Realising economic returns of reducing waste through utilisation of discards in the GAB Trawl Sector of the SESSF

Matt Koopman, Ian Knuckey, Ingrid van Putten, Aysha Fleming, Alistair Hobday and Shijie Zhou

2017

FRDC Project 2015/204

CSIRO

fishwell CONSULTING

Australian Government
Fisheries Research and Development Corporation

GABIA

Realising economic returns of reducing waste through utilisation of discards in the GAB Trawl Sector of the SESSF

Matt Koopman, Ian Knuckey, Ingrid van Putten, Aysha Fleming, Alistair Hobday and Shijie Zhou

2017

FRDC Project 2015/204

ISBN 978-0-9954122-2-4

Title: Realising economic returns of reducing waste through utilisation of discards in the GAB Trawl Sector of the SESSF

FRDC Project 2015/204

2017

This publication (and any information sourced from it) should be attributed to Koopman, M., Knuckey, I., van Putten, I., Fleming, A., Hobday, A. and Zhou, S. (2017). Realising economic returns of reducing waste through utilisation of discards in the GAB Trawl Sector of the SESSF*.* FRDC Project 2015/204. Fishwell Consulting 91 pp.

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

Researcher Contact Details

Name: Matt Koopman
Address: Fishwell Consulting
27 Hesse St, Queenscliff, VIC 3225
Phone: +61 3 5258 4399
Fax: +61 3 5258 4399
Email: matt@fishwell.com.au
Web: www.fishwell.com.au/

FRDC Contact Details

Address: 25 Geils Court
Deakin ACT 2600
Phone: 02 6285 0400
Fax: 02 6285 0499
Email: frdc@frdc.com.au
Web: www.frdc.com.au

In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

Table of Contents

List of Figures

List of Tables

Acknowledgments

The project would not have been possible without co-operation of Jim Raptis, David Salter and staff from A Raptis & Sons for providing valuable information that contributed to all sections of this report.

We would like to acknowledge the support of the Great Australian Bight Fishing Industry Association (GABIA), particularly Jeff Moore, Marcia Valente and Christian Pyke who facilitated discussions with industry, and provided advice on aspects of this project.

Advice on suitable mincing machines for processing bycatch into silage was provided by Chester Mead (Viking Food Solutions), who also facilitated testing of the recommended mincer. Adam Guillot (Corporate Alliance Enterprises) provided the bycatch for testing the mincer, and Andy McLaughlin (McLaughlin Seafood) is thanked for providing access to it from the Melbourne Seafood Centre.

We thank John Garvey and staff in AFMA's data management team for providing the fisheries logbook and observer data requested. We would also like to thank Christopher Izzo and an anonymous reviewer for providing comments on the draft report. Finally, we appreciate the input to the survey and interviews that helped us to understand a range of market and supply issues.

Executive Summary

Fisheries bycatch reduction and utilisation is an important topic in the western world in both policy and research developments. At an international level, the FAO Code of Conduct for Responsible Fisheries directs management agencies and fisheries to reduce discards through development and implementation of technologies and operational methods, including reducing post-harvest losses and waste and improving the use of bycatch to the extent that this is consistent with responsible fisheries management practices. Australian management agencies and fisheries also seek to minimise bycatch in line with international guidelines, and specific domestic policies, objectives and community expectations.

Bycatch issues can be addressed by fishers (targeting practices), the supply chain (increased utilization) and by consumers (wider purchasing habits). There are a range of issues associated with these strategies, which may impact on the portfolio of approaches to minimise wastage. Here, we examine options to utilise fish that are currently discarded to both decrease wastage and increase profitability of the Great Australian Bight Trawl Sector (GABTS).

First we analysed logbook and observer data to characterise the discarded catch. On average, 44% of the total weight of the catch is discarded but it can vary based on season, region and depth of fishing. We found that although a wide range of species are discarded, discards are dominated by a few species. Latchet and Ocean Jacket are commercially marketable species, yet they account for about a third of the weight of discarded species in the GABTS. There is also significant discarding of stingarees, dogfish, barracouta and various skates and rays. Small amounts of many other species the comprise the remainder of the discarded bycatch.

We conducted a review of the international experience of demand- and supply-side barriers of landing and selling bycatch. A range of barriers and solutions to those barriers are described, some of which are common to seafood consumption in general. The main barriers particular to improved utilisation of discards in the GABTS are related to a lack of restaurateur, chef and consumer knowledge of the product and how to cook it. These can be best resolved through education and publicity. We also investigated the different international markets for fish products for direct and indirect human consumption, non-human consumption, and products not for consumption.

Based on the above investigations, there is considerable potential for increased utilisation of GABTS discards; particularly Latchets and Ocean Jackets. Of the main discarded species in the GABTS, Ocean Jacket show the greatest potential for export to the Asian market or distribution to the local Asian market. Leatherjackets caught in Australia also attract a higher price from Asian export markets than those caught elsewhere. There are also potential local markets for barracouta and dogfish.

Profitability of the fleet can be improved by wise use of the commonly discarded species. At a minimum, the threshold price for the landed product needs to be adequately high to compensate fishing costs. The processors who first purchase the bycatch species from the fishing vessels in turn must be able to make a profit when selling to the market. Our analysis shows that GABTS vessels are not apparently restricted by hold capacity, and landing more Latchet and Ocean Jacket has potential

to increase the profitability of the fishery, as long as there is demand for the product. Fish traders, buyers, and processors have to show a willingness to purchase bycatch product from the fishers at prices that are adequate to promote a long term economically viable fishery. Our analysis suggests that the fish could be on-sold at a competitive price in the Adelaide, Sydney and Melbourne markets whilst covering the potential price of transport from the main landing ports. In addition, our overseas market and price survey suggests there is opportunity to export bycatch products to Asia, by building on existing industry relationships in these export markets and trialling different products.

There is an ongoing opportunity for fresh “bycatch” species to be more aggressively marketed, first in the domestic market, but also to potentially lucrative export markets. After all, Australian consumers of fresh and processed fish product also have a responsibility in reducing fish wastage and sustaining an important local fishery. Through minor preference adjustments, some fish imports could easily be replaced with locally-caught, excellent eating fish which is currently discarded back into the ocean as bycatch.

Other main bycatch species are less suitable for human consumption (e.g. stingarees, skates and rays), but along with the very small individual amounts of the many species that make up the rest of the discards, they would be suitable for products such as fish silage[1]. Potential for installation of an onboard silage plant on GABTS vessels was investigated, costed, and could be profitable. There is underutilised hold capacity on GABTS vessels that could be retro-fitted to process and store species not suitable for human consumption, but this requires at-sea trials to test feasibility and performance. Clarification of AFMA’s bycatch management requirements and elucidation of a suitable and consistent market also would be needed before this could be considered a viable utilisation method.

Overall, we conclude that there are some important issues that need to be resolved to ensure better utilisation of species currently discarded in the GABTS, and we have identified a range of potential strategies for utilisation that may also be suitable for other fisheries landing underutilized species.

Keywords: Bycatch utilisation, GABTS, trawl fishery, supply chain, silage, discards

[1] Fish silage is defined by the FOA as a” liquid product made from whole fish or parts of fish that are liquefied by the action of enzymes in the fish in the presence of an added acid” (Tatterson and Windsor, 1974).

1. Introduction

Not all fish captured by fisheries are landed for sale, and both marketable and non-marketable species are sometimes discarded at sea. Such “bycatch” is a core concern for fisheries management worldwide. Fishing activities, whether on a large industrial scale or a small artisanal scale, creates bycatch. Based on data from 1992–2001, the Food and Agriculture Organisation (FAO) estimated that an average of about 7.3 million tonnes of catch was discarded annually by the world’s marine fisheries (Kelleher, 2005). Globally, discards account for around 8% by volume of total global catch (Seafish, 2012), however this varies greatly, particularly between fishing gear types. The main cause of low levels of utilisation is attributed to economic reasons rather than technological limitations (Clucas, 1997). There are, however, many reasons that even marketable fish species (including quota managed) are discarded at sea. Internationally, two of the most common reason for these discards are the absence of a market or, the fish are not of acceptable market size (Northwest Fisheries Science Centre, 2003; Murawski, 1996). There are also many other supply and demand related reasons for discarding species at sea, such as the lack of transport options (supply chain issues), the lack of space for storage on board the vessel (sometimes leading to high-grading where, for instance, the more valuable or larger fish are retained and the less desirable proportion is discarded), or market unfamiliarity with the species (Petruny-Parker *et al.*, 2003).

The FAO Code of Conduct for Responsible Fisheries (FAO, 1995) requested that "States, with relevant groups from industry, should encourage the development and implementation of technologies and operational methods that reduce discards”. The Code also requested that “States should encourage those involved in fish processing, distribution and marketing to: a) reduce post-harvest losses and waste; and b) improve the use of bycatch to the extent that this is consistent with responsible fisheries management practices”. Internationally, it has been proposed that discard problems can be resolved (Alverson *et al.*, 1994 and references within) at least in part, through broader use of the species being discarded (Snell, 1978; Herzberg and Shapira, 1978; Elsy, 1986; Barratt, 1986; Mocking and Machava, 1985; Luna, 1981; Musuishi, 1981; Peterson, 1981). These studies do emphasise that for bycatch species that are not quota-managed, there are some important governance challenges that need to be addressed to avoid increasing catches to the extent that overfishing can then occur. Despite governance and economic challenges, substantial utilization of bycatch does take place in many of the world's fisheries (e.g. Grantham, 1980; Peterkin, 1982; references in Andrew and Pepperell, 1992 quoted in Kennelly, 1995), including the trawl fisheries — for example in Norway where bycatch is value-added before sale (see Table 7 of this report).

1.1. An Australian case study - Great Australian Bight Trawl Sector

The Great Australian Bight Trawl Sector (GABTS) has historically discarded around 40–50% of its catch while “market fishing” on the continental shelf (for example see Knuckey and Brown; 2002). The drivers for the discards do not seem related to on-board storage limitations but rather are related to price and market issues (see later chapters). The Great Australian Bight Fishing Industry Association (GABIA) aims to reduce discards and through increased utilisation of current bycatch, ensure lower wastage and improve the economic viability of fishing operations in the GABTS. Past studies of the GABTS suggest that there are different opportunities to utilise bycatch species, including use as surimi (Knuckey, 2006). However, increasing bycatch utilisation for the potentially marketable bycatch species requires a range of constraints to be overcome. Turning bycatch into a commercial opportunity requires that:

i. it is commercially viable to not only catch the fish, but retain and land the bycatch (i.e. it needs to be economically viable for GABTS fishers);

ii. the potential markets for products that can be produced from bycatch are investigated (i.e. there needs to be viable and logistically possible routes to market for different potential products);

iii. the supply-chain limitations and requirements to bring these products to market are investigated (i.e. determine if it is viable and possible to overcome supply change barriers); and,

iv. a long term ecologically sustainable and economically viable fishery are ensured (i.e. avoid unintended consequences — overfishing).

In this study we were interested in evaluating different approaches to increase utilisation of key bycatch species and other species that are currently discarded in the GABTS.

1.2. Bycatch, byproduct, secondary commercial and primary commercial species

The use and meaning of the term bycatch sometimes varies depending on the context. In general, the term bycatch refers to species caught in the fishing process that are not the main target species. Clucas (1997) defined bycatch as “that part of the catch which is not the primary target of the fishing effort which includes fish which is retained, marketed (incidental catch) and that which is discarded or released”. In other words, bycatch species can be retained, landed and sold (Alverson *et al*., 1994); or they can be returned to the ocean alive (released) or dead (discarded). Bycatch species that are retained and landed (with commercial value) are often referred to by Australian authors as “by-product” (Hobday *et al*., 2007). What distinguishes bycatch (that is landed) from other landed fish is that bycatch is not the primary target species for the fishing vessel and fishers could not make a profit based on bycatch landings alone. However, landing bycatch can provide some economic benefits, and hence can be desirable as a supporting species.

During the project, Australia’s revised Draft Commonwealth Harvest Strategy Policy (HSP; DAWR 2017a) and Draft Commonwealth Bycatch Policy (DAWR 2017b) were released, and they have slightly different definitions to those mentioned above. All species landed and sold are considered ‘commercial species’ and are categorised as: key commercial, secondary commercial or byproduct. Bycatch refers to the non-commercial part of the catch. These HSP definitions (Table 1**Error! Reference source not found.**) are summarised as:

- ***Key commercial species*** are almost always retained and landed and make a significant contribution to the value of the catch in a fishery;
- ***Secondary commercial species*** make some contribution to the value of the catch in a fishery, but are not the most valuable species caught in a fishery. They are usually retained and landed;
- ***Byproduct species*** make a minor contribution to the value of the catch in a fishery. They are occasionally landed and retained—ranging from rarely encountered and usually retained, to frequently encountered and rarely retained; and,
- ***Bycatch species*** are those that physically interact with fishing vessels and/or fishing gear which are not usually retained by commercial fishers and do not make a contribution to the economic value of the fishery.

Classification of the main GABTS commercial species under the HSP definitions is provided in Table 2. Regardless of whether they may be variously defined as “byproduct” or “bycatch”, this project was focused on utilisation of fish that are generally discarded.

Table 1. Australian Commonwealth definitions of fishery catch and their over-arching policy documents (adapted from DAWR 2017a).

	Harvest Strategy Policy (Commercial)			Bycatch Policy (Non-commercial)	
Category	**Key commercial**	**Secondary commercial**	**Byproduct**	**Bycatch**	**Protected**
Definition	A species that is targeted and is usually retained. Significant contribution to value of the fishery.	A species that is usually retained. Some contribution to the value of the fishery.	A species that is occasionally retained. May include species that are rare and usually retained through to species that are frequently encountered but rarely retained. Minor contribution to the value of the fishery.	A species that is not usually retained. No contribution to the economic value of the fishery.	A species listed under Part 13 of the EPBC Act (excluding listing as conservation dependent).

2. Objectives

1. Characterise GABTS bycatch species by location, season, quantity and size, through literature reviews, data summaries, and statistical analysis.
2. Conduct domestic market surveys to determine the potential demand of edible product from different bycatch species.
3. Conduct international market reviews for fresh product and value-added products, including dry and preserved fish, surimi, fishmeal, and similar products.
4. Develop a supply chain model representing current GABTS product flows and potential future supply chains for the distribution of edible product from GABTS discards.
5. Determine the feasibility of vessel-based facilities for processing species not suitable for human consumption.

3. Methods

3.1. Characterise GABTS bycatch species by location, season, quantity and size, through literature reviews, data summaries, and statistical analysis

There are several data sources available for the characterisation of bycatch in the GABTS. Commercial fishers are required to report catch and effort for every shot in daily logbooks. Daily logbook catch weights are generally estimates. Historically those data contain only retained catch by species, but there is an increasing move towards also recording discards in daily logbooks. Species resolution varies in the logbook data depending on the skipper, and small catches of retained non-quota species as well as discarded non-quota species are often recorded as "mixed fish"[2]. Fishers are also required to complete catch disposal records (CDRs) upon landing the catch. CDRs comprise measured weights of each species landed, but the data contains no effort information (apart from start and end trip dates) and no information on the discarded catch.

Fisheries observers have monitored GABTS catches since 2000 (Knuckey and Brown, 2002). Observers record estimates of retained and discarded catch by species for each shot. While observer data contains a more complete record of the catch composition, observer coverage is only about 3–4% of the fishing effort (Patterson *et al*., 2016), and in some years there is none. Catch composition also varies longitudinally across the spatial extent of the fishery, so we used the established fishery "zones" (Figure 1) to describe the fishery catch where necessary. As it turned out, there was insufficient observer data available by each zone to use this in any quantitative analyses.

To address objectives 1, 4 and 5, the following daily logbook, CDR and observer data were requested from AFMA:

- Daily logbook: January 2005 – November 2015 (because data was provided for only part of 2015, that year was omitted);
- CDR: January 2005 – December 2014;
- Observer data: February 2005 – December 2014.

Based on the volume, value and fate of the catch, species were categorised into key, secondary, byproduct, and bycatch species in accordance with **Error! Reference source not found.**, summarised in Table 2. Species in each of the four categories are discarded by the GABTS.

[2] If the total retained weight of a single non-quota species is less than 10 kg, it can be combined with another non-quota species of less than 10 kg and recorded as 'mixed fish'. For the period of data used in this report, recording of discards was voluntary, however it has been mandatory since early 2016.

Table 2. GABTS fish species by HSP species category

Category	Species
Key commercial species	Deepwater Flathead, Bight Redfish, Gemfish, Ocean Jacket, Orange Roughy, Gummy Shark, Yellowspotted Boarfish, Blue Grenadier
Secondary commercial species	Ornate Angelshark, Jackass Morwong, Tusk, Latchet, Gould's Squid, Blue Morwong,
Byproduct species	Knifejaw, Ling, King Dory, Angel Sharks, Saw Sharks, Red Gurnard, Snapper, Ocean Perch, Silver Trevally, BigSpine Boarfish, Wobbegong, Silver Warehou, Hapuku, Ribaldo, Rubyfish, Boarfish, Southern Calamari, Blackspot Boarfish, Blue-eye Trevalla, Conger Eel, Squids, Platypus shark, Spikey Oreodory, John Dory, Southern Calamari, Leatherjacket, Blue Warehou, Common Gurnard Perch, Silver Dory, Bugs - Shovel Nosed And Slipper Lobsters, Cuttlefishes, School Shark, Redbait, Australian Angelshark, Ghost Shark, Slender Orange Perch, Mirror Dory, Bronze Whaler, Spikey Dogfish, Black Shark, Common Veilfin, Rosy Dory, Mixed Fish, Swallowtail, Jack Mackerel, Oreodory, Spotted Wobbegong, Silver Trevally, Bigeye Ocean Perch, Butterfly Gurnard, Stargazer, Smooth Oreodory, Samsonfish, Elephantfish, Moonlighter, Dogfishes, Barracouta, Short Boarfish, Giant Boarfish, Oilfish, Armoured Gurnard, Yellow-Eyed Nannygai, Whiskery Shark, Cosmopolitan Rubyfish, Redfish, Mackerel, Dealfish, Darwin's Roughy, Scorpionfish, Blue Mackerel, Southern Eagle Ray, Skates, Smooth Hammerhead, Yellowfin Tuna, Trevallas, Black Bream, Broadnose Shark, Hammerhead Shark, Dories, Black Trevally, Ray's Bream, Flathead, Frostfish, Endeavour Dogfish, Banded Morwong, Sunfish, Pelagic Armourhead, Black Shark, Magpie Perch, Mixed Sharks and Rays, Rudderfish, Alfonsino, Southern Fiddler Ray, Cuttlefish, Thresher Shark, whiptails and rat-tails, White Warehou, Splendid Perch, Giant Crab, King George Whiting, Sponges, Longfin Mako, Blackfin Ghostshark, Longsnout Boarfish, Threespine Cardinalfish, Velvet Scampi, Thetis Fish, Seaperch, Yellowtail Kingfish, Blacktip Cucumberfish, Blue Shark, Giant Crab, Stingray, Sea Perch, Grey Morwong, Scalloped Hammerhead, Albacore, Moonfish, Octopuses, Skipjack Tuna, Oxeye Oreodory, Silverbiddy, Sergeant Baker, Black Spinyfin, Shortfin Mako, Black Oreo, Yellowtail Scad
Bycatch species	Jellyfish, Champagne Crab, Port Jackson Shark, Draughtboard Shark, Brier Shark, Greeneye Spurdog, Lantern Fishers, Messmate Fish, Rough Oreodory, Oarfish, Pearl Perch, Toadfishes, Porcupinefishes

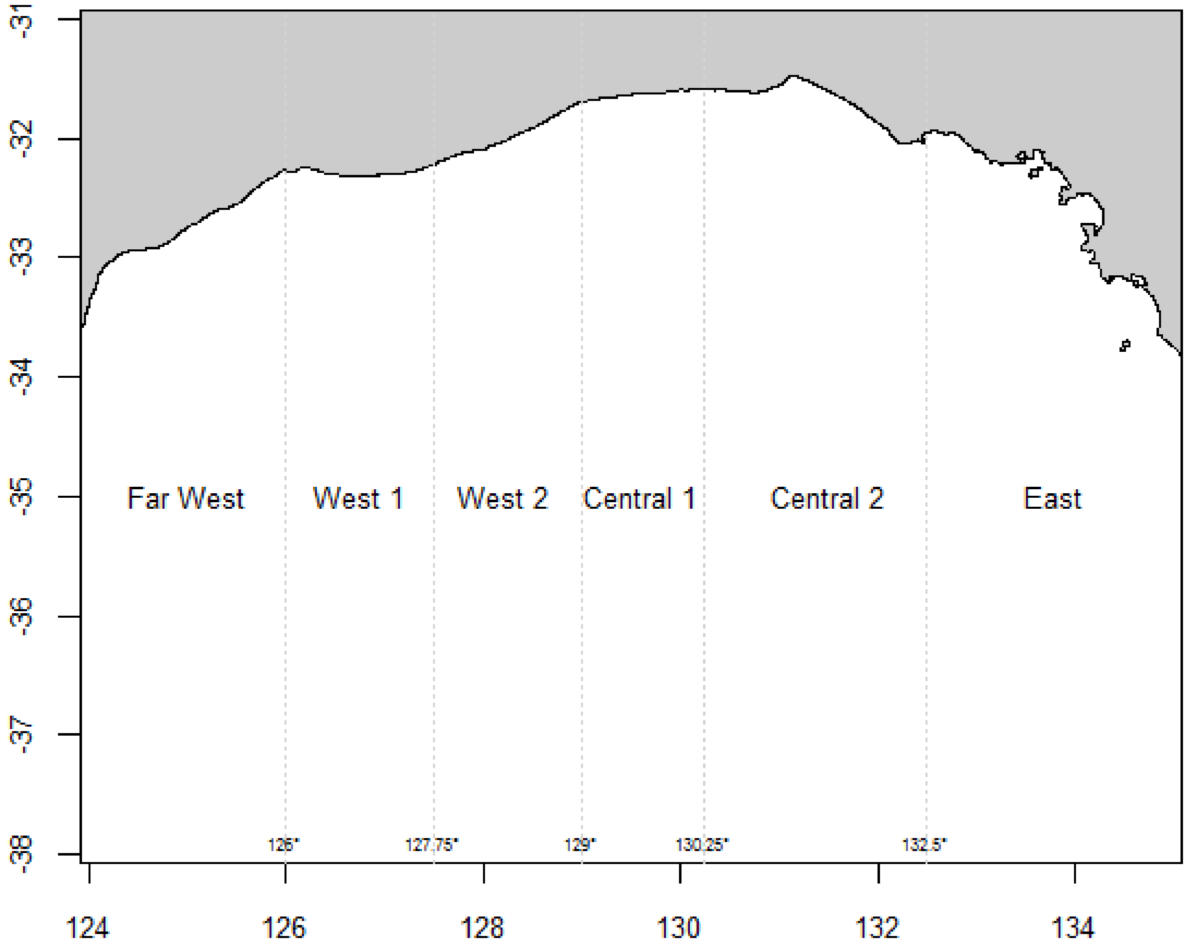


Figure 1. Fishery zones used describe the longitudinal extent of the fishery.

3.2. Conduct domestic market surveys to determine the potential demand of edible product from different bycatch species

Based on the characterisation of the catch it was possible to determine which individual species comprised the majority of the discards from the various catch categories. Although there were hundreds of fish species that were often discarded, there were only a few species that were caught in sufficient volumes to warrant consideration of species-specific marketing options. These were Latchet, stingarees, Ocean Jacket, dogfish and Barracouta, which combined, comprised about 50% of the weight of the discards. Although not necessarily highly valued in the Australian domestic markets, they had potential value in niche markets, particularly in Asian food stores or to predominantly Asian clientele. An online survey was designed and follow-up phone interviews were used to assess demand for these major discard species from the GABTS fishery.

3.2.1. Online survey

In order to obtain information on potential domestic markets for the selected species, a short online survey was developed in Survey Monkey which was sent to fish processors in Adelaide, Melbourne and Sydney.

A total of 41 fish trading businesses identified by the researchers and an internet search for email addresses yielded 31 contacts. An email with a link to the 5-minute (10 question) survey was sent out with an option to be contacted for a follow up phone interview and be entered in the draw for one of five $100 vouchers. Ethics approval for the survey implementation was obtained under the CSIRO Human Research Ethics (project: 042/16).

The survey showed a picture of each species (Latchet, Stingarees, Ocean Jacket, Dogfish and Barracouta) and included a matrix table to select options of scale (e.g. a price range or frequency range) for each species under each question.

The questions were (more details are shown in Appendix 3):

1. Which of these species do you currently purchase for your seafood business?
2. How do you rate the consistency of the quality of these fish when you purchase them?
3. What weight do you typically buy in week?
4. What price do you usually pay for these species?
5. What form do you prefer to buy each species?
6. How often would you like to purchase this species?
7. What is the maximum weight you could sell in a week if supply was guaranteed?
8. Overall, how do you feel about purchasing each of these species for your seafood business?
9. What is the main factor limiting your purchase of these species?
10. If you would be happy to participate in a short follow-up interview please include your name below.

Example screen shots of the survey are shown below.


Improved utilisation of trawl bycatch

Thank you for participating in this 10 minute survey.

We seek your input as part of a Fisheries Research and Development Corporation (FRDC) project focusing on the Great Australian Bight Trawl Fishery. We are interested in understanding the market for several minor species in this fishery, and will ask you about the quality and availability of several species that you may purchase as part of your seafood business. You answers will help the research team (CSIRO and Fishwell Consulting) to develop improved fish supply for Australia.

There are 10 questions about six species: Latchet, Stingarees, Ocean Jacket, Barracouta, Skates and Rays and Dogfish. Please answer for any/all of the species relevant to your business.

All responses will be treated anonymously in project reporting. Survey respondents who complete a survey, and are willing to have a brief follow up discussion by phone with a member of the project team will go in the draw for one of five $100 vouchers - your comments will still be de-identifed after this interview.

This survey has received ethics approval from CSIRO, CSSHREC number: 042/16

Figure 2. Example screen shot 1 of survey.

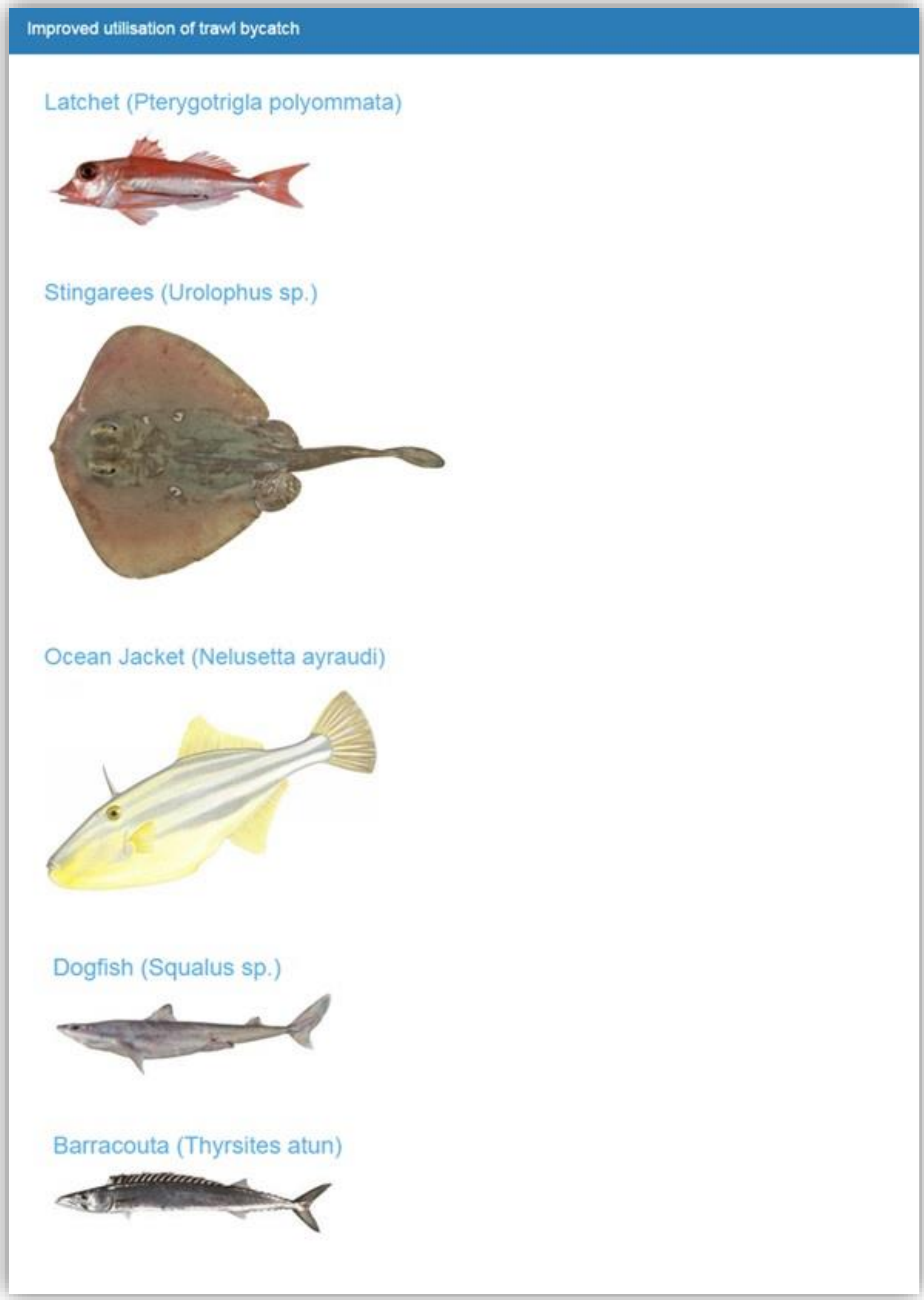


Figure 3. Example screen shot 2 of survey.

1. Which of these species do you currently purchase for your seafood business?

	Yes	No
Latchet	○	○
Stingarees	○	○
Ocean Jacket	○	○
Barracouta	○	○
Skates and rays	○	○
Dogfish	○	○

2. How do you rate the consistency of the quality of these fish when you purchase them?

	All high quality	Mostly high quality	Mix of high and low quality	Mostly low quality	All low quality	Not applicable
Latchet	○	○	○	○	○	○
Stingarees	○	○	○	○	○	○
Ocean Jacket	○	○	○	○	○	○
Barracouta	○	○	○	○	○	○
Skates and rays	○	○	○	○	○	○
Dogfish	○	○	○	○	○	○

3. What weight do you typically buy in a week?

	Less than 30kg	30-60kg	60-120kg	120-300kg	More than 300kg	Not applicable
Latchet	○	○	○	○	○	○
Stingarees	○	○	○	○	○	○
Ocean Jacket	○	○	○	○	○	○
Barracouta	○	○	○	○	○	○
Skates and rays	○	○	○	○	○	○
Dogfish	○	○	○	○	○	○

Figure 4. Example screen shot 3 of survey.

A week after sending the email only 7 survey responses were received and 2 respondents indicated they were willing to participate in a follow-up interview. This small number was likely due to a number of factors including: not differentiating the survey from other 'spam' type messages for similar surveys; not feeling able to answer (all) the questions; being too busy; not checking emails; and, finding the topic of little interest. Despite attempts to increase the response rate by phoning participants to identify / legitimate the survey and having the email sent via an industry email, no new responses were received. This demonstrates the difficulty of online surveys for this target audience and face-to-face interactions may be necessary in the future.

3.2.2. Phone interviews

The follow-up semi-structured interview with two seafood store owners asked for more detail on each of the survey questions (see list below) and probed for examples as well as discussion of opportunities and barriers to growing the market for these species. It also allowed general feedback on the research (survey, species chosen etc.).

1. What did you think of the reason for the survey and the survey questions? Any comments?
2. Are there any other GABTS species you think are underutilised?
3. The first question was a rating for each species, can you tell me what factors contributed to your rating for each species/group? Is there any way this might be improved?
4. What are the major factors that limit the sales of each of these species, for example, lack of supply, lack of demand, variability in supply, low season, poor quality, etc.?
5. The second question was a rating for the consistency of the quality, can you tell me what factors contributed to your rating for each species/group? Any ways this might be improved?
6. Tell me about issues with seasonality in supply for each of these species– volume available varies over the year
7. What are the main barriers for selling more of each of these species?
8. If you could access more of each species, how likely would you be to buy it?
9. What would most improve the market for selling more of each of these species?
10. Is there a particular price point threshold which is important?
11. Are there any other risks or opportunities you can see in the market of each species?
12. How do you see the future of this market of each species?
13. Is there anyone else we should be talking to?

3.3. Conduct international market reviews for fresh product and value-added products, including dry and preserved fish, surimi, fishmeal, and similar products

A review of the international situation was carried out to help understand the international experience with respect to supply- and demand-side barriers to landing discarded species and inform opportunities in Australia. An overview of the different products that can be produced from fish is also presented, with a focus only on white fish products, not crustaceans).

3.3.1. Desktop review

A literature review on various seafood products including surimi, fishmeal, fish oil, and biological compounds was conducted. Relevant information was obtained from published books, reports, articles, and the internet. The focus was particularly on Asian countries where demand for these products is high. However, some information was also gathered from other regions, including Europe and North America.

3.3.2. Direct market information from local government and wholesalers

Market information was also gathered based on the research team's personal connections in Asian countries. International connections provided first-hand knowledge about the local market, although it was recognised that the local information may not be representative of the overall situation in the country or region. In addition, it is important to note that the fish prices obtained are indicative only, as they are not based on statistically designed representative survey.

3.4. Develop a supply chain model representing current GABTS product flows and potential future supply chains for the distribution of edible product from GABTS discards

The research components for this section consisted of several different aspects, as described in Figure 5. The overall aim was to increase the understanding of opportunities to use bycatch in the GABTS (and increase industry profits) starting at the top of the figure. In order to achieve this there is a need to address supply and demand side issues for the GABTS. The methods used to consider the demand side components are outlined in 3.2 and 3.3 (underpinned by bycatch data analysis presented in section 3.1).

After reviewing bycatch experiences and barriers elsewhere, and gaining an overview of the different fish products that can be produced, supply-side issues in the GABTS were investigated using an economic and supply-chain analysis (left hand side of Figure 5).

An **economic model** was developed to assess the commercial viability of retaining and landing the bycatch species (shown as 'improve catch sector profits' in Figure 5). The economic model provides insight into break-even bycatch quantities and landing prices to make retention of bycatch financially attractive to the operators. The economic model uses catch, price, and cost estimates, based on the typical GABTS fishing vessel approach, using several different industry based data sources (industry pers. comm. in confidence). The costs, returns and profit estimates represent a 'typical GABTS fishing vessel' and do not represent any particular operator. A 'typical GABTS fishing vessel' is intended to represent the average for the fishery.

To complement the economic analysis, a solid understanding of the current logistics and domestic supply chain provided a foundation for potential future expansion, adjustment, or change in the supply chain required for alternative products and market destinations of bycatch (Hobday *et al.*, 2014). The **supply chain approach** developed here highlights potential market routes for edible bycatch species, processing and transport costs and the existence of any distributional challenges.

The discarded species of interest to GABTS stakeholders were narrowed down to those where industry felt that potential exists for increased utilisation. The species initially identified were leatherjacket (mostly Ocean Jacket) and Latchet. Four other species were later added as part of the market survey: stingarees, barracouta, skates and rays, and dogfish.

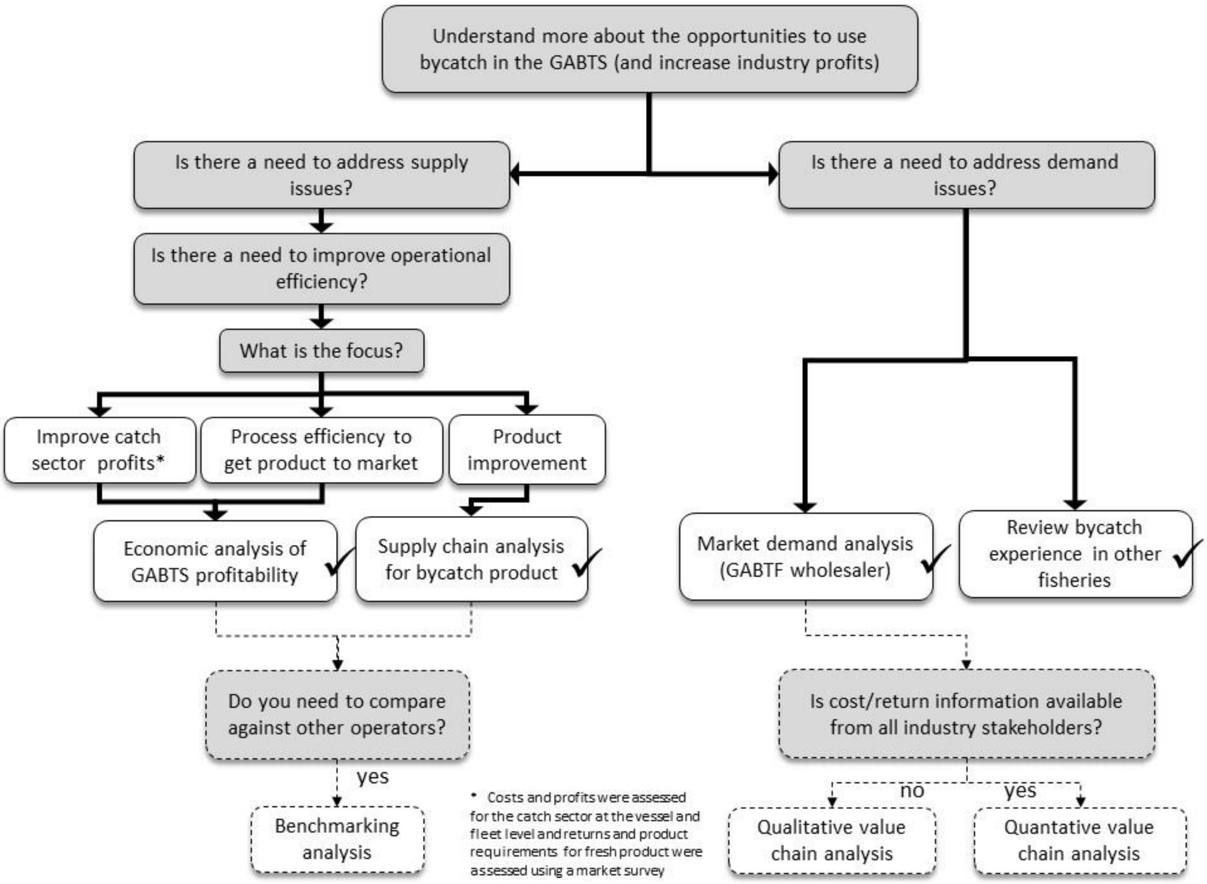


Figure 5. Decision tree for bycatch analysis for the GABTS. The heavy arrows indicate the project logic and the boxes with the tick marks are the endpoints of this current research. Boxes with a dashed outline are suggested for future research.

3.5. Determine the feasibility of vessel-based facilities for processing species not suitable for human consumption

Based on characterisation of the GABTS discards, there were hundreds of species which were not caught in sufficient quantities individually, to warrant looking for species-specific markets. For these, we explored the option of mincing and producing a fish hydrolysate as one of the most feasible and cost-effective methods of utilising this multi-species part of the discarded catch (e.g. Knuckey, 2004; 2006). The layout and capacity available on board a GABTS vessel (obtained from a general arrangement diagram), estimates of inedible bycatch per shot, and requirements for existing fish silage facilities, components for vessel based processing system were identified and costed. A suitable mincer was tested by mincing trawl bycatch into the required piece size. An economic analysis of the vessel-based processing plant was undertaken incorporating capital costs, consumables and expected bycatch levels.

4. Results and Discussion

4.1. Characterise GABTS bycatch species by location, season, quantity and size, through literature reviews, data summaries, and statistical analysis

4.1.1. Distribution of fishing and observer effort, catch and port of landing

Overall, the GABTS is currently a fishery operating predominantly on the continental shelf (Figure 6) targeting the main quota species: Deepwater Flathead and Bight Redfish. Historically, it has had periods of significant fishing for Orange Roughy in deep water (>700 m depth) and to a lesser extent, for Western Gemfish and Blue Grenadier over the continental slope (240 m – 700 m). Thus, most of the information presented in this report relates to the shelf fishery unless stated otherwise.

Most effort in the GABTS from 2005 – 2014 was in Central 2 zone, but during 2011 and 2012, most of the effort (39%) took place in the Central 1 zone (Figure 7). Combined, more than 50% of the total effort takes place in those two zones. Effort in the West 1 and West 2 zones has ranged between 15 – 24% of the total effort. More often than not, the observer program has monitored a disproportionate number of shots in the western zones, particularly West 1 (Figure 7)[3] but some observer coverage has been undertaken in all six GABTS zones in five of the seven years shown. There is no observer data for 2009, 2011 and 2013 because the GABTS observer program runs biennially to offset years in which the fishery independent survey is undertaken. The distribution of catch largely mirrors that of effort (Figure 7), however there are some small differences. For example, catches from the East and West 1 zones comprise larger percentages of the total as effort.

The location at which the catch is landed (onshore) can influence a range of costs involved with processing and transport of fish to market. From 2005–2014, 55% of the GABTS catch was landed at Thevenard, while 31% was landed at Port Lincoln (Figure 8). Only 3.9% and 3.8% of the catch reported were landed at Port Adelaide and Adelaide respectively. The percent of annual retained catch landed at each port fluctuated over the ten year period, with more than 60% of the catch landed at Thevenard in some years (Figure 8). Since 2012, more than 89% of total landings were at either Thevenard or Port Lincoln. Landings at Adelaide and Port Adelaide were highest in 2011 at about 15% of the total landings.

On average, based on logbook data during 2004–2015, about 44% of the total catch is retained and 56% is discarded (Figure 9; not including targeted Orange Roughy fishing), but this proportion is variable depending on the season, region and depth of fishing.

[3] This is largely caused by the duration of fishing trips, whereby only 4–6 trips are carried out in any one year, and because observer coverage in GABTS is biennial (every two years). In addition, getting a representative spread of observer coverage across zones is difficult because the fishing plan can, and does, change after trips have been scheduled.

4.1.2. Retained catch

Fourteen species comprised 90% of the total retained catch weight (Figure 10) and it included all key commercial species and all secondary commercial species except Australian Tusk. The only byproduct species in those 14 species was Knifejaw. The eight key commercial species comprised 77% of the total retained catch and 82% of the total catch value between 2005–2014 (Figure 11). The six secondary commercial species made up 12% of the catch weight and 9% of the value, while the 153 byproduct species made up the remaining 11% of the catch weight and 9% of the catch value (Figure 11).

The two main quota species — Deepwater Flathead and Bight Redfish — comprised over half of the GABTS total retained catch and 64% of the catch value (Figure 12). While Ocean Jacket was the third most caught species by weight, the higher priced Gemfish was third in value. Main secondary species by weight were Ornate Angel Shark and Latchet (Figure 13), and Knifejaw was the byproduct species caught in the greatest quantity (Figure 14).

Consistent with the reduction in effort in the GABTS (see for example Patterson *et al*., 2016), overall catch of key, secondary and byproduct species has decreased since 2006 (Figure 15 and Figure 16). Catches of key species (other than Orange Roughy and Yellowspotted Boarfish) were generally highest during summer months and lowest during late autumn and winter (Figure 15). Bight Redfish were caught in the greatest quantities during February — April. In contrast, catches of Deepwater Flathead appear relatively consistent throughout the year. Of the secondary species, Gould's Squid and Jackass Morwong were caught in the greatest quantities from January to May, while more Latchet was caught in the winter months (Figure 16).

The largest Orange Roughy catches occurred in June and July as a result of deepwater fishing off the continental shelf. Although this component of the GABTS fishery has not operated in recent years, it has very little byproduct or bycatch and is not included further in the results.

4.1.3. Discarded catch

Information on the catch composition of the discarded catch is better derived from the observer data than logbook data, where it is grouped into only a few major species or species groups. Due to the limited number of seadays available, however, observer coverage is not always representative of the entire fishery. Observer coverage and fishing effort for the period 2005–2014 are shown in Table 5. There has not been much fishing in waters over the continental slope in recent years and no fishing occurred on the slope during October of November throughout this time series. As a consequence, observer coverage of fishing on the continental slope has not been consistent across months, and the number of shots observed exceeded 10 in only three months. Small sample sizes and a lack of seasonal representation[4] suggest that these data from fishing on the continental slope (rather than the shelf) should be treated cautiously, particularly for patchily distributed species (such as Gemfish). However, to inform

[4] as per footnote 2

Objectives 4 and 5, estimates of total discards and the seasonality and variability of discards were required.

The species composition of the discarded catch was more diverse than the retained catch. More than 300 discard species have been recorded by observers, with 42 species representing 90% of the total discarded weight (Figure 10). The five species discarded in the greatest quantities during 2005–2014 were Latchet (25% of all discards observed), Wide Stingaree (10%), Ocean Jacket (5%), Stingarees (including Wide[5] and Giant Stingarees, 4%), Barracouta (4%) and Eastern Fiddler Ray (3%) (Figure 17). The top 20 discard species by weight recorded in the observer data are shown in Table 4 . Discarded Latchet were recorded from 942 of the 1174 shots observed in that time. Note that the percent composition (24%) differs slight from that shown in Figure 17 (25%), because the latter is based on data weighted by effort. Barracouta were discarded from 489 of the shots and comprised 4% of the discards. Because most of the fishing and observer effort is on the continental shelf rather than from the continental slope (or deepwater), composition of discards from fishing on the shelf is very similar to the total discard for the GABTS from 2005–2014 (Figure 18). Main species discarded from catches on the continental slope were Gemfish (14%), Latchet (14%), White-spotted Skate (6%), Barracouta (6%), Scaled Stargazer (5%) and Greeneye Dogfish (5%).

All key species in the GABTS are discarded to some extent, but discards rates for quota species are very low. There is very little discarding of Deepwater Flathead and Bight Redfish—the two major quota species in the GABTS (Figure 20).

Summary figures showing mean monthly discarded catch per shot for the top six discarded species were developed by the project team, but cannot be reproduced here because they contravene the 5 boat rule. The main patterns show that mean discarded catch per shot of Latchet was 2.5–3.5 times higher in April, May, September and October than in January – March and July. Discards of Wide Stingaree were lowest from December – April and in July. No Wide Stingaree were reported as discarded in August, however it is very likely that they were recorded under the group code stingaree and giant stingaree, which themselves were only recorded in 5 months of the year — two of those month in which Wide Stingaree had very low catches. Future bycatch studies of the GABTS should consider combining those species / groups. Discarded catches of Ocean Jacket were highest during April, however that was largely due to a single very large catch. Discarded catches were also relatively high in September and October. Mean discarded catch of Barracouta was highest in June, but as for Ocean Jacket in April, this was largely due to a small number of very large catches. There was no consistent seasonal trend in discarded catches of Barracouta. Discards of Eastern Fiddler Ray were lowest from December to March and highest in June, July, September and October. No Eastern Fiddler Ray were recorded by observers in August or November, however the distribution of Eastern Fiddler Ray overlaps with that of Southern Fiddler Ray, and they may have been recorded as that species. There are records of Southern Fiddler Ray in the observer database from the months of August and November.

[5] In some cases observers might have recorded Wide Stingaree as the generic Stingarees species code.

Spikes in the estimated retained and discarded catches of Gemfish during February on the shelf and March on the slope are the result of a combination of large mean discarded catches and being recorded from a relatively high percentage of the total shots observed. Due to spatial and temporal patchiness of the data, it is difficult to determine accurate estimates of the discards of gemfish. Overall, they were caught and discarded throughout the year, but mostly from September through to April Discarding is consistently low during May – August. Very little Orange Roughy, Gummy Shark, Yellowspotted Boarfish and Blue Grenadier is discarded (Figure 22). Latchet were discarded in large quantities throughout the year, particularly during April – May and September – October (Figure 23). Discarded catches of Ornate Angelshark and Jackass Morwong were also consistent throughout the year, but discarding of other secondary species shown in Figure 23 and Figure 24 varied throughout the year, probably more a reflection on low sampling effort rather than true patterns in discarding. Almost all Wide Stingaree, stingarees and giant stingarees, Barracouta and Eastern Fiddler Ray were discarded, with catches highest during winter and spring (Figure 25).

No size data was available for Wide Stingaree, stingarees and giant stingarees, Barracouta, Eastern Fiddler Ray or Southern Fiddler Ray. Size frequency data are provided in Figure 26 for Latchet, Ocean Jacket and Gemfish. Those data are raw length frequencies, and so care should be taken in comparing relative frequencies of retained and discarded fish. As expected, the retention of Latchet increased with size (Figure 26). Discarded Latchet ranged 17 – 43 cm with a mode of 27 cm, with retained fish ranging 28 – 48 cm and a mode of 36 cm. The size of Ocean Jacket discarded wat not influenced by fish length as much as for Latchet with a similar range of sizes for retained and discarded fish, and the frequency distribution across fish sizes relatively flat until about 42 cm length. Gemfish from a wide range of lengths were measured with discarded fish ranging 19 – 64 cm, and retained fish ranging 40 – 112 cm respectively.

4.1.1. Potential utilisation of discards in the GABTS

The project focused on two separate methods of potential utilisation of discards: Option 1) improved individual marketing of a few major discard species or species groups as seafood; and Option 2) bulking and mincing the remaining small amounts of hundreds of species to produce a fish hydrolysate or “silage”. Based solely on the species composition — not the feasibility to achieve it — the potential total utilisation of discards is shown in Figure 19. In reality, this probably over-represents the amount of species-specific utilisation that would occur, because crews rarely keep very small catches of individual species, even though they might have some commercial value.

Based on the analyses above and discussion with industry, there were only a few commonly discarded species that were caught in sufficient volumes to warrant consideration of species-specific marketing (Option 1). These were Latchet, stingarees (including Wide and Giant Stingarees), Ocean Jacket, dogfish, Barracouta, skates and rays, and Gemfish which combined, comprised about 64% of the weight of the discards (Table 6). If the estimated discards of these seven species (or species groups) listed in bold and highlighted in Table 4 were landed (2,157 t per year on average) the total estimated increase in income (at current prices shown in Table 4) would be $2.75 million annually for the GABTS. Including all discards of key and secondary species (about 2,311 t), that figure increases to $3.2 million per year (see total in column 5 of Table 4). The figures mentioned here do not include the value that could be achieved from the hydrolysis of the small amounts of hundreds of other discards (Option 2), which is described elsewhere.

Obviously not all species are 'saleable' or indeed legally sold (as some of the discards may in fact be undersize or protected) and the estimated value of discards therefore represents the maximum value given current estimates of average bycatch for each species. In addition, it is possible that the price of bycatch fish would fall if increasing quantities were landed, which is not taken into consideration in this analysis.

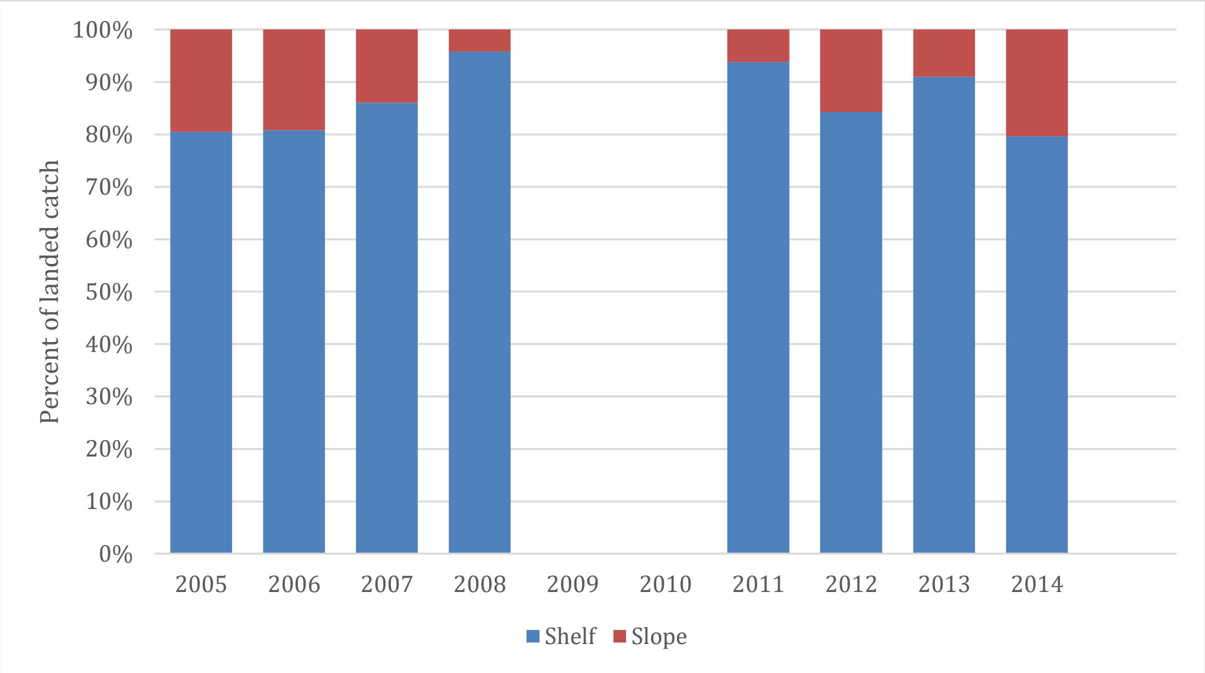


Figure 6. Percent of annual catch taken from the shelf and slope by the GABTS. Note that data from 2009 and 2010 comprised of less than 5 vessels and so have been omitted from the graph.

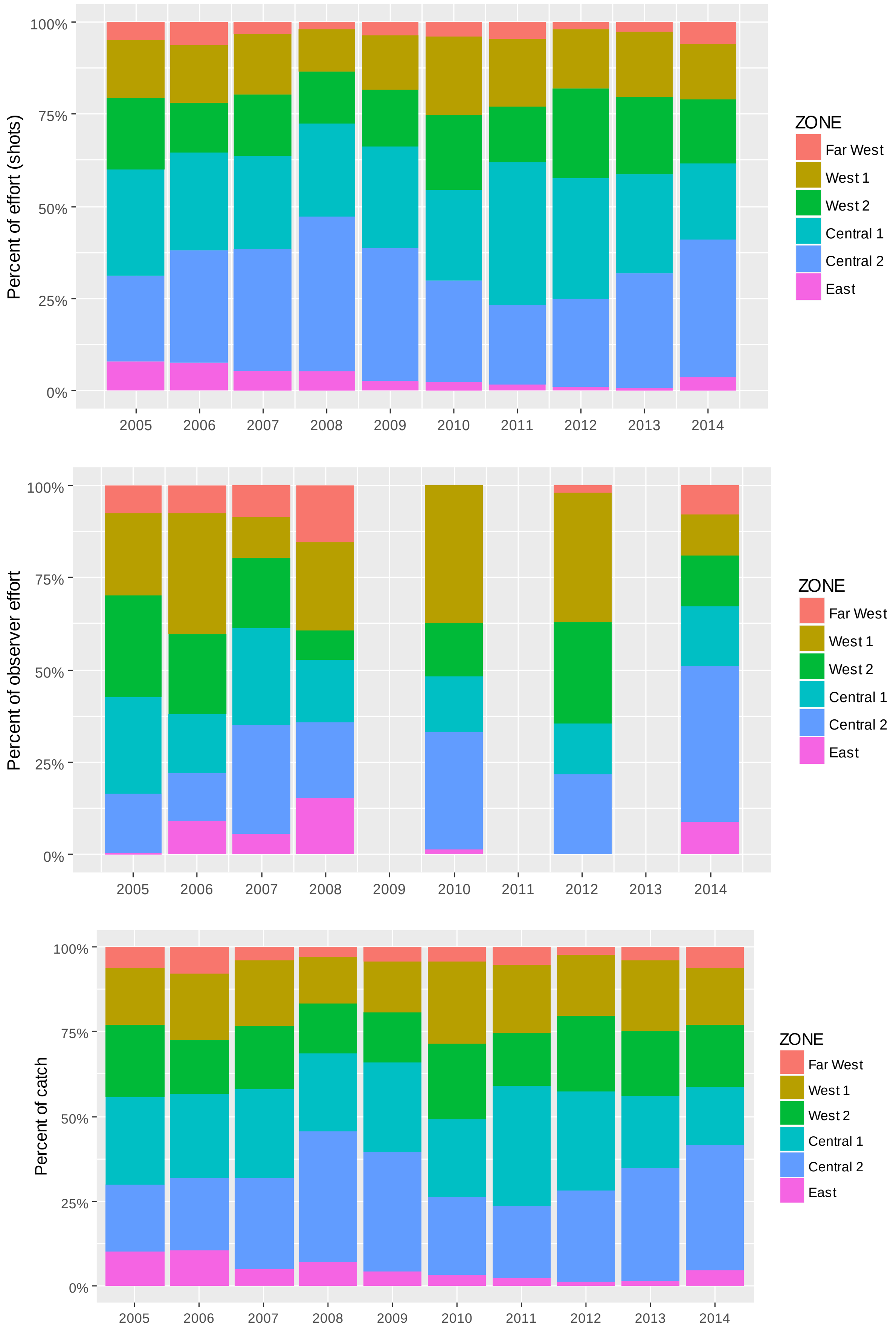


Figure 7. Percent of annual GABTS effort (number of shots) (top panel), shots observed by observers (middle panel) and catch (bottom panel) by zone. See Figure 1 for zones used.

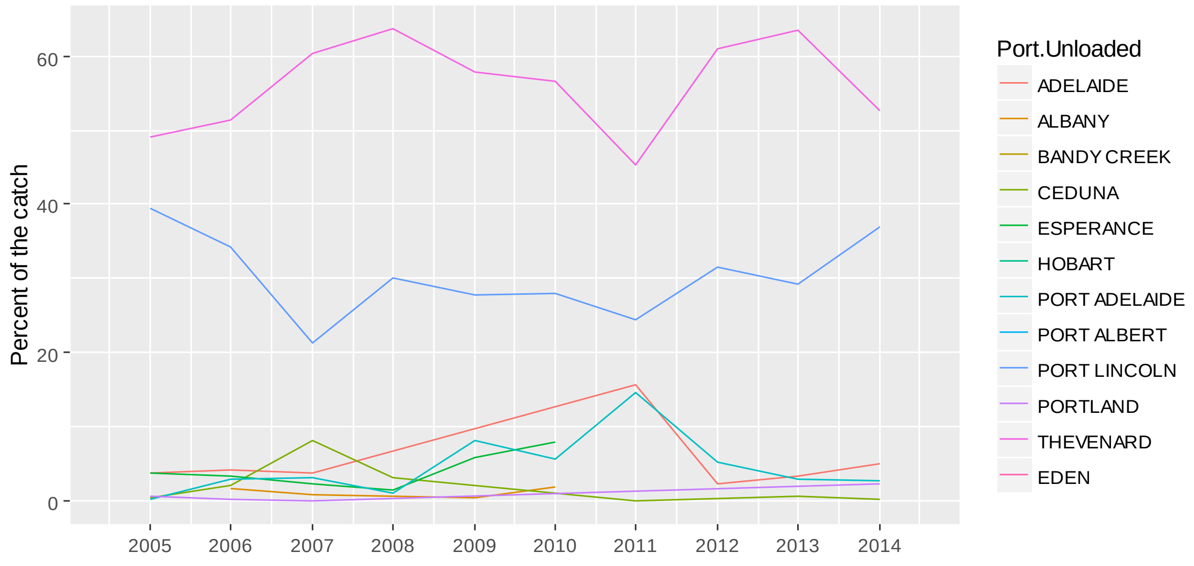


Figure 8. Percent of annual GABTS catch landed at each port.

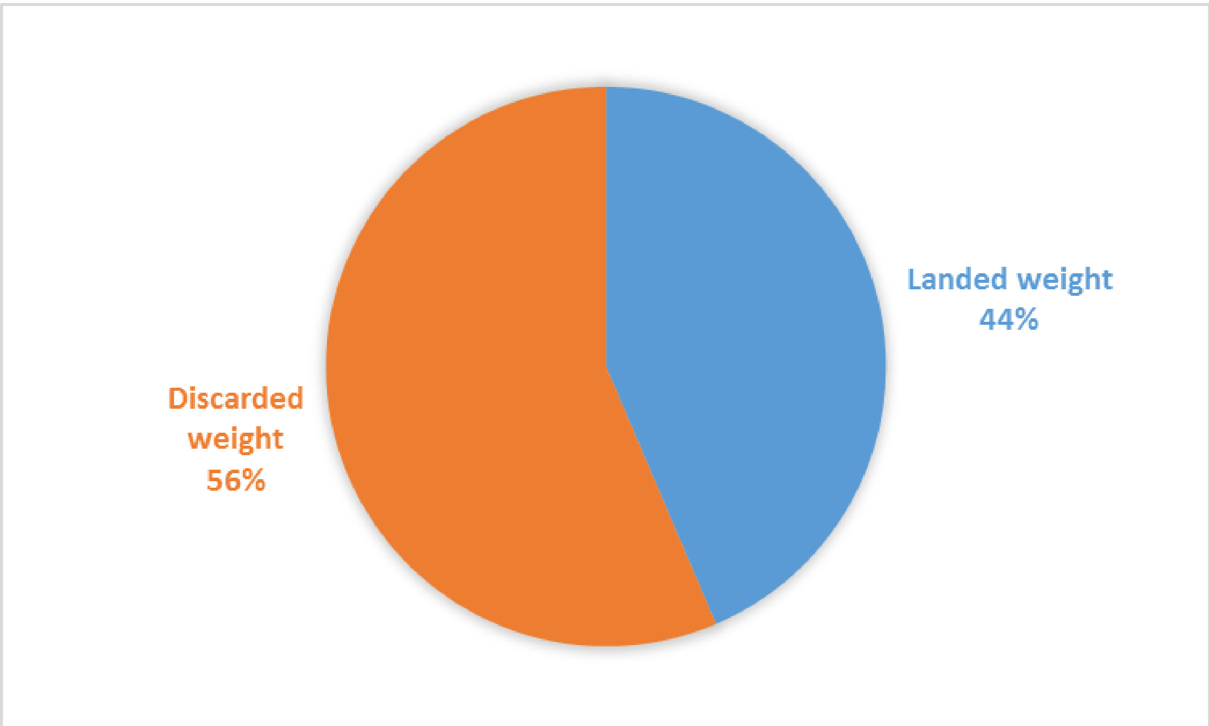


Figure 9. Average retained and discarded catch of the GABTS based on logbook and observer data 2005-2014. Deepwater fishing for Orange Roughy is not included.

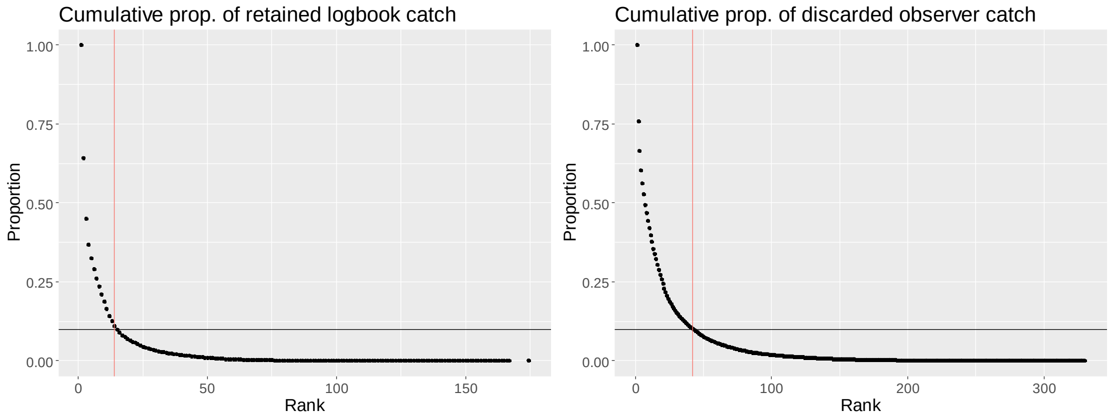


Figure 10. Left panel — ranked, cumulative catch of each retained species reported in logbooks. Right panel — ranked, cumulative catch of each discarded species reported in observer data. Horizontal black lines are at 0.1, and the vertical red lines show the points at which the horizontal line intersects with the catch curve. Species to the left of the red line comprised 90% of the total retained and discarded catch in logbooks and observer data respectively.

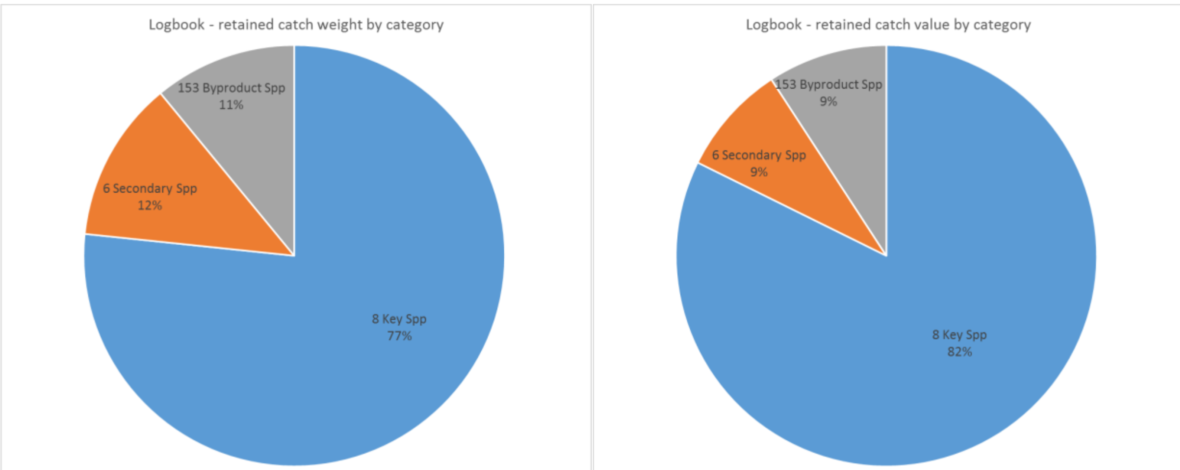


Figure 11. Proportion of total retained catch weight (left panel) and value (right panel) of each species category in logbooks from 2005–2014.

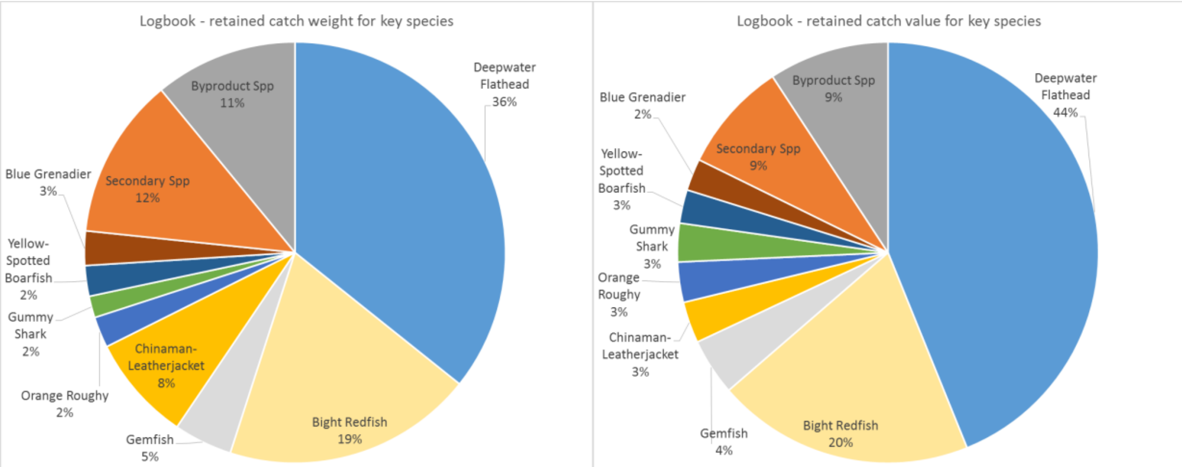


Figure 12. Proportion of total retained catch weight (left panel) and value (right panel) of each key species and other species categories in logbooks from 2005–2014.

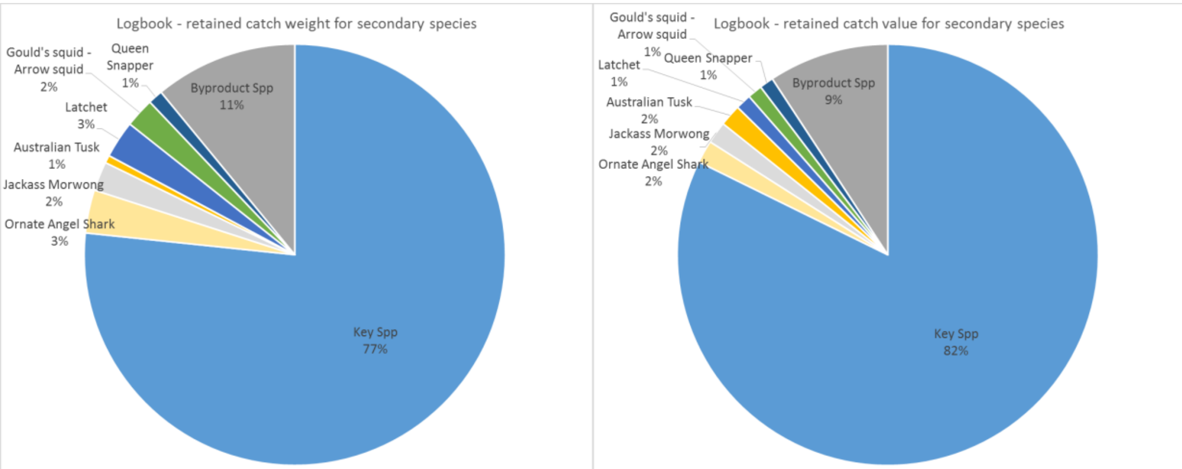


Figure 13. Proportion of total retained catch weight (left panel) and value (right panel) of each secondary species and other species categories in logbooks from 2005–2014.

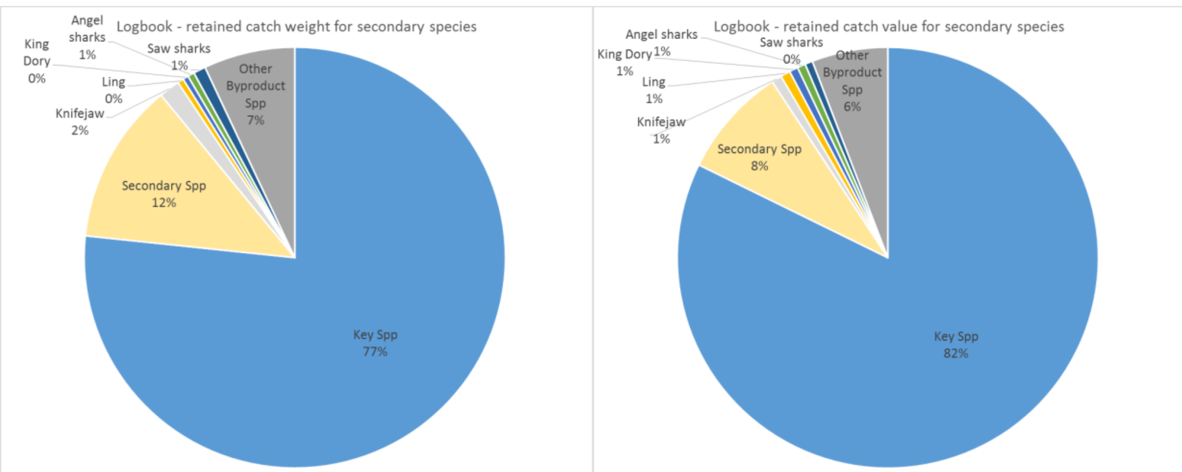


Figure 14. Proportion of total retained catch weight (left panel) and value (right panel) of the top 5 byproduct species and other species categories in logbooks from 2005–2014.

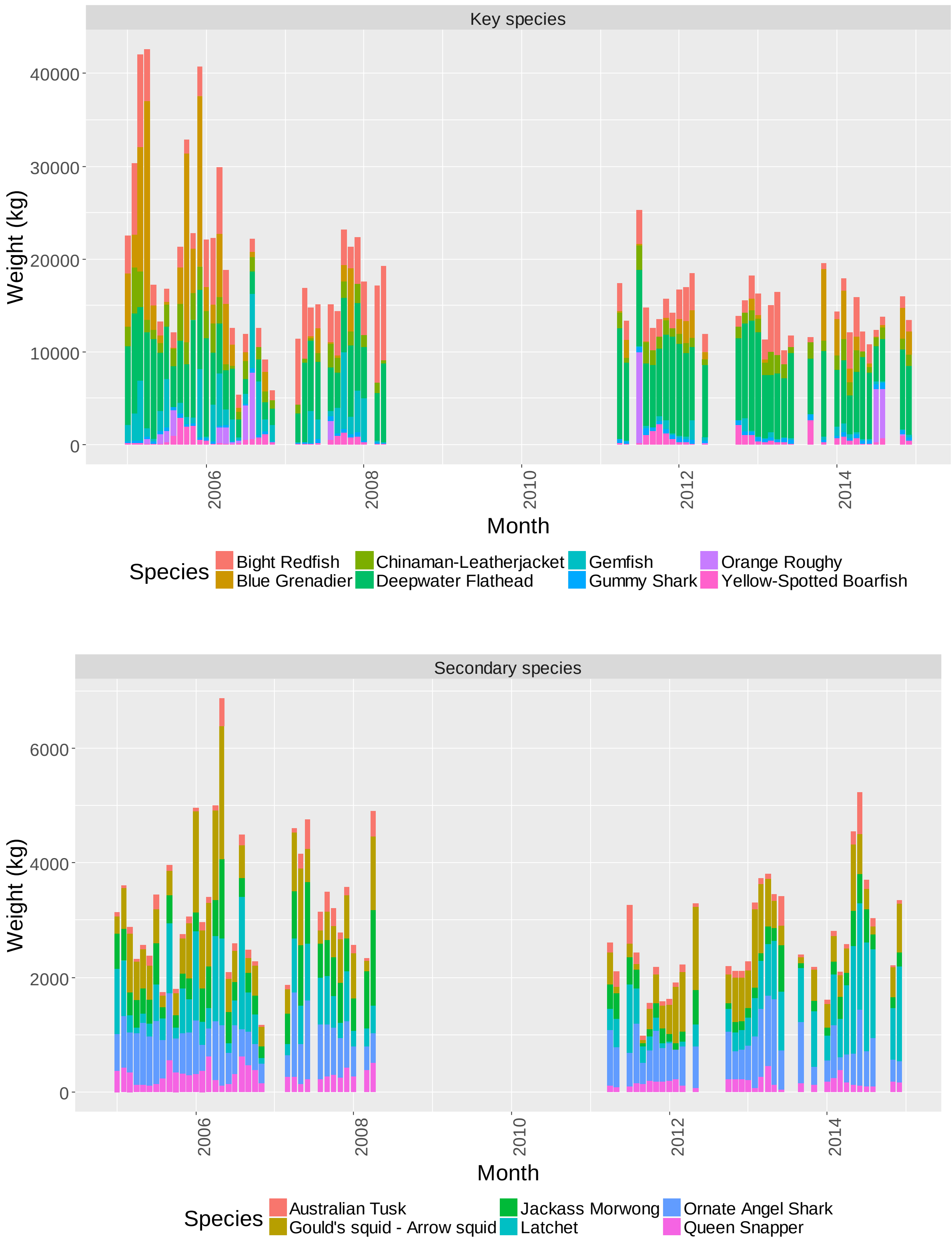


Figure 15. Average monthly non-zero catches per trip (kg) of key (top panel) and secondary (bottom panel) species from January 2005 – December 2014 recorded in logbooks. Note that X-axis labels appear under the month of January. Months comprising data from less than 5 vessels have been removed to protect confidentiality.

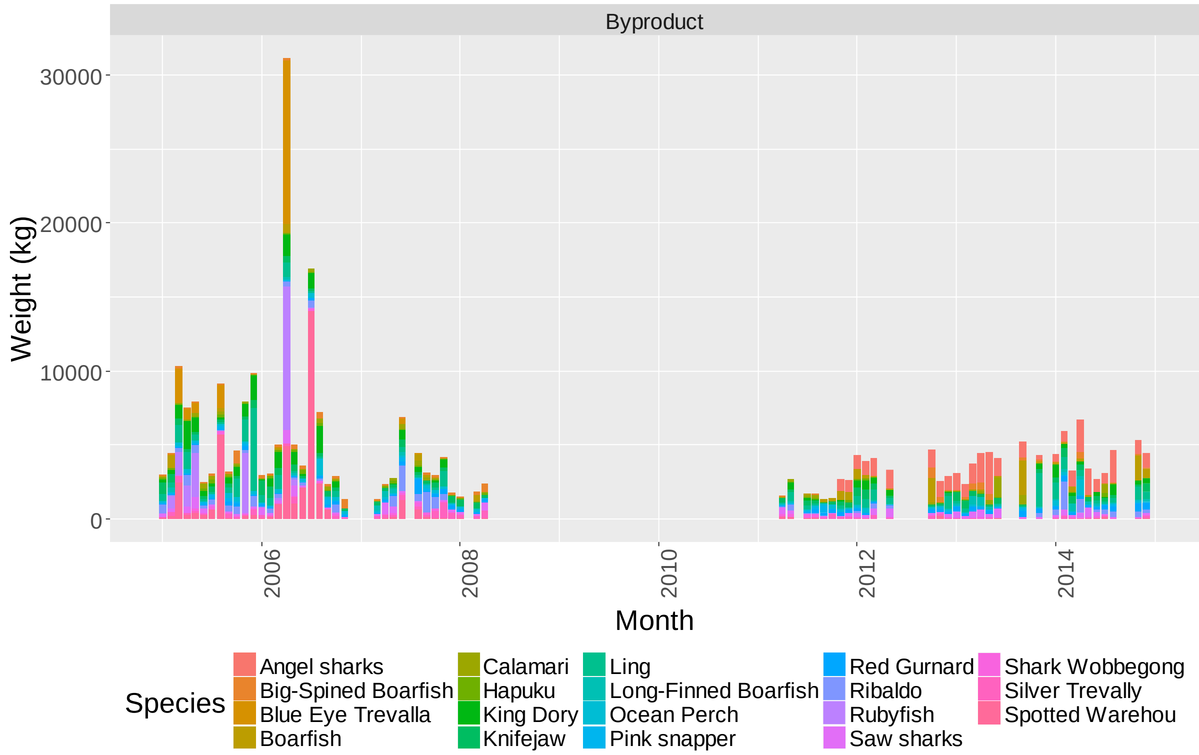


Figure 16. Average monthly non-zero catches per trip (kg) of byproduct species from January 2005 – December 2014 recorded in logbooks. Note that X-axis labels appear under the month of January. Months comprising data from less than 5 vessels have been removed to protect confidentiality.

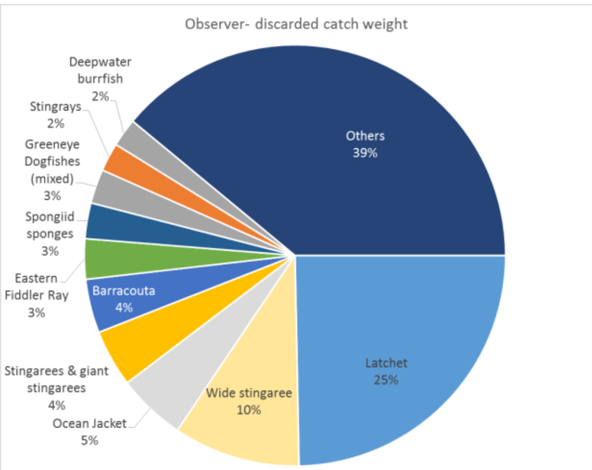


Figure 17. Proportion of total discarded catch weight of the top 10 species from observer data (weighted by effort) from 2005–2014.

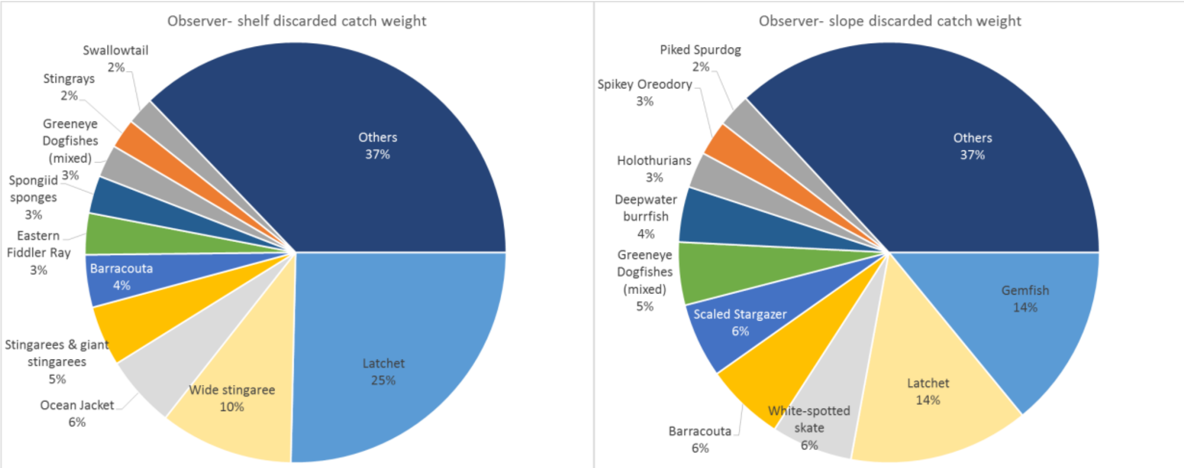
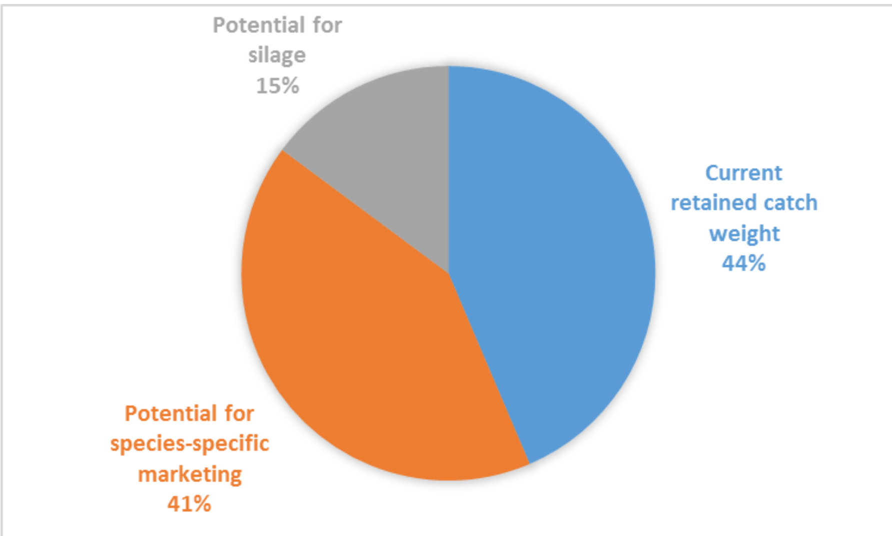


Figure 18. Proportion of total discarded catch weight of the top 10 species recorded by observers from 2005–2014 (weighted by effort) over the shelf (left panel) and slope (right panel).

Table 3. Discard composition of main species or species groups based on GABTS observer data from 2005 – 2014. Note, % composition differs slightly to Figure 18 because they are calculated from raw data, not weighted catches.

Species/Group	Percent of discards	Cumulative Percent
Latchet	24%	24%
Stingarees	14%	38.00%
Skates and rays	12%	50.00%
Ocean Jacket	6%	56.00%
Barracouta	4%	60.00%
Dogfish	4%	64.00%
Other	36%	100.00%



.

Figure 19. Potential utilisation of the currently discarded catch based on species composition —not the feasibility of achieving total utilisation.

Figures removed because they contravene the 5 boat rule

Figure 20. Mean monthly discarded catch per shot (kg ± SE) of main discard species from 2005–2014 observer data. Annotations are the number of shots observed.

Table 4. Catch classification table for GABTS trawl species, average annual catches, discards, prices, market and stock status information. Stock status was taken from Patterson *et al*. (2016). Stock status indicators are for fishing mortality / biomass: green = not subject to overfishing / not overfished; orange = uncertain if subject to overfishing / overfished.

Key species	Average CDR catch GABTS (between 2005-2014) (kg/year)**	Estimated average annual discards for GABTS between 2005-2014 (kg)***	Proportion discarded	Average price whole fish ($/kg)	Estimated value of discarded catch ($/year)	Stock status
Deepwater Flathead	907,586	4,852	0.005	$5.33	$25,861	
Bight Redfish	471,141	421	0.001	$4.73	$1,991	
Gemfish	**39,729**	**50,275**	**0.559**	**$2.70**	**$135,743**	
Ocean Jacket	**217,643**	**165,713**	0.432	**$1.86**	**$308,558**	
Orange Roughy	57,140	1,656	0.028	$4.65	$7,700	
Gummy Shark	44,867	1,027	0.022	$6.59	$6,768	
Yellowspotted Boarfish	68,473	923	0.013	$3.55	$3,277	
Blue Grenadier	20,502	712	0.034	$2.48	$1,766	
Secondary species						
Ornate Angelshark	77,690	45,502	0.369	$1.79	$81,449	
Jackass Morwong	58,092	10,726	0.156	$3.28	$35,181	
Australian Tusk	18,283	1,224	0.063	$14.67	$17,956	
Latchet	**62,314**	**780,284**	0.926	**$1.46**	**$1,136,094**	
Gould's Squid	48,441	11,108	0.187	$2.08	$23,105	
Blue Morwong	32,094	275	0.008	$3.34	$919	
Byproduct						
Knifejaw	42,194	20,417	0.326	$2.83	$57,780	
Pink Ling	7,131		0.000	$5.72	$0	
King Dory	6,714	220	0.032	$6.18	$1,360	
Barracouta	**119**	**138,554**	0.999	**$1.00***	**$138,554**	
Sawsharks	25,994	17,529	0.403	$2.14	$37,512	
Red Gurnard	32,246	14,986	0.317	$2.93	$43,909	
Snapper	10,916	197	0.018	$7.68	$1,513	
Reef Ocean Perch	364	1,458	0.800	$3.27	$4,768	
Skates & Rays (Banjo shark, Skates, Skates & rays, Southern Eagle ray)	**617**	**365,910**	**0.998**	**$1.00***	**$365,910**	
Silver Trevally	16,604	7,725	0.318	$4.27	$32,986	
Bigspine Boarfish	1,161	179	0.134	$3.01	$539	
Wobbegongs blind nurse carpet & zebra shark	9,398	217	0.023	$1.92	$417	
Dogfish (dogfishes, Endeavour dogfish, Spurdog)	**3,225**	**199,577**	**0.984**	**$1.00***	**$199,577**	
Silver Warehou	16,849	121	0.007	$1.82	$220	
Hapuku	2,216		0.000	$8.01	$0	
Ribaldo	4,446	1,059	0.192	$2.05	$2,171	
Rubyfish (mixed)	13,359		0.538	$5.16	$80,135	
Stingarees	**72**	**456,568**	**1.000**	**$1.00***	**$456,568**	
Boarfishes	4,258		0.018	$3.63	$283	
Southern Calamari	16,476	1,115	0.063	$11.72	$13,068	
Blackspot Boarfish	9,330	10,697	0.534	$1.98	$21,180	
Total	2,435,876	2,311,227			$3,247,604	

* The price for the bycatch species is set at a conservative price of $1.00 per kilo reflecting the market survey where processors indicated they were willing to pay less than $2 per kilo.

** Average annual catch (average taken over the last ten years) from logbook data. Note that catches reported in logbook data are generally lower than catch disposal data (as listed in SESSF stock assessment reports).

*** Average discarded catch (average taken over 10 years but not all years have observations for some species) using monthly observer data for selected species.

Table 5. Total number shots observed and percent of shots observed by the observer program from 2005–2014 by month, and total number of daily logbook shots over the same time period

Month	Total number of shots observed (%)		Total number of shots in logbook	
	Shelf	Slope	Shelf	Slope
Jan	97 (2.4%)	1 (0.5%)	3992	191
Feb	88 (2.4%)	10 (7.7%)	3703	130
Mar	147 (3.8%)	3 (1.3%)	3865	226
Apr	86 (2.4%)	5 (1.8%)	3648	279
May	79 (2.5%)	2 (0.3%)	3219	584
Jun	25 (1%)	11 (1.8%)	2549	601
Jul	62 (3.3%)	51 (9.2%)	1875	556
Aug	38 (1.5%)	32 (7.8%)	2458	412
Sep	88 (2.8%)	9 (7.8%)	3100	116
Oct	165 (4.7%)		3481	0
Nov	61 (1.7%)		3633	0
Dec	79 (2.6%)	1 (0.7%)	3041	137

Table 6. Species composition recorded by the observer program of main bycatch discarded from the Great Australian Bight Trawl Fishery from 2005 – 2014. Note, % composition differs slightly to Figure 17 because they are calculated from raw data, not weighted catches.

CAAB code	Common Name	Number of Shots	Percent of discards	Cumulative Percent
37288006	Latchet	942	24%	24%
37038008	Wide Stingaree	332	9%	33%
37465006	Ocean Jacket	450	6%	40%
37038000	Stingarees & giant stingarees	72	4%	44%
37439001	Barracouta	489	4%	47%
37027006	Eastern Fiddler Ray	306	3%	51%
10114000	Sponges	338	3%	53%
37469002	Deepwater Burrfish	453	2%	56%
37020901	Greeneye Dogfishes (mixed)	172	2%	58%
37288003	Butterfly Gurnard	88	2%	60%
37258005	Swallowtail	346	2%	62%
37020006	Piked Spurdog	362	2%	64%
37035000	Stingrays	123	2%	66%
37031000	Skates	136	2%	68%
37027011	Southern Fiddler Ray	146	2%	69%
37031900	Skate (mixed)	64	2%	71%
37024002	Ornate Angelshark	420	2%	73%
37038004	Sparsely-spotted Stingaree	23	1%	74%
37439002	Gemfish	150	1%	76%
37035001	Short-tail Stingray	159	1%	77%
	Other species			23%

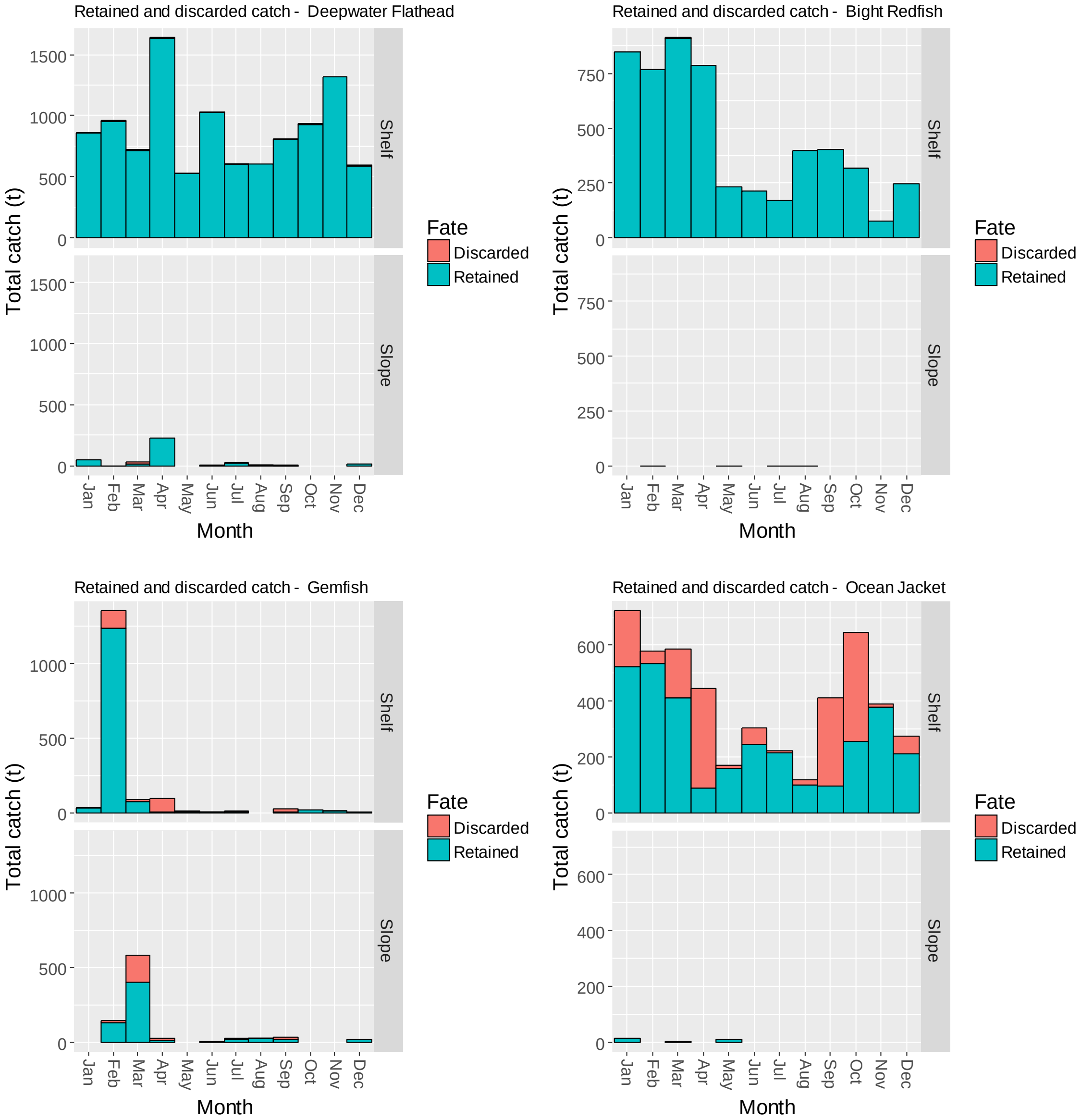


Figure 21. Weighted up (by total effort) retained and discarded observer data from 2005–14 by month and depth category for the key species Deepwater Flathead, Bight Redfish, Gemfish and Ocean Jacket.

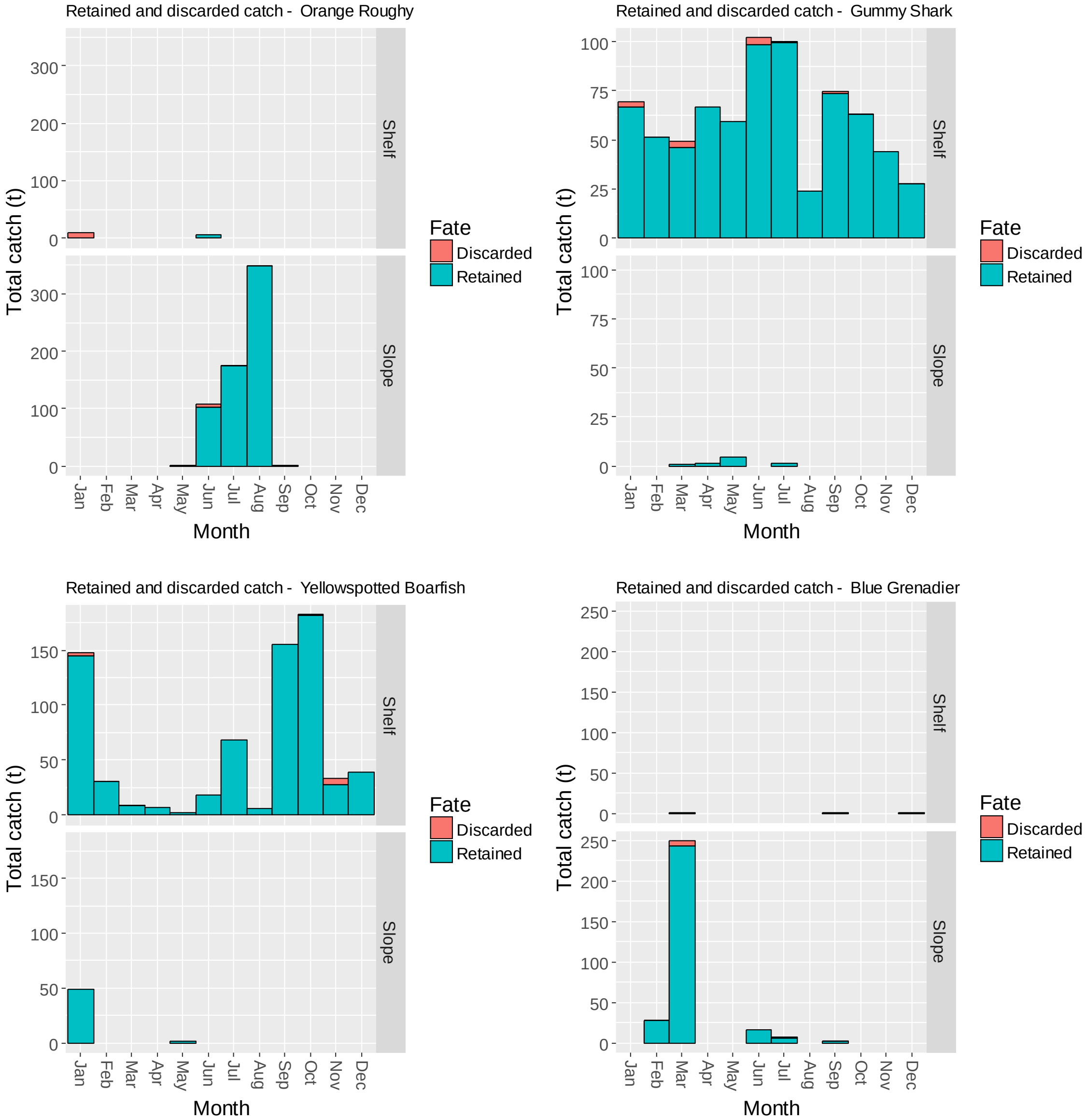


Figure 22. Weighted up (by total effort) retained and discarded observer data from 2005–14 by month and depth category for the key species Orange Roughy, Gummy Shark, Yellowspotted Boarfish and Blue Grenadier.

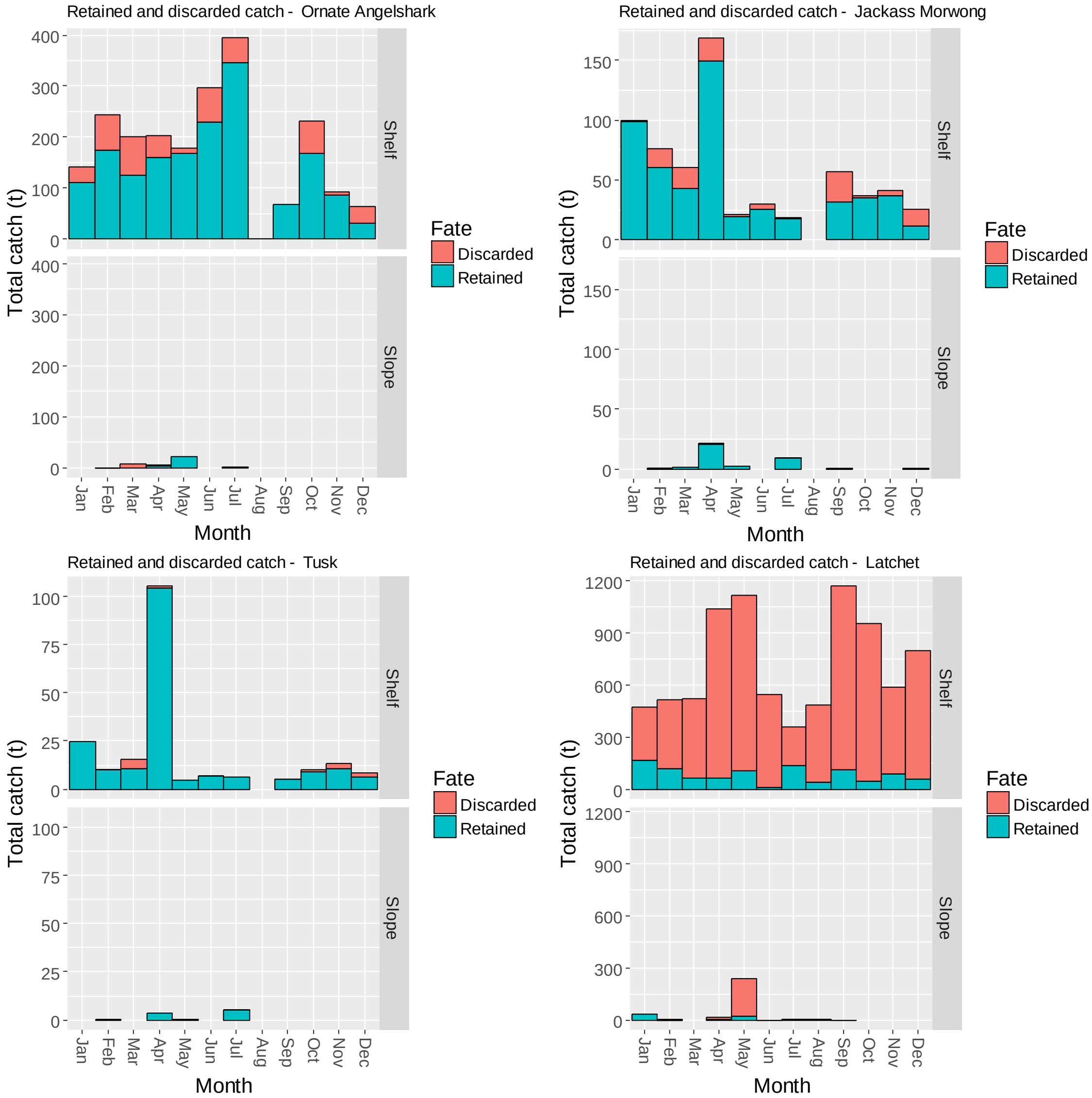


Figure 23. Weighted up (by total effort) retained and discarded observer data from 2005–14 by month and depth category for the secondary species Ornate Angelshark, Jackass Morwong, Australian Tusk and Latchet.

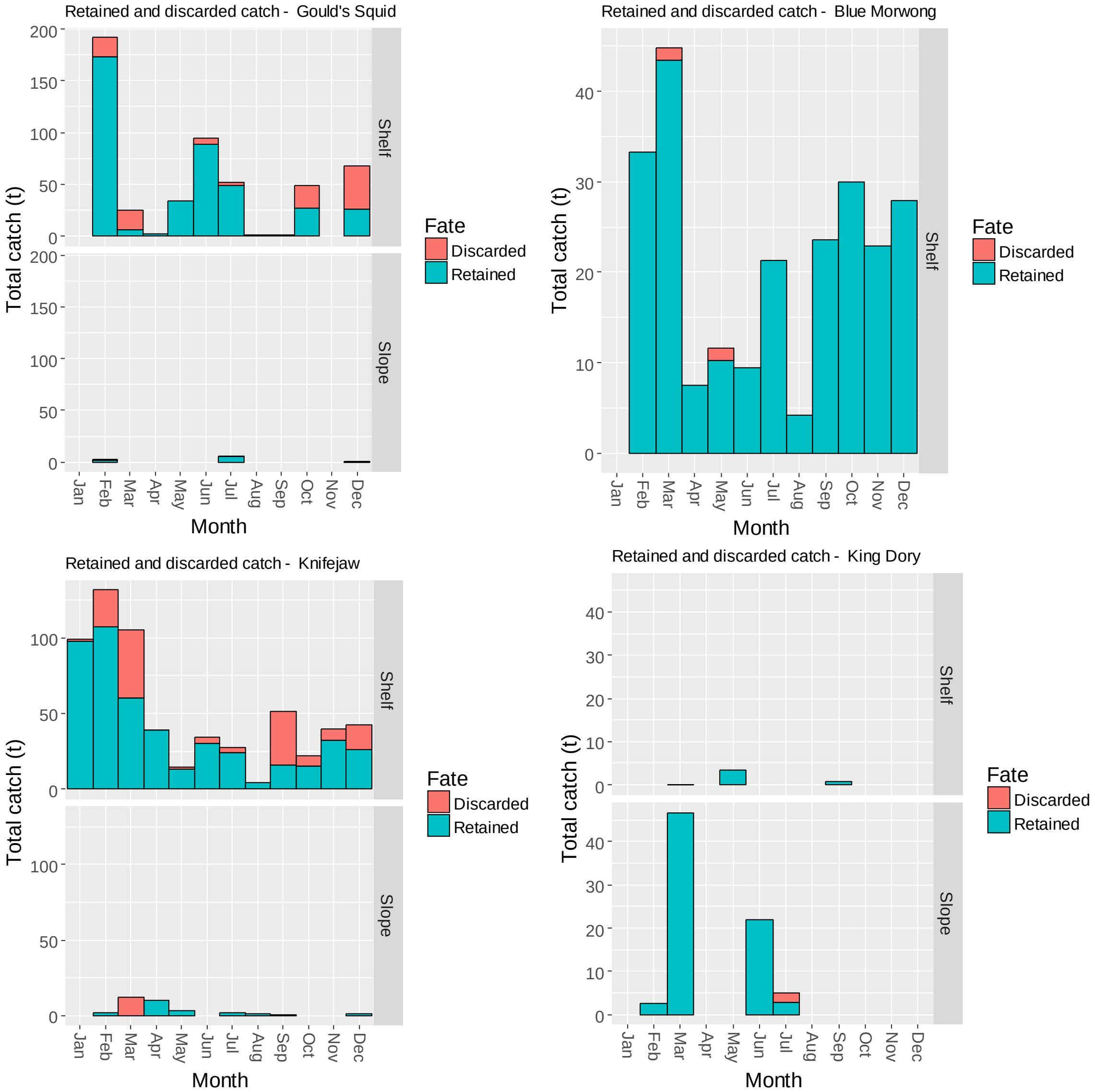


Figure 24. Weighted up (by total effort) retained and discarded observer data from 2005–14 by month and depth category for the secondary species Gould's Squid, Blue Morwong, and byproduct species Knifejaw and King Dory.

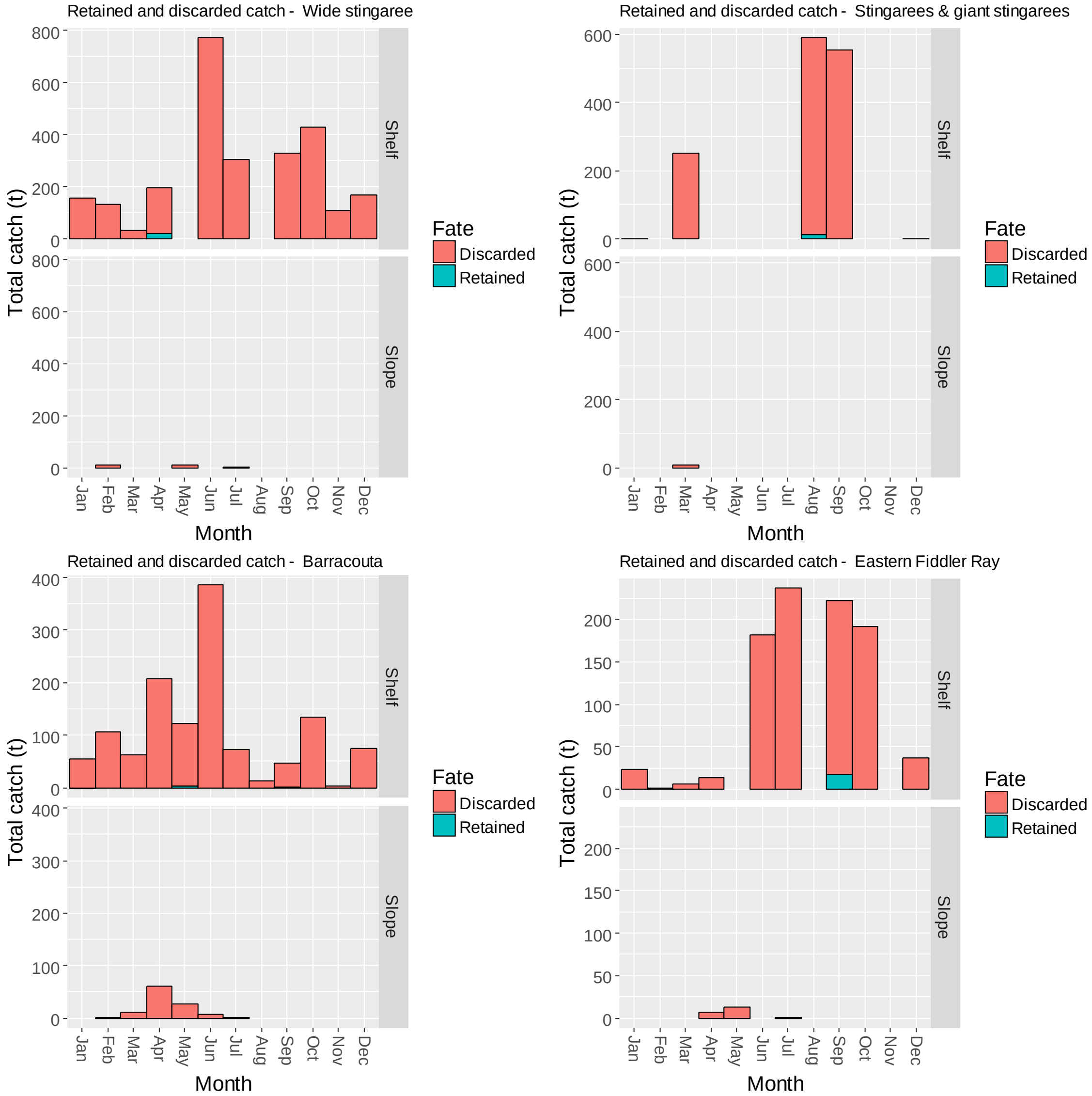


Figure 25. Weighted up (by total effort) retained and discarded observer data from 2005–14 by month and depth category for the main discard species Wide Stingaree, Stingarees and Giant Stingaree, Barracouta and Eastern Fiddler Ray (note that Latchet is shown in Figure 23).

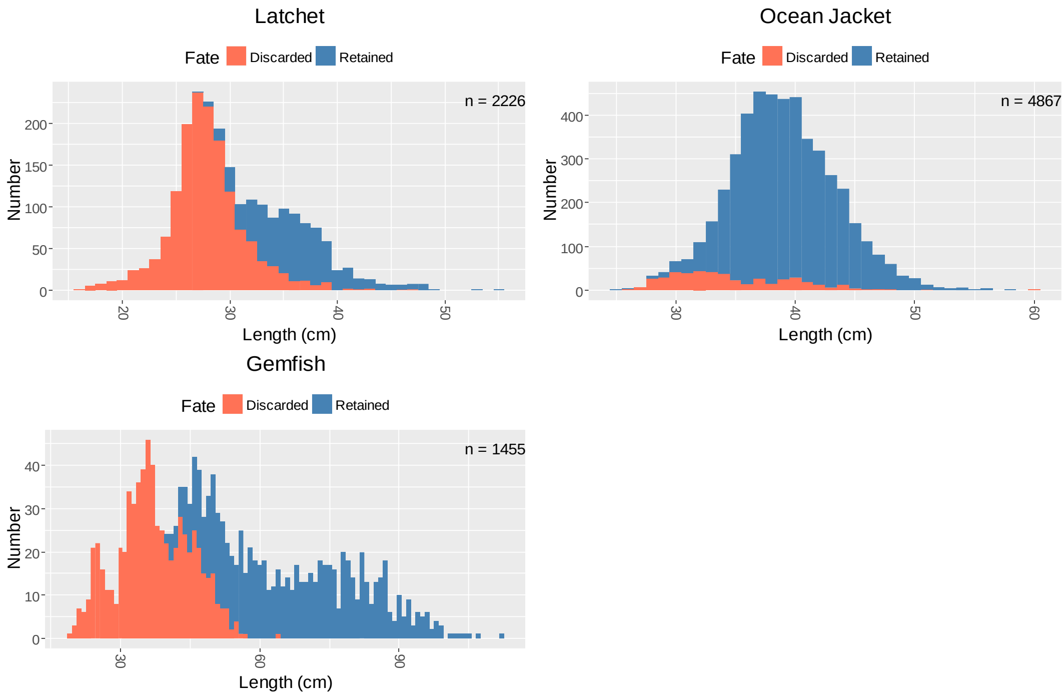


Figure 26. Length frequency distribution of retained and discarded catch of main discard species recorded by observers. Frequency is not catch weighted. There was no size data for Wide Stingaree, stingarees and giant stingarees, Barracouta or Eastern Fiddler Ray.

4.2. Conduct domestic market surveys to determine the potential demand of edible product from different bycatch species

4.2.1. Bycatch utilisation in the western world

In most western fisheries discarding has been on the agenda as an important issue that needs to be resolved. The EU Common Fisheries Policy (CFP) reform is aimed at the elimination of discarding of quota species in EU commercial fisheries. The CFP is a progressive policy that may ultimately bring an end to discarding and at the same time create incentives to utilise discarded fish.

Several initiatives and incentives have been developed in the EU to promote the sale of bycatch for human consumption. Iceland developed a programme to promote low value fish to consumers. A “bycatch bank” was set up that purchased blocks of non-commercial species from boats and arranged taste panels, promotion schemes and sales to restaurants (Clucas, 1997). Activities such as "strange fish weeks" were organized and manuals of identification of new species and recipe booklets were provided.

In the UK, a “Fishing for the Markets” program was initiated in 2011 with the aim of finding new ways of getting more of the unfamiliar and less popular fish caught by

English trawlers to market[6]. Focused activities which stimulate consumer demand for underutilised species (for human consumption) could help more underutilised species to reach market.

In addition to human consumption, non-human consumption has been explored in England and Scotland (Steward, 2014). The bait industry may have some potential to absorb some of the underutilised fish species which are currently discarded. Use of discards as bait was studied by UK government and industry (de Rozarieux, 2014). This study found that English pot fleet targeting crab uses more than 40,000 ton of fish as bait annually. This estimated demand for bait is significantly larger (~68%) than the potential supply from fish that would have previously been discarded.

In North America, some prohibited species that are caught as bycatch are disposed of through hunger relief agencies (thus entering the human food chain without creating artificial demand for these species). This has enabled the establishment of private, non-profit organisations which access surplus or unmarketable fish from seafood companies for distribution to feed needy Americans through national food bank networks (Clucas, 1997).

4.2.2. Barriers and solutions to landing bycatch

There are a number of reasons that fish are not landed (discarded) due to either supply-side or demand-side barriers. Such barriers for landing bycatch were identified from the literature and informal conversations with national and international experts (Table 7). Supply and demand barriers were further divided into sub-categories. For instance, a number of supply-side barriers were specific to the 'on-board' situation, such as the lack of storage space, or the absence of the right equipment. Generally, the barriers related broadly to a particular fishery or country, but in our review, it was not possible to identify if these barriers were species-specific. There is much that can be learned from successful solutions that have overcome the supply and demand barriers. Other reasons for discarding include high grading and regulatory restriction on landing some species.

Many countries have tried to address or overcome these common barriers with different level of success (Table 8[7]). For example as early as 1973, the government of Guyana (South America) developed a shrimp bycatch utilisation program (Peterkin, 1982). In the United States, Alaska produces more fisheries catch than any other region in the USA (Queirolo *et al*., 1995) and studies there have focused on bringing even more fresh product, including bycatch species, to market.

[6] http://www.seafish.org/media/492490/seafishsummary_fishingforthemarkets_201105.pdf

[7] Information based on personal communication with GABTS representatives, industry interviews and Åsmund Bjordal, Kjell Harald Nedreaas, and Jon Helge Vølstad from IMR in Bergen, Norway about issues pertaining to the demersal fleet. Additional information is sourced from Kennelly 1995; Kelleher, 2005; NMFS 2011; LEI 2013 and others in reference list.

Table 7. Known supply and demand barriers to the use of bycatch.

	Barriers	Australia	Norway#	EU*	USA/ Canada**	Other
Supply	**Product**					
	Boom – bust catches (irregularity of supply)	✓				
	Low overall quantities			✓		
	Low value species	✓				
	Varied species composition of bycatch and toxicity of some species					
	Sale price insufficient to cover processing costs and price to the trawlers			Netherlands[1]		Bay of Bengal
	Product quality assurance					
	Limited shelf life	✓			✓	
	Bacterial counts and diseases	✓		✓	✓	
	On-board					
	Lack of storage space on board		✓	✓	✓	
	Absence of the right equipment (freezers)	✓	✓			
	Lack of adequate personnel / deckhands			✓		✓
	Additional work for already busy crew (to sort catch)		✓			
	Difficulties with handling fish (species identification)	✓				✓
	Additional investment in (special) fishing gear					
	Additional administrative requirements					
	Transport and logistics					
	Large distance to market	✓	✓	✓		
	Difficult logistics to get to market		✓			
	Lack of cooperation/opportunity to combine catch				✓	
	Illegal to use mother boat / freezer boat at sea	✓				
	Inadequate product for at-sea transfer	✓		✓		
	Disparate fleet (landing fish in many & distant ports)		✓			
	Expense or lack of interim storage facilities	✓	✓			
	Lack of supply chain flexibility & options			✓		
	Fisher & processor related					
	Low interaction with other fishers who supply same products			✓		✓
	Low knowledge of supply chain options					✓
	Low knowledge of market options					✓
	Absence /lack of market contacts	✓				
	No direct relationship of producers and processors, food service and retail customers	✓				✓
	Processor					
	Lack of alternative product options (e.g. non-food)				✓	
	Processors disinterest in developing new products					✓
	Limited packaging options					✓
	Limited storage facilities in relevant harbours			✓		
	Expense of processing equipment		✓			
	High local wages (compete with low wage countries)	✓		✓		
Demand	**Consumer**					
	Multiple product substitutes		✓			
	Lack of consumer knowledge (how to cook the fish)	✓	✓			
	Product presentation		✓			
	Product smells/odours	✓			✓	
	Markets					
	Variability in product quality		✓			
	Variable in product size and look		✓			
	Lack of fishery wide advocacy / marketing body			✓		
	Expense of marketing product	✓		✓		
	Long (research) lead times for product development		✓	✓		
	Sales outlet					
	Limited distribution channels			✓		
	Supermarkets unwillingness to accept new fish		✓			
	Restaurants & chefs lack of product knowledge	✓	✓			
	Lack of consumer exposure to unusual edible species	✓	✓			
	concentration of power at the wholesale supply level	✓				
	Additional skill requirements at retail stores	✓				

* EU issues pertain to all fleets and are as a consequence of the landing obligation.
** Arrowtooth flounder (0.44), rock sole (0.32), and flathead sole (0.23) are bycatch species in Alaska flatfish trawl fisheries (http://www.nmfs.noaa.gov/by_catch/National_Bycatch_Report/2011/ExecutiveSummary.pdf.)

[1] Low price that can be offered for fishmeal locally (although better prices if exported to Norway where existing and large fishmeal companies exist).

Table 8. Solutions to address different categories of supply & demand barriers to bycatch use.

	Barriers	Solution to overcome barrier
Supply	Product*	- Target local markets by direct sales from the vessel - bulk slurry ice system to improve product quality from trawlers - Sales from fish coop (showcased at seafood directions) – where customers buy a bag of mixed fish (not selected by species). - combine bycatch with bycatches from another fishery (which happens in most fish producing countries). For instance, fish offcuts and offal from the consumption industry are collected in the UK and Germany where these materials are used to produce white fish meal. Similarly, in South Africa fish meal is made from rock lobster carapaces and other parts which are not utilized (FAO, 1986). - Overcoming the perception of "low-value" and applying correct catching and processing techniques to make bycatch available to the domestic market supply chain. - Collective search for new markets (NMFS, 2011)
	Quality assurance	- Process to dry product so that it can be exported economically (to low income countries) and without affecting product quality over longer distances (FAO, 1996)
	On-board	- Hordafor AS is a Norwegian company based in Austevoll - annually handling 200,000t of fish byproducts mainly from the fish farming production (fish oil and protein concentrate). They also include waste and bycatch from commercial fisheries with specialized vessels collecting the fish waste. Three vessels have onboard silaging.
	Transport and logistics	- Improvement of cold chain logistics for fresh fish. - The silage industry has commissioned a vessel to collect the bycatch at sea to ensure the holds are not filled with low value fish rather than the key species (pers. comm.). - The larger vessels (i.e. pelagic vessels) have enough space to retain the bycatch and bring it back to port. Here they can simply pump the bycatch out at a central collection point for it to be processed to fishmeal (pers. Comm.). Improving the capacity of the domestic market to better distribute a wider range of seafood, so that local product will capture the scale to provide a substitute for some imported product. Particularly, the potential for lower valued products to directly substitute imported mass processed product. This could also bring more stability to the retail range on offer (Street 2006).
	Fisher & processor related	- Ownership and management of the processing business and factories is maintained by fishers and the fishing industry as in FF Skagen who are one of the largest producers of fishmeal and fish oil in the world. The group's two factories are located at two main ports (Skagen and Hanstholm) where 130 employees transform approximately 500,000 t of fresh fish into 170,000 t of fishmeal and fish oil annually (http://www.ffskagen.dk/Default.aspx?ID=522). - Specialisation of the fleet into catching the fish for the sole purpose of fishmeal production happens, for example, in Chile, Peru, Norway, Denmark, South Africa and the USA) (FAO 1986). Specialised fish meal fishery and fleet ensure the quantities become adequate over time at the right price - The fishing industry working closely with domestic retailers to improve their performance, there is potential to provide an understanding of retailer priorities and practices that can be translated into marketing and support dealings with retailers in export markets. This can flow on to increase export market performance (Street 2006).
	Processor	- Provide easy methods to source and identify sustainable seafood (using certification as a marketing tool) - Export bycatch to another country. For instance, Netherlands exports to Norway due to lack of local processor. However, the local (Netherlands) processor who now only handles other animal waste (and not fish) is interested in investing if the quantities become adequate to make it financially worthwhile.
Demand	Consumer	- Show/teach the local consumer how to cook and prepare new species (tv cooking shows can help) (Seafish, 2012) - Provide cooking advice/incentives to chefs in the (high end) restaurants
	Markets	- Preferential distribution to large urban centres because opportunities exist in the food market driven in part by differing consumption preferences of immigrant populations (who are largely located in urban centres)
	Sales outlet	- Encouraging fashionable restaurants 'specialising' in serving up unusual fish species. - Sell new species at low prices first- because starting at high prices is a disincentive - Sell cheap frozen bags of bycatch as 'assorted seafood' or 'seafood medley'

4.2.3. Phone survey and interview results

4.2.3.1. Internet-based Survey

More than 40 businesses likely to receive GABTS species were identified and sent the online survey, with follow-up phone calls to request completion.

Although the response rate was low (7 out of 31 surveys - 22%), we can still glean insight with regard to demand from processors and markets. From the survey responses, it appears that while all the species listed in Section 3.2.1 are purchased, Latchet and Ocean Jacket are the most popular, with Barracouta and dogfish less popular. The quality rating did vary between species, with Latchet, Ocean Jacket and Barracouta receiving the highest rating and dogfish, skates and rays and stingarees the lowest. The weight of each species purchased each week also varied, with Ocean Jacket showing the largest range in responses, as six participants bought less than 30 kg and one participant more than 300 kg a week. Participants purchased less than 30 kg of dogfish, stingarees, skates and rays and barracouta a week, while quantities of Latchet varied, with three participants purchasing less than 30 kg a week, one 30–60 kg and one 60-120 kg a week. The lowest price was selected for stingarees, skates and rays and dogfish (less than $2.00 per kg), while the highest price given was for Ocean Jacket at $6.00-8.00 per kg. Most respondents preferred to purchase the whole fish, except for Ocean Jacket and skates and rays where trunked, flapped or gutted product achieved slightly higher preference. The preferred frequency for purchasing Ocean Jacket and skates and rays was weekly, with the others variable — barracouta was preferred monthly and Latchet had the biggest range from 2–3 times a week to seasonally. The maximum weight that could be sold in a week, with guaranteed supply was variable, with Ocean Jacket and Latchet rated the highest at more than 300 kg by one participant and all of the species rating less than 30 kg by at least one participant. Overall Latchet and Ocean Jacket received the highest rating for desirability, with neutral the most common response across all species and no negative responses recorded. Finally, the main limiting factor noted in the surveys were lack of demand noted for all species, price the consumer will pay noted for Latchet only, and consumer preferences noted for dogfish, Ocean Jacket and stingarees.

4.2.3.2. Interviews with two seafood “shop” owners – follow-up to online survey

Results from this limited interview pool (n=2) were generally consistent with more extensive market research conducted in other projects (Lawley 2015). The low sample size was reluctance from online survey respondents to consent to follow up interviews.

The first interviewee advocated improving the bycatch market by targeting high profile people in the industry to use and promote bycatch recipes on social media to create awareness and demand. The interviewee saw the future of the seafood market as bright, given the increasing focus on sustainability and potential of Asian markets, especially for shellfish, but noted that it is important that bycatch stays cheap (less than $10 or even $5 per kg) and does not become a target species in response to market demand. Bycatch species with minimal waste was noted as more appealing (sharks and leatherjacket that is already headed for example), and that a major deterrent for customers currently is the name of a fish and / or how recognisable it is — dogfish for example won’t sell but leatherjacket will. This interviewee reported making diverse and variable purchasing choices, although mainly shark, skate wings and calamari and has an ability to receive an increased supply. Seasonality and consistency of supply was not considered as a constraint, given diversity of choice.

The second interviewee thought that the main issue with selling the nominated bycatch species is that consumers are not very aware or confident in how to prepare these species. Older people, who used to go fishing to provide food to the family are prepared to deal with a range of fish, but today's generation want it ready-to-go (e.g. fileted and boned). Whole fish was reported as not popular and bones were undesirable. This respondent would not purchase rays as the average consumer from his business would not purchase it. Other species, such as leatherjacket were desired, at a purchase price of up to $4 per kg (with a sale price around $7 per kg). The interviewee regularly buys dogfish, trunked, for $3-4 per kg and sells it filleted for $11-14 per kg as flake[8], and buys whole latchet at $4 kg per kg and sells for $7 per kg as a good substitute for flathead. This interviewee was not interested in buying more of these focal species, but thought the market was likely to remain stable. This wholesaler also sells a lot of farmed fish and thinks that customers interested in sustainability are more likely to buy farmed species. There was also some preference for farmed fish because of their consistent size. Seasonality of supply of the focal species was also not considered important and was recognized as a normal feature of the industry. The interviewee noted that quality does vary between fishing vessels, and purchasing choices were restricted to vessels that "do things properly on the boat". Growth opportunities mentioned included additional fish processing (e.g. with fishcakes). The amount of imported seafood was seen as a big issue. This interviewee focuses on selling Australian seafood and has to educate customers that because labour costs are so high, it will be 2, 3 or even 4 times more expensive, especially if filleted. Recently (in the last two weeks – when interviews were conducted) the interviewee employed a chef to work in his shop and also do cooking demonstrations for less popular fish/bycatch.

4.3. Conduct international market reviews for fresh product and value-added products, including dry and preserved fish, surimi, fishmeal, and similar products.

4.3.1. Utilizing and value adding bycatch

Globally more than 86% of fish (136 million tonnes) is destined for human consumption, while the rest is used for non-food products (in particular fishmeal and fish oil) (FAO, 2014). Live and fresh (or chilled) fish is often the most preferred and highly priced product form (shown at the top of Figure 27), comprising almost 50% of fish going to human consumption in 2006[9]. Just under half of the fish consumed undergoes some form of processing[9.] Main fish processing methods of fish for human

[8] Flake used to refer to a number of shark species sold as "fish and chips" but the Australian Fish Names Standard now categorises flake as one of two species, *Mustelus antarcticus* (Gummy Shark) and *Mustelus lenticulatus* (Gummy Shark or "Rig" in New Zealand).

[9] http://www.greenfacts.org/en/fisheries/l-2/04-utilization.htm (accessed 13/9/2016)

consumption in 2006 were freezing (50%), prepared and preserved (29%) and cured fish (21%)[9].

Fish can be seen as a 'commodity' brought to market in unprocessed form (live or whole — fresh, frozen, or chilled). But there is potential to add value to fish including bycatch (Knuckey, 2006). At present most Australian-produced value-added items are derived from aquaculture products (salmon, trout and shellfish) and not many value-added products are derived from wild-capture fisheries (Knuckey, 2006).

Nevertheless, there are a vast number of ways in which value can be added to fish. Potential uses for fish and fish by-products[10] can be categorised as intended for: direct human consumption; indirect human consumption; non-human consumption; and products that are not for consumption (Figure 27; detail for each of the products is provided in Appendix 5 and are also briefly described in the sections below).

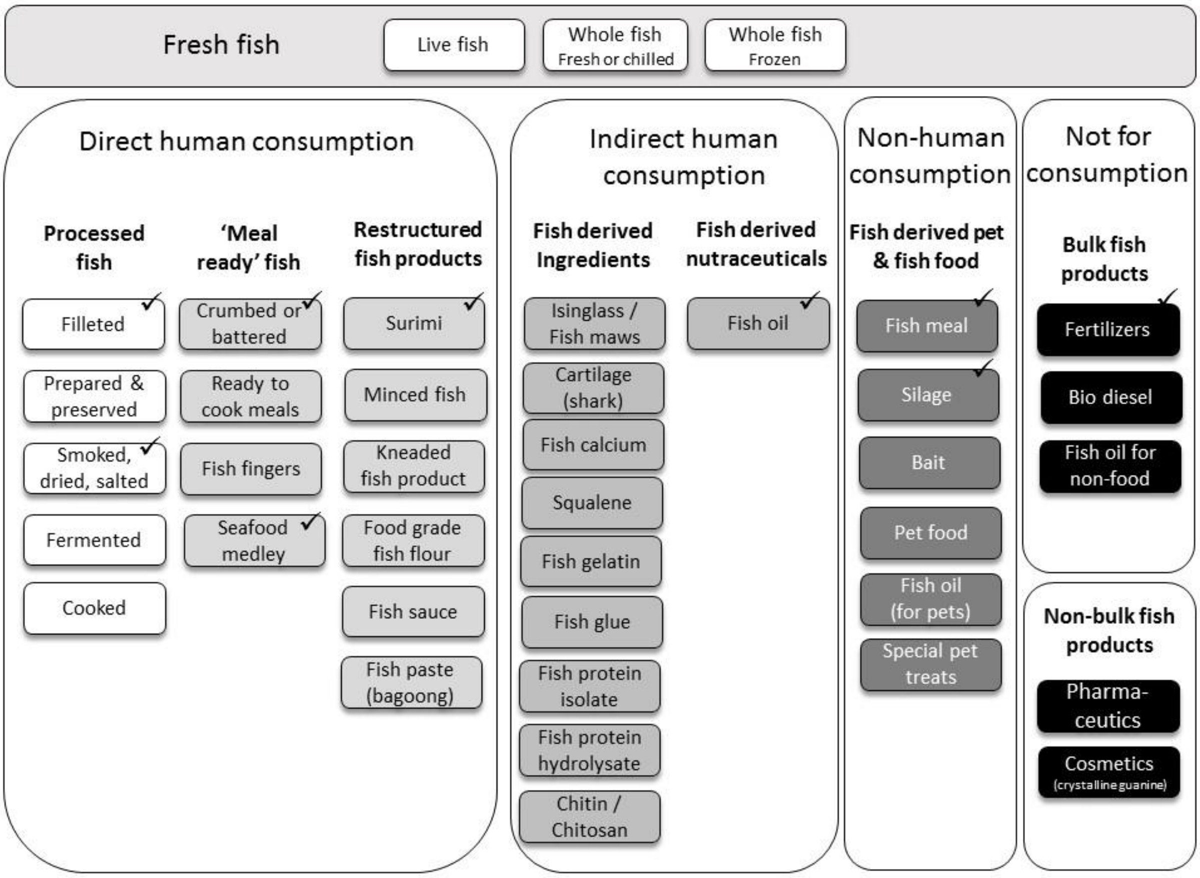


Figure 27. Fish product that can be derived from fish similar to the GABTS bycatch species. Those products with a tick-mark were mentioned in previous studies as having potential for further exploration (Knuckey, 2006) for the GABTS.

As a general rule, products with higher prices per kilo require greater levels of handling and / or processing, and are thus more costly to produce. An example is

[10] Fish by-products are the parts of the fish that remain after fillet and other fish parts are removed for human consumption. In some countries the heads are not considered a by-product but instead are a premium part of the fish that is consumed whole.

pharmaceuticals which are higher priced, and at the same time the amount of this higher priced product that the market is able to absorb is generally lower.

Globally there are numerous value-added fish products that are for direct consumption including, for instance, smoked fillets, crumbed and battered fish fillets, ready to cook meals, and packaged portions, in addition to surimi, minced fish, and fish sauces. Aside from adding value through innovations in 'product processing' (e.g. new quality products, improvements to old products), value can also be added through innovations in marketing (e.g. collective marketing, labels of origin, and ecolabels) and innovations in the applications of information technology (e.g. internet selling, traceability). However, marketing and information technology solutions are not part of this current research.

4.3.2. Direct human consumption

4.3.2.1. Processed and meal ready products

The most familiar edible value-added products include dried fish, dried salted fish, smoked fish, and pickled fish. Dried fish is a traditional fish preservation method used in most Asian countries (Sultana *et al.*, 2013). The most common method is to dry the fish under sunlight; the other method is using hot air. The price for dried fish can be several times higher than that for fresh product. For example, the wholesale price for dried leatherjacket can be more than AU$13/kg, which is about four times of frozen fresh fish price (https://www.alibaba.com).

Besides the traditional dried, salted, smoked, and pickled products, there seems to be an increasing demand for 'meal ready' fish products, where fish are cooked and prepared with seasoning. Meal ready fish products also come prepared as dried fish. These dried products can be used as snacks or with other food such as rice in regular meals and also sell for a higher price than fresh fish. For example, products of small juvenile fish can be sold up to AU$50/kg (molfish, pers. comm., https://www.alibaba.com).

4.3.2.2. Restructured fish products – Surimi

Surimi is a paste of minced, processed fish used in the preparation of imitation seafood. *Surimi* is a frozen block of fish protein made from different fish species, whereas *surimi product* is fresh or frozen final product, such as the popular imitation crabmeat sticks made of surimi mixed with other raw material (Vidal-Giraud and Chateau, 2007). The top producing countries include China, USA, Korea, and Vietnam, followed by Thailand, Japan, India and Chile. Currently, about 30 species have been used for surimi production. The largest surimi production uses Alaska Pollock. Other species include whiting, hoki, hake, sardine, anchovy, mackerel, ribbon fish, and leatherjacket (Vidal-Giraud and Chateau, 2007). Since 2013, the world surimi market volume has exceeded a million and a half tons a year (http://www.hermes-sojitz.com/review-of-the-2013-world-surimi-market/). The Asian markets drive this high demand for surimi and surimi product (Park, 2013; Vidal-Giraud and Chateau, 2007) partly due to rapidly growing populations.

The current wholesale price for surimi typically varies between AU$1/kg and AU$5/kg. For example, from April to June 2016, the export surimi price was between AU$1.89/kg and AU$4.38/kg (mean AU$3.02/kg) (https://www.zauba.com/export-

SURIMI+GRADE-hs-code.html). Future prices are expected to increase if fisheries resource and catch quotas continue to decline.

4.3.1. Indirect human consumption

4.3.1.1. Fish oil

Fish oil is derived from the tissues of oily fish. In modern-days, people are most familiar with fish oil capsules that contain the omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Fish oils are widely used in the manufacture of edible oils and fats, for example margarine (Windsor, 2001). Other uses include the paint and varnish industry. In addition, there are several other specialized uses, such as metallic soaps used in lubricating greases and waterproofing agents (FAO, 1986). Small quantities of fatty acids are used pharmaceutically and medicinally, and for scientific research purposes.

The price of raw fish oil continues its steady rise, reaching US$2,100/tonne in August 2013 (http://www.thefishsite.com/fishnews/21957/fish-oil-prices-continue-to-soar/). China remains the leading import country for fish oil and after prices increased until late 2014 they have stabilized since 2015 (http://www.fao.org/in-action/globefish/market-reports/resource-detail/en/c/384232/).

4.3.1.2. Biological compounds

Historically, a large proportion of fishery production was considered to be of low value and costly to dispose of — for example waste such as heads, offal, scales, bones, crustacean shells and skins. Researches have identified a number of biologically active compounds from fish wastes that have valuable human uses (Jayathilakan *et al.*, 2012; Kim, 2014). These byproducts include proteins, peptides, amino acids, enzymes, fish oil, phospholipids, gelatin, minerals, nucleic acids, chitosan, glucosamine, athaxanthin and vitamins.

4.3.2. Non-human consumption

4.3.2.1. Fishmeal

Some products that are for indirect human consumption, non-human consumption or not for consumption can be manufactured using fish by-products (or fish waste). One of the products for non-human consumption is fishmeal. Fish used for fishmeal may be divided into three categories: (1) fish caught for the sole purpose of fishmeal production (for example small pelagic species), (2) bycatches, and (3) fish offcuts and offal (FAO, 1986). In fact, virtually any fish or shellfish can be used to make fishmeal, except a few rare species that would produce a poisonous meal (Windsor, 2001). The nutritional value of proteins from vertebrate fish differs little from one species to another, while whole shellfish would however give a nutritionally poorer meal because of the low protein content of the shell. Most of the world's fishmeal is made from whole fish, and pelagic species are used most for this purpose. Since 2000, fishmeal prices continue to increase. Price varied between US$1,388 and US$2,388 (mean 1,790) per metric ton (Figure 28, World Bank, http://www.indexmundi.com/commodities/?commodity=fish-meal&months=360).

Figure 28. Global fishmeal price between May 1986 and May 2016 (source: World Bank).

4.3.1. Fish prices in Asian markets

Fish (including invertebrates such as crabs, prawns, clams, squids, cuttlefish, octopus, etc.) is traditionally used predominantly as food for human consumption. Some species are more valuable than others because of their size, taste, texture, and other qualities. In addition, tradition and culture have a large influence on fish prices. For example, in western countries, large fish usually have higher prices because they can be easily cut into fillets. Fish with thin and elongated body shapes tend to have a lower price. However, people in Asian countries prefer medium size fish which can be served whole. Fish that cannot be filleted can still sell for a 'good' price in Asian countries, such as ribbon fish and small flatfish.

Australia imports more fish than it exports and Australia's white fish export value (not including crustaceans etc.) was 20% of the import value in 2013–14. Australian export volume was only 11.6% of imports: 18,608 t and 160,811 t respectively in 2013–14 (Savage and Hobsbawn, 2015). Australia exports mainly frozen product and imports prepared and preserved product (see Figure 42 to Figure 44 in Appendix 6 for details on white fish product exports from Australia). Even though exports are much lower than imports, the average prices obtained for different Australian products are much higher (aside from prepared and preserved product). In particular, smoked (dried or salted) stands out at an average price of just over $80/kg in 2013–14. Even though the price for smoked product is high, the comparative quantities that are exported are low, and have been so since 2009. While export prices for all fish products have been relatively stable between 2009 and 2014, over time there has been a sharp decline in the quantity of fresh or chilled product and an increase in frozen product. The average price for these two fish products is similar — $13.54/kg for fresh or chilled and $11.98/kg for frozen export product (Savage and Hobsbawn, 2015).

Seafood prices in Asian markets are typically comparable but sometimes even higher than in Australian markets. For example, the average wholesale price for 26 common species in Hong Kong in June 2016 is higher than typical species in Australia (Table

9, http://www.fmo.org.hk/). Amongst the 25 species caught in GABTS, the average current wholesale price is AU$3.47/kg in Australia and $3.08 in China (Table 10). Half of the species listed sell at a higher price in China than in Australia. Four species stand out as being more valuable (50% higher) in China: leatherjacket, Orange Roughy, Gould's Squid, and Silver Warehou.

The demand for leatherjacket in China is high. This species can be found in all fish markets from the coast to inland (molfish, China, pers. comm). The typical wholesale price for leatherjacket is about $3.00/kg in China (http://www.alibaba.com/). Australian prices for leatherjacket exports to China are higher (Raptis, South Australia, pers. comm.). The beach price for leatherjacket at Australian landing sites (e.g. Port Lincoln) is about $3.50/kg for headed, gutted (with skin on). When adding the cost of packing, freezing, and transportation, the CNF (Cost & Freight, or Cost, no Insurance, Freight) price in China is about $4.50/kg. This means that Chinese consumers are willing to pay a higher price for Australian fish than they will pay for leatherjacket from other countries.

Latchet is the top bycatch species by weight in GABTS fishery (Knuckey and Brown, 2002). The price is low in Australia because of its small size (< 35 cm). Latchet is a traditional species in Asian markets. It is common in all fish markets along the coast in China. However, Latchet abundance in coastal fisheries is relatively high, perhaps partially resulting from depletion of large predatory fish (e.g. Szuwalski *et al*., 2016). The high yield of latchet in China keeps the price stable and affordable for the general public.

Table 9. Wholesale price per kg for selected fish species in Hong Kong, June 2016. The exchange rate is 1 AU$ = 5.78 HK$.

Chinese Name	English Name	Scientific Name	Hong Kong Dollar			Australia dollar		
			High	Low	Average	High	Low	Average
青根	Horse-head	*Branchiostegus auratus*	115.50	69.30	92.40	19.98	11.99	15.99
黃腳	Yellow-finned Sea Brean	*Acanthopagrus latus*	148.50	107.25	127.9	25.69	18.56	22.12
白飯魚	Ice Fish	*Salanx chinensis*	148.50	148.50	148.5	25.69	25.69	25.69
黑鯧	Black Pomfret	*Formio niger*	82.50	62.70	72.60	14.27	10.85	12.56
瓜核	Melon Seed	*Psenopsis anomala*	75.90	56.10	66.00	13.13	9.71	11.42
鮫魚	Mackerels Scads	*Scomberomorus sp.*	128.70	69.30	99.00	22.27	11.99	17.13
泥鯭	Rabbit Fish	*Siganus oramin*	75.90	62.70	69.30	13.13	10.85	11.99
狗肚	Bombay Duck	*Harpodon nehereus*	79.20	49.50	64.35	13.70	8.56	11.13
泥斑	Mud Grouper	*Epinephelus brunneus*	156.75	123.75	140.25	27.12	21.41	24.26
鰦魚	Mackerel Scads	*Decaprerus sp.*	42.90	26.40	34.65	7.42	4.57	5.99
鷹鯧	Chinese Pomfret	*Stromateoides sinenesis*	742.50	577.50	660.00	128.46	99.91	114.19
沙鑽	Sand Borers	*Sillago sp.*	107.25	66.00	86.63	18.56	11.42	14.99
木棉	Big-eyes	*Priacanthus sp.*	141.90	74.25	108.08	24.55	12.85	18.70
瓜衫	Melon Coat	*Nemipterus japonicus*	75.90	41.25	58.58	13.13	7.14	10.13
鱸魚	Sea Perch	*Lateolabrax japonicus*	79.20	62.70	70.95	13.70	10.85	12.28
牛鰍	Flathead	*Platycephalus indicus*	90.75	74.25	82.50	15.70	12.85	14.27
馬友	Thread Fin	*Eleutheronema tetradactylus*	495.00	247.50	371.25	85.64	42.82	64.23
紅衫	Golden Thead	*Nemipterus virgatus*	138.60	85.80	112.20	23.98	14.84	19.41
沙鯭	File Fish	*Monacanthus sp.*	90.75	59.40	75.08	15.70	10.28	12.99
龍脷	Soles	*Cynoglossus sp.*	82.50	52.80	67.65	14.27	9.13	11.70

烏頭	Grey Mullet	*Mugil cephalus*	69.30	59.40	64.35	11.99	10.28	11.13
白□	White Sea Bream	*Acanthopagrus berda*	141.90	95.70	118.80	24.55	16.56	20.55
牙帶	Hair-tails	*Trichiurus sp.*	105.60	62.70	84.15	18.27	10.85	14.56
黃花	Yellow Croaker	*Pseudosciaena crocea*	148.50	95.70	122.10	25.69	16.56	21.12
青門鱔	Green Conger-pike Eel	*Muraensox talabanoides*	99.00	59.40	79.20	17.13	10.28	13.70
白鯧	White Pomfret	*Stromateoides argenteus*	156.75	90.75	123.75	27.12	15.70	21.41

Table 10. Price of major GABTS species in Australia and China. The exchange rate is 1 AU$ = 4.77 Yuan.

	Australia	China	
	(AU$/kg)	(Yuan/kg)	(AU$/kg)
Deepwater Flathead	$5.33	20	4.19
Bight Redfish	$4.73		
Gemfish	$2.70	18	**3.77**
Ocean Jacket	**$1.86**	13	**2.73**
Orange Roughy	$4.65	50	**10.48**
Gummy Shark	$6.59		
Yellowspotted Boarfish	$3.55	12	2.52
Blue Grenadier	$2.48	9	1.89
Ornate Angel Shark	$1.79	9	1.89
Jackass Morwong	$3.28	18	**3.77**
Australian Tusk	$14.67		
Latchet	**$1.46**	9	**1.89**
Gould's Squid (Arrow Squid)	$2.08	15	**3.14**
Blue Morwong (Queen Snapper)	$3.34	20	**4.19**
Knifejaw	$2.83	15	**3.14**
Pink Ling	$5.72		
King Dory	$6.18		
Angel sharks	$1.79	8	1.68
Saw sharks	$2.14	9	1.89
Red Gurnard	$2.93	6	1.26
Snapper	$7.68	15	3.14
Ocean Perch	$3.27	15	3.14
Silver Trevally	$4.27	6	1.26
Big-Spined Boarfish	$3.01	12	2.52
Shark Wobbegong	$1.92	9	1.89
Silver Warehou	$1.82	13	**2.73**
Hapuku	$8.01		
Ribaldo	$2.05		
Rubyfish	$5.16	28	**5.87**
Boarfish	$3.63	20	**4.19**
Calamari	$11.72	12	2.52
Long-Finned Boarfish	$1.98	6	1.26

4.4. Develop a supply chain model representing current GABTS product flows and potential future supply chains for the distribution of edible product from GABTS discards

4.4.1. Profitability of retaining bycatch in the GABTS

The GABTS fishery supplies fresh fish to markets in Adelaide, Melbourne, Sydney, and Brisbane (Patterson *et al*., 2016). Most fish caught by the GABTS, including Deepwater Flathead, Bight Redfish, Yellowspotted Boarfish and Orange Roughy is landed whole. Ocean Jacket, Gemfish and Blue Grenadier are generally headed and gutted, while Gummy Shark are trunked (with fins on). There are a number of species that are currently discarded and for which the GABTS is potentially not realising revenue.

GABTS bycatch species that are suitable for human consumption are classified as byproduct species in Table 2. For GABTS fishers to retain species that are currently discarded (or only occasionally retained), their retention has to be financially viable for the catch sector (shown conceptually in Figure 29). The fishery participants interviewed for this project indicated that income may be increased by selling to higher value markets and by adding value (the subject of this research).

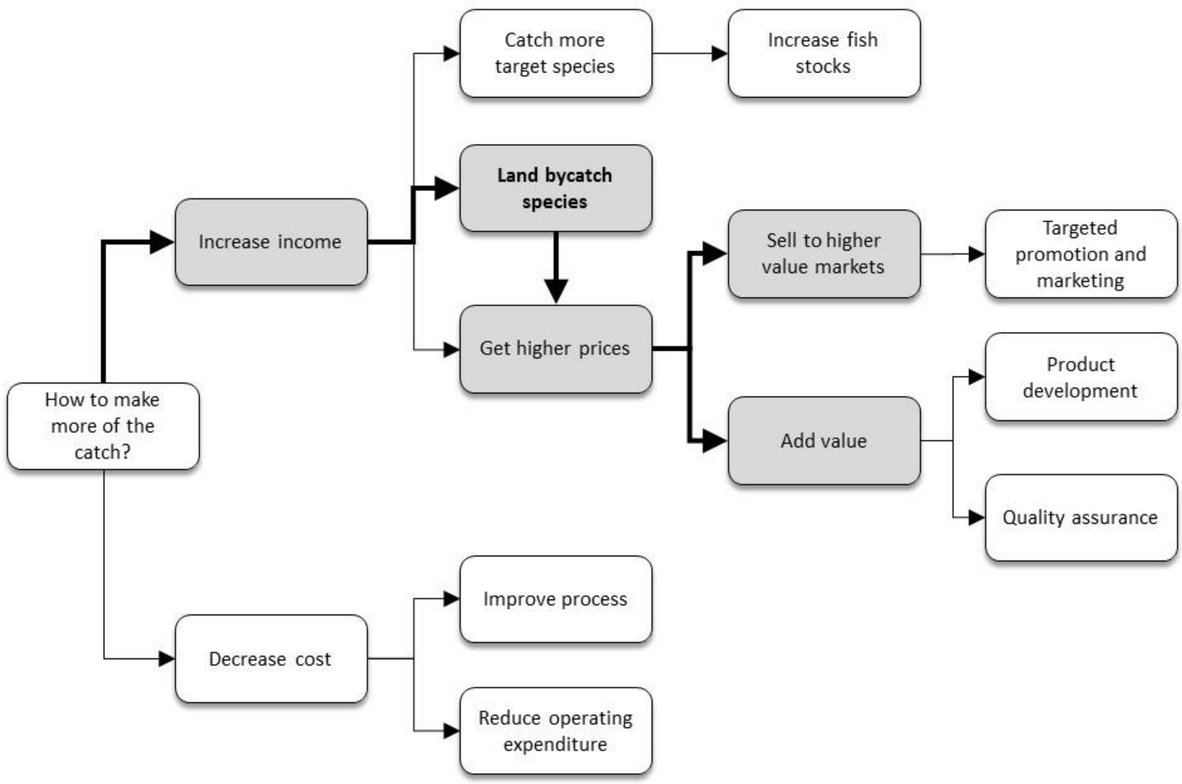


Figure 29. Conceptual model to increase income for the GABTS by landing bycatch (adapted from Dundas-Smith and Mahoney, 1996)

To assess the financial viability of retaining species that are currently discarded, an economic model for a 'typical GABTS fishing vessel' was developed in which the fleet's average operating costs and returns were estimated for: i) normal operations where the species are discarded; and ii) discarded species are instead retained and landed. The cost, return, and profit estimates that are presented here do not represent any one operator but represent fleet averages.

Assessing the financial viability of retaining species provides information on minimum (threshold) bycatch prices and quantities, and more generally, thresholds for profitability. This information is essential as retaining and landing commonly discarded species is largely contingent on whether this is profitable for the catch sector.

4.4.2. The fishery, fleet, and trip characteristics

The main assumptions that underpin the economic model are based on the CDR catch data for 2005–2014 and observer data for discards for the same time period. The annual average number of fishing trips for the GABTS, fishing trips per vessel, the fishing trip length, and average catch per trip were estimated based on these datasets (Table 11). On average, a vessel undertakes around 24 fishing trips per year. The average length of a fishing trip has increased somewhat over the past 3 years to around 9.7 days fishing per trip (excluding the time spent steaming). A 14 day return trip is assumed to be the industry average in 2014 (pers. comm. – industry operator). On average a vessel will land around 17.5t of fish per fishing trip. The estimated number of shots per fishing trip for each vessel is around 35 (three year average) based on logbook data (Table 12).

Table 11. Fishing trip details per year (based on logbook data).

Year	Fishing trips per year for GABTS (number)	Average fishing trips per vessel (number)*	Average fishing trip length (days)#	Average catch per fishing trip per vessel (kg)
2005	200	24.7	8.1	21,438
2006	173	23.7	5.9	15,027
2007	136	21.8	6.6	17,615
2008	116	26.3	8.0	18,175
2009	120	30.0	7.7	16,841
2010	100	25.0	7.9	17,284
2011	111	24.3	8.7	16,489
2012	114	23.8	9.7	15,633
2013	113	23.3	9.7	15,729
2014	114	22.5	9.6	15,566
10 year average (2005-2014)	130	24.4	8.2	17,521**

* Based on four vessels operating in 2014.
# This does not include steaming time as the figure is based on days on which there was trawling activity.
** There is variation around the average catch with some operators quoting up to 2300 kilo per day.

Table 12. Shots per trip based on four vessels

	Shots per trip* (number)
2012	33.68
2013	35.26
2014	35.64
3 year average	34.86

* Based on four vessels operating in 2014.

4.4.3. Catches and discards

Retained catch data presented are from CDRs, while discards were estimated from a combination of observer and daily logbook catch and effort data (Table 13). Deepwater Flathead and Bight Redfish were caught in the greatest quantities, with an average of 178 t and 92 t respectively caught annually per vessel, or 7.4 t and 3.8 t per vessel each trip. In contrast, each vessel discards less than 1 t of each of those species each year. An estimated 32 t of leatherjacket was discarded at sea per vessel each year, while over 42 t of leatherjacket was retained per vessel each year. Only 12 t of Latchet was retained per vessel while an estimated 152 t of Latchet was discarded at sea each year.

Average profits (per annum, per vessel and per trip) are determined on the basis of the estimated fishing costs and returns. The costs are broken down by cost centre (A to J in Table 22 – Appendix 4). Depending on the cost centres incorporated in the profit calculation, gross profit, accounting profit, economic profit, and net profit can be estimated.

4.4.4. Fleet profitability

Knuckey (2006) found that the crew are unlikely to expend effort in sorting, icing and storing fish unless they get a reasonable return from the sale (they are usually paid on a percentage of the catch). As a rule of thumb, Knuckey (2006) found that a minimum price to the boat of $0.60 – $0.80 was required before it was deemed commercially viable to land the fish from wet boats. We estimate that currently the cost of catching 1 kg of fish (regardless of the species) in the GABTS is around $0.94 per kg (based on a typical GABTS vessel) (first column in Table 14).

Based on current catches and discards, income per vessel per year is estimated at just under $2 million. Gross profit (see definitions of profit in Table 14) per vessel per year is estimated at around half a million per year. However, if all costs are taken into account (including variable costs, wages, depreciation, and debt and interest payments), net profit per vessel is negative by around $180 thousand per year. This means that the fleet is able to cover operating costs in the short term, but may have financial trouble in the longer term if they are unable to cover their fixed costs.

Table 13. Per vessel and per trip catch and estimated discards for the GABTS. Main discard species are in bold.

	Average annual **catch** PER VESSEL # 2005-2014 (kg/vessel/year)	Average annual **catch** PER TRIP # 2005-2014 (kg/trip/year)	Average annual **discards** PER VESSEL ** 2005-2014 (kg/vessel/year)
Deepwater Flathead	177,958	7,415	951
Bight Redfish	92,381	3,849	82
Gemfish	7,790	325	9,858
Ocean Jacket	**42,675**	**1,778**	**32,493**
Orange Roughy	11,204	467	325
Gummy Shark	8,798	367	201
Yellowspotted Boarfish	13,426	559	181
Blue Grenadier	4,020	168	140
Ornate Angel Shark	15,233	635	8,922
Jackass Morwong	11,390	475	2,103
Australian Tusk	3,585	149	240
Latchet	**12,218**	**509**	**152,997**
Gould's Squid (Arrow Squid)	9,498	396	2,178
Blue Morwong (Queen Snapper)	6,293	262	54
Knifejaw	8,273	345	4,003
Pink Ling	1,398	58	0
King Dory	1,317	55	43
Barracouta	**23**	**1**	**27,167**
Saw sharks	5,097	212	3,437
Red Gurnard	6,323	263	2,938
Snapper	2,140	89	39
Ocean Perch	71	3	286
Skates & Rays	**121**	**5**	**71,747**
Big-Spined Boarfish	228	9	35
Shark Wobbegong	1,843	77	43
Dogfish	**623**	**26**	**39,133**
Hapuku	434	18	0
Ribaldo	872	36	208
Stingarees	**14**	**1**	**89,523**
Boarfish	835	35	0
Calamari	3,231	135	219
Long-Finned Boarfish	1,829	76	2,097
TOTAL	468,444	**19,519**	451,643

based on CDR data

** Estimates based on observer data

4.4.5. The economics of discard retention

From the logbook data it can be deduced that the GABTS vessels catch around 17.5 t of fish per fishing trip and the vessels are not constrained in terms of on-board capacity (based on average vessel size). Species that are currently discarded could be retained without needing to reduce the retention of other species and not incurring additional operating costs. If currently discarded volumes were retained and landed, and the average price for bycatch species were obtained (shown in Table 4), turnover could be increased by 18% from $1.97m to $2.32m (Table 14). If the discards are retained and landed (and the fishers are paid the prices as listed in Table 4) the returns per kilo of retained fish (the whole catch including regular species and discards) will increase from $0.79 to $0.86 per kilo of retained fish. At the same time the average cost per kilo of retained fish (for the whole catch) will fall from $0.94 to $0.79 per kilo because spare capacity is available and no significant additional costs are likely incurred.

Table 14. Current profit estimates if bycatch is retained (for 6 species (or species groups) shown in bold in Table 13 at the prices per kilo shown in Table 4).

	Current profit estimates ($/vessel/year)	as % of turnover	Profit estimates when retaining bycatch** ($/vessel/year)	as % of turnover (when retaining bycatch)
TOTAL RETURNS (turnover)*	$1,970,263		$2,323,699	
GROSS PROFIT (variable cost only)	$543,663	28%	$897,099	46%
ACCOUNTING PROFIT (variable cost + wages)	-$5,411	0%	$348,025	18%
ECONOMIC PROFIT (variable cost + wages + depreciation)	-$121,917	-6%	$231,519	12%
NET PROFIT (all costs included)	-$181,917	-9%	$171,519	9%
Cost per kilo of fish	0.94		0.79	
Returns per kilo of fish	0.79		0.86	
Net profit per kilo of fish	-0.15		0.07	

* Based on current average prices.
** assuming fishing costs don't increase substantially to retain the catch.

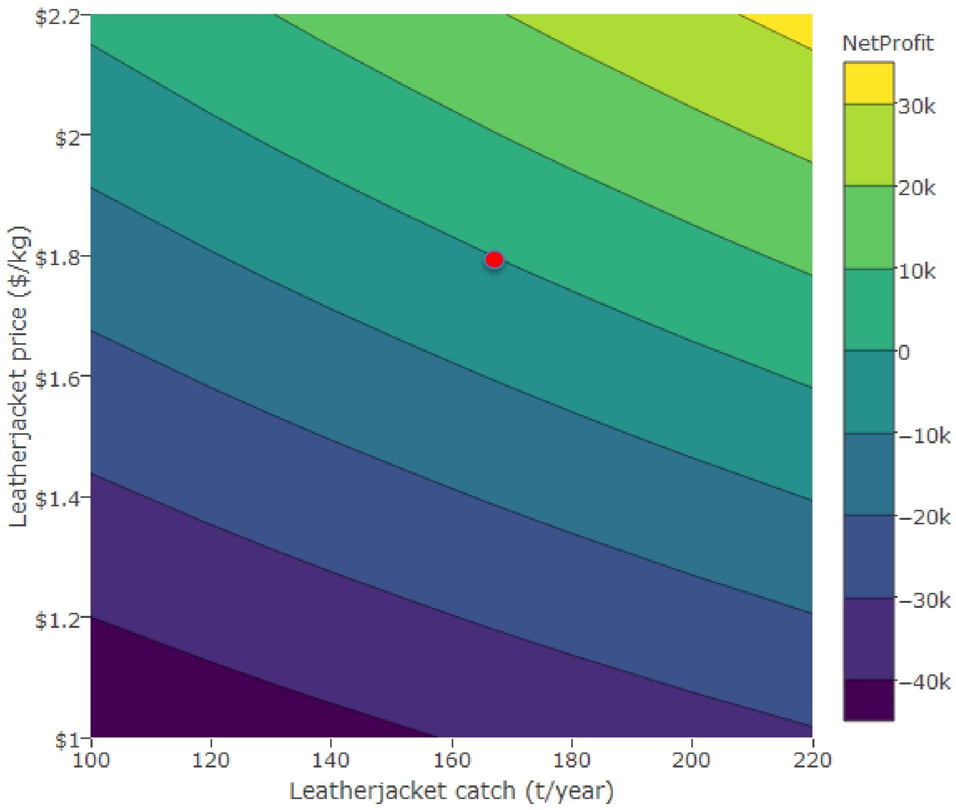


Figure 30. Estimated net yearly profit range for GABTS vessel for different landing price levels for leatherjacket if both leatherjacket and latchet were retained. Assuming that the catch is based on current discard estimates of 165,713 kg of leatherjacket (32,493 kg/vessel/year) and 780,284 kg of Latchet (152,997 kg/vessel/year). The red dot indicates the threshold price for leatherjacket at current discard level.

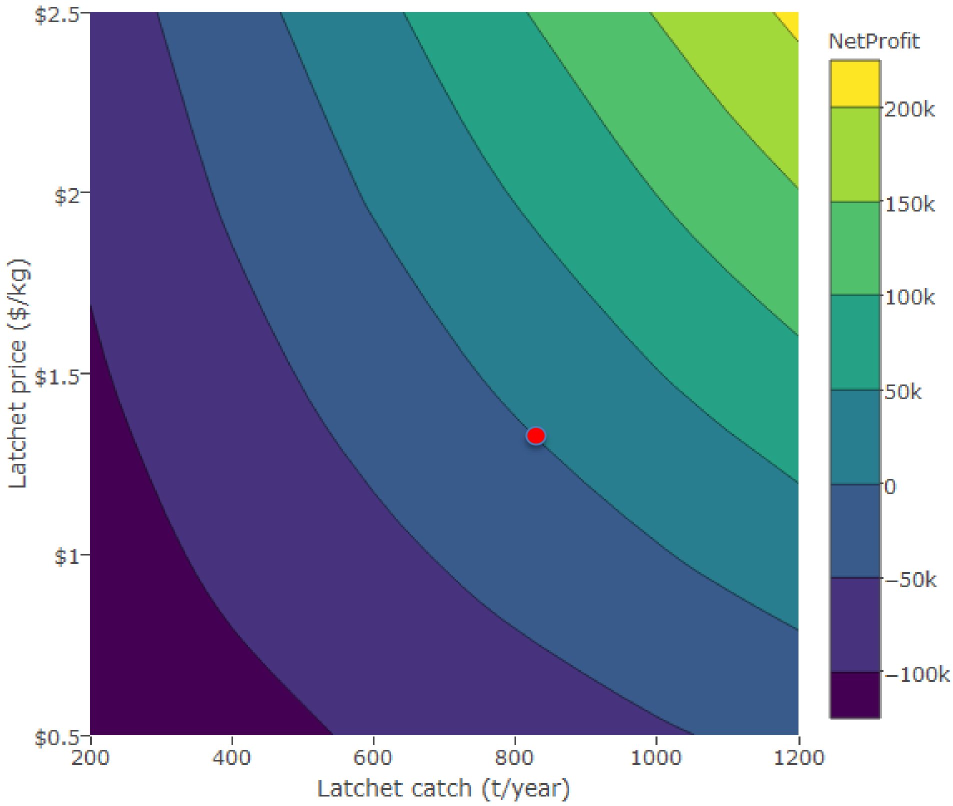


Figure 31. Estimated net yearly profit range for GABTS vessel for different landing price levels for latchet if both leatherjacket and latchet were retained. Assuming that the catch is based on current discard estimates of 165,713 kg of leatherjacket (32,493 kg/vessel/year) and 780,284 kg of Latchet (152,997 kg/vessel/year). The red dot indicates the threshold price for latchet at current discard level.

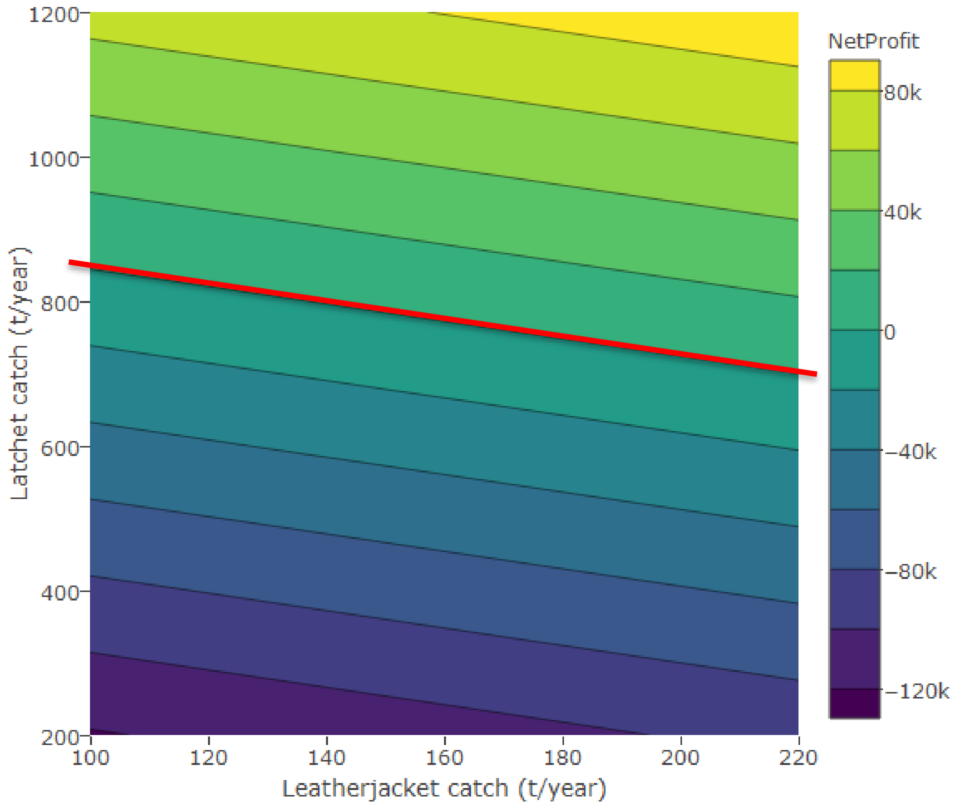


Figure 32. Estimated net yearly profit range per GABTS vessel for different retained catches of leatherjacket and latchet. Based on current average prices of $1.86/kg for leatherjackets and $1.46/kg for Latchet. The area below the red line indicates net profit is negative.

If only leatherjacket (165,713 kg) and Latchet (780,284 kg) bycatch were landed, a vessel would break even (i.e. make zero net profit — meaning they would cover all costs) if $1.81 per kg was paid for leatherjacket and $1.43 per kg for latchet (Figure 30 and Figure 31). It needs to be noted that if a growing amount of discards are landed there may be a drop in price associated with quantity increases. It may be assumed that the lowest price fishers are willing to accept is likely to be the amount it cost them to catch the fish (estimated around $0.94 cents per kg). However, at the cost price of $0.94 per kg the fishers would not be breaking even.

Annual catches are also likely to vary, which will affect the bottom line (Figure 32). Assuming current average market prices for leatherjacket and latchet are paid (which are slightly above threshold prices at $1.86 per kg for leatherjacket and $1.46 per kg for latchet), profits are still likely to be negative at low quantities for either species.

If the fishers only retain leatherjackets (and discard Latchet), the price of leatherjacket would need to be significantly higher ($4.85 per kg) at current volumes (of around 160 t) to break even (where net profit is zero). If Latchet was retained (but leatherjackets were discarded) at current volumes (around 780 t) a net profit of zero would be achieved at a price of $1.88 per kg.

4.4.6. Supply chain and additional bycatch transport costs

After assessing the minimum catches and landing prices necessary to make it financially attractive for GABTS fishers to land the bycatch, the rest of the supply chain must be considered to determine if it is possible to bring the product to market. Assuming the bycatch is landed and can be sold in an existing market in Australia, it is likely to follow the same supply chain path as current fish product from the GABTS (Figure 33).

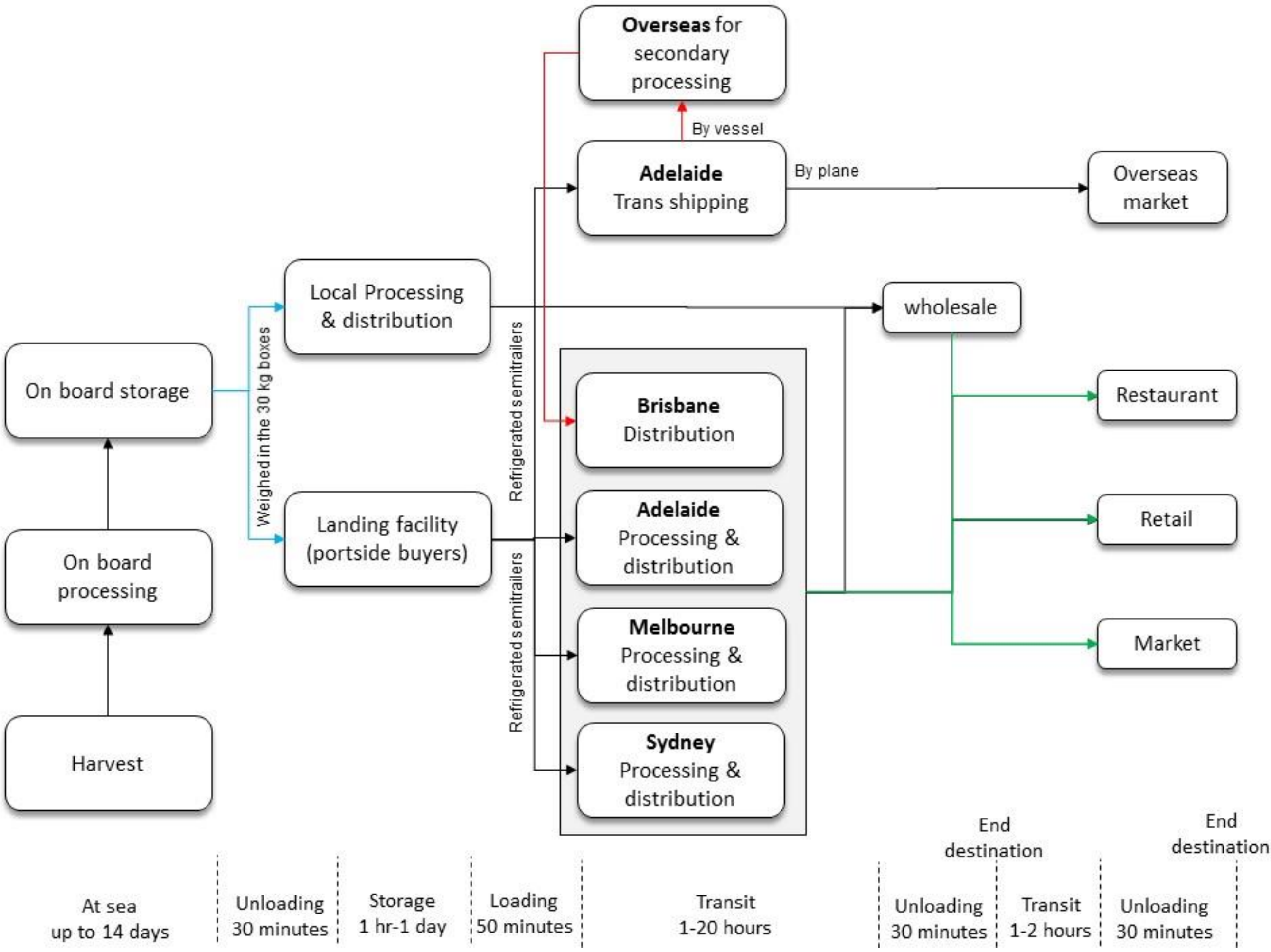


Figure 33. Generic supply chain for key species of the GABTF. The red arrow indicates product that is shipped overseas for processing and re-imported mainly into Brisbane destined for the Australian market.

The GABTS land fish in a number of different ports, mostly along the South Australian and Western Australian southern coast. Although there is some variation over the years, as a proportion of the catch, Thevenard receives most product followed by Port Lincoln. However, there is some variation between the species, for instance, Figure 34 shows that most Orange Roughy is landed in Port Lincoln and almost none in Thevenard (although Orange Roughy volumes are very low). In contrast, almost 90% of the Gemfish catch is landed in Thevenard and less than 5% in Port Lincoln.

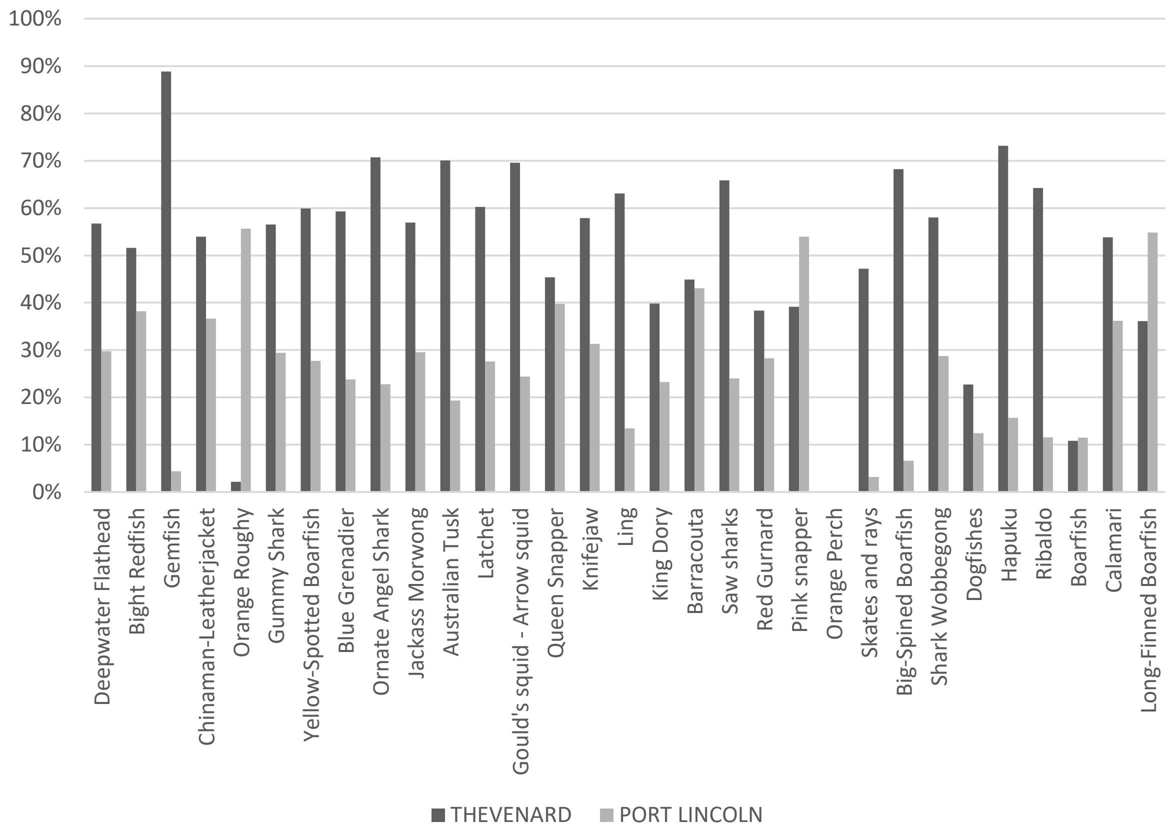


Figure 34. Proportion of the landing by species in Port Lincoln and Thevenard between 2005 and 2014.

The cost of transport will need to be considered if the GABTS is to land bycatch and deliver it to market as a fresh product. Currently, because prices paid for fish discarded are too low, so it is not landed. If the discard species currently do get landed and sent to market, fishers may end up not covering their transport costs (transport costs are higher than the additional returns from discard sales). The price of bycatch therefore have to be adequately high enough to cover the additional transport costs incurred to get product to market.

The cost of transport estimated here is somewhat speculative as it is based on a number of key assumptions around which there is a high level of uncertainty (Table 15). The cost estimates are based on website information (e.g. http://www.harders.com.au/network/) and discussions with two different transporters based in South Australia.

Table 15. Key assumption for transport cost estimation.

Key assumption for transport cost estimation	Value
Small truck capacity	1000 kg
Small truck capacity	Around 50 eskies
Minimum cost for full truck	$0.15/kg
Maximum cost for small amounts (in eskies)	$2.75/kg
Fuel surcharge	9.5% -12%
Cost per kilometre per 1000kg **truckload of fish**	Around $0.26/km

* Distance to market in km is shown in Appendix 7

Refrigerated semi-trailers can handle a much larger amount of product (i.e. 25 t — http://www.harders.com.au/network/), but given the small amounts of bycatch landed each fishing trip, it is more likely that small quantities will be transported in one load. Filling up a refrigerated semi-trailer to maximum capacity is not likely due to the variation in the catches (both seasonally and by location). Based on the estimated cost per kilometre, the minimum cost per truckload from the different landing ports to the market can be estimated (Figure 35).

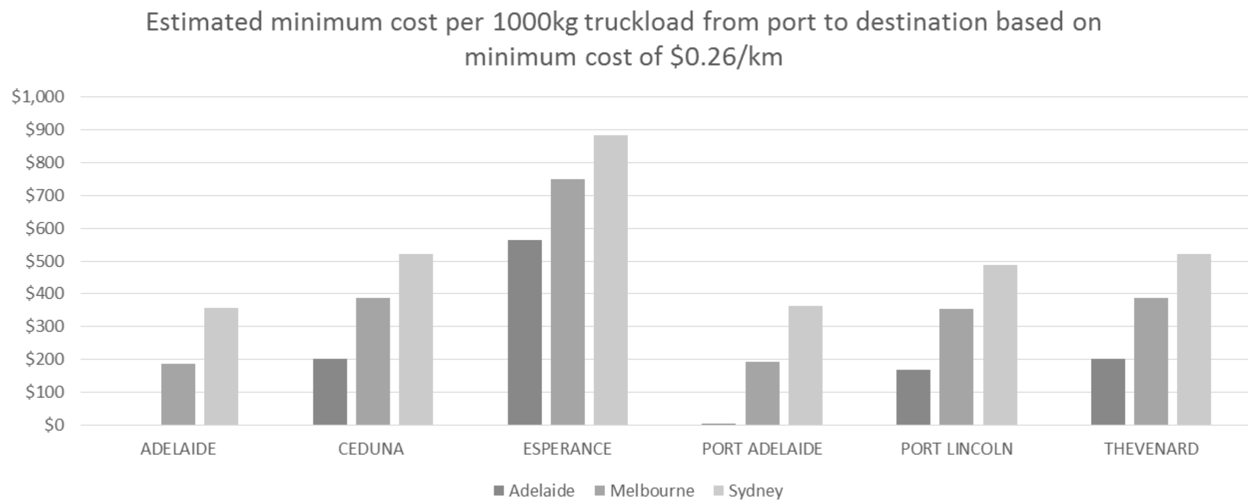


Figure 35. Estimated minimum cost per 1000kg truck from port to destination if estimated cost per kilometre are $0.26/km. The costs may be as high as $4.75/km if small amounts were transported. The total volume of discards to be transported each year per vessel are 423,060 kg.

As the relative landing location for each species is known (over the period 2004–2014), it is possible to estimate the minimum additional cost to bring the bycatch species to market based on past landing patterns. Assuming the catch is mostly landed at Port Lincoln and Thevenard, the transport cost will lie between $168 and $522, from Port Lincoln to Adelaide and from Thevenard to Sydney respectively. Based on this expected bycatch volume per vessel, the annual cost of transporting that catch to market is estimated at a minimum of $69,394 and $215,774 for each vessel operating in the GABTS.

4.4.7. Summary: sale of bycatch from GABTS

The spare capacity on board GABTS vessels suggests that the cost of catching fish can be reduced from a current estimate of $0.94/kg to $0.79/kg if bycatch were landed and sold. Net profits per kg of fish are estimated to increase from $0.79/kg to $0.86/kg when bycatch is retained and sold. The fishery would be able to cover fixed costs and make a net profit instead of only making a gross profit and only being able to cover variable costs — therefore not being viable in the long run.

The fishery is more likely to remain viable in the longer term if bycatch is landed, but a buyer and market are essential. The price paid to fishers for the main bycatch species (leatherjacket and Latchet) will need to be at least $1.81 and $1.43 per kg respectively to break even. Any price below this will not cover fishing costs and will return no net profit. The prices will need to be higher at lower catch volumes.

The bycatch will need to be transported to market incurring transport costs. If the bycatch fish were landed at the main ports of Port Lincoln and Thevenard the transport costs are estimated to lie between $69 and $215 thousand per year per vessel (or between $0.17 and $0.52 per kilo of bycatch) depending on the final destination (i.e. Adelaide or Sydney). Cheaper rates will be likely if the fishery were to time and combine their catches (if possible), as larger single transport volumes incur lower costs per kilometre.

4.5. Determine the feasibility of land/vessel based facility for processing species not suitable for human consumption

4.5.1. Background

While there is potential for greater sale of bycatch for human consumption, many species are not suitable for human consumption for a number of reasons including containing poisons (e.g. toadfishes), very small and perishable (e.g. lanternfish) or a lack of meat (e.g. bellowfish). However, other than those containing poisons, virtually any fish or shellfish can be used to make fishmeal (Windsor, 2001). The raw product for fish meal and fish hydrolysate is of relatively low value and should not reduce the hold capacity of market fish, nor greatly increase the work of the deck crew. GABTS trips are generally 10–14 days duration, during which the catch is mostly stored in refrigerated iced bins (Musgrove, 2012), and sometimes in mesh bags submerged in chilled brine water. One of the greatest challenges of providing raw product for fish hydrolysate is storage of the product for the trip duration so that it neither reduces the hold capacity of market fish, greatly increase work for the deck crew nor spoils.

Fish begins deteriorating immediately after death. Fish are particularly susceptible to spoilage because of their high moisture content and the availability of nutrients for microorganisms growth (Singh *et al*., 2011). The three main processes that lead to spoilage are autolytic deterioration (breaking down of cells or tissues by the fishes own digestive enzymes), oxidation (the process which causes lipids to become rancid) and microbial spoilage (FAO, 1986).

Retaining the fish not destined for human consumption in their natural form would be inefficient for both transport and storage. Instead, the bycatch should be processed into a form that is easy and efficient to store and transport. Processing to fish meal is common on larger “factory” vessels, however fishmeal plants have the disadvantages of high capital and running costs and requirement engineers and technical staff. An alternative is production of silage or fish hydrolysate, which requires lower capital costs and can be produced without the need for engineers and technical staff (Tatterson and Windsor, 1974). Production of fish silage is a viable alternative to fish meal, especially in locations where small amounts of fishery waste or bycatch is produced (Abdullah, 1983).

4.5.1. Fish hydrolysate (silage)

Fish hydrolysate (also called silage) is a liquid product made from the addition of acids (e.g. formic, propionic hydrochloric or sulphuric acid) to minced fish. The liquefaction process is done by the enzymes in the fish in the presence of acid. The bycatch is first minced into small particles (about 10 mm) and then immediately mixed with acid at a rate of about 3.5% weight of 85% formic acid (Tatterson and Windsor, 1974). This should result in an acidity of pH 4 or lower which will prevent bacterial action and spoilage. Silage does not need to be refrigerated, and the speed of the process increases with temperature, taking about two days to liquefy at 20˚C, and 5–10 days at 10˚C. The liquid can be stored in any acid resistant container, but metal tanks should have a polyethylene liner to prevent corrosion. Silage can be easily transported in bulk.

Silage can be used as stock feed in the same way as fishmeal. It is commonly used as pig feed in Scandinavia (Archer, 2001). In Norway, silage is used to make moist feed pallets for fish aquaculture (Archer, 2001). It is also being used as an agricultural fertiliser (Knuckey *et al.,* 2004). For example, Karim *et al*. (2015) found the application of what they called liquid fish silage at concentrations of 5–10% were as effective as a commercial fertilizer in terms of plant growth, yield, pigment content and post-harvest quality.

4.5.2. Silage system in the GABTS

The first step in assessing the feasibility of a vessel-based facility for processing bycatch is to set the parameter on which to design the facility. Figure 36 shows a basic schematic of the proposed system that comprises a hopper, mincer, acid injector and storage container.

Specifications of one GABTS vessel (the Explorer S) were obtained for the general deck arrangement diagrams (Figure 37 and Figure 38) and discussions with the vessel manager. The Explorer S is a 30 m stern trawler that, on top of having refrigerated storage below deck, has four refrigerated brine tanks. Two of the brine tanks have a capacity of 25,000 L, while the other two are of 20,000 L capacity. During market fishing trips, two of those brine tanks are not used, and would be available for storage of fish hydrolysate. From the general arrangements diagram, two areas potentially suitable for a fish mincer have been identified with dimensions 3 x 1 m and 2 x 1 m respectively. The vessel has 3 phase power, which is necessary for powering a large industrial mincer.

Based on observer data, an average of 471 kg (range 0.5–5,592 kg) of bycatch per shot would be available for mincing when fishing shelf waters, and 249 kg (range 0.02–4,174 kg) when fishing the slope (Table 16). Geometric means (shelf - 286 kg and slope - 41 kg) and medians (shelf - 302 kg and slope - 40 kg) however were much smaller (Table 16). While most catches of bycatch are less than 500 kg, catches 500–1000 kg of bycatch per shot are common on the shelf and slope, and about 10% of shots on the shelf have more than 1,000 kg of bycatch per shot available for mincing (Figure 39). In order to be able to handle bycatch from the majority of shots, a mincer should have a capacity of at least 1,000 kg per hour. For the economic evaluation of the silage system, both mean and median values were used.

It is anticipated that after sorting the catch on deck to bin up the fish for human consumption, remaining bycatch would be binned up prior to placing in the hopper. The size of the hopper will be restricted by the space available and delivery system to the mincer — we have assumed a 200 kg hopper in this feasibility study. Species / material not suitable for mincing would be disposed of as normal — this would include sponge, Bailer Shell, corals, benthos, TEP species and very large animals such as stingrays and sharks. Bins would be manually tipped into the hopper, which would deliver the fish to the mincer.

Mincers have limitations regarding the size of items that will be drawn into them. Large items either won't get taken in by the screw, or could block the throat. The size of the largest "commonly caught" bycatch (Table 17) should be used to define the maximum fish size that the mincer can take. Their very large size and weight, and the occupational health and safety (OH&S) risk they pose, means that Black Stingrays and Smooth Stingray are not suitable for mincing and should be discarded. While Barracouta can attain 1.5 m length, they are much more commonly caught at less than 1 m length, and are a narrow shaped, soft skinned, soft fleshed fish. It appears that a maximum fish size of 1 m long fish should be used in designing the system, which would accommodate a vast majority of the bycatch.

Specifications on which to base the design of the mincing system are shown in Table 18. The specifications were sent to Viking Food Solutions[11] — a company renowned for developing innovative food processing solutions — who recommended and priced an appropriate mincer.

Hydrolysing acid should be delivered at a rate of about 30 L per tonne of fish. To cover an entire trip, and assuming that both bladder-filled brine tanks are used, a total of 1,350 L of acid is required to be carried onboard. The reservoir capacity of the acid injector should be greater than that required for one shot, and be large enough so as to not take up too much of the crews' time. A reservoir volume of 120 L would most likely be sufficient for a full days fishing, however the acid injector would most likely be fed dirctly from the transport container (e.g. a 1,000 L Intermediate Bulk Container — IBC).

Bladders to line the brine tanks must be resistent to a pH of at least 4, and idealy, take up the majority of the brine tank space available. Bladders are required to have both inlet and outlet pumps and hoses.

4.5.3. Example system

4.5.3.1. Mincer

Viking Food Solutions recommended the Thompson 3000 mixer/mincer which met the desired specifications (Figure 40). This model is a compromise between size and production rate (Table 19). The dimension of this unit is 1.1 m wide x 1.15 m depth x 1.4 m height (with legs and wheels, or 1.1 m without). The specified production rate of the primary cut is 3,000 kg/hr, and 1,800 kg/hr for the second cut. It is robustly constructed of heavy gauge stainless steel seam welded inside and outside. The gears and motor are sealed for protection against liquids. It has a safety isolation switch, and the lid is fitted with a safety cut out switch. Very little maintenance is required for this machine. Speco inserts are the main wearing part, and it is likely that they would need to be changed 3 or 4 times per trip (they cost about $26 each). The mincer plate

[11] https://www.vikingfoodsolutions.com.au/

and shank pin are other wearing parts; however, they have a much longer working life than the inserts.

A sample of bycatch from a SESSF Commonwealth Trawl Sector (CTS) vessel comprising 75 kg of Thetis Fish (*Neosebastes thetidis*) was obtained so that the mincer/mixer could be tested. These were considered appropriate for the testing as they are a bycatch species in the GABTS, and they are a tough, spiny fish. Testing took place at Viking Food Solutions on 11/1/2017.

Fish were added to the bowl one bin at a time so that they could be observed getting drawn in by the feedscrew. The mincer/mixer had no problem processing the fish. Output comprised mostly of 10 mm tubes of mince, but at time was more like sludge (Figure 40). This was generally near the end of processing each bin, and was attributed to the ice that was mixed in with the fish. There were no blockages and no adjustments were required to process the fish. Each bin (weighing 25 kg) took approximately 1 minute to process, and so 300 kg of bycatch would be processed in about 12 minutes if fed continuously. After each bin, some course mince remained in the feedscrew. This was mostly ejected by running an extra fish through the mincer/mixer to push the remnants out. The Thetis Fish have robust swim bladders that were fully inflated. They sometimes remained in the bowl, but were forced into the feedscrew when more fish was added. At the end of the test, about 6 intact airbladders remained in the feedscrew (out of approximately 150 fish). The throat of the mincer appeared large enough to accept the main bycatch species apart from large stingrays and skates. It is likely that Wide Stingarees would be processed, but there is a possibility of the throat getting blocked by a large stingaree laying across it.

4.5.3.2. Other main components

Variable flow rate chemical dosing systems are readily available. Polyvinylidene difluoride (PVDF) systems are resistant to solvents, acids and bases. The LMI C146-36 (LMI pumps — www.dosingsystems.com.au) has a manually adjustable flow rate of up to 50 L/hr which would be more than sufficient to for dosing the silage.

A pump is required to transfer minced fish into storage tanks and to pump silage out of the vessel into a transport vehicle. The 200PR Crommelins Subaru 2" Chemical Waste Pump[12] is constructed of corrosion-resistant polyester, a stainless steel shaft seal with carbon ceramic faces and 316 stainless steel fasteners. It has a maximum head and flow rate of 38 m and 43,800 L/hr, more than sufficient for most circumstances.

4.5.4. Potential costs, revenue and profits

The mincer / mixer is the greatest initial capital cost (about $22,000), but with its rugged construction, and minimal wearing parts, this can be expected to have a long lifespan (for the purposes of this study we assume a lifespan of 10 years). While maintenance is simple, if used regularly it can be expected that the cost of replacement parts (e.g. cutting inserts, insert holders, mincer plates and shank pins) would total about $2,300 per year. By far the greatest ongoing cost is the sulphuric acid required to reduce the pH to 3.5–4. The required dosage rate is 40 L/t, with a cost of $0.80 per L (Table 20).

[12] http://www.mygenerator.com.au/crommelins-subaru-2-chemical-waste-pump.html

Assuming the mincing of about 10.3 t of bycatch per trip (or 246 t per year), that equates to a cost of about $330 per trip, or $7,900 per year.

Total estimated costs over the ten year period is about $158,000, 60% of which is consumables (mostly acid and pump fuel). Silage currently produced by land based processors is valued at about $400 per t (Wayne Street, pers. comm.). Assuming that the median bycatch of 302 kg per shot (246.4 t per year) is processed into silage, and that current prices are paid "from the wharf", the 10-year revenue would be about $986,000, with a profit of $827,000 (Table 21). Because the cost of consumables increases directly with production, any increase in production results in a one to one increase in profits (Figure 41).

4.5.5. Potential issues

Sulphuric acid (98% solution) is listed as a corrosive and a hazardous substance, and should always be used in accordance with *Australian Standard AS 3780: The storage and handling of corrosive substances* [13]. It is highly corrosive on most metals including stainless steel, and although most types of stainless steel are resistant at either low or high concentrations, corrosion increases with temperature[14]. Care must be taken to ensure the integrity of acid supply system (hoses, pumps, fittings), a leak in which would spill highly concentrated sulphuric acid directly onto the deck. Perhaps even more concerning however is the potential for a leak in the storage bladder that may go unnoticed for some time, releasing dilute concentrations of acid (in the silage) into the holding tanks. This could be a particular issue if the silage was subject to evaporation, increasing the concentration to intermediate levels. An additional hazard associated with contact between sulphuric acid and metals is the release of hydrogen gas, which is flammable and explosive. Adequate ventilation must be ensured, and smoking and other ignition source should be in the vicinity of the storage or pipe works and equipment. Recommended personal protective equipment should be worn while setting up cleaning up spills, performing maintenance on equipment and changing over storage containers. It is likely that some additional training of crew in working with hazardous materials would be required to reduce these risks.

Mixer / mincers have a number of mechanical risks and hazards including:

- entanglement by rotating shafts;
- crushing by hard surfaces moving together;
- severing by a shearing action; and
- cutting from sharp edges.

The Thompson 3000 is built to Australian Standards and Regulations, and has inbuilt controls for mechanical risk, including an isolation switch, and a safety cut out switch built into the lid that stops the machine when the lip is opened. Proving it is either not modified, or that modifications made meet the Australian Standards and Regulations, there should be little risk of using the mixer / mincers on a stable platform. On a fishing

[13] https://www.amsa.gov.au/environment/national-plan/supporting-documents/documents/Sulfuric%20Acid%20(98%25%20Solution)%20MSDS.pdf (Accessed 12/1/2017)

[14] http://www.bssa.org.uk/topics.php?article=33

vessel exposed to unstable ocean conditions and wind however, there may be additional risks. The lid does have a lock and is low profile. It is uncertain if the lock could shake loose under certain conditions at sea, whereby the lid may blow open. Additional mechanical controls and procedures could be deployed to mitigate this risk.

4.5.6. Summary: feasibility of vessel based facility for processing species not suitable for human consumption

Silage production has been shown to be viable in land based situations such as seafood processing facilities. Knuckey (2004) reported a that feasibility study of installing a fish silage processing plant at Sydney Fish Market was *attractive from both an environmental and financial point of view*, *provided a solution to the stringent waste disposal regulations* and under almost all scenarios, *provided a sound annual pre-tax return on investment.* Of these benefits, probably the most significant to the GABTS is the financial benefit, however the environmental benefits may also assist the industry by improving the public perception and social licence of the fishery.

Discussion with industry members revealed that GABTS vessels are not limited by onboard storage space, space that could be used to carry silage. Equipment suitable for producing silage onboard a fishing vessel is readily available in Australia, and components that could meet the minimum specifications required have been described. Based on median levels of bycatch available for mincing, an estimated 246.4 t of silage could be produced annually, with an estimated 10-year profit of about $827,000.

Importantly, clarification of AFMA's bycatch management requirements and elucidation of a suitable and consistent market also would be needed before this could be considered a viable utilisation method. Further, consideration needs to be given to mitigating the risks highlighted in Section 4.5.5.

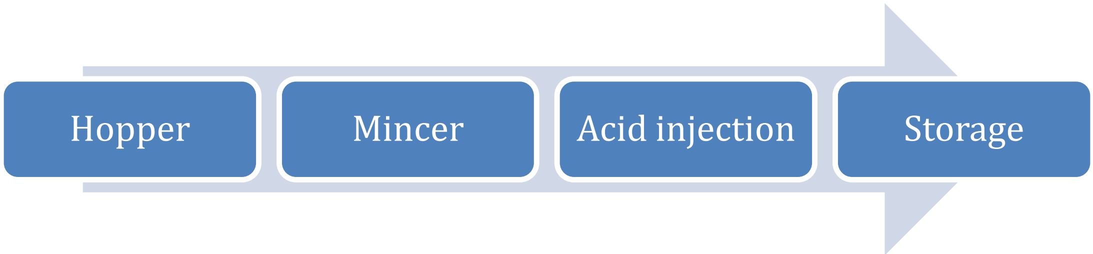


Figure 36. Process diagram for proposed onboard fish mincing system.

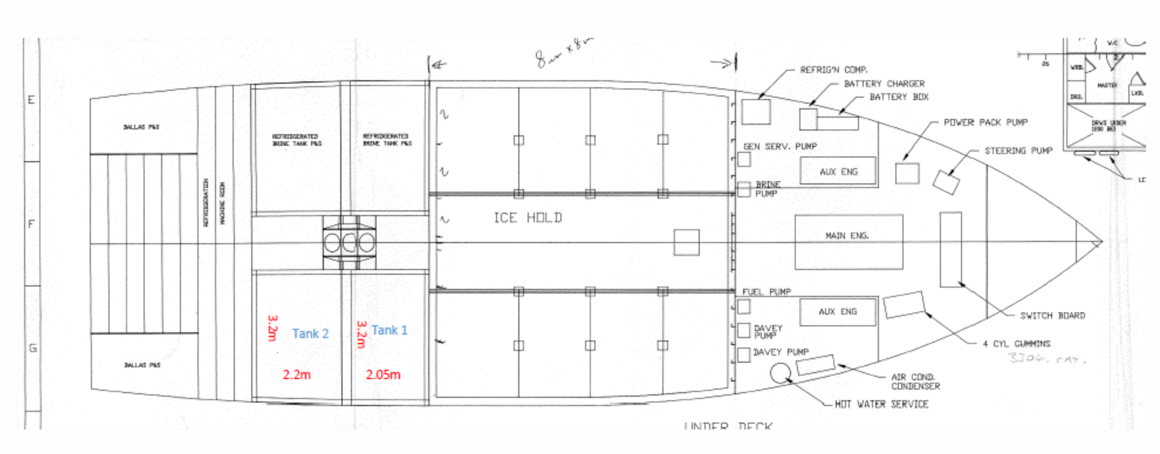


Figure 37. General arrangements diagram of the Explorer S showing the location and dimensions of the starboard brine tanks.

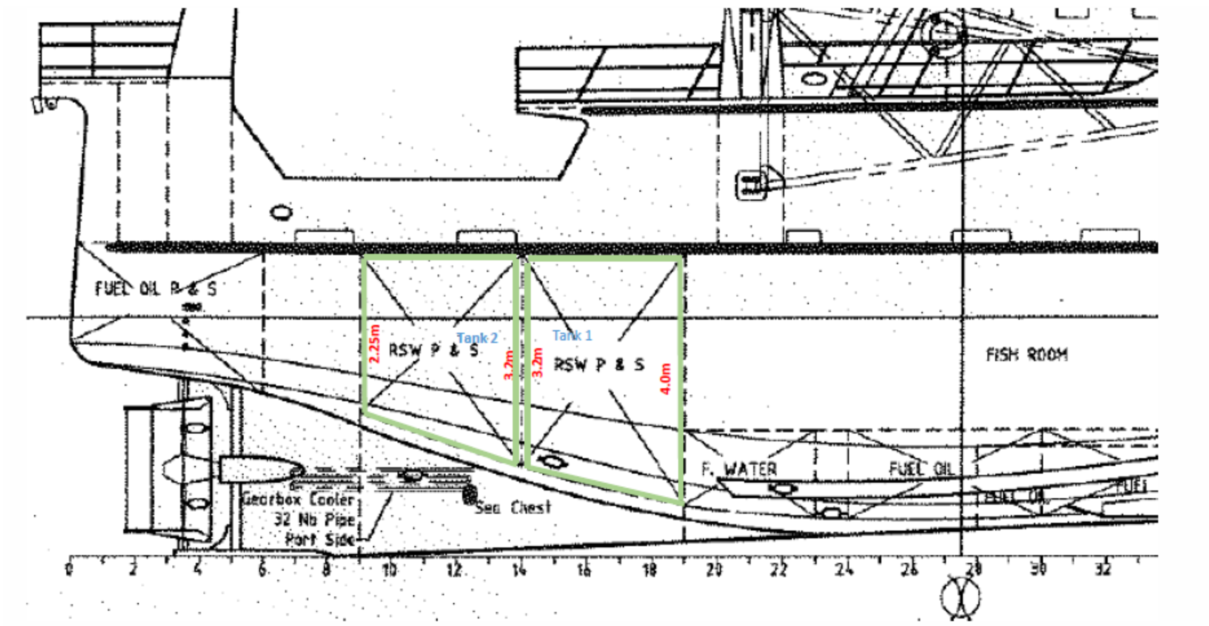


Figure 38. Side view of the Explorer S showing the location and dimensions of the starboard brine tanks.

Table 16. Minimum, mean (+ S.E.) and maximum discarded, median and geometric mean catch per shot (t) from shots on the shelf and slope that might be suitable for mincing. Latchet, Ocean Jacket, Barracouta, all dogfish as well as other species not suitable for mincing such as sponge, Bailer Shell, corals, benthos and TEP species have been removed.

	Discarded catch per shot (kg)						
	Minimum	Average (+ S.E.)	Maximum	95% CI	Median	Geometric mean	Geometric 95% CI

Shelf	0.5	471 (± 6)	5592	439–504	302	286	240-342
Slope	0.02	249 (± 23)	4174	161–337	40	41	5.7-291

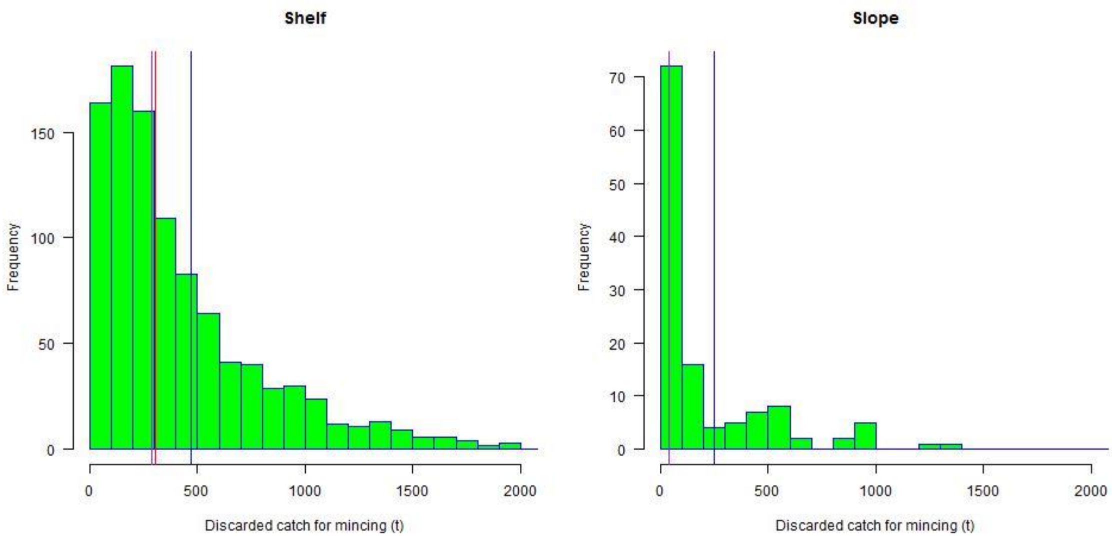


Figure 39. Frequency of discarded catches of species considered suitable for mincing of shelf and slope shots. Latchet, Ocean Jacket, Barracouta, all dogfish as well as other species not suitable for mincing such as sponge, Bailer Shell, corals, benthos and TEP species have been removed. Red, purple and blue vertical lines are the median, geometric mean and mean values respectively. Note that the x-axis was limited to 2000 t and the red and purple lines are near overlapping.

Table 17. Maximum reported size of commonly caught large bycatch species.

Species	Maximum size
Black Stingray	180 cm disc width[1]
Smooth Stingray	210 cm disc width[1]
Southern Fiddler Ray	97 cm total length[1]
Spikey Dogfish	62 cm total length[1]
Wide Stingaree	47 cm total length[1]
Barracouta	1.5 m total length[2]

1. Last, P.R. and Stevens, J.D. (1994). Sharks and Rays of Australia. CSIRO Australia.
2. Gomon, M., Bray, D. and Kuiter, R. (2008). Sea Fishes of Southern Australia. Reed New Holland, Sydney.

Table 18. Preliminary specifications for fish hydrolysis processing system

Part	Characteristic	Desired level
Mixer mincer	Mincing rate	~1,000 kg/hr
	Plate size	10 mm
	Power	3 phase[1]
	Current	20 amps minimum[1] (the vessel has 2 gensets outputting >100 KVA.
	Size	2 x 1 m
	Maximum size of fish	1 m
Hopper	Volume	200 kg
Acid injector	Rate	About 30 L per tonne of fish (or 30 L per hour)
	Reservoir volume	120 L
	Onboard storage	1350 L
Bladder	Volume	25,000 L + 20,000 L
	Weight of product	25,000 kg + 22,000 kg
	Strength	
	Dimensions	L 2.1 m x W 3.2 m x H 4 m L 2.2 m x W 3.3 m x H 3.7 m
	Chemical resistance	pH 4

[1] This is a requirement of industrial grinders

Table 19. Examples of potential components of fish hydrolysis processing system

Part / model/supplier/cost	Characteristic	Rated level
Mixer mincer Thompson 3000 Mixer Mincer Viking Food Solutions $22,000	Mincing rate Plate size Power Supply Dimensions Size Bowel capacity	Max 3,000 kg/hr 10 mm 415 V, 20 Amp D 1.15 m x W 1.1 m x H 1.4 m. 2 x 1 m 200L/150 kg
Acid injector LMI GA45D4T(2) Dosing Systems Australia : $1,560.00 + Freight + GST	Rate Power Chemical resistance	Manual adjustment 50 Litres Per Hour into 10 Bar 240 V PVDF Liquid End
Pump 200PR Crommelins Subaru 2" Chemical Waste Pump, 2yr Warranty http://www.mygenerator.com.au/crommelins-subaru-2-chemical-waste-pump.html $1,609.00	Hose diameter Maximum head Maximum flow rate Fuel consumption	2” 38 m 43,800 L/hr 1.7 L / h
Hose 30 m HOSE RBR SUCT/DEL CHEMICAL UHMWPE 51MM https://www.blackwoods.com.au/ $2,227.50	Working Pressure	1.66 Mpa
SS fittings 2" or 50mm 316 Stainless Steel Director / Hose Tail - 2" Male BSP thread x 50mm hose tail http://www.irrigationwarehouse.com.au/category58_1.htm $34.01 each		

Figure 40. The Thomson 3000 Mixer/Mincer. Top right: with 25 kg of Thetis Fish. Middle left: Starting mincing through 10 mm plate. Middle right: Mincing through 10 mm plate. Bottom left: Residue left over after 75 kg of fish minced. Bottom right: Total output. The majority of the output is mince, however it is largely covered by sludge that was ejected near the end of each bin, and rose to the surface.

Table 20. Inputs into economic assessment of feasibility of onboard silage system.

Item	Unit cost	Assumption
Plant equipment		
Mixer / mincer	$22,000	10 year life span
Acid injector	$2,000	10 year life span
Bladder	$5,000	5 year lifespan
30m chemical hose	$2,228	5 year lifespan
Fittings	$34	4 needed, 5 year lifespan
Pump	$1,609	5 year lifespan
Servicing and maintenance		
Mixer mincer	$2,309	Replacement of 1 insert holder, 72 inserts, 1 mincer plate and 1 shank pin.
Consumables		
Sulphuric acid	$0.80 per L	Wayne Street pers. comm.
Acid dosage rate	40 L/t	Wayne Street pers. comm.
Pump fuel	$1.20 per L	
Pump fuel consumption	$1.7 L/hr	Assume 1 hour per shot
Fishery information		
Trips per year	24	Section 4.4
Number of shots per trip	34	Section 4.4
Median weight of bycatch available for mincing	302 kg	Mean weight is 471 kg
Base wharf price	$400 per tonne	Wayne Street pers. comm.

Table 21. Summary of costs, revenue and profit over 10 years based on the base wharf price and median bycatch estimate.

Plant equipment	$ -39,718
Servicing and maintenance	$ -23,090
Consumables	$ -95,505
Revenue	$ 985,728
Profit	**$ 827,416**

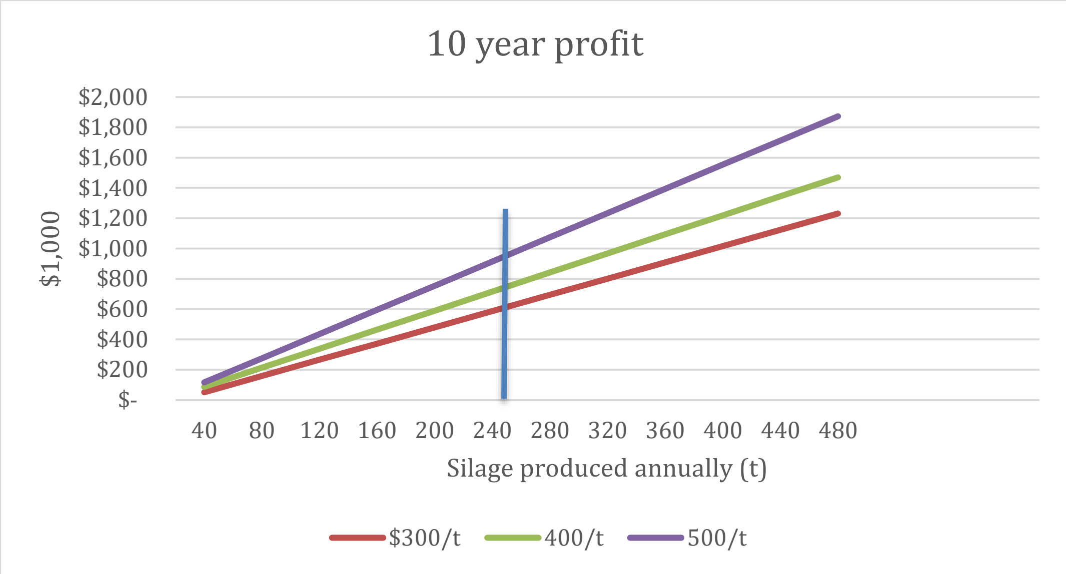


Figure 41. Potential profit for a range of annual silage volumes and wharf prices. Based on the median discards available. The vertical blue line shows the annual silage produced based on median bycatch available.

5. Conclusions

The discarded catch in the GABTS is characterised as highly diverse, but dominated by a few species in particular, and lacking almost entirely the two main target species (Deepwater Flathead and Bight Redfish) (Section 4.1). While hundreds of species are discarded, 90% of the discarded weight was comprised of 42 different species (Figure 10). Latchet made up 25% of all discards (Figure 17) followed by Wide Stingaree (10%), Ocean Jacket (5%), stingarees and giant stingarees (4%), Barracouta (4%) and Eastern Fiddler Ray (3%). Only six species or species groups comprised 64% of the discarded catch. Of those six species / species groups, we consider Latchet and Ocean Jacket to have the best prospects in terms of improved utilisation of discards for species specific marketing and human consumption. Importantly, not only are Latchet discarded in the greatest quantities, discards of that species were recorded in the majority (80%) of shots observed. Ocean Jacket discards were recorded in about 38% of shots observed. Latchet were caught consistently throughout the year (Figure 23), while catches of Ocean Jacket appeared higher in summer and early autumn (Figure 21). Discarding of Latchet is clearly size dependent (although large latchet are sometimes discarded) — the modal length of discarded fish was 27 cm, and there were no fish of that length or smaller measured from the retained catch (Figure 26). Latchet less than 35 m long are considered “small” by the Sydney Fish Market (Sydney Fish Market, 2013). While discarding of Ocean Jacket was higher for fish smaller than 35 cm, the distribution was relatively flat, and fish measured from the retained catch encompassed the full range of lengths of discards (Figure 26).

This study identified a number of supply and demand barriers to use of bycatch (Table 7), many of which are common to seafood in general (Section 4.2). For example, in a report prepared for the FRDC, Intuitive Solutions (2016) found that the odours of seafood were off-putting when purchasing, preparing and cooking and eating seafood, that there was a lack of confidence in preparing and cooking seafood. Considering Latchet and Ocean Jacket in the supply-side barriers identified, the consistency in potential supply is not an issue as they are caught regularly throughout the year. They are considered low value species, and this would need to be addressed through marketing and education. We are not aware of any particular concerns regarding the shelf life of each of those species, however it is an issue for the GABTS in general, given the typical duration of fishing trips (10–14 days). Freezer vessels were used in the fishery during the mid-2000s, but to our knowledge, no vessels currently in the fishery have freezers onboard. Latchet and Ocean Jacket are easily identifiable, and pose no problem for identification by crew members. Section 7, part 48 (1)(b) states that *the holder of a fishing concession must ensure that fish is not moved from the nominated boat to another boat*, however part 48 (9)(a and b) facilitate for this to occur, stating *However, this section does not apply if the holder receives written approval from AFMA before: (a) the nominated boat carries fish caught by another boat; or (b) fish is moved from the nominated boat to another boat while at sea.* The most relevant demand-side barriers to those species are likely to be high costs to consumers due to high local wages and the expense of marketing the products, a lack of restaurateur, chef and consumer knowledge of the product and how to cook it. Solutions to these demand side barriers could include export to another country form processing, public education through for example cooking TV shows, providing incentives to high end restaurants via for example lower prices in the short term, and encouraging restaurants to specialising in serving “unusual” species.

A wide range of fish products were identified from international literature (Section 4.3) ranging from those that can be classified as for direct human consumption, to products not for consumption at all (such as fertiliser and pharmaceuticals). A review of Asian markets found that demand for leatherjacket is high in China, and that product source from Australia receives a higher price than that from elsewhere. Latchet is also commonly eaten in China, however a good supply from local fisheries keeps the price stable and affordable to the locals.

Catches by GABTS vessels are generally not constrained by hold capacity. If the other supply and demand barriers to landing more Ocean Jacket and Latchet are removed, there is potential for retention of those species to increase the profitability of GABTS vessels. The break-even prices for landing all discarded Latchet (estimated at about 780 t per year) and leatherjacket (estimated at about 166 t per year) are relatively low ($1.43 and $1.81 per kg respectively), however this may be higher at low catch volumes (Section 4.4). For example, if only 500 t of the discarded Latchet was landed annually, the breakeven price would be about $2.5 per kg, while if only 100 t of the discarded leatherjacket was landed annually, the breakeven price would be about $2.15 per kg.

Apart from Latchet and leatherjacket, some other main discard species are unlikely to find a market for human consumption, especially given the break-even prices (assuming they are similar to Latchet and leatherjacket). Examples of such species are Wide Stingarees and Barracouta (Figure 18). Bulk processing of these species into silage together with the many other species currently discarded provides an opportunity for reducing discarding, while increasing returns to the vessel (Section 4.5). Capital costs of silage plants are relatively inexpensive, however the ongoing costs of consumables are significant, and increase directly in proportion to the amount of silage produced. Over a 10-year period and assuming about 300 kg of bycatch is processed per shot (the median calculated from the observer data) at current prices, a profit of about $827,000 could be expected.

6. Further Development

Education and marketing of byproduct species is required to break down the main demand-side barriers to increased use of Latchet and leatherjacket, such that the GABTS could realise benefits described in this study. Currently there appears to be a lack of consumer awareness of their own role in addressing bycatch issues in this fishery. Creating consumer knowledge of bycatch issues and exposing consumer to the qualities of the fresh locally caught byproduct (replacing lower quality imported fish) is an important first step. In addition, helping consumers gain knowledge, experience, and confidence in how to use and cook these species and become a more regular part of their diet will help sustain this local industry into the future (Table 7). There are a number of ways to address this though education and marketing, as identified by previous FRDC-funded initiatives. However, prior to education and marketing campaigns, it is important to first better understand consumer preferences for the different discard species. For instance, the way in which their 'discard status' interacts with other attributes of the product and purchase environment may be an important aspect that can be usefully applied in successfully marketing the species. Consumer surveys are one way of providing information for this important future research area.

Consumer education can be targeted through TV or online media. Encouraging TV cooking shows for example to use different species not only increases awareness of the product, but also educates people on how to prepare and cook the fish. Some high-end restaurants incorporate providence into the dining experience, and telling a seafood story that involves improving the environmental operation of a fishery (i.e. reducing discards) could be considered an attractive option.

While onboard silage processing appears viable in principle (Section 4.5), a proof of concept trial is needed to demonstrate that it works in the field. Potential issues and uncertainties include the variability of the bycatch supply, how the machinery operates on an unstable platform, implications for stability of the vessel and the actual wharf price that the product will attract.

In contrast to some other fisheries the GABTS fishery has a small number of operators and a benchmarking analysis for bycatch product at the vessel level may not add much valuable information. However, a facilitated approach to discuss the potential for regionally combining bycatch and thus potentially gaining some economies of scale in relation to transport and other value chain costs, may lower some additional barriers to landing the bycatch species.

There were insufficient survey responses, and thus costs and return information from the fish processing, fish buyers/trader, and transport components of the supply chain in this current analysis. This means that it was not possible to undertake a thorough qualitative and quantitative value chain analysis. However, to solve the bycatch issue for the GABTS (and similarly for other Australian fisheries) in the short to medium term, it is important that all supply chain participants are willing to contribute to solving fishing industry-specific problems. The fish processors, fish buyers and traders, and transport industries should be included in research project design in the future. In addition, a greater 'interest' in solving a fishing industry specific problem should be created in these supply chain components. This may occur by providing examples of explicit benefits in using bycatch that may exist. Knowledge of the benefits at all levels may lead to greater value chain transparency and cooperation between supply chain components. It may also lead to increased future collaboration and participation of all supply chain levels in fisheries research projects that are aimed at solving wastage problems.

7. Extension and Adoption

An article describing this project appeared in the FRDC's FISH magazine during March 2017 (see Appendix 8).

Primary publications are also planned based on results reported here.

With respect to use of a fish silage plant on a commercial fishing vessel, the best extension would be to fund a case study as an example to show other fishermen.

8. References

Abdullah, J., (1983). Utilization of bycatches for the production of fish silage. Philippine J. Vet. Anim. Sci.

Alverson, D.L., Freeberg, M.H., Murawski, S.A. and Pope, J.G. (1994). A global assessment of fisheries bycatch and discards, FAO, 339, FAO, Rome.

Andrew, N.L. and Pepperell. J.G. (1992). The bycatch of shrimp trawl fisheries. In: Margaret Barnes, A.D. Ansell, and R.N. Gibson, eds. Oceanography and Marine Biology Annual Review. Vol. 30. UCL Press, United Kingdom. pp. 527–565.

Archer, M., Watson, R. and Denton, J.W. (2001). Fish Waste Production in the United Kingdom: The Quantities Produced and Opportunities for Better Utilisation. The Sea Fish Industry Authority Seafish Technology. Seafish Report Number SR537.

Barratt, F. (1986). A study on the feasibility of utilising prawn bycatch for human consumption. FAO FI RAS/85/004. UN/FAO, South Pacific Fisheries Development Programme, Rome, Italy. 23 pp.

Bimbo, A.P. (1989). Technology of production and industrial utilization of marine oils. In: Ackman R.G. (ed) Marine biogenic lipids, fats and oils. CRC Press, Boca Raton, pp 401–431.

Clucas, I. (1997). A study of the options for utilization of bycatch and discards from marine capture fisheries. FAO Fisheries Circular. No. 928. Rome. 59 pp.

DAWR (2017a). Commonwealth Fisheries Harvest Strategy Policy. Department of Agriculture and Water Resources DRAFT for Consultation: March 2017.

DAWR (2017b). Commonwealth Fisheries Bycatch Policy. Department of Agriculture and Water Resources DRAFT for Consultation: March 2017.

de Rozarieux, N.A. (2014). Use of discards in bait. National Federation of Fishermen's Organisations, York. 44 pp.

Dundas-Smith, P. and Mahoney, D. (1996). Investing for tomorrow's catch. IN BREMNER, A., DAVIS, C. & AUSTIN, B. (Eds.) Seafood Symposium 25-27 July 1996. Brisbane.

Elsy, R. (1986). Marketing and development options for shrimp bycatch products in Bangladesh. FAO FI BGD/80/025. 44 pp.

FAO. (1986). The production of fish meal and oil. Fishery Industries Division, FAO Fisheries Department, Food and Agriculture Organization, Rome.

FAO. (1995). Code of Conduct for Responsible Fisheries. Food and Agriculture Organisation, Rome.

FAO. (1996). Fisheries and aquaculture in Sub-Saharan Africa: situation and outlook in 1996. FAO Fisheries Circular. No. 922. Rome, FAO. 44p.

FAO. (2014). The state of the world fisheries and aquaculture: Opportunities and challenges, FAO, FAO, Rome.

Grantham, G.J. (1980). The prospects for bycatch utilization in the Gulf area. Regional Fishery Survey and Development Project. FI:DP/RAB/71/278/14. UN/FAO, Rome, Italy. 43 pp.

Herzberg, A. and Shapira, N. (1978). Development prospects for less attractive species of fish: an ecological approach. Proceedings of the Symposium on Fish Utilization Technology and Marketing in the IPFC Region, Manila, Philippines, March 8–11, 1978. pp. 488–491.

Hobday, A.J., Bustamante, R.H., Farmery, A., Frusher, S., Green, B., Jennings, S., Lim-Camacho, L., Norman-Lopez, A., Pascoe, S., Pecl, G., Plaganyi, E., van Putten, E.I., Schrobback, P., Thebaud, O. and Thomas, L. (2014). Growth opportunities & critical elements in the supply chain for wild fisheries & aquaculture in a changing climate. Final Report. FRDC-DCCEE Marine National Adaptation Program 2011/233.

Hobday, A.J., Smith, A.D.M., Webb, H., Daley, R., Wayte, S., Bulman, C., Dowdney, J., Williams, A., Sporcic, M., Dambacher, J.M., Fuller, M., and Walker. T. (2007). Ecological Risk Assessment for the Effects of Fishing: Methodology. Report R04/1072 for the Australian Fisheries Management Authority, Canberra.

Intuitive Solutions. (2016). Unpacking the consumer seafood experience. Intuitive Solutions. Report to the Fisheries Research & Development Corporation, Novemebr 2016.

Jayathilakan, K., Sultana, K., Radhakrishna, K., and Bawa, A. S. (2012). Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review. Journal of Food Science and Technology, 49: 278–293.

Karim, N.U., Lee, M.F.M.A, and Arshad, A.M. (2015). The effectiveness of fish silage as organic fertilizer on post-harvest quality of pak choy. European International Journal of Science and Technology, 4: 163–174.

Kelleher, K. (2005). Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper. No. 470. Rome, FAO. 131p.

Kennelly, S.J. (1995). The issue of bycatch in Australia's demersal trawl fisheries. Reviews in Fish Biology and Fisheries, 5: 213–234.

Kim, J.S. and Park, J.W. (2006). Mince from seafood processing by-products and surimi as food ingredients. In Maximising the value of marine by-products. London, Woodhead Publishing Cambridge: pp.198-227.

Knuckey, I., Sinclair, C. Surapaneni, A. and Ashcroft, W. (2004). Utilisation of seafood processing waste – challenges and opportunities. SuperSoil December 5-9 2004 University of Sydney, Sydney, Australia.

Knuckey, I.A. (2004). South East Fishery Industry Development Subprogram: Assessing the Commercial Viability of Utilising Fish Processing Wastes. FRDC Project No. 2002/405.

Knuckey, I.A. (2006). Southern and Eastern Scalefish and Shark Fishery – Bycatch Utilisation Scoping Study, Department of Primary Industries Agribusiness Group, Department of Primary Industries Agribusiness Group, Victoria.

Knuckey, I.A. and Brown, L.P. (2002). Assessment of Bycatch in the Great Australian Bight Trawl Fishery. Department of Natural Resources and Environment. FRDC Project No. 2000/169

Kompiang, I.P. (1977). Nutritional value of fish silage processed with the addition of formic acid. J Pen Teknol Perik 2:34–39

Kristinsson, H.G. and Rasco, B.A. (2000). "Fish protein hydrolysates: Production, biochemical and functional properties. Critical reviews." Food Science and Nutrition 40(1): 43-81.

Lawley, M. (2015). A final seafood omnibus: evaluating changes in consumer attitudes and behaviours’. FRDC Project Number 2015/702. University of the Sunshine Coast, Maroochydore, Qld. http://frdc.com.au/research/final-reports/Pages/2015-702-DLD.aspx

LEI. (2013). Economische effecten van een aanlandplicht voor de Nederlandse visserij. LEI-rapport 2013-062. LEI Wageningen UR, Den Haag.

Luna, J. (1981). Advances in unconventional fish foods. ICLARM Newsletter 4(1):85, 86, 88.

Mocking, G., and Machava, A. (1985). Storage life on ice of the bycatch from the shrimp fishery. In: Proceedings of Fish Processing in Africa, Expert Consultation on Fish Technology in Africa, Lusaka, Zambia, January 21– 25, 1985. UN/FAO, Rome, Italy. FIIU/R329. pp. 74–80.

Murawski, S.A. (1996). Factors Influencing Bycatch and Discard Rates: Analyses from Multispecies/Multifishery Sea Sampling. Journal of the Northwest Atlantic Fishery Science 19, 31-39.

Musgrove, R. (2012). Maintaining Post – harvest Quality of Key Species from the Great Australian Bight Trawl Sector. FRDC Project No: 2010/220. South Australian Research and Development Institute.

Musuishi, I. (1981). Economic profiles for three (minced fish) products made from bycatch (in Panama). In: Fish Bycatch--Bonus from the Sea. Report of a Technical Consultation on Shrimp Bycatch Utilization, Georgetown, Guyana, October 27, 1981. IDRC, Ottawa, Canada. pp. 118–119.

National Marine Fisheries Service. (2011). U.S. National Bycatch Report [W. A. Karp, L. L. Desfosse, S. G. Brooke,Editors]. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-117E, 508 p.

Northwest Fisheries Science Centre. (2003). West coast groundfish observer program: Initial data report and summary analyses. Unpublished report.

Park, J.W. (2013). Surimi and Surimi Seafood. CRC Press, Boca Raton. 636 pp.

Patterson, H., Noriega, R., Georgeson, L., Stobutzki, I. and Curtotti, R. (2016). Fishery status reports 2016, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra. CC BY 3.0.

Peterkin, F.A. (1982). Developinga shrimp bycatch utilization program. *In* Proceedings of the Gulf and Caribbean Fisheries Institute, 34, pp. 112–119.

Petersen, T.E. (1981). The Guyana project: industrial use of (fish) bycatch. In: Fish Bycatch--Bonus from the Sea. Report of a Technical Consultation on Shrimp Bycatch Utilization held in Georgetown, Guyana, October 27–30, 1981. IDRC, Ottawa, Canada. pp. 69–76.

Petruny, M.E., Parker, K.M., Castro, M.L. Schwartz, L.G. Skrobe, and B. Somers (eds.) (2003). Proceedings of the New England By catch Workshops. Rhode Island Sea Grant, Narragansett, R.I. 52pp.

Queirolo, L.E., Fritz, L.W., Livingston, P.A., Loeffland, M.R., Colpo, D.A., and DeReyner, Y.L. (1995). Bycatch, utilization, and discards in the commercial groundfish fisheries of the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. 148 pp. http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-58.pdf.

Savage, J. and Hobsbawn, P. (2015). Australian fisheries and aquaculture statistics 2014, Fisheries Research and Development Corporation, project 2014/245, Fisheries Research and Development Corporation, Canberra.

Seafish. (2012). The Seafish guide to discards. Grimsby, UK, Seafish.

Singh, P., Danish, M. and Saxena, A. (2011). Spoilage of fish-process and its prevention. Department of Fishery Biology, College of Fisheries, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttrakhand, India. (http://aquafind.com/articles/spolage.php).

Snell, P. (1978). The production of fish balls and fish cakes in Sabah and the possible use of trawler bycatch for such products. In: Proceedings of the Symposium on Fish Utilization Technology and Marketing in the IPFC Region, Manila, Philippines, 8–11 March, 1978. UN/FAO, Rome, Italy. pp. 581–600.

Steward, H. 2014. Review of Management Options for the Landing Obligation. Marine Scotland Science, the Scottish Government. 79 pp.

Sultana, R., Jamil, K. and Khan, S.I. (2013). Chapter 13. Bycatch utilization in Asia. *In* Seafood Processing By-Products: Trends and Applications, pp. 244–284. Ed. by S.-K. Kim. Springer Science Business Media, New York.

Sydney Fish Market. (2013). Seafood Handling Guidelines. Sydney Fish Market Pty Ltd, Australia.

http://www.sydneyfishmarket.com.au/Portals/0/PDF/seafoodhandlingguidelines.pdf

Szuwalski, C.S., Burgess, M.G., Costello, C. and Gaines, S.D. (2016). High fishery catches through trophic cascades in China. PNAS 114 (4) 717-721.

Tatterson, I.N. and Windsor, M.L. (1974). Fish silage. Ministry of Agriculture, Fisheries and food Torry Research Station, Torry advisory note No. 64. http://www.fao.org/wairdocs/tan/x5937e/x5937e00.htm

Vidal-Giraud, B. and Chateau, D. (2007). World Surimi Market. GLOBEFISH Research Programme, Vol. 89, Rome, FAO. 125 pp.

Windsor, M.L. (2001). Fish Meal. Torry Advisory Note No. 49. FAO. http://www.fao.org/wairdocs/tan/x5926e/x5926e00.htm#Contents.

Yunizal, N.S. (1985). Technology for silage processing. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 117–125, in Indonesian.

Appendix 1 – Intellectual Property

No intellectual property has arisen from this project.

Catch and effort data provided by AFMA was aggregated and filtered in accordance with AFMA's information disclosure policy (FMP 12).

Appendix 2 - Staff

Name	Organisation	Project Involvement
Ian Knuckey	Fishwell Consulting	Principle Investigator
Alistair Hobday	CSIRO	Co-PI
Ingrid van Putten	CSIRO	Researcher (international market review, supply and demand side barriers, product types economic model, supply chain)
Matt Koopman	Fishwell Consulting	Researcher (bycatch and fish silage)
Aysha Fleming	CSIRO	Researcher (market survey)
Shijie Zhou	CSIRO	Researcher (product types, Asian market prices)

Appendix 3 - Survey question responses for Section 4.4

Numbers indicate the number of survey respondents who identified each species or option. Responses for questions 2-9 were sometimes made only for the species identified in earlier questions.

Q1 Which species do you currently purchase?

- Latchet – 7
- Stingarees – 2
- Ocean jacket – 7
- Barracouta – 1
- Skates and rays – 4
- Dogfish – 2

Q2 How do you rate the quality of the fish?

- Latchet – 'Mostly high quality'-3; 'Mix of high and low quality'-2; 'Mostly low quality'-2
- Stingarees – 'Mix of high and low quality'-1; 'All low quality'-1
- Ocean jacket – 'Mostly high quality'-4; 'Mix of high and low quality'-1; 'Mostly low quality'-2
- Barracouta – 'Mostly high quality'-1
- Skates and rays – 'Mostly high quality'-1; 'Mix of high and low quality'-2; 'All low quality'-1
- Dogfish – 'Mix of high and low quality'-1; 'All low quality'-1

Q3 What weight do you typically buy in a week?

- Latchet – 'Less than 30 kg'-3; '30-60kg'-2; '60-120kg'-1
- Stingarees – 'Less than 30 kg'-1
- Ocean jacket – 'Less than 30 kg'-6; 'More than 300kg'-1
- Barracouta – 'Less than 30 kg'-1
- Skates and rays – 'Less than 30 kg'-3
- Dogfish – 'Less than 30 kg'-1

Q4 What price do you usually pay?

- Latchet – '$2.00-4.00/kg'-5; '$4.00-6.00/kg'-2
- Stingarees – 'Less than $2.00/kg'-1; '$4.00-6.00/kg'-1
- Ocean jacket – '$2.00-4.00/kg'-2; '$4.00-6.00/kg'-4; '$6.00-8.00/kg'-1
- Barracouta – '$4.00-6.00/kg'-1
- Skates and rays – 'Less than $2.00/kg'-1; '$2.00-4.00/kg'-2; '$4.00-6.00/kg'-1
- Dogfish – 'Less than $2.00/kg'-1; '$2.00-4.00/kg'-1

Q5 What form do you prefer?

- Latchet – 'Whole'-7

- Stingarees – ‘Whole’-1; ‘Other (trunks, flaps, gutted, etc.)’-2
- Ocean jacket – ‘Whole’-3; ‘Other (trunks, flaps, gutted, etc.)’-4
- Barracouta – ‘Whole’-2
- Skates and rays – ‘Whole’-1; ‘Other (trunks, flaps, gutted, etc.)’-3
- Dogfish – ‘Whole’-1; ‘Other (trunks, flaps, gutted, etc.)’-2

Q6 How often would you like to purchase?

- Latchet – ‘2-3 times per week’-3; ‘Weekly’-2; ‘Monthly’-1; ‘Seasonally’-1
- Stingarees – ‘2-3 times per week’-1; ‘Weekly’-1
- Ocean jacket – ‘2-3 times per week’-1; ‘Weekly’-5
- Barracouta – ‘Monthly’-1
- Skates and rays – ‘Weekly’-3
- Dogfish – ‘2-3 times per week’-1; ‘Weekly’-1

Q7 What is the maximum you could sell in a week (if supply guaranteed)?

- Latchet – ‘Less than 30kg’-2; ’30-60kg’-4; ‘More than 300kg’-1
- Stingarees – ‘Less than 30kg’-1; ‘120-300kg’-1
- Ocean jacket – ‘Less than 30kg’-4; ’30-60kg’-1; ‘More than 300kg’-1
- Barracouta – ‘Less than 30kg’-1
- Dogfish – ‘Less than 30kg’-1; ‘120-300kg’-1

Q8 Overall how do you feel about purchasing this species?

- Latchet – ‘Very positive’-1; ‘Positive’-3, ‘Neutral’-3
- Stingarees – ‘Positive’-1; ‘Neutral’-3
- Ocean jacket – ‘Very positive’-1; ‘Positive’-4, ‘Neutral’-2
- Barracouta – ‘Positive’-1; ‘Neutral’-1
- Skates and rays – ‘Positive’-2; ‘Neutral’-3
- Dogfish – ‘Positive’-1; ‘Neutral’-1

Q9 What is the main factor limiting your purchase?

- Latchet – ‘Lack of demand’-5; ‘Price that consumer will pay’-2
- Stingarees – ‘Lack of demand’-3; ‘Consumer preferences’-1
- Ocean jacket – ‘Lack of supply’-1; ‘Lack of demand’-4; ‘Quality of supply’-1; ‘Consumer preferences’-1
- Barracouta – ‘Lack of demand’-2
- Dogfish – ‘Lack of demand’-1; ‘Consumer preferences’-1

Appendix 4 – Cost of fishing

Table 22. The estimated cost of fishing (by cost centre) and returns per vessel and per trip for the GABTS. A negative number means that costs are higher than income and the vessel is running at a financial loss.

	Annual costs for GABTS	Estimated cost ($/vessel/year)	Estimated cost ($/vessel/trip)
A	Operating cost	$138,500	$5,771
B	Net fuel costs	$604,128	$25,172
C	Unloading fee, freight cost, and marketing	$184,972	$7,707
D	Vessel cost	$3,500	$146
E	Licence and registration fees	$191,000	$7,958
F	Insurance cost	$41,000	$1,708
G	Office and consumables cost	$60,000	$2,500
H	Repairs and maintenance cost	$203,500	$8,479
I	Annual labour cost	$549,074	$22,878
J	Depreciation capital equipment	$116,506	$4,854
K	Debt and interest payments	$60,000	$2,500
L	**TOTAL COST** (A to K)	**$2,167,044**	**$90,294**
M	**TOTAL RETURNS** (turnover)	$1,987,556	$82,815
(M- [A to H])	**GROSS PROFIT** (variable cost only)	$543,663	$22,653
(M- [A to I])	**ACCOUNTING PROFIT** (variable cost + wages)	-$5,411	-$225
(M- [A to J])	**ECONOMIC PROFIT** (variable cost + wages + depreciation)	-$121,917	-$5,080
(M-L)	**NET PROFIT**	-$181,917	-$7,580

* Please note that some vessels catch above average amounts meaning that these vessels would not incur the financial losses shown here. We have assumed an average catch/vessel/year of 451,151kg and average catch/vessel/trip of 18,798kg.

Appendix 5 – Description of fish products

Table 23. Fish products

Product (short name)	Description	Reference
Fish derived product for human consumption		
Surimi	Surimi originates from Japan where it has been a traditional food source for centuries. This Japanese food product is intended to mimic the meat of lobster, crab, and other shellfish. It is typically made from white-fleshed fish (such as pollock or hake) that has been pulverized to a paste and attains a rubbery texture when cooked.	http://www.nordicinnovation.org/Global/_Publications/Reports/2010/Maximum%20resource%20utilisation%20-%20Value%20added%20fish%20by-products.pdf https://en.wikipedia.org/wiki/Fish_products
Minced fish	Minced fish is a comminute flesh produced by separation from skin and bones. Separation is a mechanical process (for producing minced fish) whereby the skin and bone is removed from the flesh. Small amounts are used in fish cakes and in less expensive grades of fish fingers and some are used to fill voids in frozen laminated blocks of fillets from which portions and fingers are cut.	http://www.nordicinnovation.org/Global/_Publications/Reports/2010/Maximum%20resource%20utilisation%20-%20Value%20added%20fish%20by-products.pdf
Kneaded fish products	Several kneaded products like kamaboko, chikuwa, hampen, fish ham and sausage are processed using surimi and incorporating other ingredients. The method of processing all these products involves grinding together of the various ingredients to a fine paste and some sort of heat treatment at some stage.	http://aquafind.com/articles/Value-Added-Fish-Process.php
Food-Grade Fish Flour	Surimi can be processed further by means of steaming, pressing, and drying to produce food-grade fish flour. This product has been explored to use as a fortificant in the processing of several products, i.e., 10 % fish flour added to extrusion products and breads; 20 % added to biscuits and crackers, as well as 13 % added to jam.	file:///C:/Users/van40f/Downloads/Seafood%20Processing%20By-Products%20-%20Trends%20and%20Applications.pdf
Fish sauce	A condiment that is derived from fish that have been allowed to ferment. It is an essential ingredient in many curries and sauces.	https://en.wikipedia.org/wiki/Fish_products http://download.springer.com/static/pdf/853/chp%253A10.1007%252F978-1-4614-9590-1_9.pdf?originUrl=http%3A%2F%2Flink.springer.com%2Fchapter%2F10.1007%2F978-1-4614-9590-1_9&token2=exp=1472605227~acl=%2Fstatic%2Fpdf%2F853%2Fchp%25253A10.1007%25252F978-1-4614-9590-1_9.pdf%3ForiginUrl%3Dhttp%253A%252F%252Flink.springer.com%252Fchapter%252F10.1007%252F978-1-4614-9590-1_9*~hmac=a8d00a44e3ca3745919514de8a48e34c2d67f3365a4b3ce52fffe14b6b099c00

Fish paste (bagoong)	This is a product from Eastern Asia. It is made from whole or ground fish, fish roe, or shellfish. It is reddish brown in colour, although this will depend on the raw materials used, and is slightly salty with a cheese-like odour.	http://www.fao.org/Wairdocs/X5434E/x5434e0f.htm
Fish derived product that are ingredients in products for human consumption		
Isinglass / Fish maws	Is a substance obtained from the swim bladders of fish (especially sturgeon), it is used for the clarification of wine and beer. It is used mainly for clarifying beverages, as an adhesive base in confectionery products, glass pottery and leather and also as an edible luxury..	https://en.wikipedia.org/wiki/Fish_products http://aquafind.com/articles/Value-Added-Fish-Process.php
Shark cartilage	Shark cartilage assumes importance because of the presence of chondriotic sulphate, which is a mucopolysaccharide. Chondriotin sulphate has therapeutic uses and is purportedly effective in reducing cancer related tumours and inflammation, and pain associated with arthritis, psoriasis and enteritis. The bones separated from the shark are cleaned and preserved by drying.	http://aquafind.com/articles/Value-Added-Fish-Process.php
Fish calcium	Calcium powder processed from the backbone of tuna can be used to combat calcium deficiency. The method of production of calcium mainly involves removing the gelatin from the crushed bones and pulverizing the remaining portion.	
Squalene	Squalene is an unsaturated hydrocarbon found in the unsaponifiable fraction of fish oils, especially of certain species of sharks. Squalene is widely used in pharmaceuticals and cosmetics.	http://aquafind.com/articles/Value-Added-Fish-Process.php
Fish gelatin	Gelatin is derived from collagen, which is the principal constituent of connective tissues and bones. It is well known that cold water fish gelatin exhibit good emulsifying and film forming properties. The main application area is therefore the embedding of oil-based vitamins. Supplier of vitamins use cold water fish gelatin for the micro-encapsulation of oil soluble substances such as vitamins A, D, E and carotenoids. Cold water fish gelatin is also used in pharmaceutical fast-dissolving tablets and as a protein additive for neutraceutical, cosmetic and food applications	http://www.nordicinnovation.org/Global/_Publications/Reports/2010/Maximum%20resource%20utilisation%20-%20Value%20added%20fish%20by-products.pdf
Fish glue	Fish glue is made by boiling the skin, bones and swim bladders of fish and is used in many different products	https://en.wikipedia.org/wiki/Fish_products
Fish protein isolate (FPI) (also referred to as fish glue)	FPI is fish protein which has been purified to a protein content of at least 90% of the dry material. Fish protein injection is believed to enhance the yield and improve the frozen stability of fish fillet (Kim & Park 2006). FPI can be used as a dipping solution in battering and breading process to reduce absorption of oil in fried products.	http://www.nordicinnovation.org/Global/_Publications/Reports/2010/Maximum%20resource%20utilisation%20-%20Value%20added%20fish%20by-products.pdf
fish protein hydrolysates (FPH)	FHP are ground up fish carcasses. After the usable portions are removed for human consumption, the remaining fish body – guts, bones, cartilage, scales, meat, etc. – are put into water and ground up.	http://www.nordicinnovation.org/Global/_Publications/Reports/2010/Maximum%20resource%20utilisation%20-%20Value%20added%20fish%20by-products.pdf

	fish protein hydrolysates (FPH) with well expressed functional and antioxidant properties in food are a subject of interest due to their ability to make products with desirable physical and sensory properties, and to produce protein enriched and oxidative stable seafood. FPH have been tested as ingredients in different food such as cereal products, fish and meat products, desserts and crackers etc. (Kristinsson & Rasco, 2000). There are some limitations in the utilization due to e.g. unacceptable taste and smell, bitterness and also competition with other functional ingredients on the market. The main quantity of FPH produced in the Nordic countries today goes into the feed and petfood industry, however there are companies, such as Marinova, that are producing food grade FPH for the food industry.	
Chitin and chitosan	One of the most recent research focuses is chitin and its derivative, chitosan, the second most abundant compound on earth after cellulose. Chitin can be extracted from crustacean shells in the seafood industry and is utilized in numerous industries, such as wastewater treatment, surgical equipment production, dietary supplement, and nutraceuticals. Today's markets for chitin and chitosan in Europe is shifting to dietary supplements as glucosamine and cosmetics for skin protection due to the compound's biosafety, high binding capacity, and dense viscosity	
Fish derived product nutraceuticals for human consumption		
Fish oil	Fish oil contains the omega-3 fatty acids, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), precursors to eicosanoids said to reduce inflammation throughout the body	https://en.wikipedia.org/wiki/Fish_products
Fish derived product for non-human consumption		
Pet food - High quality food	Transforming his low-grade fish products into high-value dog treats. Using the tail of the fish, the skin, and the meat (frames are discarded or can be used in fertiliser)	http://www.abc.net.au/news/2016-08-19/fishy-products-go-down-a-treat-in-global-pet-market/7766402
Pet food - special treats	Fish 'rollups' are a tasty, healthy treat for dogs	http://www.abc.net.au/news/2016-08-19/fish-rollups-a-tasty-healthy-treat-for-dogs/7766832
Pet food - Pharmaceutical pet product	Natural fish oil products to treat arthritis in dogs. Fish oil is a good calorie source and growth stimulant for livestock. A homologue of linoleic acid at high concentration is responsible for the growth stimulant characteristic in fish oil	http://www.abc.net.au/news/2016-08-19/fishy-products-go-down-a-treat-in-global-pet-market/7766402 file:///C:/Users/van40f/Downloads/Seafood%20Processing%20By-Products%20-%20Trends%20and%20Applications.pdf
Fish Silage	Silage is a liquid product that is made from the addition of acids to fish, such as formic acid and propionic acid. Also, it could be produced biologically by using acid-producing bacteria (Kompiang 1977). Silage can be further processed into silage flour by drying (Yunizal 1985) or by adding filler, such as corn meal, prior to drying	file:///C:/Users/van40f/Downloads/Seafood%20Processing%20By-Products%20-%20Trends%20and%20Applications.pdf
Use fish waste to grow mushrooms	Mix cooked fish waste with coir pith, woodchips and sugarcane bagasse can be used in artificial cultivation of edible mushrooms	http://www.academicjournals.org/journal/AJB/article-full-text-pdf/4DDFBEA44269

Fish meal	Fish meal is made from both whole fish and the bones and offal from processed fish. It is a brown powder or cake obtained by rendering pressing the whole fish or fish trimmings to remove the fish oil. It used as a high-protein supplement in aquaculture feed.	https://en.wikipedia.org/wiki/Fish_products
Fish emulsion / fertilizer	Fish emulsion / fertilizer is produced from the fluid remains of fish processed for fish oil and fish meal industrially	https://en.wikipedia.org/wiki/Fish_products
Bait	Some of the bycatch fish species can be used for bait	
Other fish derived products		
Bio diesel	Increasing interest in alternative energy sources other than fossil fuels has raised the use of biodiesel and biogas from natural wastes. Seafood wastes are also suggested to be available for biodiesel and biogas. Recent plants and funding has promoted biodiesel and biogas production in Europe from seafood oil in the coming years.	
Fish Oil in Non-food Industries	Fish oil is used in non-food industries to produce elastic and long polymers due to its uniqueness and high unsaturation degrees of fatty acids. This unique composition causes fish oil to have flexible applications. Fish oil-based non-food products that have been developed are fatty acid products and their derivatives, with applications such as detergents, tanning oils, protective coatings in varnish and paint, lubricant oils, plastics, pesticides, fungicides, and polyurethane foam (Bimbo 1989b).	file:///C:/Users/van40f/Downloads/Seafood%20Processing%20By-Products%20-%20Trends%20and%20Applications.pdf
Cosmetics (crystalline guanine)	The shiny effect in cosmetics is caused by crystalline guanine, extracted from fish scales.	http://www.herbhedgerow.co.uk/animal-products-in-cosmetics/#ixzz4J31wh6xf

Appendix 6 – Australian fish exports and imports

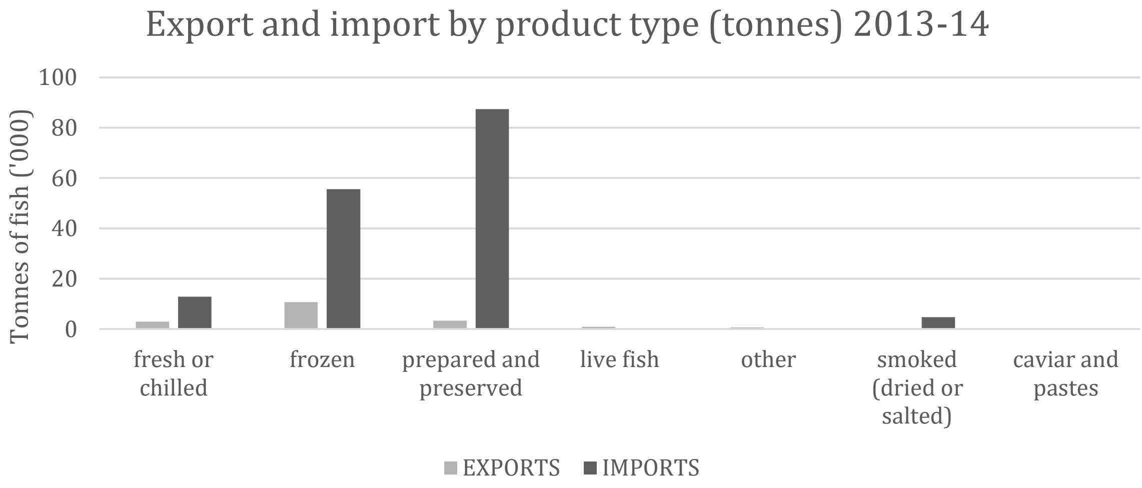


Figure 42. Fish products exported from- and imported to Australia in 2013-2014 (Savage and Hobsbawn 2015).

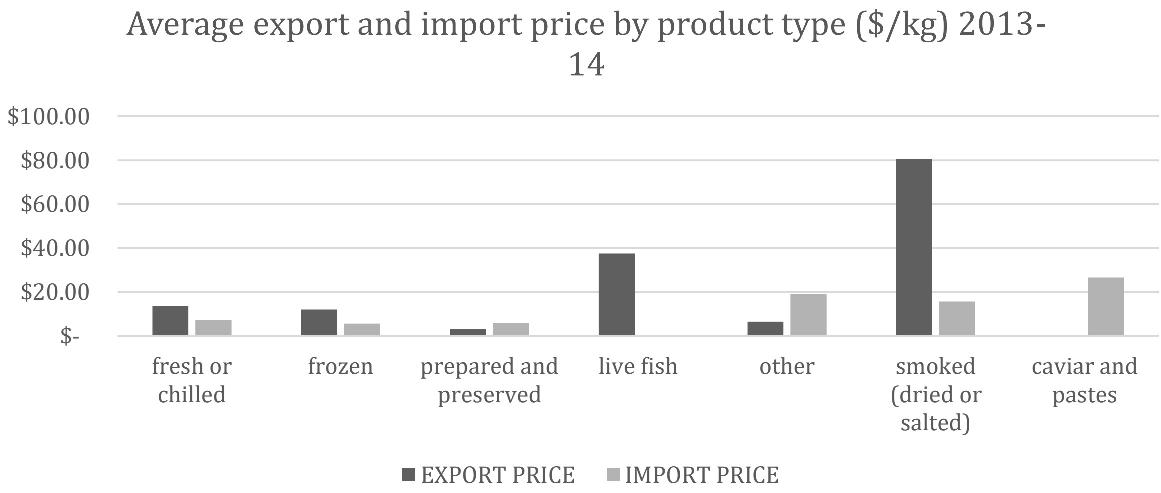


Figure 43. Average per kilo prices for fish products exported from- and imported to Australia in 2013-2014 (Savage and Hobsbawn 2015).

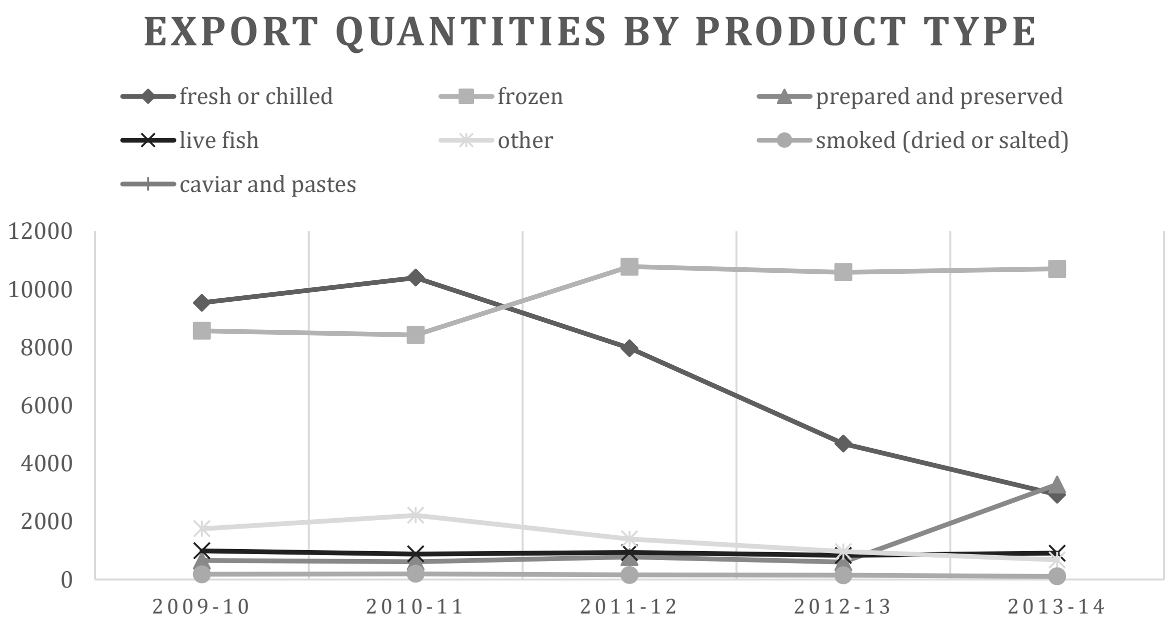


Figure 44. Volumes of fish products exported from Australia between 2009 and 2014 (Savage and Hobsbawn 2015).

Appendix 7 – Distance to market

Table 24. Distance to market from different fish landing ports

	Distance (km)		
Port	**to Adelaide**	**to Melbourne**	**to Sydney**
ADELAIDE		726	1379
ALBANY	2626	3347	3867
BANDY CREEK	2178	2944	3419
CEDUNA	775	1495	2016
EDEN	1281	562	547
ESPERANCE	2178	2898	3419
HOBART	1440	723	1596
PORT ADELAIDE	12	743	1404
PORT ALBERT	948	229	879
PORT LINCOLN	649	1370	1890
PORTLAND	543	352	1220
THEVENARD	777	1497	2018

Appendix 8 – Extension materials

Article that appeared in the FRDC's FISH magazine during March 2017. http://www.frdc.com.au/knowledge/publications/fish/Documents/Fish_March_2017_LR.pdf

MORE INFORMATION
www.frdc.com.au
Ian Knuckey, ian@fishwell.com.au
FRDC RESEARCH CODES 2015-204

WILD HARVEST 17

Ocean Jackets, Latchets and liquid fish

Raising demand for selected bycatch species or creating a protein blend are potential outcomes from research that aims to create value from fish that would otherwise be discarded

By Catherine Norwood

Just two species – Deepwater Flathead *(Platycephalus conatus)* and Bight Redfish *(Centroberyx gerrardi)* – make up the bulk of the catch for fishers in the Great Australian Bight Trawl Sector (GABTS) off the South Australian coast.

Yet over the years, fishers in the sector have identified almost 300 different species in their nets.

Small quantities of non-target species are often retained for sale; however, discards can account for a significant portion of the catch, depending on the time of year and fishing location. It is something the Great Australian Bight Fishing Industry Association is keen to change.

The association has been working with researchers from CSIRO and Ian Knuckey, of Fishwell Consulting, as part of an FRDC-funded project to identify ways to reduce discards and increase the viability of the fishery.

Ten years worth of data from vessel logbooks, onboard observer reports and independent fisheries surveys have been collated to assess the mix and catch volumes of different species, in order to identify those with market potential. "There are two species that make up to 40 per cent of the bycatch: Ocean Jacket *(Nelusetta ayraudi)* and Latchet *(Pterygotrigla polyommata)*," Ian Knuckey says. "If we can develop markets for these, we can immediately reduce discards by a substantial volume."

The project has investigated export sales of these species into Asia and potential new markets and product opportunities. Ian Knuckey says some species that are not well known or commonly eaten by Australian consumers are valued by Asian consumers.

"We need to better understand the market acceptability and obtain realistic prices for non-traditional species," he says. "We're working with skippers to send small quantities of selected bycatch species to seafood retailers in Australian and Asian markets.

"This will help test the market and gather vital data including sale price, species, volume, desired fish characteristics and seasonality."

CSIRO is using additional information on processing, packing and transportation costs to assess the economic viability of retaining these species.

Ian Knuckey says in trying to maximise economic yields in Australian fisheries, people often overlook the potential value of using all of the catch.

However, he says many Asian countries, which also target high-value species and have substantial volumes of bycatch, make greater use of bycatch through a range of processing techniques. These include curing, fermenting, hydrolysis, mincing and dehydrating lower-value seafood to produce protein-rich foods and other products.

In addition to new markets, the GABTS project has also evaluated potential processing techniques that could be adopted for either onboard or land-based processing of bycatch, particularly mincing or liquefying fish protein though hydrolysis.

These processes would allow fishers to value-add to the entire catch and effectively eliminate discards.

Use of an onboard processing plant is being investigated to hydrolyse fish protein, with the liquid potentially sold into fish feed or fertiliser markets. Ian Knuckey says while the targeted catch might sell for $4 to $5 per kilogram, hydrolysed fish protein might be 30 to 40 cents per kilogram.

"We're also looking at whether the boats can be modified to incorporate a mincer and storage for the product," he says.

Trawlers in the GABTS have enough storage capacity to process all of their bycatch. Markets and support for new products in the supply chain are more crucial issues to the success of greater resource use.

The project will include an economic analysis and modelling of the supply chain for distribution of bycatch species and alternative fish products, and is expected to be finalised later in 2017.

Left Identifying bycatch species that are worth sorting and keeping for potential new markets is part of the research underway to assist fishers in the Great Australian Bight. Photo: Fishwell Consulting

FISH MARCH 2017