prior to release. Interactions with TEPS (capture and/or behaviour around the gear) and habitat (e.g. presence of sessile benthic organisms in the meshes) were also documented.

Table 2: Condition indices (stages) assigned to gillnet caught fish.

Condition	Description
1	Lively, no visible damage.
2	Lively, minor damage: <5% scale loss, minor barotrauma, minor cut.
3	Alive, moderate damage: >5% scale loss, major barotrauma, moderate cut.
4	Alive but in poor condition (limited responsiveness): Extensive body damage, cuts, scale loss and/or severe barotrauma.
5	Dead.

Table 3: Indices assigned to gillnet caught fish describing how the individual was 'meshed'.

Meshed	Description
Mouthed	Mesh from the net caught in the fish's mouth.
Snouted	The fish's snout is in the net but the meshes had not passed the maxilla.
Gilled	Net encircling the maxilla and/or gills.
Wedged	Mesh has passed the gills and the body of the fish is entangled by the net.
Tangled	The fish is not caught in any of the above ways and is either bagged in the net, rolled up, or the mesh is tangled on spines, claspers or other appendages.

Commercial catch sampling

To investigate the catch composition and operational parameters of the commercial gillnet fishery, researchers observed fishing activities during normal fishing operations of a number of cooperating commercial fishers. This sampling focussed on the Banded Morwong sector as it is the largest in terms of fishing effort and landings (André *et al.*, 2014), although a smaller amount of sampling took place with generalist fishers, particularly in the southeast, as the two sectors have been shown to be distinct in their fishing practices (Ziegler *et al.*, 2013) and landings (André *et al.*, 2014).

Sampling was spatially stratified in the northwest, northeast, east and southeast coasts, where the majority of commercial fishing takes place (André *et al.*, 2014), and data were analysed regionally using the existing biogeographic regions that are used for management purposes (Figure 1). The D'Entrecasteaux Channel, Norfolk Bay and Frederick Henry Bay within the southeast region are declared SRAs and for the purpose of regional analyses have been treated as a distinct region, the southeast SRA. While on-board, identical data were recorded to that for research fishing (described above) in addition to recording whether individuals were retained or discarded.

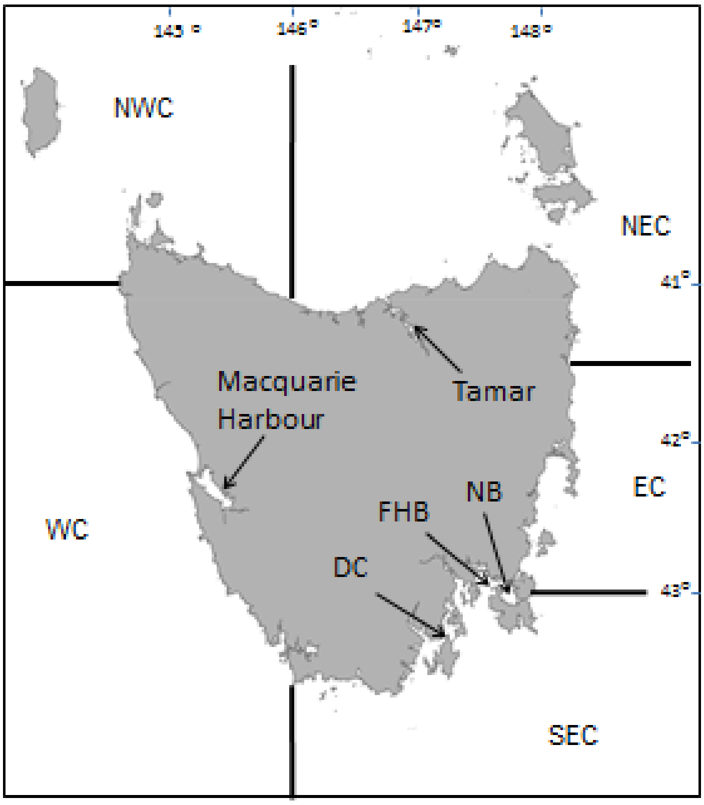

Figure 1: Zonation of the Tasmanian gillnet fishery. SEC refers to the Southeast coast, EC the East coast, NEC the Northeast coast, NWC the Northwest coast, WC the West coast, DC the D'Entrecasteaux Channel, FHB Frederick Henry Bay and NB Norfolk Bay.

Effects of gillnet soak time on capture condition

To facilitate statistical analysis, the period of time between deployment and hauling of gillnets (*soak duration*) was binned into five *soak time* categories: 1) <2.5 h, 2) 2.5 – 3.5 h, 3) 3.5 – 5 h, 4) 5 – 8 h, and 5) overnight deployments. The effect of soak time on capture condition was explored with Kruskal-Wallis tests using the ‘kruskal.test’ function in base R, version 3.0.1 (Copyright 2013 The R Foundation for Statistical Computing). The non-parametric Kruskal-Wallis approach was used due to the ordinal and non-normal distribution of the data (Chan and Walmsley, 1997). When significant differences were identified between the soak time categories, post-hoc pairwise comparisons were made with Mann-Whitney U tests (also known as the Wilcoxon rank sum test) using the ‘pairwise.wilcox.test’ function in base R, with alpha values corrected for multiple pairwise comparisons with the Benjamini and Yekutieli method (Benjamini and Yekutieli, 2001). The Mann-Whitney test is applicable in this instance due to the ordinal nature of the data, the non-normality of its distribution and it is only slightly less powerful than a *t*-test (Lehmann and D'Abrera, 1975).

Ordinal regression was also carried out on these data and although it replicated the Kruskal-Wallis test to an extent, it enables quantitative predictions of how soak duration influences condition stage. This is achieved by taking the exponent of the coefficient, which is calculated as the log-odds-ratio for modelling purposes.

The effect of gillnet soak time and season, herein defined as warm water season (November – April) and cool water season (May – October) on initial mortality (IM), i.e. individuals that were dead upon retrieval of the net (Stage 5), was investigated using binary logistic regression in base R with the ‘glm’ function.

The initial Generalised Linear Model (GLM) was performed with soak duration (hours) as a continuous variable and when a significant relationship existed, multiple pairwise comparisons of soak time categories (as defined above) were investigated using Tukeys contrasts with corrected alpha values (Benjamini and Yekutieli, 2001). This was achieved using the 'glht' function within the 'multcomp' package in R. As soak time was found to affect IM rates in most species a Welch t-test (not assuming equal variance) was used to test for differences in the mean soak durations between warm and cool sampling periods, which was necessary as heteroscedasticity could not be achieved. Similarly, mean soak duration was compared between warm and cool sampling periods in overnight deployments in Macquarie Harbour using the same method.

Effects of fish size on how fish are meshed

To investigate the relationship between fish length and how fish were caught in the net (Table 3) a Welch ANOVA was used as equality of heterogeneity could not be achieved. The Welch ANOVA was done using the 'k.sample.test' function within the 'Deducer' package of R. Post hoc pairwise comparisons were made using a Welch t-test (not assuming equal variance) and alpha values corrected for multiple pairwise comparisons using the aforementioned methods. To investigate how the way fish were caught by the gear (meshed) influenced capture condition stage a Kruskal-Wallis test was used and post hoc comparisons were made using Mann-Whitney U tests corrected for multiple pairwise comparisons.

Post release survival of gillnet caught fish

Tank trials

Individuals of the most commonly encountered species were retained post capture to assess their PRS, or more specifically, delayed mortality (DM). Fish were assessed for condition as per normal, tagged or fin-clipped (to enable association with operational parameters and condition at capture) and then placed in a 250 L, baffled and aerated tub of seawater on-board the netting vessel. If travel times were extended due to adverse weather conditions or high catch rates the water in the tub was refreshed at approximately 30 minute intervals. Fish were then promptly transported to 4000 L flow through aquaria at IMAS Taroona where their survival was monitored for a minimum of 72 hours. This length of time was chosen as most mortality has been shown to occur within 24 hours of capture (Lyle *et al.*, 2007; Grixti *et al.*, 2008; Benoit *et al.*, 2010) and the results obtained from the first 48 hours are an excellent predictor of the mortality of up to 5 days (Benoit *et al.*, 2010). Fish in healthy condition at the end of the holding period were released near to where they were captured; those that were moribund were euthanized.

The effect of capture condition (condition stage) on DM was investigated using binomial logistic regression. Pairwise comparisons were made using Tukeys contrasts with alpha levels corrected for multiple pair-wise comparisons (Benjamini and Yekutieli, 2001) using the 'glht' function within the 'multcomp' package in R. In some species, individuals in excellent condition (Stage 1) were rare, or, alternatively, no mortalities regardless of condition were recorded, preventing generalised linear modelling. Further, in some species, there were no significant differences in DM rates between fish in Stages 1, 2 and sometimes 3, and in such instances these condition categories were pooled to increase the statistical power of the analyses. The fit of each logistic model was assessed via analysis of deviance (likelihood ratio test) using the 'Anova' function in base R. To explore variation in the delayed mortality rate of fish with water temperature (season), sampling was divided into warm and cool sampling periods and differential mortality tested using logistic regression as described above. This analysis was performed separately to the DM analysis as it was not necessary to combine condition stages.

Tag-release-recapture techniques

An alternative approach to assessing PRS is using tag-release-recapture techniques. This portion of the study was carried out as part of an honours project and utilises the relative risk equation, which is regularly used in health sciences to compare clinical trials or exposure when there is a binary outcome. The relative risk equation examines the relationship between the probability of an outcome for an exposed group to the probability of the same outcome in a non-exposed group. In terms of PRS, it can be used to compare the proportion of recaptures relative to the condition of fish when released (Hueter *et al.*, 2006). Confidence intervals were then calculated using the 'freq' procedure in SAS (version 9.2 of the SAS system for Windows, Copyright 2008, SAS institute, Inc.) using the methods outlined by Hueter *et al*. (2006).

This method requires several assumptions be made: first, there is no differential long-term mortality between each of the different condition indices (i.e. if fish survive capture and the subsequent recovery period there is no difference in mortality rates); second, the catchability, and hence probability of recapture, is equal irrespective of the condition fish were in when initially captured; and third, artefacts arising from the tagging procedure, such as tag shedding and tag-induced mortality, are equivalent irrespective of condition when captured. Further, if it is assumed that all Stage 1 fish survive, it is possible to estimate absolute PRS rates based on capture condition.

The focus of this work was a small area of relatively isolated reef on the north-east coast of Bruny Island (between One Tree Point and Yellow Bluff) in south-eastern Tasmania. To maximise the possibility of recaptures, tagging was concentrated on Bluethroat Wrasse, Banded Morwong, Bastard Trumpeter, Marblefish and Draughtboard Shark, which are abundant species that are assumed to, or have been shown to, demonstrate a high degree of site fidelity (Barrett, 1995a; Buxton *et al.*, 2010; Awruch *et al.*, 2012). Fishing and fish handling was carried out as previously described; however, prior to release, fish were tagged with uniquely coded T-bar tags. Recaptures were recorded throughout the study period but only recaptures of >3 days at liberty (defined as the recovery period) were considered for analysis.

Physiological effects of gillnet capture

To investigate the physiological demands gillnet capture imposes on fish, blood samples were taken from six commonly encountered species (Banded Morwong, Draughtboard Shark, Bastard Trumpeter, Bluethroat Wrasse, Elephantfish and Marblefish) and tested for whole blood lactate and glucose concentrations. Blood lactate and glucose concentrations have been shown to be good indicators of exhaustive exercise, hypoxia and fatigue in fish (Wells and Tetens, 1984; Pottinger, 1998; Beecham *et al.*, 2006; Brown *et al.*, 2008; Cooke *et al.*, 2008).

Fish were removed from the net as per normal, inverted, immobilised in a moistened cushion, while ~2 mL of blood was drawn via caudal venepuncture with a 21 gauge needle and heparinised vacutainer (http://www.bd.com/vacutainer/). This process took less than one minute to complete. Samples were retained on ice to prevent glycolysis (Lin *et al.*, 1976) and processed as soon as practical (always within six hours). Lactate concentration was tested with a Lactate Pro lactate analyser (http://www.lactatepro.com.au/lactatepro/HOME.html), which has been validated for use in fish (Brown *et al.*, 2008). Glucose concentration was tested using an Accu-Chek^{R} blood glucose meter (https://www.accu-chek.com/index.html), also validated for use in fish (Beecham *et al.*, 2006; Cooke *et al.*, 2008).

In order to obtain pseudo-baseline lactate and glucose concentrations, blood samples were obtained from 3 – 6 healthy Banded Morwong, Draughtboard Shark, Bastard Trumpeter, Bluethroat Wrasse and Marblefish that were held in 4000 L tanks for one week following survival trials. To minimise the stress of capture for baseline assessments, fish were retained in pairs in 80 L floating caufs for 72 hours prior to sampling. This period of time has been shown to be sufficient for lactate and glucose concentrations to return to baseline levels in fish (Wells and Tetens, 1984; Pottinger, 1998). This protocol enabled blood samples to be drawn quickly (< 1 min) following removal from the cauf.

Elephantfish were excluded from this treatment as they remain in an agitated state and generally showed signs of declining health while held in the aquaria suggesting that baseline levels determined as described above are unlikely to be indicative. Instead, baseline data were obtained from 90 fish that were caught with rod and reel and retained for 10 – 15 days in 20 000 L flow through aquaria at the Marine and Freshwater Fisheries Research Institute of Department of Primary Industries, Victoria (C. Martins, Monash University, unpublished data). These fish are of superior condition to those captured in gillnets; however, for sampling they had to be captured from the large tank using dip nets and therefore their blood levels may not be truly representative of baseline levels. Blood was drawn similarly to the present study but was centrifuged and plasma glucose and lactate concentrations were measured analytically. Glucose concentration is generally lower when whole blood is measured with an Accucheck meter, however, a strong linear relationship ($r^2 = 0.98$) exists between the two and values can be converted using the following regression;

$$y = 1.010x - 15.820$$

where y is the glucose level measured by the Accucheck meter and x is the glucose level measured analytically (Beecham *et al.*, 2006). Similarly, lactate concentration is lower when whole blood is measured with Lactate Pro but can be corrected using the following linear regression;

$$y = 0.083 + 0.942x$$

where y is the Lactate Pro reading and x is the analytical reading from plasma (Brown *et al.*, 2008). Data obtained for Elephantfish from Victoria were converted using these regressions.

Whether glucose and lactate concentrations increased from baseline levels was explored with a Welch t-test (not assuming equal variance) using the ‘two.sample.test’ function within base R. The Welch t-test was necessary as heteroscedasticity could not be achieved with standard transformation techniques as baseline groups had consistently low concentrations whereas fish sampled from gillnets were highly variable. Blood chemistry data were analysed for a linear relationship between soak time and both lactate and glucose concentrations using the ‘lm’ function in base R and the level of variability and significance of the regression was explored by analysis of variance (ANOVA) also within the ‘lm’ function.

Spatial and temporal variation in the abundance and diversity of fish communities

Two data sources were available to examine medium-term (almost two decades) variation in the abundance of key gillnet species; previous research gillnetting and on-board observation of commercial gillnet operations, and underwater visual census survey data.

IMAS has accrued a large dataset of catch compositions from both research gillnetting and through on-board observation of commercial gillnetting operations since the mid-1990s. Fishing methods have remained consistent through time and the recording of catch details, apart from noting fish capture condition and whether individual fish were retained or not, has also been consistent with the present study. Unfortunately, data were insufficient to standardise for seasonal and fisher effects on catch composition and catch rates. However, to minimise the impact of seasonal variation in sampling, data from the winter months were omitted as catch rates of most species decrease at this time of year.

Underwater visual census surveys quantifying species composition and abundance have been undertaken for a number of projects conducted between 1992 – 2012, mostly associated with monitoring the effectiveness of Marine Protected Areas (MPAs). Detailed methodology can be found in Edgar and Barrett (1997). In the interest of brevity, the survey method involves divers recording the number and size of all fish observed while swimming up one, then down the other, side of 4 x 50 m transects resulting in a total of 2000 m^2 coverage per site. These methods, despite the experimental design being carried out in a quantitative fashion, are subject to a variety of systematic biases and cannot provide absolute abundances; however, they do provide a robust method for estimating relative abundance (Edgar and Barrett, 1997; Edgar *et al.*, 2004). For the purpose of the present study, sites were grouped into the same regions defined for monitoring of the gillnet fishery (i.e. northeast, east and southeast coasts) and only sites located outside of MPAs were considered as they are subject to gillnetting pressure. Further, data were only analysed for fish >30 cm only as smaller individuals are not selected for well by graball nets and therefore unlikely to be impacted by gillnetting.

Both data sets were analysed using the same univariate techniques and the commercial catch composition data was further analysed using multivariate techniques – underwater visual census data lacked high numbers of larger individuals. Data were aggregated by region and year for univariate analyses and, for gillnetting data, the mean catch per unit effort (CPUE) calculated as the number of fish per 100 metre-net hour whereas for underwater visual census data, the mean number of fish per site was calculated. A non-linear smoother was fitted to each indicator series with a generalised additive model (GAM) using the 'gam' function within the 'mgcv' package of R. This method uses a thin plate regression spline with automatic estimation of the degree of smoothness using generalised cross validation (Wood, 2006). A parametric bootstrap was used to take uncertainty within the indicator time series into account (Trenkel and Rochet, 2009; Blanchard *et al.*, 2010). If the GAM significantly described the indicator series an intersection-union test, Mann-Kendal test and linear regression were performed (R code developed by Verena Trenkel, Infremer) to investigate whether there has been a significant increase or decrease in the indicator series within the specified time frame (Trenkel and Rochet, 2009; Blanchard *et al.*, 2010). Two time series were selected to test for change in abundances – the most recent 5 and 10 years. Due to highly variable catch rates, these statistical tests were insignificant in almost all instances; as such, these analyses were not considered further and the GAMs were used to identify trends visually only. Secondly, for multivariate analyses of the on-board observation data, data were imported into PRIMER 6 with PERMANOVA+ add-on (Clarke and Gorley, 2006). Following the methods outlined by Clarke and Warwick (2001), data were log (x + 1) transformed and a Bray-Curtis similarity matrix constructed. Bray-Curtis similarities were depicted visually by creating non-metric multidimensional scaling ordination plots from each region. Two-way permutational multivariate analysis of variance (PERMANOVA) was used to test for regional and annual variation in species composition. If a significant result was obtained, one way PERMANOVA was used to test for annual variation within each region and, if significant, SIMPER analysis was used to identify the species most responsible for typifying species composition in a given year followed by pairwise analysis of similarity (ANOSIM) to identify where pairwise differences exist. SIMPER was then used to distinguish the species responsible for annual differences. In most instances, the cut-off for typifying and distinguishing was set at 0.05 (i.e. species that were responsible for typifying or distinguishing 5% or greater of the variation within a region or a year). However, in the analysis of graball net data it was necessary to reduce the cut-off for typifying to 0.02 due to the high variation in species composition encountered when using these nets.

The abovementioned multivariate techniques were also used to analyse raw gillnet catch composition data available from four recreational fishery surveys (2000/01, 2007/08, 2010 and 2012/13). These data provide daily catch information (date, location, number and type of nets used, soak duration and catch composition, including numbers kept and number released/discarded by species) and rely on self-reporting by fishers and appear to under-report the full range of by-catch species. Furthermore, because recreational fishers individually use much lesser quantities of gear, individual daily catches are limited in comparison with commercial CPUE data. As such, catch and effort data were aggregated for each month within each region and this measure of CPUE was used as the primary sampling unit, which enables seasonal trends to be incorporated in the analysis.

Threatened, endangered and protected species analysis

In addition to the above analyses, TEPS were subject to further scrutiny as they are of particular importance to the management of fisheries. In the case of protected species such as Sygnathids (seahorses and sea dragons) and seabirds, incidental captures were rare and occurred in low numbers, precluding any meaningful quantitative analysis. It should be recognised, however, that research gillnetting was designed to avoid areas where there was potential for high rates of interaction with seabirds (e.g. adjacent to Penguin colonies). Presence/absence was explored temporally and spatially with chi-squared tests using the 'chisq.test' test in base R and multiple pairwise comparisons made using 'chisqPostHoc' function within the NCStats package with alpha correction (Benjamini and Yekutieli, 2001). Chi-square tests become unreliable when expected values are <5, therefore, when necessary, Fishers exact test was supplemented using the 'fisher.test' function in base R. In addition, presence/absence data was investigated with binomial logistic regression for an effect of net depth using the methods described above.

The endangered Maugean Skate was captured regularly in research gillnets set in Macquarie Harbour and it was thus possible to apply generalised linear modelling (GLM) techniques to analyse for a range of factors that influence catches. Initially GAMs were created to describe how the variables affected CPUE and then, based on the patterns identified by the GAM, appropriate GLMs were selected. GAMs were fitted using the methods described previously. Variables were added to the GLM in a forward stepwise manner until they failed to improve the model fit, assessed using the Akaike information criterion (AIC).

Recreational fisher survey

The motivations for fishing, consumptive orientation, implications of recent management changes on recreational gillnetting practices and issues relating to interactions with wildlife were surveyed amongst recreational gillnet licence holders. Gillnet fishers represent a specialist sub-group within the general recreational fishing community so by understanding the motives and attitudes of this group, management can be targeted more effectively to maximise acceptance and compliance with regulations as well as predicting how changes will impact fishers and fisher behaviour.

Respondents (holders of recreational gillnet net licences in 2009/10 and/or 2010/11) were initially selected at random from the recreational fishing licence database administered by DPIPWE and invited to participate in a 12-month telephone-diary survey (Lyle and Tracey 2012). At end of the survey, diarists were offered a structured questionnaire seeking information about motives, attitudes and experiences to do with gillnet fishing. The survey was administered as a telephone interview and conducted during January-February 2011.

The questionnaire comprised four sections: the first examined motivation and consumptive orientation of gillnet fishers; the second investigated attitudes to recent management changes; the third considered issues relating to the availability of key target species; and the final section dealt with seal and seabird interactions with gillnetting. The survey was conducted with respondents aged 18 years and older.

In order to examine how demographics and experience influenced responses, survey participants were stratified by four grouping factors: age (18-29 years, 30-44 years, 45-59 years and 60 years and older); residence (Australian Bureau of Statistics regions - Greater Hobart, Southern, Northern and Mersey-Lyell statistical divisions); gillnet experience (0-4 years, 5-9 years, 10-14 years, 15-19 years, 20-29 years, and 30 or more years); and avidity (gillnet effort during 2010 – 0 days, 1-4 days, 5-9 days, 10 or more days). Age and residence were based on information provided in the licence database, years of gillnetting experience was determined as a response to a survey question, and avidity was based on information provided by respondents during the diary survey (Lyle and Tracey, 2012).

The effect of each of the grouping factors on responses to questions was explored with Kruskal-Wallis tests using the ‘kruskal.test’ function in base R. When significant differences were identified, post-hoc pairwise comparisons were made with Mann-Whitney using the ‘pairwise.wilcox.test’ function in base R with alpha values corrected for multiple pairwise comparisons with the Benjamini and Yekutieli method (Benjamini and Yekutieli, 2001). Level of statistical significance was set at $\alpha = 0.05$.

Responses to motivation and consumptive orientation questions for gillnet fishers were also compared with those obtained from previous general fisher surveys conducted in 2001 and 2008 (Frijlink and Lyle, 2010).

Ecological risk assessment

Ecological risk assessments were carried out for the sub-fisheries (detailed later) within the Tasmanian gillnet fishery using the Ecological Risk Assessment for the Effects of Fishing (ERAEF) approach (Hobday *et al.*, 2007; Hobday *et al.*, 2011). This method is an ecosystem based approach investigating the impact of a fishery on target species, by-product and by-catch species, TEPS, habitats, and ecological communities (Hobday *et al.*, 2007). The ERAEF uses a hierarchical approach beginning with Scoping and then three levels of assessment:

- Scoping, provides the background information relating to the fishery and sub-fisheries that enable researchers, managers and stakeholders to agree on the scope of the fishery(s) and allows irrelevant components to be identified and removed from further analysis.

- Level 1 Scale, Intensity Consequence Analysis (SICA) is a qualitative screening process that further removes low risk activities while identifying those that require further, more detailed, investigation

- Level 2 Productivity Susceptibility Analysis (PSA) is a semi-quantitative process that analyses available biological and ecological attributes of each component. Where information is not available from the literature expert opinion can be sought to provide the most conservative estimate. Where there is no published information and expert opinion cannot make a reliable judgement a precautionary approach to uncertainty is taken. Thus, PSA analysis is more likely to result in false positives than in false negatives and the list of high risk species should not be interpreted as all being at high risk from fishing, rather that these are species that require a more detailed exploration before they can be classified as low risk (Walker *et al.*, 2007a).

- Level 3 is a fully quantitative assessment – in fisheries science this typically a stock assessment. This is a labour intensive process and requires detailed fishery, ecological and biological data.

Within the present project, scoping and levels 1 and 2 were carried out to enable species that are of potentially high risk to gillnetting to be identified, thus providing insight into where further research and/or management responses should be directed.

Four sub-fisheries were identified based on gillnet mesh size, catch composition and the habitat in which the gear is deployed. These were: the commercial Banded Morwong sector; the commercial and recreational graball sectors that operates on, or near, reef habitats; the commercial and recreational graball sector that operates within SRA and fishes predominantly on soft sediment habitats; and, the small mesh sector that includes the commercial north coast small mesh fishery and recreational fishers using mullet nets[2]. Species lists for stage 2 PSA of each sub-fishery were populated based on the following:

- Graball (reef); species were included if they were listed in the logbook records of commercial graball fishers that are not in possession of a Banded Morwong endorsement, if they were observed during any on board catch sampling of this sector, if they were listed in the catch of recreational graball gillnet fishers during any telephone diary surveys carried out by IMAS, or, if they have been encountered during any research fishing using graball gillnets,
- Graball (Banded Morwong); species were included if they were listed in the logbook records of commercial fishers in possession of a Banded Morwong entitlement, or, if they were observed during any on board catch sampling of this sector,
- Graball (non-reef); species were included if they were listed in the logbook records of commercial graball fishers that were operating within SRA, if they were listed in the catch of recreational graball gillnet fishers operating within SRA during any telephone diary surveys, or, if they have been encountered during any research fishing using graball gillnets in SRA,
- Small mesh; species were included if they were listed in the logbook records of north coast small mesh fishers, if they were observed during any on board catch sampling of this sector, if they were listed in the catch of recreational mullet gillnet fishers during any telephone diary surveys, or, if they have been encountered during any research fishing using mullet gillnets.

TEPS were included in all gillnetting sectors if there has ever been any evidence that they have been encountered in any one of the Tasmanian gillnetting sectors. This includes firm, anecdotal and vague reports to ensure that any potential encounters with TEPS were considered. Southern right, humpback and killer whales, common and bottlenose dolphins and Australian and New Zealand fur Seals were included due to vague reports of ‘whales’, ‘seals’ or ‘dolphins’ becoming entangled in gillnets. They are the only marine mammals common in Tasmanian waters and are therefore, by far, the most likely to have been the

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[2] It was logical to combine the commercial north coast small mesh fishery with the mullet net fishery as, although recreational mullet nets can be used throughout the state, it occurs almost exclusively on the north coast.

species in question. All other cetaceans are reportedly pelagic and/or oceanodromous and reports within Tasmanian state managed waters are infrequent and typically restricted to stranding events.

Biological attributes of each species were populated from existing ERA's (Hobday *et al.*, 2007; Walker *et al.*, 2007a) or using a range of published and online resources. The references are recorded within the PSA worksheet but were largely derived from FishBase (Froese and Pauly, 2014), which uses a cross-referencing technique to estimate key life history traits from closely related species.

Due to a lack of detailed spatial data, susceptibility was not able to be quantitatively assessed as has been the case for Commonwealth fisheries using this ERA framework. As such it was necessary to populate the 'availability' section based on available literature on species distribution within Tasmania (Edgar, 2000; Kuiter, 2000; Last and Stevens, 2009; Froese and Pauly, 2014) and the 'encounterability' section using the relative catch rates of each species during the present study (i.e. the frequency each species is captured in gillnets, within each fishing sector, given their distribution and abundance). These data were entered into the expert override of the susceptibility workbook, along with post capture mortality information obtained within the present study and in each instance, a precautionary approach to uncertainty was undertaken. Each of these variables is assessed within the PSA in a categorical fashion so it is not anticipated that the lack of detail available in this assessment will have a major bearing on susceptibility or the 'ecological risk' assigned to each species.

Summary information is provided within the present report, a full copy of the ERAEF is available upon request.

Results

Tasmanian gillnet fisheries

Commercial sector

Graball net

The Tasmanian commercial graball net fishery can be divided into two main sub-fisheries; one targeting Banded Morwong for the domestic live-fish trade and the other a general scalefish fishery that targets a variety of species (but cannot legally land Banded Morwong). Since the mid-1990s commercial gillnet catches and effort have declined steadily, with graball net effort in 2012/13 around a quarter of its level in 1995/96 and only 71 vessels reporting activity compared with 257 at the start of the period (Figure 2). Catches too have trended downwards, from a peak of almost 500 tonnes in 1998/99 to around 100 tonnes in 2012/13. Much of the decline has resulted from management initiatives to reduce effort, including the introduction of limits on gillnet gear usage, reductions in the number of scalefish licences (achieved through non-transferability of certain licence categories), limited entry for Banded Morwong and subsequent quota management, as well as the impacts of reduced availability of key gillnet species, in particular Blue Warehou and Bastard Trumpeter, since the early 2000s.

Banded Morwong fishery

Banded Morwong fishers use large mesh graballs (133 – 140 mm, typically referred to as ‘banded morwong’ or ‘flounder’ nets[3]) to target the species for the live-fish trade. Commercial logbook fishing data for the period January 2011 to April 2013 indicated that Banded Morwong fishers accounted for the majority (~70%) of the gillnet effort, with activity concentrated on the East coast, followed by the Southeast and Northeast coasts, and only minor activity in other regions of the state (Figure 3). Landings from this sub-fishery also dominated (57%) the overall catch taken by the commercial graball fishery (Figure 4); with Banded Morwong alone accounting half of the total graball catch and 87% of the catch taken by the sub-fishery. Banded Morwong fishers also landed moderate quantities of Bastard Trumpeter, Longsnout Boarfish and Blue Warehou (Figure 5), although individually each of these species represented <5% of the total catch. Forty-five other species are also landed, though in very low quantities (see Appendix Table A1. 2 for a full catch breakdown).

Recognising the significance of the Banded Morwong fishery, on-board catch sampling was with particular focus on this sector off the Southeast, East and Northeast coasts (Table 4). This sampling yielded over 3100 fish representing 49 species (Appendix Table A1. 3). The target species, Banded Morwong, accounted for just over half of the catch (51%) by number, followed by Draughtboard Shark (16%), Marblefish (12%), Longsnout Boarfish (6%), Bluethroat Wrasse (5%), Bastard Trumpeter (3%) and Purple Wrasse (2%), with each of the remaining species encountered in very low numbers. Just under half (48%) of the total monitored catch by number was retained, conversely just over half (52%) of the catch was released/discarded and constituted, by definition, by-catch. In relation to the target species, sampling revealed that 21% of the Banded Morwong fell outside of the slot size limit (360 – 460 mm) and were discarded (Figure 6). In relation to non-target species typically retained as by-product, the discard rate for Bastard Trumpeter was relatively low (17%), with the majority exceeding the LML, whereas most (57%) of the Longsnout Boarfish were below the LML (450 mm) and consequently discarded (Figure 6). Several other commonly caught species, namely Draughtboard Shark, Marblefish, Bluethroat Wrasse and Purple Wrasse were rarely retained, with discard rates exceeding 90% (Figure 6). The majority of the remaining species captured constituted by-catch, exceptions being

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[3] There are no differences between mesh size and monofilament gauge specifications for ‘banded morwong’ and ‘flounder’ nets; hanging ratios may, however, differ and as the name indicates, Flounder are the prime target species for flounder nets, which are set on soft sediments rather that over reefs.

Jackass Morwong and Blue Warehou, which have some commercial value. Catch compositions and retention rates are presented in Appendix Table A1. 3 and length frequency distributions of the catch from the Banded Morwong fishery can be found in Figure A1. 1.

On-board catch sampling data conducted opportunistically since 1995 indicates that the catch composition for the Banded Morwong fishery has varied significantly both temporally and spatially[4] (Table 5). The target species has consistently typified catch compositions in the Northeast, East and Southeast coasts along with Marblefish and Draughtboard Shark in the Southeast, Marblefish and Longsnout Boarfish in the East, and Bluethroat Wrasse in the Northeast (Table 6). Catch rates of Banded Morwong varied significantly between regions, being highest in the Northeast followed by the Southeast and East coasts (Table 6).

General graball fishery

Commercial fishers without Banded Morwong licences tend to use ‘standard graballs’ of smaller mesh size (105 - 125 mm) that select for Bastard Trumpeter and Blue Warehou more efficiently, although there is limited fishing effort with larger mesh sizes targeting Flounder mainly in sheltered waters (André *et al*., 2014). Effort in this general graball net fishery is concentrated off the Northeast, Northwest and Southeast coasts, with relatively low levels of activity reported in other regions (Figure 3). Catches, however, revealed a slightly different pattern, with higher catches taken from the Southeast than elsewhere (Figure 4). Based on logbook returns, this fishing sector lands a broad diversity of species with obvious regional differences (refer Appendix Table A1. 2).

Overall, between January 2011 and April 2013, Australian Salmon were landed in the greatest quantities, representing 25% of the total catch for gillnet fishers without a Banded Morwong licence, and were captured around the state (Figure 7). Bastard Trumpeter and Blue Warehou were also landed in moderately high quantities, accounting for 16 and 14% of the state-wide landings respectively, with the greatest quantities of these being caught on the East, Southeast and West coasts (Figure 7). Other species of significance to this fishery (in descending order) include Atlantic Salmon, Gummy Shark, Bearded Rock Cod, Bluethroat Wrasse, Striped Trumpeter, Elephantfish, Rainbow Trout, Jackass Morwong and Silver Trevally. A unique aspect of this fishery occurs in Macquarie Harbour where commercial fishers occasionally target Atlantic Salmon and Rainbow Trout that have escaped from sea cages, these species represented 8% of the catch from the general graball fishery. Apart from these species, reported landings of a wide variety of other species were very low (individually <1% of the total catch weight), suggesting they represent non-target species that are retained as by-product.

On-board catch sampling of the general graball sector identified that, in addition to the main target Bastard Trumpeter, Blue Warehou and Australian Salmon, a variety of other species are caught. Morwong and Elephantfish are retained as by-product, whereas species such as Bluethroat Wrasse, Banded Morwong, Marblefish, Draughtboard Shark and various species of Leatherjackets and constituted the main by-catch with discard rates of 60 – 100% (Figure 6; Appendix Table A1. 3). Since operators are not permitted to land Banded Morwong, this species represents by-catch in this fishery, regardless of fish size. Discard rates for target species were generally lower than 20% and mainly influenced by adherence to LMLs, although as observed in the Banded Morwong fishery, discard rates were higher for Longsnout Boarfish as a consequence of its large LML.

Length frequency distributions of the catch from general graball nets (research and commercial combined) are presented in Appendix Figure A1. 2.

Small mesh net fishery

The commercial small mesh fishery operates on the north coast of Tasmania and is substantially smaller than the graball fishery, with recent landings of around 10 tonnes p.a., though catches have risen over the past two years to 17 tonnes in 2012/13. Since the mid-1990s landings have generally declined (Figure 8),

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[4] Temporal variation in catch composition is explored in detail in a later section.

principally due to the halving of effort between 1995/96 and 2012/13 and number of active vessels falling from 19 to just 10 in 2012/13. The majority of the small mesh catch and effort occurs in the Northwest coast region, with the Northeast and Tamar minor components (Figure 9 and Figure 10). Overall small mesh net fishery landings between January 2011 and April 2013 were dominated by 'Pike' (Longfin Pike and Snook) (32%), Australian Salmon (31%), Rock Flathead (10%) and Blue Warehou (5%), along with a further 56 species landed in very small quantities (see Table A1. 4 for a full species breakdown of the returns from this gillnetting sector).

The small mesh net catch composition exhibited some regional variability, with Australian Salmon, Pike, Blue Warehou and Rock Flathead dominating Northwest coast catches, Pike and Rock Flathead dominating in the Northeast, and Australian Salmon and Yelloweye Mullet the main species taken in the Tamar Estuary (Figure 11).

On-board observations, though limited, indicated that the bulk of the target as well as some non-species were retained (Figure 6). In addition, this sector appears to be opportunistic, landing a broad diversity of species that are discarded by other sectors (e.g. Purple Wrasse and Magpie Perch). The main by-catch species were Bluethroat Wrasse, Leatherjackets and Herring Cale, which were caught in relatively high numbers.

Table A1. 3 displays a full species composition and discard rates derived from on-board observation.

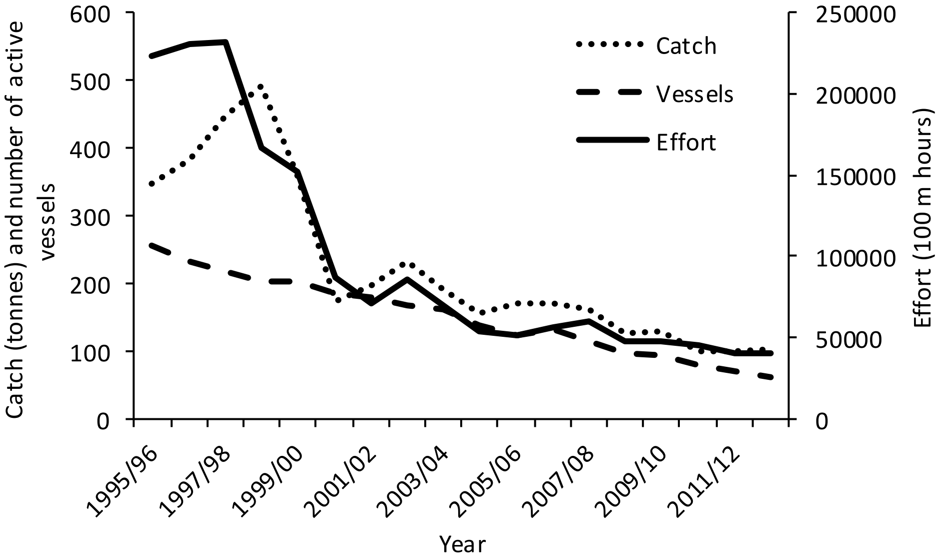

Figure 2: Annual catch, number of active vessels and total effort (100 m net hours) since 1995/96 for the commercial graball net fishery.

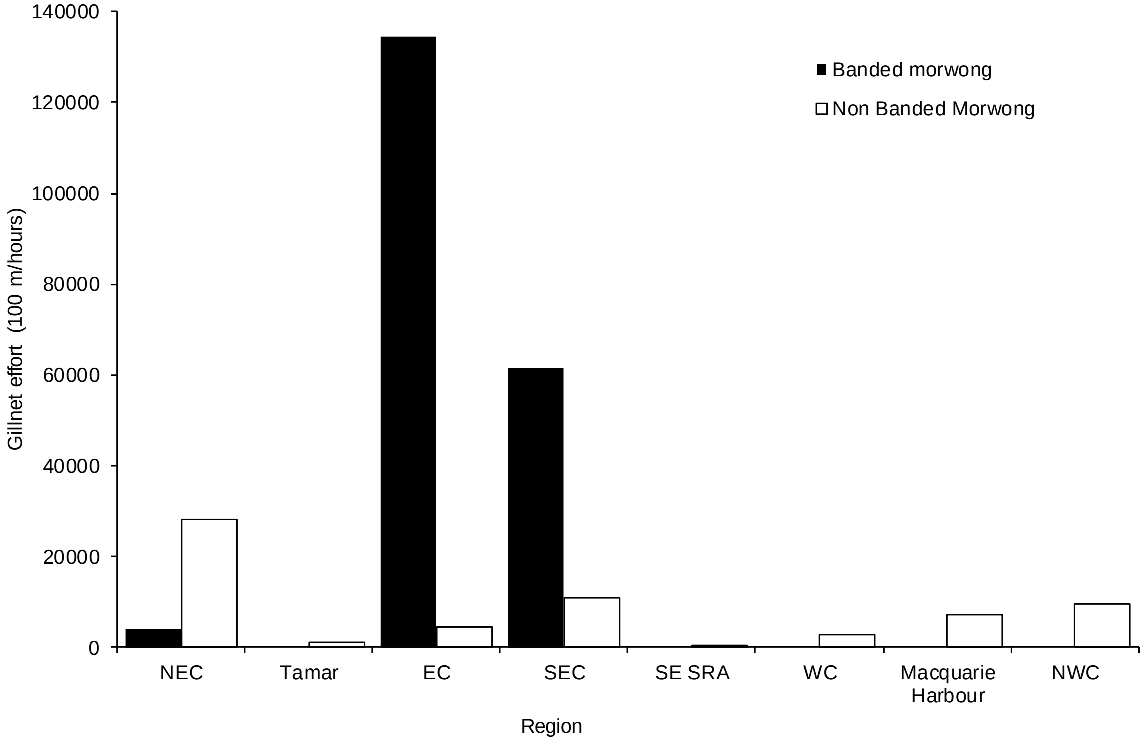

Figure 3: Graball effort by region for the period Jan 2011 to Apr 2013 by operators with and without Banded Morwong licences.

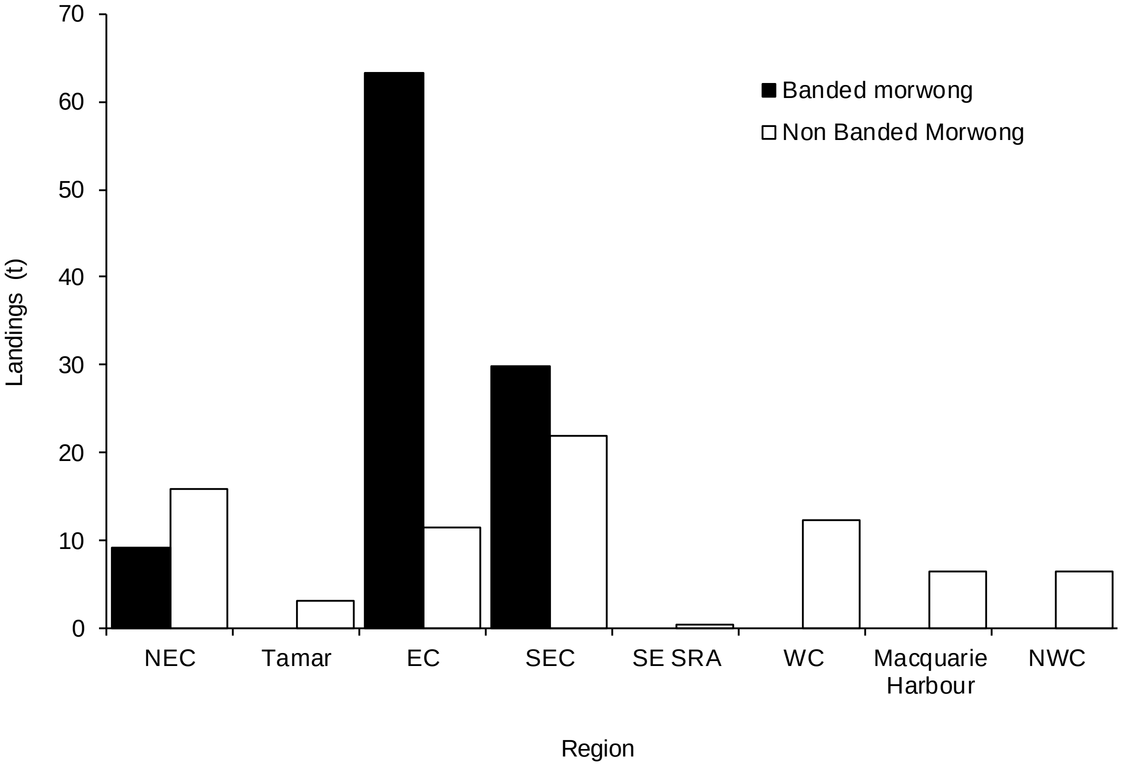

Figure 4: Graball landings by region for the period Jan 2011 to Apr 2013 taken by operators with and without Banded Morwong licences.

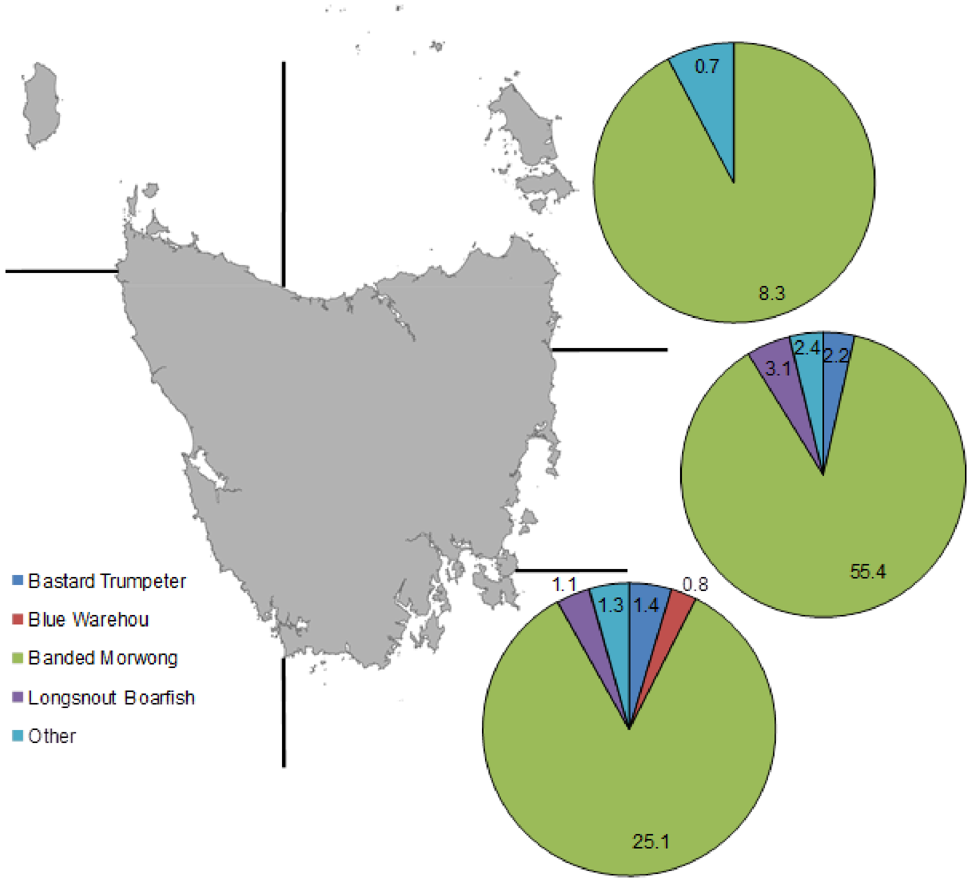

Figure 5: Retained catch composition (tonnes) by region for the period Jan 2011 to Apr 2013 taken by operators with a Banded Morwong licence. Minimal catches were reported for the west and northwest coasts (not shown).

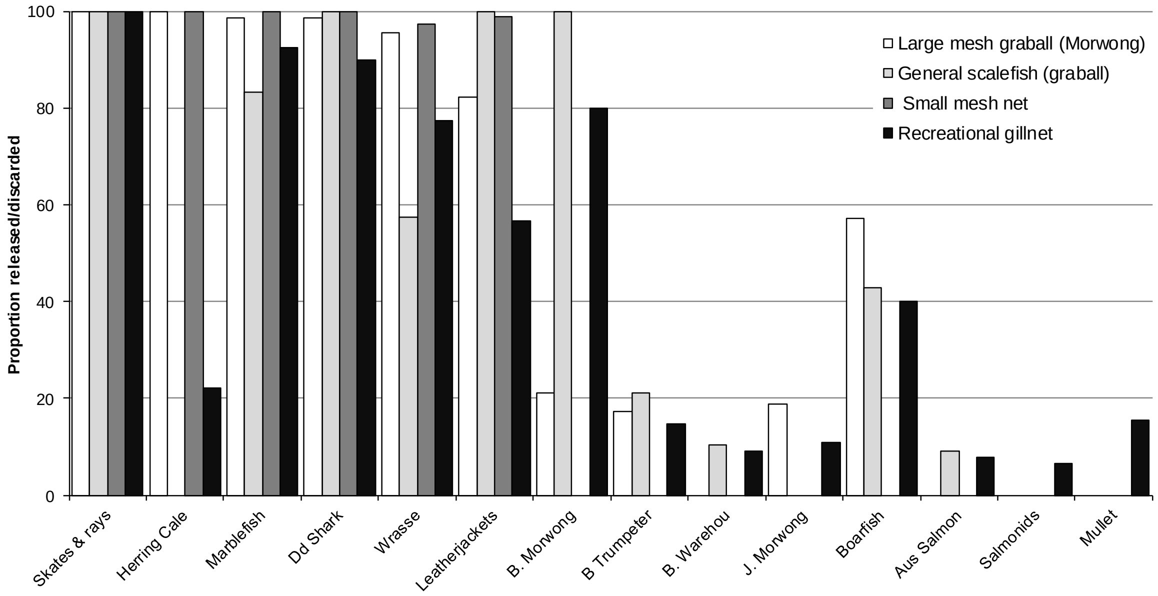

Figure 6: Discard rates for key species in the different Tasmanian gillnet sub-fisheries and sectors. Based on on-board commercial catch sampling - Large mesh graball (Morwong), General scalefish (graball) and Small mesh net - and 2010 recreational gillnet survey data – Recreational gillnet (Lyle and Tracey, 2012).

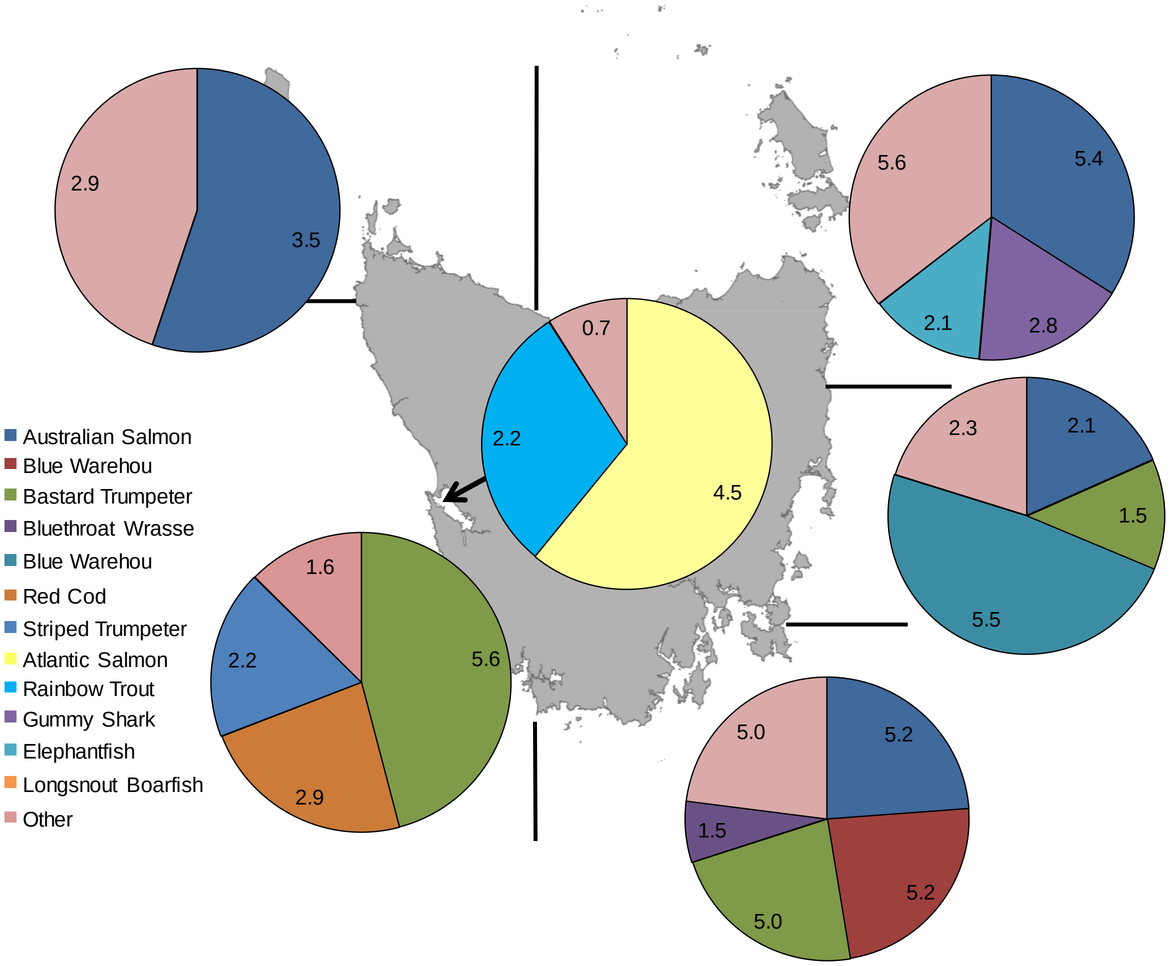

Figure 7: Retained catch composition (tonnes) by region for the period Jan 2011 to Apr 2013 taken by commercial operators without a Banded Morwong licence.

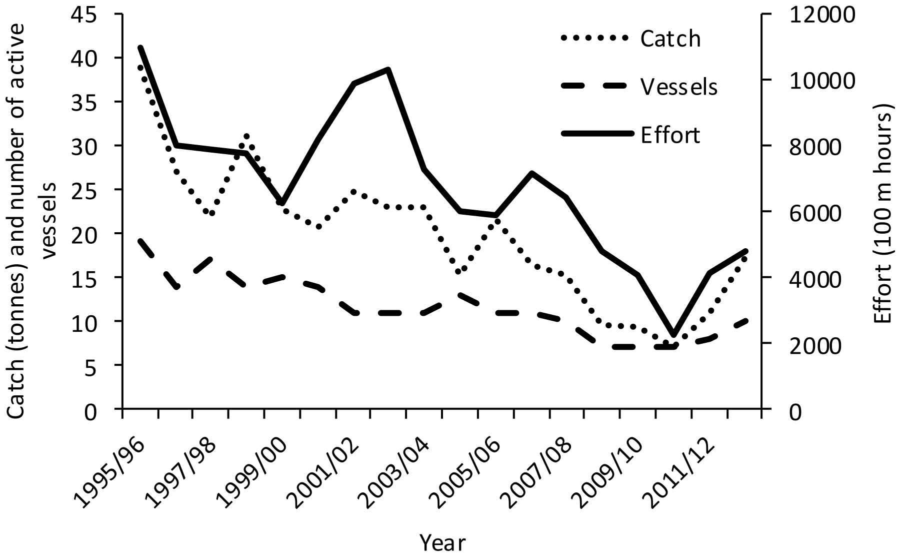

Figure 8: Annual catch, number of active vessels and total effort (100 m net hours) since 1995/96 for the commercial small mesh net fishery.

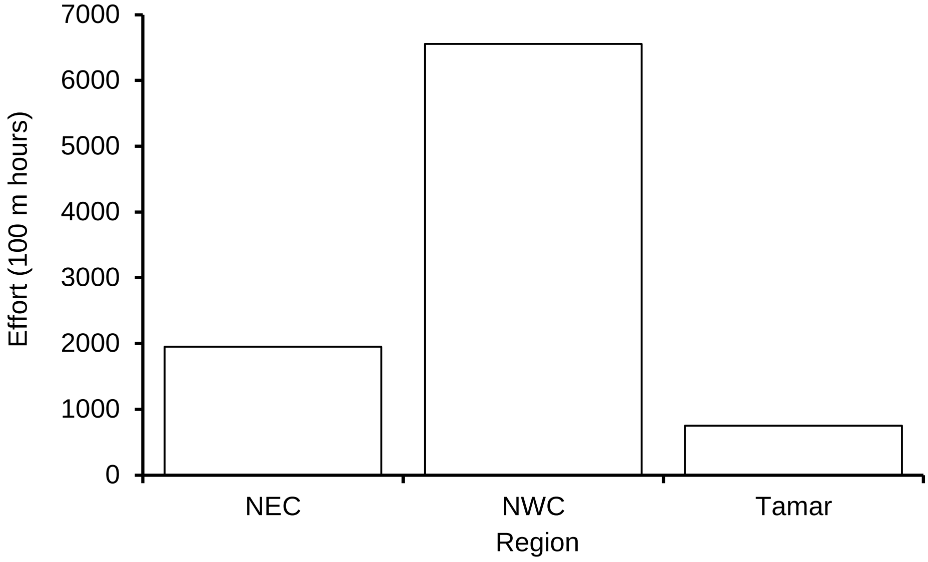

Figure 9: Commercial small mesh net effort by region for the period Jan 2011 to Apr 2013.

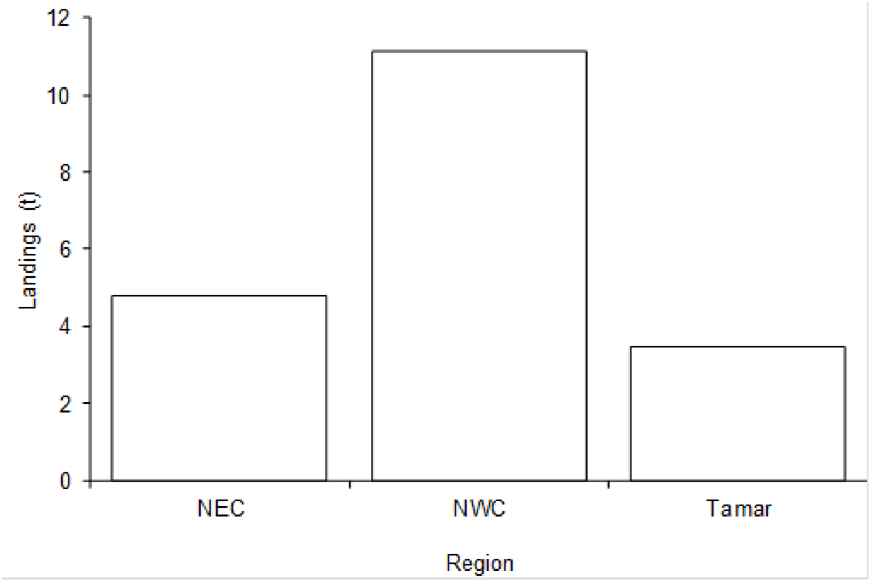

Figure 10: Commercial small mesh net landings by region for the period Jan 2011 to Apr 2013.

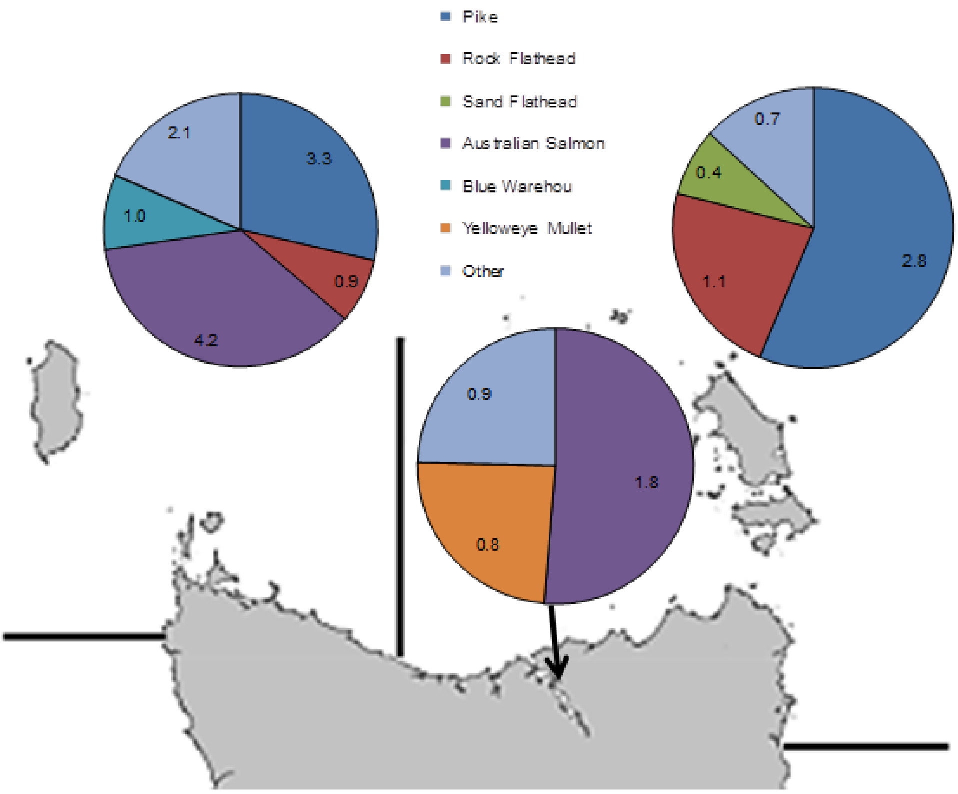

Figure 11: Retained catch composition (tonnes) by region for the period Jan 2011 to Apr 2013 taken by commercial small mesh gillnet fishers.

Table 4: Number of commercial (Com.) and research (Res.) gillnet deployments available for analysis in the present study by region.

	Region												
	East coast		Northwest coast		Northeast coast		Southeast coast		Southeast SRA		West coast		
Year	Com.	Res.	Com.	Res.	Com.	Res.	Com.	Res.	Com.	Res.	Com.	Res.	Total
2011	56	81	21	57	53		233	342	20	233		65	1161
2012		77		88	125		50	951		277		220	1788
2013	97						64	174		82		88	505
Total	153	158	21	145	178	0	347	1467	20	592	0	373	3454

Table 5: Two-way PERMANOVA exploring regional (east, southeast and northeast coasts), and temporal (1995 – 2013) variation in CPUE of ichthyofauna in large mesh (Banded Morwong) graballs based on commercial catch sampling.

Source	Permutations	*df*	Pseudo-F	*p*
Region	995	2	3.9179	<0.001***
Year	999	12	3.4188	<0.001***
Region X year	995	16	1.5293	0.002**

Table 6: R Statistic values and significance levels for pairwise ANOSIMs exploring regional variation in the CPUE of fish species in large mesh graball nets based on commercial catch sampling.

The species determined by SIMPER as most responsible for typifying the ichthyofaunal compositions in each region (shaded boxes) and for distinguishing between the ichthyofaunal compositions of each region are shown. $^+$indicates species more abundant in the region at the top of the column.

	Southeast	East	Northeast
Southeast	Banded Morwong Marblefish Draughtboard Shark		
East	0.054*** Banded Morwong$^+$ Draughtboard Shark$^+$ Marblefish$^+$	Banded Morwong Marblefish Longsnout Boarfish	
Northeast	0.152** Banded Morwong Marblefish$^+$ Draughtboard Shark$^+$	0.140** Banded Morwong Draughtboard Shark$^+$ Longsnout Boarfish$^+$	Banded Morwong Bluethroat Wrasse

Recreational gillnet fishery

The number of persons purchasing recreational gillnet licences increased from about 5600 in 1995/96 to 9000 in 2006/07, with licence numbers falling slightly since 2009/10 (Figure 12). By comparison, during 1983 an estimated 14 824 persons used a graball net at least once a year (Anon, 1984). At that time there was no requirement for recreational gillnets to be licensed and the actual number of gillnets used and owned was not estimated. Furthermore, gillnet catch and effort for that period was not estimated. Nonetheless it is evident that gillnetting continues to be a popular activity amongst recreational fishers in Tasmania.

In terms of the statewide catches, the most recently completed survey of recreational gillnet fishing in Tasmania (2010) established that Bastard Trumpeter, Blue Warehou and Wrasse collectively accounted for 45% of the total catch numbers (Lyle and Tracey 2012, Appendix Table A1. 5). Other species of significance included Atlantic Salmon, Leatherjackets, Australian Salmon, various Shark species and Marblefish, representing a further 25% of the total catch. Of these eight most frequently caught species, over half of the Leatherjackets, three-quarters of the Wrasse and 90% of the Sharks and Marblefish were released or discarded (Figure 6; Table A1. 5). Overall, 35% of the total catch (by number) taken by recreational gillnetting during 2010 represented by-catch.

Recreational gillnet composition has varied both spatially and temporally across four surveys conducted since 2000/01 (Table 7). The following analysis focuses on spatial variation in catch composition and temporal changes are dealt with in a later section. Catch composition based on raw survey data for 2010 (derived from Lyle and Tracey, 2012) and gillnetting activity reported as part of the 2012/13 general fishing survey (Lyle, unpubl. data) were spatially variable, with significant regional differences in all pairwise comparisons apart from the East and Northeast coasts (Table 8). Wrasse typified the recreational gillnet catch composition in each of the regions apart from the West coast (Table 8). The other major regional differences were driven by proportionally higher CPUE for Bastard Trumpeter, Blue Warehou and Leatherjackets on the Southeast coast, Bastard Trumpeter and Atlantic Salmon in the Southeast SRA, Bastard Trumpeter and Jackass Morwong on the East coast, Banded Morwong on the Northeast coast, Australian Salmon and Mullet on the Northwest coast, and Bastard Trumpeter, Atlantic Salmon and Flounder on the West coast.

Figure 12: Numbers of recreational gillnet licences issued annually since 1995/96. Solid line indicates graball nets, dashed line indicates mullet nets.

Table 7: Two way PERMANOVA exploring variation in the CPUE of ichthyofaunal composition of recreational gillnet captures based on 2000/01, 2007/08, 2010 and 2012/13 fishing surveys.

Source	**Permutations**	***df***	**Pseudo-F**	***p***
Region	995	5	4.082	<0.001***
Survey	997	3	2.765	<0.001***
Region X survey	997	15	2.203	0.001**

Table 8: R statistic values and significance levels for pairwise ANOSIMs exploring regional variation in catch composition for recreational gillnets (mullet and graball nets combined) based on 2010 and 2012/13 fishing surveys.

The species determined by SIMPER as most responsible for typifying the ichthyofaunal compositions in each region (shaded boxes) and for distinguishing between the ichthyofaunal compositions of each region are shown. $^+$indicates species more abundant in the region at the top of the column.

	East coast	Northwest coast	Northeast coast	Southeast coast	Southeast SRA	West coast
East coast	Bastard Trumpeter Wrasse Jackass Morwong					
Northwest coast	0.212*** Mullet Jackass Morwong$^+$ Sweep Wrasse$^+$ Bastard Trumpeter Australian Salmon	Mullet Wrasse Australian Salmon				
Northeast coast	0.042	0.205*** Mullet$^+$ Jackass Morwong Sweep$^+$ Wrasse Australian Salmon$^+$	Banded Morwong Wrasse			
Southeast coast	0.137*** Jackass Morwong$^+$ Bastard Trumpeter Wrasse Blue Warehou Leatherjackets$^+$	0.345*** Mullet$^+$ Sweep$^+$ Australian Salmon$^+$ Bastard Trumpeter$^+$ Wrasse$^+$	0.208*** Jackass Morwong$^+$ Bastard Trumpeter Leatherjacket$^+$ Blue Warehou Banded Morwong$^+$ Wrasse$^+$	Bastard Trumpeter Blue Warehou Leatherjackets Wrasse		
Southeast SRA	0.297*** Jackass Morwong$^+$ Bastard Trumpeter Wrasse	0.367*** Mullet$^+$ Sweep$^+$ Australian Salmon$^+$ Wrasse$^+$	0.374*** Jackass Morwong$^+$ Wrasse$^+$ Banded Morwong$^+$ Leatherjacket$^+$ Bastard Trumpeter$^+$ Blue Warehou Mullet	0.080** Bastard Trumpeter$^+$ Blue Warehou$^+$ Wrasse Leatherjacket$^+$	Bastard Trumpeter Wrasse Atlantic Salmon	
West coast	0.275*** Bastard Trumpeter Jackass Morwong$^+$ Wrasse Flounder$^+$	0.313*** Mullet$^+$ Bastard Trumpeter Australian Salmon$^+$ Sweep$^+$ Wrasse$^+$ Flounder$^+$	0.391*** Bastard Trumpeter Jackass Morwong$^+$ Wrasse$^+$ Banded Morwong$^+$ Flounder$^+$ Leatherjackets$^+$	0.191*** Bastard Trumpeter Flounder$^+$ Blue Warehou$^+$ Wrasse Leatherjackets$^+$	0.138*** Bastard Trumpeter Flounder$^+$ Wrasse$^+$ Mullet Atlantic Salmon$^+$	Bastard Trumpeter Flounder Atlantic Salmon

Condition and survival of gillnet caught fish

A total of 10 587 marine organisms (scalefish, sharks and invertebrates) were captured during on-board observation of commercial gillnet fishing and research gillnetting during the present study. Invertebrates, including Southern Rock Lobster, Blacklip Abalone and a variety of urchin, crab and starfish species, although rare were captured alive and largely undamaged. The subsequent PRS of these species was not assessed as part of this project.

The focus of the following analysis is on how gillnet soak times affected capture condition (Table 9) and rates of initial mortality (IM) (Table 10), with the latter also explored seasonally (Table 10). Where soak duration significantly influenced condition or IM, soak times were binned into five soak time categories and compared in a pairwise fashion (see Table A1. 7 for post-hoc multiple comparisons of condition stage, Table A1. 8 for a breakdown of the numbers of fish captured by condition stage within each soak time and Table A1. 9 for pairwise comparisons of IM rate). While this approach may be tedious, it is important to identify critical points in relation to soak times that will assist in reducing impacts on by-catch.

The number/proportion and primary rationale for the allocation of key species into the poor condition category (Stage 4) is provided in Table A1. 10. Additionally, ordinal regression analysis was carried out on these data and the results are presented in Table A1. 11. While replicating the previous analysis, this modelling is quantitative (unlike the non-parametric analysis) and is therefore useful for extrapolative purposes. These analyses focus on the most commonly encountered fish species (>30 individuals caught).

In addition to quantifying capture condition, 729 fish, representing 31 species, were retained for tank trials to investigate the relationships between capture condition and rates of delayed mortality (DM) (see Table A1. 12 for species breakdown). Delayed mortality was only able to be investigated statistically for the five most commonly encountered species (Table 11) and even so in some instances it was necessary to combine condition stages to strengthen the modelling (assessed in Table 12). An unavoidable deficiency of logistic regression is that it is only possible when there are a reasonable number of observations in each of the binomial categories. Post hoc multiple pairwise comparisons for this analysis are located in Table A1. 13. These analyses also investigated the effect of season on DM rates (Table 13). Reasonable numbers of several other species were also retained for tank trials enabling a semi-quantitative assessment of PRS rates.

There was no significant difference in the mean soak times between seasonal sampling based on cool and warm water periods (as defined in the Methodology section) during daytime net deployments (Welch t-test, $t = 0.725$, $df = 7679$, $p = 0.468$) or overnight deployments in Macquarie Harbour (Welch t-test, $t = -0.510$, $df = 621$, $p = 0.610$); thus, all data were used when comparing initial and delayed mortality rates of fish during cool and warm water seasons.

Banded Morwong

Banded Morwong are a relatively robust species, which is what makes them ideally suited for the live fish trade. The overwhelming majority of individuals were in condition Stages 1 and 2 irrespective of soak time (Table A1. 8). Nevertheless, fish did display declining condition with increasing soak duration (Table 9), with fish from soak time 4 (5 – 8 hours) being in significantly poorer condition than those from all shorter soak times (Table A1. 7). This was predominantly due to an increase in the proportion of Stage 3 individuals in the catches, the result of increased scale loss and bruising due to capture. Unexpectedly, fish from soak time 2 (2.5 – 3.5 hours) had a greater proportion of Stage 1 individuals than the shortest soak time category and there was no significant difference between the condition of fish in soak time categories 1 and 3. This result can best be explained by the relatively minor differentiation between Stages 1 and 2, both of which are indicative of fish in very good condition, with little or no obvious net damage. Fish were generally ranked as stage 4 due to the presence of gill bleeding and barotrauma (Table A1. 10).

There was no significant increase in the IM rate of Banded Morwong with increased soak duration (overall 1.3%) and this did not vary between cool and warm water sampling (Table 10). Delayed mortality was also low, with the vast majority of individuals surviving the tank trial period, including Stage 4 fish (Table A1. 12). Due to the very low mortality rates the logistic regression model was unable to adequately fit the data initially, however, by combining Stages 1 – 3, which were not statistically different from each other (Table A1. 13), the model performed adequately (Table 12) and indicated a significant increase in DM for Stage 4 fish (Table 11). There was no seasonal difference in DM for Banded Morwong (Table 13).

Bluethroat Wrasse

Due to the sexual dimorphism in size, male Bluethroat Wrasse dominated gillnet catches, and often sustained considerable damage. Females and juveniles were generally mouthed and typically captured in good condition. Conversely, males were usually tightly gilled with a large amount of scale loss, bruising and cuts where they were in contact with the meshes, which was the major reason that individuals were ranked as stage 4. Further, due to the territoriality of males, those that were entangled often had ancillary damage, presumably from rival males attacking them and associated with this behaviour, it was not uncommon to capture two or more males within close proximity of each other.

Fish condition declined as soak duration increased (Table 9), with fish from soak time 4 (5 – 8 hours) being in significantly poorer condition than those from shorter sets. Initial mortality rates increased significantly with soak time (Table 10), with fish from soak times 3 and 4 (i.e. >3.5 hours) being less likely to survive capture than fish from shorter soak times. There was also a significantly higher incidence of IM in fish captured during sampling in the warmer months of the year (Table 10).

Due to the survival of all Stage 1 fish in the tank trials, the logistic model could not converge (Table 11, Table 12). When Stages 1 and 2 were combined the model fit was significant (Table 12) but, as there was no difference in DM rates for combined Stages 1 – 2 and 3, these Stages were combined, which further strengthened the model. The DM for this combined category was significantly lower than for Stage 4 fish and there was no significant seasonal effect on DM in Bluethroat Wrasse (Table 13). Due to the nature of the injuries sustained by some individuals held in the tank trials (potentially exacerbated by confinement, an example pictured in Figure 13) it is possible that not all of the fish that survived the holding period would have survived longer-term; the tagging study reported below, however, suggests that Bluethroat Wrasse may be able to recover from relatively severe injuries.

Bastard Trumpeter

Bastard Trumpeter survive capture in gillnets relatively well but often suffer ancillary net damage to the opercular region (where they are gilled) and occasionally around the caudal peduncle as they often get their tail entangled (Figure 13). The latter damage may be accentuated by handling while disentangling them from the nets. On occasions, they also suffer from considerable scale loss where they have worked multiple meshes over their body or are wedged tightly in the net. In aquaria, these regions can become infected (Figure 13) and it is possible that such individuals would not survive in the longer-term.

Increasing soak durations caused a significant decline in the condition Stage of Bastard Trumpeter (Table 9). There was no significant difference in the condition of fish from soak times 1 and 2 (<3.5 hours), whereas fish from the longer soak times were in significantly poorer condition, with fish from soak time 4 (5 – 8 hours) in poorer condition than those from soak time 3 (3.5 – 5 hours). Soak time did not, however, influence IM rates and there was no seasonal effect on IM (Table 10).

All Stage 1 fish survived the holding period and Stage 2 fish experienced a very low DM rate (3%), and as a consequence, the logistic model did not initially fit the data (Table 12). The model performed adequately if Stages 1 – 3 were combined; the DM rate of Stage 4 fish being significantly greater than that for the combined stages (Table 11). Delayed mortality was not influenced by season (Table 13).

Marblefish

Marblefish are a robust species that rarely sustained substantial net damage and survived capture relatively well. This is somewhat unexpected given that a large proportion of those caught were very tightly gilled and often rolled in the net and entangled in multiple meshes. Furthermore, when removing fish from the net they often lost much of their protective slime coating. Heavy bleeding due to mesh cuts to the gills was the primary reason for ranking fish as being in Stage 4.

Overall, fish in Stages 1 and 2 dominated catches regardless of soak time, although there was a significant decline in condition with increased soak duration (Table 9) and fish from soak time category 4 (5 – 8 hours) were in significantly poorer condition than those from soak time 2 (2.5 – 3.5 hours). Soak duration also had a significant effect on the IM rate (Table 10), although none of the post-hoc pairwise comparisons were significant. The lack of significance probably resulted from the conservative nature of the method used to correct for multiple pairwise comparisons. There was no significant difference in IM based on season (Table 10).

The lack of DM in each of the condition stages other than Stage 4 meant that the logistic model fitted the data poorly (Table 12) and there was no significant relationship between DM and condition stage nor DM and season (Table 11 and Table 13). Interestingly, the majority (88%) of the Stage 4 fish survived the tank trial period despite all bleeding heavily from the gills at capture; each of the survivors appeared to have fully recovered prior to their release.

Draughtboard Shark

Draughtboard Shark are an extremely robust species and even when gilled tightly in the nets, were in good condition. No instances of initial or delayed mortality were observed irrespective of soak time or capture condition, with almost all individuals captured in Stages 1 or 2. As a result there were no significant relationships between soak time and condition, IM or condition and DM (Table 10 and Table 11).

Elephantfish

Elephantfish were generally in good condition (Stages 1 – 3) when retrieved from gillnets. They were rarely gilled but usually tangled by the dorsal spine or, in males, their tenaculum. The species does have a tendency to roll up in the net, causing superficial damage to their dermis which is unprotected by placoid scales and can scar badly. Further, when they roll in the net some individuals sustain damage to their eyes that can result in blindness[5], which only became evident after about a week in aquaria (Figure 13). These fish generally survived the tank trial period but may not survive in the longer-term.

Increasing soak duration had a negative impact on capture condition (Table 9), with fish from overnight sets (soak time 5) in poorer condition than fish from all other soak times. There was no significant difference in the condition of fish from day sets (soak times 1 – 4). Soak duration had a negative impact on IM (Table 10) but there were no pairwise differences between soak time categories, probably due to the relatively low number of mortalities that were observed.

There were insufficient numbers of Elephantfish in Stages 1 and 4 to enable meaningful statistical analysis of DM. The available data did suggest moderately high rates of survival (80 – 100%) for individuals in Stages 1 – 3. Season had no significant influence on IM or DM (Table 10 and Table 13).

Australian Salmon

Australian Salmon were usually gilled tightly when caught in gillnets and tended to suffer substantial scale loss and a relatively high IM rate, reaching over 50% for soak times exceeding 3.5 hours (soak time categories 3 – 5). Due to the low number of samples in overnight sets this group was excluded from subsequent analyses. Increased soak time resulted in a significant decline in condition (Table 9) and all pairwise comparisons, other than between soak times 3 and 4, were significant. There was a significant increase in IM with soak duration (Table 10), with higher mortality rates in soak times 3 and 4 than in soak times 1 and 2 but no difference within each of these groups. The IM rate was higher in the warmer months (Table 10).

Delayed mortality rates increased from 0% for Stage 1 to 50% for Stage 4 fish. However, many of the fish that survived the tank trial period exhibited substantial scale loss (Figure 13) and it is probable that

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[5] While it is possible that the occurrence is an artefact of confinement, J. Bell has retained this species in aquaria for other studies (Hyodo *et al*. 2005) and has not observed this phenomenon in fish captured using hooks or with seine nets.

additional mortality may have occurred over a longer time frame assuming this damage was not artefact of confinement.

Purple Wrasse

Purple Wrasse appear to be more resilient to gillnet capture than Bluethroat Wrasse, with IM rates of between 0 and 13% for the day set soak time categories. Being smaller than Bluethroat Wrasse, the majority of the Purple Wrasse captured were mouthed, rather than gilled as was the case for Bluethroat Wrasse (especially males).

There was no significant decline in condition with increasing soak time (Table 9) and no significant increase in IM rate with increasing soak duration (Table 10). Of those individuals retained for tank trials, most were in good condition and all survived; consequently, the logistic regression could not be used to investigate delayed mortality. Neither IM nor DM varied with season (Table 10 and Table 13).

Leatherjackets (combined species)

Leatherjackets are a robust group that are typically captured in good condition, with little or no obvious net damage. They do not have a calcified operculum and are typically wedged in the net or their spine becomes entangled in the meshes. Leatherjackets are also offered a degree of protection by their tough leathery skin.

There was no significant decline in condition with soak time (Table 9) and the IM rate, which was close to 0%, was unaffected by soak duration and season (Table 10). There was only a single mortality during tank trials (Stage 3); as a result it was not possible to model variation in DM with condition or season.

Longsnout Boarfish

Longsnout Boarfish are a robust species that is often tangled in the meshes by their dorsal, pectoral and/or anal spines rather than being meshed around the gills. Although the membrane between the spines was regularly damaged there was no indication that this caused infection or mortality, at least within the timeframe fish were monitored in tank trials. Otherwise, they appear to sustain little physical damage from capture and there was no significant relationships between condition and soak duration (Table 9), soak duration and IM, or season and IM (Table 10). Longsnout Boarfish do, however, suffer from barotrauma, particularly when fishing at depths Banded Morwong fishers tend to operate and upon release such individuals have difficulty descending. Several fish showing symptoms of barotrauma were retained for tank trials and each of these fish equalised within the tank trial period – we were not able to release the pressure on the swim bladder in this species. All of the Longsnout Boarfish retained for tank trials were in good condition (Stages 1 – 3) and all survived the holding period; as a result it was not possible to model variation of DM with fish condition or season using logistic regression.

Herring Cale

Herring Cale, due to their cylindrical body morphology, were almost exclusively mouthed when caught, yet, were often dead (overall IM rate of 32%) with no observable physical damage. It is difficult to explain why this is the case as they are capable of remaining immobile and can regularly be seen at rest hidden amongst kelp when diving.

There was no significant relationship between soak time and condition (Table 9) but there was a negative relationship between soak duration and IM (Table 10). There were no pairwise differences in post hoc comparisons, probably due to the conservative correction for multiple pairwise comparisons, suggesting the difference was relatively minor and there is not a threshold beyond which IM increased rapidly. IM rate was greater during warm water sampling period (Table 10).

Herring Cale are not very abundant in catches from the Southeast region meaning this species was underrepresented in tank trials; of the five individuals retained, two died, suggesting that DM may be relatively high. There was insufficient data to model the DM rate by condition or season.

Blue Warehou

Blue Warehou did not survive capture in gillnets well, with an overall IM rate of around 42%. Capture condition declined significantly with soak time (Table 9) but there were no pairwise differences, probably due to the relatively low sample size and the correction for multiple pairwise comparisons. Initial mortality rates increased from around 30% for the shorter soak time categories (< 3.5 hours) to over 50% for soak times 3 and above, the relationship between IM and soak duration was not, however, significant (Table 10). Although there was a significant increase in IM during the warmer season (Table 10), this result is based on a relatively low sample size for the cool water season.

Blue Warehou are retained by all fishing sectors; as such, none were retained for DM assessment.

Blue Grenadier

Blue Grenadier (juveniles) were encountered exclusively in Macquarie Harbour and, despite all being mouthed, displayed very high IM rates (> 98 % overall). Although condition declined significantly with increasing soak duration (Table 9) there was no significant effect of soak time on IM rate (Table 10). This latter result was due to the very high IM rate regardless of soak duration. As the vast majority of Blue Grenadier were caught on a single sampling trip it was not possible to explore seasonal variation in IM.

Whitespotted Dogfish

Whitespotted Dogfish were the most commonly encountered species in Macquarie Harbour, particularly when set depths exceeded 8 m. Both males and females were captured, though rarely concurrently, suggesting a degree of sexual segregation. Due to considerable differences in the size of males and females, the smaller males were generally mouthed whereas the larger females were more likely to be gilled in the nets. Both sexes had a tendency to roll up tightly in the meshes, increasing the damage they sustained and presumably contributing to the proportion of individuals in poor condition and moderate IM levels (12% overall).

There was a significant negative relationship between soak duration and capture condition of the (Table 9), with individuals from overnight sets (soak time 5) being in poorer condition than those from all other soak time categories. There were no significant differences in capture condition between any of the shorter soak time categories, with the majority of individuals from day time deployments in relatively healthy condition. Soak duration also had a significantly negative influence on IM (Table 10) but due to the low level of mortality in day sets there was only a significant pairwise difference between soak times 2 (2.5 – 3.5 hours) and 5 (overnight sets); however, it was clear that IM was far higher in overnight deployments than for day sets.

For practical considerations, namely sampling off the remote west coast, Whitespotted Dogfish were not retained for tank trials. Nonetheless, it is feasible to assume that not all released individuals would survive, particularly following overnight deployments where a relatively high proportion of fish were in poor condition (Stage 4, gill bleeds and/or unlively).

Gummy Shark

Gummy Shark were captured in moderate numbers within the D'Entrecasteaux Channel and Frederick Henry Bay, both are designated SRAs and state legislation requires fishers to release any sharks (excluding Elephantfish) captured in such areas. Gummy Shark are targeted outside of SRAs by commercial and recreational fishers who have catch and size limits that may necessitate some of the catch to be released.

Gummy Shark were often in poor condition as a result of capture and a relatively high proportion of individuals did not survive capture (IM rate of 24% overall), despite the majority being caught in sets of short duration (<3.5 h). Similar to other shark species, Gummy Shark have a tendency to roll up tightly in the nets and, even though they possess spiracles, presumably die from asphyxia. While there was no relationship between soak time and condition (Table 9) or soak duration and IM (Table 10), this analysis was limited by the small number of Gummy Shark represented in sets with soak times >3.5 hours. There was no significant seasonal effect on IM (Table 10) though few Gummy Shark were caught during cooler months so this result may not be robust. DM was not assessed for this species.

Jackass Morwong

Jackass Morwong are moderately robust, with an overall IM rate of 22%. Condition declined with soak duration (Table 9) with an apparent threshold since there were no significant differences in capture condition between soak times 1 and 2 or soak times 3 and 4 but all other pairwise comparisons were different. Initial mortality rate increased with soak duration but was not influenced by season (Table 10).

Comparatively few Jackass Morwong were caught off the southeast coast and as a result very few individuals were available for tank trials (n = 6, 2 of which died) and therefore DM could not be assessed quantitatively for this species.

Flounder

Greenback and Longsnout Flounder are managed as a single entity in Tasmania and results have been combined to increase the statistical power of the analyses. Flounder are a robust group, with very high survival rates, even in overnight sets. Flounder were generally wedged in the meshes and most of those caught while research fishing were undersized, or marginally above legal size (230 mm), reflecting size selectivity of the 114 mm mesh size utilised. Commercial and recreational fishers use larger mesh sizes (~140 mm) to target Flounder and undoubtedly achieve a much higher proportion of legal-sized fish in their catches than in our research nets.

Soak time negatively impacted the condition of Flounder (Table 9), a result that was largely influenced by several individuals being predated upon during overnight deployments in Macquarie Harbour. There were no post hoc pairwise significant differences between soak time categories, which was due to the overwhelming majority of individuals being in good condition irrespective of soak time. There was no significant difference in the IM rate for Flounder with increasing set duration and this did not vary seasonally (Table 10), results influenced by the very low IM rate across all soak times. Due to their rarity in catches taken in the southeast, only five individuals were retained for tank trials, all of which survived.

Maugean Skate

Maugean Skate were regularly encountered during research fishing throughout Macquarie Harbour, being the second most commonly caught species in that area. Due to their body morphology they tend to be lightly entangled in gillnets, with their long snout protruding through one or more meshes and the thorns present around their eyes and dorsal region occasionally also catching meshes.

Maugean Skate were generally in excellent condition when captured and all individuals caught during daytime deployments were in Stages 1 or 2. Most individuals captured in overnight deployments were also in good condition, however, on three occasions mortalities (Stage 5) and/or individuals in poor condition (Stage 4) were observed. On two of these occasions there was evidence of predation, one apparently involving Whitespotted Dogfish and the other a combination of crab and sea lice (copepods) predation. On the third occasion (24/04/2012), while the cause of the mortalities was not readily apparent, soak durations were substantially longer than was typical for overnight sets (up to 20 hours); a result of unexpectedly high catch rates and the project team assisting other researchers who were undertaking biological examination of the Maugean Skate. Recognising that such long set durations are unlikely to be representative of typical gillnetting practices, condition and IM data were analysed including all of the data and with data from the 24/04/2012 excluded (Table 9 and Table 10).

The impact of soak time on condition was similar for both datasets, with a significant negative influence on condition (Table 9). When all data were included Maugean Skate taken in overnight deployments were in significantly poorer condition than those from all other soak times apart from soak time 4. When data from the 24/04/2012 are excluded the only significant pairwise comparison was between soak times 1 and 5. The lack of significance in the other pairwise comparisons is likely a result of the small number of individuals encountered in the shorter soak time categories, the fact that the overwhelming majority of the Maugean Skate were in good condition irrespective of soak time and the correction for multiple pairwise comparisons.

Soak duration was found to significantly influence the IM rate when all data were included (Table 10), with soak time 5 (overnight sets) significantly different to all other soak time categories. Exclusion of data from 24/04/2012 resulted in a non-significant relationship between IM and soak time (Table 10). There was no seasonal effect on IM. DM was not assessed for this species.

Southern Sand Flathead

Southern Sand flathead were generally in good condition when captured, although mortalities did occur, particularly when caught in mullet nets. In these nets the species tended to be tightly entangled in multiple meshes, whereas in graball nets fish tend to be more loosely meshed, mainly by their spines, and in better condition as a result.

Condition (Table 9) and IM (Table 10) were not influenced by soak duration, nor was there a significant seasonal effect on IM (Table 10). Several individuals in good condition (stages 1 and 2) were retained for tank trials and, although not sufficient numbers for statistical analysis, all survived the holding period.

Yelloweye Mullet

Yelloweye Mullet were most frequently captured in mullet nets, particularly during the warmer months, with only occasional catches in graball nets. The species tended to lose large quantities of scales and experienced gill damage and bleeding in gillnets, resulting in a high proportion of fish being either dead (70% overall) or in poor condition upon capture. Increasing soak duration had a significant negative impact on fish condition (Table 10) with fish from soak time 4 being in significantly worse condition than those from soak times 1 and 2. Initial mortality rate also increased significantly with soak duration (Table 10), with soak time 4 fish more likely to be dead than those from soak times 1 and 2. Yelloweye Mullet were encountered almost exclusively during the warmer months and thus seasonal effects on mortality rates were not assessed. DM was not assessed for the species.

Magpie Perch

Magpie Perch were very robust; the vast majority of individuals were in condition stages 1 or 2 irrespective of soak time and they had a very low overall mortality rate (5%). Relationships between soak time and condition (Table 9), soak duration and IM, and season and IM (Table 10) were each non-significant and of 22 individuals retained for tank trials there was only single mortality. Although it was not possible to explore the effects of condition or season on DM, the data suggest that post release survival in Magpie Perch is likely to be very high.

Atlantic Salmon

Escapee Atlantic Salmon are considered an exotic species and therefore have no LML and, up until recently, no possession limit in Tasmania. Being a target species for many recreational gillnet fishers few, if any, are likely to be released. Nevertheless, the present results may have relevance to fisheries elsewhere.

Apart from the shortest soak time category (< 2.5 hours), when most fish were in Stage 2 condition, Atlantic Salmon did not survive capture in gillnets particularly well. In all other soak time categories at least 40% of individuals were dead, with ~60% dead in overnight net deployments. Soak time had a significant negative influence on fish condition (Table 9), with fish from overnight deployments being in significantly poorer condition than those from soak time 1. Increasing soak duration also had a significant negative impact on IM (Table 10), with fish from overnight deployments significantly more likely to be dead than those from soak time 1, but no other soak time categories. There was no seasonal effect on IM (Table 10).

Silverbelly

Silverbelly were encountered exclusively in mullet nets when set over seagrass habitats. They are not a particularly robust species and displayed a very high IM rate (71% overall). There was a significant decline in condition with soak time category (Table 9) but soak duration did not significantly influence IM, reflecting the high proportion of mortalities irrespective of soak duration. Thirteen Silverbelly were retained in tank trials, all of which died, suggesting DM is very high for this species. It is possible, however, that this result may have been confounded by the effects of transportation and retention in tanks.

Cowfish (Shaw's and Ornate)

Both species of Cowfish displayed minimal evidence of net damage and there were no mortalities irrespective of soak duration, probably because they tended to be loosely tangled in the meshes by their body spines. As a result there was no relationship between soak duration and fish condition (Table 9), soak duration and IM or season and IM (Table 10). Insufficient numbers were retained for tank trials to reliably gauge DM, though it should be mentioned that these species do show symptoms of barotrauma and can experience difficulties descending when released. As a result there may be some ancillary DM.

Stingarees (Banded and Sparsely Spotted)

Both species are robust and no mortalities were observed, probably because they tend to be lightly tangled in the meshes by their tail spine. Although there was a significant decline in condition with soak duration (Table 9), all individuals were in good condition (Stages 1 to 3). No IM was observed and these species were not retained for tank trials. It is clear that these species suffer minimal physical damage and incidental mortality rates are likely to be very low as a direct result of gillnet capture, although injuries deliberately inflicted by fishers seeking to make the Stingarees easier to handle, are a possibility.

Red Cod

Red Cod were not resilient to gillnet capture, with an overall IM rate of 65% and of the remainder, a high proportion were in Stages 3 and 4. Condition declined with increasing soak duration (Table 9) and soak duration also had a significant negative impact on IM (Table 10). Season had no influence on IM (Table 10). Insufficient numbers of Red Cod were retained for tank trials (n = 4) to statistically analyse DM, though the majority (75%) died during the holding period.

Gurnards (Thetis fish and Common Gurnard Perch)

Gurnards were typically tangled by the spines located around their mouth, opercula and dorsal region, and were generally in good condition, with only one mortality recorded in this study (in an overnight set). As a result there was no relationship between soak duration and fish condition (Table 9), soak duration and IM, or season and IM (Table 10). Gurnards were not retained for tank trials but it seems unlikely they would suffer significant post release mortality based on the healthy condition of most fish in the net. Post capture injuries deliberately inflicted by fishers seeking to make the fish safer to handle, are a distinct possibility with this species.

Table 9: Kruskal-Wallis test for the effect of gillnet soak time on capture condition.

Species	χ^2	*df*	*p*
Banded Morwong	46.685	3	<0.001***
Bluethroat Wrasse	66.390	3	<0.001***
Bastard Trumpeter	65.421	3	<0.001***
Marblefish	16.948	3	0.001**
Draughtboard Shark	3.384	3	0.336
Elephantfish	16.217	4	0.003**
Purple Wrasse	6.199	3	0.102
Leatherjackets (all species)	6.913	3	0.075.
Longsnout Boarfish	2.485	3	0.478
Herring Cale	1.708	3	0.635
Blue Warehou	13.546	4	0.009**
Blue Grenadier	13.348	4	0.009*
Whitespotted Dogfish	25.010	4	<0.001***
Australian Salmon	23.049	3	<0.001***
Gummy Shark	6.089	3	0.107
Jackass Morwong	15.636	3	0.001**
Flounder (all species)	10.103	4	0.03*
Maugean Skate (all data)	30.983	4	<0.001***
Maugean Skate (24/04/2012 omitted)	24.141	4	<0.001***
Southern Sand Flathead	6.815	3	0.078.
Yelloweye Mullet	15.371	3	0.002**
Magpie Perch	4.475	3	0.214
Atlantic Salmon	14.596	4	0.005**
Silverbelly	9.048	3	0.029*
Ornate/Shaw's Cowfish	4.264	3	0.234
Banded/Sparsely Spotted Stingarees	15.278	3	0.002**
Red Cod	28.497	4	<0.001***
Gurnard	3.332	3	0.343

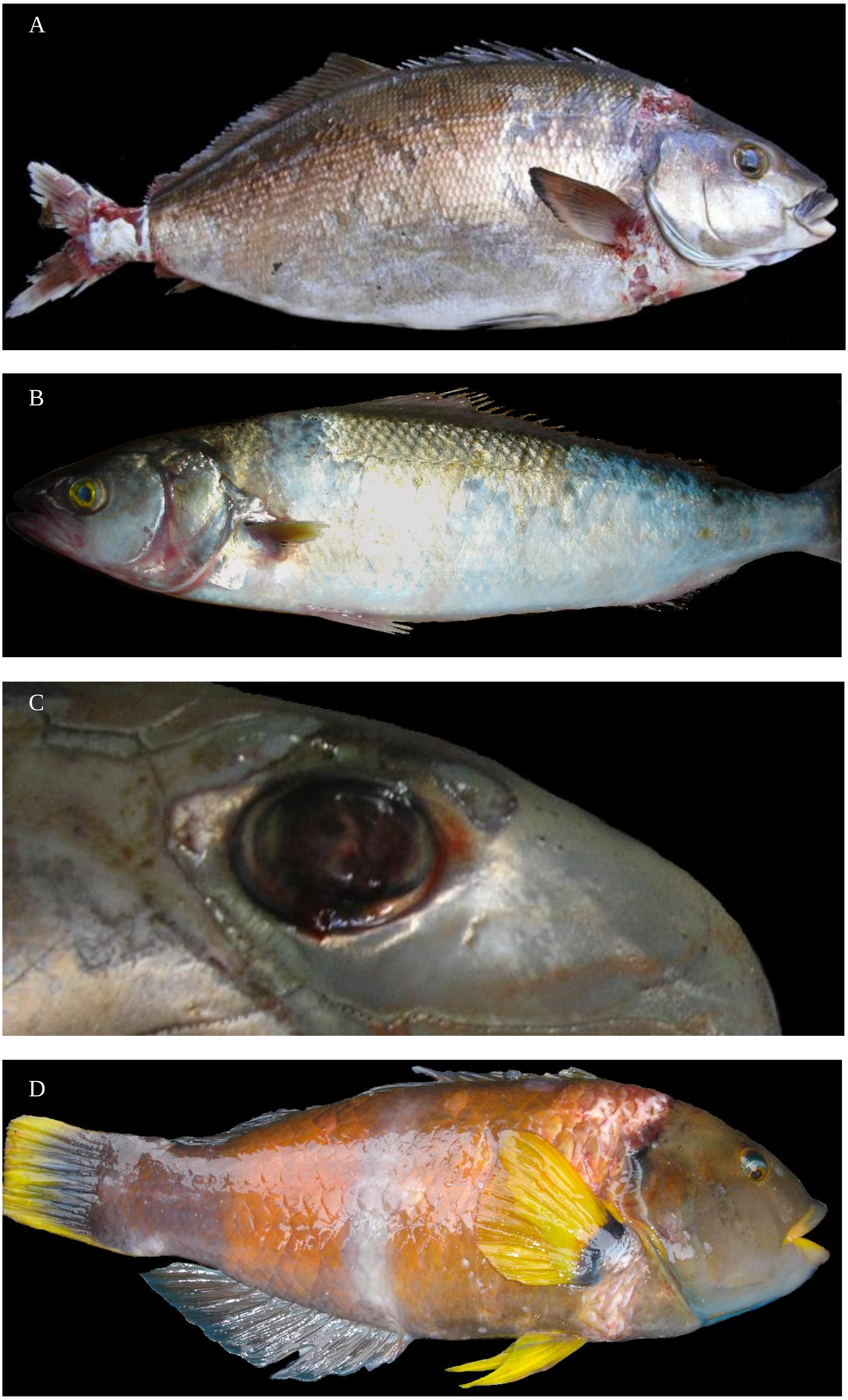

Figure 13: Injured fish surviving the four day tank trial period.
A) Bastard Trumpeter, 8 days post capture with severe wounds and infection (initial condition stage 3); B) Australian Salmon, 7 days post capture with severe scale loss (initial condition stage 2); C) Blinded Elephantfish, 10 days post capture; D) Bluethroat Wrasse, 5 days post capture with a large area of scale loss (initial condition stage 3).

Table 10: Logistic regression of variation in initial mortality rate due to soak duration and due to sampling in warm (November – April) and cool months (May – October).

Species	Coefficient	Estimate	Std. error	z value	*p*
Banded Morwong	Soak duration	-0.166	0.132	-1.259	0.208
	Season	0.595	0.371	1.603	0.109
Bastard Trumpeter	Soak duration	-0.082	0.128	-0.644	0.520
	Season	0.411	0.277	1.484	0.138
Marblefish	Soak duration	-0.289	0.105	-2.762	0.005**
	Season	0.560	0.270	2.072	0.038*
Draughtboard Shark	Soak duration	0.000	6706.000	0.000	1.000
	Season	0.000	11400.000	0.000	1.000
Bluethroat Wrasse	Soak duration	-0.410	0.048	-8.460	<0.001***
	Season	0.351	0.082	4.284	<0.001***
Longsnout Boarfish	Soak duration	-1.640	1.439	-1.140	0.254
	Season	-10.030	2382.910	-0.004	0.997
Elephantfish	Soak duration	-0.136	0.051	-2.699	0.007**
	Season	-0.406	0.273	-1.489	0.136
Australian Salmon	Soak duration	-0.321	0.110	-2.913	0.003**
	Season	0.761	0.184	4.142	<0.001***
Blue Warehou	Soak duration	-0.076	0.041	-1.862	0.063.
	Season	0.997	0.210	4.755	<0.001***
Blue Grenadier[6]	Soak duration	-0.319	0.214	-1.488	0.137
Whitespotted Dogfish	Soak duration	-0.086	0.024	-3.583	<0.001***
	Season	0.151	0.260	0.582	0.561
Southern Sand flathead	Soak duration	-0.253	0.155	-1.629	0.103
	Season	-0.441	0.427	-1.034	0.301
Purple Wrasse	Soak duration	-0.276	0.180	-1.534	0.125
	Season	0.338	0.327	1.034	0.301
Gummy Shark	Soak duration	-0.382	0.264	-1.448	0.148
	Season	-0.108	0.374	-0.288	0.773
Jackass Morwong	Soak duration	-0.684	0.202	-3.380	<0.001***
	Season	0.177	0.302	0.584	0.559
Leatherjackets (all species)	Soak duration	-0.070	0.171	-0.406	0.685
	Season	-0.017	0.462	-0.037	0.971
Herring Cale	Soak duration	-0.364	0.160	-2.280	0.023*
	Season	0.534	0.241	2.215	0.027*
Magpie Perch	Soak duration	0.077	0.271	0.283	0.777
	Season	0.090	0.445	0.202	0.840
Flounder (all species)	Soak duration	-0.027	0.075	-0.357	0.721
	Season	-0.134	0.719	-0.187	0.852
Gurnard (all species)	Soak duration	-3.331	1559.049	-0.002	0.998
	Season	0.000	59760.000	0.000	1.000
Red Cod	Soak duration	-0.207	0.046	-4.547	<0.001***
	Season	0.896	0.574	1.560	0.119

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[6] Blue Grenadier were not captured during the cool season so it was not possible to test for differential mortality with season.

Table 10 (continued)

Species	Coefficient	Estimate	Std. error	z value	*p*
Banded/Sparsely Spotted Stingarees	Soak duration	-3.331	1559.049	-0.002	0.998
	Season	0.000	46600.000	0.000	1.000
Ornate/Shaw's Cowfish	Soak duration	1.63^{-10}	31040.000	0.000	1.000
	Season	0.000	59440.000	0.000	1.000
Silverbelly	Soak duration	-0.308	0.227	-1.355	0.175
	Season	0.810	0.359	2.259	0.024*
Atlantic Salmon	Soak duration	-0.123	0.053	-2.328	0.020*
	Season	0.445	0.277	1.608	0.108
Whitespotted Dogfish	Soak duration	-0.085	0.025	-3.356	<0.001***
	Season	0.506	0.142	3.572	<0.001***
Maugean Skate (all data)	Soak duration	-0.487	0.152	-3.200	0.001**
	Season	7.674	734.026	0.010	0.992
Maugean Skate (24/04/2012 omitted)	Soak duration	-1.362	0.945	-1.441	0.150
	Season	8.971	3121.759	0.003	0.998

Table 11: Logistic regression of survival probability (0 = mortality, 1 = survive) by condition stage. Each condition stage is compared to the lowest possible category (i.e. condition 1 when all conditions are included, then condition stages 1 and 2 combined, and so on as indicated in the table).

Species	Condition	Estimate	Std. error	z value	*p*
Banded Morwong (all conditions)	(Intercept)	20.570	3780.000	0.005	0.996
	2	-16.820	3780.000	-0.004	0.996
	3	0.000	6062.000	0.000	1.000
	4	-19.180	3780.000	-0.005	0.996
Banded Morwong	(Intercept)	3.980	0.714	5.576	<0.001***
(condition 1 and 2 combined)	3	15.586	2874.131	0.005	0.996
	4	-2.593	1.326	-1.955	0.051.
Banded Morwong	(Intercept)	4.103	0.713	5.755	<0.001***
(condition 1, 2 and 3 combined)	4	-2.716	1.326	-2.049	0.041*
Bluethroat Wrasse	(Intercept)	19.570	2109.040	0.009	0.993
(all conditions)	2	-16.680	2109.040	-0.008	0.994
	3	-17.540	2109.040	-0.008	0.993
	4	-19.460	2109.040	-0.009	0.993
Bluethroat Wrasse	(Intercept)	3.434	0.718	4.780	<0.001***
(condition 1 and 2 combined)	3	-1.406	0.862	-1.632	0.103
	4	-3.329	0.853	-3.903	<0.001***
Bluethroat Wrasse	(Intercept)	2.659	0.391	6.802	<0.001***
(condition 1, 2 and 3 combined)	4	-2.554	0.603	-4.233	<0.001***
Bastard Trumpeter	(Intercept)	16.570	1385.380	0.012	0.990
(all conditions)	2	-12.980	1385.380	-0.009	0.993
	3	-14.470	1385.380	-0.010	0.992
	4	-15.220	1385.380	-0.011	0.991
Bastard Trumpeter	(Intercept)	3.664	1.013	3.618	<0.001***
(condition 1 and 2 combined)	3	-1.564	1.101	-1.420	0.156
	4	-2.314	1.098	-2.107	0.035*
Bastard Trumpeter	(Intercept)	2.531	0.393	6.446	<0.001***
(condition 1, 2 and 3 combined)	4	-1.182	0.578	-2.044	0.041*
Marblefish	(Intercept)	20.570	4179.000	0.005	0.996
(all conditions)	2	-17.010	4179.000	-0.004	0.997
	3	0.000	6786.000	0.000	1.000
	4	-18.620	4179.000	-0.004	0.996
Marblefish	(Intercept)	3.970	1.009	3.933	<0.001***
(condition 1 and 2 combined)	3	15.596	3242.457	0.005	0.996
	4	-2.024	1.261	-1.605	0.108
Marblefish	(Intercept)	4.159	1.008	4.127	<0.001***
(condition 1, 2 and 3 combined)	4	-2.213	1.260	-1.757	0.079.

Table 12: Analysis of deviance table (likelihood ratio test) assessing the goodness of fit of each logistic regression model in describing DM by fish condition (Table 11).

Species	Model	*df*	χ^2	*p*
Banded Morwong	All condition stages	3	3.170	0.366
	Stage 1 and 2 combined	2	3.823	0.148
	Stage 1, 2 and 3 combined	1	4.197	0.041*
Blue-throat wrasse	All condition stages	3	13.866	0.003**
	Stage 1 and 2 combined	2	17.668	<0.001***
	Stage 1, 2 and 3 combined	1	17.920	<0.001***
Bastard Trumpeter	All condition stages	3	4.643	0.1999
	Stage 1 and 2 combined	2	4.922	0.085.
	Stage 1, 2 and 3 combined	1	4.178	0.041*
Marble fish	All condition stages	3	1.619	0.655
	Stage 1 and 2 combined	2	2.577	0.276
	Stage 1, 2 and 3 combined	2	2.577	0.276

Table 13: Logistic regression of the delayed mortality rate of fish during cool (May – October) and warm (November – April) sampling periods (season).

Species	Coefficients	Estimate	Std. error	z value	*p*
Banded Morwong	(Intercept)	2.962	0.592	5.002	<0.001***
	Season	18.604	3571.311	0.005	0.996
Marblefish	(Intercept)	3.555	1.014	3.506	<0.001***
	Season	-0.487	1.246	-0.391	0.696
Bastard Trumpeter	(Intercept)	1.885	0.310	6.083	<0.001***
	Season	1.006	0.790	1.274	0.203
Bluethroat Wrasse	(Intercept)	1.777	0.326	5.449	<0.001***
	Season	0.421	0.573	0.734	0.463

Estimating post release survival using mark-recapture techniques

A total of 581 fish representing four key species – Banded Morwong, Bluethroat Wrasse, Bastard Trumpeter and Marblefish – were tagged at the One Tree Point study site; of these 143 (24.6%) were recaptured (Table 14). Recapture rates for both Banded Morwong and Marblefish increased rather than decreased between Stages 1 and 3 and there was also slight increase in recapture rates for Bluethroat Wrasse between Stages 2 and 3 (Table 14 and Figure 14). Bastard Trumpeter was the only species to display the expected decrease in recapture rate with increasing condition stage (Table 14 and Figure 14), although in this species no Stage 1 individuals were available for tagging. While small sample sizes in some condition categories may have contributed to the unexpected patterns, it is notable that none of the 22 Banded Morwong judged as Stage 1 were recaptured and that sample sizes for each of the Marblefish condition categories were sufficiently large so as to suggest that there may have been other confounding factors.

Due to the results outlined above, if Stage 1 fish were assumed to have 100% PRS, this would imply higher survival rates for Stages 2 and 3 in Banded Morwong and Marblefish (Table 14). For Bastard Trumpeter Stage 2 was used as the condition category against which relative survival of the other categories was assessed. Using data from tank trials, where the survival rate of Stage 2 fish was 97%, the corrected survival rates for Stages 3 and 4 were estimated as 80% and 54%, respectively.

To investigate reasons behind the unpredicted and inconsistent patterns observed above and to investigate whether any of the assumptions of this technique were violated, further analyses focussed on fish size and how this influenced the way fish were captured by the gear (i.e. meshed) and how this, in turn, influenced fish condition. This analysis made use of all research graball (114 mm stretched mesh) data available from these species. For each of these species, fish size varied significantly depending on how the fish were caught by the gillnet (Table 15 and Figure 15). Most pairwise comparisons were significantly different (Table A1. 14 in Appendix 1), although in Banded Morwong, the length of fish that were mouthed, tangled and snouted did not vary significantly, while in Bluethroat Wrasse there was no significant difference between the size of gilled and tangled fish. Furthermore, apart from Bastard Trumpeter, how the fish were meshed in the gear significantly influenced fish condition (Table 16). Pairwise comparisons indicated there was no significant difference in fish condition between gilled and wedged individuals of any species, nor was the condition of mouthed, tangled and snouted fish significantly different (Table A1. 15). For each of the species however, gilled and wedged fish were in significantly poorer condition than those that were mouthed, tangled or snouted. These results suggest that individuals within the size range that is most catchable based on the mesh selectivity characteristics of the gear (i.e. fish that are gilled and wedged) were more likely to sustain greater injury from the encounter than fish that are of a size that is less catchable (i.e. fish that are mouthed, tangled or snouted). As such, if fish survive the encounter with the net and subsequent recovery period, those that were gilled and wedged (and on average in poorer condition) have a greater selection probability of being recaptured than fish that were mouthed, snouted and tangled and consequently in proportionally better condition. This phenomenon may explain why

Banded Morwong, Marblefish and to a lesser extent Bluethroat Wrasse displayed increasing recapture rates with poorer condition stages and may also account for why this technique worked adequately for Bastard Trumpeter, where available fish sizes did not influence how the fish was meshed, and therefore did not influence capture condition.

Table 14: Numbers of fish tagged and recaptured, proportion recaptured, and relative survival rates (β) and confidence intervals, by condition category.

*Note: SAS uses a correction of 0.5 in every cell that contains zero values (i.e. Banded Morwong condition 4) so the β calculation is not exact. No Bastard Trumpeter were captured in condition 1 therefore condition 2 was used as a basis on which to base relative survival (β).

Species	Condition	Number tagged	Number recaptured	Proportion recaptured	β	Confidence interval
Banded Morwong	1	22	0	0.00	–	–
	2	47	14	0.30	1.000	–
	3	9	3	0.33	1.119	0.402 – 3.112
	4	2	0	0.00*	0.552	0.042 – 7.184
Bluethroat Wrasse	1	2	1	0.50	1.000	–
	2	60	11	0.18	0.367	0.083 – 1.619
	3	78	18	0.23	0.462	0.109 – 1.956
	4	54	6	0.11	0.222	0.046 – 1.077
Bastard Trumpeter	1	0	–	–	–	–
	2	9	4	0.44	1.000	–
	3	50	17	0.34	0.765	0.335 – 1.748
	4	22	5	0.23	0.511	0.177 – 1.479
Marblefish	1	25	4	0.16	1.000	–
	2	146	44	0.30	1.884	1.884 – 4.781
	3	35	12	0.34	2.143	2.143 – 5.875
	4	20	4	0.20	1.250	0.356 – 4.385

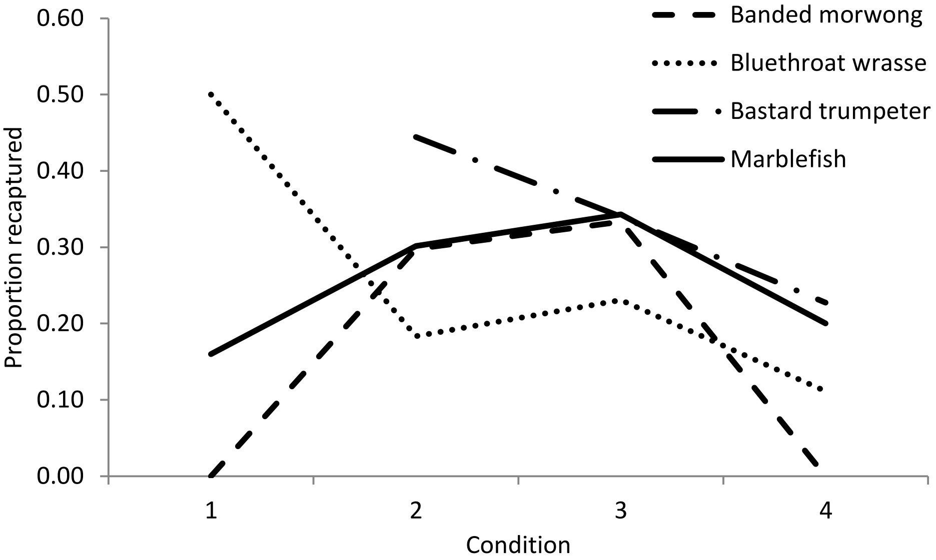

Figure 14: Recapture rates based on initial capture condition.

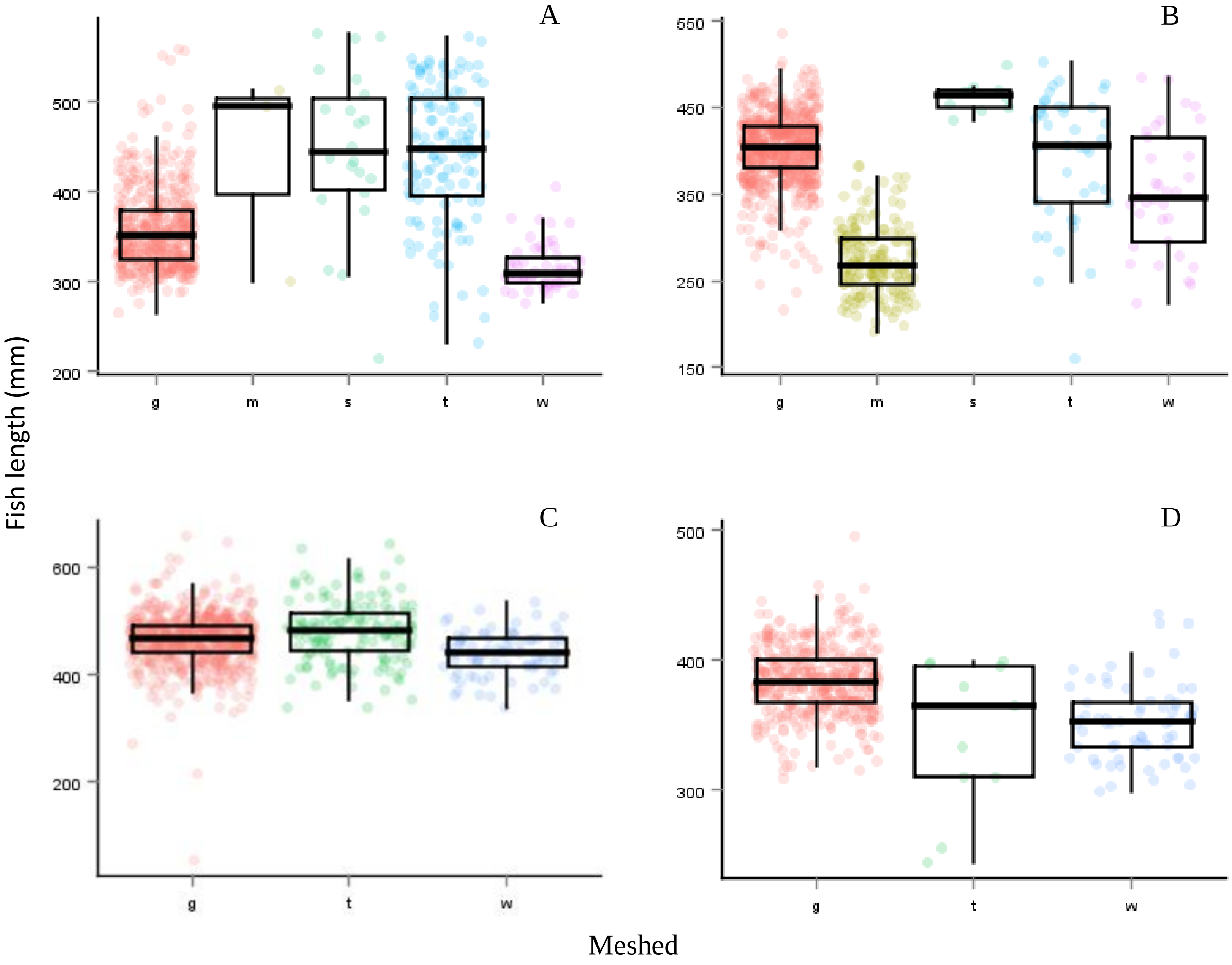

Figure 15: Boxplots of how (A) Banded Morwong, (B) Bluethroat Wrasse, (C) Marblefish (C) and (D) Bastard Trumpeter were meshed in research graball nets relative to fish length. Meshed variables are; gilled (g), mouthed (m), snouted (s), tangled (t) and wedged (w). Insufficient mouthed and snouted Bastard Trumpeter and Marblefish were encountered to warrant analysis.

Table 15: Welch ANOVA of variation in the size of fish depending on how they were meshed in the research graball nets.

Species	F	*df*	*p*
Banded Morwong	71.267	4	<0.001***
Bluethroat Wrasse	398.715	4	<0.001***
Marblefish	20.360	2	<0.001***
Bastard Trumpeter	33.793	2	<0.001***

Table 16: Table: Kruskal-Wallis test of how fish condition varies with how the fish was meshed in the research graball nets.

Species	χ^2	*df*	*p*
Banded Morwong	173.220	4	<0.001***
Bluethroat Wrasse	150.240	4	<0.001***
Marblefish	94.860	2	<0.001***
Bastard Trumpeter	1.250	2	0.535

Physiological effects of gillnet capture

Bluethroat Wrasse, Banded Morwong, Marblefish and Bastard Trumpeter displayed highly significant increases in lactate and glucose concentrations from pseudo-baseline levels following capture in gillnets (Table 17). Elephantfish displayed a significant increase in lactate concentration but not in glucose, the latter result may have been influenced by the method used to determine baseline levels for this species, which involved capturing fish held in 20 000 L tanks and potentially stressing individuals in the process.

A positive relationship existed between glucose concentration and soak duration in all species (Figure 16), although this relationship was only significant for Bastard Trumpeter and close to significant in Draughtboard Shark (Table 18). Confidence intervals of the regressions (Figure 16) and standard errors identified by ANOVA (Table 18) indicate high variability in glucose concentrations.

The stressed blood glucose concentration fluctuated greatly between species; with Draughtboard Shark being <2.5 mmol/L, Banded Morwong around 3 – 4 mmol/L, Marblefish 5 – 6 mmol/L, Bastard Trumpeter 3 – 6 mmol/L, Elephantfish around 6 mmol/L and Bluethroat Wrasse 7 – 8 mmol/L. This pattern more or less correlated with the initial and delayed mortality rates for these species, i.e. Draughtboard Shark had the lowest stress glucose concentrations and highest survival in gillnets progressing through to Bluethroat Wrasse, which had the highest glucose concentration and relatively low PRS compared with the other species.

The trend in lactate concentration was less clear and in several study species declined as soak duration increased (Figure 17). Again, Bastard Trumpeter and Draughtboard Shark had the strongest positive relationship, although both were only significant at $\alpha = 0.1$ (Table 19).

Blood lactate concentration was species specific but the pattern differed to that for glucose, with Banded Morwong ~2 mmol/L, Draughtboard Shark 1 – 4 mmol/L, Bluethroat Wrasse 4 – 5 mmol/ L, Bastard Trumpeter 2 – 6 mmol/L, Marblefish 7 – 8 mmol/L, and Elephantfish ~9.5 mmol/L. In contrast to glucose, Bluethroat Wrasse had a relatively low blood lactate concentration despite comparatively poor PRS, whereas the more robust Marblefish that had high PRS had relatively high lactate concentrations.

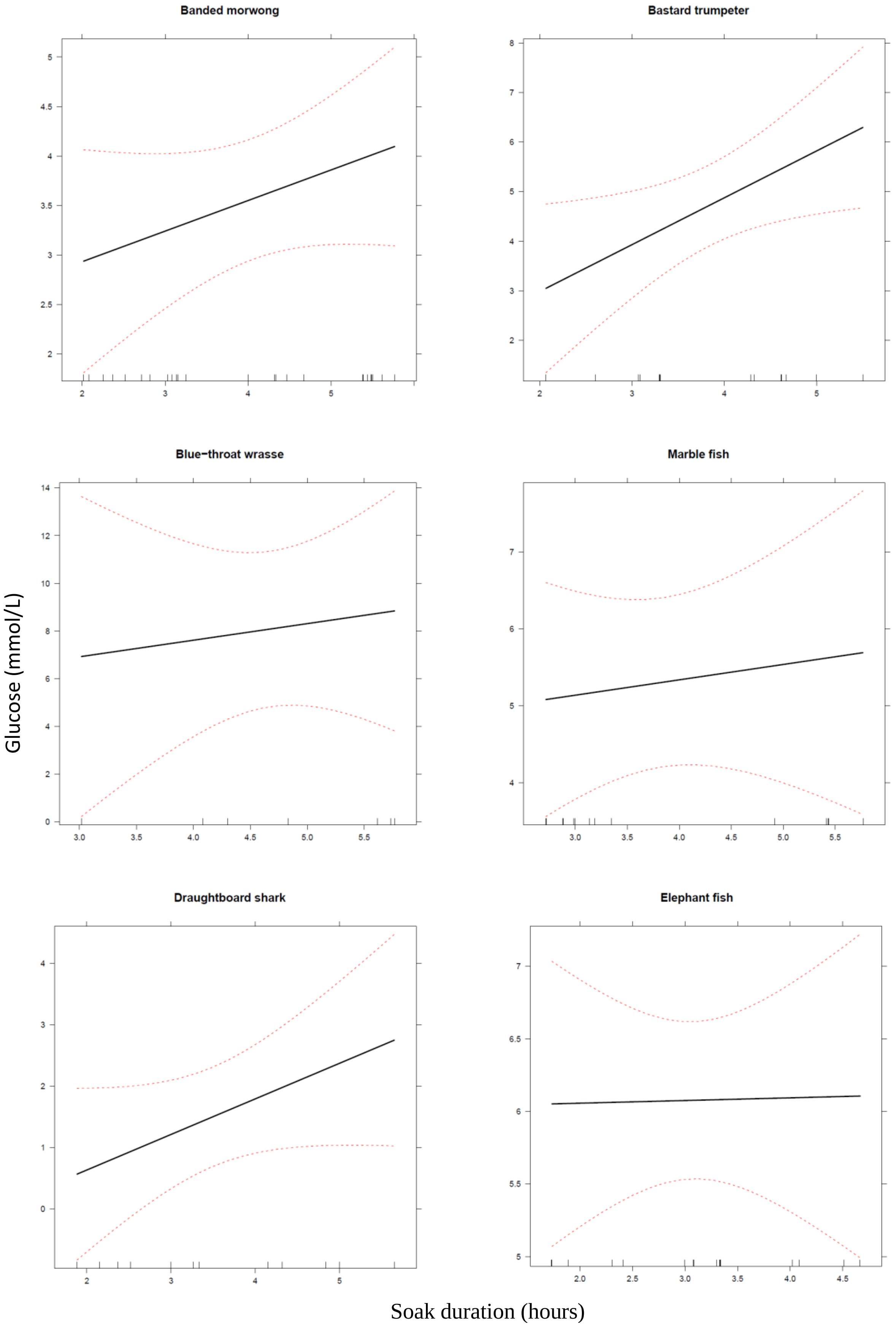

Figure 16: Linear regression of glucose concentration and gillnet soak duration (hours). Red broken lines indicate 95% confidence intervals.

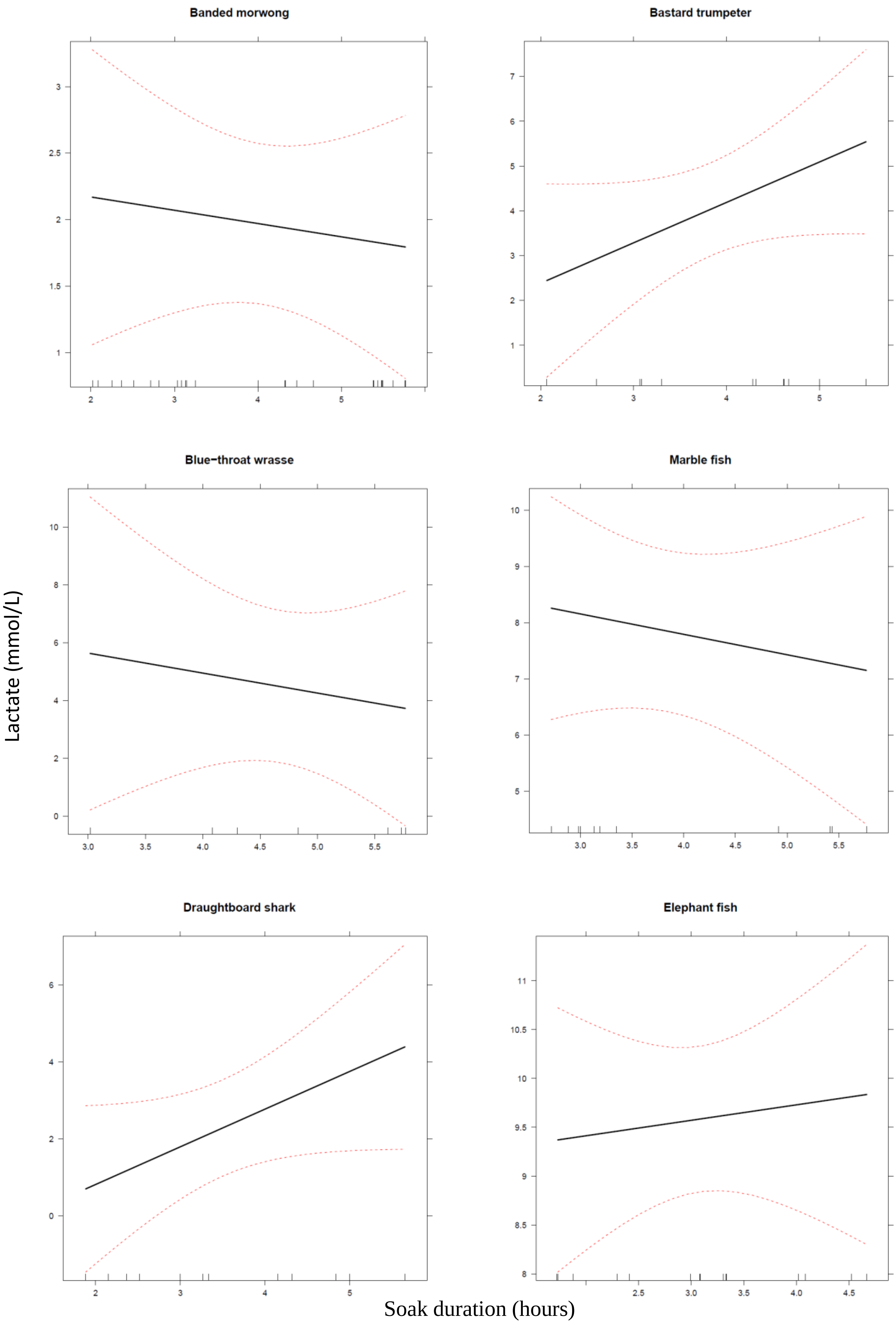

Figure 17: Linear regression of lactate concentration and gillnet soak time. Red broken lines indicate 95% confidence intervals.

Table 17: Welch t-test comparing resting (pseudo-baseline) lactate and glucose levels with those from fish that had been captured in gillnets.

			Lactate			**Glucose**		
Species	**Baseline (n)**	**Gillnet (n)**	**t value**	***df***	***p***	**t value**	***df***	***p***
Banded Morwong	3	29	-5.073	28.000	<0.001***	-6.450	27.826	<0.001***
Bluethroat Wrasse	4	8	-3.886	7.000	0.006**	-5.684	7.282	<0.001***
Bastard Trumpeter	5	14	-6.535	13.927	<0.001***	-5.340	16.232	<0.001***
Marblefish	6	14	-10.289	15.572	<0.001***	-9.613	13.318	<0.001***
Draughtboard Shark	4	13	-2.817	12.000	0.016*	-2.495	12.000	0.028*
Elephantfish	90	17	-25.256	17.304	<0.001***	-1.979	67.325	0.052.

Table 18: Adjusted coefficient of determination and ANOVA table of variability within linear regression models fitted to glucose concentration (y) and soak time (x) of fish caught in gillnets.

Species	**Adjusted R^2**	***df***	**Estimate**	**Std. error**	**t value**	**F-statistic**	***p***
Banded Morwong	0.030	27	0.309	0.227	1.364	1.859	0.184
Bastard Trumpeter	0.277	12	0.945	0.387	2.445	5.977	0.031*
Bluethroat Wrasse	-0.123	6	0.696	1.443	0.482	0.238	0.647
Marblefish	-0.064	12	0.120	0.428	0.466	0.218	0.649
Elephantfish	-0.066	15	0.018	0.287	0.064	0.004	0.950
Draughtboard Shark	0.158	11	0.580	0.322	1.804	3.256	0.099.

Table 19: Adjusted coefficient of determination and ANOVA table of variability within linear regression models fitted to lactate concentration (y) and soak duration (x) of fish caught in gillnets.

Species	Adjusted R^2	*df*	Estimate	Std. error	t value	F-statistic	*p*
Banded Morwong	-0.029	27	-0.010	0.223	-0.447	0.200	0.658
Bastard Trumpeter	0.155	12	0.903	0.491	1.840	3.384	0.091.
Bluethroat Wrasse	-0.102	6	-0.691	1.163	-0.594	0.353	0.574
Marblefish	-0.047	12	-0.363	0.558	-0.650	0.423	0.528
Elephantfish	-0.055	15	0.159	0.396	0.401	0.161	0.694
Draughtboard Shark	0.074	11	0.982	0.497	1.975	3.900	0.074.

Interactions with threatened, endangered and protected species and habitat

During gillnet fishing operations undertaken as part of this study a number of interactions involving TEPS and benthic habitat were recorded. The nature of these interactions and operational factors contributing to them are examined in the following sections.

Maugean Skate

Maugean Skate were the second most commonly caught species in Macquarie Harbour, mainly encountered at intermediate depths of 6 – 12 metres, which represented the peak in CPUE, but were occasionally encountered in gillnet sets outside of this range[7] (Figure 18). For those individuals for which the actual depth of capture was recorded (i.e. depth under the vessel when a skate was brought to the surface), the minimum capture depth was 6 m and maximum was 12 m (Figure 19). Maugean Skate were often caught close to the edge of drop-offs or contours in bottom topography. It should be noted, however, that as very little fishing was conducted in depths of greater than about 15 m, inferences cannot be made about the depth distribution range of the Maugean Skate on the basis of this study.

Based on the GAM, the relationship with maximum net depth was best described by a second order polynomial model. Both the positive and negative components of the polynomial model describing the maximum depth of the net were significant (Table 20). Catch rate (CPUE) was not significantly influenced by soak duration, though there was a weak negative relationship ($p = 0.071$.), suggesting that Maugean Skate were not more catchable in the overnight net deployments, providing little evidence for differences in diurnal activity levels. These results are, however, preliminary and must be interpreted with caution since the decrease in CPUE with time was very minor and only significant at $\alpha = 0.01$. Other than locality, none of the other operational variables (season, daytime v overnight, minimum net depth, average net depth) were significant in the GLM. Locality was highly significant ($p = <0.001$) but when included in the model it dominated all other variables so was investigated independently and graphically (Figure 20).

CPUE for the Maugean Skate was spatially variable, being highest at Rum Point in the upper reaches of the estuary (Figure 20). Interestingly, the relatively high catch rate for this area was largely influenced by a single days fishing whereas on other occasions few individuals were encountered. By contrast, the relatively high catch rates at Liberty Point and Table Head tended to be more consistent between sampling periods. Maugean Skate were captured at all of other locations sampled within the estuary, although catch rates were lower than at the aforementioned localities (Figure 20).

Maugean Skate were generally in good condition when captured in nets, typically only lightly meshed by the snout area. Virtually all individuals caught during the day time deployments were judged to be in Stages 1 or 2 condition, as were most skate from overnight deployments. There were, however, three occasions involving overnight deployments in which skate in poor condition (Stage 4) or mortalities were experienced. On the first occasion, a single skate was dead upon retrieval of the net, this individual had clearly been predated as it had a large bite out of its pectoral fin (wing), probably from a Whitespotted Dogfish based on the bite radius. On the second occasion, 50 Maugean Skate, along with almost 100 other fish, were captured in eighteen graball nets that had been set overnight. Eleven of the skate were dead when the nets were retrieved, one individual showed signs of predation but the cause of death of the remainder was not obvious. The only difference between that particular sampling event was that effective soak times for some of the nets were much longer than usual (up to 20 hours in some instances), due in part to the large catch and the fact that the project team was assisting another researcher who was taking a range of additional biological information from each of the Maugean Skate[8], which effectively slowed the retrieval operation. On the third occasion, 25 skate were captured in five nets set overnight, and of these, 23 were in good condition and released immediately; however, two individuals, while still alive showed signs of predation by crabs and/or sea lice and were in Stage 4. One individual was clearly moribund, with

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[7] In the GAM, depth is the maximum depth of the net set, average depth was not particularly informative since most nets were set over depth ranges from 1 to >10 m.

[8] Treloar, M., Barrett, N. and Edgar, G. (2013) Biology and ecology of the endangered Maugean Skate, Report to the Winifred Violet Scott Charitable Trust, Institute for Marine and Antarctic Studies, University of Tasmania.

sea lice having penetrated the body cavity so was euthanized to prevent further suffering, the other individual had less damage and sea lice were not observed to have entered the body cavity so was released. Although capture in gillnets did not appear to be directly responsible for the observed mortalities on at least two of the three occasions, it is probable that being restrained in the nets enabled opportunistic predators to take advantage of the skate's lack of mobility. These results clearly indicate that Maugean Skate are susceptible to a degree of incidental mortality from gillnet capture (overall IM rate for overnight sets was 9%), especially in overnight sets.

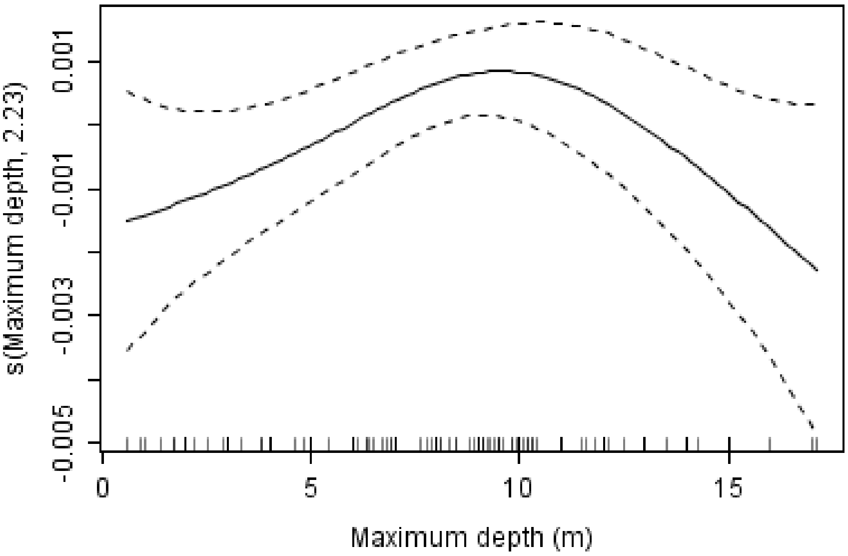

Figure 18: GAM of variation in Maugean Skate CPUE with the maximum depth of the gillnet. Lines on x-axis depict individual observations.

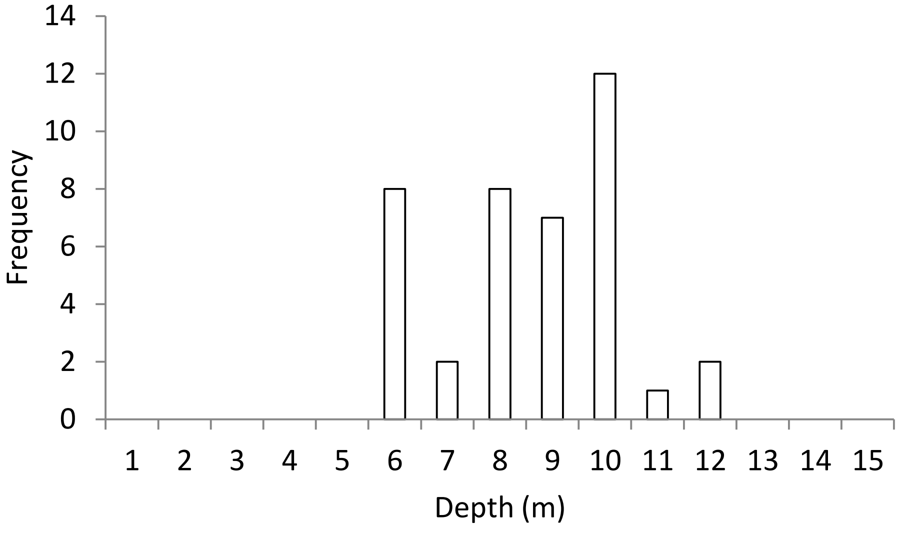

Figure 19: Depth distribution of Maugean Skate captures.

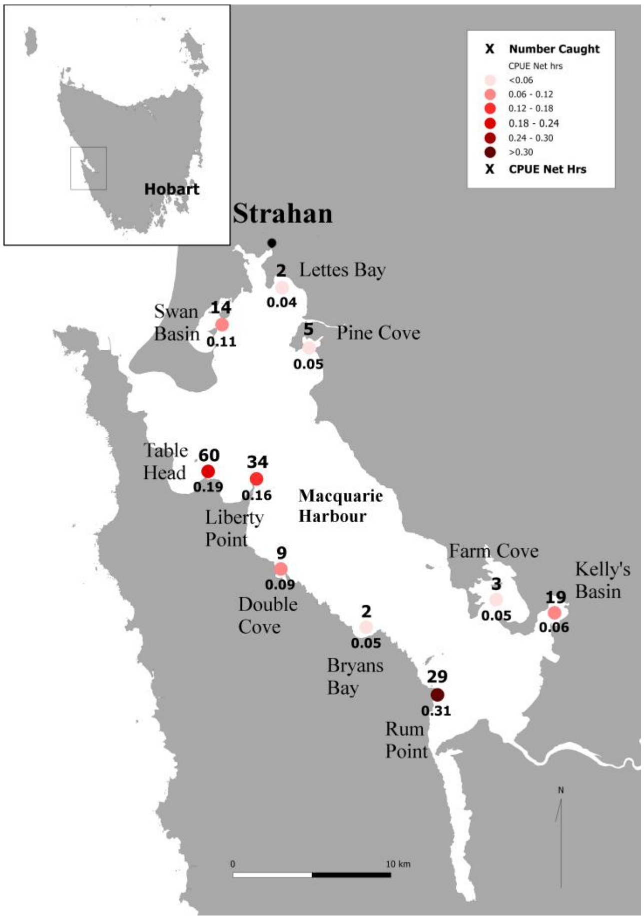

Figure 20: Numbers and CPUE (number per 50 m net hour) of Maugean Skate caught during research fishing in Macquarie Harbour in net deployments that exceeded 5 m (maximun net depth).

Table 20: Generalised linear model of variation in Maugean Skate CPUE with the maximum depth of the net and soak time.

Two parameters for the model are provided, the first for the positive portion of the two-phase polynomial model, the second for the negative portion of the model.

Coefficient	Estimate	Std. error	t value	*p*
(Intercept)	0.003	0.001	5.957	<0.001***
Maximum depth (1)	0.017	0.005	3.812	<0.001***
Maximum depth (2)	-0.012	0.005	-2.602	0.010**

Fur Seals

Australian and/or New Zealand Fur Seals (*Arctocephalus* spp)[9] were regularly observed actively feeding on fish that were entangled in gillnets (obvious interactions) or were seen either diving or loitering around the gillnets (suspected interactions). No Fur Seals were caught in gillnets (research or commercial) nor was there any evidence that individuals had become entangled in the meshes and subsequently escaped.

There was a significantly higher suspected interaction rate in the monitored commercial fishing operations than in our research fishing; however, there was no significant difference between obvious interaction rates for commercial or research fishing (Table 21). As these differences in suspected interaction rates could be due to regional variability in sampling intensity, data from both commercial and research fishing

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[9] It is difficult to identify to species without close inspection.

was combined for spatial analysis. There were significant regional differences in obvious interaction rates ($\chi^2 = 140.498$, *df* = 5, *p* <0.001), with Northwest coast interaction rates being greater than all other regions but no other regional differences (Table 22 and Table A1. 16). Similarly, there was a significant spatial difference in suspected interaction rates ($\chi^2 = 252.445$, *df* = 5, *p* <0.001), with the rates for the Northwest coast being greater than all other regions, the East and Northeast coasts being higher than the remaining areas but not different to each other (Table 22 and Table A1. 16). No Seal interactions were recorded in fishing trials conducted on the West coast (including Macquarie Harbour).

Table 21: Differences in obvious and suspected Seal interaction rate between commercial and research sampling.

Sampling	Interaction	Commercial	Research	χ^2 test statistic	*df*	*p*
Seal seen and suspected of interaction	No	407 (90.646%)	2288 (97.528%)	49.762	1	<0.001***
	Yes	42 (9.354%)	58 (2.472%)			
Obvious Seal interaction	No	441 (98.218%)	2322 (98.977%)	1.305	1	0.253
	Yes	8 (1.782%)	24 (1.023%)			

Table 22: Seal interaction rates (obvious and suspected) with gillnets (net deployments) by region.

	Obvious Seal encounter		Suspected Seal encounter	
Region	No	Yes	No	Yes
Northwest coast	129 (89.0)	16 (11.0)	112 (77.2)	33 (22.8)
Northeast coast	177 (99.4)	1 (0.6)	159 (89.3)	19 (10.7)
East coast	249 (97.6)	6 (2.4)	230 (90.2)	25 (9.8)
Southeast coast	1363 (99.5)	7 (0.5)	1351 (98.6)	19 (1.4)
Southeast coast SRA	472 (99.6)	2 (0.4)	470 (99.2)	4 (0.8)
West coast	373 (100)	0 (0)	373 (100)	0 (0)

Seabirds

Cormorants

Three cormorant species were caught in the present study – Great Cormorant (*Phalacrocorax carbo*), Black-faced Cormorant (*P. fuscescens*) and Little-pied Cormorant (*Microcarbo melanoleucos*), all of which were drowned when the net was retrieved. Cormorants were encountered during both research gillnetting (n = 16) and while observing commercial gillnet fishers (n = 10). There was no significant difference in the interaction rate between the two fishing methods (Fishers exact test, *p* = 0.074.) and when these data were pooled there was no significant difference in the encounter rate between regions (Fishers exact test, *p* = 0.264). There was, however, a significant difference in the encounter rate of cormorants between banded morwong commercial fishing (1.246%), research graball (0.509%) and small mesh nets (1.754%) (Fishers exact test, *p* = 0.019*). No cormorants were encountered in commercial graball nets, possibly influenced by the fact that the majority of observed effort occurred at night when cormorants are roosting. Based on all gillnet data pooled, logistic regression analysis indicated that no significant relationship existed between the minimum set depth and whether a cormorant was caught or not (estimate = 0.015, St. error = 0.042, z value = 0.365, p = 0.715).

Penguins

Five Little Penguins were caught while research fishing and one was observed in a commercial gillnet. Of these, one individual was still alive and able to be released while the remaining five individuals had drowned. Due to the low encounter rate (< 0.2% of deployments) it was not possible to analyse these data to investigate operational, seasonal or regional differences in the rate of capture.

Other bird species

No other bird species were captured in the present study.

Sygnathids

All species of Sygnathids (Seahorses, Seadragons and Pipefishes) are listed protected species under Commonwealth and State law. Two species of Sygnathid were captured in gillnets in the present study; the Big-bellied Seahorse (*Hippocampus abdominalis*) and the Common Seadragon (*Phyllopteryx taeniolatus*). These species do not generally become entangled in the meshes but rather cling onto the meshes with their tails. Big-bellied Seahorse were most commonly encountered in Macquarie Harbour (n = 8), with two specimens captured on the East coast and a single specimen in the D’Entrecasteaux Channel. Two Common Seadragons were captured, one in the D’Entrecasteaux Channel and the other at Betsy Island on the Southeast coast. All individuals were in excellent condition and were released alive.

Interactions with habitat

Macroalgal material was often found in gillnets when they were set on rocky reef habitats, although it was often difficult to ascertain whether the material had been dislodged by the gillnets or was already free and drifting. Most often, interactions were with the brown algae species *Ecklonia radiata* and *Phyllospora comosa*, although a variety of other species were also encountered including *Macrocystis* spp. In most instances only blades were retrieved, leaving the holdfast and stipe intact. The entire alga was removed from the substrate in 3.6% and 5.2% of commercial and research gillnet deployments respectively, representing a significant difference in rate of occurrence for the two sectors (χ^2 = 601.582, df = 1, p = <0.001). Potentially contributing to this difference is the tendency for Banded Morwong fishers to deploy their gear at greater depths than where much of the research fishing occurred, therefore experiencing reduced effects of wave surge than can result in nets becoming entangled with macroalgae.

On occasions, benthically attached Ascidians (*Pyura australis* and *P. gibbosa*), known by fishers as sea tulips, were entangled in gillnets in relatively high numbers and are unlikely to survive; however, due to the damage these species cause to gillnets they tend to be avoided by commercial fishers where possible. A single sponge was caught during the study, although it is possible that interactions may have been higher with dislodged sponges having fallen out of the meshes during the net retrieval process.

Variation in the abundance and diversity of fish communities with links to gillnetting

There was sufficient historic on-board observation data to examine temporal changes in species composition and abundance for the Southeast, East and Northeast coasts (Table A1. 17). In the *Tasmanian gillnet fisheries- Catch composition* section, two way PERMANOVA indicated that both region and year significantly affected the catch composition for the large mesh (‘banded morwong’) graball nets and that there was a significant region-year interaction, suggesting that temporal differences were not consistent among regions (Table 7). This was further demonstrated by the post-hoc one-way PERMANOVA for each region, which identified significant annual differences in species composition within the Northeast, East and Southeast regions (Table 23). Southeast coast species composition and abundances also varied temporally based on sampling with ‘standard’ mesh graballs (research nets and general graball net fishers) (Table 23).

Annual variation in species composition and abundances were, therefore, analysed using CPUE from large mesh graball nets for the Northeast, East and Southeast regions and standard mesh graballs in the Southeast. Due to the dominance of Banded Morwong, Bastard Trumpeter, Marblefish, Bluethroat Wrasse, Longsnout Boarfish and Draughtboard Shark in the catch composition of both net types, these species were considered for detailed analyses. Herring Cale, are a moderately abundant species that with low PRS following gillnet capture (refer the section *Condition and survival of gillnet caught fish*), so it was envisaged that the variability in abundance of this species may also reflect changes in gillnetting effort and fishing practices. The low encounter rates of the other species meant it was difficult to identify temporal trends in abundance based on gillnet catch rates.

Due to the high level of inter-annual variation in catch rates for each of the key study species, the intersection union test, linear model and Mann-Kendal test detected few significant trends in species abundance and the results are therefore not provided herein. Nevertheless, the GAMs were useful for visually exploring smoothed abundance trends.

Southeast coast

Species composition on the Southeast coast, as determined by large mesh graball net catches, was primarily typified by Banded Morwong in each year, with relatively few other species playing a significant role during the earlier period (1995 – 2002) (Table 24). Most differences between the earlier and more recent years were due to declines in the abundance of Banded Morwong, which meant that non-target species such as Draughtboard Shark, Marblefish, Longsnout Boarfish, Bluethroat Wrasse and Bastard Trumpeter have begun to play a more dominant role in typifying species composition (Table 24). This pattern was evident despite declines in the abundance of both Draughtboard Shark and Marblefish throughout the study period (Figure 21). By contrast, Bluethroat Wrasse appear to have increased in relative abundance (Figure 21), however, the trend is noisy and since large-mesh nets select for large individuals (predominantly males) the pattern may not be a reliable indicator of trends in population abundance. Interestingly, despite the particularly high abundance of Bastard Trumpeter in 1996 (reflecting the presence of the large 1993 year class, Murphy and Lyle, 1999) (Figure 21), catch compositions have been dominated so strongly by Banded Morwong and Marblefish that Bastard Trumpeter were not responsible for any significant differences between any of the other years (Table 24). Post 2003, Banded Morwong abundances appear to have stabilised at a lower level (Figure 21) and, in the main, there have been few significant differences in catch composition since that time. In fact catch compositions have remained aggregated since 2003 (Figure 22) suggesting that the system may have settled into a new equilibrium state.

Based on the entire time series, 2012 appears to be an outlier, with virtually all annual pairwise species composition comparisons with this year being significantly different (Table 24). In 2012 Banded Morwong catch rates were also significantly lower than in all other years (Figure 21), a result potentially influenced by sampling being conducted with a single operator, but not inconsistent with the trend in standardised CPUE determined for Banded Morwong in the Southeast region (André *et al*., 2014).

Overall the catch composition of standard graball nets was similar to that for large mesh graballs, though the former tend to be less selective for larger fish and as a consequence Marblefish, Bastard Trumpeter, Bluethroat Wrasse as well as Banded Morwong typify catch composition to varying degrees each year (Table 25). There were significant differences between each annual pairwise comparison with the major drivers being decreased abundances of Marblefish and Banded Morwong during 2011 – 2013 compared to 1995 – 1999 (Table 25 and Figure 23). This resulted in a clear separation in species composition between the two time periods (Table 25 and Figure 24). Blue Warehou were significantly more abundant in 1999 than in all other years (Table 25) and did not distinguish between species composition in any other year. Bastard Trumpeter were more abundant during the earlier sampling period than in later years apart from 2013 (Figure 23), when they were significantly more abundant than in all other years (Table 25). In the latter sampling period, 2011 can be partially distinguished from 2012 – 2013 (Figure 24); the separation influenced to some extent by a greater portion of the fishing effort in 2011 occurring on the Tasman Peninsula, the general area that the majority of fishing took place during the 1990s. Sampling in 2012 – 2013 was primarily conducted along the Bruny Island coastline and as such, temporal changes in species composition may also have been influenced by spatial variability in fish community structure within the broader Southeast coast region.

There were insufficient underwater visual census survey data to establish meaningful temporal tends in relative abundance for the key gillnet species in the Southeast region. Furthermore, many of the survey sites were visited infrequently and they were in a broad diversity of habitats (i.e. some sites are within the D'Entrecasteaux Channel others are on exposed coastal regions on the Tasman Peninsula).

East coast

In addition to gillnet data, long-term monitoring of sites around Bicheno and Maria Island based on underwater visual census surveys were used to examine temporal trends in abundance of key East coast gillnet species (Table A1. 17).

Based on large-mesh graball CPUE, Banded Morwong were the principal species responsible for typifying ichthyofauna on the East coast in each of the years for which data were available (Table 26). Marblefish, Draughtboard Shark and Longsnout Boarfish also typified species composition in various years, with Longsnout Boarfish becoming more predominant in the last ten years (Figure 25). Most pairwise differences occurred during the early years of the fishery and were mainly due to variation in Banded Morwong abundance and, to a lesser extent, Marblefish, Longsnout Boarfish, Bluethroat Wrasse and Draughtboard Shark.

Catch rates of the major species were, in general, highly variable on the East coast (Figure 26 and Figure 25). From 2005 onwards there have been few significant pairwise differences in catch composition, which could be interpreted as indicating that the relative abundances of the key species have remained relatively stable. More likely though, is that high inter-annual variability in catch composition, as indicated by a lack of aggregation in the multidimensional scaling plot (Figure 26), has limited the ability of ANOSIM to detect significant differences.

Individual species abundances generally exhibited similar temporal patterns based on gillnet catch rates (Figure 25) and underwater visual survey densities (Figure 27): Draughtboard Shark abundances have increased since the early 2000s; Bastard Trumpeter displayed no obvious trend through time though there were infrequent peaks in abundance (e.g. 1997, 2001 and 2011); Banded Morwong abundances peaked in the mid-2000s before declining to the present time, the dive survey data did, however, indicate an earlier decline (1992 – 2000), which was not evident in the gillnet data; Bluethroat Wrasse displayed conflicting trends with gillnet data being convex and dive survey data being concave, though in both cases the changes were relatively minor suggesting that overall abundance has remained relatively stable; Marblefish appeared to have increased in abundance based on dive survey data but showed a decline up to 2005, before stabilising and subsequently increasing, in gillnet CPUE; Longsnout Boarfish abundances have remained relatively stable at a low level in both cases; and, dive survey data indicate that Herring Cale have undergone a marked increase in abundance since the mid-2000s whereas gillnet data indicate no obvious trend for this species.

Northeast coast

Banded Morwong were the primary species responsible for typifying species composition in large mesh graball nets on the Northeast coast region, although in 2012 Draughtboard Shark were more important than Banded Morwong (Table 27). Interestingly, Marblefish appeared to play less of a role in typifying and distinguishing species compositions on the Northeast coast than in other regions (Table 27) and, unlike the other regions, there was no indication that their abundance had declined through time (Figure 28). Banded Morwong have, however, decreased in abundance (Figure 28), being significantly more abundant between 1995 – 2003 than 2011 – 2012 (Table 27). Conversely, the abundance of Draughtboard Shark appeared to have increased slightly through time (Figure 28) and was significantly greater in 2011 and 2012 than in most of the previous years (Table 27).

Bluethroat Wrasse were responsible for typifying species composition on the Northeast coast region in some years, being particularly abundant in 2001 and 2003 (Figure 28); however, in more recent years, the species has played less of a role (Table 27). Despite this there was no obvious long-term trend in gillnet CPUE for this species (Figure 28). Similarly, Longsnout Boarfish were responsible for distinguishing between some years; the species being relatively abundant in 2003 and 2007 but less so in earlier and later sampling periods (Figure 28). Mosaic Leatherjackets were relatively abundant in the Northeast and, unlike the other regions, played a role in distinguishing between species composition in some years (Table 27). Conversely, unlike the east and southeast regions, Bastard Trumpeter did not typify or distinguish species composition in the Northeast. Multidimensional scaling suggested that species composition in 2011 and 2012 was distinctly different than all earlier sampling periods (Figure 29). It also indicated that species composition in 2001 was different that derived from other sampling in the 1990’s and 2000’s, which is likely due to the very high catch rates of Bluethroat Wrasse and Bastard Trumpeter during that year (Figure 28).

There was insufficient underwater visual census data to establish meaningful tends in relative abundance in the Northeast.

Table 23: One-way PERMANOVAs exploring variation in the abundance of ichthyofauna between years (1995 – 2013) on the southeast, east and northeast coasts of Tasmania as estimated by large mesh (banded morwong) graball CPUE (all regions) and standard graball CPUE in the southeast.

Region	Permutations	*df*	Pseudo-F	*p*
Southeast coast (large mesh graball)	999	11	2.750	<0.001***
Southeast coast (standard graball)	997	6	9.062	<0.001***
East coast	998	11	2.247	<0.001***
Northeast coast	998	6	3.322	<0.001***

Table 24: R Statistic values and significance levels for pairwise ANOSIMs for the ichthyofaunal compositions of various years derived from the matrix constructed using the CPUE of each species in large mesh graball nets in the southeast coast region.

The species determined by SIMPER as most responsible for typifying the ichthyofaunal compositions of the various years (shaded boxes) and for distinguishing between the ichthyofaunal compositions in each pairing of those years are shown. $^+$ denotes species more abundant in the year at the top of the column.

	1995	1996	1997	2001	2002	2003	2005	2007	2009	2011	2012	2013
1995	Banded Morwong Marblefish											
1996	-0.011	Banded Morwong Marblefish										
1997	0.019	-0.024	Banded Morwong Marblefish Draughtboard Shark									
2001	-0.020	0.080	0.300* Banded Morwong$^+$ Draughtboard Shark$^+$	Banded Morwong Longsnout Boarfish								
2002	0.020	0.025	0.262** Banded Morwong$^+$ Draughtboard Shark$^+$ Marblefish$^+$	0.528** Banded Morwong Longsnout Boarfish$^+$	Banded Morwong							
2003	-0.167	-0.090	0.082	0.429** Draughtboard Shark Banded Morwong$^+$	0.644*** Banded Morwong$^+$ Draughtboard Shark Marblefish	Banded Morwong Draughtboard Shark Marblefish Longsnout Boarfish Bluethroat Wrasse Bastard Trumpeter						
2005	-0.150	-0.165	-0.065	0.556** Draughtboard Shark$^+$ Banded Morwong$^+$	0.561* Banded Morwong$^+$ Draughtboard Shark Marblefish Bastard Trumpeter$^+$	0.463* Banded Morwong Draughtboard Shark	Banded Morwong Draughtboard Shark Marblefish Bastard Trumpeter					
2007	-0.180	-0.088	0.077	0.012	0.540* Banded Morwong$^+$ Marblefish Draughtboard Shark	0.262	0.481* Draughtboard Shark$^+$ Banded Morwong$^+$	Banded Morwong Marblefish Longsnout Boarfish Draughtboard Shark Purple Wrasse Bluethroat Wrasse				
2009	-0.254	-0.165	0.007	-0.323	0.468. Banded Morwong$^+$ Marblefish	0.109	0.250	0.500. No single species represents >5% of the dissimilarity	Banded Morwong Longsnout Boarfish Marblefish Bluethroat Wrasse Draughtboard Shark			
2011	-0.039	0.010	0.130	0.399*** Draughtboard Shark$^+$ Banded Morwong$^+$	0.727** Banded Morwong$^+$ Draughtboard Shark Marblefish	-0.070	-0.156	-0.271	-0.183	Banded Morwong Marblefish Draughtboard Shark		
2012	0.126	0.280* Banded Morwong$^+$ Marblefish$^+$ Draughtboard Shark$^+$	0.378* Banded Morwong$^+$ Draughtboard Shark$^+$ Marblefish$^+$	0.531* Banded Morwong$^+$ Marblefish	0.833*** Banded Morwong$^+$ Marblefish	1.000* Banded Morwong$^+$ Draughtboard Shark$^+$	0.704* Draughtboard Shark$^+$ Banded Morwong$^+$	0.630. Banded Morwong$^+$	1.000. Banded Morwong$^+$	0.208	Banded Morwong Marblefish Longsnout Boarfish Bluethroat wrasse Draughtboard Shark Bastard Trumpeter	
2013	-0.133	-0.102	0.082	0.468** Draughtboard Shark$^+$ Marblefish Banded Morwong$^+$	0.632*** Banded Morwong$^+$ Marblefish Draughtboard Shark	0.275	0.010	0.185	-0.071	-0.089	0.593. Banded Morwong Marblefish Draughtboard Shark	Banded Morwong Marblefish Draughtboard Shark Longsnout Boarfish Bastard Trumpeter

Table 25: R Statistic values and significance levels of pairwise ANOSIMs for the ichthyofaunal compositions based on the matrix constructed using CPUE of each species in standard graball nets on the southeast coast.

The species determined by SIMPER as most responsible for typifying the ichthyofaunal compositions of the various years (shaded boxes) and for distinguishing between the ichthyofaunal compositions in each pairwise comparison are shown. $^+$ indicates species more abundant in the year at the top of the column.

	1995	1996	1997	1999	2011	2012	2013
1995	Marblefish Banded Morwong						
1996	0.126* Marblefish$^+$ Bastard Trumpeter Banded Morwong Draughtboard Shark	Banded Morwong Marblefish Bastard Trumpeter					
1997	0.070. Marblefish$^+$ Bastard Trumpeter Banded Morwong$^+$ Draughtboard Shark	-0.018	Marblefish Bastard Trumpeter Banded Morwong				
1999	0.517*** Marblefish$^+$ Banded Morwong$^+$ Draughtboard Shark$^+$ Bastard Trumpeter$^+$ Blue Warehou	0.605*** Marblefish$^+$ Banded Morwong$^+$ Bastard Trumpeter$^+$ Draughtboard Shark$^+$ Blue Warehou$^+$	0.487*** Marblefish$^+$ Bastard Trumpeter$^+$ Banded Morwong$^+$ Blue Warehou Draughtboard Shark$^+$	Bastard Trumpeter Banded Morwong Blue Warehou			
2011	0.648*** Marblefish$^+$ Banded Morwong$^+$ Bastard Trumpeter$^+$ Draughtboard Shark$^+$	0.555*** Banded Morwong$^+$ Bastard Trumpeter$^+$ Marblefish$^+$ Draughtboard Shark$^+$	0.596*** Marblefish$^+$ Bastard Trumpeter$^+$ Banded Morwong$^+$ Draughtboard Shark$^+$	0.357*** Banded Morwong$^+$ Blue Warehou$^+$ Marblefish Bastard Trumpeter Bluethroat Wrasse Draughtboard Shark	Bastard Trumpeter Banded Morwong Marblefish Bluethroat Wrasse Draughtboard Shark		
2012	0.880*** Marblefish$^+$ Banded Morwong$^+$ Draughtboard Shark$^+$ Bastard Trumpeter$^+$	0.809*** Banded Morwong$^+$ Bastard Trumpeter$^+$ Marblefish$^+$ Draughtboard Shark$^+$	0.892*** Marblefish$^+$ Bastard Trumpeter$^+$ Banded Morwong$^+$ Draughtboard Shark$^+$	0.607*** Banded Morwong$^+$ Blue Warehou$^+$ Bluethroat Wrasse Marblefish Bastard Trumpeter$^+$	0.161*** Bastard Trumpeter$^+$	Bluethroat Wrasse Marblefish Banded Morwong Bastard Trumpeter	
2013	0.583*** Marblefish$^+$ Banded Morwong$^+$ Bastard Trumpeter Draughtboard Shark$^+$	0.637*** Bastard Trumpeter Banded Morwong$^+$ Marblefish$^+$ Draughtboard Shark$^+$ Bluethroat Wrasse$^+$	0.554*** Bastard Trumpeter Marblefish$^+$ Banded Morwong$^+$ Draughtboard Shark$^+$	0.212*** Bastard Trumpeter Banded Morwong$^+$ Blue Warehou$^+$ Marblefish Bluethroat Wrasse	0.099* Bastard Trumpeter	0.142* Bastard Trumpeter	Marblefish Bluethroat Wrasse Banded Morwong Bastard Trumpeter

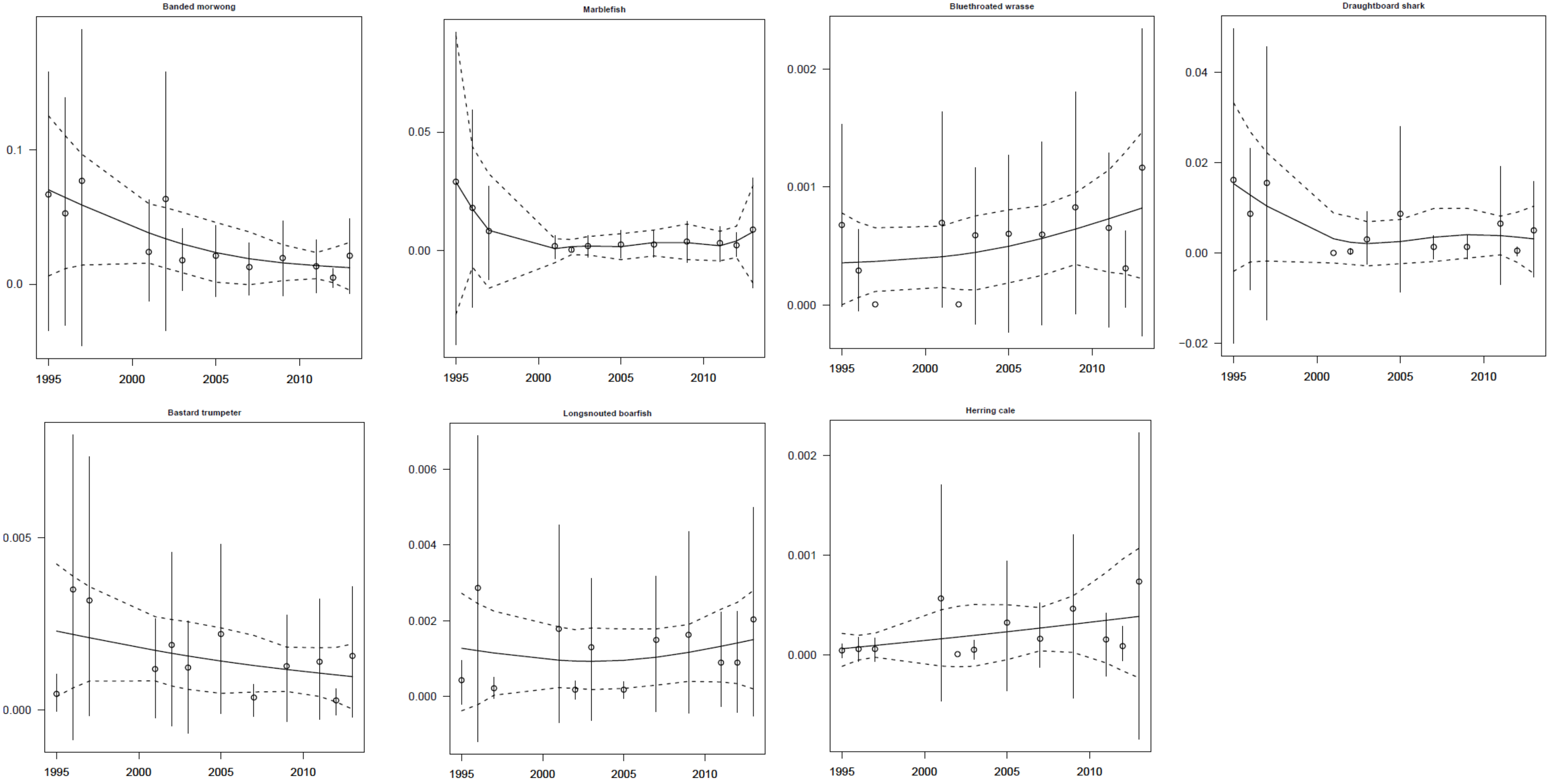

Figure 21: Changes to the relative abundance of selected ichthyofaunal on the southeast coast from 1995 – 2013 using the CPUE of large mesh graball nets. Trends in abundance smoothed using a GAM with 95% confidence intervals (dashed line) and coefficient of variation (solid vertical lines) used for bootstrapping.

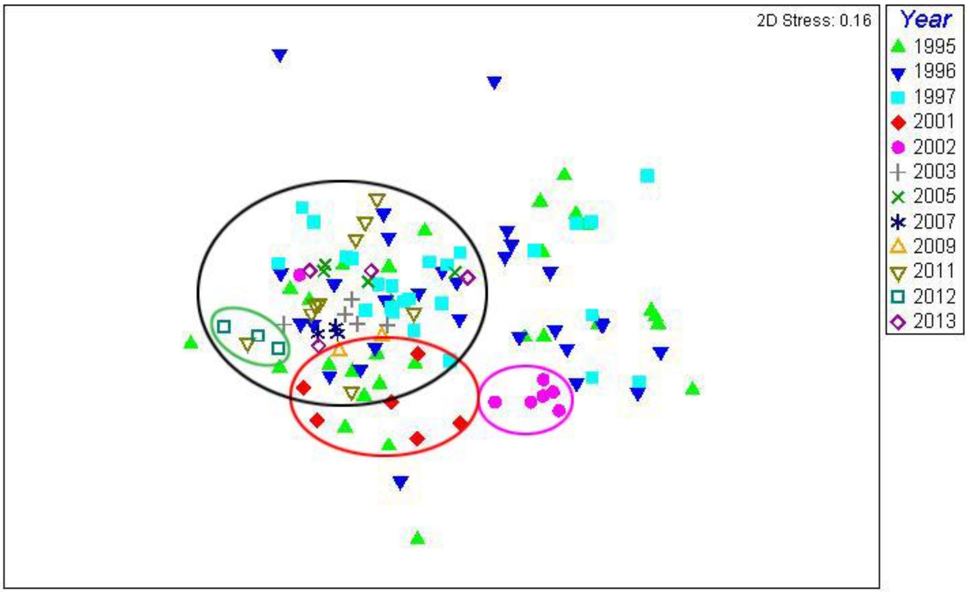

Figure 22: Multidimensional scaling plot of Bray Curtis similarities of daily CPUE of the ichthyofaunal catch composition for large mesh graball nets on the southeast coast of Tasmania. Black neighbourhood contains the days observed in 2003 – 2013.

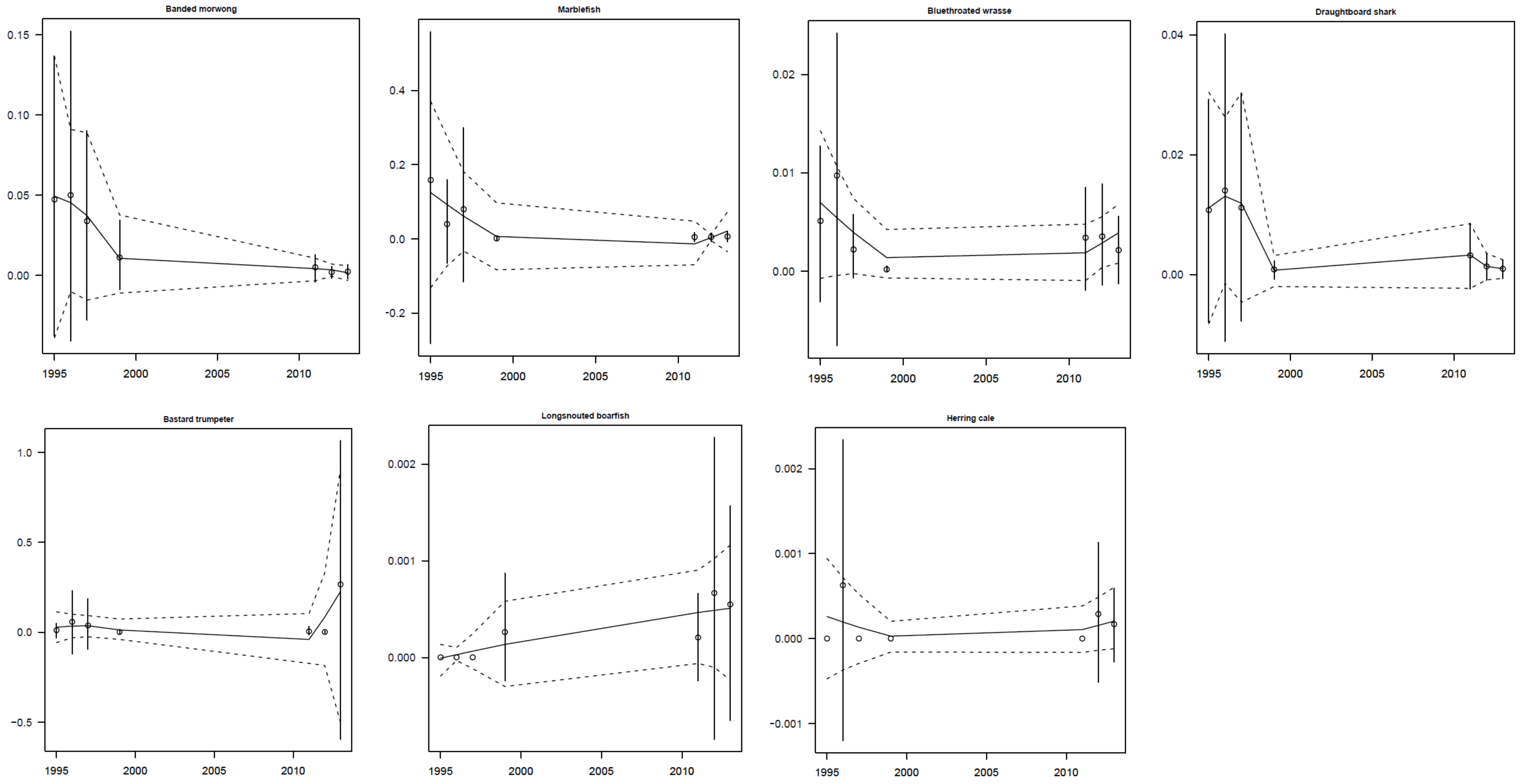

Figure 23: Changes to the relative abundance of selected ichthyofaunal on the southeast from 1995 – 2013 using the CPUE of standard graball nets. Trends in abundance smoothed using a GAM with 95% confidence intervals (dashed line) and coefficient of variation (solid vertical lines) used for bootstrapping.

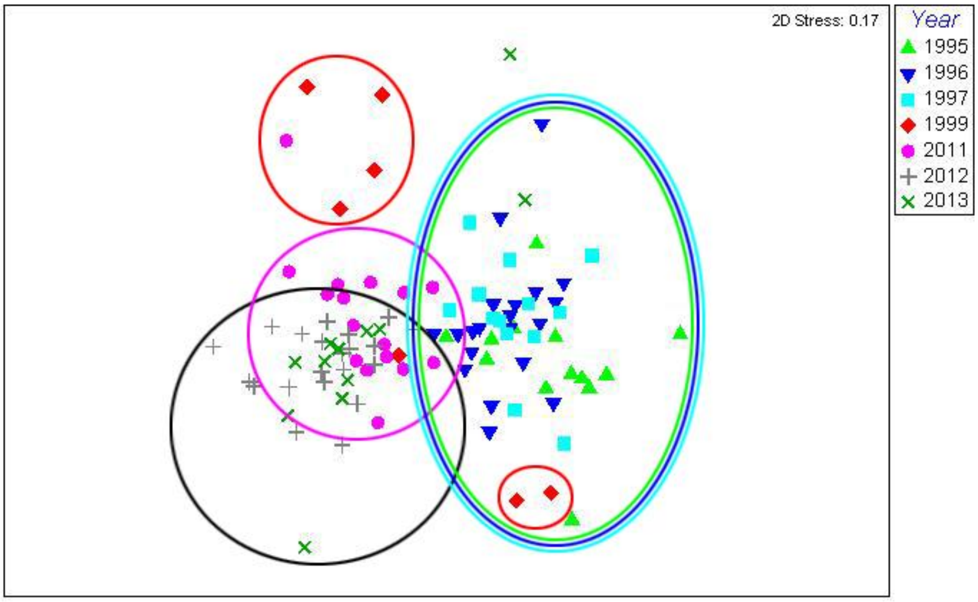

Figure 24: Multidimensional scaling plot of Bray Curtis similarities of daily CPUE of the ichthyofaunal catch composition for standard graball nets in southeast Tasmania.
Black neighbourhood contains the days observed in 2012 – 2013.

Table 26: R Statistic values and significance levels for pairwise ANOSIMs for the ichthyofaunal compositions of the various years derived from the matrix constructed using the CPUE of each fish species in large mesh graball nets in the east coast region.
The species determined by SIMPER as most responsible for typifying the ichthyofaunal compositions of the various years (shaded boxes) and for distinguishing between the ichthyofaunal compositions in each pairing of those years (shaded boxes) are shown.

	1995	1996	1997	2001	2002	2003	2004	2005	2007	2009	2011	2013
1995	Banded Morwong Draughtboard Shark Marblefish											
1996	0.026	Banded Morwong Marblefish										
1997	0.070* Banded Morwong Marblefish$^+$	-0.006	Banded Morwong Marblefish Longsnout Boarfish									
2001	0.384*** Banded Morwong Bluethroat Wrasse$^+$ Draughtboard Shark Purple Wrasse	0.257* Banded Morwong Bluethroat Wrasse$^+$ Purple Wrasse	0.230* Banded Morwong	Banded Morwong Bluethroat Wrasse								
2002	0.299* Banded Morwong Longsnout Boarfish Marblefish$^+$ Draughtboard Shark$^+$	0.200* Banded Morwong Longsnout Boarfish	0.164. Banded Morwong$^+$ Longsnout Boarfish	-0.050	Banded Morwong Longsnout Boarfish							
2003	0.217* Banded Morwong Longsnout Boarfish Draughtboard Shark	0.190* Banded Morwong Draughtboard Shark$^+$	0.114	0.211* Banded Morwong$^+$ Draughtboard Shark	0.031	Banded Morwong Longsnout Boarfish Marblefish Draughtboard Shark						
2004	0.065	0.086	0.033	0.269* Draughtboard Shark Banded Morwong$^+$	0.202* Banded Morwong$^+$ Draughtboard Shark Longsnout Boarfish$^+$	0.007	Banded Morwong Draughtboard Shark Longsnout Boarfish Marblefish					
2005	-0.020	0.073	0.177	0.224	0.123	-0.151	0.531* Banded Morwong$^+$	Banded Morwong Draughtboard Shark Bluethroat Wrasse				
2007	0.146	-0.016	-0.152	-0.254	-0.338	-0.267	-0.104	1.000	Banded Morwong Longsnout Boarfish Draughtboard Shark			
2009	0.272. Banded Morwong Longsnout Boarfish Draughtboard Shark	0.301. Draughtboard Shark Banded Morwong Longsnout Boarfish	0.198	0.129	0.036	-0.110	0.080	0.500	0.167	Banded Morwong Draughtboard Shark Longsnout Boarfish Bluethroat Wrasse		
2011	-0.214	-0.066	0.097	0.379.	0.188	0.134	0.771* Banded Morwong$^+$ Draughtboard Shark$^+$	1.000	1.000	0.917. Banded Morwong$^+$ Draughtboard Shark$^+$ Longsnout Boarfish$^+$	Banded Morwong Longsnout Boarfish Marblefish Draughtboard Shark	
2013	0.071	0.176	0.124	0.332* Banded Morwong$^+$ Draughtboard Shark	0.171	-0.051	0.131	-0.273	-0.255	0.005	0.091	Banded Morwong Draughtboard Shark Longsnout Boarfish Marblefish

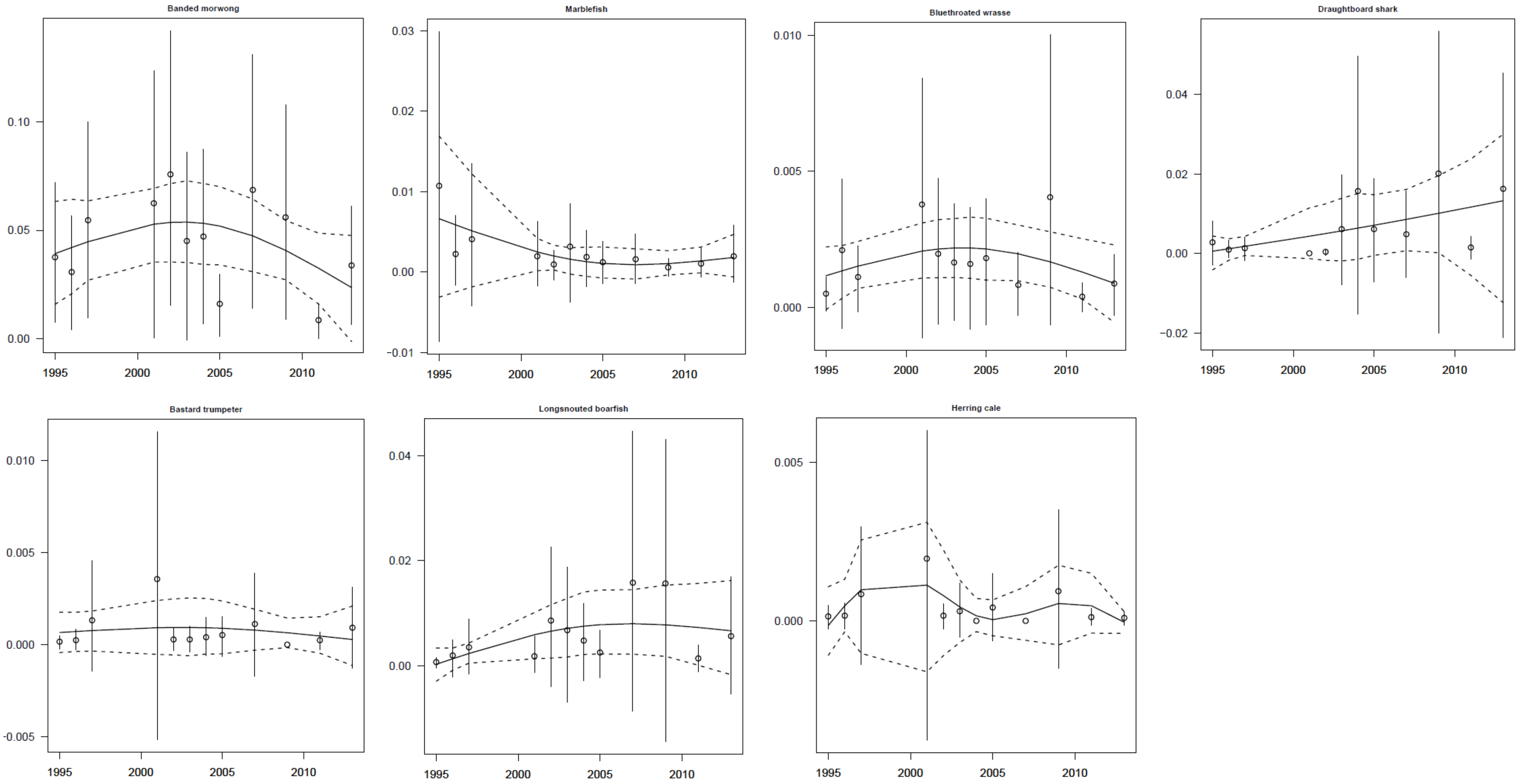

Figure 25: Changes to the relative abundance of selected ichthyofaunal on the east coast from 1995 – 2013 using the CPUE of large mesh graball nets.
Trends in abundance smoothed using a GAM with 95% confidence intervals (dashed line) and coefficient of variation (solid vertical lines) used for bootstrapping.

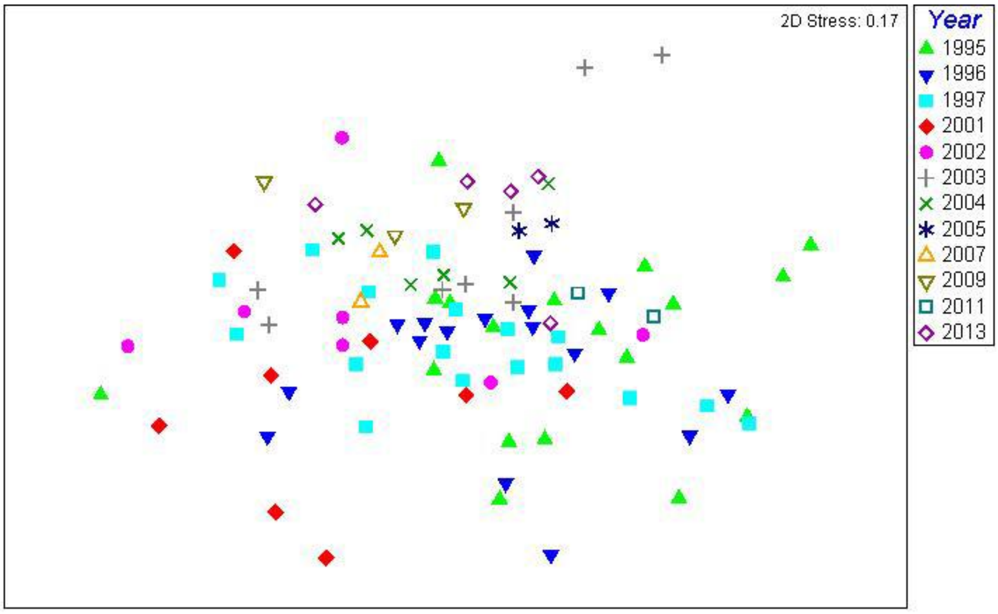

Figure 26: Multidimensional scaling plot of Bray Curtis similarities of daily CPUE of the ichthyofaunal catch composition for large mesh graball nets on the east coast of Tasmania.

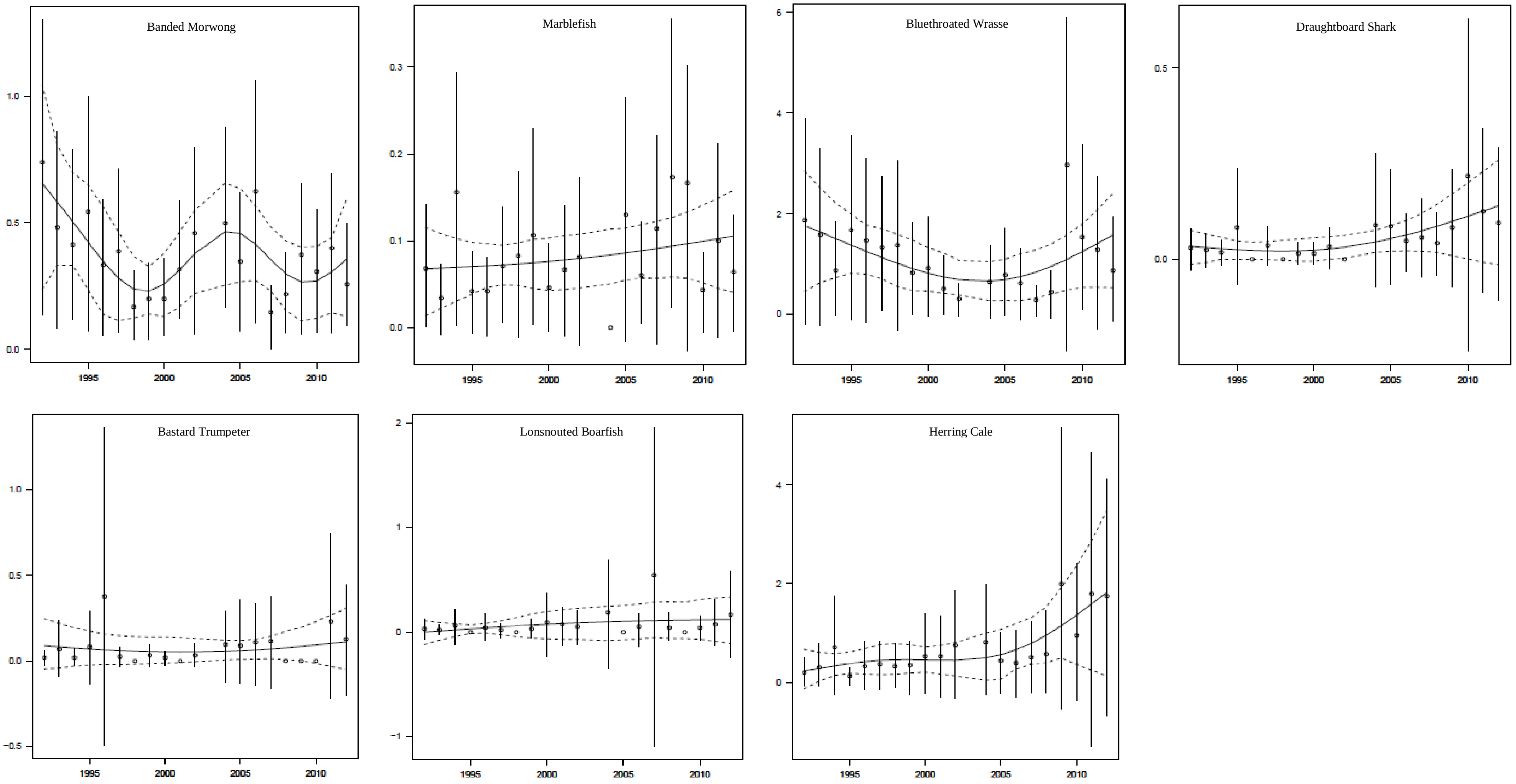

Figure 27: Changes to the relative abundance of selected ichthyofaunal on the central east coast of Tasmania from 1992 – 2012 based on underwater visual census (number of fish observed/2000m^2).

Trends in abundance smoothed using a GAM with 95% confidence intervals (dashed line) and coefficient of variation (solid vertical lines) used for bootstrapping.

Table 27: R Statistic values and significance levels for pairwise ANOSIMs for the ichthyofaunal compositions of the various years derived from the matrix constructed using the CPUE of each fish species in large mesh graball nets in the northeast coast region.

The species determined by SIMPER as most responsible for typifying the ichthyofaunal compositions of the various years (shaded boxes) and for distinguishing between the ichthyofaunal compositions in each pairing of those years (shaded boxes) are shown. ANOSIM is unable to carry out a pairwise test when n = 1 for both years; thus a pairwise comparison was not available for 2007 and 2011.

	1995	2001	2002	2003	2007	2011	2012
1995	Banded Morwong Bluethroat Wrasse Draughtboard Shark Marblefish						
2001	0.604** Banded Morwong^{+}	Banded Morwong Bluethroat Wrasse					
2002	0.283* Banded Morwong^{+}	0.325* Banded Morwong Bluethroat Wrasse^{+} Purple Wrasse	Banded Morwong				
2003	0.327. Banded Morwong Longsnout Boarfish	0.136	0.496* Banded Morwong^{+} Longsnout Boarfish Bluethroat Wrasse Marblefish Mosaic Leatherjacket	Banded Morwong Bluethroat Wrasse			
2007	-0.044	0.156	-0.369	-0.333	NA		
2011	0.444	0.933	0.787. Banded Morwong^{+} Draughtboard Shark Bluethroat Wrasse Marblefish	-0.111	NA	NA	
2012	0.858* Banded Morwong^{+} Draughtboard Shark	0.944* Banded Morwong^{+} Draughtboard Shark	0.915** Banded Morwong^{+} Draughtboard Shark Bluethroat Wrasse	0.519. Banded Morwong^{+} Longsnout Boarfish^{+} Draughtboard Shark Mosaic Leatherjacket	1.000	-0.556	Draughtboard Shark Banded Morwong

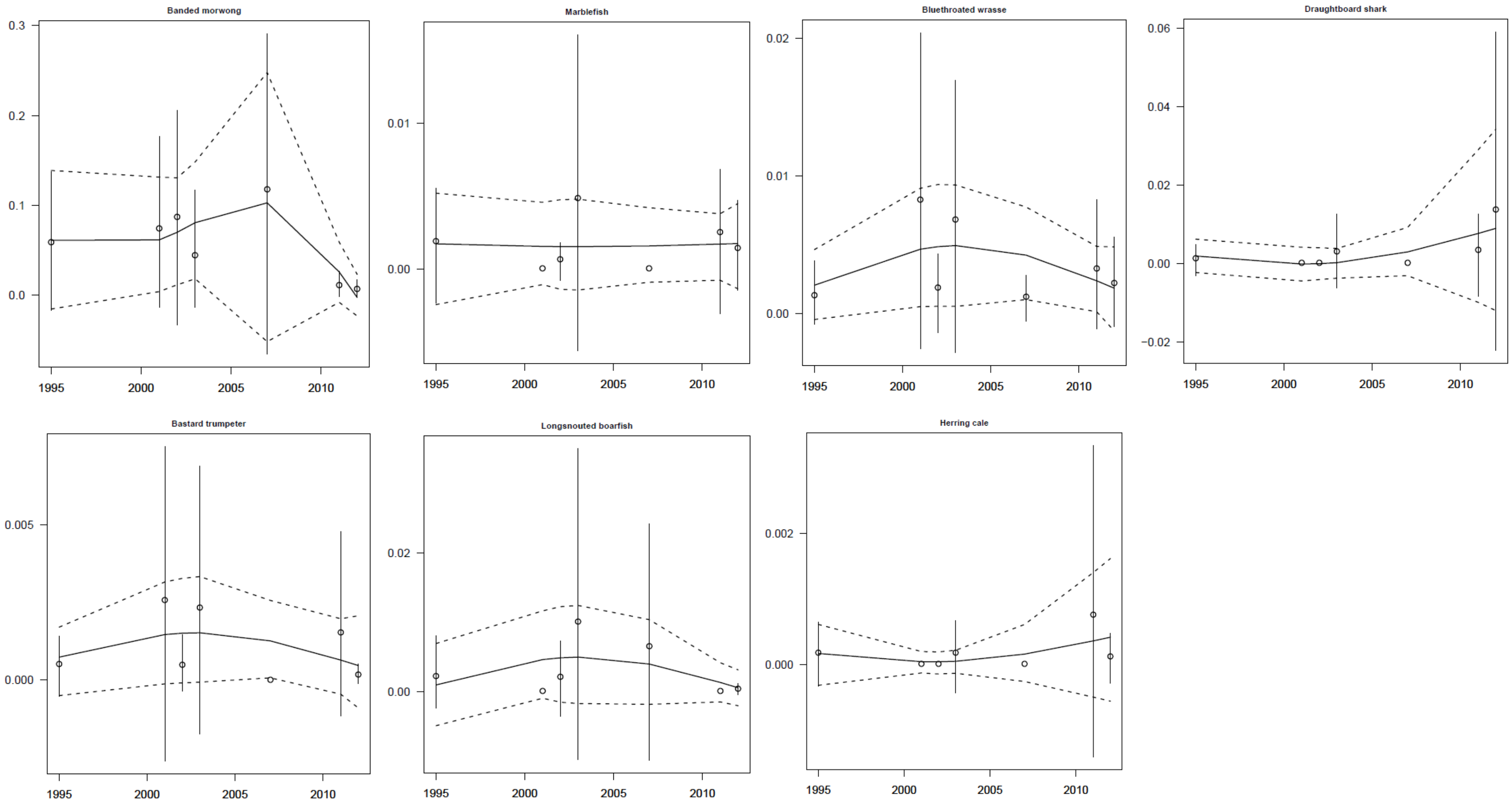

Figure 28: Changes to the relative abundance of selected ichthyofauna on the northeast coast from 1995 – 2013 using the CPUE of large mesh graball nets.

Trends in abundance smoothed using a GAM with 95% confidence intervals (dashed line) and coefficient of variation (solid vertical lines) used for bootstrapping.

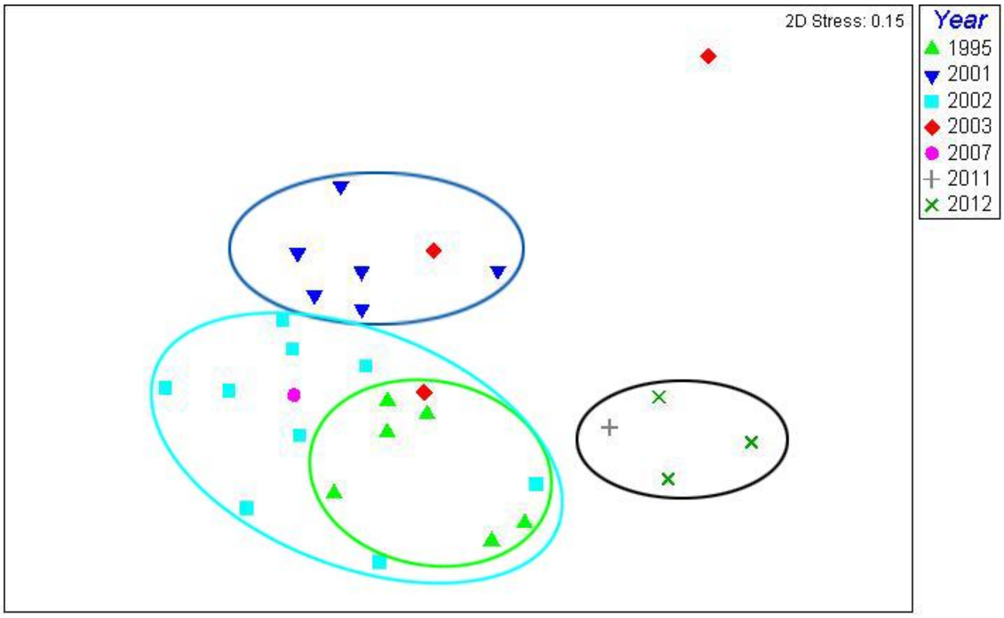

Figure 29: Multidimensional scaling plot of Bray Curtis similarities of daily CPUE of the ichthyofaunal catch composition for large mesh gillnets on the northeast coast of Tasmania. Black neighbourhood contains days observed in 2012 – 2013.

Motivations, behaviour and attitudes of recreational gillnet fishers

Respondent profile

Out of a total 601 eligible gillnet licence-holders (i.e. aged 18 years or older and who had completed the diary survey), 578 (96%) responded to the questionnaire. Respondents ranged in age from 18 to 86 years, with a mean age of 51.4 (SD 13.6) years; 96% (557) of whom were male. By comparison the mean age of gillnet licence-holders (18 years and over) registered in 2009-10[10] was significantly lower, at 49.4 years (p<0.001), indicating a bias towards older respondents in the survey sample.

Respondents reported an average of 26 (SD 14.9) years of gillnetting experience, with almost half of the sample having fished with gillnets for 30 or more years (Figure 30).

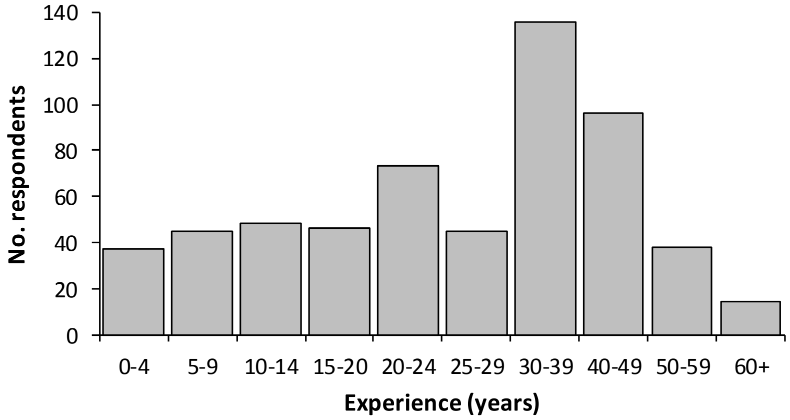

Figure 30: Years of gillnetting experience of survey respondents

Fishing motivation

Respondents were presented with nine motivational items chosen to represent both catch and non-catch related facets of the recreational fishing experience and asked to rate each as being either ‘not at all important’, ‘not very important’, ‘quite important’, or ‘very important’. For analysis, values have been assigned to the responses, on a scale from 1 (not at all important) to 4 (very important). The highest ranked motivation in terms of overall importance score (mean 3.74) was consumptive (“to catch fish to eat”), with non-catch motives (“to be outdoors … in the fresh air … to enjoy nature” and “to relax or unwind”) next in importance (Figure 31). Motivations based around social interactions (“to spend time with other friends” and “to spend time with family”) were also rated highly whereas spending time alone (“to be on your own … to get away from people”) was identified as being not important by most respondents, emphasising that recreational fishing is a social activity. The experiential catch motive (“the enjoyment or challenge of catching fish”) and providing fish to share with friends and family were also important attributes whereas catching large fish (“to catch a trophy-sized fish”) was rated as unimportant for the vast majority of respondents (overall score of 1.66).

In order to assess the primary motive for fishing, an individual’s response to each statement was compared to determine which was assigned the highest importance. If unclear, respondents were asked to nominate the motive that best represented the main reason for fishing. The motives were then grouped into five key categories; relaxation (“to relax or unwind” and “to be on your own … to get away from people”), social (“to spend time with family” and “to spent time with other friends”), environment (“to be out doors … in

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[10] The age of licence-holders was determined as at 1 January 2011.

the fresh air … to enjoy nature”), catch (“for the enjoyment or challenge of catching fish” and “to catch a trophy-sized fish”), and consumption (“to catch fish to eat” and “to catch fish to share with friends and family”). Respondents who were unable to identify a single main reason were recognised having multiple main motives for fishing.

Fishing to catch fish to consume was identified by almost 40% of gillnet fishers as their most important reason for fishing. Non-catch motives relating to relaxation (~ 20%) and socialising (~ 15%) were next in importance followed by the experience of catching fish (~ 10%). Interestingly, although being outdoors, enjoying fresh air and nature was a highly valued attribute (Figure 32), the overall importance of the environmental experience was ranked lower than all other categories.

Of the grouping factors considered, avidity did not emerge as a significant factor in response to any of the motivational items and none of the grouping factors proved to be significant in relation to the response to motives related to consumption (Table 28). Age, residence and experience were significant factors in relation to the importance that fishers attributed to relaxation and, based on pairwise comparisons of responses, the oldest age group afforded lower overall importance to this motive compared with each of the other age groups, and Hobart residents rated it significantly less important when compared with residents from the Mersey-Lyell region. Age and experience were significant factors in terms of the social reasons for fishing, with respondents in the 30 – 44 years age group according significantly higher importance to spending time with family and friends than respondents in any of the other age groups. Age also emerged as being significant in terms of the environmental motive, with the oldest age group affording lower importance to this attribute compared with respondents in both the 30 – 44 and 45 – 59 years age groups.

Comparison with other recreational fishers

Previous surveys of recreational fishers in Tasmania have established that non-catch motives (“to be outdoors … in the fresh air … to enjoy nature” and “to relax and unwind”) are ranked as being more important than catching fish to eat, although mean scores for gillnet fishers were higher for these non-catch motives (Figure 31). Within each of the motivational items, apart from spending time alone, response distributions differed significantly between surveys and in each of these instances, pairwise comparisons indicated that the response from gillnet fishers differed to those for both general population surveys.

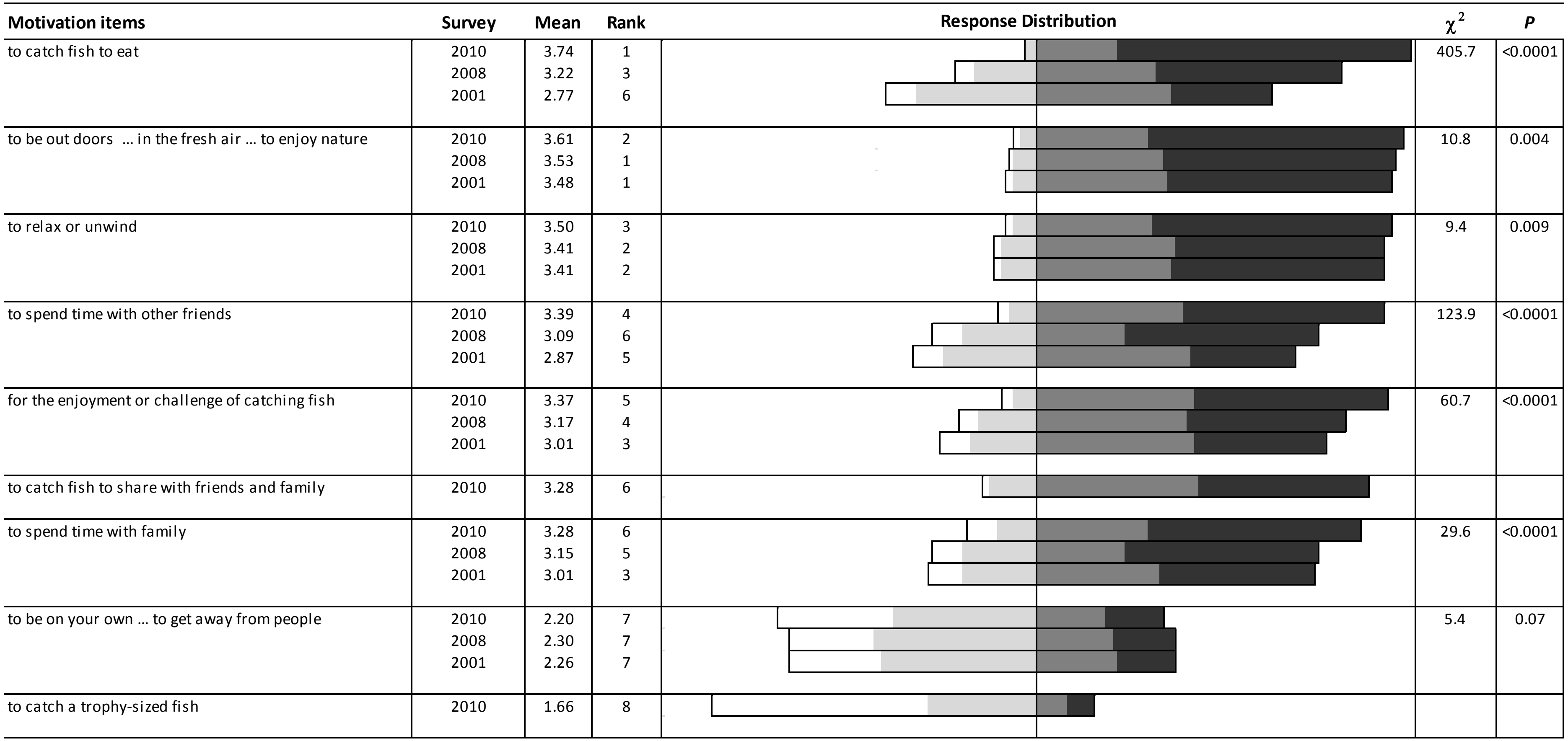
Consumptive orientation

In the context of recreational fishing consumptive orientation is the degree to which fishers value the catch-related aspects of the fishing experience and is typically used to evaluate fisher’s attitudes to four experiential components: (1) catching ‘something’ as a factor contributing to a satisfying fishing experience; (2) catching numbers of fish; (3) catching large fish; and (4) retaining fish. Item statements pertaining to each of these components were used, plus an additional statement relating directly to consumption of catch. For each of the eight statements used in this study, respondents indicated a level of agreement on a scale from 1 (strongly disagree) to 5 (strongly agree), with 3 being neutral (neither agree nor disagree).

Consumption of fish had the highest mean score (4.77), with 98% respondents agreeing with the statement “I usually eat the fish I catch”. This was followed in level of agreement (mean score 4.44) by the statement “I would rather keep just enough fish for a feed than take the bag limit” to which 90% respondents were in agreement (Figure 33). In relation to catching something (or more precisely the prospect of catch nothing), the vast majority (86%) of respondents agreed that they would still consider a fishing trip successful even if no catch was taken (mean score 4.22) and disagreed (71%) with the statement that if they thought they would not catch any fish they would not go fishing (reverse coded score 3.69). These statements highlight the sentiment that fishers derive benefits from the fishing experience that are unrelated to catching fish. Catching large fish and catching many fish elicited more polarised responses from fishers, with slightly more respondents tending to disagree with statements relating to these catch-related aspects.

Age and avidity were not significant factors in responses to any of the statements relating to consumptive orientation (Table 29). Residence was, however, in both statements relating to catching something, with respondents from the Greater Hobart and Northern regions indicating stronger disagreement with the statement “if I thought I wouldn’t catch any fish I wouldn’t go fishing” to residents from the Mersey-Lyell region. Experience was a significant factor in terms of the response to the statement relating to catching large fish rather than smaller fish.

The relative ranking of responses in terms of levels of agreement or disagreement to statements relating to retaining fish, catching something, catching large fish and catching numbers of fish were comparable for the present survey of gillnet fishers and the 2008 survey of recreational fishers (Figure 33). There were, however, significant differences in responses between surveys for each of the statements with the exception of “the more fish I catch, the happier I am”. The strongest difference related to catching large fish, with much greater agreement for this statement from the general population of recreational fishers.



Motivation items	Survey	Mean	Rank	Response Distribution	χ^2	P
to catch fish to eat	2010	3.74	1		405.7	<0.0001
	2008	3.22	3			
	2001	2.77	6			
to be out doors … in the fresh air … to enjoy nature	2010	3.61	2		10.8	0.004
	2008	3.53	1			
	2001	3.48	1			
to relax or unwind	2010	3.50	3		9.4	0.009
	2008	3.41	2			
	2001	3.41	2			
to spend time with other friends	2010	3.39	4		123.9	<0.0001
	2008	3.09	6			
	2001	2.87	5			
for the enjoyment or challenge of catching fish	2010	3.37	5		60.7	<0.0001
	2008	3.17	4			
	2001	3.01	3			
to catch fish to share with friends and family	2010	3.28	6			
to spend time with family	2010	3.28	6		29.6	<0.0001
	2008	3.15	5			
	2001	3.01	3			
to be on your own … to get away from people	2010	2.20	7		5.4	0.07
	2008	2.30	7			
	2001	2.26	7			
to catch a trophy-sized fish	2010	1.66	8			

Response Key: Not at all important □ Not very important ░ Quite important ▒ Very important ■

Figure 31: Mean scores and response distribution for the importance of motivational factors for recreational fishing provided by recreational gillnet fishers (2010 survey).

Results from previous state-wide surveys of recreational fishers are also presented (2001 and 2008). Rankings are based on the overall level of importance given to each statement.

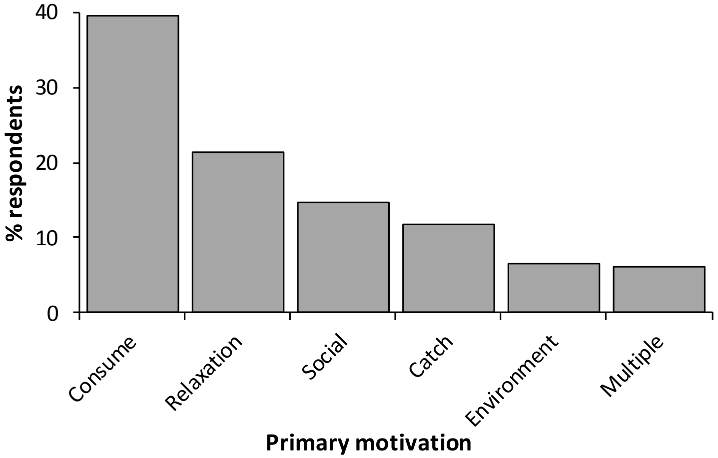


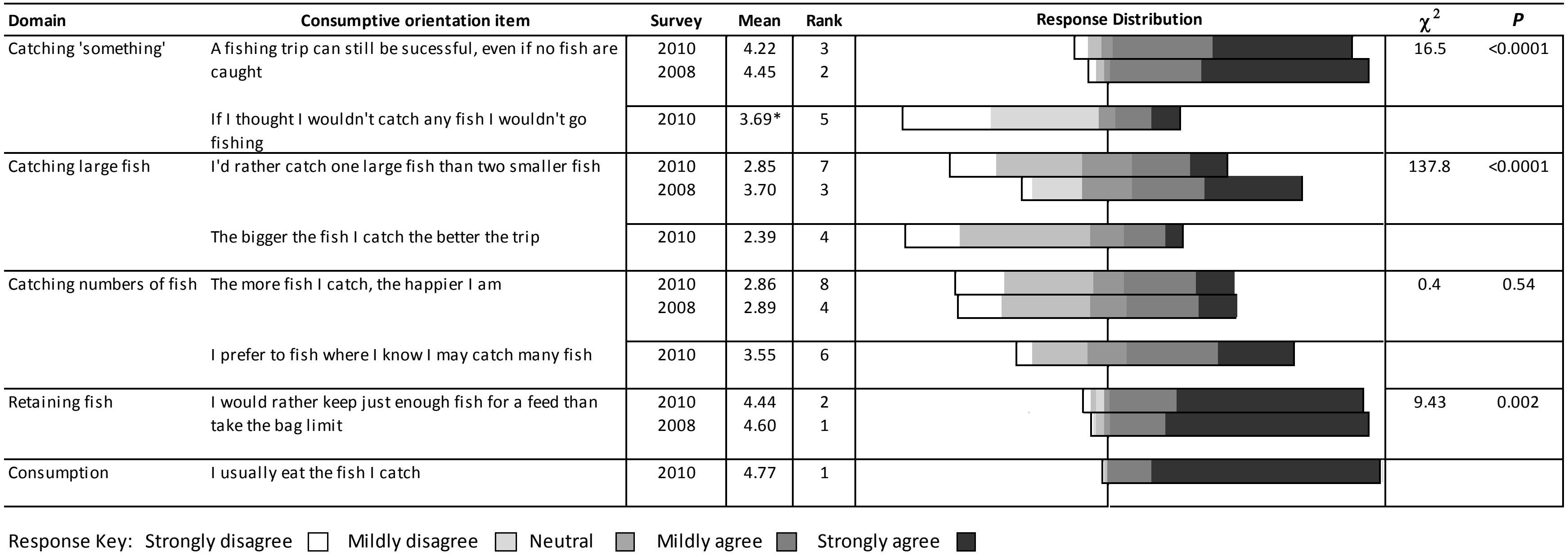
Figure 32: Main motivational categories identified by gillnet fishers

Table 28: Kruskal-Wallis test for the effect of respondent grouping factors on the importance of motivational factors for recreational fishing.

Motivation category	**Statement**	**Age**			**Residence**			**Avidity**			**Experience**		
		χ^2	**df**	***p***	χ^2	**df**	***p***	χ^2	**df**	***p***	χ^2	**df**	***p***
Catch	for the enjoyment or challenge of catching fish	8.40	3	0.038	3.49	3	ns	1.73	3	ns	5.41	5	ns
	to catch a trophy-sized fish	3.94	3	ns	2.59	3	ns	4.85	3	ns	9.56	5	ns
Consumption	to catch fish to eat	7.68	3	ns	3.31	3	ns	2.18	3	ns	4.57	5	ns
	to catch fish to share with friends and family	0.99	3	ns	0.11	3	ns	1.85	3	ns	4.43	5	ns
Relaxation	to relax or unwind	21.50	3	<0.001	10.18	3	0.017	3.12	3	ns	11.53	5	0.041
	to be on your own … to get away from people	3.32	3	ns	1.64	3	ns	4.81	3	ns	5.30	5	ns
Social	to spend time with family	24.12	3	<0.001	2.94	3	ns	1.24	3	ns	15.29	5	0.009
	to spend time with other friends	15.14	3	0.002	3.50	3	ns	5.27	3	ns	5.55	5	ns
Environment	to be outdoors ... in the fresh air … to enjoy nature	17.47	3	<0.001	6.44	3	ns	0.17	3	ns	8.70	5	ns

Table 29: Kruskal-Wallis test for the effect of respondent grouping factors on responses to consumptive orientation statements.

Consumptive		Age			Residence			Avidity			Experience		
Domain	**Statement**	χ^2	**df**	***p***	χ^2	**df**	***p***	χ^2	**df**	***p***	χ^2	**df**	***p***
Catch something	a fishing trip can be successful, even if no fish are caught	5.92	3	ns	8.05	3	0.045	0.07	3	ns	4.19	5	ns
	if I thought I wouldn't catch any fish I wouldn’t go fishing	4.76	3	ns	12.79	3	0.005	2.34	3	ns	2.22	5	ns
Catching large fish	I'd rather catch one large fish than two smaller fish	5.88	3	ns	4.42	3	ns	1.76	3	ns	16.28	5	0.006
	the bigger the fish I catch the better the trip	4.74	3	ns	3.28	3	ns	5.62	3	ns	8.04	5	ns
Catching numbers of fish	the more fish I catch the happier I am	5.64	3	ns	2.00	3	ns	0.75	3	ns	5.04	5	ns
	I prefer to fish where I know I may catch many fish	0.77	3	ns	6.52	3	ns	0.52	3	ns	1.13	5	ns
Retaining fish	I would rather keep just enough fish for a feed rather than take the bag limit	4.04	3	ns	2.04	3	ns	1.25	3	ns	6.77	5	ns
Consumption	I usually eat the fish I catch	7.68	3	ns	3.31	3	ns	2.18	3	ns	4.57	5	ns



Domain	Consumptive orientation item	Survey	Mean	Rank	Response Distribution	χ^2	*P*
Catching 'something'	A fishing trip can still be sucessful, even if no fish are caught	2010 2008	4.22 4.45	3 2		16.5	<0.0001
	If I thought I wouldn't catch any fish I wouldn't go fishing	2010	3.69*	5			
Catching large fish	I'd rather catch one large fish than two smaller fish	2010 2008	2.85 3.70	7 3		137.8	<0.0001
	The bigger the fish I catch the better the trip	2010	2.39	4			
Catching numbers of fish	The more fish I catch, the happier I am	2010 2008	2.86 2.89	8 4		0.4	0.54
	I prefer to fish where I know I may catch many fish	2010	3.55	6			
Retaining fish	I would rather keep just enough fish for a feed than take the bag limit	2010 2008	4.44 4.60	2 1		9.43	0.002
Consumption	I usually eat the fish I catch	2010	4.77	1			

Response Key: Strongly disagree ☐ Mildly disagree ░ Neutral ▒ Mildly agree ▓ Strongly agree ■

Figure 33: Mean scores and response distribution to consumptive orientation statements provided by recreational gillnet fishers (2010 survey). Results from the 2008 state-wide surveys of recreational fishers are also presented. Ranking is based on the degree of consistency in the responses, whether in agreement or disagreement with the statement.* reverse coded to be consistent with the domain of Catching something.

Centrality to lifestyle

The vast majority of respondents (97%) reported some type of fishing activity during 2010, 62% had fished with gillnets whereas 90% had done some inshore/coastal line fishing and 66% fished for Rock Lobster using pots or rings (Figure 34). A variety of other fishing activities were also reported indicating that gillnet licence-holders engage in range of recreational fisheries. Based on the activity identified by respondents as their main fishery during 2010, less than 5% of the active fishers reported that gillnetting was their main activity, this compared with 53% for inshore/coastal line fishing, 14% for rock lobster potting, 10% for offshore bottom fishing and 6% freshwater fishing.

In terms of centrality to lifestyle, respondents were asked three questions relating to the importance of recreational fishing and gillnetting in particular. Over half of the respondents (57%) agreed that amongst all their recreation/leisure activities, recreational fishing was their most important activity (mean score 3.42) (Figure 35). In relation to gillnetting, only 9% agreed that if they could not gillnet they would probably give up fishing altogether (mean score 1.64) but responses were more polarised about whether they would give up gillnet fishing if they were unable to use gillnets in the areas they currently go, with 43% in agreement (mean score 2.83).

Respondent grouping factors did not significantly influence the response to the question about the importance of recreational fishing as a leisure activity (Table 30). Avidity did, however, emerge as significant factors in relation to both questions relating to gillnet fishing. Age, residence and experience were not significant factors.

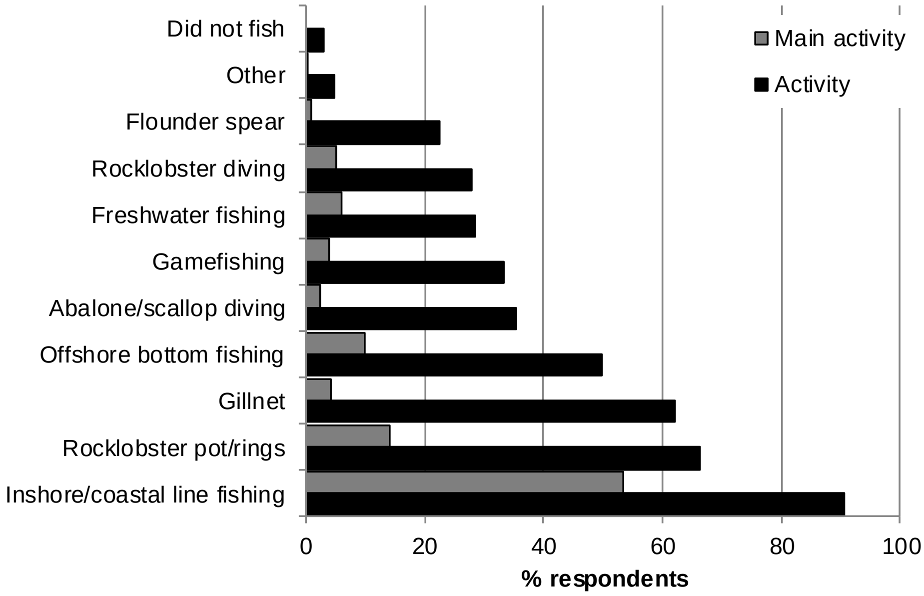
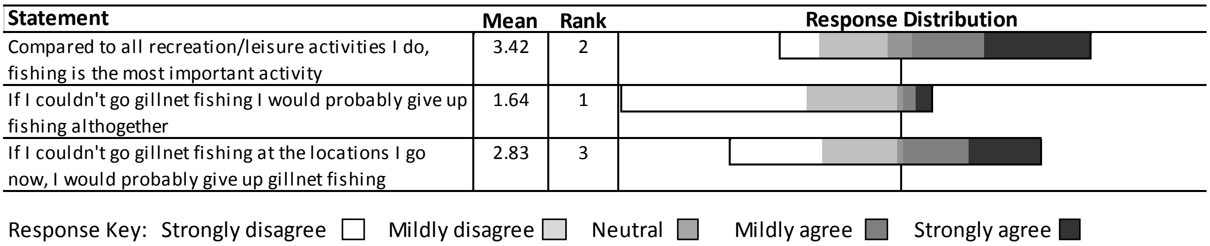


Figure 34: Proportion of respondents who participated in different fishing activities during 2010 and their main fishing activity during that period.



Statement	Mean	Rank
Compared to all recreation/leisure activities I do, fishing is the most important activity	3.42	2
If I couldn't go gillnet fishing I would probably give up fishing althogether	1.64	1
If I couldn't go gillnet fishing at the locations I go now, I would probably give up gillnet fishing	2.83	3

Figure 35: Mean scores and response distribution to statements relating to recreational fishing and gillnetting by recreational gillnet fishers.
Ranking is based on the degree of consistency in the responses, whether in agreement or disagreement with the statement.

Table 30: Kruskal-Wallis test for the effect of respondent grouping factors on responses to centrality to lifestyle questions.

	Age			Residence			Avidity			Experience		
Statement	χ^2	**df**	***p***	χ^2	**df**	***p***	χ^2	**df**	***P***	χ^2	**df**	***p***
Compared to all recreation/leisure activities I do, fishing is the most important activity	2.63	3	ns	0.65	3	ns	4.31	3	ns	6.45	5	ns
If I couldn't go gillnet fishing I would probably give up fishing altogether	0.86	3	ns	0.56	3	ns	10.06	3	0.018	6.83	5	ns
If I couldn't go gillnet fishing at the locations I go now, I would probably give up gillnet fishing altogether	0.57	3	ns	3.38	3	ns	6.22	3	0.010	9.67	5	ns

Management and fishing practices

Respondents were reminded of recent management changes relevant to gillnet usage in Tasmania - reduction in the number of graball net per person, reduction in the maximum length of mullet nets (from 50 to 25 m), ban on night netting in most areas, and the introduction of maximum soak times - measures that had been implemented to improve fishing practices and reduce by-catch and wastage. Respondents were then asked a series of questions relating to these changes. Overall two-thirds agreed that the changes would be effective in improving fishing practices and also reducing wastage and by-catch, while around one third reported that the measures had influenced how often they went gillnet fishing and less than 20% considered that the changes had affected where they fished and the species they targeted (Figure 36). The prohibition on night netting and maximum soak time requirements were identified as key constraints on how often respondents went fishing; night netting prohibition, soak time requirements (especially in SRAs) and expansion of no-netting areas were the main contributors influencing where respondents fished; and the ban on night netting was seen as a major impediment when fishing for species such as Blue Warehou, Greenback Flounder and to a lesser extent Bastard Trumpeter and Atlantic Salmon.

Respondent grouping factors did not influence responses to questions associated with the effectiveness of the management measures in improving fishing practices or reducing wastage and were not significant in terms of whether the management changes had influenced what species the respondents targeted with nets (Table 31). Residence and experience were, however, significant factors in the respect to the impact of management change on how often respondents fished, while age and experience influenced responses to where respondents went fishing with gillnets.

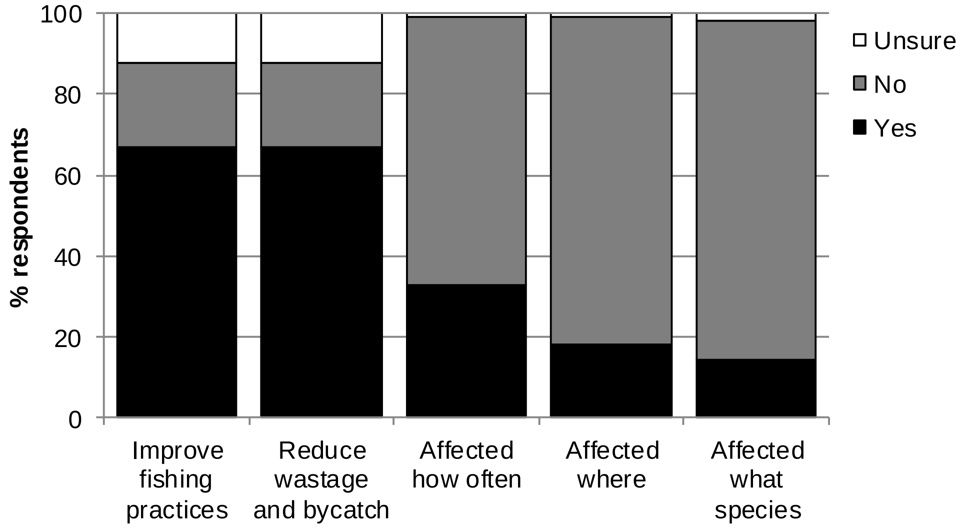


Figure 36: Responses to questions relating to recent management changes to gillnetting in Tasmania (refer text)
(No. respondents = 578)

Table 31: Kruskal-Wallis test for the effect of respondent grouping factors on responses to management and fishing behaviour questions.

	Age			Residence			Avidity			Experience		
Statement	χ^2	**df**	*p*	χ^2	**df**	*p*	χ^2	**df**	*p*	χ^2	**df**	*p*
Do you think that recent management changes will be effective in improving fishing practices?	2.79	3	ns	7.34	3	ns	2.49	3	ns	6.96	5	ns
Do you think these management measures will be effective in reducing wastage and by-catch?	7.20	3	ns	1.94	3	ns	2.51	3	ns	3.34	5	ns
Have these management measures affected your fishing in terms of **how often** you go fishing?	2.14	3	ns	12.71	3	0.005	1.55	3	ns	11.20	5	0.05
Have these management measures affected your fishing in terms **where** you go fishing?	9.60	3	0.02	3.45	3	ns	0.97	3	ns	11.93	5	0.04
Have these management changes affected your fishing in terms of **what species** you target with nets?	0.81	3	ns	4.01	3	ns	3.48	3	ns	10.69	5	ns

Fish availability

Respondents were asked to identify the main species (up to two) that they targeted using gillnets, approximately half of all respondents identified Blue Warehou and/or Bastard Trumpeter as their main target species (both species that are rarely taken by other fishing methods). Almost 20% identified Atlantic Salmon as a key target species, with a variety of other species also reported.

Having identified target species, respondents were presented with a scenario that involved the catch rates for these species being very low. Almost half of the respondents suggested that they would be likely to fish less or even give up net fishing, 20% indicated that they would probably fish about the same, while 14% suggested they would switch to targeting other species (Table 32). Relatively few respondents suggested that they would fish more to at least have a chance of catching something.

Respondents were then asked whether they had observed any changes in the abundance of their main target species in recent years. Relatively few reported increases, with more or less equal numbers suggesting either declines or no change (Table 33). Of interest is the observation that almost half of those respondents who identified Atlantic Salmon as a target species also noted that abundances of aquaculture escapees had declined. .

Respondents who identified a change in abundance were also asked whether they considered changes in fishing pressure (either increase or decrease) had contributed to the observed changes. Increased abundances were attributed to changes (reduction) in fishing pressure from commercial and recreational sectors (collectively 46%) as well as non-fishing related factors (38%), here interpreted as natural variability (Table 34). By contrast, declines were mostly (63%) seen as fishery induced, and in particular due to commercial fishing pressure.

Table 32: Responses to question relating to responses to a scenario where catch rates for key gillnet target species were very low

Response	%
Fish more	7.1
Switch target	13.8
Fish less (or stop fishing)	49.1
No change	20.7
Unsure	9.4
No respondents	566

Table 33: Responses (%) to question relating to perceived changes in abundance, including analysis based on nominated key target species.

		Key target species		
	All	Blue Warehou	Bastard Trumpeter	Atlantic Salmon
Increase	12.0	11.4	10.5	12.0
Decrease	40.0	44.8	42.2	49.0
No change	37.9	34.9	38.7	30.0
Unsure	10.1	8.9	8.7	9.0
No. respondents	575	281	287	100

Table 34: Responses (%) to question relating to perceived factors that have influenced the increase or decrease in abundance of target species.

	Increase	Decrease
Commercial fishing	20.3	35.4
Recreational fishing	10.1	3.1
Both	15.9	24.5
Not due to fishing	37.7	22.3
Unsure	15.9	14.8
No. respondents	69	229

Wildlife interactions

Interactions between gillnet fishing and wildlife, specifically seals and seabirds, is a particularly sensitive issue and was explored through a series of questions. The majority (75%) of gillnet fishers reported having experienced at least interactions involving seals during their lifetime, the vast majority of whom reported experiencing loss of fish (92%) and damage to nets (87%) as a consequence of these interactions (Table 35). Seal interactions were reported as common occurrences, with 46% of respondents suggesting that they occurred on more than half of the days they fished, with a strong perception that interaction rates had increased in recent years.

Residence, avidity and experience of respondents were significant factors in the responses to the question relating to seal interactions (Figure 37). Not unexpectedly, the least avid and least experienced gillnet fishers reported significantly lower occurrence of seal interactions, while the proportion of fishers having observed interactions generally increased with avidity and years of gillnetting experience.

Entanglement of seabirds in gillnets is a contentious issue and just over a quarter of respondents reported having ever experienced such an event at some time whilst gillnetting, however, the frequency of such interactions was noted as being very rare (i.e. less than once per 20 days fished) in the majority (79%) of cases (Table 36). In the related recreational gillnet fishing survey conducted throughout 2010 (Lyle and Tracey 2012), information on by-catch, including seabirds, was canvassed. Overall seabird interactions were reported in less than 0.1% of gillnet deployments, potentially representing an under estimate of the actual interaction rate.

Respondents who reported bird entanglements were asked to identify which species had been involved. Out of 129 respondents who answered this question, 62% reported the incidental capture of cormorants, 39% reported penguins, 6% mutton birds, 3% gannets and 2% sea gulls. Several respondents noted that some birds were released alive, highlighting that not all entanglements necessarily result in mortality.

Each of the grouping factors were significant in the responses to the question relating to seabird entanglements (Figure 38). As age, avidity and experience increased so did the reported experience of seabird by-catch. Mersey-Lyell residents reported the lowest experience of seabird by-catch whereas residents of the Southern region were the most likely to have had experience of seabirds tangled in their gillnets.

Recognising that seabird by-catch is an issue, respondents were asked whether they considered that there was a need for additional restrictions on gillnetting in areas close to rookeries and penguin colonies. While over half of the respondents suggested that current management measures were adequate, those supporting additional measures were more in favour of spatial rather than temporal closures (Table 37). Respondent grouping factors did not significantly influence responses to this question.

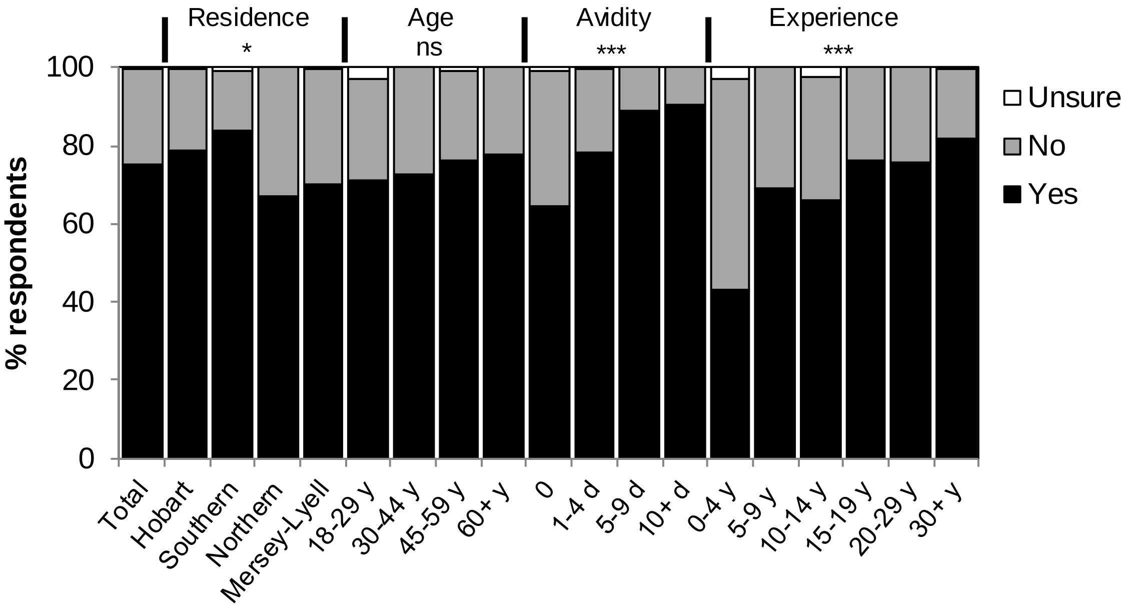


Figure 37: Responses to a question about whether respondents had experienced seal interactions when gillnetting, total sample by respondent grouping factors.

Significance of Kruskal-Wallis test are indicated for each grouping factor. ns not significant; * $p< 0.05$; ** $p<0.01$; *** $p< 0.001$

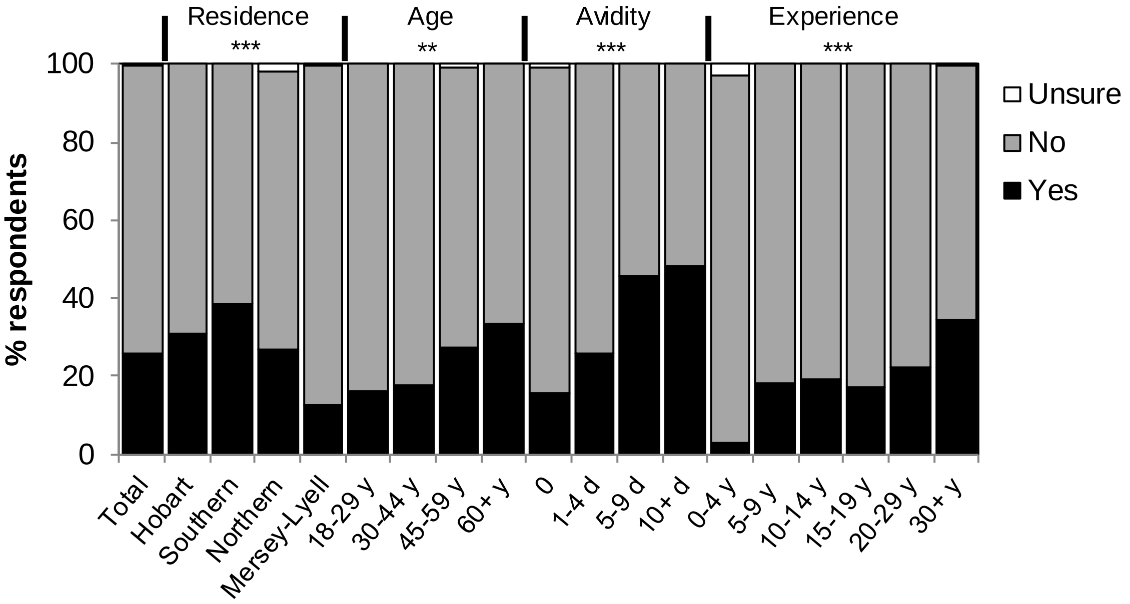


Figure 38: Responses to a question about whether respondents had experienced seabird interactions when gillnetting, total sample by respondent grouping factors.

Significance of Kruskal-Wallis test are indicated for each grouping factor. ns not significant; * $p< 0.05$; ** $p<0.01$; *** $p< 0.001$

Table 35: Responses to questions relating to seal interactions.
N = no. respondents

Question	Response	%
With your recreational netting, have you ever experienced interactions with seals (*N* = 572)		
	Yes	75.3
	No	24.1
	Unsure	0.5
IF YES Did the interactions involve damage to gear, loss of fish or neither (*N* =440)		
	Gear damage	3.4
	Loss of fish	9.0
	Both	83.2
	Neither	4.3
Would you say these interactions have been rare (less than once per 10 days), occasional (up to 5 times per 10 days) or frequent (more than half of all days) (*N*= 440)		
	Rare	22.3
	Occasional	31.4
	Frequent	45.7
	Unsure	0.7
Based on your experience, would you say seal interactions have generally increase, changed little or decreased in recent years (*N*= 451)		
	Increased	74.5
	Changed little	17.5
	Decreased	4.0
	Unsure	4.0

Table 36: Responses to questions relating to seabird entanglements.
N = no. respondents

Questions	Response	%
In your experience with net fishing have you ever had seabirds tangled in your net? (N = 572)		
	Yes	26.0
	No	73.6
	Unsure	0.3
IF YES Would you say these interactions have been very rare (less than once per 20 days), rare (less than once per 10 days) or more often than that? (*N*= 136)		
	Very rare	79.4
	Rare	14.7
	Occasional	5.9

Table 37: Response to questions relating to accidental capture of seabirds in nets.

Question	Response	%
Is there a need to close areas that are near to rockeries or penguin colonies, or would it be better to prohibit net usage during periods when bids are most active, or are recent management changes to netting sufficient to reduce the problem (*N*= 568)		
	Closed areas	20.1
	Closed periods	9.2
	No new measures	57.6
	Unsure	13.2

Ecological risk assessment

Scoping

Four sub-fisheries were identified during scoping:

- Graball (Banded Morwong) sub-fishery. Separated on the basis that fishers targeting this species operate quite differently than those from the graball (reef) sub-fishery. They use larger mesh sizes (133 – 140 mm), they fish almost exclusively in depths of 10 – 20 m, and they exclusively operate on exposed coastal reef habitats. As such, this sector has a unique catch composition,

- Graball (reef) sub-fishery. While similar to the Banded Morwong sub-fishery the graball (reef) sub-fishery generally uses smaller mesh sizes (105-125 mm) and have a tendency to fish shallower bays and more protected regions where Blue Warehou, in particular, aggregate. As such the catch composition is different than other sectors. This sector includes both recreational and commercial fishers,

- Graball (non-reef) sub-fishery. Different to reef fisheries with standard and large mesh graball nets deployed, predominantly on soft sediment habitats, to target Atlantic Salmon and Flounder. This sector predominantly operates within SRAs and Macquarie Harbour, and has a very different catch composition that the other fisheries,

- Small mesh fisheries. This sector includes both recreational mullet net fishers and commercial small mesh fishers. Both use smaller mesh sizes than other sectors and fish over soft sediment habitats. As such this sector has a unique catch composition.

Objectives were identified for each component of the fishery and are identical in each sub-fishery. For the target, by-product and by-catch, and TEPS components a detailed breakdown of the specific objectives, indicators and rationale in relation to population size, geographic range, genetic structure, age/size/sex structure, reproductive capacity and behaviour/movement is detailed in scoping document S3. For the habitats component a detailed breakdown of specific objectives, indicators and rationale in relation to water quality, air quality, substrate quality, habitat types and habitat structure and function is detailed in scoping document S3. For the communities component a detailed breakdown of specific objectives, indicators and rationale in relation to species composition, functional group composition, distribution of the community, trophic/size structure and bio- and geo-chemical cycles is detailed in scoping document S3. The core objectives identified on which to base consequence scores in level 2 SICA were:

- Target species – avoid recruitment failure. Avoid negative consequences for the species as a whole and population sub-components;
- By-product and by-catch species – avoid recruitment failure. Avoid negative consequences for the species as a whole and population sub-components;
- TEPS – avoid recruitment failure. Avoid negative consequences for the species as a whole and population sub-components. Avoid negative impacts on the population due to fishing;
- Habitats – avoid negative impacts on the quality of the environment. Avoid reductions in the amount and quality of habitat; and
- Communities – avoid negative impacts on the composition/ function/ distribution/ structure of the community.

Level 1: Scale, intensity and consequence analysis

Graball (reef) sub-fishery

Of the five components, three (target species, by-catch and by-product species and TEPS) had consequence scores above moderate (consequence score of 3 or greater) for at least one within fishery activity (Table 38); the habitats and communities components had maximum rankings of 2. The within fishery hazards responsible for moderate or greater risk were ‘capture by fishing’ with target species ranked as 4 due to the long term decline in the abundance of Bastard Trumpeter and Blue Warehou. By-catch and by-product species were ranked as 4 due to the long term decline in the abundance of School Shark and TEPS were ranked as 3 due to the relatively high interaction rate with seabirds. It should be noted that the impact on seabird populations is unknown so a consequence of 3 is considered precautionary.

Target species also ranked as moderate for the effect of 'fishing without capture', which was due to the relatively common occurrence of large Blue Warehou falling out of the net without being captured or being predated by seals (Table 38). All other factors were ranked below moderate.

Several external hazards were identified as having moderate or greater consequence to all the components of the graball (reef) sub-fishery (Table 38). The consequence of other fisheries was scored as 4 for target species as Blue Warehou are captured by several sectors within the SESSF; it was also scored a 4 for by-catch and by-product species as Draughtboard Shark, Gummy Shark, School Shark, Australian Salmon, Jackass Morwong and many others are caught by various sectors of the SESSF and other TSF fishing methods; it was scored a 3 for TEPS as various other state, interstate and Commonwealth fisheries catch seabirds; and scored a 3 for the impact on habitat and communities since the removal of Southern Rock Lobster by the lobster fishery (commercial and recreational) can reduce predation pressure on sea urchin populations, which in turn may have substantial impacts on rocky reef habitats and communities. Aquaculture was identified as having a consequence of 3 for target species, by-catch and by-product species, TEPS and habitats, and was ranked as 4 for communities (Table 38). This ranking was predominantly due to increased nutrient loads, which can alter communities and habitats, and have flow on impacts throughout the ecosystem. While aquaculture does not occur over rocky reef habitats there is potential to impact these habitats if in close proximity. Further, the aquaculture industry has direct impacts for both seals and seabirds (especially cormorants), both beneficially through provisioning and negatively due to mortalities. Similarly, coastal development can impact ecosystem structure and function with either positive or negative implications for associated species and therefore consequence was rated moderate or greater for most components (Table 38).

Graball (Banded Morwong) sub-fishery

The target, by-catch and by-product, and TEPS components were the only ones to have hazard scores of moderate or greater (Table 39). The consequence of fishing 'capture' on the target species was ranked as 4 due to the long term decline in Banded Morwong CPUE. By-catch and by-product species were scored 3 due to the long term decline in Bastard Trumpeter, noting that Banded Morwong nets do not select for this species particularly well and this sector is unlikely to be primarily responsible for the decline. TEPS were ranked as 3 due to the interaction with seabirds. Due to the relatively high rate of predation by seals on Banded Morwong in gillnets, the target species component was ranked as a consequence of 3 for the fishing hazard of 'direct impact without capture'. None of the other within fishery factors are ranked as 3 or greater in consequence and the habitats and communities components had maximum rankings of 2 (Table 39).

The external hazards for this sub-fishery are very similar to those identified for the graball (reef) sub-fishery (Table 39). Noticeably, there is less of an impact on the target species from other fisheries as Banded Morwong are strongly reef associated and rarely caught in Commonwealth or other state fisheries. Aquaculture and coastal development are also likely to have less of an impact on target, by-product and by-product species (Table 39) as the sub-fishery is centred on exposed reefs rather than more sheltered areas where these activities/developments have their greatest presence.

Graball (non-reef) sub-fishery

Again, target, by-catch and by-product, and TEPS components were the only components to have hazards ranked as moderate or greater (Table 40). The consequence on target species by fishing 'capture' was only ranked as 3 as there is no indication Flounder populations have declined and Atlantic Salmon are an exotic species. Blue Warehou and Bastard Trumpeter are taken within this fishery but in small quantities as by-product. The consequence assigned to by-product and by-catch was ranked as a 4 as this sub-fishery catches School Shark, which have declined in abundance and the habitats fished tend to also represent key shark refuge areas. TEPS were ranked as 4 as the endangered Maugean Skate are captured in Macquarie Harbour and mortalities may occur. No other within fishery factors were ranked as 3 or greater in consequence and the habitats and communities components had maximum rankings of 2 (Table 40).

While few other fisheries operate within SRAs, many of the species encountered within them are encountered in other fisheries and, as a result, target species, by-catch and by-product species and TEPS were all scored with a consequence of 3. Other fisheries were also scored a 3 for the impact on communities since the Commonwealth shark fishery has had a very large impact on School Shark stocks, which would otherwise be abundant in SRAs. Aquaculture scored 3 or greater for all components (Table 40) as the industry is well developed in many SRAs and may impact on habitats, the species that inhabit them and the marine ecosystem more generally. Coastal development also consistently had consequences of 3 or greater (Table 40) as SRAs tend to be located in coastal embayments, which are generally surrounded by industrial, rural and/or residential developments. Furthermore, Macquarie Harbour has also had many years of mining activity within the catchment that has had a variety of negative impacts on water quality.

Small mesh sub-fishery

As for the other sub-fisheries, target, by-catch and by-product, and TEPS components were the only ones to have hazards of moderate or greater (Table 41). The consequence of fishing ‘capture’ on target species was ranked as 3 as there is no indication that any of these species are overfished although some may be fully exploited. The consequence assigned to by-product and by-catch was ranked as 4 as this sub-fishery catches Blue Warehou, which have a long term decline in CPUE. Due to the high rate of predation by seals on the north coast where the commercial fishery exists and most of the Mullet net recreational fishing effort occurs, the target and by-product, and by-catch components were ranked as a consequence of 3 for the fishing hazard of ‘direct impact without capture’. TEPS were ranked as 3 due to interactions with seabirds. No other within fishery factors are ranked as 3 or greater in consequence and the habitats and communities components had maximum rankings of 2 (Table 41).

The external hazards scoring moderate or greater were primarily associated with other fisheries and coastal development (Table 41). The broad diversity of species encountered within this sub-fishery means that the target, by-catch and by-product, and TEPS are all caught by a variety of Commonwealth and other state fisheries. Most are relatively productive though and as a result the consequence is ranked as 3. While small mesh nets are not allowed to be used recreationally within SRAs, commercial fishers are allowed to operate in the Tamar estuary where there has been aquaculture at times. Further, many species encountered in this sub-fishery are also common in inshore areas where aquaculture occurs so there are potential impacts of aquaculture on habitats and communities associated with this fishery, thus this component was ranked by taking a precautionary approach (Table 41). Coastal development is likely to have had a moderate impact on most components of this fishery as the Tamar Estuary is heavily developed and there have been documented declines in seagrass cover. Further, there has been considerable coastal development along the north coast, particularly associated with shipping ports such as Devonport and Burnie.

Progression to level 2 analysis

As a result of the preliminary SICA analysis, the components to be examined at Level 2 (those with any consequence scores of 3 or greater) for all four sub-fisheries are:

- Target species
- By-product/by-catch species
- TEP species

The SICA removed the same two components of in each of the four sub-fisheries from further analysis as they were judged to be impacted with low consequence by the set of activities considered. The excluded components are:

- Habitats
- Communities

Several external hazards (aquaculture, other fisheries and coastal development) were identified as being of medium – high consequence for most components of most sub-fisheries. While it is important to identify these hazards, it is outside the scope of the present study to explore them at level 2.

Table 38: Summary of SICA results – Graball (reef) sub-fishery. Components with consequence scores of moderate or greater shaded with those of high confidence in bold.

Direct impact	Activity	Target species	By-product and by-catch species	TEP species	Habitats	Communities
Capture	Bait collection	0	0	0	0	0
	Fishing	**4**	**4**	**3**	2	2
	Incidental behaviour	0	0	0	0	0
Direct impact without capture	Bait collection	0	0	0	0	0
	Fishing	**3**	2	2	1	2
	Incidental behaviour	0	0	0	0	0
	Gear loss	2	2	2	2	1
	Anchoring/ mooring	1	1	1	1	1
	Navigation/ steaming	1	1	1	1	1
Addition/ movement of biological material	Translocation of species	2	2	2	2	2
	On-board processing	1	1	1	1	1
	Discarding catch	2	1	2	2	1
	Stock enhancement	0	0	0	0	0
	Provisioning	0	1	2	1	1
	Organic waste disposal	1	1	1	1	1
Addition of non-biological material	Debris	1	1	1	1	1
	Chemical pollution	1	1	1	1	1
	Exhaust	1	1	1	1	1
	Gear loss	2	2	2	1	1
	Navigation/ steaming	1	1	1	1	1
	Activity/ presence on water	1	1	1	1	1
Disturb physical processes	Bait collection	0	0	0	0	0
	Fishing	1	1	1	1	1
	Boat launching	1	1	1	1	1
	Anchoring/ mooring	1	1	1	1	1
	Navigation/steaming	1	1	1	1	1
Note: external hazards are not considered at Level 2 in the PSA analysis						
External hazards	Other fisheries	4	4	3	3	3

Direct impact	Activity	Target species	By-product and by-catch species	TEP species	Habitats	Communities
(specify the particular example within each activity area)						
	Aquaculture	3	3	3	3	**4**
	Coastal development	3	3	2	1	**3**
	Other extractive activities	0	0	0	0	0
	Other non-extractive activities	0	0	0	0	0
	Other anthropogenic activities	1	1	1	1	1

Table 39: Summary of SICA results – Graball (Banded Morwong) sub-fishery. Components with consequence scores of moderate or greater shaded with those of high confidence in bold.

Direct impact	Activity	Target species	By-product and by-catch species	TEP species	Habitats	Communities
Capture	Bait collection	0	0	0	0	0
	Fishing	**4**	**3**	**3**	2	2
	Incidental behaviour	0	0		0	0
Direct impact without capture	Bait collection	0	0	0	0	0
	Fishing	**3**	2	2	1	2
	Incidental behaviour	0	0	0	0	0
	Gear loss	2	2	2	2	1
	Anchoring/ mooring	1	1	1	1	1
	Navigation/ steaming	1	1	1	1	1
Addition/ movement of biological material	Translocation of species	2	2	2	2	2
	On-board processing	1	1	1	1	1
	Discarding catch	2	2	2	2	1
	Stock enhancement	0	0	0	0	0
	Provisioning	1	1	2	1	1
	Organic waste disposal	1	1	1	1	1
Addition of non-biological material	Debris	1	1	1	1	1
	Chemical pollution	1	1	1	1	1
	Exhaust	1	1	1	1	1
	Gear loss	2	2	2	1	1
	Navigation/ steaming	1	1	1	1	1
	Activity/ presence on	1	1	1	1	1

Direct impact	Activity	Target species	By-product and by-catch species	TEP species	Habitats	Communities
	water					
Disturb physical processes	Bait collection	0	0	0	0	0
	Fishing	1	1	1	1	1
	Boat launching	1	1	1	1	1
	Anchoring/ mooring	1	1	1	1	1
	Navigation/steaming	1	1	1	1	1
Note: external hazards are not considered at Level 2 in the PSA analysis						
External hazards (specify the particular example within each activity area)	Other fisheries	2	2	3	2	3
	Aquaculture	2	2	3	1	**4**
	Coastal development	2	3	2	1	**3**
	Other extractive activities	0	0	0	0	0
	Other non-extractive activities	0	0	0	0	0
	Other anthropogenic activities	1	1	1	1	1

Table 40: Summary of SICA results – Graball (non-reef) sub-fishery. Components with consequence scores of moderate or greater shaded with those of high confidence in bold.

Direct impact	Activity	Target species	By-product and by-catch species	TEP species	Habitats	Communities
Capture	Bait collection	0	0	0	0	0
	Fishing	**3**	**4**	**4**	1	2
	Incidental behaviour	0	0	0	0	0
Direct impact without capture	Bait collection	0	0	0	0	0
	Fishing	**3**	3	2	1	2
	Incidental behaviour	0	0	2	0	0
	Gear loss	2	2	2	2	1
	Anchoring/ mooring	1	1	1	1	1
	Navigation/ steaming	1	1	1	1	1
Addition/ movement of biological material	Translocation of species	2	2	2	2	2
	On-board processing	1	1	1	1	1
	Discarding catch	1	2	2	1	1
	Stock enhancement	0	0	0	0	0

Direct impact	Activity	Target species	By-product and by-catch species	TEP species	Habitats	Communities
	Provisioning	1	0	1	1	1
	Organic waste disposal	1	1	1	1	1
Addition of non-biological material	Debris	1	1	1	1	1
	Chemical pollution	1	1	1	1	1
	Exhaust	1	1	1	1	1
	Gear loss	2	2	2	1	1
	Navigation/ steaming	1	1	1	1	1
	Activity/ presence on water	1	1	1	1	1
Disturb physical processes	Bait collection	0	0	0	0	0
	Fishing	1	1	1	1	1
	Boat launching	1	1	1	1	1
	Anchoring/ mooring	1	1	1	1	1
	Navigation/steaming	1	1	1	1	1
Note: external hazards are not considered at Level 2 in the PSA analysis						
External hazards (specify the particular example within each activity area)	Other fisheries	**3**	**3**	**3**	2	3
	Aquaculture	3	3	3	3	**4**
	Coastal development	3	3	3	2	**3**
	Other extractive activities	0	0	0	0	0
	Other non-extractive activities	0	0	0	0	0
	Other anthropogenic activities	1	1	1	1	1

Table 41: Summary of SICA results – Small mesh sub-fishery. Components with consequence scores of moderate or greater shaded with those of high confidence in bold.

Direct impact	Activity	Target species	By-product and by-catch species	TEP species	Habitats	Communities
Capture	Bait collection	0	0	0	0	0
	Fishing	**3**	**3**	**3**	1	2
	Incidental behaviour	0	0	0	0	0
Direct impact without capture	Bait collection	0	0	0	0	0
	Fishing	**3**	3	2	1	2
	Incidental behaviour	0	0	0	0	0

Direct impact	Activity	Target species	By-product and by-catch species	TEP species	Habitats	Communities
	Gear loss	2	2	2	2	1
	Anchoring/ mooring	1	1	1	1	1
	Navigation/ steaming	1	1	1	1	1
Addition/ movement of biological material	Translocation of species	2	2	1	2	2
	On-board processing	1	1	1	1	1
	Discarding catch	2	2	2	1	1
	Stock enhancement	0	0	0	0	0
	Provisioning	1	1	2	1	1
	Organic waste disposal	1	1	1	1	1
Addition of non-biological material	Debris	1	1	1	1	1
	Chemical pollution	1	1	1	1	1
	Exhaust	1	1	1	1	1
	Gear loss	2	2	2	1	1
	Navigation/ steaming	1	1	1	1	1
	Activity/ presence on water	1	1	1	1	1
Disturb physical processes	Bait collection	0	0	0	0	0
	Fishing	1	1	1	1	1
	Boat launching	1	1	1	1	1
	Anchoring/ mooring	1	1	1	1	1
	Navigation/steaming	1	1	1	1	1
Note: external hazards are not considered at Level 2 in the PSA analysis						
External hazards (specify the particular example within each activity area)	Other fisheries	**3**	**3**	**3**	2	3
	Aquaculture	2	2	2	**3**	**4**
	Coastal development	3	3	3	**3**	**3**
	Other extractive activities	0	0	0	0	0
	Other non-extractive activities	0	0	0	0	0
	Other anthropogenic activities	1	1	1	1	1

Level 2: Productivity, susceptibility analysis

Graball (reef) sub-fishery

Bastard Trumpeter was the only species to be ranked as high vulnerability within this sub-fishery (Table 42). This was due to the fishery operating through much of their range, their high selectivity in the mesh sizes used and high rates of retention. It should be noted that although adult Bastard Trumpeter apparently inhabit deeper water, we chose to retain a high encounterability score as inshore reefs are the key nursery for this species and it is these (immature) individuals on which the fishery is focussed.

A total of 38 species had medium vulnerability rankings, which included most of the marine mammals, seabirds, chondrichthyans and a large number of teleosts (Table 42). This represents >30% of the species encountered in this sub-fishery and is considerably higher than for other fisheries. This is due to the broad spatial scale of the fishery, which encompasses much of the state, and is also due to the greater number of species selected by the mesh sizes commonly used. Of note is the presence of Longsnout Boarfish and Blue Warehou in the medium vulnerability category (target/by-product) and Draughtboard Shark and Herring Cale (common by-catch species).

Table 42: Graball (reef) sub-fishery PSA.

The reason species ranked as high vulnerability are; 1. >3 missing attributes, 2. Low overlap, 3.High susceptibility (<1.5), low productivity (>2.5), 4. Missing spatial, 5. High still (Hobday *et al.*, 2011).

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3-high)	Susceptibility (1- low, 3-high)	Vulnerability value (low-high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Marine mammals										
New Zealand Fur-seal	TEP	N	0	0	2.43	1.20	2.71	Y	Med	
Southern Right Whale	TEP	N	0	0	2.71	1.05	2.91	Y	Med	
Humpback Whale	TEP	N	0	0	2.71	1.05	2.91	Y	Med	
Bottlenose Dolphin	TEP	N	0	0	2.86	1.13	3.07	Y	Med	
Australian Fur-seal	TEP	N	0	0	2.29	1.20	2.58	Y	Low	
Common Dolphin	TEP	N	0	0	2.29	1.13	2.55	Y	Low	
Seabirds										
Little Penguin	TEP	N	1	0	2.14	1.58	2.66	Y	Med	
Blackfaced Cormorant	TEP	N	1	0	2.57	1.58	3.02	Y	Med	
Great Cormorant	TEP	N	1	0	2.57	1.65	3.06	Y	Med	
Little Pied Cormorant	TEP	N	1	0	2.57	1.65	3.06	Y	Med	
Short-tailed Shearwater	TEP	N	1	0	2.43	1.43	2.82	Y	Med	
Chondrichthyans										
Broadnose Sevengill Shark	DI	N	0	0	2.57	1.05	2.78	Y	Med	
Thresher Shark	BP	N	0	0	2.57	1.05	2.78	Y	Med	
Draughtboard Shark	DI	N	2	0	2.57	1.43	2.94	Y	Med	
Bronze Whaler	BP	N	0	0	2.86	1.05	3.04	Y	Med	
Southern Sawshark	BP	N	0	0	2.14	2.33	3.16	Y	Med	
Australian Angel Shark	BP	N	0	0	2.57	1.65	3.06	Y	Med	
School Shark	TA	N	0	0	2.57	1.58	3.02	Y	Med	
Gummy Shark	TA	N	0	0	2.29	1.88	2.96	Y	Med	
Whitespotted Dogfish	DI	N	0	0	2.57	1.43	2.94	Y	Med	
Common Sawshark	BP	N	0	0	2.43	1.43	2.82	Y	Med	

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3-high)	Susceptibility (1- low, 3-high)	Vulnerability value (low-high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Grey Nurse Shark	TEP	N	0	0	2.71	1.05	2.91	Y	Med	
Great White Shark	TEP	N	0	0	2.86	1.05	3.04	Y	Med	
Port Jackson Shark	DI	N	1	0	2.29	1.13	2.55	Y	Low	
Elephantfish	BP	N	0	0	1.71	1.88	2.54	Y	Low	
Rusty Catshark	DI	N	2	0	2.29	1.05	2.52	Y	Low	
Banded Stingaree	DI	N	0	0	1.71	1.43	2.23	Y	Low	
Southern Eagle Ray	DI	N	0	0	2.29	1.08	2.53	Y	Low	
Whitleys Skate	DI	Y	2	2	2.43	1.00	2.63	Y	Low	
Thornback Skate	DI	N	1	2	1.86	1.03	2.12	Y	Low	
Yellowstriped Leatherjacket	DI	Y	2	2	1.71	1.43	2.23	Y	Low	
Orange Spotted Catshark	DI	Y	2	2	1.71	1.43	2.23	Y	Low	
Maugean Skate	TEP	Y	2	2	2.29	1.20	2.58	Y	Low	
Teleosts										
Bastard Trumpeter	TA	N	0	0	1.71	3.00	3.46	Y	High	4
Bluespotted Flathead	BP	N	0	0	1.43	2.33	2.73	Y	Med	
Longfin Pike	BP	N	3	0	2.14	1.88	2.85	Y	Med	
Old Wife	DI	N	3	0	2.29	1.88	2.96	Y	Med	
Longsnout Boarfish	BP	N	3	0	2.00	2.33	3.07	Y	Med	
Blue Warehou	TA	N	0	0	1.29	2.33	2.66	Y	Med	
Smooth Stingray	DI	Y	3	2	2.86	1.08	3.05	Y	Med	
Red Velvet Fish	DI	Y	4	2	2.43	1.65	2.94	Y	Med	
Zebra Fish	DI	N	1	2	1.43	2.33	2.73	Y	Med	
Snook	BP	N	1	2	2.00	1.88	2.74	Y	Med	
Senator Wrasse	DI	N	3	0	1.86	2.33	2.98	Y	Med	
Herring Cale	DI	Y	3	2	2.14	1.65	2.70	Y	Med	
Ornate Cowfish	DI	Y	4	2	2.14	2.33	3.16	Y	Med	
Globefish	DI	Y	4	2	2.14	1.88	2.85	Y	Med	
Southern Conger Eel	DI	Y	2	2	2.29	1.88	2.96	Y	Med	
Ruddy Gurnard Perch	BP	N	3	0	2.14	1.43	2.57	Y	Low	
Southern Sand Flathead	BP	N	0	0	1.43	1.05	1.77	Y	Low	
Rock Flathead	BP	N	0	0	1.14	1.28	1.71	Y	Low	
Yellowtail Kingfish	BP	N	0	0	1.71	1.13	2.05	Y	Low	
Silver Trevally	BP	N	0	0	1.57	1.88	2.45	Y	Low	
Australian Salmon	TA	N	0	0	1.57	1.58	2.22	Y	Low	
Snapper	BP	N	0	0	1.71	1.13	2.05	Y	Low	
Black Bream	DI	N	0	0	1.29	1.08	1.68	Y	Low	
Bluelined Goatfish	BP	N	0	0	1.14	1.18	1.64	Y	Low	
Bluethroat Wrasse	BP	N	0	0	1.29	1.58	2.03	Y	Low	
Common Stargazer	DI	N	1	0	1.86	1.43	2.34	Y	Low	
Blue Mackerel	DI	N	0	0	1.29	1.05	1.66	Y	Low	
Silver Dory	BP	N	0	0	1.29	1.20	1.76	Y	Low	
Latchet	BP	N	0	0	1.29	1.13	1.71	Y	Low	
Sea Sweep	BP	N	0	0	1.14	2.33	2.59	Y	Low	
Magpie Perch	BP	N	0	0	1.29	1.28	1.81	Y	Low	
Dusky Morwong	BP	N	0	0	1.43	1.88	2.36	Y	Low	
Banded Morwong	DI	N	0	0	1.43	1.43	2.02	Y	Low	

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3-high)	Susceptibility (1- low, 3-high)	Vulnerability value (low-high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Atlantic Salmon	BP	N	0	0	1.71	1.20	2.09	Y	Low	
Bearded Rock Cod	BP	N	2	0	1.86	1.58	2.44	Y	Low	
Rock Ling	BP	N	1	0	2.00	1.58	2.55	Y	Low	
Pink Ling	BP	N	1	0	2.14	1.20	2.46	Y	Low	
Striped Trumpeter	TA	N	0	0	1.86	1.58	2.44	Y	Low	
Jackass Morwong	TA	N	0	0	1.43	1.28	1.91	Y	Low	
Spotted Warehou	BP	N	0	0	1.43	1.43	2.02	Y	Low	
Barracouta	BP	N	0	0	1.57	1.28	2.02	Y	Low	
Jack Mackerel	DI	N	0	0	1.29	1.13	1.71	Y	Low	
Brown Trout	BP	N	0	1	1.71	1.13	2.05	Y	Low	
Rainbow Trout	BP	N	0	2	1.71	1.43	2.23	Y	Low	
Thetis Fish	DI	N	0	0	1.29	1.18	1.74	Y	Low	
Spiny Gurnard	DI	N	0	0	1.29	1.43	1.92	Y	Low	
King George Whiting	BP	N	0	1	1.43	1.28	1.91	Y	Low	
Red Bait	DI	Y	2	2	1.57	1.05	1.89	Y	Low	
Silverbelly	DI	Y	2	2	1.57	1.43	2.12	Y	Low	
Common Bullseye	DI	N	2	1	1.57	1.65	2.28	Y	Low	
Black Drummer	BP	N	1	1	1.43	1.88	2.36	Y	Low	
Marblefish	DI	Y	3	2	2.00	1.65	2.59	Y	Low	
Yelloweye Mullet	BP	N	0	2	1.00	1.28	1.62	Y	Low	
Purple Wrasse	BP	N	1	0	1.71	1.43	2.23	Y	Low	
Rosy Wrasse	DI	N	2	0	1.57	1.88	2.45	Y	Low	
Southern Maori Wrasse	DI	N	1	2	1.71	1.58	2.33	Y	Low	
Rainbow Cale	DI	N	1	2	1.29	1.43	1.92	Y	Low	
Longsnouted Flounder	BP	N	1	2	1.57	1.43	2.12	Y	Low	
Greenback Flounder	BP	Y	2	2	1.71	1.43	2.23	Y	Low	
Toothbrush Leatherjacket	BP	N	1	2	1.43	1.58	2.13	Y	Low	
Horseshoe Leatherjacket	BP	Y	2	2	1.71	1.43	2.23	Y	Low	
Velvet Leatherjacket	DI	N	1	2	1.57	1.28	2.02	Y	Low	
Brownstriped Leatherjacket	DI	Y	2	2	1.71	1.58	2.33	Y	Low	
Six-spined Leatherjacket	BP	Y	2	2	1.71	1.58	2.33	Y	Low	
Shaw's Cowfish	DI	Y	4	2	2.14	1.18	2.44	Y	Low	
Ringed Toadfish	DI	Y	2	2	1.57	1.13	1.93	Y	Low	
Albacore	BP	N	0	0	1.71	1.05	2.01	Y	Low	
Garfish	BP	N	0	2	1.14	1.13	1.60	Y	Low	
Gunn's Leatherjacket	DI	Y	2	2	1.71	1.28	2.14	Y	Low	
Luderick	BP	N	0	2	1.14	1.43	1.83	Y	Low	
Mirror Dory	BP	N	0	0	1.43	1.20	1.87	Y	Low	
Ocean Perch	BP	N	0	0	1.86	1.43	2.34	Y	Low	
Real Bastard Trumpeter	DI	N	1	2	1.57	1.88	2.45	Y	Low	
School Whiting	BP	N	0	2	1.29	1.28	1.81	Y	Low	
Sea Mullet	BP	N	1	2	1.43	1.88	2.36	Y	Low	
Skipjack Tuna	BP	N	0	0	1.57	1.20	1.98	Y	Low	
Tailor	BP	N	0	0	1.43	1.43	2.02	Y	Low	
Common Seadragon	TEP	N	0	0	1.57	1.28	2.02	Y	Low	
Spotted Pipefish	TEP	N	0	0	1.43	1.13	1.82	Y	Low	

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3-high)	Susceptibility (1- low, 3-high)	Vulnerability value (low-high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Bigbellied seahorse	TEP	N	0	0	1.43	1.13	1.82	Y	Low	
Crustaceans										
Spider Crab	DI	Y	6	2	2.71	1.18	2.96	Y	Med	
Piecrust Crab	DI	Y	6	2	2.71	1.08	2.92	Y	Med	
Speedy Crab	DI	Y	6	3	2.71	1.65	3.18	Y	Med	
Southern Rock Lobster	DI	N	1	1	1.57	1.18	1.96	Y	Low	
Eleven-arm Seastar	DI	N	2	1	2.00	1.08	2.27	Y	Low	
Southern Calamari	BP	N	0	0	1.43	1.43	2.02	Y	Low	
Molluscs										
Gould's Squid	BP	N	1	1	1.71	1.03	2.00	Y	Low	
Maori Octopus	BP	N	0	1	1.57	1.13	1.93	Y	Low	
Blacklip Abalone	DI	N	0	1	1.14	1.20	1.66	Y	Low	

Graball (Banded Morwong) sub-fishery

No species achieved a ranking of high vulnerability within the Banded Morwong fishery (Table 43). This occurred for several reasons: first, there is minimal gillnet effort on the west coast and many of the species encountered by the fishery are distributed around the entire coastline of state; second, the fishery predominantly operates in depths of <25 m and many of species inhabit greater depths; third, many of the smaller species are not selected well by the larger mesh sizes used by the fishery; and finally, the current study has shown that PRS for many of the key by-catch species is high.

Species of medium vulnerability include most of the marine mammals and seabirds, several chondrichthyans (including Great White and Grey Nurse Sharks) and invertebrates, and the teleosts, Banded Morwong, Longsnout Boarfish, Red Velvet Fish and Globefish (Table 43). The ranking of the marine mammals, seabirds and chondrichthyans was due to their low productivity, whereas the invertebrates, Red Velvet Fish and Globefish were ranked as such due to missing attributes. Banded Morwong and Longsnout Boarfish are both caught throughout a large proportion of their range by this fishery, are highly selected by the gear and retained when of legal size.

Table 43: Graball (Banded Morwong) sub-fishery PSA.

The reason species ranked as high vulnerability are; 1. >3 missing attributes, 2. Low overlap, 3.High susceptibility (<1.5), low productivity (>2.5), 4. Missing spatial, 5. High still (Hobday *et al.*, 2011).

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3- high)	Susceptibility (1- low, 3- high)	Vulnerability value (low-high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Marine mammal										
New Zealand Fur-seal	TEP	N	0	0	2.43	1.20	2.71	Y	Med	
Southern Right Whale	TEP	N	0	0	2.71	1.05	2.91	Y	Med	
Humpback Whale	TEP	N	0	0	2.71	1.05	2.91	Y	Med	
Bottlenose Dolphin	TEP	N	0	0	2.86	1.13	3.07	Y	Med	
Australian Fur-seal	TEP	N	0	0	2.29	1.20	2.58	Y	Low	
Common Dolphin	TEP	N	0	0	2.29	1.13	2.55	Y	Low	
Seabirds										
Blackfaced Cormorant	TEP	N	1	0	2.57	1.28	2.87	Y	Med	
Great Cormorant	TEP	N	1	0	2.57	1.65	3.06	Y	Med	
Little Pied Cormorant	TEP	N	1	0	2.57	1.65	3.06	Y	Med	
Short-tailed Shearwater	TEP	N	1	0	2.43	1.43	2.82	Y	Med	
Little Penguin	TEP	N	1	0	2.14	1.28	2.49	Y	Low	
Chondrichthyans										
Broadnose Sevengill Shark	DI	N	0	0	2.57	1.05	2.78	Y	Med	
Thresher Shark	BP	N	0	0	2.57	1.05	2.78	Y	Med	
Draughtboard Shark	DI	N	2	0	2.57	1.28	2.87	Y	Med	
Australian Angel Shark	BP	N	0	0	2.57	1.43	2.94	Y	Med	
School Shark	BP	N	0	0	2.57	1.58	3.02	Y	Med	
Gummy Shark	BP	N	0	0	2.29	1.43	2.69	Y	Med	
Common Sawshark	BP	N	0	0	2.43	1.43	2.82	Y	Med	
Grey Nurse Shark	TEP	N	0	0	2.71	1.05	2.91	Y	Med	
Great White Shark	TEP	N	0	0	2.86	1.13	3.07	Y	Med	
Port Jackson Shark	DI	N	1	0	2.29	1.13	2.55	Y	Low	
Elephantfish	BP	N	0	0	1.71	1.43	2.23	Y	Low	
Southern Sawshark	BP	N	0	0	2.14	1.43	2.57	Y	Low	
Banded Stingaree	DI	N	0	0	1.71	1.43	2.23	Y	Low	
Southern Eagle Ray	DI	N	0	0	2.29	1.08	2.53	Y	Low	
Whitleys Skate	DI	Y	2	2	2.43	1.00	2.63	Y	Low	
Maugean Skate	TEP	Y	2	2	2.29	1.20	2.58	Y	Low	
Teleosts										
Longsnout Boarfish	BP	N	3	0	2.00	2.33	3.07	Y	Med	
Banded Morwong	TA	N	0	0	1.43	2.33	2.73	Y	Med	
Smooth Stingray	DI	Y	3	2	2.86	1.08	3.05	Y	Med	
Red Velvet Fish	BP	Y	4	2	2.43	1.43	2.82	Y	Med	
Globefish	DI	Y	4	2	2.14	1.88	2.85	Y	Med	
Ruddy Gurnard Perch	BP	N	3	0	2.14	1.43	2.57	Y	Low	
Southern Red Scorpion Fish	BP	N	1	0	1.43	1.43	2.02	Y	Low	
Southern Sand Flathead	BP	N	0	0	1.43	1.05	1.77	Y	Low	
Longfinned Pike	BP	N	3	0	2.14	1.43	2.57	Y	Low	
Yellowtail Kingfish	BP	N	0	0	1.71	1.13	2.05	Y	Low	
Silver Trevally	BP	N	0	0	1.57	1.43	2.12	Y	Low	
Australian Salmon	BP	N	0	0	1.57	1.28	2.02	Y	Low	
Old Wife	DI	N	3	0	2.29	1.20	2.58	Y	Low	

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3- high)	Susceptibility (1- low, 3- high)	Vulnerability value (low- high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Grey Morwong	BP	N	0	0	1.29	1.20	1.76	Y	Low	
Bastard Trumpeter	BP	N	0	0	1.71	1.88	2.54	Y	Low	
Bluethroat Wrasse	BP	N	0	0	1.29	1.38	1.88	Y	Low	
Common Stargazer	DI	N	1	0	1.86	1.20	2.21	Y	Low	
Blue Mackerel	DI	N	0	0	1.29	1.05	1.66	Y	Low	
Silver Dory	BP	N	0	0	1.29	1.20	1.76	Y	Low	
Sea Sweep	BP	N	0	0	1.14	1.58	1.95	Y	Low	
Magpie Perch	DI	N	0	0	1.29	1.18	1.74	Y	Low	
Dusky Morwong	BP	N	0	0	1.43	1.88	2.36	Y	Low	
Bearded Rock Cod	DI	N	2	0	1.86	1.58	2.44	Y	Low	
Rock Ling	BP	N	1	0	2.00	1.58	2.55	Y	Low	
Striped Trumpeter	BP	N	0	0	1.86	1.58	2.44	Y	Low	
Jackass Morwong	BP	N	0	0	1.43	1.18	1.85	Y	Low	
Blue Warehou	BP	N	0	0	1.29	1.58	2.03	Y	Low	
Jack Mackerel	DI	N	0	0	1.29	1.13	1.71	Y	Low	
Thetis Fish	DI	N	0	0	1.29	1.08	1.68	Y	Low	
Barber Perch	DI	Y	2	2	1.57	1.05	1.89	Y	Low	
Common Bullseye	DI	N	2	1	1.57	1.43	2.12	Y	Low	
Marblefish	DI	Y	3	2	2.00	1.20	2.33	Y	Low	
Yelloweye Mullet	DI	N	0	2	1.00	1.05	1.45	Y	Low	
Snook	BP	N	1	2	2.00	1.13	2.29	Y	Low	
Senator Wrasse	DI	N	3	0	1.86	1.20	2.21	Y	Low	
Purple Wrasse	BP	N	1	0	1.71	1.13	2.05	Y	Low	
Rosy Wrasse	DI	N	2	0	1.57	1.28	2.02	Y	Low	
Herring Cale	DI	Y	3	2	2.14	1.43	2.57	Y	Low	
Rainbow Cale	DI	N	1	2	1.29	1.13	1.71	Y	Low	
Greenback Flounder	BP	Y	2	2	1.71	1.20	2.09	Y	Low	
Toothbrush Leatherjacket	DI	N	1	2	1.43	1.18	1.85	Y	Low	
Mosaic Leatherjacket	DI	Y	2	2	1.71	1.13	2.05	Y	Low	
Velvet Leatherjacket	DI	N	1	2	1.57	1.18	1.96	Y	Low	
Brownstriped Leatherjacket	DI	Y	2	2	1.71	1.18	2.08	Y	Low	
Six-spined Leatherjacket	DI	Y	2	2	1.71	1.08	2.02	Y	Low	
Shaw's Cowfish	DI	Y	4	2	2.14	1.08	2.40	Y	Low	
Albacore	BP	N	0	0	1.71	1.05	2.01	Y	Low	
Australian Bonito	BP	N	0	0	1.57	1.05	1.89	Y	Low	
Degen's Leatherjacket	DI	Y	2	2	1.71	1.08	2.02	Y	Low	
Gunn's Leatherjacket	DI	Y	2	2	1.71	1.18	2.08	Y	Low	
John Dory	BP	N	0	0	1.43	1.28	1.91	Y	Low	
Johnston's Weedfish	DI	Y	4	2	2.14	1.13	2.42	Y	Low	
Luderick	BP	N	0	2	1.14	1.43	1.83	Y	Low	
Mirror Dory	BP	N	0	0	1.43	1.20	1.87	Y	Low	
Real Bastard Trumpeter	DI	N	1	2	1.57	1.88	2.45	Y	Low	
Rough Leatherjacket	DI	Y	2	2	1.71	1.08	2.02	Y	Low	
White-ear	DI	N	1	2	1.29	1.03	1.64	Y	Low	
Common Seadragon	TEP	N	0	0	1.57	1.13	1.93	Y	Low	
Spotted Pipefish	TEP	N	0	0	1.43	1.05	1.77	Y	Low	
Bigbellied seahorse	TEP	N	0	0	1.43	1.05	1.77	Y	Low	

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3- high)	Susceptibility (1- low, 3- high)	Vulnerability value (low- high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Crustaceans										
Piecrust Crab	DI	Y	6	2	2.71	1.03	2.90	Y	Med	
Speedy Crab	DI	Y	6	3	2.71	1.43	3.07	Y	Med	
Southern Rock Lobster	DI	N	1	1	1.57	1.18	1.96	Y	Low	
Eastern Rocklobster	DI	N	1	1	1.57	1.18	1.96	Y	Low	
Echinoderms										
Longspine Sea Urchin	DI	Y	6	3	2.71	1.13	2.94	Y	Med	
Molluscs										
Gould's Squid	BP	N	1	1	1.71	1.03	2.00	Y	Low	
Southern Calamari	BP	N	0	0	1.43	1.13	1.82	Y	Low	
Blacklip Abalone	DI	N	0	1	1.14	1.13	1.60	Y	Low	

Graball (non-reef) sub-fishery

Species to obtain a high vulnerability rating in the graball (non-reef) sub-fishery included Atlantic Salmon, Rainbow Trout, Maugean Skate and Whitespotted Dogfish (

Table 44). The salmonids were ranked as such because they are believed to be largely restricted to SRAs, related to the location of aquaculture farms, are well selected for by graball nets and are retained when caught. Maugean Skate predominantly obtained this ranking due to missing biological attributes in addition to restricted distribution. Whitespotted Dogfish are more widespread but have particularly conservative life history characteristics.

Species of medium vulnerability include seabirds (Cormorant species and Short-tailed Shearwaters), marine mammals (fur seals, whales and dolphins), several chondrichthyan species (Tasmanian Numbfish, Southern Eagle Ray and Broadnose Sevengill, Great White, Gummy, Draughtboard and School Sharks) and several teleosts (Longfin Pike, Blue Warehou, Greenback Flounder, Longsnouted Flounder and Globefish) (

Table 44). In the case of the seabirds, this ranking was due to the relatively high encounter rate and the high mortality of individuals when entangled. Marine mammals have very conservative life histories and were assigned medium vulnerability despite low distributional overlap with the fishery and the low probability of entanglement. Similarly, the chondrichthyans were generally ranked as medium risk due to their conservative life histories; however, Draughtboard Shark were assigned a medium ranking due to precautionary defaults that arose from missing biological attributes. This was also the reason the majority of teleosts were ranked medium, though the number was few (n=5).

Table 44: Graball (non-reef) sub-fishery PSA.
The reason species ranked as high vulnerability are; 1. >3 missing attributes, 2. Low overlap, 3.High susceptibility (<1.5), low productivity (>2.5), 4. Missing spatial, 5. High still (Hobday *et al.*, 2011).

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3- high)	Susceptibility (1- low, 3- high)	Vulnerability value (low- high range = 1.41-4.24)	Susceptibility override used?	PSA ranking	Reason for high ranking
Marine mammals										
New Zealand Fur-seal	TEP	N	0	0	2.43	1.20	2.71	Y	Med	
Southern Right Whale	TEP	N	0	0	2.71	1.05	2.91	Y	Med	
Humpback Whale	TEP	N	0	0	2.71	1.05	2.91	Y	Med	
Bottlenose Dolphin	TEP	N	0	0	2.86	1.13	3.07	Y	Med	
Australian Fur-seal	TEP	N	0	0	2.29	1.20	2.58	Y	Low	
Common Dolphin	TEP	N	0	0	2.29	1.13	2.55	Y	Low	
Seabirds										
Little Penguin	TEP	N	1	0	2.14	1.58	2.66	Y	Med	
Blackfaced Cormorant	TEP	N	1	0	2.57	1.58	3.02	Y	Med	
Great Cormorant	TEP	N	1	0	2.57	1.65	3.06	Y	Med	
Little Pied Cormorant	TEP	N	1	0	2.57	1.65	3.06	Y	Med	
Short-tailed Shearwater	TEP	N	1	0	2.43	1.43	2.82	Y	Med	
Chondrichthyans										
Whitespotted Dogfish	DI	N	0	0	2.57	1.88	3.18	Y	High	4
Maugean Skate	TEP	Y	2	2	2.29	2.33	3.26	Y	High	1
Broadnose Sevengill Shark	DI	N	0	0	2.57	1.05	2.78	Y	Med	
Draughtboard Shark	DI	N	2	0	2.57	1.08	2.79	Y	Med	
Southern Eagle Ray	DI	N	0	0	2.29	1.43	2.69	Y	Med	
School Shark	DI	N	0	0	2.57	1.58	3.02	Y	Med	
Gummy Shark	DI	N	0	0	2.29	1.88	2.96	Y	Med	
Tasmanian Numbfish	DI	Y	3	2	2.43	1.18	2.70	Y	Med	
Common Sawshark	DI	N	0	0	2.43	1.43	2.82	Y	Med	
Grey Nurse Shark	TEP	N	0	0	2.71	1.05	2.91	Y	Med	
Great White Shark	TEP	N	0	0	2.86	1.05	3.04	Y	Med	
Port Jackson Shark	DI	N	1	0	2.29	1.13	2.55	Y	Low	
Elephantfish	TA	N	0	0	1.71	1.88	2.54	Y	Low	
Southern Sawshark	BP	N	0	0	2.14	1.43	2.57	Y	Low	
Banded Stingaree	DI	N	0	0	1.71	1.43	2.23	Y	Low	
Whitespotted Skate	DI	Y	2	2	1.86	1.00	2.11	Y	Low	
Whitleys Skate	DI	Y	2	2	2.43	1.03	2.64	Y	Low	
Thornback Skate	DI	N	1	2	1.86	1.03	2.12	Y	Low	
Teleosts										
Atlantic Salmon	TA	N	0	0	1.71	3.00	3.46	Y	High	4
Rainbow Trout	TA	N	0	2	1.71	3.00	3.46	Y	High	4
Longfin Pike	BP	N	3	0	2.14	1.88	2.85	Y	Med	
Blue Warehou	TA	N	0	0	1.29	2.33	2.66	Y	Med	
Longsnouted Flounder	TA	N	1	2	1.57	2.33	2.81	Y	Med	

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3- high)	Susceptibility (1- low, 3- high)	Vulnerability value (low-high range = 1.41-4.24)	Susceptibility override used?	PSA ranking	Reason for high ranking
Greenback Flounder	TA	Y	2	2	1.71	2.33	2.89	Y	Med	
Globefish	DI	Y	4	2	2.14	1.88	2.85	Y	Med	
Ruddy Gurnard Perch	BP	N	3	0	2.14	1.43	2.57	Y	Low	
Southern Sand Flathead	BP	N	0	0	1.43	1.05	1.77	Y	Low	
Yellowtail Kingfish	BP	N	0	0	1.71	1.13	2.05	Y	Low	
Silver Trevally	BP	N	0	0	1.57	1.88	2.45	Y	Low	
Australian Salmon	BP	N	0	0	1.57	1.88	2.45	Y	Low	
Snapper	BP	N	0	0	1.71	1.13	2.05	Y	Low	
Black Bream	DI	N	0	0	1.29	1.18	1.74	Y	Low	
Bluelined Goatfish	BP	N	0	0	1.14	1.28	1.71	Y	Low	
Old Wife	DI	N	3	0	2.29	1.13	2.55	Y	Low	
Longsnout Boarfish	BP	N	3	0	2.00	1.20	2.33	Y	Low	
Bastard Trumpeter	BP	N	0	0	1.71	1.28	2.14	Y	Low	
Bluethroat Wrasse	BP	N	0	0	1.29	1.38	1.88	Y	Low	
Common Stargazer	DI	N	1	0	1.86	1.88	2.64	Y	Low	
Blue Mackerel	DI	N	0	0	1.29	1.05	1.66	Y	Low	
Latchet	BP	N	0	0	1.29	1.13	1.71	Y	Low	
Sea Sweep	BP	N	0	0	1.14	1.43	1.83	Y	Low	
Magpie Perch	BP	N	0	0	1.29	1.13	1.71	Y	Low	
Dusky Morwong	BP	N	0	0	1.43	1.88	2.36	Y	Low	
Banded Morwong	DI	N	0	0	1.43	1.13	1.82	Y	Low	
Bearded Rock Cod	DI	N	2	0	1.86	1.58	2.44	Y	Low	
Rock Ling	BP	N	1	0	2.00	1.58	2.55	Y	Low	
Pink Ling	BP	N	1	0	2.14	1.20	2.46	Y	Low	
Striped Trumpeter	BP	N	0	0	1.86	1.13	2.17	Y	Low	
Blue Grenadier	DI	N	0	0	1.71	1.28	2.14	Y	Low	
Jackass Morwong	BP	N	0	0	1.43	1.05	1.77	Y	Low	
Barracouta	BP	N	0	0	1.57	1.28	2.02	Y	Low	
Jack Mackerel	DI	N	0	0	1.29	1.13	1.71	Y	Low	
Brown Trout	BP	N	0	1	1.71	1.58	2.33	Y	Low	
Southern Shortfin Eel	BP	N	0	2	2.00	1.05	2.26	Y	Low	
Spiny Gurnard	DI	N	0	0	1.29	1.43	1.92	Y	Low	
King George Whiting	BP	N	0	1	1.43	1.28	1.91	Y	Low	
Marblefish	DI	Y	3	2	2.00	1.13	2.29	Y	Low	
Yelloweye Mullet	DI	N	0	2	1.00	1.43	1.74	Y	Low	
Purple Wrasse	BP	N	1	0	1.71	1.03	2.00	Y	Low	
Herring Cale	DI	Y	3	2	2.14	1.05	2.39	Y	Low	
Toothbrush Leatherjacket	BP	N	1	2	1.43	1.18	1.85	Y	Low	
Brownstriped Leatherjacket	DI	Y	2	2	1.71	1.18	2.08	Y	Low	
Six-spined Leatherjacket	BP	Y	2	2	1.71	1.18	2.08	Y	Low	

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3- high)	Susceptibility (1- low, 3- high)	Vulnerability value (low-high range = 1.41-4.24)	Susceptibility override used?	PSA ranking	Reason for high ranking
Shaw's Cowfish	DI	Y	4	2	2.14	1.18	2.44	Y	Low	
Prickly Toadfish	DI	Y	3	2	1.86	1.43	2.34	Y	Low	
Garfish	BP	N	0	2	1.14	1.13	1.60	Y	Low	
Luderick	BP	N	0	2	1.14	1.43	1.83	Y	Low	
Mirror Dory	BP	N	0	0	1.43	1.20	1.87	Y	Low	
School Whiting	BP	N	0	2	1.29	1.13	1.71	Y	Low	
Skipjack Tuna	BP	N	0	0	1.57	1.20	1.98	Y	Low	
Tailor	BP	N	0	0	1.43	1.43	2.02	Y	Low	
Common Seadragon	TEP	N	0	0	1.57	1.28	2.02	Y	Low	
Spotted Pipefish	TEP	N	0	0	1.43	1.13	1.82	Y	Low	
Bigbellied seahorse	TEP	N	0	0	1.43	1.13	1.82	Y	Low	
Crustaceans										
Spider Crab	DI	Y	6	2	2.71	1.38	3.04	Y	Med	
Piecrust Crab	DI	Y	6	2	2.71	1.00	2.89	Y	Med	
Southern Rock Lobster	DI	N	1	1	1.57	1.03	1.88	Y	Low	
Molluscs										
Gould's Squid	BP	N	1	1	1.71	1.03	2.00	Y	Low	
Maori Octopus	BP	N	0	1	1.57	1.03	1.88	Y	Low	
Southern Calamari	BP	N	0	0	1.43	1.43	2.02	Y	Low	
Echinoderms										
Eleven-arm Seastar	DI	N	2	1	2.00	1.08	2.27	Y	Low	

Small mesh sub-fishery

Within the small mesh sub-fishery (north coast commercial mesh and recreational mullet net), three species were ranked as having high vulnerability to the effects of fishing (Table 45): Rock Flathead and Snook due to both species only being abundant on the north coast, both species inhabiting inshore areas where the fishery is concentrated, both species being highly selected by the mesh size used and both species being retained the majority of the time. Great Cormorants were ranked as high due to their low biological productivity and low PRS when they encounter the gear.

Species assigned a rank of medium include the remaining seabirds, most of the marine mammals, several teleosts that are either limited to, or most abundant on, the north coast (King George Whiting, Bluespotted Flathead, Blue Rock Whiting and Blue-lined Goatfish) and several chondrichthyans (School Shark, Draughtboard Shark, Grey Nurse Shark and Australian Angel Shark) (Table 45). The marine mammals, seabirds and chondrichthyans are ranked as medium due to their relatively low productivity and tendency toward low PRS. The teleosts ranking was a result of the high overlap between the sub-fishery and the core distribution of each species. Grey Nurse Sharks were included due to vague and unsubstantiated reports of them inhabiting the north coast and being caught by ‘fishers’, although there is no firm evidence that this species inhabits Tasmanian waters. Spider Crabs were also ranked as medium in terms of vulnerability but this is due to the species lacking six biological attributes: it is not envisioned that this sub-fishery is of any real threat to this species.

Table 45: Small mesh net sub-fishery PSA.

The reason species ranked as high vulnerability are; 1. >3 missing attributes, 2. Low overlap, 3.High susceptibility (<1.5), low productivity (>2.5), 4. Missing spatial, 5. High still (Hobday *et al.*, 2011).

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3- high)	Susceptibility (1- low, 3- high)	Vulnerability value (low-high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Marine mammals										
New Zealand Fur-seal	TEP	N	0	0	2.43	1.05	2.65	Y	Med	
Southern Right Whale	TEP	N	0	0	2.71	1.13	2.94	Y	Med	
Humpback Whale	TEP	N	0	0	2.71	1.13	2.94	Y	Med	
Australian Fur-seal	TEP	N	0	0	2.29	1.13	2.55	Y	Low	
Bottlenose Dolphin	TEP	N	0	0	2.86	1.20	0.00	Y	Low	
Common Dolphin	TEP	N	0	0	2.29	1.20	0.00	Y	Low	
Seabirds										
Great Cormorant	TEP	N	1	0	2.57	2.33	3.47	Y	High	4
Little Penguin	TEP	N	1	0	2.14	1.65	2.70	Y	Med	
Blackfaced Cormorant	TEP	N	1	0	2.57	1.65	3.06	Y	Med	
Little Pied Cormorant	TEP	N	1	0	2.57	1.43	2.94	Y	Med	
Short-tailed Shearwater	TEP	N	1	0	2.43	1.43	0.00	Y	Low	
Chondrichthyans										
Draughtboard Shark	DI	N	2	0	2.57	1.00	2.76	Y	Med	
Australian Angel Shark	BP	N	0	0	2.57	1.28	2.87	Y	Med	
School Shark	BP	N	0	0	2.57	1.13	2.81	Y	Med	
Grey Nurse Shark	TEP	N	0	0	2.71	1.20	2.97	Y	Med	
Elephantfish	BP	N	0	0	1.71	1.03	2.00	Y	Low	
Rusty Catshark	DI	N	2	0	2.29	1.03	2.51	Y	Low	
Southern Sawshark	BP	N	0	0	2.14	1.20	2.46	Y	Low	
Southern Eagle Ray	DI	N	0	0	2.29	1.28	2.62	Y	Low	
Gummy Shark	BP	N	0	0	2.29	1.13	2.55	Y	Low	
Whitleys Skate	DI	Y	2	2	2.43	1.00	2.63	Y	Low	
Yellowstriped Leatherjacket	DI	Y	2	2	1.71	1.28	2.14	Y	Low	
Maugean Skate	TEP	Y	2	2	2.29	1.00	2.49	Y	Low	
Great White Shark	TEP	N	0	0	2.86	1.13	0.00	Y	Low	
Teleosts										
Rock Flathead	BP	N	0	0	1.14	3.00	3.21	Y	High	4
Snook	TA	N	1	2	2.00	3.00	3.61	Y	High	4
Bluespotted Flathead	BP	N	0	0	1.43	2.33	2.73	Y	Med	
Old Wife	DI	N	3	0	2.29	1.88	2.96	Y	Med	
King George Whiting	TA	N	0	1	1.43	2.33	2.73	Y	Med	
Blue Rock Whiting	BP	N	1	2	1.43	2.33	2.73	Y	Med	
Common Seadragon	TEP	N	0	0	1.57	2.33	2.81	Y	Med	
Bigbellied seahorse	TEP	N	0	0	1.43	2.33	2.73	Y	Med	
Ruddy Gurnard Perch	BP	N	3	0	2.14	1.13	2.42	Y	Low	
Southern Sand Flathead	BP	N	0	0	1.43	1.58	2.13	Y	Low	
Longfin Pike	TA	N	3	0	2.14	1.20	2.46	Y	Low	
Yellowtail Kingfish	BP	N	0	0	1.71	1.43	2.23	Y	Low	
Silver Trevally	BP	N	0	0	1.57	1.28	2.02	Y	Low	
Australian Salmon	BP	N	0	0	1.57	1.88	2.45	Y	Low	
Snapper	BP	N	0	0	1.71	1.13	2.05	Y	Low	
Bluelined Goatfish	BP	N	0	0	1.14	2.33	2.59	Y	Low	

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3- high)	Susceptibility (1- low, 3- high)	Vulnerability value (low- high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Longsnout Boarfish	BP	N	3	0	2.00	0.98	2.23	Y	Low	
Grey Morwong	BP	N	0	0	1.29	1.13	1.71	Y	Low	
Bastard Trumpeter	BP	N	0	0	1.71	1.00	1.98	Y	Low	
Bluethroat Wrasse	BP	N	0	0	1.29	1.18	1.74	Y	Low	
Blue Mackerel	BP	N	0	0	1.29	1.13	1.71	Y	Low	
Silver Dory	BP	N	0	0	1.29	1.05	1.66	Y	Low	
Latchet	BP	N	0	0	1.29	1.20	1.76	Y	Low	
Sea Sweep	BP	N	0	0	1.14	1.88	2.20	Y	Low	
Magpie Perch	BP	N	0	0	1.29	1.03	1.64	Y	Low	
Dusky Morwong	BP	N	0	0	1.43	1.88	2.36	Y	Low	
Banded Morwong	DI	N	0	0	1.43	1.05	1.77	Y	Low	
Atlantic Salmon	BP	N	0	0	1.71	1.05	2.01	Y	Low	
Sergeant Baker	DI	N	3	0	2.14	1.43	2.57	Y	Low	
Bearded Rock Cod	DI	N	2	0	1.86	1.43	2.34	Y	Low	
Rock Ling	BP	N	1	0	2.00	1.28	2.37	Y	Low	
Pink Ling	BP	N	1	0	2.14	1.13	2.42	Y	Low	
Striped Trumpeter	BP	N	0	0	1.86	1.05	2.13	Y	Low	
Jackass Morwong	BP	N	0	0	1.43	1.13	1.82	Y	Low	
Blue Warehou	TA	N	0	0	1.29	1.28	1.81	Y	Low	
Spotted Warehou	BP	N	0	0	1.43	1.28	1.91	Y	Low	
Barracouta	BP	N	0	0	1.57	1.43	2.12	Y	Low	
Jack Mackerel	BP	N	0	0	1.29	1.05	1.66	Y	Low	
Rainbow Trout	BP	N	0	2	1.71	1.13	2.05	Y	Low	
Barber Perch	DI	Y	2	2	1.57	1.13	1.93	Y	Low	
Silverbelly	DI	Y	2	2	1.57	1.28	2.02	Y	Low	
Common Bullseye	DI	N	2	1	1.57	1.13	1.93	Y	Low	
Zebra Fish	DI	N	1	2	1.43	1.13	1.82	Y	Low	
Victorian Scalyfin	DI	N	1	2	1.43	1.43	2.02	Y	Low	
Marblefish	DI	Y	3	2	2.00	1.03	2.25	Y	Low	
Yelloweye Mullet	TA	N	0	2	1.00	1.43	1.74	Y	Low	
Senator Wrasse	DI	N	3	0	1.86	1.20	2.21	Y	Low	
Purple Wrasse	BP	N	1	0	1.71	1.08	2.02	Y	Low	
Rosy Wrasse	DI	N	2	0	1.57	1.20	1.98	Y	Low	
Herring Cale	DI	Y	3	2	2.14	1.13	2.42	Y	Low	
Butterfly Mackerel	DI	Y	2	2	2.00	1.05	2.26	Y	Low	
Greenback Flounder	BP	Y	2	2	1.71	1.05	2.01	Y	Low	
Toothbrush Leatherjacket	BP	N	1	2	1.43	1.05	1.77	Y	Low	
Mosaic Leatherjacket	BP	Y	2	2	1.71	1.18	2.08	Y	Low	
Horseshoe Leatherjacket	BP	Y	2	2	1.71	1.28	2.14	Y	Low	
Velvet Leatherjacket	DI	N	1	2	1.57	1.03	1.88	Y	Low	
Brownstriped Leatherjacket	DI	Y	2	2	1.71	1.08	2.02	Y	Low	
Six-spined Leatherjacket	BP	Y	2	2	1.71	1.13	2.05	Y	Low	
Stars and Stripes Leatherjacket	DI	Y	2	2	1.57	1.28	2.02	Y	Low	
Shaw's Cowfish	DI	Y	4	2	2.14	1.43	2.57	Y	Low	
Prickly Toadfish	DI	Y	3	2	1.86	1.28	2.25	Y	Low	
Globefish	DI	Y	4	2	2.14	1.43	2.57	Y	Low	
Crested Weedfish	DI	Y	3	2	2.14	1.20	2.46	Y	Low	

Species	Role in fishery	Missing > 3 attributes (Y/N)	Missing productivity attributes (out of 7)	Missing susceptibility attributes (out of 4)	Productivity (1- low, 3-high)	Susceptibility (1- low, 3-high)	Vulnerability value (low-high range = 1.41-4.24)	Susceptibility override used?	PSA rank	Reason for high ranking
Garfish	BP	N	0	2	1.14	1.13	1.60	Y	Low	
Luderick	BP	N	0	2	1.14	1.43	1.83	Y	Low	
Ocean Perch	BP	N	0	0	1.86	1.43	2.34	Y	Low	
Real Bastard Trumpeter	DI	N	1	2	1.57	1.43	2.12	Y	Low	
School Whiting	BP	N	0	2	1.29	1.05	1.66	Y	Low	
Sea Mullet	BP	N	1	2	1.43	1.43	2.02	Y	Low	
Southern Conger Eel	DI	Y	2	2	2.29	1.05	2.52	Y	Low	
Tailor	BP	N	0	0	1.43	1.43	2.02	Y	Low	
Spotted Pipefish	TEP	N	0	0	1.43	1.20	1.87	Y	Low	
Crustaceans										
Spider Crab	DI	Y	6	2	2.71	1.18	2.96	Y	Med	
Southern Rock Lobster	DI	N	1	1	1.57	1.13	1.93	Y	Low	
Echinodermata										
Eleven-arm Seastar	DI	N	2	1	2.00	1.00	2.24	Y	Low	
Molluscs										
Gould's Squid	BP	N	1	1	1.71	1.03	2.00	Y	Low	
Maori Octopus	BP	N	0	1	1.57	1.03	1.88	Y	Low	
Southern Calamari	BP	N	0	0	1.43	1.13	1.82	Y	Low	

Discussion

Catch and by-catch in Tasmanian gillnet fisheries

Catch composition

Commercial fishery

During the past two decades the levels of both commercial (André *et al.*, 2014) and recreational (Lyle and Tracey, 2012) gillnet catch and effort have declined markedly, driven by a combination of management measures and initiatives, and declining abundances of several key target species, in particular Blue Warehou (Anon, 2012; Woodhams *et al.*, 2012), Banded Morwong (André *et al.*, 2014) and Bastard Trumpeter (André *et al.*, 2014). Key management measures influencing commercial gillnet effort have included the implementation of gear restrictions (maximum net lengths), non-transferability of certain licence categories, progressive expansion of no netting areas, increases in legal minimum lengths, introduction of trip and catch limits for some gillnet species, maximum soak durations and attended night netting requirements. Management measures influencing recreational effort include reductions in the quantity of gear that individuals can licence, introduction of a ban on overnight netting and, most recently, introduction of maximum soak duration. In addition, increases in legal minimum lengths, reductions in bag limits and expansion of non-netting areas have been contributing factors to the decline in activity.

Commercial graball net fisheries in Tasmania target a range of habitats, including reef and non-reef areas, landing a wide diversity of fish species, with over 90 taxa reported in catch returns for this sector. The small mesh net fishery, which is restricted to coastal waters off north coast of Tasmania, also catches a wide variety of fish species (over 60 taxa landed). The recreational gillnet fishery, with the notable exception of Banded Morwong, targets much the same species as the commercial fisheries and there is considerable overlap in the areas fished between sectors. For each of the sectors (and their sub-fisheries) not only do comparatively few species account for the majority of the landings but there is also a component of the catch that is discarded, either because of regulation (size or catch limits, closed seasons, prohibited or protected species) or because of market and/or fisher preferences.

Over the past five years commercial graball net production has averaged around 110 tonnes p.a. whereas small mesh catches are much lower, averaging around 10 tonnes p.a. Within the commercial graball net fishery, the graball (Banded Morwong) sub-fishery dominated catches between 2011 and early 2013, accounting for 57% of state-wide production. This sub-fishery is highly selective, a function of mesh selectivity and fishing practices, with the target species dominating landings (>85%); only Bastard Trumpeter and Longsnout Boarfish are of any significance amongst the other species harvested. The sector of the commercial gillnet fishery not licensed to catch Banded Morwong is less species specific, with target species determined by the region and habitats fished. Overall Australian Salmon, Bastard Trumpeter and Blue Warehou are the main target species (collectively accounting for 52% of landings); other species landed in moderate quantities and representing by-product include Gummy Shark, Bluethroat Wrasse, Elephantfish and Striped Trumpeter. In addition, Atlantic Salmon and Rainbow Trout, escapees from marine farming operations in Macquarie Harbour, are targeted by commercial gillnetters engaged by the aquaculture industry to remove them from the environment. Catches in the small mesh fishery, although low, are dominated by Australian Salmon, ‘Pike’ (Longfin Pike and Snook), Rock Flathead, Blue Warehou and Yelloweye Mullet, which collectively account for over 81% of landings by mass. A relatively large number of other taxa are also taken by this fishery but in very low quantities.

Recreational fishery

The recreational catch composition is spatially variable although the bulk of effort appears to take place on rocky reef habitats targeting Bastard Trumpeter and Blue Warehou in the Southeast and East coasts. Exceptions being on the West coast and Southeast SRA where escapee salmonids are targeted with gillnets. Flounder are also targeted in Macquarie Harbour while Mullet are targeted off northern Tasmania using small mesh mullet nets. The retained catch (based on numbers) taken by the recreational sector is dominated by Bastard Trumpeter and Blue Warehou (accounting for almost 45% of the total), with Atlantic salmon, Australian Salmon, Jackass Morwong, Mullet, Wrasse and Leatherjackets collectively accounting for a third of the total harvest. In the context of overall gillnet production in 2010, the estimated recreational harvest (expressed in terms of weight) exceeded that for the commercial gillnet sector for each of the above species (Lyle and Tracey, 2012), highlighting the significance of the recreational sector as a component of the broader Tasmanian gillnet fishery.

By-catch

Overall discard rates as a proportion of total catch numbers (all species), determined from on-board observations of commercial operations and as reported by recreational fishers, were relatively high; at 52% for Banded Morwong fishers, 49% for the general graball fishery, 66% for the small mesh fishery and 35% for the recreational gillnet fishery. It is acknowledged, however, that sampling of the general graball and small mesh fisheries was limited and as a consequence their overall discard rates may not be representative. In addition, as recreational data was self-reported it is feasible that catches of non-target and by-catch species may have been underestimated. Notwithstanding these reservations, it is clear that a considerable proportion of the gillnet catch taken by each of the sectors is not retained and it is the fate of this by-catch that is of particular interest when assessing the impacts of gillnetting on by-catch and biodiversity as well as the direct impacts on the target and retained species.

As for the retained component, by-catch was comprised of a wide diversity of species that included target as well as non-target species, but in terms of overall contribution to by-catch numbers, relatively few species accounted for the bulk of the discards. For instance, five species accounted for almost 90% of the total by-catch (by number) in the Banded Morwong fishery; namely Draughtboard Shark (30%), Marblefish (22%), Banded Morwong (21%), Bluethroat Wrasse (9%) and Longsnout Boarfish (7%). Similarly, in the general graball fishery just six species accounted for almost 80% of by-catch numbers; Banded Morwong (20%), Bluethroat Wrasse (18%), Draughtboard Shark (14%), Bastard Trumpeter (14%), Skates and Rays (10%) and Marblefish (4%). In the small mesh fishery five species accounted for the bulk (85%) of the by-catch; Bluethroat Wrasse (53%), Leatherjackets (24%), Herring Cale (4%), Draughtboard Shark (2%) and Marblefish (2%). As for the recreational fishery, seven species accounted for 75% of the total by-catch; Wrasse (26%), Marblefish (10%), Sharks (other than School and Gummy)[11] (10%), Leatherjackets (9%), Bastard Trumpeter (8%), Banded Morwong (7%) and Flounder (5%). This analysis highlights three things; first, relatively few species account for most of the gillnet by-catch, second, key by-catch species are similar for both commercial and recreational sectors, and third, target species represent a key component of the by-catch. The reason for the latter is mainly due to size limit regulations or, as in the case of Banded Morwong, non-endorsed commercial fishers not being permitted to take the species whereas recreational fishers consider the species to have poor eating qualities and often discard them (Lyle and Tracey, 2012).

When discard rates for individual species are considered it is evident that there is considerable consistency between commercial and recreational sectors (refer Figure 6). For instance, Marblefish, Wrasse (Bluethroat and Purple Wrasse), Skates and Rays, Sharks (other than School and Gummy Sharks, principally Draughtboard Shark), Leatherjackets, and Herring Cale tend to be discarded at rates of greater than 80% in most of the gillnet fisheries, whereas discard rates for target and non-target by-product species such as Banded Morwong (live-fish fishery), Bastard Trumpeter, Blue Warehou, Jackass Morwong, Australian Salmon and Mullet tend to be much lower, typically ranging between about 10 – 20% of catch numbers. Longsnout Boarfish are an exception with discard rates of around 40%, which is largely a consequence of the large LML that applies for this species. Motives for the non-retention of specific species were determined as part of the 2010 survey of recreational gillnetting and clearly established that LMLs were a key factor determining the release of target and non-target species, whereas for the typical by-catch species (especially Wrasse, Draughtboard Shark, Marblefish, Banded Morwong, Leatherjackets) it was perceptions relating to poor eating qualities (Lyle and Tracey, 2012). For the commercial sector, market desirability and demand is a key factor in determining whether a species is retained or not. It is noteworthy that although Bluethroat and Purple Wrasse are targeted using hooks and traps for a live-fish fishery, gillnet caught fish are not generally considered to be of suitable quality to

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[11] Mainly Draughtboard Shark

market live due to the effects of net damage (in particular scale loss) and are thus either discarded or retained in small quantities for human consumption or for use as bait for Rock Lobster (André *et al.*, 2014).

The implications of wastage due to discarding by-catch are directly proportional to post release survival, which is explored in detail in following sections.

Condition and survival of gillnet caught fish

Capture condition (including IM) and DM rates of gillnet caught fish varied between species, with some species apparently resilient to gillnet capture and others experiencing high mortality rates, such species specific variability in post release survival is consistent with previous investigations on a range of fish species (Broadhurst *et al.*, 2008; Benoît *et al.*, 2012; Braccini *et al.*, 2012).

In order to estimate PRS for gillnet caught fish we have applied a variety of approaches that integrate available capture condition and DM data. For the more commonly caught species, where there was sufficient information about condition stages across a range of soak times, as well as a relationship between condition and DM, PRS was estimated for each soak time category as the sum of survival rates based on condition stage weighted by the relative proportion of each condition stage in the catch. For species with limited DM data, PRS was approximated as the total survival rate based on the tank trials (irrespective of capture condition) multiplied by the relative proportion of the catch (irrespective of soak time) in capture condition Stages 1 – 4 (alive). Finally, for species lacking DM data but with sufficient capture condition information, an imputed DM value for that portion of the catch alive at capture was applied using the relationship between initial survival rate (i.e. proportion of individuals in condition Stages 1 – 4) and delayed survival rate (generated from tank trials) for species for which DM data were available (Figure 39).

Several species were found to be particularly resilient to capture in gillnets, suffering minimal physical damage and low rates of initial and delayed mortality, and thus have high overall PRS (>85%), irrespective of soak duration (Table 46). Species in this category include Banded Morwong, Bastard Trumpeter, Marblefish, Draughtboard Shark, Purple Wrasse, Leatherjackets (various species), Longsnout Boarfish, Magpie Perch, Greenback Flounder, Melbourne Skate and Maugean Skate. Based on the fishing practices applied in the current study, should these species be released alive the vast majority are likely to survive the event, irrespective of soak duration. Importantly, amongst this group are several of the major by-catch species taken in Tasmanian gillnet fisheries (e.g. Marblefish, Draughtboard Shark and Leatherjackets); survival rates for which are especially high (>93%). Included in this group of resilient species are several target species that tend to be mainly retained (e.g. Banded Morwong, Bastard Trumpeter, Longsnout Boarfish), although a relatively small proportion, sometimes representing a significant component of the overall by-catch, are also discarded with a high probability of surviving.

Species with moderately high PRS rates (70 – 85%) included Elephantfish, Whitespotted Dogfish and Bluestriped Goatfish (Table 46). Bluethroat Wrasse also fell within this category, although PRS rates fell with increasing soak times, in particular for longer sets (>5 h) when survival rates were estimated at to be 59%, but were >80% for soak durations <3.5 h. Southern Sand Flathead, Gummy Shark and Jackass Morwong had lower PRS rates (50 – 70%), which in the case of the former species were substantially lower than those determined for the release of hook caught individuals (Lyle *et al*., 2007). Survival rates for a suite of other species tended to be lower than 50% and in the case of Blue Grenadier, Red Cod, Yelloweye Mullet and Silverbelly were especially low (<20%) indicating that if caught in gillnets the vast majority of individuals would not survive if released. Species such as Blue Warehou, Australian Salmon and Atlantic Salmon were also not particularly resilient to gillnet capture (20 – 50% PRS rates) but since they tend be retained, by-catch mortality is a minor issue in these instances. Herring Cale, although a relatively minor gillnet species, tend to be discarded and had relatively low survival rates.

For most of the species studied here condition and survival rates declined as gillnet soak duration increased, a pattern that is consistent with most PRS studies (Hickford and Schiel, 1996; Benoît *et al.*, 2012; Braccini *et al.*, 2012). As such, many species would benefit from a decrease in the current maximum permitted soak time to improve the survival potential of any discarded catch. However, some of the less resilient species including Australian Salmon, Atlantic Salmon, Blue Grenadier, Blue Warehou, Gummy Shark, Herring Cale, Red Cod, Southern Sand Flathead, Silverbelly and Yelloweye Mullet experience relatively high initial mortality rates irrespective of soak time and any reduction in maximum permitted soak duration would be of limited benefit in reducing the impacts of gillnetting on by-catch survival. Species for which shorter soak times are likely to significantly reduce initial mortality rates include Bluethroat Wrasse and Jackass Morwong. We did not test how longer soak durations (i.e. overnight) influence mortality in the present study as this practice has been prohibited since 2009. However, the fact that IM, fish condition, and therefore DM increased in almost all species suggests that this practice would have considerably increased the negative impact of gillnetting in Tasmania, particularly as it was common practice to leave nets for extended periods of time (at times >24 hours). Decreasing the maximum permitted soak duration has almost certainly decreased the relative gillnetting effort, which will have further limited the negative impact of this fishery.

Of the commonly encountered by-catch species only Bluethroat Wrasse did not survive capture well. This species is targeted by commercial hook and line fishers and is valuable to the live fish trade; as such, any wastage from the gillnet fishing is undesirable. Due to the moderate level of mortality in shorter soak times, the high incidence of mortality in long soak times, the relatively high level of DM and the relatively high encounter rate, it is likely that gillnetting inflicts a considerable quantity of residual mortality on this species. Additionally, Bluethroat Wrasse had a relatively high incidence of barotrauma and, as such, additional mortality is likely (we deflated the swim bladder but commercial and recreational fishers are unlikely to do the same). Further, we observed increased mortality of individuals with barotrauma from seals and sea eagles. Bluethroat Wrasse are offered some respite due to sexual dimorphisms in their morphology; both sexes grow to similar lengths (Barrett, 1995b) but females are more fusiform than males and are not selected for particularly well by gillnets of 114 – 140 mm mesh size. This selection toward males, including from the hook and line live fishery, could potentially result in insufficient males in the population to ensure successful recruitment; however, there is no indication that this has occurred (Hartmann and Lyle, 2011).

Due to the low productivity of chondrichthyans, they are frequently negatively impacted by fisheries, whether retained or not (Bonfil, 1994; Stevens *et al.*, 2000; Graham *et al.*, 2001) and therefore of particular interest in studies such as this. Of the chondrichthyans regularly encountered, only Draughtboard Shark and the Batoids had high PRS (Maugean Skate will be discussed in the TEP section). Draughtboard Shark appeared to be immune to negative impacts of gillnet capture though they occasionally ingested air and struggled to descend. Experiments on this phenomenon have showed that there is minimal physiological impact and all individuals eventually expel the air (Van Rijn, 2009). The close relative of Draughtboard Shark, Whitefin Swell Shark (*Cephaloscyllium albipinnum*) was one of few chondrichthyan species not to show a dramatic decline after 20 years of trawl fishing on the continental slope of New South Wales, which was attributed to the high PRS of this species (Graham *et al.*, 2001). However, Walker *et al.* (2005) described a 54% decline in the abundance of Draughtboard Shark in Bass Strait between 1973 – 76 and 1998 – 2001, which cannot be explained by post release mortality or retention of this species, suggesting there may be other, currently unknown, factors involved.

Gummy Shark, Elephantfish and Whitespotted Dogfish were the other commonly encountered chondrichthyans with all three species exhibiting moderate PRS, which appears to be related to impaired respiration resulting from their habit of rolling in the net. Due to the presence of spiracles in the sharks and an opercula in Elephantfish, none of them require constant movement to respire; however, they roll themselves up so tightly it appears to prevent them passing water through their spiracles/operculum, over the gills and out of the mouth. It was not possible to measure DM in these species as they were not encountered in large numbers near the holding facilities and their large size made it difficult to transport and house them. The DM of Gummy Shark has been found to be relatively high and is caused by intramuscular acidosis resulting from overexertion (Frick *et al.*, 2010a). A study is currently underway to explore factors affecting mortality of Elephantfish (Camilla Martins, Monash University) but it is clear from the present study that additional mortality may occur, from blinding in particular. This occurrence is unlikely to be an artefact of confinement as previous studies that have held this species for extended periods of time have not observed this phenomenon when they were caught by hook and line or seine methods (Hyodo *et al.*, 2007).

While there are restrictions in place in SRAs to minimise the impact on sharks, even within the two hour maximum soak duration requirement for such areas, it was evident that mortalities still occurred. Gummy Shark and Elephantfish are highly productive for chondrichthyans (Walker, 1998; 2007; Bell, 2012) and abundant throughout southern Australia and therefore the impacts of by-catch mortality arising from Tasmanian gillnet fishers, while undesirable, are likely to be relatively minor in terms of impacting populations, especially in comparison with targeted fisheries for these species. Whitespotted Dogfish, on the other hand, are not particularly common in Australian waters, apart from around Tasmania (Walker *et al.*, 2005). They are one of the least productive chondrichthyans known due to their slow growth, late attainment of sexual maturity and low fecundity (Ketchen, 1972; Saunders and McFarlane, 1993; Avsar, 2001). The species was particularly common in Macquarie Harbour catches and, when taken in overnight sets, individuals either in poor condition or dead accounted for about one third of the catch, suggesting that the PRS estimates in Table 46 are likely to underestimate mortality rates for overnight deployments. Post release survival rates for this species have been estimated at 33% (Rulifson, 2007), which may be more indicative of survival rates in gillnet sets of long duration. Given the high rate of capture and their extremely low productivity, PRS is of particular importance for this species, which would benefit from further restriction of soak duration in Macquarie Harbour and/or limiting netting effort in depths where the species is prevalent (> 10 m). It is however, acknowledged that most recreational fishers actively try to avoid this species, which is considered an undesirable by-catch, by setting gillnets in relatively shallow areas of Macquarie Harbour.

A single School Shark was encountered within an SRA in the present study, despite being captured regularly in graballs in the past (Williams and Schaap, 1992). This species has undergone a dramatic decrease in abundance throughout Australian waters and while this decline is predominantly believed to have been due to overfishing in the Commonwealth shark fishery, the impact of incidental captures within Tasmanian waters is likely to have implications for stock recovery, especially since SRAs represent critical pupping and nursery areas for this species.

Aside from the obvious direct effects of gillnet capture on short-term survival, there may also be a range of sub-lethal effects, none of which were investigated in the present study. Such effects include increased vulnerability to predation due impaired predator avoidance and decreased burst swimming speed (Campbell *et al.*, 2010), stress related impacts resulting in immunosuppression and increased vulnerability to infectious agents (Lupes *et al.*, 2006), and suppression of reproductive development (Baker and Schindler, 2009). Furthermore, species such as Purple Wrasse, Marblefish and a close relative of Bastard Trumpeter, *Latridopsis cilaris*, have been shown to escape gillnets 40 – 60% of the time when meshed (Hickford and Schiel, 2008). It would be reasonable to assume that this would occur in many other similarly agile reef associated species and, as such, an unknown proportion of such individuals, in unknown condition, escaped the gear in our study. It is impossible to quantify how much additional mortality this contact with the gear and subsequent escape might impose but it is likely that the majority are able to escape because they are outside the optimal size selection for the meshes and thus likely to be in good condition with a high likelihood of survival.

Due to a number of potential biases, direct translation of our finding to the commercial and recreational gillnet fisheries should be done with care. For instance, although tank trials enable survival to be monitored directly it is possible that survival may be enhanced by removal of predatory interactions or conversely underestimated due to the impacts of transportation and confinement. Ideally, PRS studies should include controls to account for potential confounding effects arising from confinement and handling (Wilde *et al.*, 2003). In practice, most of the target species and many of the non-target species are difficult to capture using alternative fishing techniques. Notwithstanding this, the fact that virtually all Stage 1 condition fish survived the holding period suggests that transportation and confinement were not significant factors influencing survival rates. Another consideration is that researchers are expected to adhere to animal ethics requirements and our handling techniques, in particular designed to minimise additional damage and stress during the removal of fish from gillnets, may not be representative of typical fisher behaviour. Furthermore the presence of observers may have resulted in commercial fishers, consciously or sub-consciously, altering their fishing behaviour to reduce potential impacts on by-catch (including by-catch rates). Finally, the three day holding period provides an estimate of short-term survival but does not account for longer-term lethal effects of capture. For instance, several fish that survived the holding period showed evidence of deteriorating condition (scale loss and infection) that may have resulted in subsequent mortality. The present study nonetheless provides the first estimates of PRS based on 'best practice' for the main gillnet by-catch species.

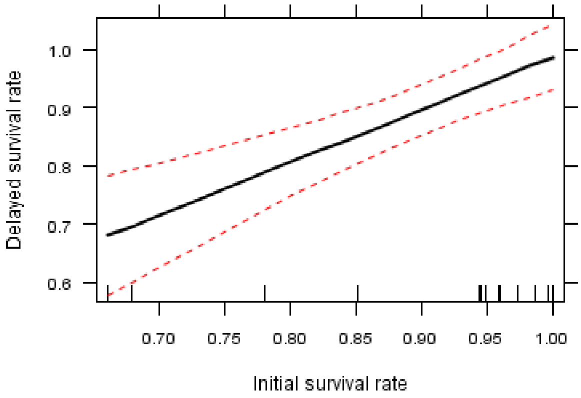

Figure 39: Linear model of the relationship between delayed and initial survival rates.
The relationship derived from this model is: DS = 0.90410(IS) + 0.08229 (p = <0.001, R^2 = 0.685), where DS is delayed survival rate and IS is initial survival rate. Silverbelly were removed from this analysis as the DS rate of 0% was considered unrealistic and was based on few individuals).

Table 46: Estimated post release survival rates for common gillnet species.
Differences in the mortality rate of species relative to soak time were investigated in species with sufficient samples. For those with moderate sample size, the overall mortality was explored (denoted by $^+$) and for those with too few samples, DM was estimated using the linear model in Figure 39 (denoted by *). Insufficient Blue Grenadier were captured in day sets to analyse this individually.

Species	Soak time	Survival (%)	Species	Soak time	Survival (%)
Bastard Trumpeter	1	88.2	Leatherjackets$^+$	All	95.0
	2	86.7	Magpie Perch$^+$	All	90.6
	3	94.6	Longsnout Boarfish$^+$	All	99.7
	4	83.7	Silverbelly$^+$	All	0
Banded Morwong	1	97.3	Purple Wrasse$^+$	All	93.6
	2	97.8	Jackass Morwong$^+$	All	52.1
	3	97.8	Greenback Flounder$^+$	All	96.1
	4	97.4	Herring Cale$^+$	All	40.7
Bluethroat Wrasse	1	82.9	Red Cod*	All	14.1
	2	81.5	Gummy Shark*	All	58.7
	3	70.9	Bluestriped Goatfish*	All	73.5
	4	59.0	Melbourne Skate*	All	98.6
Marblefish	1	96.8	Yelloweye Mullet*	All	10.3
	2	95.7	Blue Warehou*	All	34.9
	3	94.5	Southern Sand Flathead*	All	50.4
	4	93.2	Blue Grenadier*	All	17.0
Draughtboard Shark	1	100	Maugean Skate* (all sets)	All	87.2
	2	100	Maugean Skate* (day sets)	All	98.6
	3	100	Whitespotted Dogfish* (all sets)	All	77.3
	4	100	Whitespotted Dogfish* (day sets)	All	85.8
Australian Salmon	1	41.9	Atlantic Salmon* (all sets)	All	40.7
	2	61.3	Atlantic Salmon* (day sets)	All	48.7
	3	19.7			
	4	28.4			
Elephantfish	1	79.7			
	2	82.1			
	3	73.9			
	4	81.3			

Estimating post release survival using mark-recapture techniques

The relative risk method appeared to work relatively well for Bastard Trumpeter, providing survival estimates that were comparable to those found in the tank trial experiments (80% survival for Stage 3 and 54% survival for Stage 4 fish). While these estimates were slightly lower than for tank trials, it should be noted that this method takes into account longer-term mortality (given most recaptures occurred a considerable time following release) and potential sub-lethal effects that are not accounted for in tank trials. Furthermore, the estimates have low precision and should, therefore, be interpreted with a degree of caution.

By contrast, the method did not perform adequately for Banded Morwong, Bluethroat Wrasse or Marblefish. For these species it became apparent that a fundamental assumption of the method was not met; the probability of recapturing individuals that survived their encounter with the gear and subsequent recovery time was equal. Gilled and wedged individuals were more likely to suffer a higher degree of damage by the nets but, should they survive, were also more likely to be recaptured due to mesh selectivity characteristics of the gear, noting the nature of mesh selectivity functions (Hamley, 1975). On the other hand, fish that are mouthed, tangled or snouted tended to be in better condition and in theory were more likely to survive. However, these fish were also expected to have lower mesh selection probabilities based on their size and thus a lower likelihood of recapture, which would imply poorer survival rates based on the model. Our data support this as a plausible explanation as to why survival rates for Banded Morwong, Bluethroat Wrasse and Marblefish appeared to increase with decreasing fish condition, whereas Bastard Trumpeter (which covered a relatively small size range and the vast majority of which were gilled or wedged) declined as expected.

In the study that developed this method there was minimal variation in the condition of the Blacktip (*Carcharhinus limbatus*) and Bonnethead (*Sphyrna tiburo*) sharks relative to size (Hueter *et al.*, 2006). Furthermore, in the area where these species are common, sub-adults ranging from ~50 – 100 cm dominated catches irrespective of meshes size deployed (Baremore *et al.*, 2011) indicating a relatively low degree of size selective capture. In Blacktip Sharks this occurs because they accelerate when they encounter the gear then roll in the net whereas Bonnethead Sharks tend to be tangled by the cephalophoil (Thorpe and Frierson, 2009). Our study has, however, highlighted that the relative risk method is not well suited to species that are highly selected by the fishing gear in relation their size and where condition varies with size. Sharks are probably an ideal group for such studies as their behaviour tends to result in a lesser degree of gillnet mesh selectivity and mortality is often related to anoxia induced by immobility rather than physical damage caused by the net. In teleosts, the nature of the net damage is often related to fish size and, related to gillnet mesh selectivity properties, size selectivity will impact the probability of recapture should an individual survive the recovery period. Consequently, we recommend that pilot studies be conducted to explore relationships between fish size and how fish are meshed, fish condition and mesh selectivity before applying the capture-tag-recapture method.

Physiological effects of gillnet capture

Increasing levels of the stress hormones cortisol and catecholamines (e.g. adrenaline) cause an increased release of glucose in preparation of glycolysis to provide for the fight or flight response (Barton *et al.*, 2002). Lactate is created when lactate dehydrogenase converts pyruvate, the final product of glycolysis, when oxygen is absent or in limited supply, such as following exhaustive exercise, hypoxia or fatigue (Brown *et al.*, 2008). As such, measurement of glucose and lactate concentrations is a common procedure to investigate metabolic responses to stress (Barton, 2002), physiological consequence of exhaustive exercise and fatigue (Wood, 1991), the effects of aquaculture manipulations (Brown *et al.*, 2008) and impacts of capture methods (Pottinger, 1998; Frick *et al.*, 2010a; Frick *et al.*, 2010b; Frick *et al.*, 2012).

Each of the species examined, with the exception of Elephantfish for glucose (significant at $\alpha = 0.1$ level), displayed a significant increase from pseudo-baseline in both lactate and glucose concentrations when caught in gillnets. This increase suggests all species were stressed and preparing for the fight or flight response, and the significant increase in lactate suggests all species entered anaerobic respiration while trapped by the gillnets. This is to be expected since fish generally struggle to exhaustion in gillnets, movement is restricted preventing ram-jet ventilation, and opercula movement may also be restricted further inducing hypoxia. The lack of significant relationship for glucose in Elephantfish resulted from the large variability in baseline levels, with some fish having extremely high glucose concentrations suggesting they were already stressed when sampled (based on DPI Victoria data). Two factors may have contributed to this variability; first Elephantfish do not cope with capture, transportation and captivity well and some individuals may not have acclimatised to their captive conditions, and second, as it is necessary to maintain the species in a large enclosures to promote survival (20 000 L tanks in this instance) it is possible that some individuals may have been become stressed during the process of capture from within the large tank.

The only species to consistently display increasing trends in blood chemistry parameters with soak duration was Bastard Trumpeter, although the relationship was only significant for glucose. There are several possible explanations for the lack of a relationship in the other species: first, and most importantly, the length of time that individual fish were entangled in the gillnet was unknown; second, it is likely that fish exhaust themselves relatively quickly once they become entangled and therefore reach peak muscle lactate and blood glucose concentrations relatively quickly – it then takes a period of time for lactate to pass into the blood stream, depending on species, anywhere from 0.5 – 6 hours to reach a maximum (Wells and Tetens, 1984; Pottinger, 1998; Frisch and Anderson, 2000; Frick *et al.*, 2012); third, it is likely that fish struggle periodically while entangled, therefore maintaining elevated, but variable, glucose and lactate concentrations; and, finally, sharks tend to take longer for maximum lactate and glucose levels to be obtained following exhaustive exercise (Frick *et al.*, 2010a; Frick *et al.*, 2010b). This latter point may explain why Draughtboard Shark displayed a weak positive relationship for lactate, i.e. a long enough period of time had passed for lactate to pass from muscle tissue into the blood stream for the longer soak durations.

The response to stress differs between species and also between measureable factors; for example an animal that displays the greatest increase in cortisol may not show the greatest increase in glucose or lactate (Frisch and Anderson, 2000; Barton *et al.*, 2002). An increasing trend in blood glucose concentration with increasing trend in the species susceptibility to IM was identified in the present study. That is, the species that experienced the highest IM rates (Bluethroat Wrasse and Elephantfish) also had the highest glucose concentrations whereas the species with the lowest IM rates (Draughtboard Shark and Banded Morwong) had the lowest blood glucose concentrations. While an interesting and potentially significant finding, this result needs to be interpreted with some caution since the ANOVA models and regressions indicate a high level of variation, and because many of the capture variables were not controlled. Further research would be required to establish whether this relationship can be generalised to other species.

Most previous studies have demonstrated that the severity and duration of the stressor has a strong relationship with the degree of disturbance to tertiary performance characteristics and as such measuring various primary and secondary responses to stress has become common practice (Barton *et al.*, 2002). Barton *et al.* (2002) emphasise, however, that the relationship between physiological stress and mortality are poorly understood and, to date, little has progressed in this field of research. One particularly good example where physiological stress could be correlated with mortality involved Gummy Shark that were stressed by capture in gillnets (Frick *et al.*, 2010a). Moribund Gummy Shark had significantly elevated lactate and potassium concentrations when compared to those that survived the capture event; however, the changes did not become evident until three hours post capture (Frick *et al.*, 2010a). These experiments were carried out under laboratory conditions enabling the duration of time the animals were entrapped to be accurately monitored. While controlling variables that exist under ‘wild’ conditions is desirable for several reasons, laboratory results cannot necessarily be translated directly to represent post release survival of fish caught in the wild. One field study was able to identify five blood chemistry parameters, including lactate, that were able to signify moribund blue sharks and these authors validated their results with PSAT tags (Moyes *et al.*, 2006). As PSAT tags become smaller and more affordable this technology will play a vital role in conducting field experiments on the physiological factors that influence survival.

In conclusion, each of the species examined provided physiological evidence of stress due to capture but it was not possible to link either of the measured blood chemistry parameters to subsequent mortality (or survival) potential. Future research into this field should also include other blood chemistry parameters and perhaps most importantly, hormones such as cortisol and catecholamines as these may provide more detailed insights into stress physiology. A particularly useful study would be to explore blood oxygen saturation, which, apart from providing insights into anaerobic exercise, may provide insight as to whether some species asphyxiate due to an inability to ram-jet ventilate whilst immobilised.

Interactions with threatened, endangered and protected species

Maugean Skate

The Maugean Skate was first discovered scientifically in 1988 and is known only from two localities, Macquarie Harbour (western Tasmania) and Bathurst Harbour (southwestern Tasmania). The total range of the species is thought to be no more than 100 km² and the population size has been estimated to be in the order of 1000 individuals (Last and Gledhill, 2007). However, this population size estimate is not based on any quantitative information and, given the frequency that the species was observed in the present study, along with anecdotal reports from recreational fishers, is likely to be a significant underestimate. Based on its rarity and limited geographic range the species has been listed as endangered under the Threatened Species Protection Act (Tasmania) and Environmental Protection and Biodiversity Conservation Act (Commonwealth). According to the listing, the main potential threats to the Maugean Skate in Macquarie Harbour are heavy metal pollution (in the sediments) from historic mining operations, incidental capture in fishing activities (in particular recreational and commercial gillnets), the introduction of non-native marine species, and an increase in tourism pressure.

Very little is known about the biology, habitat utilisation, population size and ecological requirements of the Maugean Skate. Previously reported captures of the skate have been mainly restricted to relatively shallow waters (< 15m) giving rise to the suggestion that the species mostly inhabits the shallower upper regions of the estuaries (Last and Gledhill, 2007). In the present study, however, the species was caught throughout the system, ranging from the upper reaches of the estuary (Kelly’s Basin and Rum Point), close to major tributaries and areas likely to receive considerable freshwater influx, to the lower reaches (Liberty Point, Table Head and Swan Basin) close to the entrance of the estuary and likely to receive greater marine influence. Although salinities were not recorded whilst sampling, environmental monitoring programs indicate a dramatic increase in salinities at 3 – 10 m depth in the central harbour depending on the time of the year (Anon, 2005). As the vast majority of individuals were caught in depths between about 5 – 15 m it is possible that Maugean Skate have limited osmoregulatory capacity and therefore select brackish to marine waters. Furthermore, due to the high level of stratification in Macquarie Harbour, waters >15 m tend to have relatively low dissolved oxygen levels (<5 mg/L) (Anon, 2005), which may account for the apparent lack of individuals from deeper waters. Whether the distribution of the species is restricted to a relatively narrow strip around the periphery of Macquarie Harbour between the surface layer of freshwater and the low oxygen mid-depths is unclear and will be addressed in another study (Movement, habitat utilisation and population status of the endangered Maugean skate and implications for fishing and aquaculture operations in Macquarie Harbour, FRDC 2013/008).

Macquarie Harbour is subject to a number of human impacts that may have relevance to the Maugean Skate, these include:

- widespread mining has occurred throughout the catchment for over 100 years and has resulted in greatly reduced water quality (Carpenter *et al.*, 1991);
- the hydrology of the system has been altered due to damming of the Gordon, Huon and King rivers for hydroelectricity generation (Carpenter *et al.*, 1991);
- large-scale salmonid aquaculture occurs within the harbour with plans to double production by 2030 (Anon, 2005);
- commercial fishing has taken place since the development of Strahan, and probably before, with approximately 20 commercial fishers active at the start of the 20th century (Ware, 1908) when landings were valued at ~£3000 ($520,000 in present day terms). A low level of commercial fishing activity still occurs in the area but is now directed primarily at salmonid escapees; and
- recreational fishing is a common activity within the harbour with fishers using hook and line and gillnets. Hook and line was once the preferred method with fishers targeting Red Cod and Rock Ling along with gillnetting for Flounder. Apparent declines in the availability of these species and growth of the marine farming sector fishers has resulted in gillnets being increasingly used to target escapees in recent times.

Anecdotal reports from fishers with long-term experience (> 50 years) of fishing in Macquarie Harbour confirm that Maugean Skate have been taken as a regular by-catch in recreational and commercial gillnets over many years, as well as being caught occasionally by hook and line. While sometimes retained for human consumption, the species was traditionally seen as a nuisance and thus may not always have been returned to the water alive. Given the historic environmental impacts and a long period of incidental capture of the species it is encouraging to note that a relatively large population of Maugean Skate continues to persist in Macquarie Harbour. By contrast, in Bathurst Harbour, which is located within the Tasmanian Wilderness World Heritage Area and afforded full protection from fishing, the species has not been observed for more than 20 years despite regular surveys and dedicated searches carried out in 2012[12].

Although no data were gathered on commercial fishing on the west coast during the present study, a previous study recorded Maugean Skate (and Whitespotted Dogfish) as a by-catch of commercial gillnetting for escapee salmonids in Macquarie Harbour (Steer and Lyle, 2003). Recreational fishers also reported ‘skate’ (presumed to be Maugean Skate) as a by-catch of gillnetting in Macquarie Harbour (Lyle and Tracey, 2012).

The vast majority of the Maugean Skate caught in the present study were in good condition and all individuals captured during day time deployments (up to ~6 hour soak duration) were healthy when released and considered to have a very high chance of survival (effectively 100%). Maugean Skate in poor condition and mortalities were only observed in overnight deployments. On two occasions there was evidence of predator damage (Whitespotted Dogfish, sea lice and/or crabs being implicated) associated with the mortalities, though it could not be determined whether the predator damage was the primary cause of death or had occurred post-mortem. On a third occasion, soak durations of some individual nets were much longer than usual (around 20 hours), a consequence of unexpectedly high catch rates and extended hauling and handling times as the project team assisted another researcher taking a range of additional biological information from the Maugean Skate. This additional activity may have influenced the survival of the Maugean Skate in several ways; first, it greatly increased the period of time it took to haul the nets resulting in soak durations that may have exceeded a physiological threshold in some individuals; second, hauling each net was slow and may have meant that some individuals were held above the halocline for extended periods, which may have been physiologically intolerable; and finally, while hauling the nets the vessel would have inevitably drifted and dragged the net potentially subjecting some individuals to additional physical pressure as the meshes tightened. If being retained in the freshwater layer was a contributing factor it is likely because partially euryhaline elasmobranches cannot defend against large osmotic gradients and tend to only make short term excursions into freshwater as, in time, they begin to osmoconform, which has significant negative physiological implications (Dowd *et al.*, 2010). Apart from the mortalities experienced on this occasion, the remaining individuals (39 out of 50) were still in good condition and swam away strongly when released. Whatever the cause, the results from that day highlight the importance of preventing overly long soak durations and clearing the net as soon as practicable and the recent management intervention restricting soak duration in Macquarie Harbour has likely benefited Maugean Skate.

Based on the relatively high catch rates achieved in this study, it appears highly likely that the Maugean Skate is far more abundant in Macquarie Harbour than has been assumed previously. Our data indicate that the species is widely distributed throughout the system and vulnerable to capture in gillnets, especially when nets are set in the 5 – 15 m depth range. Although anecdotal reports from fishers confirm that individuals are infrequently captured in shallower depths (including depths of less than 2 m), our data suggest that limiting the depth that gillnets are fished in Macquarie Harbour to less than about 5 m would substantially reduce the incidental capture of species. Despite the fact that most individuals are lightly meshed (mainly by the snout region) and can be released in healthy condition (often by simply shaking the net), mortality of some individuals is inevitable, especially in overnight sets. Predation whilst in the nets is also a problem, with the abundant Whitespotted Dogfish a potential predator along with sea lice and crabs; the latter two being more likely to attack weak or moribund individuals, which is likely to occur due to the stress of being restrained by the net for prolonged periods of time.

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[12] Treloar, M., Barrett, N. and Edgar, G. (2013) Biology and ecology of the endangered Maugean Skate, Report to the Winifred Violet Scott Charitable Trust, Institute for Marine and Antarctic Studies, University of Tasmania.

Seals

Fur Seals were regularly observed either inspecting nets or feeding on entangled fish but there were no entanglements or mortalities observed in either commercial or research fishing operations. Interaction rates were highest on the North coast, possibly related to the fact that most seal breeding colonies are located in Bass Strait (Kirkwood *et al.,* 2010). Differences between interaction rates for commercial and research fishing were influenced by the concentration of the research effort off the Southeast coast, where interaction rates were relatively low compared with other regions.

Around three-quarters of recreational gillnetters reported having experienced seal interactions with gillnets at least once in their fishing career, with loss of fish and/or damage to the nets the main outcomes. Respondents suggested that such interactions were relatively common and that the frequency of the interactions had generally increased in recent years, presumably linked to increasing seal numbers and habituation to fisher's activities.

In the main it is likely that seals obtain minor benefits, through provisioning, from gillnet activity by being able to access large reef associated species, whereas the bulk of their natural diet typically consists of small pelagic fish (Redbait and Jack Mackerel) and squid (Gales *et al.*, 1993; Gales and Pemberton, 1994). Although no entanglements were recorded in this study, commercial fishers have confirmed occasionally catching drowned seals in their gear but such events are apparently exceedingly rare and unlikely to have a detectable impact on seal populations. In fact Fur Seal populations have increased over recent decades and a number of new pupping colonies have established throughout Tasmania and Bass Strait (Kirkwood *et al.*, 2010), suggesting that incidental mortalities arising from fishing (all fisheries) are not exceeding recruitment despite moderate numbers of fishing induced mortalities in the Commonwealth SESSF (Tilzey *et al.*, 2006) and Small Pelagic Fishery (Lyle and Willcox, 2008); in particular associated with trawling operations.

Seabirds

To some extent all species of diving seabirds have the potential to become entangled in gillnets and while most such entanglements are likely to involve low numbers, large numbers of individuals have occasionally been caught in Tasmania. These events have, in particular, involved Short-tailed Shearwaters and Little Penguins, which feed in groups or, in the case of the latter, travel to and from rookeries in groups. In the present study and based on over 3400 commercial and research gillnet deployments we recorded a total of 22 seabirds entangled in gillnets (Little Penguins and three species of cormorant), with all but one individual (penguin) having drowned.

Although a survey of commercial gillnet fishers was not undertaken, over one in four recreational gillnetters surveyed reported catching seabirds in gillnets at least once during their fishing career. Not unexpectedly, the more avid fishers, and those with greater years of gillnetting experience, tended to be more likely to have experienced such interactions. Cormorants were the most commonly cited species encountered, followed by Penguins, Short-tailed Shearwaters, Gannets and Seagulls. For the vast majority of fishers, encounter rates were ranked as being very rare (< once every 20 trips) and it was also noted that not all encounters resulted in mortalities.

In the present study interaction rates with cormorants ranged between 0.5 – 1.7% of gillnet deployments; the higher rate occurred in the smaller mesh sizes (small mesh and mullet nets) and may have been influenced by the fact that these nets select for smaller fish which are of appropriate size for cormorants to eat. In several instances cormorants were located in meshes within a metre of fish that had damage consistent with that caused by a cormorant's beak. The lack of a significant relationship between set depth and the capture of cormorants was unexpected but probably resulted because most of netting effort (both commercial and research) was in depths of <20 m, which is likely to be within the diving range of all local cormorant species. For example, the Imperial Cormorant was recently found to dive regularly to 50 m, far deeper than was considered possible (Laich *et al.*, 2012). While we are unaware of any studies that have specially explored the diving ranges of the species encountered in the present study, the Great Cormorant has been estimated to have an average dive depth of 5.7 m (Grémillet *et al.*, 1998), which is reflective of its benthic feeding behaviour and within the range of much of the gillnetting effort that occurs in

Tasmania. Further, it is likely this species is capable of diving to much greater depths and spends considerable time at depths greater than the reported average.

Although interactions with Little Penguins were very rare (about 0.2% of deployments) there is anecdotal evidence indicating that, on occasion, large numbers have been caught in gillnets and one study has implicated gillnetting as a major contributor to a decline in Little Penguin abundance in several colonies (Stevenson and Woehler, 2007). The risk of encounters with large numbers of penguins increases if gillnets are deployed near rookeries or are used within corridors used by the penguins to access these colonies. At the present time there are no legislative requirements to prevent fishing in such areas or at times of the day that penguins are likely to moving to, or from, the rookeries. Since penguins spend >75% of their time in the top 5 m and <2% at depths greater than 15 m (Gales *et al.*, 1990) there may be some potential to minimise encounters near rookeries by minimising gillnet effort in shallow waters, perhaps under a fishing code of practice.

The need for additional restrictions on gillnetting in areas close to rookeries and penguin colonies was canvassed directly with recreational fishers. Although most were not supportive of any further restrictions as they believe that existing management measures, including the prevention of night netting and maximum soak durations, were sufficient to reduce the risk of accidental capture of seabirds. Amongst those supportive of the need for additional measures to manage seabird interactions, most were in favour of spatial rather than temporal closures.

Sygnathids

Low numbers of Sygnathids (Seahorses and Seadragons) were encountered in the present study and all individuals were in excellent condition and released alive with a high chance of survival. At the levels these species were observed and the fact that all were unlikely to have suffered any long-term negative impacts, it is unlikely that gillnetting poses a threat to Sygnathid populations.

Interactions with habitat

As a passive fishing method, there was no indication that gillnets caused significant damage to benthic habitats. Small quantities of benthic habitat forming organisms (i.e. macroalgae, sea tulips and sponges) were occasionally dislodged by the gear when set over hard bottom, with the majority of the macroalgae in the nets being drift algae or blades rather than holdfast and stipe. Similarly, when nets were set over seagrass occasional blades were retrieved in the net but it is probable that most were already dislodged from the plants. Given the high abundance and productivity of these invertebrates and marine plants, it is unlikely that gillnets themselves would have any direct negative impacts on the benthos or benthic invertebrates.

Ghost fishing by lost gear has been highlighted as an issue in many gillnet fisheries (Matsuoka *et al.*, 2005). Although we did not experience gear losses in this study, we are aware of instances where gillnets have been lost and there are anecdotal reports of lost gear being found (often by divers). Unlike pelagic gillnets, demersal gillnets of the type used in Tasmania have a tendency to roll up tightly after a time, reducing their capacity to fish continuously and effectively (Matsuoka *et al.*, 2005). Notwithstanding this however, in the context of the overall quantities of gear that have been used by both commercial and recreational sectors since European settlement, ghost fishing represents a risk, albeit presumably minor compared to the direct implications for target and non-target fish populations of gillnetting.

Variation in the abundance and diversity of fish communities with links to gillnetting

Gillnet catch composition and individual species abundances since the mid-1990s have been highly variable both spatially and temporally. As a result, testing individual species trends in abundance using the intersection union test, Mann-Kendal tests and linear models was not appropriate. This variation also limited the ability of ANOSIM to identify variation between years. Unfortunately, due to a paucity of data in many years, it was not possible to standardise CPUE using traditional techniques (reviewed by Maunder and Punt (2004)). In particular it would have been beneficial to standardise for the effect of 'season' and 'fisher' as both factors are likely to influence catch rates. Nonetheless, in an attempt to minimise this bias, sampling during winter was excluded and only data based on on-board observation of experienced Banded Morwong fishers or research gillnetting data available from a number of studies was used.

Banded Morwong, in particular, but also Marblefish, Bluethroat Wrasse and Draughtboard Shark have tended to typify the large mesh graball net catch composition off Tasmania's coastal reefs over the past two decades, with Longsnout Boarfish also significant on the Southeast and East coasts and Bastard Trumpeter a key component defining community structure in the Southeast coast. General graball catch compositions were similar to those for the large mesh nets although, being less selective for the larger reef species, Banded Morwong was less prominent in typifying catch compositions than the other key species. The relative lack of species responsible for typifying >5% of species composition in any given year is an indication that this sampling technique is highly selective toward certain species. Perhaps the most obvious change in gillnet catch composition during the past 20 years has been the tendency for species compositions to become progressively more aggregated, especially in the Southeast. This suggests that the fish community structure may have shifted into a new equilibrium state that seems to have been particularly influenced by marked declines in the abundance of several key gillnet species during the 1990s and early 2000s.

The most conspicuous of these changes was the reduction in the abundance of Banded Morwong. The live-fish fishery for Banded Morwong first developed in Tasmania during the early 1990s (Murphy and Lyle, 1999) and the impact on Banded Morwong abundance by what was, at the time, a largely unregulated fishery, is apparent, suggesting that fishing mortality was unsustainably high. Subsequent management initiatives, in particular the introduction of quota management (2008) and recent quota reductions appear to have arrested the rate of decline in Banded Morwong abundance and catch rates have generally stabilised (André *et al*., 2014).

Bastard Trumpeter, an important target species for commercial and recreational gillnet sectors, on the other hand has exhibited no obvious, or consistent, trend in abundance based on either gillnet and underwater visual survey data but has exhibited sporadic pulses in abundance, which appear to be associated with recruitment variability (Murphy and Lyle, 1999). Although not obvious from our analyses, there appears to have been a long-term decline in the abundance of Bastard Trumpeter in Tasmanian coastal waters, the general decline occurring since records began in the early 20th century (Harries and Croome, 1989), and thus current stock levels may well be substantially depleted when compared with the unfished status (Frijlink and Lyle, 2013). Management restrictions have been progressively tightened on this species, with increasing LMLs and decreasing possession/trip limits. Nevertheless, current management may still be insufficient to promote recovery if growth and recruitment overfishing are occurring, noting that the exploited inshore stocks consist entirely of juvenile and sub-adult fish (Harries and Lake, 1985). It remains somewhat of a mystery where adult Bastard Trumpeter go; however, moderate quantities are caught by the Commonwealth SESSF in deep waters (Walker *et al.*, 2005; Walker *et al.*, 2007b), suggesting the species probably migrates offshore as it approaches maturation (Murphy and Lyle, 1999). With that said, it is likely that inshore gillnetting pressure imposes a relatively high level of fishing mortality on Bastard Trumpeter stocks since abundances within MPAs have been found to be up to two orders of magnitude greater than surrounding areas open to fishing (Edgar and Barrett, 1999). Natural recruitment variability, including protracted periods of low recruitment, appears to be characteristic of this species and this, in conjunction with the effects of fishing, may ultimately mask any benefits from recent management initiatives for this species.

Another key target species for commercial and recreational gillnet fishers in Tasmania is Blue Warehou, the species being represented sporadically in our dataset and without an obvious trend over time. This is a schooling species that occurs seasonally in Tasmanian waters, the availability and abundance of the species seems to be influenced by variation in migration patterns, presumably linked to oceanography and availability of key prey (salps) (Hartmann and Lyle, 2011). Although not evident in our analyses, Blue Warehou stocks have declined markedly since the 1990s associated with general overfishing mainly within the SESSF (Woodhams *et al*., 2012). The Commonwealth have now implemented a stock rebuilding strategy to enable this species to recover (Anon, 2012) and commercial catches in Tasmanian waters have remained low (<50 tonnes p.a.) for the past decade (André *et al*., 2014).

While extractive fishing can be expected to reduce abundances of target species, changes in the abundance of by-catch species are particularly important as these species are not generally investigated in stock assessments and the impacts of fishing on these species can therefore go by unnoticed. Within the present study, Marblefish was one of few by-catch species to display a consistent decline in abundances, evident in most regions, during the 1990s, before stabilising at a lower level during the past decade. This is perhaps an unexpected finding since Marblefish are rarely retained and are a particularly robust species, experiencing very low IM and high PRS (>90%). Several possible explanations exist; first, recreational and commercial fishers may not handle fish carefully when removing them from nets or even intentionally inflict damage to the fish resulting in mortality (the species is seen very much as a nuisance); second, some fishers set gillnets to gather bait for lobster pots and as such, Marblefish may be retained as bait (in such instances the species represents by-product rather than by-catch); third, soak durations in the present study were restricted to those recently implemented (2009) in the fisheries regulations, whereas previous fishing practices (in particular overnight netting) may have had a far greater negative impact on this species; and finally, Marblefish are occasionally retained by commercial fishers (the species has been trialled for the live-fish markets), although commercial logbook data suggest that landed quantities have been low (<5 tonnes p.a., André *et al*., 2014). It is likely, therefore, that a combination of factors attributed to the impacts of gillnetting are responsible for the decline in Marblefish abundances, a conclusion supported by an increase in Marblefish abundances within the Maria Island MPA following its creation (Barrett *et al*., 2007). There is no biological information available for Marblefish and little available on the genus in general. One study on a closely related species, *Aplodactylus punctatus*, aged five individuals that were collected from nursery habitats – the largest individual was two years old at 157 mm (Stephien, 1990). This is a very slow growth rate for a juvenile although is not particularly surprising given the herbivorous diet of the lineage (Stephien, 1990; Choat and Clements, 1992). If this slow growth rate is common to other members of the genus it may explain why Marblefish have been slow to recover following improvements in gillnetting practices and the reduction in overall fishing effort.

Draughtboard Shark are also a common by-catch of gillnetting but despite very high PRS have declined in abundance in the Southeast region since the 1990s. This trend was not, however, reflected in all regions, with relative abundances having risen off the East and Northeast coasts. Walker *et al.* (2005) describe a 54% decline in the abundance of Draughtboard Shark in Bass Strait between 1973 – 76 and 1998 – 2001, which cannot be explained by low PRS or retention of this species. The decline observed in the present study, and that by Walker *et al.* (2005) suggests there may have been poor fishing practices at times (i.e. purposefully killing this species) or there have been ecological changes that have been detrimental to their abundance. Interestingly the close relative of Draughtboard Shark, Whitefin Swell Shark (*Cephaloscyllium albipinnum*) was one of few chondrichthyan species not to show a dramatic decline in abundance after 20 years of trawl fishing on the continental slope of New South Wales, which was attributed to their high PRS (Graham *et al*., 2001).

Bluethroat Wrasse, while a significant component of the gillnet by-catch are the target for a live-fish fishery that employs hook and trap methods, with landings averaging around 60 t p.a. in recent years. Catch rates for this live-fish fishery rose steadily as the fishery expanded between the mid-1990s until around 2006/07 but have subsequently declined to levels similar to those of the mid-1990s (André *et al*., 2104). The harvest from the target fishery, in conjunction with gillnet by-catch mortality, noting that Bluethroat Wrasse do not survive gillnet capture particularly well, seem to have had limited impact on the abundance of the species, at least up until recently. Interestingly, following the establishment of MPAs in Tasmania the abundance of Bluethroat Wrasse did not increase within the MPAs but rather average sizes increased (Edgar and Barrett, 1999). As a territorial species it is possible that as areas are fished by gillnets (and lines and traps), individuals (especially territorial males) move in from adjacent marginal habitats to replace those that have been removed (or died), thereby maintaining population numbers (and stabilising catch rates) to some extent. Furthermore, as a protogynous hermaphrodite, the selective removal of the larger males from the population by gillnets and the live fish fishery (noting that the LML of 300 mm) will result in catches being dominated by males.

Longsnout Boarfish abundances have remained relatively stable over time in each of the regions, although catch and sighting rates have tended to be associated with considerable variability. Due to the large LML (450 mm) for the species, Longsnout Boarfish experience a relatively high rate of release from gillnets and post release survival rates are high, which, in combination, probably contribute to reducing the impacts of fishing on the coastal populations.

Monitoring based on underwater visual census and fishing methods (i.e. gillnetting) do, however, sample differing components of fish communities and may not necessarily correlate well (Hickford and Schiel, 1995). Gillnetting appears to be good at sampling certain species that may not be particularly abundant, whereas visual census techniques sample smaller, abundant species particularly well (Hickford and Schiel, 1995). It so happens that some reef associated species are adept at avoiding capture, probably because they are well adapted to life in a complex environment and behave as if gillnets are simply another part of their environment, swimming through holes in the net, or over the top, without coming into contact with the meshes (Hickford and Schiel, 2008). Consistent with the observations of Hickford and Schiel (1995), the most abundant species observed in underwater visual census surveys were rare, or absent from the gillnet catches – species such as Herring Cale, Silver Sweep, Rosy Wrasse, Senator Wrasse and Toothbrush Leatherjacket (Edgar and Barrett, 1999; Barrett *et al.*, 2007; Stuart-Smith *et al.*, 2008; Stuart-Smith *et al.*, 2010). As would be expected, most of these species did not display significant increases in abundance following the formation of the Maria Island MPA (Barrett *et al.*, 2007). Another Tasmanian study based on underwater visual surveys also failed to find an increase in the abundance or size of selected reef fish including Herring Cale, Senator Wrasse or Rosy Wrasse, with increasing distances from access points (boat ramps) (Stuart-Smith *et al.*, 2008), again indicating that fishing does not negatively impact many of the smaller, abundant reef associated species. By contrast, however, the size and abundance of gillnet target species Banded Morwong and Bastard Trumpeter were found to increase with increasing distances from access points. Bastard Trumpeter abundances also increased in most MPAs when compared with fished areas (Barrett *et al.*, 2007), findings that are clearly explained by the impacts of gillnet fishing in non-protected areas.

The inability of the present study to detect rapid increases in the abundance of common species since the implementation of improved management practices (the prohibition of overnight netting in particular) is somewhat surprising. As mentioned above, the rate of decline of Banded Morwong and Marblefish appears to have plateaued and, given many of these species are either known to be, or are likely to be, long lived, it may be too soon to detect any change. Further, it may be that the considerable noise within both the gillnet CPUE and underwater visual census data is sufficient to mask any recovery at present.

Motivations, behaviour and attitudes of recreational gillnet fishers

Recreational fishers have a long history of gillnet usage in Tasmania (Harries and Lake, 1985; Frijlink and Lyle, 2013), targeting species such as Bastard Trumpeter, Blue Warehou, Flounder and Yelloweye Mullet that have traditionally been difficult to catch using line fishing methods. The recent development of the salmonid aquaculture industry has also provided further opportunities for recreational gillnet fishers, with escapee Atlantic Salmon and Rainbow Trout readily taken by gillnets. However, poor fishing practices, notably excessively long soak times have long been seen as a major contributor to wastage and by-catch in gillnets, including the incidental capture of wildlife (e.g. seabirds). Furthermore, the perceived indiscriminate nature of gillnets coupled with high and largely unregulated levels of recreational netting effort and have given rise to general concerns about the impacts of netting on inshore fish communities. Since the introduction of licensing in 1995, a series of management measures have been progressively introduced to improve recreational fishing practices, reduce wastage and by-catch.

The earliest survey of recreational gillnet fishing was conducted in 1995 and established that about 70% of graball fishers either ‘occasionally’ or ‘mostly’ set nets overnight (Lyle and Smith, 1998). The common practice of overnight netting was confirmed in a more in-depth examination of net fishing conducted between 1996-98, with approximately three quarters of all recreational gillnet effort involving overnight sets (Lyle, 2000). In the same study it was also established that more than one in four overnight sets were deployed in the morning and not checked or hauled until the following day, resulting in effective soak times of 24 hours or greater. Following the introduction in late 1998 of a requirement to differentially mark (buoy) nets as being daytime or overnight sets to reduce such excessive soak times, night netting was still found to account for over half of all gillnet sets in 2000/01 (Lyle, 2005). The prohibition on night netting in most areas was implemented in late 2004 and appears to have had a significant and dual impact on netting effort, not only has the ban achieved a marked reduction in the proportion of night sets (< 10% in 2010; Lyle and Tracey, 2012) but there has been a concomitant and substantial reduction in overall recreational netting effort. For instance, recreational gillnet effort (based on net sets) in 2010 was about 60% of the level in 1997 and this has occurred despite there being 40% more gillnet licence-holders in 2010 than in 1997 (Lyle and Tracey, 2012).

Amongst gillnet fishers surveyed in 2011, almost 40% identified catching fish to consume as their most important reason for recreational fishing, with non-catch motives relating to relaxation and socialising of lesser importance. By comparison, a similar analysis involving representatives from the general recreational fishing community of Tasmania, identified that social and relaxation attributes of the fishing experience were the most highly ranked reasons for fishing whereas catching fish to eat was ranked third (17%) in overall importance (Frijlink and Lyle, 2010). This difference not only highlights the extent of heterogeneity within the recreational fisher population but consistent with the use of gillnets to catch fish for consumption rather than for ‘sport or recreation’. Furthermore, while the degree to which gillnet fishers value the catch-related aspects of the fishing experience, often referred to as consumptive orientation (namely catching something, the numbers of fish caught, numbers of fish retained, size of the fish caught, and consumption of the catch), were generally similar to that determined for the general population of recreational fishers (Frijlink and Lyle, 2010), gillnet fishers were much less concerned about the size of the fish caught (specifically catching large fish) than other recreational fishers. This difference again reflects the fact that gillnet usage is not perceived to be a sport, where catching trophy (large) fish tends to be important.

Recreational fishing was the most important recreation/leisure activity for over half of the gillnet fishers surveyed and virtually gillnet fishers also engaged in other types of fishing. In fact just one in twenty respondents indicated that gillnet fishing was their main recreational fishing activity, with one in ten suggesting that if they could not go gillnetting they would probably give up fishing altogether. Responses were more polarised about whether they would give up gillnet fishing if they were unable to continued gillnetting in the areas they currently fished. These results indicate that for most gillnet fishers, gillnetting represents one of a range of fishing activities in which they participate and suggests that should the method be no longer permitted they could substitute gillnetting with other fishing activities. This does not, however, imply in any way a lack of interest or connection to gillnetting or that recreational gillnet fishers would be indifferent should gillnetting opportunities be further restricted or prohibited.

Amongst gillnet fishers there was general agreement (around two-thirds of respondents) that recent management changes have been effective in improving fishing practices and reducing wastage and by-catch. Interestingly, however, only a small minority indicated that the most recent management changes had influenced how often and/or where they went gillnet fishing and/or what species they targeted. For these respondents, the prohibition on night netting and maximum soak time requirements were identified as key constraints on how often they went fishing; night netting prohibition, soak time requirements (especially in SRAs) and expansion of no-netting areas were the main contributors influencing where respondents fished; and the ban on night netting was seen as a major impediment when fishing for species such as Blue Warehou, Greenback Flounder and to a lesser extent Bastard Trumpeter and Atlantic Salmon.

Consistent with their relative importance the gillnet catches (refer Table A1. 4), Blue Warehou, Bastard Trumpeter and Atlantic Salmon were identified as key target species by the majority of recreational gillnetters. About 10% of respondents considered that abundances of each of these species had increased in recent years (due to the combination of natural variability and reduction in fishing pressure) whereas almost half of respondents considered abundances had declined (mainly due to fishing pressure) while the remainder considered that abundances were stable or were unsure about the status. Of interest is the observation that almost half of those respondents who identified Atlantic Salmon as a target species also noted that abundances had declined, suggesting that aquaculture escapees are less abundant (fewer losses) and/or that competition amongst netters for the species may have increased (Lyle and Tracey, 2012).

Considering a scenario that involved catch rates for key target species being very low, almost half of the respondents suggested that they would be likely to fish less or even give up gillnet fishing whereas about one in six respondents suggested they would switch to target other species. Relatively few respondents suggested that they would increase their fishing effort so that they would at least catch something.

While variability in the abundance of target species has undoubtedly influenced levels of recreational catch and effort, there is little doubt that changes in fishing practices (no night netting, shorter average set durations[13]), reduction in the length of mullet nets, larger LMLs for some species (influencing release/discard rates) have also contributed to the reduction in recreational gillnet catch and effort over the past decade.

Ecological risk assessment

The ecological risk assessment of gillnetting based on the ERAEF framework (Hobday *et al.*, 2011) identified that impacts on habitat and communities had low consequence (Level 1: Scale, intensity and consequence analysis), and as a result these components were not progressed in the Level 2 Productivity Susceptibility Analysis (PSA). The PSA was undertaken separately for each of the sub-fisheries and included consideration of impacts on target species, by-product/by-catch species and TEPS. Several high risk species were identified by this analysis, each of which being specific to one sub-fishery rather than across fisheries (Table 47); a result that reflects, to a large extent, differences in gear selectivity (mesh selectivity characteristics) as well as differences in the spatial coverage of the fisheries.

Bastard Trumpeter was the only species ranked as high risk in the reef sub-fishery, predominantly because in the assessment we did not compensate for the probability that they also inhabit deeper waters, where fishing interactions are low. It was decided that the TSF should take responsibility for the species as a whole since inshore Tasmanian reefs represent the core habitat for juveniles and sub-adults, even though the species probably migrates into deeper water following maturation (Harries and Lake, 1985). This assessment suggests that measures to facilitate recruitment and the ongoing sustainability of the fishery and the species as a whole should be considered by management.

None of the species that interact with the graball (Banded Morwong) sub-fishery were ranked as high risk, predominantly due to the high level of selectivity achieved for the target species by the large mesh size. In some respects it was unexpected outcome that Banded Morwong did not obtain a greater vulnerability ranking than medium as this species is long-lived and there is evidence that the population has been impacted by fishing as is currently assessed as transitional depleting (André *et al.*, 2014). A feature of the ERAEF framework is that it does not require catch and effort data, information that are frequently unavailable for TEPS and by-catch species (Hobday *et al.*, 2011). However, for species with quantitative stock assessments, such as Banded Morwong, it is preferable to give priority to such assessments as they are likely to be a more accurate reflection of the risks and impacts posed by the fishery. The ERA process, on the other hand, has been designed specifically to identify species, or communities and habitats, that are at greater potential of risk due to their biology or exposure to hazards from fishing (Hobday *et al.*, 2011).

Interestingly, Atlantic Salmon and Rainbow Trout were ranked as having high vulnerability in the graball (non-reef) sub-fishery, these species are escapees from aquaculture operations and thus introduced exotics. High vulnerability in this context can be considered as a positive, with fishing pressure contributing to their removal from the environment. Maugean Skate and Whitespotted Dogfish were also identified a high vulnerability species. The Maugean Skate has a highly restricted distributional range and if the population size is low as has been suggested (Last and Gledhill, 2007), any fishing impacts will pose some level of risk to this species. The lack of information about key biological attributes for the species also contribute to uncertainty about this risk, and in the PSA this contributes to a precautionary, in this instance the high vulnerability assessment. Whitespotted Dogfish on the other hand are more widely distributed, being particularly common in Macquarie Harbour as well as other fished inshore areas, but importantly

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[13] For instance, the average duration of a day set in the late 1990s was 6.8 hours (Lyle, 2000) whereas in 2010 it was down to 4.6 hours (Lyle and Tracey, 2012).

they are amongst the least productive chondrichthyan species known (Ketchen, 1972; Hanchet, 1988; Saunders and McFarlane, 1993; Avsar, 2001), a characteristic that has a major influence in determining the vulnerability ranking.

Within the small mesh fishery, Great Cormorants were ranked as high vulnerability due to their low biological productivity and high mortality rates when they encounter the gear. Rock Flathead and Snook were also ranked as having high vulnerability, predominantly because they are targeted throughout much of their distributional range within Tasmanian waters, which is largely limited to the north coast. In reality, however, small mesh net fishing effort and catches are low and both species have much wider distributions extending throughout southern Australia so the actual vulnerability of the populations as a whole may not be as high as implied by this analysis. Nonetheless, given this result both species should be incorporated in future fishery assessments undertaken by IMAS in support of the management of the TSF (André *et al.*, 2014).

Rankings for several species, particularly among those ranked as medium, were consistent across the PSAs for each of the sub-fisheries. (Table 47). These included most marine mammals and seabirds, and several chondrichthyans and invertebrates. The former three groups share low productivity for which there is likely to be a risk posed by fishing, the invertebrates, however, were categorised as medium due to missing attributes. Given their high productivity and the fact they are only rarely captured in gillnets, there is unlikely to be any real threat posed to any of the invertebrates by gillnetting.

Somewhat surprisingly, seabirds were generally ranked as medium risk and in some instances low risk, despite at least one study suggesting gillnetting is responsible for the decline of Little Penguins (Stevenson and Woehler, 2007). The PSA analysis was conducted using the information we found in the present study in which the encounter rate with penguins was very low. We did not take into account anecdotal reports of higher encounter rates, though had we done so, these species would have been ranked as high risk in most sub-fisheries. Further, the life history of seabirds has been relatively well studied meaning their attributes within the PSA were complete, which reduces the sensitivity of the PSA analysis. These attributes also suggest that most seabirds are reasonably productive.

Draughtboard Shark are a particularly common by-catch in graballs and were ranked as a medium risk across several of the sub-fisheries, primarily due to missing attributes. These attributes relate to fecundity and ageing and reflect the difficulty in estimating the fecundity of oviparous chondrichthyans and ageing Scyliorhinids (their vertebrae tend to be poorly calcified and they do not possess dorsal spines). However, Draughtboard Shark exhibit very high post release survival suggesting that the species warrants being placed in the low risk category.

Due to biological attributes that tend toward high productivity, broad distributional ranges and low level of mesh selectivity, the overwhelming majority of teleost species taken by gillnets in Tasmania were ranked as low vulnerability risk in each of the sub-fisheries. This pattern is consistent with the only other available ecological risk assessment undertaken for a gillnet fishery, the Commonwealth shark fishery (Walker *et al.*, 2007a).

Assessing sub-fisheries separately (and in isolation of other fisheries that might impact individual species) has limitations in that the collective impacts of these fisheries may be underestimated. For instance, some target and non-target species are encountered in several of the gillnet sub-fisheries as well as other Tasmanian (André *et al.*, 2014), interstate and Commonwealth managed fisheries (Walker *et al.*, 2007a; Walker *et al.*, 2007b). While it was beyond the scope of the present study to investigate overlaps with other state and Commonwealth fisheries, it is important that the cumulative impacts of all fisheries are also considered and thus we recognise that risk rankings for some of the species presented in this study may underestimate the full impacts posed by fishing.

Table 47: Summary of level 2 PSA results, included are species to receive PSA vulnerability rankings of medium or high.

'-' indicates species not recorded from that sub-fishery.

	Sub-fishery			
Species	Graball (general)	Banded Morwong	Graball (non-reef)	Small mesh
Marine mammals				
New Zealand Fur-seal	Med	Med	Med	Med
Southern Right Whale	Med	Med	Med	Med
Humpback Whale	Med	Med	Med	Med
Bottlenose Dolphin	Med	Med	Med	Low
Australian Fur-seal	Low	Low	Low	Low
Common Dolphin	Low	Low	Low	Low
Seabirds				
Great Cormorant	Med	Med	Med	High
Shorttailed Shearwater	Med	Med	Med	Low
Little Penguin	Med	Low	Med	Med
Blackfaced Cormorant	Med	Med	Med	Med
Little Pied Cormorant	Med	Med	Med	Med
Chondrichthyans				
Maugean Skate	Low	Low	High	Low
Whitespotted Dogfish	Med	-	High	-
Southern Eagle Ray	Low	Low	Med	Low
Gummy Shark	Med	Med	Med	Low
Great White Shark	Med	Med	Med	Low
Draughtboard Shark	Med	Med	Med	Med
School Shark	Med	Med	Med	Med
Grey Nurse Shark	Med	Med	Med	Med
Australian Angel Shark	Med	Med	-	Med
Broadnose Sevengill Shark	Med	Med	Med	-
Thresher Shark	Med	Med	-	-
Bronze Whaler	Med	-	-	-
Southern Sawshark	Med	Low	Low	Low
Common Sawshark	Med	Med	Med	-
Tasmanian Numbfish	-	-	Med	-
Teleosts				
Rock Flathead	Low	-	-	High
Snook	Med	-	-	High
Bastard Trumpeter	High	Low	Low	Low
Atlantic Salmon	Low	-	High	Low
Rainbow Trout	-	-	High	Low
Banded Morwong	Low	Med	Low	Low
Longsnout Boarfish	Med	Med	Low	Low
Greenback Flounder	Low	Low	Med	Low
Longfinned Pike	Med	Low	Med	Low
Blue Warehou	Med	Low	Med	Low
Globefish	Med	Med	Med	Low
Common Seadragon	Low	Low	Low	Med
Bigbellied seahorse	Low	Low	Low	Med
Old Wife	Med	Low	Low	Med
King George Whiting	Low	-	Low	Med
Bluespotted Flathead	Med	-	-	Med
Red Velvet Fish	Med	Med	-	-
Blue Rock Whiting	-	-	-	Med
Senator Wrasse	Med	Low	-	Low
Ornate Cowfish	Med	-	-	-
Herring Cale	Med	Low	Low	Low
Southern Conger Eel	Med	-	-	Low
Zebra Fish	Med	-	-	Low
Invertebrates				
Spider Crab	Med	-	Med	Med
Speedy Crab	Med	Med	-	-
Piecrust Crab	Med	Med	Med	-
Longspine Sea Urchin	-	Med	-	-

Conclusion

This study is the first to comprehensively assess all sectors of the Tasmanian gillnet fishery in terms of their catch composition (target, by-product, by-catch and interactions with TEPS), how fishing practices affect the survival of by-catch, fisher attitudes and behaviour as a result of management initiatives, and how these factors may have impacted catch composition and species abundances over the past 20 years.

Key findings in relation to each of the project objectives are provided below:

Objective 1 - Synthesise available gillnetting information, with particular reference to links between operational parameters and catch composition

- A range of information available information based on previous research and commercial gillnet catch sampling studies was collated and assessed to examine for regional and temporal changes in target and non-target species abundance (information that was used to address Objectives 2-5).

Objective 2 - Determine catch composition and levels of by-catch associated with the main commercial gillnet fisheries

- Commercial and recreational gillnet catch and effort has declined markedly over the past two decades, driven by a combination of management initiatives and declining abundances of several key target species, in particular Blue Warehou, Banded Morwong and Bastard Trumpeter.
- The recreational gillnet fishery, with the notable exception of Banded Morwong, targets much the same species as the commercial fisheries and there is considerable overlap between sectors in the areas fished.
- For both commercial and recreational sectors (and their sub-fisheries) comparatively few species accounted for the majority of the landings. Catches in the commercial Banded Morwong fishery are dominated by the target species (>85%), only Bastard Trumpeter and Longsnout Boarfish are of any significance amongst the other species harvested. The general graball net fishery (commercial) targets a range of species with Bastard Trumpeter, Blue Warehou and Australian Salmon key components of the catch while Bastard Trumpeter, Blue Warehou and Atlantic Salmon (escapees from fish farms) comprise the main species retained by the recreational gillnet sectors. Catches in the small mesh net fisheries (commercial and recreational), although low, are dominated by Australian Salmon, ‘Pike’ (Snook and Longfin Pike) and Yelloweye Mullet.
- For each of the gillnet fisheries a component of the catch is not retained (by-catch), either because of regulation (size or catch limits, closed seasons, prohibited or protected species) or because of market and/or fisher preferences. The by-catch component, as a proportion of total catch numbers was relatively high; 52% for commercial Banded Morwong fishers, 49% for the general graball fishery, 66% for the small mesh fishery and 35% for the recreational gillnet fishery, although the latter may be an underestimate as it is based on self-reported information.
- By-catch was comprised of a wide diversity of species that included target as well as non-target species, but in terms of overall contribution to by-catch numbers relatively few species accounted for the bulk of the discards.

Objective 3 - Assess implications of recent management changes on recreational netting practices

- Overnight netting was a common practice for recreational fishers prior to its prohibition in most areas in 2004. This ban appears to have had a significant and dual impact on netting effort, not only has it achieved a marked reduction in the proportion of overnight sets but there has been a concomitant and substantial reduction in overall recreational netting effort and this has occurred despite recreational gillnet licence numbers remaining high.

- Virtually all recreational gillnet fishers also engage in other types of recreational fishing, with only a small proportion identifying gillnet fishing as their main recreational fishing activity. These findings suggest that most gillnet fishers would substitute gillnetting for other fishing activities, but does not imply that these fishers would be indifferent should gillnetting opportunities be further restricted or prohibited.

- Amongst gillnet fishers there was general agreement that recent management changes have been effective in improving fishing practices and in reducing wastage and by-catch.

- A minority of recreational fishers (about 25%) reported having ever experienced entanglements of seabirds in gillnets. Most fishers were not supportive of the need for further restrictions to reduce such interactions, considering that existing management measures, including the ban on night netting and maximum soak duration, were sufficient to reduce the risk of accidental entanglements.

Objective 4 - Assess the relationships between gillnet soak times, capture condition and by-catch survival

- Capture condition and delayed mortality rates of gillnet caught fish varied between species and were influenced by operational factors including soak duration and in some instances season.

- Several species were particularly resilient to capture in gillnets, suffering minimal physical damage and low rates of initial and delayed mortality, and thus experience high post release survival (>85%) irrespective of soak duration. Species in this category included Banded Morwong, Bastard Trumpeter, Marblefish, Draughtboard Shark, Purple Wrasse, Leatherjackets (various species), Longsnout Boarfish, Magpie Perch, Greenback Flounder, Melbourne Skate and Maugean Skate. Amongst this group are several of the major by-catch species taken in Tasmanian gillnet fisheries (Marblefish, Draughtboard Shark and Leatherjackets), while others are target species that tend to be mainly retained (Banded Morwong, Bastard Trumpeter, Longsnout Boarfish).

- Species with moderately high post release survival rates (70 – 85%) included Elephantfish, Whitespotted Dogfish and Bluestriped Goatfish. Bluethroat Wrasse also fell within this category, although post release survival rates fell sharply with increasing soak duration, in particular for longer gillnet sets (>5 h). Southern Sand Flathead, Gummy Shark and Jackass Morwong had lower post release survival rates (50 – 70%), while survival rates for a suite of other species tended to be less than 50%. Species such as Blue Warehou, Australian Salmon and Atlantic Salmon were not particularly resilient to gillnet capture (20 – 50% post release survival) but since they tend to be retained, by-catch mortality is a minor issue when compared with the level and impact of harvest on stocks.

- For most of species, capture condition and survival rates declined as gillnet soak duration increased, and a decrease in the current maximum permitted soak duration would improve the survival potential of any discarded catch. However, for the less resilient species which experience relatively high initial mortality rates irrespective of soak time, any reduction in maximum permitted soak duration would be of limited benefit in reducing the impacts of gillnetting on by-catch survival. Conversely, for very resilient species, any decrease in soak duration will have little benefit in increasing survival of by-catch. Discounting overnight sets, species for which shorter soak durations would be most beneficial in reducing initial mortality rates include Bluethroat Wrasse and Jackass Morwong.

Objective 5 - Evaluate the impacts of gillnetting on the biodiversity of key inshore ecosystems and potential strategies to mitigate these impacts

- Banded Morwong, Marblefish, Bluethroat Wrasse and Draughtboard Shark have tended to typify the graball net catch composition off Tasmania's coastal reefs over the past two decades, with Longsnout Boarfish also significant on the Southeast and East coasts and Bastard Trumpeter a key component defining community structure in the Southeast coast.

- The most conspicuous change in gillnet catch composition during the past 20 years has been a decrease in the abundance of Banded Morwong resulting in other species (Draughtboard Shark, Longsnout Boarfish and Marblefish) becoming progressively more prevalent in typifying species composition.

- A number of interactions involving threatened, endangered and protected species were observed in this study, involving Fur Seals, seabirds, Sygnathids, and the endangered Maugean Skate.

    - Fur Seals were commonly observed in the vicinity of gillnets, the majority of direct interactions with the gear typically involved provisioning (removal and consumption of entangled fish). There were no observed instances involving entanglement of seals.
    - Entanglement and drowning of seabirds in gillnets was observed, though these incidences were rare making it difficult to identify contributing factors. Seabird entanglements included Cormorants (three species) and Little Penguins.
    - Sygnathids (Seahorses and Seadragons) were encountered in very low numbers with all individuals appearing to use the gillnet meshes as a substrate on which to hang on and thus were unharmed.
    - The Maugean Skate was caught regularly in gillnets set in depths of between about 5 – 15 m in Macquarie Harbour, one of only two known localities inhabited by the species. Individuals captured during the daytime deployments (< ~6 h) were in excellent condition (typically only lightly meshed) and were lively when released. While the vast majority of individuals caught in overnight sets were also in excellent condition, a small proportion (~ 10%) were either in poor condition, or had died, confirming some by-catch mortality associated with these longer soak durations.

- A formal ecological risk assessment using the ERAEF Framework was conducted based on four sub-fisheries that make up the Tasmanian gillnet fishery. These are the large mesh graball fishery for Banded Morwong (commercial), the general graball net fishery comprised of reef and non-reef sub-fisheries(commercial and recreational), the latter which occurs predominately within shark refuge areas, and the small mesh fishery, which includes the commercial small mesh and recreational mullet net fisheries.

    - Level 1, Scale, Intensity and Consequence Analysis identified that target, by-catch/by-product and TEPS components had consequence scores above moderate for several hazards (principally 'capture by fishing', 'fishing without capture' and 'external hazards').

    - Level 2 Productivity Susceptibility Analysis (PSA) assessment identified a number of species at high risk, each of which was specific to a sub-fishery, a result that reflects differences in mesh selectivity as well as differences in the spatial coverage of the fisheries:
        - Bastard Trumpeter was the only species ranked as high risk in the graball (reef) sub-fishery, largely because inshore reefs represent the core habitat for juveniles and sub-adults and the species is particularly susceptible to gillnet capture.
        - None of the species that interact with the graball (Banded Morwong) sub-fishery were ranked as high risk, predominantly due to the high level of selectivity achieved for the target species by the large mesh size.
        - Atlantic Salmon and Rainbow Trout were ranked as having high vulnerability in the non-reef sub-fishery, but being introduced exotics this is considered to be a positive ranking, with fishing pressure contributing to their removal from the environment. Maugean Skate and Whitespotted Dogfish were also identified as high vulnerability

species, the former has a highly restricted distributional range, presumed low population size and biological attributes are unknown. Whitespotted Dogfish on the other hand are more widely distributed, but are amongst the least productive chondrichthyan species known, a characteristic that has a major influence in determining the vulnerability ranking.

  - Within the small mesh fishery, the Great Cormorant, Rock Flathead and Snook were ranked as having high vulnerability, the latter two species predominantly because they are targeted throughout much of their distributional range in Tasmania. Low catches and distributions that extend throughout southern Australia suggest the actual vulnerabilities may not be as high as implied by this analysis.
  - Most marine mammals, seabirds and several chondrichthyans considered in the PSA were ranked as medium vulnerability, mainly due to low productivity.

- Specific strategies to mitigate the impacts and reduce ecological risks associated with gillnetting are provided in the Recommendations section below.

Implications

Gillnetting is often portrayed as a non-selective and indiscriminate fishing method that results in considerable wastage and incidental mortality of non-target species (Bryan, 2009; Bell, 2010; Glaetzer, 2010). The present study provides the first comprehensive assessment of the impacts of gillnetting in Tasmania with focus on catch composition, levels of by-catch and implications for the survival non-retained catch. Gillnets catch a broad diversity of target and non-target species, determined to some extent by the habitat fished and gear characteristics (in particular mesh size). Discard rates varied from 52%, by number, in the Banded Morwong sub-fishery to 35%, by number, in the recreational fishery, although the latter was based on self-reporting and may be an underestimate. Interestingly, both landings and bycatch are dominated by relatively few species. Furthermore, target species may dominate by-catch, with fishers either required to release/discard target species due to size and catch limits, or, choosing to release them due to perceived poor eating qualities.

Quantities of the majority of species captured by gillnet in Tasmania are relatively low, though the implications for individual species will be determined by population status, life history stages susceptible to gillnet capture and other population stressors (including fishing pressure exerted by other methods). Thus, in assessing the implications of gillnetting for by-catch and biodiversity, it is necessary to recognise the direct impacts on the target species (sustainability of harvest levels), implications for non-target species, either due to removals (taken as by-product) or incidental mortality and/or potential sub-lethal impacts arising from capture. Fishing practices, including soak duration, gear characteristics (mesh size, monofilament gauge, hanging ratios) and fish handling procedures as well as habitat and environmental conditions (including water temperature) contribute to determining catch composition and fate of by-catch.

Recent management initiatives, especially the recreational ban on night netting, the introduction of maximum soak durations and the introduction of a quota system for Banded Morwong (and recent quota reductions), along with non-transferability of selected commercial licence categories have contributed to recent declines in gillnet catch and effort for both sectors. Perhaps the most significant management change has been the prevention of recreational night netting which, along with maximum soak durations appears to have substantially improved recreational fishing practices by reducing the level of wastage (spoilage, damage due to predation or over limit catches) that was associated with the common practice of leaving nets unattended for excessive periods of time, often up to 24 hours or more (Lyle, 2000). The results of the present study clearly display that gillnet soak duration results in increased mortality (both IM and DM due to decreased fish condition); however, the benefits of reducing maximum permitted soak durations were ambiguous with species abundance, as measured by catch per unit effort of gillnets, being highly spatially and temporally variable. As a result, there were no clear increases in abundance following the implementation of these improved management measures.

Notwithstanding these improvements, there is significant latent capacity in the recreational sector to activate and increase effort (there is no limit on the total numbers of recreational gillnet licences that can be issued) should opportunities arise, as is the case when large escape events of salmonids occur or target species such as Blue Warehou are abundant in Tasmania waters. Commercial fishers can also be responsive to the availability of target species but it is possible to manage this sector more directly by imposing either trip limits (e.g. Bastard Trumpeter, Striped Trumpeter , Longsnout Boarfish), quotas (Banded Morwong) or total allowable catches (SESSF for Blue Warehou).

Banded Morwong, Bastard Trumpeter, Blue Warehou, Australian Salmon, Longsnout Boarfish and Atlantic Salmon collectively account for the bulk of the retained catch taken by commercial and recreational gillnets in Tasmania. Banded Morwong, Blue Warehou and Bastard Trumpeter populations have each been impacted by fishing. Banded Morwong is classified transitional depleting (André *et al*., 2014) and is managed by output controls (quotas), whereas as Blue Warehou is classified as overfished (Woodhams *et al*., 2012) and the subject of stock rebuilding strategy by the Commonwealth (Anon, 2012). Bastard Trumpeter, on the other hand, do not have a stock assessment available; however, based on the steady decline in commercial production, historic trends in catches (Harries and Croome, 1989; Frijlink and Lyle, 2013) and underwater visual census (Barrett *et al.*, 2007; Stuart-Smith *et al.*, 2008), it is clear that stocks have been impacted by gillnetting. Therefore, there may be a need to implement additional measures, such as no netting areas and review trip and bag limit regulations to reduce pressure on Bastard Trumpeter stocks, noting that the recreational sector currently dominates the catch. Of the other main gillnet species, Australian Salmon is classified as sustainable (Flood *et al.*, 2012), Longsnout Boarfish has not been assessed (André *et al*., 2014), while Atlantic Salmon (and Rainbow Trout) represent escapees from marine farms and the targeted fisheries are largely opportunistic.

Based on post release survival, species could be grouped broadly in accordance with their resilience to capture. In relation to the main by-catch species - Draughtboard Shark, Banded Morwong, Marblefish, Bluethroat Wrasse, Leatherjackets and Skates/Rays – all apart from Bluethroat Wrasse were resilient to gillnet capture, with high PRS, implying that the impacts of fishing should be minor. In addition to this group, Longsnout Boarfish, Magpie Perch, Purple Wrasse and Flounder exhibited very high PRS (> 85%); Elephant fish, Jackass Morwong, Gummy Shark, Bluestriped Goatfish, Southern Sand Flathead, Whitespotted Dogfish exhibited moderate PRS (50 – 80%); Australian Salmon, Atlantic Salmon, Blue Warehou and Herring Cale exhibited low PRS (20 – 45%); and Red Cod, Yelloweye Mullet, Blue Grenadier and Silverbelly exhibited very poor PRS (<20%). These differing species specific vulnerabilities have implications for effectiveness of management measures such as soak time regulations that are designed to reduce impacts on by-catch.

Condition and survival rates declined for most species as gillnet soak durations increased, and thus any decrease in the current maximum permitted soak duration of six hours would improve the survival potential of many species if released, especially those in the moderate PRS category. For the very high and very poor PRS groups, shorter maximum soak durations would be of limited benefit in improving survival rates because, for the former, survival rates are high irrespective of soak duration, whereas for the latter, these species experience relatively high IM rates regardless of soak duration. Even with a two hour maximum soak time in SRAs, incidental mortalities of sharks, in particular Gummy Shark, appear inevitable. There was insufficient information to assess by-catch levels or survival for School Shark but given the status of this species (classified as overfished, Woodhams *et al.*, 2012) and the role of SRAs as pupping and nursery areas, any incidental mortality due to gillnetting is of concern.

Due to interactions with seabirds and Little Penguins in particular, there has been considerable public support for netting closures around known rookeries; either spatial or during times when penguins are actively moving to and from the rookeries. The recent prohibition on overnight netting is likely to have reduced the incidental capture of penguins, which are active early in the morning and late evening, times that nets are now generally no longer in the water. It is unlikely, however, that the introduction of maximum soak durations will have much of an impact on increasing survival of entangled seabirds since drowning is likely to occur soon after entanglement, and certainly within timeframes much shorter than even shortest practical set times. Attended netting has been proposed as a strategy to help address this issue, but has been opposed by most gillnet fishers (Frijlink and Lyle, 2012). Although not observed in this study, there are occasional reports of large numbers of Short-tailed Shearwaters entangled in gillnets, suggesting that if flocks of these birds are present gillnets should not be deployed.

It is evident from this study that the endangered Maugean Skate is particularly susceptible to capture in gillnets in Macquarie Harbour, especially when nets are deployed at 5 – 15 m depth. This species appears to be distributed widely through Macquarie Harbour and, although apparently robust and likely to survive the vast majority of encounters, especially short daytime sets, we did identify the potential for mortalities to occur in overnight sets. These findings have a number of implications regarding the continuance of overnight netting and there is a need to develop strategies to minimise impacts.

The present study has identified long-term declines in the abundance of several species that appear to be linked with the impacts of fishing; for instance the decline in Banded Morwong can be explained by extractive fishing and mirrors that of modelling for stock assessment (Hartmann and Lyle, 2011). Although Bastard Trumpeter and Blue Warehou populations have been impacted by gillnetting, recruitment variability in the former and variability in availability in Tasmanian waters for the latter have tended to dominate long-term patterns. Also of interest was the decline in Marblefish and Draughtboard Shark abundances, especially during the 1990s and early 2000s, which given the high discard rates and high post release survival for both species, suggests that poor fishing practices, including leaving gillnets unattended for extended periods and purposeful killing of by-catch, may have been factors.

Recommendations

This study has identified a number of issues that have particular relevance to the future management of gillnetting in Tasmania, noting that gillnet usage has emerged as an area of particular focus in the 2014 review of the Scalefish Management Plan. In this regard, submissions to this review that relate to the banning of recreational gillnets on the grounds that it is not a fishing method that aligns with the 'ethos of recreational fishing', recreational use of gillnets is not consistent with mainland states, gillnetting is a non-discriminate fishing method (especially when used by inexperienced operators) that impacts both target and non-target species, by-catch survival is assumed to be poor, catch limits can be exceeded (resulting in wastage), interactions with wildlife (seabirds and mammals) and other TEPS result in mortalities, and gear losses result in ghost fishing, have been received. Other submissions focus on strategies to reduce interactions with seabirds, the Maugean Skate in Macquarie Harbour, and expansion of no-netting areas to provide specific protection for vulnerable fish species, in particular Bastard Trumpeter. While it is beyond the scope of the present study to make firm recommendations on whether or not gillnetting should be banned this study does provide key information that will assist in informing this debate.

There is little doubt that gillnetting in Tasmania has had demonstrable impacts on the populations of the key target species, Banded Morwong, Bastard Trumpeter and Blue Warehou:

- In relation to Banded Morwong, management arrangements that include quota management for the commercial sector and defined reference points are now in place to effectively manage this fishery for long-term sustainability, this is not the case for the other two species.

- Bastard Trumpeter stocks have been impacted by many years of heavy netting pressure and are likely to be in a depressed state, with the occasional good recruitment event sustaining the population. The gillnet fishery for Bastard Trumpeter is based almost entirely on juveniles, with adults apparently moving offshore into deep waters where they are occasionally taken by Commonwealth fishers (by-catch in shark nets or deep water fish traps), and thus growth overfishing is a possibility. Commercial landings of the species are at current historic lows, partly influenced by low market demand and recent management initiatives (including introduction of a trip limit), whereas recreational catches have remained relatively stable over the past two decades and this sector now dominates the fishery (André *et al*., 2014). An increase in LML to match the size at maturity would mean that the vast majority, if not all Bastard Trumpeter, caught by graballs would be sub-legal. Implementation of no-netting areas represents an alternative strategy to provide protection to the juvenile Bastard Trumpeter; such areas would need to recognise that the species is relatively mobile (Murphy and Lyle, 1999; Buxton *et al*., 2010) and thus would need to be relatively large in order to be effective. Clearly such a strategy would have implications for other gillnet fisheries (e.g. Banded Morwong fishery) in which Bastard Trumpeter are a very minor component of the catch and thus would be unpopular amongst netters. Given reported improvements in overall fishing quality in some areas where netting has been removed (e.g. Duck Bay, Georges Bay) such initiatives may, however, receive support from the wider fishing community.

- Commonwealth trawl and deepwater gillnet fisheries were mainly responsible for overfishing Blue Warehou stocks during the 1990s but at that time significant catches were also taken by recreational and commercial gillnet sectors in Tasmanian waters (up to 400 t in some years), contributing to this situation. Both Tasmanian sectors remain responsive to the seasonal availability of the species and thus it is recommended that catches be monitored closely given the overfished status of the stocks and efforts to rebuild stocks by the Commonwealth.

Based on the current maximum gillnet soak time regulations and appropriate handling of by-catch, post release survival of many of the key by-catch species is expected to be high. While there would be some benefit, albeit only minor, for by-catch survival in reducing the maximum soak time to less than six hours, the prohibition on night netting and introduction of the soak time regulations appear to have been quite successful in reducing wastage and impacts on non-target species.

Interactions with seabirds, in particular vulnerable species such as Penguins, appear to be an inevitable consequence of gillnetting in shallow coastal waters:

- In order to minimise such impacts it is recommended that consideration be given to establishing no-netting areas around key colonies, such an initiative would reduce the likelihood of incidentally capturing large groups of individuals. The size and location of such areas should be informed by groups with expertise in penguin populations, biology and behaviour. Outside of the main colonies, however, it is recognised that the present ban on night netting is likely to have reduced interactions with individuals travelling to and from nesting sites, particularly because penguins tend to return to their colonies during the early evening when gillnets are no longer permitted to be used..

- Although not observed in this study, large numbers of Short-tailed Shearwaters have occasionally been caught in gillnets in Tasmania. Such occurrences arise from flocks of feeding birds encountering gillnets in shallow waters thus such interactions would be difficult to predict in both space and time. Nevertheless, avian experts may be able to provide insight into temporal and spatial patterns that could be used to minimise interactions. Development of a code of practice for gillnet usage that involves the cessation of gillnet activities while large flocks of Short-tailed Shearwaters are present in an area would undoubtedly reduce the risk of interactions.

Maugean Skate are susceptible to capture in gillnets and although the vast majority are expected to survive, some mortalities, especially in overnight sets, occur. As a listed endangered species, options to reduce such interactions should be considered. There are a number of strategies that would help to miminise Maugean Skate by-catch and mortality, these include a ban on overnight netting (bringing Macquarie Harbour into line with the remainder of the state), an expansion of the areas closed to netting, and/or restricting gillnet usage to shallow waters. Mauguean Skate are distributed widely throughout Macquarie Harbour so any expansion of the no netting area (currently around the entrance to the Gordon River in the upper reaches of the system) would provide additional protection. The implemention of a strategy based on fishing depths may be best achieved through a code of practice and education, noting that from our data and reports from experienced local fishers, the main target species – Salmonids and Flounder – are most commonly caught in shallow areas (< ~5 m). By deploying gillnets in shallow waters fishers are able to reduce, or avoid, catching Maugean Skate as well as Whitespotted Dogfish, which are considered a nuisance speices by fishers.

Further development

There are a number of areas for further development that follow on from this study. Significant progress was achieved in understanding the relationships between factors such as soak time, capture condition and post release survival for the main gillnet species. There is, however, scope to expand this to include factors such as how mesh size, hanging ratio and line diameter influences catch composition (including levels of by-catch) and catch condition, noting that for some species, how they were meshed influenced capture condition, which in turn influenced survival. Fish handling, including how fish are removed from the meshes, is also likely to influence the survival of individuals when released. In addition, it was not possible to retain the larger species for PRS studies (e.g. Gummy Shark), or those that were caught in remote areas (e.g. Macquarie Harbour) in the present study. Benefits would be gained by further research into post release survival for species such as Gummy Shark, Whitespotted Dogfish and Maugean Skate as each have significance from either a conservation or economic viewpoint.

There is a need to better understand the extent and nature of interactions between seabirds and gillnetting; this would assist in assessing the impacts on seabird populations, help identify factors that contribute to these interactions and evaluate the effectiveness of management measures intended to reduce such impacts (e.g. spatial closures around rookeries).

The present study has highlighted the nature of interactions with the Maugean Skate in Macquarie Harbour. A project that seeks to further develop this theme, with specific aims to determine population status, biology, movement and habitat usage of the species and implications for fishing (especially gillnetting) and aquaculture operations has recently commenced with funding provided by FRDC (Movement, habitat utilisation and population status of the endangered Maugean skate and implications for fishing and aquaculture operations in Macquarie Harbour, FRDC 2013/008). In addition, this project has incorporated a component that seeks to understand the dispersal patterns of escapee salmonids within the Harbour, as this has relevance not only for the commercial fish-down of major escape events but also fishing activities of recreational gillnetters targeting salmonids.

As established in the present study, commercial and recreational gillnetting is heavily focussed on shallow coastal reef habitats targeting species such as Banded Morwong, Bastard Trumpeter and Blue Warehou, with Longsnout Boarfish, Wrasse, Marblefish and Draughtboard Shark also commonly caught. Most of these species also occur in deeper offshore reefs and such habitats may, therefore, be important refuges from fishing pressure and, for Bastard Trumpeter (and Striped Trumpeter) possibly represent critical adult habitat. The lack of quantitative information on the significance of such deep reef habitats as refuges, and/or their role in population structuring, limits our ability to undertake informed risk assessments of the impacts of current fishing practices and evaluate alternative management options. Addressing these questions is the subject of a recently funded research proposal (Tasmania's coastal reefs: deep reef habitats and significance for finfish production and biodiversity, FRDC 2014/012).

Overall, this project has successfully covered many of the issues regarding gillnet fishing in Tasmania and its impacts on fish communities as well as highlight the value of gathering long term datasets. Future studies using gillnets should therefore endeavour to record data that is compatible with that of the present study to enable expansion of the present findings.

Extension and Adoption

Gillnetting is generally perceived as a non-selective and destructive fishing method within the general community and its future management, including continuation of recreational gillnetting has been identified as a key issue in the 2014 Tasmanian Scalefish Fishery Management Plan review. The present study provides the first quantitative assessment of the impacts of gillnet fishing in Tasmania and is expected to play a crucial role in dictating the future management of this gear type within both recreational and commercial fishing sectors.

The results of this study will be used by fishery managers and stakeholder groups as an important reference source on which to inform decision making as part of the Tasmanian Scalefish Fishery Management Plan review.

- A number of specific issues relevant to the future management of gillnetting in Tasmania have been proposed for consideration as part of the 2014 review of the Scalefish management plan but at the time of publication remain subject to Ministerial approval before they can be released for public consultation (a change in the government of Tasmania has resulted in this approval being delayed). As the present study directly addresses a number of the issues likely to be approved for public consultation it is intended that IMAS will provide a formal submission to the review based on findings from this study.

To date, progress and results of the study have been communicated formally to the peak recreational and commercial fishing bodies and resource managers on a number of occasions, in addition to on-going informal communications:

- The project aims and preliminary findings were presented to the board of the recreational peak body, the Tasmanian Association for Recreational Fishing (TARFish) in September 2011, seeking feedback from its members, particularly in regard to the recreational use of gillnets.
- A project update was provided to the Recreational Fishery Advisory Committee (RecFAC) in November 2011.
- Findings from the present study, including information relevant to target, by-catch and TEP interactions, were presented at an Ecological Risk Assessment (ERA) Workshop for the Tasmanian Scalefish Fishery. The workshop, conducted in July 2013 was chaired by Professor Greg Jenkins (University of Melbourne) and participants included representatives from DPIPWE (Marine Resources Branch and Resource Management and Conservation Branch), key industry stakeholders, RecFAC, the Scalefish Fishery Advisory Committee (SFAC), and IMAS researchers. A report from that workshop is in the final stages of preparation. It should be noted that the ERA presented in this report represents a much more in-depth analysis.
- Key findings were presented separately to RFAC and SFAC during September 2013, and included a focus on catch composition, by-catch, effects of soak times on condition and survival, long-term trends in fish abundances and TEPS interactions. These presentations were timed to assist these groups in determining issues to be developed for public consultation as part of the management plan review.
- Findings relevant to wildlife interactions, in particular seabirds and Maugean Skate, were presented to DPIPWE's Resource Management and Conservation Branch in October 2013 to provide information to assist that group in determining issues to be raised for consideration as part of the management plan review.

The full report will be made available to key stakeholder groups (commercial and recreational sectors, resource managers and conservation groups) in Tasmania in addition to summary articles prepared for key industry (*Fishing Today* and *Fish*) and recreational fishing magazines (*Tasmanian Fishing and Boating News*). Results will also be presented at a conference, which will inform researchers and managers on key outcomes of this study.

A number of scientific publications are planned from this research, these include:

- Post release survival of common by-catch of Tasmanian gillnet fisheries – this paper will examine post release survival of Banded Morwong, Bastard Trumpeter, Bluethroat Wrasse, Draughtboard Shark and Marblefish.
- Estimating post release survival of gillnet caught fish using mark-recapture techniques – this paper will describe the attempt to apply mark-recapture techniques in the present study and discuss how species specific size selectivity can confound results.

- Effect of gillnet soak time on the condition and survival of gillnet caught fish – this paper will detail the effects of soak duration on fish condition, IM and PRS.

Project coverage

The project has been covered in print and radio media:

- A media release in late July 2010 resulted in an article about the project being published in *The Mercury* newspaper on 30 July 2010 and the project being covered on local ABC radio news. The PI interviewed for ABC's Country Hour on 30 July 2010 about the project.

- An article about the project was published in *Fishing Today* (Vol 23 (4); p26).

Articles are being prepared for the September 2014 edition of *Fishing Today* and *Tasmanian Fishing and Boating News* (recreational fishing magazine) to highlight the key findings of this study and we expect to provide an article on the project for FRDC's *Fish* magazine.

Appendix 1: Staff list

Dr Jeremy Lyle
Dr Ben Chuwen (2010-2012)
Dr Justin Bell (2012-2014)
Prof Colin Buxton
Dr Neville Barrett
Dr Sean Tracey
Edward Forbes
Amos Mapleston
Graeme Ewing

Appendix 2: Intellectual Property

The research relating to this project is for the public domain and the report and any resulting publications are intended for broad dissemination and promotion.

Appendix 3: Data summaries and additional statistical analyses

Table A1. 1: Common and scientific names of the species encountered during the present study.

Chondrichthyans and teleosts

Common name	Scientific name	Common name	Scientific name
Atlantic Salmon	*Salmo salar*	Maori Wrasse	*Ophthalmolepis lineolatus*
Austalian Bonito	*Sarda australis*	Marblefish	*Aplodactylus arctidens*
Australian Angelshark	*Squatina australis*	Maugean Skate	*Zearaja maugeana*
Australian Salmon	*Arripis spp.*	Melbourne Skate	*Raja whitleyi*
Banded Morwong	*Cheilodactylus spectabilis*	Mirror Dory	*Zenopsis nebulosus*
Banded Stingaree	*Urolophus cruciatus*	Mosaic Leatherjacket	*Eubalichthys mosaicus*
Barber Perch	*Caesioperca rasor*	Old Wife	*Enoplosus armatus*
Barracouta	*Thyrsites atun*	Orange Spotted Catshark	*Asymbolus sp.d*
Bastard Trumpeter	*Latridopsis forsteri*	Ornate Cowfish	*Aracana ornata*
Bearded Rock Cod	*Pseudophycis barbatus*	Pink Ling	*Genypterus blacodes*
Big/Pot-Belly Seahorse	*Hippocampus sp.*	Porcupine Fish	*Allomycterus pilatus*
Bigscale Bullseye	*Pempheris multiradiata*	Port Jackson Shark	*Heterodontus portusjacksoni*
Blue Grenadier	*Macruronus novaezealandia*	Prickly Toadfish	*Contusus brevicaudas*
Blue Mackerel	*Scomber australasicus*	Purple Wrasse	*Notolabrus fucicola*
Blue Warehou	*Seriolella brama*	Rainbow Cale	*Odax acroptilus*
Blue Weed-Whiting	*Haletta semifasciata*	Rainbow Trout	*Oncorhynchus mykiss*
Bluespotted Goatfish	*Upeneichthys vlamingii*	Real Bastard Trumpeter	*Mendosoma lineatum*
Bluestriped Goatfish	*Upeneichthys lineatus*	Red Cod	*Pseudophycis bachus*
Bluethroat Wrasse	*Notolabrus tetricus*	Red Gurnard	*Chelidonichthys kumu*
Broadnose Shark	*Notorhynchus cepedianus*	Red Velvetfish	*Gnathanacanthus goetzeei*
Brown Trout	*Salmo trutta*	Redbait	*Emmelichthys nitidus*
Brownstriped Leatherjack	*Meuschenia australis*	Ringed Toadfish	*Omegophora armilla*
Butterfly Gurnard	*Lepidotrigla vanessa*	Rock Blackfish	*Girella elevata*
Butterfly Mackerel	*Gasterochisma melampus*	Rock Ling	*Genypterus tigerinus*
Butterfly Perch	*Caesioperca lepidoptera*	Rosy Wrasse	*Pseudolabrus psittaculus*
Common Gurnard Perch	*Neosebastes scorpaenoides*	Rusty Carpetshark	*Parascyllium ferrugineum*
Common Sawshark	*Pristiophorus cirratus*	Southern Sand Flathead	*Platycephalus bassensis*
Common Seadragon	*Phyllopteryx taeniolatus*	Scalyfin	*Parma victoriae*
Common Stargazer	*Kathetostoma laeve*	School Shark	*Galeorhinus galeus*
Draughtboard Shark	*Cephaloscyllium laticeps*	Sea Sweep	*Scorpis aequipinnis*
Dusky Morwong	*Dactylophora nigricans*	Senator Wrasse	*Pictilabrus laticlavius*
Elephantfish	*Callorhynchus milii*	Sergeant Baker	*Aulopus purpurissatus*
Globefish	*Diodon nichthemerus*	Shaw's Cowfish	*Aracana aurita*
Greenback Flounder	*Rhombosolea tapirina*	Silver Dory	*Cyttus australis*
Grey Morwong	*Nemadactylus douglasi*	Silver Drummer	*Kyphosus sydneyanus*
Gummy Shark	*Mustelus antarcticus*	Silver Sweep	*Scorpis lineolata*
Gunn's Leatherjacket	*Eubalichthys gunnii*	Silver Trevally	*Pseudocaranx dentex*
Herring Cale	*Odax cyanomelas*	Silverbelly	*Parequula melbournensis*
Horseshoe Leatherjacket	*Meuschenia hippocrepis*	Sixspine Leatherjacket	*Meuschenia freycineti*
Jack Mackerel	*Trachurus declivis*	Smooth Stingray	*Dasyatis brevicaudatus*
Jackass Morwong	*Nemadactylus macropterus*	Snook	*Sphyraena novaehollandiae*
King George Whiting	*Sillaginodes punctatus*	Southern Shortfin Eel	*Anguilla australis*
Largescaled Flounder	*Ammotretis macrolepis*	Southern Eagle Ray	*Myliobatis australis*
Long Snouted Flounder	*Ammotretis rostratus*	Southern Red Scorpionfish	*Scorpaena papillosa*
Longfin Pike	*Dinolestes lewini*	Southern Sawshark	*Pristiophorus nudipinnis*
Longsnout Boarfish	*Pentaceropsis recurvirostris*	Sparsely-Spotted Stingaree	*Urolophus paucimaculatus*
Luderick	*Girella tricuspidata*	Spiny Gurnard	*Lepidotrigla papilio*

Magpie Perch	*Cheilodactylus nigripes*	Spotted Pipefish	*Stigmatopora argus*

Table A1. 1 continued: Common and scientific names of the species encountered during the present study.

Chondrichthyans and teleost (continued)	
Stars-And-Stripes Leatherjacket	*Meuschenia venusta*
Striped Trumpeter	*Latris lineata*
Tailor	*Pomatomas saltatrix*
Tasmanian Numbfish	*Narcine tasmaniensis*
Thetis Fish	*Neosebastes thetidis*
Thornback Skate	*Raja lemprieri*
Tiger Flathead	*Neoplatycephalus richardsoni*
Toothbrush Leatherjacket	*Acanthaluteres vittiger*
Velvet Leatherjacket	*Parika scaber*
White-Ear	*Parma microlepis*
Whitespotted Dogfish	*Squalus acanthias*
Whitespotted Skate	*Raja cerva*
Yelloweye Mullet	*Aldrichetta forsteri*
Yellowstriped Leatherjacket	*Meuschenia flavolineata*
Yellowtail Kingfish	*Seriola lalandi*
Zebrafish	*Girella zebra*
Aves	
Black Faced Cormorant	*Phalacrocorax fuscescens*
Great Cormorant	*Phalacrocorax carbo*
Little Pied Cormorant	*Microcarbo melanoleucos*
Little Penguin	*Eudyptula minor*
Invertebrates	
Blacklip Abalone	*Haliotis rubra*
Cleft-Fronted Shore Crab	*Plagusia chabrus*
Cuttlefish Sp.	*Sepia sp.*
Eleven-Arm Seastar	*Coscinasterias muricata*
Gould's Squid	*Nototodarus gouldi*
Great Spider Crab	*Leptomithrax gaimardii*
Longspine Sea Urchin	*Centrostephanus rodgersii*
Maori Octopus	*Octopus maorum*
Nectria Sp.	*Nectria sp.*
Northern Pacific Seastar	*Asterias amurensis*
Pie Crust Crab	*Metacarcinus novaezelandiae*
Red Rock Crab	*Plagusia chabrus*
Rough Seastar	*Uniophora granifera*
Sea Cucumber	*Holothuroidea*
Sea Tulip	Pyuridae
Southern Calamari	*Sepioteuthis australis*
Southern Rocklobster	*Jasus edwardsii*
Sponge	Porifera
Unidentified Urchin	*Echinometridae*
Velvet Crab	*Nectocarcinus tuberculosus*
Alga	
Ecklonia	*Ecklonia radiata*
Kelp	Alariaceae

Table A1. 2: Total retained catch (kg) from graball nets by fishing region (refer Figure 1) for the period January 2011 – April 2013 as reported by fishers with a Banded Morwong licence (Yes) and those without (No).

Data are based on General Fishing Catch Returns. *Undefined region refers to landings for which no regional data were reported in the logbook or incorrect/unreliable data were reported. Southeast SRA includes Norfolk and Frederick Henry Bays.

	Northeast coast		East coast		Southeast coast		Region undefined*		Northwest coast	Tamar estuary	Southeast SRA	West coast	Macquarie Harbour	
Species	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No	No	Total
Banded Morwong	0	8292	0	55393	0	25111	0	4941	0	0	0	0	0	93737
Australian Salmon	5371	0	2087	0	5227	10	17	0	3541	841	4	388	24	17510
Bastard Trumpeter	210	76	1474	2236	4974	1395	253	180	199	0	130	5645	140	16913
Blue Warehou	42	0	5518	50	5179	847	44	126	128	2	20	181	20	12156
Longsnout Boarfish	33	147	353	3121	75	1094	2	101	8	0	13	1	0	4948
Atlantic Salmon	0	0	0	0	95	0	0	0	0	0	0	0	4524	4619
Bluethroated wrasse	617	264	196	349	1524	302	161	46	305	109	10	79	0	3961
Gummy Shark	2754	0	71	72	398	59	27	8	237	11	0	12	0	3649
Bearded Rock Cod	5	0	75	7	59	2	19	9	9	27	6	2856	285	3359
Striped Trumpeter	0	0	252	222	209	98	23	10	32	0	0	2244	94	3184
Elephantfish	2084	0	2	4	176	25	70	0	149	79	14	0	0	2603
Rainbow Trout	0	0	0	0	0	0	0	0	0	0	0	0	2234	2234
Jackass Morwong	9	0	939	389	426	74	16	7	17	0	1	4	0	1882
Purple Wrasse	178	0	46	153	379	197	17	9	207	43	8	259	0	1495
Silver Trevally	785	0	39	4	11	0	57	0	297	204	0	50	0	1447
Southern Sand Flathead	548	0	16	149	250	49	6	5	15	67	14	0	0	1118
Leatherjackets (unspecified)	587	84	33	1	100	9	1	0	114	70	6	0	0	1005
Greenback Flounder	120	0	0	0	1	0	0	0	2	654	51	0	109	937
Magpie Perch	44	99	80	192	3	6	1	0	380	32	3	0	0	840
Bluespotted Flathead	725	0	0	0	0	0	0	0	0	0	0	0	0	725
Broadnose Shark	240	7	0	0	317	0	27	0	0	0	0	20	0	611
Yelloweye Mullet	180	0	0	0	0	0	3	0	0	379	0	0	0	562
Jack Mackerel	9	0	9	0	377	120	0	0	1	0	0	0	0	516
Trevalla (unspecified)	0	0	0	0	493	0	0	0	7	0	0	0	0	500
Marblefish	6	0	9	0	175	58	27	0	49	0	0	155	0	479

	Northeast coast		East coast		Southeast coast		Region undefined*		Northwest coast	Tamar estuary	Southeast SRA	West coast	Macquarie Harbour	
Species	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No	No	Total
Herring Cale	237	1	2	0	0	1	0	0	102	117	0	3	0	463
Thresher Shark	6	0	0	12	390	0	0	0	28	0	0	0	0	436
Boarfish (unspecified)	3	0	12	292	3	0	0	50	0	0	0	0	0	360
Luderick	15	3	0	30	10	4	0	0	243	0	0	22	0	327
Ocean Perch	11	0	4	63	91	83	0	3	21	0	0	0	0	275
Southern Calamari	27	0	31	72	34	15	0	0	4	10	30	30	0	253
Longfin pike	132	0	0	0	0	0	0	0	0	86	0	0	0	218
Bluestriped Goatfish	84	0	0	0	0	0	0	0	3	115	0	0	0	202
Draughtboard Shark	6	0	0	25	25	140	5	0	0	0	0	0	0	201
Rock Flathead	196	0	0	0	0	0	0	0	2	0	0	0	0	198
King George Whiting	108	0	0	0	0	0	2	0	9	64	0	0	0	182
Sweep	7	14	0	0	0	13	0	0	145	0	0	0	0	179
Conger Eel	0	0	0	0	20	0	0	0	5	0	0	148	0	173
Cod (unspecified)	2	0	0	4	155	0	1	0	8	1	0	0	0	171
School Shark	0	0	0	6	40	12	55	0	26	0	0	12	0	151
Blue Morwong	0	8	0	140	0	0	0	0	0	0	0	0	0	148
Trumpeter (unspecified)	0	0	0	0	95	0	0	0	0	0	0	50	0	145
Skates & Rays (unspecified)	0	0	0	0	33	0	18	0	70	0	0	22	0	143
Barracouta	23	0	0	0	105	0	0	0	7	6	0	0	0	141
Yellowtail Kingfish	2	0	0	0	119	10	0	0	4	0	0	0	0	135
Mullet (unspecified)	127	0	0	0	0	0	0	0	0	0	0	0	0	127
Blue Mackerel	0	0	5	100	0	0	0	0	0	11	0	0	0	116
Butterfish	90	0	0	0	0	0	0	0	0	15	0	0	0	105
Bronze Whaler	5	0	96	0	0	0	0	0	0	0	0	0	0	101
Other (44 species)	190	10	70	100	383	57	34	16	54	20	43	115	0	1091

Table A1. 3: The retention rate of each species caught by commercial fishers by sub-fishery (based on-board observations).

	Banded Morwong		Standard graball		Small mesh		
Species	Number caught	Proportion retained	Number caught	Proportion retained	Number caught	Proportion retained	Total caught
Banded Morwong	1619	0.790	25	0.000	0	-	1644
Draughtboard Shark	498	0.014	18	0.000	9	0.000	525
Bluethroat Wrasse	153	0.030	38	0.421	213	0.005	404
Marblefish	370	0.014	6	0.167	10	0.000	386
Longsnout Boarfish	187	0.428	7	0.571	2	1.000	196
Bastard Trumpeter	109	0.826	81	0.790	0	-	190
Toothbrush Leatherjacket	7	0.143	0	-	74	0.000	81
Blue Warehou	2	1.000	19	0.895	52	1.000	73
Purple Wrasse	51	0.078	2	0.500	14	0.357	67
Bluestriped Goatfish	0	-	0	-	61	0.967	61
Australian Salmon	0	-	11	0.909	37	1.000	48
Herring Cale	28	0.000	0	-	18	0.000	46
Jackass Morwong	16	0.813	11	1.000	0	-	27
Magpie Perch	1	0.000	0	-	22	0.864	23
Melbourne Skate	1	0.000	12	0.000	3	0.000	16
Snook	1	0.000	0	-	11	1.000	12
Bigscale Bullseye	10	0.000	1	0.000	0	-	11
Longfin Pike	10	0.300	1	0.000	0	-	11
Barracouta	0	-	0	-	10	1.000	10
Brownstriped Leatherjack	1	0.000	4	0.000	5	0.000	10
Shaw's Cowfish	10	0.000	0	-	0	-	10
Yellowstriped Leatherjacket	0	-	0	-	10	0.000	10
Common Gurnard Perch	1	0.000	2	0.0	5	0.000	8
Velvet Leatherjacket	2	0.500	0	-	6	0.000	8
Banded Stingaree	7	0.000	0	-	0	-	7
Barber Perch	0	-	0	-	7	0.000	7
Red Cod	4	0.000	2	1.000	0	-	6
Silver dory	6	0.000	0	-	0	-	6
Sixspine Leatherjacket	5	0.800	0	-	1	0.000	6
Zebrafish	0	-	0	-	6	0.000	6
Scalyfin	0	-	0	-	5	0.000	5
Blue Mackerel	0	-	0	-	4	0.250	4
Jack Mackerel	3	0.000	1	0.000	0	-	4
Silver Trevally	0	-	0	-	4	0.000	4
Elephantfish	0	-	3	0.667	0	-	3
Greenback Flounder	3	1.000	0	-	0	-	3
Gummy Shark	0	-	3	0.000	0	-	3
King George Whiting	0	-	0	-	3	1.000	3

	Banded Morwong		Standard graball		Small mesh		
Species	Number caught	Proportion retained	Number caught	Proportion retained	Number caught	Proportion retained	Total caught
Port Jackson Shark	3	0.000	0	-	0	-	3
Rainbow Cale	3	0.000	0	-	0	-	3
Silverbelly	0	-	0	-	3	0.000	3
Butterfly Perch	2	0.000	0	-	0	-	2
Globefish	2	0.000	0	-	0	-	2
Grey Morwong	2	1.000	0	-	0	-	2
Gunn's Leatherjacket	2	0.000	0	-	0	-	2
Longspine Sea Urchin	2	0.000	0	-	0	-	2
Real Bastard Trumpeter	2	0.000	0	-	0	-	2
Red Velvetfish	2	0.000	0	-	0	-	2
Rosy Wrasse	2	0.000	0	-	0	-	2
Sand Flathead	0	-	2	0.000	0	-	2
Senator Wrasse	2	0.000	0	-	0	-	2
Sergeant Baker	0	-	0	-	2	0.000	2
Silver Sweep	0	-	0	-	2	0.500	2
Southern Rocklobster	2	1.000	0	-	0	-	2
Southern Sawshark	2	1.000	0	-	0	-	2
Sparsely-spotted Stingaree	1	0.000	1	0.000	0	-	2
Stars-and-Stripes Leatherjacket	0	-	0	-	2	0.000	2
Australian bonito	1	1.000	0	-	0	-	1
Bearded Rock Cod	1	0.000	0	-	0	-	1
Common Stargazer	1	0.000	0	-	0	-	1
Cuttlefish spp	1	0.000	0	-	0	-	1
Horseshoe Leatherjacket	0	-	0	-	1	1.000	1
Mirror Dory	1	1.000	0	-	0	-	1
Mosaic Leatherjacket	0	-	1	0.000	0	-	1
Porcupine Fish	1	0.000	0	-	0	-	1
Rusty Carpetshark	0	-	0	-	1	0.000	1
School Shark	0	-	1	1.000	0	-	1
Smooth Stingray	1	0.000	0	-	0	-	1
Southern Eagle Ray	0	-	1	0.000	0	-	1
Southern Red scorpionfish	1	0.000	0	-	0	-	1
Striped Trumpeter	0	-	1	0.000	0	-	1
White-ear	1	0.000	0	-	0	-	1

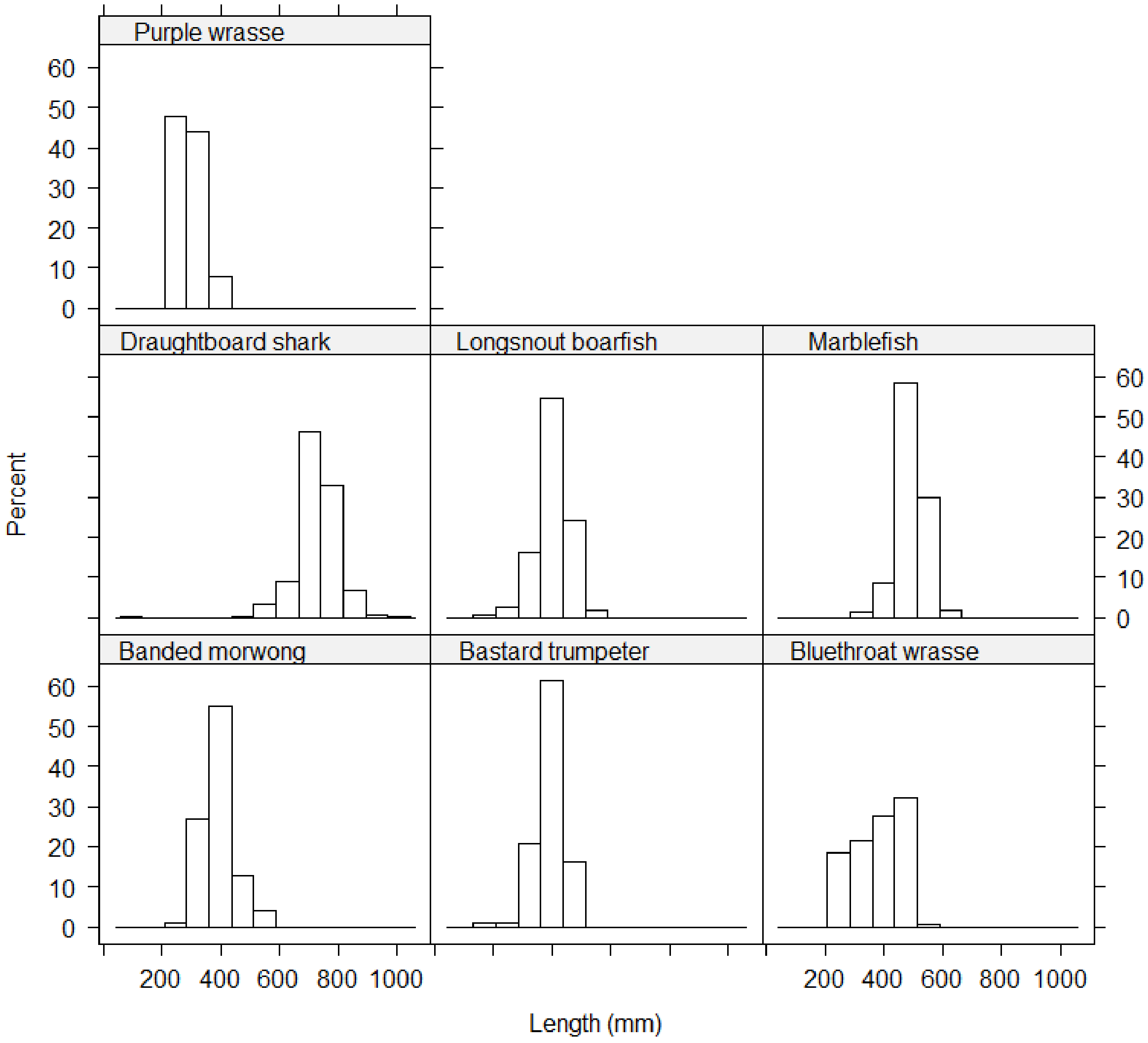

Figure A1. 1: Length frequency of the most commonly caught species (n ≥30) in Banded Morwong (138 – 140 mm) gillnets.

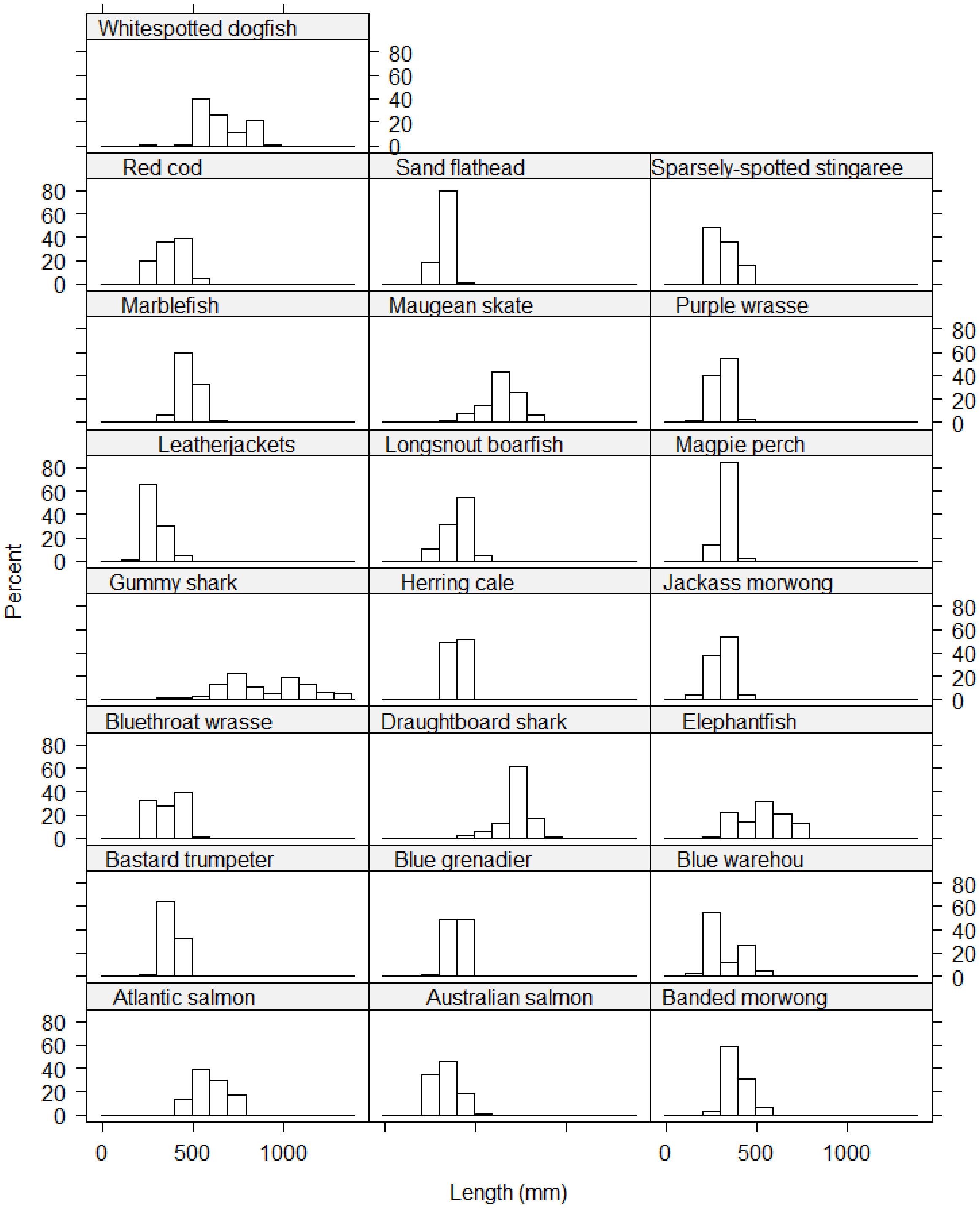

Figure A1. 2: Length frequency of the most commonly caught species (n ≥30) in graball (114 mm) gillnets.

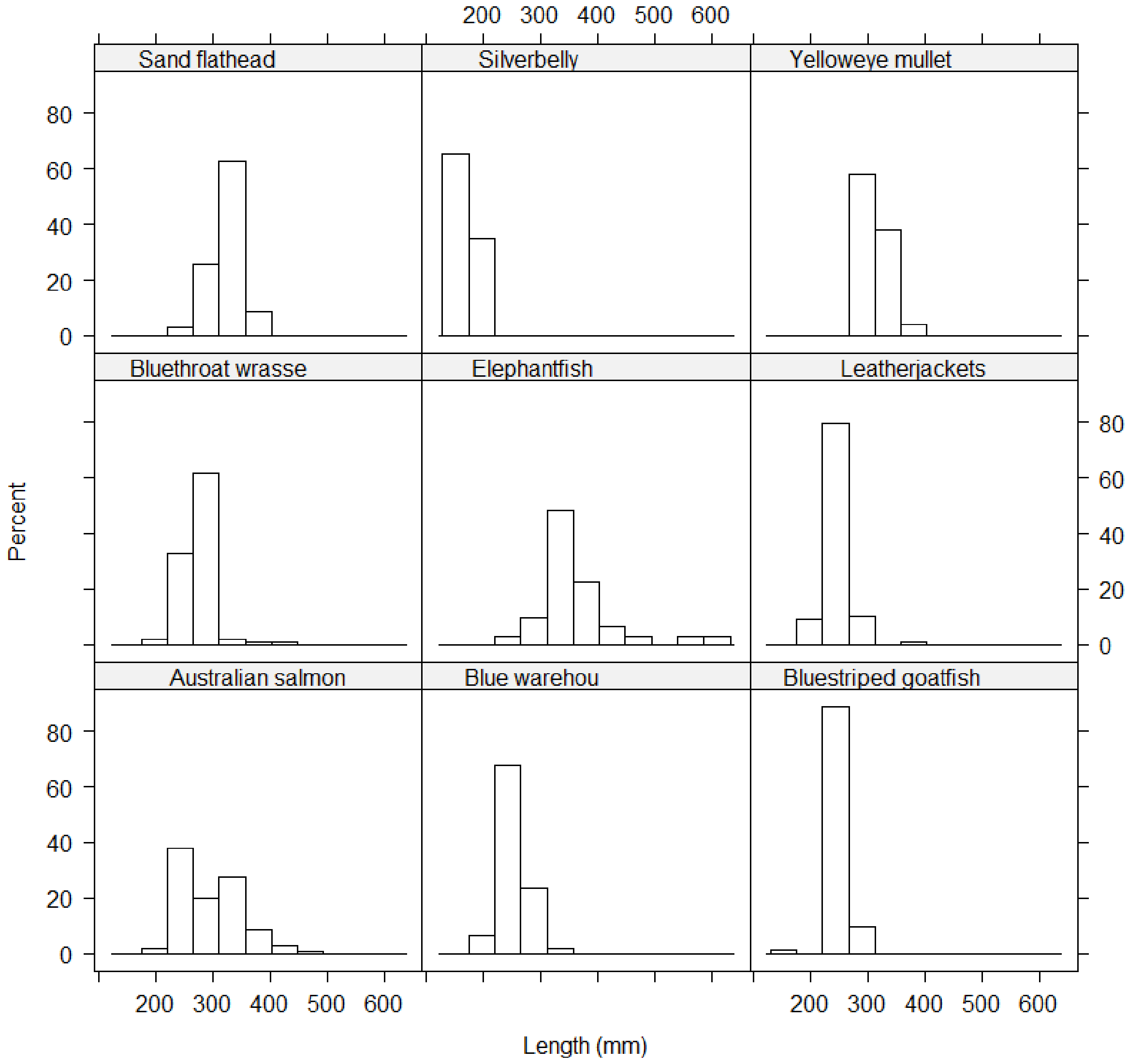

Figure A1. 3: Length frequency of the most commonly caught species (n = >30) in Mullet (64 mm) and north coast small mesh (86 mm) gillnets.

Table A1. 4: Retained catch (kg) from small mesh gillnets by region for the period January 2011 – April 2013.

Species	Northeast coast	Northwest coast	Tamar estuary	Region undefined	Species total
Australian Salmon	102	4179	1791	419	6491
Snook	138	3148	2	198	3486
Pike (unspecified)	2164	3	0	90	2257
Rock Flathead	1137	881	0	0	2018
Blue Warehou	0	1021	0	9	1030
Longfin pike	376	130	202	252	960
Yelloweye Mullet	0	0	843	0	843
Barracouta	6	356	13	95	470
Sand flathead	391	18	36	3	447
Bluethroat Wrasse	10	185	51	165	411
Red Mullet	53	224	45	23	344
King George Whiting	92	104	144	4	344
Gummy Shark	166	104	19	0	289
Magpie Perch	0	225	37	7	269
Silver Trevally	21	139	73	4	237
Herring Cale	5	25	133	0	163
Calamari	43	25	17	1	85
Leatherjacket (unspecified)	0	7	55	19	81
Blue Morwong	0	0	0	73	73
Jackass Morwong	0	0	0	73	73
Tailor	0	59	8	2	69
Elephantfish	0	51	11	0	62
Flounder (unspecified)	45	0	0	0	45
Yellowtail Kingfish	0	20	5	9	34
Sweep	0	25	4	3	32
Purple Wrasse	0	0	21	10	31
Other (37 species)	38	206	65	71	379
Regional total	4786	11131	3573	1530	21019

Table A1. 5: Statewide catch (numbers kept and released/discarded) and % released by recreational gillnetting during 2010 (Lyle and Tracey, 2012).

+ catch estimate < 500; - nil catch reported; values in parentheses represent 95% confidence limits.

Species	Kept (no.)	Rel/discard (no.)	Total catch (no.)	% released
Bastard Trumpeter	27,527 (21,517-34,155)	4,795 (3,010-6,889)	32,323 (25,424-39,829)	14.8
Blue Warehou	22,723 (16,514-29,780)	2,236 (781-44,40)	24,960 (18,258-32,526)	9.0
Wrasse	4,671 (3,030-6,465)	15,877 (11,697-20,560)	20,548 (16,009-25,616)	77.3
Atlantic Salmon	10,932 (7,139-15,429)	822 (228-1,782)	11,754 (7,643-16,599)	7.0
Leatherjacket	4,207 (2,779-5,911)	5,511 (4,234-6,953)	9,718 (7,612-12,267)	56.7
Australian Salmon	8,099 (5,555-11,336)	691 (268-1,168)	8,790 (6,082-12,050)	7.9
Other shark	668 (284-1,105)	6,026 (3,874-8,299)	6,694 (4,442-8,948)	90.0
Marblefish	+	6,049 (3,876-8,476)	6,549 (4,138-9,492)	92.4
Mullet	4,812 (1,922-9,406)	881 (373-1,541)	5,694 (2,485-10,298)	15.5
Jackass Morwong	5,024 (2,590-7,995)	606 (245-1,170)	5,630 (3,128-8,716)	10.8
Banded Morwong	1,082 (449-2,041)	4,348 (2,559-6,577)	5,430 (3,318-8,184)	80.1
Silver Trevally	4,215 (2,494-6,427)	1,048 (265-2,192)	5,264 (2,931-8,023)	19.9
Flounder	2,049 (983-3,618)	3,014 (1,431-5,236)	5,064 (2,999-7,967)	59.5
Cod	2,462 (1,353-3,765)	1,250 (667-1,974)	3,712 (2,344-5,281)	33.7
Gurnard	931 (311-1,891)	2,612 (1,335-4,361)	3,544 (1,946-5,567)	73.7
Flathead	2,856 (784-6,389)	+	3,249 (978-7,118)	12.1
Other scalefish	2,183 (1,228-3,171)	955 (562-1,444)	3,138 (2,055-4,302)	30.4
Jack Mackerel	1,954 (609-3,838)	642 (17-1,844)	2,596 (966-4,852)	24.7
Sweep	1,439 (116-3,410)	+	1,564 (137-3,713)	8.0
Black Bream	970 (205-1,990)	+	1,414 (377-2,726)	31.4
Gummy Shark	616 (358-952)	570 (362-1,035)	1,186 (869-1,856)	48.1
Trout	1,103 (608-1,768)	+	1,136 (631-1,796)	2.9
Boarfish	651 (353-976)	+	1,086 (693-1,494)	40.0
Skates & Rays	-	1,066 (731-1431)	1,066 (731-1,431)	100.0
Other taxa	+	521 (231-923)	657 (328-1,074)	79.3
Striped Trumpeter	536 (197-942)	+	608 (229-1,073)	11.9
Luderick	+	+	534 (0-1,613)	69.2
Total	112,521 (93,026-133,486)	61,401 (50,582-73,312)	173,922 (147,165-202,950)	35.5

Table A1. 6: Catches ('unweighted' numbers - kept plus discarded) reported by survey participants in the 2010 and 2012/13 recreational fishing surveys.

Species	Mullet nets						Graball nets						Total
	East coast	Northwest coast	Northeast coast	Southeast coast	Southeast SRA	West coast	East coast	Northwest coast	Northeast coast	Southeast coast	Southeast SRA	West coast	
Bastard Trumpeter	1	9	5	0	0	0	447	72	26	667	1011	925	3163
Blue Warehou	0	1	0	0	0	0	310	60	50	790	687	59	1957
Wrasse (unspecified)	2	32	0	0	0	12	312	218	79	343	618	254	1870
Mullet	29	695	25	0	91	156	0	101	26	23	3	42	1191
Jackass Morwong	0	0	0	0	0	0	878	15	158	66	56	3	1176
Leatherjacket (unspecified)	0	10	0	0	0	0	153	77	39	306	568	5	1158
Atlantic Salmon	0	0	0	0	3	0	0	0	0	65	388	671	1127
Australian Salmon	2	100	0	0	6	0	78	274	43	95	172	123	893
Flounder (unspecified)	0	1	0	0	2	17	2	21	2	34	72	482	633
Marblefish	0	8	0	0	0	0	102	44	47	132	130	103	566
Silver Trevally	0	41	0	0	0	0	73	35	48	115	128	16	456
Cod	0	0	0	0	0	3	91	1	4	88	119	131	437
Jack Mackerel	0	0	0	0	4	0	224	0	18	59	68	53	426
Banded Morwong	0	0	1	0	0	0	212	6	42	104	48	8	421
Gurnard	0	0	0	0	0	0	128	15	17	35	128	12	335
Flathead (unspecified)	0	6	0	0	2	0	16	15	10	55	211	2	317
Sweep	0	0	0	0	0	0	0	185	0	0	0	53	238
Striped Trumpeter	0	0	0	0	0	0	156	0	1	31	20	3	211
Skates & Rays	0	0	0	0	0	0	66	15	0	67	31	30	209
Gummy Shark	0	0	0	0	0	0	24	24	3	56	79	8	194
Draughtboard Shark	0	0	0	0	0	0	31	3	8	23	87	4	156
Port Jackson Shark	0	0	0	0	0	0	33	6	2	42	35	26	144
Black Bream	0	0	0	0	0	0	26	53	5	7	38	2	131
Unidentified fish	0	0	0	0	0	0	16	0	2	55	15	16	104
Spurdog (unspecified)	0	0	0	0	0	0	1	1	0	14	29	49	94
Longsnout Boarfish	0	0	0	0	0	0	18	11	3	17	37	1	87
Shark (unspecified)	0	0	0	0	3	0	21	0	0	29	16	3	72
Luderick	0	0	0	0	0	0	3	0	4	13	49	0	69

Species	Mullet nets						Graball nets						Total
	East coast	Northwest coast	Northeast coast	Southeast coast	Southeast SRA	West coast	East coast	Northwest coast	Northeast coast	Southeast coast	Southeast SRA	West coast	
Elephantfish	0	0	0	0	0	0	1	1	1	5	53	5	66
Rainbow Trout	0	0	0	0	0	0	0	0	0	0	2	63	65
Herring Cale	0	0	0	0	0	0	2	8	0	0	1	28	39
Redfish	0	0	0	0	0	0	18	0	0	2	12	3	35
Magpie Perch	0	0	0	0	0	0	0	16	0	0	0	18	34
Dory (unspecified)	0	0	0	0	0	0	1	0	2	10	21	0	34
Barracouta	0	1	0	0	0	0	0	8	0	2	10	12	33
Brown Trout	0	0	0	0	0	0	0	0	0	0	4	28	32
Ocean Perch	0	0	0	0	0	0	11	0	4	13	1	0	29
Yellowtail Kingfish	0	0	0	0	0	0	0	4	0	17	3	0	24
Garfish	0	16	0	0	0	0	6	0	0	0	0	0	22
Tailor	0	12	0	0	0	0	1	6	0	2	0	0	21
Toadfish	0	0	0	0	0	0	2	1	0	4	13	0	20
Whiting (unspecified)	0	0	0	0	0	0	0	10	0	7	0	0	17
Blue Mackerel	0	16	0	0	0	0	0	0	0	0	0	0	16
Trout (unspecified)	0	0	0	0	0	0	0	0	0	1	1	12	14
Longfin Pike	0	4	0	0	0	0	0	5	0	1	3	0	13
School Shark	0	0	0	0	0	0	7	0	0	0	5	1	13
Oldwife	0	0	0	0	0	0	4	0	0	2	0	3	9
Ling	0	0	0	0	0	0	2	0	0	0	3	4	9
Sawshark (unspecified)	0	0	0	0	0	0	0	1	1	0	5	1	8
Stargazer	0	0	0	0	0	0	1	0	0	1	4	0	6
Striped Tuna	0	0	0	0	0	0	0	0	0	5	1	0	6
Latchet	0	0	0	0	0	0	5	0	0	0	0	0	5
Southern Calamari	0	1	0	0	0	0	1	0	1	0	0	0	3
Dusky Morwong	0	0	0	0	0	0	0	0	0	0	0	2	2
Snook	0	0	0	0	0	0	0	0	0	0	1	0	1
Eel (unspecified)	0	0	0	0	0	0	0	0	0	0	0	1	1

Table A1. 7: Mann-Whitney U test of post-hoc pairwise comparisons of fish condition based on soak time category.

Species	Pairwise comparison	*p*
Banded Morwong	2 : 1	<0.001***
	3 : 1	1.000
	4 : 1	<0.001***
	3 : 2	0.045*
	4 : 2	<0.001***
	4 : 3	0.001**
Bluethroat Wrasse	2 : 1	1.000
	3 : 1	0.101
	4 : 1	<0.001***
	3 : 2	0.109
	4 : 2	<0.001***
	4 : 3	0.017*
Bastard Trumpeter	2 : 1	0.674
	3 : 1	<0.001***
	4 : 1	0.001**
	3 : 2	<0.001***
	4 : 2	<0.001***
	4 : 3	<0.001***
Marblefish	2 : 1	0.384
	3 : 1	1.000
	4 : 1	0.067.
	3 : 2	0.269
	4 : 2	0.001**
	4 : 3	0.384
Elephantfish	2 : 1	1.000
	3 : 1	1.000
	4 : 1	1.000
	5 : 1	0.001**
	3 : 2	1.000
	4 : 2	1.000
	5 : 2	0.007**
	4 : 3	1.000
	5 : 3	0.025*
	5 : 4	0.012*
Blue Warehou	2 : 1	1.000
	3 : 1	0.220
	4 : 1	0.480
	5 : 1	0.480
	3 : 2	0.130
	4 : 2	0.360
	5 : 2	0.400
	4 : 3	0.950
	5 : 3	0.950
	5 : 4	1.000

Species	Pairwise comparison	*p*
Blue Grenadier	2 : 1	-
	3 : 1	1.000
	4 : 1	1.000
	5 : 1	-
	3 : 2	1.000
	4 : 2	1.000
	5 : 2	-
	4 : 3	1.000
	5 : 3	0.161
	5 : 4	<0.001***
Whitespotted Dogfish	2 : 1	1.000
	3 : 1	1.000
	4 : 1	1.000
	5 : 1	0.005**
	3 : 2	1.000
	4 : 2	1.000
	5 : 2	0.039*
	4 : 3	1.000
	5 : 3	0.039*
	5 : 4	0.039*
Australian Salmon	2 : 1	0.030*
	3 : 1	0.026*
	4 : 1	0.007**
	3 : 2	0.002**
	4 : 2	0.006**
	4 : 3	1.000
Jackass Morwong	2 : 1	1.000
	3 : 1	0.038*
	4 : 1	0.038*
	3 : 2	0.046*
	4 : 2	0.038*
	4 : 3	1.000
Flounder (all species)	2 : 1	1.000
	3 : 1	0.110
	4 : 1	1.000
	5 : 1	1.000
	3 : 2	0.250
	4 : 2	1.000
	5 : 2	1.000
	4 : 3	0.160
	5 : 3	0.160
	5 : 4	1.000

Species	Pairwise comparison	*p*
Maugean Skate	2 : 1	1.000
	3 : 1	0.589
	4 : 1	0.589
	5 : 1	0.004**
	3 : 2	0.589
	4 : 2	0.589
	5 : 2	0.033*
	4 : 3	0.169
	5 : 3	0.010*
	5 : 4	0.589
Maugean Skate (24/4/2012 omitted)	2 : 1	1.00
	3 : 1	1.00
	4 : 1	1.00
	5 : 1	0.14*
	3 : 2	1.00
	4 : 2	1.00
	5 : 2	0.139
	4 : 3	1.00
	5 : 3	0.082.
	5 : 4	0.354
Yelloweye Mullet	2 : 1	0.364
	3 : 1	0.364
	4 : 1	0.019*
	3 : 2	0.124
	4 : 2	0.005**
	4 : 3	0.364
Atlantic Salmon	2 : 1	0.778
	3 : 1	0.090.
	4 : 1	0.090.
	5 : 1	0.026*
	3 : 2	1.000
	4 : 2	1.000
	5 : 2	0.847
	4 : 3	1.000
	5 : 3	1.000
	5 : 4	1.000
Silverbelly	2 : 1	0.110
	3 : 1	1.000
	4 : 1	1.000
	3 : 2	1.000
	4 : 2	0.310
	4 : 3	1.000

Species	Pairwise comparison	*p*
Banded/sparsely spotted Stingarees	2 : 1	0.019*
	3 : 1	0.827
	4 : 1	0.827
	3 : 2	1.000
	4 : 2	0.010*
	4 : 3	0.445
Red Cod	2 : 1	1.000
	3 : 1	0.933
	4 : 1	1.000
	5 : 1	<0.001***
	3 : 2	1.000
	4 : 2	1.000
	5 : 2	0.004**
	4 : 3	1.000
	5 : 3	0.106
	5 : 4	1.000

Table A1. 8: The proportion by condition stage of gillnet caught fish based on soak time category.

		Condition					
Species	Soak time	1	2	3	4	5	n
Atlantic Salmon	1	0.10	0.45	0.25	0.15	0.05	20
	2	0.00	0.40	0.20	0.00	0.40	15
	3	0.00	0.00	0.20	0.40	0.40	5
	4	0.00	0.28	0.17	0.06	0.50	18
	5	0.00	0.12	0.29	0.00	0.59	17
Australian Salmon	1	0.03	0.23	0.26	0.19	0.30	115
	2	0.19	0.29	0.13	0.19	0.19	52
	3	0.00	0.04	0.24	0.16	0.56	25
	4	0.04	0.15	0.08	0.15	0.58	26
	5	0.00	0.50	0.00	0.00	0.50	6
Banded Morwong	1	0.28	0.65	0.04	0.02	0.01	985
	2	0.40	0.52	0.06	0.01	0.01	737
	3	0.32	0.59	0.08	0.00	0.01	317
	4	0.17	0.70	0.10	0.01	0.01	276
	5	0.08	0.25	0.00	0.00	0.67	12
Banded Stingaree	1	0.67	0.25	0.08	0.00	0.00	12
	2	0.23	0.54	0.23	0.00	0.00	13
	3	0.50	0.50	0.00	0.00	0.00	2
	4	1.00	0.00	0.00	0.00	0.00	3
	5	0.00	0.00	0.00	0.00	0.00	0
Bastard Trumpeter	1	0.01	0.40	0.42	0.14	0.03	210
	2	0.05	0.43	0.34	0.11	0.06	175
	3	0.12	0.61	0.21	0.06	0.00	108
	4	0.02	0.26	0.36	0.31	0.05	151
	5	0.00	0.20	0.20	0.00	0.60	5
Blue Grenadier	1	0.00	0.00	0.00	0.00	1.00	1
	2	0.00	0.00	0.00	0.00	1.00	1
	3	0.00	0.00	0.06	0.00	0.94	16
	4	0.20	0.00	0.00	0.00	0.80	5
	5	0.00	0.00	0.00	0.00	1.00	92
Blue Warehou	1	0.00	0.21	0.21	0.25	0.33	24
	2	0.01	0.19	0.14	0.35	0.31	72
	3	0.00	0.07	0.07	0.07	0.79	14
	4	0.00	0.08	0.17	0.17	0.58	24
	5	0.00	0.07	0.07	0.33	0.53	15
Bluestriped Goatfish	1	0.05	0.11	0.26	0.26	0.32	19
	2	0.00	0.47	0.40	0.09	0.05	43
	3	0.00	0.00	0.00	0.00	0.00	0
	4	0.00	0.00	0.00	0.00	1.00	1
	5	0.00	0.00	0.00	0.00	0.00	0

		Condition					
Species	Soak time	1	2	3	4	5	n
Bluethroat Wrasse	1	0.14	0.43	0.27	0.08	0.08	423
	2	0.15	0.44	0.22	0.10	0.09	394
	3	0.18	0.28	0.22	0.13	0.19	119
	4	0.10	0.25	0.22	0.13	0.31	269
	5	0.00	0.00	0.33	0.00	0.67	3
Brown Trout	1	0.00	0.60	0.20	0.00	0.20	5
	2	0.00	0.00	0.00	1.00	0.00	2
	3	0.00	0.00	0.75	0.00	0.25	4
	4	0.00	0.00	0.00	0.00	1.00	2
	5	0.00	0.24	0.18	0.06	0.53	17
Brownstriped Leatherjack	1	0.48	0.44	0.04	0.04	0.00	25
	2	0.89	0.11	0.00	0.00	0.00	9
	3	0.71	0.29	0.00	0.00	0.00	7
	4	0.58	0.33	0.08	0.00	0.00	12
	5	0.00	0.00	0.00	0.00	0.00	0
Draughtboard Shark	1	0.72	0.28	0.00	0.00	0.00	451
	2	0.77	0.23	0.00	0.00	0.00	282
	3	0.76	0.23	0.01	0.00	0.00	128
	4	0.59	0.40	0.01	0.00	0.00	124
	5	0.60	0.40	0.00	0.00	0.00	5
Elephantfish	1	0.10	0.65	0.14	0.08	0.03	154
	2	0.15	0.53	0.23	0.01	0.07	81
	3	0.19	0.53	0.09	0.13	0.06	32
	4	0.08	0.59	0.24	0.00	0.08	37
	5	0.00	0.10	0.50	0.20	0.20	10
Greenback Flounder	1	0.72	0.24	0.00	0.00	0.03	29
	2	0.67	0.33	0.00	0.00	0.00	6
	3	0.29	0.71	0.00	0.00	0.00	7
	4	0.67	0.33	0.00	0.00	0.00	6
	5	0.61	0.34	0.00	0.00	0.05	44
Gummy Shark	1	0.08	0.35	0.15	0.25	0.18	40
	2	0.11	0.42	0.11	0.11	0.26	19
	3	0.00	0.00	0.00	0.25	0.75	4
	4	0.00	0.75	0.00	0.00	0.25	4
	5	0.00	0.00	0.00	0.00	0.00	0
Herring Cale	1	0.35	0.09	0.13	0.22	0.22	23
	2	0.24	0.41	0.03	0.07	0.24	29
	3	0.44	0.17	0.00	0.00	0.39	18
	4	0.29	0.14	0.00	0.00	0.57	14
	5	0.00	0.00	0.00	0.00	0.00	0

Species	Soak time	Condition					
		1	2	3	4	5	n
Jack Mackerel	1	0.25	0.00	0.50	0.00	0.25	4
	2	0.00	0.33	0.33	0.00	0.33	3
	3	0.00	1.00	0.00	0.00	0.00	1
	4	0.10	0.30	0.00	0.10	0.50	10
	5	0.00	0.00	0.00	0.00	1.00	2
Jackass Morwong	1	0.03	0.50	0.28	0.11	0.08	36
	2	0.22	0.33	0.28	0.06	0.11	18
	3	0.00	0.22	0.11	0.00	0.67	9
	4	0.00	0.11	0.22	0.11	0.56	9
	5	0.00	1.00	0.00	0.00	0.00	1
Longsnouted Flounder	1	0.50	0.33	0.00	0.00	0.17	6
	2	0.00	0.00	0.00	0.00	0.00	0
	3	0.00	0.83	0.00	0.17	0.00	6
	4	1.00	0.00	0.00	0.00	0.00	1
	5	0.48	0.39	0.09	0.00	0.04	23
Longsnout Boarfish	1	0.24	0.63	0.12	0.01	0.00	170
	2	0.26	0.59	0.12	0.02	0.00	81
	3	0.07	0.83	0.10	0.00	0.00	29
	4	0.19	0.63	0.16	0.00	0.03	32
	5	0.00	0.00	0.00	0.00	0.00	0
Magpie Perch	1	0.43	0.47	0.04	0.02	0.04	49
	2	0.40	0.49	0.03	0.00	0.09	35
	3	0.20	0.60	0.00	0.20	0.00	5
	4	0.21	0.62	0.10	0.03	0.03	29
	5	0.00	0.00	0.00	0.00	0.00	0
Marblefish	1	0.28	0.52	0.14	0.05	0.01	366
	2	0.34	0.50	0.09	0.06	0.02	384
	3	0.25	0.56	0.09	0.06	0.03	193
	4	0.21	0.56	0.10	0.09	0.04	306
	5	0.38	0.13	0.00	0.00	0.50	8
Maugean Skate	1	0.74	0.26	0.00	0.00	0.00	19
	2	0.73	0.27	0.00	0.00	0.00	11
	3	1.00	0.00	0.00	0.00	0.00	7
	4	0.46	0.46	0.08	0.00	0.00	13
	5	0.29	0.50	0.09	0.03	0.09	127
Melbourne Skate	1	0.84	0.11	0.05	0.00	0.00	19
	2	0.89	0.11	0.00	0.00	0.00	18
	3	1.00	0.00	0.00	0.00	0.00	4
	4	0.95	0.05	0.00	0.00	0.00	20
	5	0.00	0.00	0.00	0.00	0.00	0

Species	Soak time	Condition 1	2	3	4	5	n
Purple Wrasse	1	0.00	0.00	0.00	0.00	0.00	0
	2	0.45	0.35	0.18	0.00	0.02	51
	3	0.44	0.31	0.06	0.06	0.13	16
	4	0.26	0.37	0.26	0.02	0.09	57
	5	0.00	0.00	0.00	0.00	0.00	0
Red Cod	1	0.13	0.13	0.31	0.25	0.19	16
	2	0.00	0.20	0.40	0.20	0.20	5
	3	0.00	0.00	0.38	0.13	0.50	8
	4	0.00	0.00	0.00	0.00	1.00	1
	5	0.00	0.05	0.05	0.00	0.90	41
Southern Sand Flathead	1	0.52	0.18	0.00	0.09	0.21	33
	2	0.38	0.31	0.07	0.00	0.24	29
	3	0.26	0.44	0.00	0.00	0.30	27
	4	0.13	0.42	0.00	0.00	0.45	31
	5	1.00	0.00	0.00	0.00	0.00	1
Shaw's/ Ornate Cowfish	1	0.82	0.00	0.18	0.00	0.00	17
	2	0.88	0.13	0.00	0.00	0.00	8
	3	0.33	0.33	0.33	0.00	0.00	3
	4	0.75	0.25	0.00	0.00	0.00	8
	5	0.00	0.00	0.00	0.00	0.00	0
Silverbelly	1	0.00	0.19	0.19	0.27	0.35	26
	2	0.00	0.46	0.46	0.00	0.08	13
	3	0.00	0.00	1.00	0.00	0.00	1
	4	0.00	0.20	0.00	0.20	0.60	5
	5	0.00	0.00	0.00	0.00	0.00	0
Sixspine Leatherjacket	1	0.47	0.47	0.00	0.03	0.03	30
	2	0.55	0.45	0.00	0.00	0.00	11
	3	0.50	0.50	0.00	0.00	0.00	4
	4	0.25	0.50	0.25	0.00	0.00	8
	5	0.00	0.00	0.00	0.00	0.00	0
Sparsely-spotted Stingaree	1	0.60	0.40	0.00	0.00	0.00	10
	2	0.10	0.90	0.00	0.00	0.00	10
	3	0.33	0.33	0.33	0.00	0.00	3
	4	0.80	0.10	0.10	0.00	0.00	10
	5	0.00	0.00	0.00	0.00	0.00	0
Thetis Fish	1	0.24	0.41	0.35	0.00	0.00	17
	2	0.43	0.29	0.29	0.00	0.00	7
	3	0.00	0.00	1.00	0.00	0.00	1
	4	0.17	0.17	0.67	0.00	0.00	6
	5	0.00	0.25	0.50	0.00	0.25	4

		Condition					
Species	Soak time	1	2	3	4	5	n
Toothbrush Leatherjacket	1	0.60	0.37	0.00	0.02	0.00	43
	2	0.72	0.22	0.06	0.00	0.00	54
	3	0.67	0.17	0.00	0.00	0.17	6
	4	0.36	0.55	0.00	0.00	0.09	11
	5	0.00	0.00	0.00	1.00	0.00	1
Whitespotted Dogfish	1	0.12	0.56	0.16	0.09	0.08	77
	2	0.15	0.42	0.18	0.19	0.07	107
	3	0.17	0.61	0.11	0.06	0.06	18
	4	0.15	0.44	0.18	0.18	0.06	68
	5	0.06	0.37	0.24	0.15	0.18	232
Yelloweye Mullet	1	0.00	0.02	0.08	0.25	0.66	120
	2	0.00	0.00	0.27	0.17	0.56	41
	3	0.00	0.02	0.10	0.07	0.80	41
	4	0.00	0.00	0.00	0.09	0.91	35
	5	0.00	0.00	0.00	0.00	0.00	0

Table A1. 9: Tukeys contrasts multiple pairwise comparisons of variation in initial mortality rate of gillnet caught fish relative to soak time category.

Species	Soak time comparison	Estimate	Std. error	z value	*p*
Bluethroat Wrasse	2 : 1	-0.150	0.249	-0.602	0.930
	3 : 1	-0.988	0.293	-3.369	0.004**
	4 : 1	-1.627	0.222	-7.324	<0.001***
	3 : 2	-0.838	0.289	-2.896	0.019*
	4 : 2	-1.477	0.217	-6.804	<0.001***
	4 : 3	-0.639	0.267	-2.396	0.076.
Marblefish	2 : 1	-0.898	0.681	-1.318	0.544
	3 : 1	-1.311	0.713	-1.840	0.249
	4 : 1	-1.636	0.645	-2.534	0.053.
	3 : 2	-0.414	0.547	-0.755	0.871
	4 : 2	-0.738	0.456	-1.617	0.362
	4 : 3	-0.324	0.502	-0.645	0.915
Elephantfish	2 : 1	-1.099	0.661	-1.663	0.45
	3 : 1	-0.916	0.889	-1.031	0.837
	4 : 1	-1.197	0.787	-1.520	0.542
	5 : 1	-2.238	0.939	-2.384	0.116
	3 : 2	0.182	0.845	0.216	1.000
	4 : 2	-0.098	0.737	-0.133	1.000
	5 : 2	-1.139	0.897	-1.270	0.704
	4 : 3	-0.280	0.947	-0.296	0.998
	5 : 3	-1.322	1.076	-1.228	0.729
	5 : 4	-1.041	0.994	-1.048	0.829
Herring Cale	2 : 1	-0.136	0.666	-0.204	0.997
	3 : 1	-0.829	0.700	-1.185	0.636
	4 : 1	-1.569	0.740	-2.120	0.146
	3 : 2	-0.693	0.650	-1.067	0.709
	4 : 2	-1.433	0.693	-2.068	0.163
	4 : 3	-0.740	0.725	-1.020	0.737
Whitespotted Dogfish	2 : 1	0.188	0.578	0.326	0.997
	3 : 1	0.362	1.113	0.325	0.997
	4 : 1	0.302	0.668	0.452	0.990
	5 : 1	-0.962	0.458	-2.099	0.199
	3 : 2	0.174	1.101	0.158	0.999
	4 : 2	0.113	0.647	0.175	0.999
	5 : 2	-1.150	0.427	-2.696	0.048*
	4 : 3	-0.061	1.151	-0.053	1.000
	5 : 3	-1.324	1.043	-1.269	0.685
	5 : 4	-1.263	0.543	-2.327	0.121
Australian Salmon	2 : 1	0.567	0.4069	1.393	0.496
	3 : 1	-1.109	0.45177	-2.455	0.065.
	4 : 1	-1.178	0.44647	-2.639	0.040*
	3 : 2	-1.676	0.53493	-3.134	0.009**
	4 : 2	-1.745	0.53046	-3.29	0.005**
	4 : 3	-0.069	0.566	-0.122	0.999

Species	Soak time comparison	Estimate	Std. error	z value	*p*
Jackass Morwong	2 : 1	-0.319	0.962	-0.331	0.987
	3 : 1	-3.091	0.929	-3.326	0.005**
	4 : 1	-2.621	0.902	-2.906	0.019*
	3 : 2	-2.773	1.031	-2.690	0.036*
	4 : 2	-2.303	1.006	-2.288	0.10021
	4 : 3	0.470	0.975	0.482	0.963
Maugean Skate (all data)	2 : 1	0.000	4074.000	0.000	1.000
	3 : 1	0.000	4755.000	0.000	1.000
	4 : 1	0.000	3871.000	0.000	1.000
	5 : 1	-17.210	2467.000	-0.007	1.000
	3 : 2	0.000	5199.000	0.000	1.000
	4 : 2	0.000	4406.000	0.000	1.000
	5 : 2	-17.210	3242.000	-0.005	1.000
	4 : 3	0.000	5042.000	0.000	1.000
	5 : 3	-17.210	4065.000	-0.004	1.000
	5 : 4	-17.210	2983.000	-0.006	1.000
Yelloweye Mullet	2 : 1	0.411	0.369	1.113	0.668
	3 : 1	-0.761	0.439	-1.736	0.291
	4 : 1	-1.711	0.634	-2.701	0.032*
	3 : 2	-1.172	0.504	-2.324	0.087.
	4 : 2	-2.122	0.681	-3.117	0.009**
	4 : 3	-0.950	0.721	-1.318	0.536
Atlantic Salmon	2 : 1	-2.539	1.153	-2.201	0.170
	3 : 1	-2.539	1.373	-1.849	0.332
	4 : 1	-2.944	1.129	-2.608	0.064.
	5 : 1	-3.301	1.138	-2.900	0.028*
	3 : 2	<0.001	1.054	0.000	1.000
	4 : 2	-0.406	0.707	-0.573	0.978
	5 : 2	-0.762	0.722	-1.056	0.821
	4 : 3	-0.406	1.027	-0.395	0.995
	5 : 3	-0.762	1.037	-0.735	0.945
	5 : 4	-0.357	0.682	-0.523	0.984
Red Cod	2 : 1	-0.080	1.289	-0.062	1.000
	3 : 1	-1.466	0.954	-1.537	0.481
	4 : 1	-18.032	2399.545	-0.008	1.000
	5 : 1	-3.691	0.829	-4.452	<0.001***
	3 : 2	-1.386	1.323	-1.048	0.799
	4 : 2	-17.952	2399.545	-0.007	1.000
	5 : 2	-3.611	1.236	-2.922	0.021*
	4 : 3	-16.566	2399.545	-0.007	1.000
	5 : 3	-2.225	0.881	-2.524	0.065.
	5 : 4	14.341	2399.545	0.006	1.000

Table A1. 10: Numbers/proportion and primary rationale for the allocation of key species to condition stage 4.

Species	Reason	n	Proportion
Banded Morwong	Unlively	0	0.00
	Body damage	0	0.00
	Barotrauma	6	0.38
	Gill bleed	10	0.63
Bastard Trumpeter	Unlively	1	0.13
	Body damage	1	0.13
	Barotrauma	1	0.13
	Gill bleed	5	0.63
Blue Warehou	Unlively	2	0.40
	Body damage	1	0.20
	Barotrauma	0	0.00
	Gill bleed	2	0.40
Bluethroat Wrasse	Unlively	3	0.23
	Body damage	6	0.46
	Barotrauma	3	0.23
	Gill bleed	1	0.08
Elephantfish	Unlively	3	1.00
	Body damage	0	0.00
	Barotrauma	0	0.00
	Gill bleed	0	0.00
Gummy Shark	Unlively	2	1.00
	Body damage	0	0.00
	Barotrauma	0	0.00
	Gill bleed	0	0.00
Herring Cale	Unlively	2	1.00
	Body damage	0	2.00
	Barotrauma	0	2.00
	Gill bleed	0	2.00
Jackass Morwong	Unlively	0	0.00
	Body damage	0	0.00
	Barotrauma	0	0.00
	Gill bleed	1	1.00
Longsnout Boarfish	Unlively	2	1.00
	Body damage	0	0.00
	Barotrauma	0	0.00
	Gill bleed	0	0.00
Marblefish	Unlively	0	0.00
	Body damage	0	0.00
	Barotrauma	0	0.00
	Gill bleed	25	1.00
Whitespotted Dogfish	Unlively	2	0.33
	Body damage	0	0.00
	Barotrauma	0	0.00
	Gill bleed	4	0.67

Species	Reason	n	Proportion
Yelloweye Mullet	Unlively	0	0.00
	Body damage	0	0.00
	Barotrauma	0	0.00
	Gill bleed	3	1.00

Table A1. 11: Ordinal regression of how soak time (hours) influences fish condition.
In some respects, this analysis replicates the Kruskal-Wallis test; however it does not provide information on where pairwise significant differences exist. The analyses are included as they do provide predictive capabilities through the exponent of the coefficient. For example, an increase in soak time by 1 hour increases, on average, Banded Morwong condition index by a 1.103.

Species	Coefficient	Exponent of coefficient	St. error	Wald Z	*p*
Banded Morwong	0.098	1.103	0.030	3.300	0.001**
Bluethroat Wrasse	0.280	1.323	0.034	8.180	<0.001***
Bastard Trumpeter	0.139	1.150	0.046	3.030	0.002**
Marblefish	0.130	1.138	0.033	3.900	<0.001***
Draughtboard Shark	-0.070	0.932	0.050	-1.420	0.1556
Elephantfish	0.139	1.149	0.034	4.050	<0.001***
Purple Wrasse	0.130	1.139	0.076	1.720	0.086.
Leatherjackets (all species)	0.178	1.195	0.110	1.620	0.106
Longsnout Boarfish	0.115	1.121	0.086	1.330	0.182
Herring Cale	0.145	1.156	0.142	1.020	0.308
Blue Warehou	0.081	1.084	0.039	2.090	0.037*
Blue Grenadier	0.318	1.375	0.214	1.490	0.137
Whitespotted Dogfish	0.063	1.065	0.014	4.610	<0.001***
Australian Salmon	0.248	1.281	0.101	2.450	0.015*
Gummy Shark	0.184	1.202	0.233	0.790	0.429
Jackass Morwong	0.561	1.752	0.164	3.420	0.001**
Flounder (all species)	0.012	1.012	0.029	0.410	0.68
Maugean Skate (all data)	0.192	1.212	0.030	6.410	<0.001***
Maugean Skate (24/4/2012 excluded)	0.198	1.219	0.043	4.560	<0.001***
Southern Sand Flathead	0.337	1.400	0.138	2.440	0.015*
Yelloweye Mullet	0.462	1.587	0.147	3.140	0.002**

Table A1. 12: Sample size and proportion of fish in by condition stage that survived (Surv.) and died (Mort.) during the tank trial period.

	Condition 1				Condition 2				Condition 3				Condition 4				
	n		Proportion		n		Proportion		n		Proportion		n		Proportion		
Species	Mort.	Surv.	Mort.	Surv.	Mort.	Surv.	Mort.	Surv.	Mort.	Surv.	Mort.	Surv.	Mort.	Surv.	Mort.	Surv.	Total
Bastard Trumpeter	0	3	0.00	1.00	1	36	0.03	0.97	6	49	0.11	0.89	7	27	0.21	0.79	129
Banded Morwong	0	22	0.00	1.00	2	85	0.02	0.98	0	14	0.00	1.00	1	4	0.20	0.80	128
Bluethroat Wrasse	0	26	0.00	1.00	2	36	0.05	0.95	5	38	0.12	0.88	9	10	0.47	0.53	126
Marblefish	0	18	0.00	1.00	1	35	0.03	0.97	0	11	0.00	1.00	2	14	0.13	0.88	81
Draughtboard Shark	0	39	0.00	1.00	0	32	0.00	1.00	0	0	-	-	0	0	-	-	71
Australian Salmon	0	5	0.00	1.00	1	18	0.05	0.95	2	1	0.67	0.33	2	2	0.50	0.50	31
Elephantfish	0	4	0.00	1.00	2	18	0.10	0.90	1	4	0.20	0.80	1	0	1.00	0.00	30
Leatherjackets	0	13	0.00	1.00	0	15	0.00	1.00	1	0	1.00	0.00	0	0	-	-	29
Magpie Perch	0	4	0.00	1.00	1	15	0.06	0.94	0	2	0.00	1.00	0	0	-	-	22
Longsnout boarfish	0	2	0.00	1.00	0	10	0.00	1.00	0	1	0.00	1.00	0	0	-	-	13
Silverbelly	0	0	-	-	3	0	1.00	0.00	4	0	1.00	0.00	6	0	1.00	0.00	13
Purple Wrasse	0	2	0.00	1.00	0	4	0.00	1.00	0	1	0.00	1.00	0	1	0.00	1.00	8
Jackass Morwong	0	0	-	-	2	3	0.40	0.60	0	1	0.00	1.00	0	0	-	-	6
Greenback Flounder	0	4	0.00	1.00	0	1	0.00	1.00	0	0	-	-	0	0	-	-	5
Herring Cale	0	2	0.00	1.00	1	1	0.50	0.50	0	0	-	-	1	0	1.00	0.00	5
Other	1	7	0.13	0.88	1	8	0.11	0.89	2	7	0.22	0.78	4	2	0.67	0.33	32

Table A1. 13: Multiple pairwise comparison (Tukey contrasts) of the relative proportion of mortalities (0) and surviving (1) fish relative to condition stage based on tank trials.

Species	Conditions compared	Estimate	Std. error	z value	*p*
Banded Morwong	2 : 1	-16.820	3780.000	-0.004	1.000
	3 : 1	0.000	6062.000	0.000	1.000
	4 : 1	-19.180	3780.000	-0.005	1.000
	3 : 2	16.820	4739.000	0.004	1.000
	4 : 2	-2.363	1.327	-1.780	0.230
	4 : 3	-19.180	4739.000	-0.004	1.000
	1 & 2 : 3	15.586	2874.131	0.005	1.000
	1 & 2 : 4	-2.593	1.326	-1.955	0.278
	1, 2 & 3 : 4	-2.716	1.326	-2.049	0.0405*
Bluethroat Wrasse	2 : 1	-16.676	2109.036	-0.008	1.000
	3 : 1	-17.538	2109.036	-0.008	1.000
	4 : 1	-19.461	2109.036	-0.009	1.000
	3 : 2	-0.862	0.868	-0.993	0.714
	4 : 2	-2.785	0.860	-3.240	0.005**
	4 : 3	-1.923	0.661	-2.907	0.0136*
	3 : 1 & 2	-1.406	0.862	-1.632	0.230
	4 : 1 & 2	-3.329	0.853	-3.903	<0.001***
	4 : 1, 2 & 3	-2.554	0.603	-4.233	<0.001***
Bastard Trumpeter	2 : 1	-12.983	1385.378	-0.009	1.000
	3 :1	-14.466	1385.378	-0.010	1.000
	4 : 1	-15.216	1385.378	-0.011	1.000
	3 : 2	-1.484	1.102	-1.346	0.473
	4 : 2	-2.234	1.099	-2.032	0.137
	4 : 3	-0.750	0.606	-1.238	0.545
	1 & 2 : 3	-1.564	1.101	-1.420	0.320
	1 & 2 : 4	-2.314	1.098	-2.107	0.084.
	1, 2 & 3 : 4	-1.182	0.578	-2.044	0.041*
Marblefish	2 : 1	-17.010	4179.000	-0.004	1.000
	3 : 1	0.000	6786.000	0.000	1.000
	4 : 1	-18.620	4179.000	-0.004	1.000
	3 : 2	17.010	5346.000	0.003	1.000
	4 : 2	-1.609	1.265	-1.272	0.518
	4 : 3	-18.620	5346.000	-0.003	1.000
	1 & 2 : 3	15.596	3242.457	0.005	1.000
	1 & 2 : 4	-2.024	1.261	-1.605	0.205
	1, 2 & 3 : 4	-2.024	1.261	-1.605	0.108

Table A1. 14: Post hoc pairwise comparisons (Welch t-test) of how fish size influences how the fish is caught in the net (meshed).

Species	Pairwise comparison	*p*
Banded Morwong	Gilled : mouthed	0.052.
	Gilled : snouted	<0.001***
	Gilled : tangled	<0.001***
	Gilled : wedged	<0.001***
	Mouthed : snouted	1.000
	Mouthed : tangled	1.000
	Mouthed : wedged	<0.001***
	Snouted : tangled	1.000
	Snouted : wedged	<0.001***
	Tangled : wedged	<0.001***
Bluethroat Wrasse	Gilled : mouthed	<0.001***
	Gilled : snouted	<0.001***
	Gilled : tangled	0.38461
	Gilled : wedged	<0.001***
	Mouthed : snouted	<0.001***
	Mouthed : tangled	<0.001***
	Mouthed : wedged	<0.001***
	Snouted : tangled	<0.001***
	Snouted : wedged	<0.001***
	Tangled : wedged	<0.001***
Marblefish	Gilled : tangled	<0.001***
	Gilled : wedged	<0.001***
	Tangled : wedged	<0.001***
Bastard Trumpeter	Gilled : tangled	<0.001***
	Gilled : wedged	<0.001***
	Tangled : wedged	<0.001***

Table A1. 15: Post hoc pairwise comparisons of variation in the condition of fish depending on how they were caught in the net (meshed) using Mann Whitney U test corrected for multiple pairwise comparisons.

Species	Pairwise comparison	*p*
Banded Morwong	Gilled : mouthed	<0.001***
	Gilled : snouted	<0.001***
	Gilled : tangled	<0.001***
	Gilled : wedged	1.000
	Mouthed : snouted	0.642
	Mouthed : tangled	0.840
	Mouthed : wedged	<0.001***
	Snouted : tangled	1.000
	Snouted : wedged	<0.001***
	Tangled : wedged	<0.001***
Bluethroat Wrasse	Gilled : mouthed	<0.001***
	Gilled : snouted	0.012*
	Gilled : tangled	<0.001***
	Gilled : wedged	0.632
	Mouthed : snouted	0.572
	Mouthed : tangled	0.266
	Mouthed : wedged	<0.001***
	Snouted : tangled	1.000
	Snouted : wedged	0.318
	Tangled : wedged	0.066.
Marblefish	Gilled : tangled	<0.001***
	Gilled : wedged	1.000
	Tangled : wedged	<0.001***

Table A1. 16: Multiple pairwise comparison of the regional obvious and suspected Seal encounter rate.

Pairwise comparison	Obvious Seal interaction (*p*)	Suspected Seal interaction (*p*)
East coast : northwest coast	0.006**	0.003**
East coast : northeast coast	1.000	1.000
East coast : southeast coast	0.067.	<0.001***
East coast : southeast SRA	0.274	<0.001***
East coast : west coast	0.075.	<0.001***
Northwest coast : northeast coast	0.001**	0.024*
Northwest coast : southeast SRA	<0.001***	<0.001***
Northwest coast : southeast SRA	<0.001***	<0.001***
Northwest coast : west coast	<0.001***	<0.001***
Northeast coast : southeast coast	1.000	<0.001***
Northeast coast : southeast SRA	1.000	<0.001***
Northeast coast : west coast	1.000	<0.001***
Southeast coast : southeast SRA	1.000	1.000
Southeast coast : west coast	1.000	0.186
Southeast SRA : west coast	1.000	0.777

Table A1. 17: The number of gillnet deployments (commercial and recreational) and underwater visual census survey sites (2000 m^2) available for analysis of spatial and temporal trends in species composition and abundance.

	East coast		Northeast coast	Southeast coast
Year	Gillnet	Dive	Gillnet	Gillnet
1992		103		
1993		121		
1994	154	51	55	129
1995	509	24	149	886
1996	328	24	129	1027
1997	217	85		721
1998	6	24	8	8
1999	4	66		112
2000		65	1	9
2001	69	60	66	142
2002	123	37	210	154
2003	152	22	77	177
2004	74	23	1	
2005	82	115	1	76
2007	30	35	35	76
2008		23		
2009	30	24		64
2010		23		
2011	137	40	53	575
2012	77	31	125	1001
2013	97			238
Total	2093	996	910	5396

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