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The analysis of AFMA seabird mitigation trials – 2001 to 2004

Report to Fisheries Resources Research Fund

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Abstract

The incidental catch of seabirds by pelagic longline in Australia's Eastern Tuna and Billfish longline Fishery (ETBF) is an issue of ongoing concern. Three mitigation trials (employing tori poles, gear weighting, underwater setting chutes) have been conducted over the past 5 years. None have been successful in reducing catch rates below initial 0.05/1000 hooks limit rate. This paper presents results from statistical modelling which was used to identify those factors influencing both interactions and captures of seabirds by longliners. While analyses were hindered by limitations in the available data, a number of key findings and recommendations are put forth. The use of night setting, tori poles and dead baits (during the day) significantly reduced catch rates of seabirds and offers some potential for development of management options. A number of other factors were also found to be related to seabird catch rates. Seabird catches and interactions are higher where seabird abundance is higher, suggesting that spatial restrictions on fishing might be considered to reduce the likelihood of vessels encountering high abundance times and areas. It was also clear that there is a seasonal effect, with spring being the period of highest catches and winter the lowest. A more detailed spatial/seasonal analyses of captures could offer fishery managers some spatio-temporal management options (i.e. in the form of closed time-areas). Analyses should be re-run and updated as further data becomes available.

Executive summary

The incidental catch of seabirds by pelagic longline in the Eastern Tuna and Billfish Fishery is an issue of ongoing concern

Australia's Eastern Tuna and Billfish Fishery (ETBF) is a multi-species and multi-method fishery whose longline sector targets predominantly broadbill swordfish (*Xiphias gladius*), bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*). Unfortunately, this sector has also an incidental catch of a number of seabird species, an issue which is currently of significant concern to industry, managers and environmental interests.

A Threat Abatement Plan was released in 1998 to ensure strategies were pursued to reduce seabird catches in this fishery.

In 1995, longline fishing was listed as a Key Threatening Process to seabirds under the then Endangered Species Protection Act 1992. Subsequently, a Threat Abatement Plan (TAP) to reduce seabird catches was released in 1998. This stated an aim to reduce captures to less than 0.05 birds/1000 hooks. Failure to do this in the long term may result in time area closures, which would have significant negative impact on many fishers. A package of fisheries regulations was implemented in response to the TAP, including the requirement for all Commonwealth-managed longliners operating south of 30°S to set their lines at night and to carry a bird-scaring line.

Three mitigation trials have been conducted in an unsuccessful attempt to find a strategy by which catch rates can be brought below the 0.05 target

Unfortunately, the requirement to set longlines at night, while reducing seabirds captures, is uneconomical for many operators, and has been limited in success for mitigating catches of bird species which are active at night. Three industry-initiated and funded mitigation trials have subsequently been run, trialling underwater setting chutes, tori poles and line weighting regimes during daytime operations. None of these trials have reduced overall seabird capture rate to below the target level.

The current report aims to provide information pertaining to key factors associated with reduced seabird catches to assist future trial design

This report has attempted to address three key issues relating to seabird bycatch in the ETBF, so as to provide advice to industry and decision makers that will assist in design of successful mitigation strategies. These are:

1. Provide a method by which mitigation trials can be monitored to determine when they have reached the TAP target rate of 0.05 and should be terminated

2. Identify some of the factors (biological, gear, vessel related etc) that contribute to seabird bycatch mitigation

3. Predict which combinations of these factors (and levels of factors) are likely to produce the lowest seabird bycatch rates.

Statistical models were used to assess what factors influence both interactions and captures of seabirds by longliners

The effect of different vessel, gear, environmental and seasonal factors on seabird interactions with and captures by longline gear was assessed using 4 separate models. Unfortunately, a significant number of factors which might be related to seabird catches could not be included in models due to the database being incomplete. AFMA expect a fully completed database to be available for future analyses by February 2006. Each model assessed 10 to 20 different factors for their relationship to catch rates or interactions, depending on data availability.

While seabird captures are relatively infrequent, any single fishing operation can catch numerous birds

It is apparent from the analyses of observer collected data that the capture of seabirds in the ETBF longline sector is a relatively infrequent event. Of the more than 955 fishing operations observed across 3 trials and 4 years, 136 operations (14%) captured one or more seabirds. However, nearly 60 of these operations caught between 2 and 12 birds each, while one operation caught 44 birds. In total 327 seabirds were observed caught over the period for which data was examined, at a catch rate of 0.401/1000 hooks.

The analysis determined that there were nine key factors influencing seabird catch rates

Seabird abundance (number of birds counted in vicinity of the vessel during fishing) during daytime operations was positively related to both interactions with and captures of all seabirds, and to captures of fleshfooted shearwaters (when analysed separately). In other words, captures or interactions will be more frequent if there are more birds in the vicinity of the vessel.

….Night setting and the percentage of hooks set in daylight

Data restrictions (pertaining to abundance counts) meant that day and night sets were analysed in separate models. Nominal mean seabird catch rates at night were less than one quarter the daytime level. For daytime fishing operations (any set where at least some of the hooks were set in daylight), it was determined that those sets which deployed all hooks during daylight had higher catches of seabirds than those sets where some hooks were deployed in darkness. This provides further evidence for the effectiveness of night setting as a mitigation measure.

….Trial type

Both total seabird catch and catches of fleshfooted shearwaters were significantly higher in the chute trial than in the trials using tori lines, with the single tori line trial having the lowest catch rates. In contrast, the level of seabird-gear interaction (i.e. diving behaviour) by

	seabirds did not vary between trials.
…Bait life status	During the day, the use of live baits results in higher catches of seabirds than the use of dead baits. At night, analyses suggested the opposite was true, however, night time analyses may be affected by low sample numbers.
…Season	All models indicated that interactions with or catches of seabirds by pelagic longline were significantly higher during spring than in most other seasons, with catch rates being lowest in winter. These trends relate in part to seasonal changes in distribution and abundance of some species.
…tori pole use	The use of tori lines was associated with significantly reduced catch rates for all seabirds, both for daytime and nigh-time sets, and for fleshfooted shearwaters in daytime sets, but did not appear to affect the level of interactions between seabirds and fishing gear. The potential reasons for this are discussed in Chapter 5.
…bouyline length	Catches of seabirds was higher on longline gear using longer bouylines, but only for sets conducted during the day.
…lightsticks use	Results also indicated that fewer seabirds are caught at night when lightsticks are used. There is some uncertainty around the night models as there was relatively little data suitable for the analyses.
…vessel size	Catches of seabirds at night was higher for larger vessels.
A number of factors were not related to seabird catch.	A number of other factors were considered within each of these models but not included after they were found not to explain any of the variation in interactions or catches of seabirds by longline. These factors included whether a line shooter was used or not, the location of the birds relative to the boat (e.g. above line setter, off bow etc), soak time, distance between branchlines, hooks per basket, length of branchlines, leader length, size of swivel weights and the distance between the hook and the weight.
The consideration of additional factors in model based analyses should be possible in the near future	While observers have collected data on many different factors that might affect seabird catch rates, a significant number of these could not be included in the current analyses, as data entry is still in progress. Once the observer data in fully entered into the AFMA database, it will be possible for scientists to consider many more factors that might play an important role in the capture or mitigation of capture of seabird species.

Conclusions on the current analyses will be limited until such time as the full dataset becomes available.

Catch rates under different mitigation scenarios were predicted

The models were then used to make predictions about the likely catch rates of seabirds under different scenarios (i.e. using different combinations of mitigation measures). It is intended that such scenario predictions might assist in the design of future mitigation trials and in general management decision making with regard to incidental catches of seabirds by longline.

Lack of data for key factors will likely result in underestimates of predicted catch

These analyses provided information about which combinations of factors would likely result in the lowest catch of seabirds by longline. However, because many of the fishing operations which had the highest catches of seabirds could not be included (due to missing data) in models, the scenario predictions generally underestimated seabird catches. Access to all observer data in future should allow more realistic predictions.

Key recommendations result from the analyses presented in this report

In summary a number of key issues/recommendations are highlighted by the analyses presented in this report:

1. Access to the full observer database in the near future should allow more comprehensive analyses which will offer more powerful insights into what constitutes an effective mitigation regime.

2. The analyses indicated that night setting, use of tori poles and dead baits (during the day) significantly reduced catch rates of seabirds and the use of these mitigation measures offers some potential for management options.

3. Seabird catches and interactions are higher where seabird abundance is higher, suggesting that spatial restrictions on fishing might be considered to reduce the likelihood on vessels encountering high abundance times and areas.

4. It was also clear that there is a seasonal effect, with spring being the period of highest catches and winter the lowest. The value of conducting mitigation trials in winter may be limited, and not particularly cost effective, given that few birds of any species were observed caught in the fishery. A more detailed spatial, seasonal analyses of captures could offer fishery managers some spatio-temporal management options (i.e. in the form of closed time-areas).

5. The determination of a mitigation regime that will reduce seabird bycatch rates below the target level is of critical importance to the ETBF. The current analyses have set up models and an assessment framework which can, and should, be used to analyse observer data on a more regular basis (e.g. 12 monthly).

Contents

1. Introduction

1.1 Background

This report has been produced in response to significant concerns expressed by fishery managers and fishers regarding past and current levels of seabird bycatch in Australia's Eastern Tuna and Billfish Fishery (ETBF). The ETBF is a multi-species and multi-method fishery extending from the tip of Cape York to Tasmania and the South Australia – Victoria border. The longline sector targets broadbill swordfish (*Xiphias gladius*), bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) with significant catches of striped marlin (*Tetrapturus audax*), albacore (*Thunnus alalunga*) and a number of other species also taken (Caton 2003). Incidental catches include non-fish species such as seabirds.

In 1995, longline fishing was listed as a Key Threatening Process to seabirds under the then Endangered Species Protection Act 1992 (now the Environment Protection and Biodiversity Conservation Act 1999). In response to this listing, a Threat Abatement Plan (TAP) for Reducing the Incidental Catch of Seabirds During Oceanic Longline Fishing Operations was released in 1998. A package of fisheries regulations was implemented in response to the TAP, including the requirement for all Commonwealth-managed longliners operating south of 30°S to set their lines at night and to carry a bird-scaring line.

The Eastern Tuna and Billfish Fishery (ETBF) has been unable to meet the TAP target in all areas, at all times. Furthermore, the requirement to set longlines at night, a key measure to minimise bycatch of seabirds, poses considerable operational problems for the ETBF. Although this measure has undoubtedly reduced the bycatch of threatened albatross species, it is uneconomical for these operators to fish during the night, and has proven less effective in avoiding the bycatch of flesh-footed shearwaters (relative to other species), a seabird which not only forages at night but also has excellent diving capabilities.

In recent times, the Australian Fisheries Management Authority (AFMA) facilitated a number of industry-initiated and funded trials, involving an underwater-setting chute device and various line weighting regimes, aimed at mitigating seabird bycatch in the ETBF whilst setting hooks during the day. To date, these trials have not reduced the level of seabird bycatch to the required TAP level of less than 0.05 birds/1000 hooks. In the absence of controls it has been impossible to determine what, if any, these trials (measures) have had on seabird catches.

It is intended that analyses presented in this report will assist in the provision of advice regarding both the operation and design of future mitigation trials and management measures aimed at reducing catch of seabirds in the ETBF longline sector.

1.2 Need

There is a critical need to resolve the issue of seabird bycatch in the ETBF as it is facing the possibility of a seasonal closure in the area 25-35°S because of the fishery's inability to reach the target TAP level in that area. Such a closure may invariably shut down that area of the fishery—because of another seasonal closure in place for southern bluefin tuna during the opposite time of year—unless an effective mitigation measure or strategy is found.

There has been little analysis of the data from the bycatch mitigation trials to date other than an assessment against the TAP target of less than 0.05 birds/1000 hooks. Further investigation is required to gain a better understanding about the factors that contributed to the failure of the previous trials in meeting the TAP target. For example, variations in gear deployment, fishing location and other operational methods may contribute to a vessel's likelihood of catching seabirds. It is also important to investigate if any components of these trials could potentially minimise seabird bycatch.

This project aims to assist operators in meeting their requirements under the TAP by providing them with information on the factors that contribute to seabird bycatch and potential measures to reduce this bycatch. This information can be used to assist in the development of new mitigation measures to be trialled.

The project will also indirectly contribute to Australia's international commitments to reduce seabird bycatch under the UN Food and Agriculture Organisation's International Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries, and the Agreement for the Conservation of Albatrosses and Petrels under the Convention on Migratory Species of Wild Animals.

1.3 Objectives

The overall objective is to gain an understanding of the characteristics of seabird bycatch in the trials carried out in the ETBF and the possible measures that can be adopted to reduce pelagic longline bycatch of seabirds.

Specific objectives:

1. Determine the allowable number of seabirds taken as bycatch, after which seabird mitigation trials are considered to have failed.

2. Determine the temporal, spatial and other factors that contributed to the previous trials failing to meet the TAP target and determine key factors that could contribute to mitigation

3. Provide information on the rate of seabird bycatch to assist in the development of new and ongoing trials to improve chances of success in meeting the TAP target.

This report will also briefly review relevant information pertaining to seabird species caught and past and current research into seabird bycatch mitigation.

2. Species overviews

2.1 Introduction

Seabirds are primarily surface feeders, taking their prey from the top few metres of the sea (Harper *et al.* 1985). Many species are scavenges, preying on dead fish, squid and other marine life found floating on the surface and it is this scavenging behaviour that leads to seabirds supplementing their diet by feeding on discards from vessels and stealing baited hooks (Brothers *et al.* 1999a). Birds have access to baited hooks as they descend through the water when set. The baits do not always sink immediately, often kept afloat by tension on the line and propeller turbulence (Brothers *et al.* 1999a). It is during this time that birds can attempt to take baits, become hooked and drown as the weight of the gear pulls them down. Similarly, birds can become hooked when the line is pulled out of the water (hauling), but are often released alive (Brothers *et al.* 1999a). Seabird size can influence capture rates as larger birds have large gapes and can swallow large food items including bait on longline hooks. Smaller species (e.g. terns, storm petrels and auklets) cannot swallow large food items and hence are rarely caught on longlines (Brothers *et al.* 1999a). Bird mortality can also occur when hooks remain in released birds or from hooks being ingested in discarded offal and bycatch (Brothers *et al.* 1999a).

This chapter presents a review of key information pertaining to the biology, movements and behaviours of seabirds caught in Australia's Eastern Tuna and Billfish Fishery. The majority of the following information was taken from Marchant and Higgins (1990) and references therein, unless stated otherwise.

2.2 Family *Diomedeidae* (Albatrosses)

The Wandering Albatross *(Diomedea exulans)* is distributed throughout Antarctic, subantarctic and subtropical waters of the Atlantic, Pacific and Indian Ocean. It breeds on subantarctic islands including South Georgia, Gough, Prince Edward, Crozet, Kerguelen, Antipodes, Auckland and Macquarie Islands. The Wandering Albatross are biennial breeders, producing one egg every two years. Their diet consists of mostly cephalopods and fish and they have been known to follow ships and scavenge behind fishing vessels. Main foraging behaviour exhibited by the Wandering Albatross is surface-seizing however they can dive to approximately one metre below the surface. The Wandering Albatross are the most aggressive seabird species attending fishing vessels, relying on proficient diving species to retrieve baits from longlines, then chasing these birds away and taking the baits for themselves. Consequently, Wandering Albatross are highly susceptible to being caught on longlines, particularly when large numbers of other seabird species are present.

The Black-browed Albatross *(Diomedea melanophris)* is circum-polar in its distribution, widely distributed in southern oceans around South America, New Zealand, Australia, South Africa and Antarctica. The Black-browed Albatross inhabits Antarctic, subantarctic and subtropical water and is the most abundant southern albatross species. Breeding locations include islands off Australia and New Zealand including Macquarie, Heard, MacDonald, Antipodes, Snares, Campbell, Crozet, Kerguelen, Falklands and South Georgia Islands. Black-browed Albatross are annual breeders, laying one egg during the breeding season from September to December. Like many albatross species, both parents incubate the egg and rear the chick. They forage by surface-seizing while swimming or landing on top of their prey and will occasionally submerge their head or body to capture prey underwater. The Black-browed Albatross often forage in flocks and are notable ship followers, feeding on fish, crustaceans, cephalopods, krill and offal. They spend the majority of their time at sea and are the most frequently killed seabird species in some southern areas.

Like the Black-browed Albatross, the Shy Albatross *(Thalassarche cauta)* has a circum-polar distribution and is found in southern oceans around South America, New Zealand, Australia and South Africa, inhabiting subantarctic and subtropical waters. The breeding season extends from August to December and breeding occurs on islands off Australia and New Zealand including Albatross, Auckland, Bounty and Snares Islands. Foraging behaviours exhibited by the Shy Albatross include surface-seizing while swimming or landing on top of prey, shallow diving below the surface and scavenging behind vessels. Diet is comprised of fish, crustaceans, squid and offal. Shy Albatross spend the majority of their time at sea and may forage at night.

Grey-headed Albatross *(Thalassarche chrystoma)* are distributed throughout the Southern Ocean in subantarctic and Antarctic waters during summer, while in winter, their distribution extend into subtropical waters. They are biennial breeders, producing one egg every two years and breeding on a number of islands including South Georgia, Prince Edward, Kerguelen, Crozet, Macquarie and Campbell. The Grey-headed Albatross feeds nocturnally, as well as during the day, on fish, cephalopods, carrion and krill in high latitudes. They are surface feeders and can plunge dive to a depth of 15 metres.

The Indian Yellow-nosed Albatross *(Thalassarche carteri)* is found in South African, Australian and New Zealand waters, often visiting the continental shelves off southern Africa and Western Australia. Breeding is restricted to the southern Indian Ocean and locations include Prince Edward, Amsterdam, St Paul, Crozet and Kerguelen Islands. Indian Yellow-nosed Albatross are annual breeders, producing one egg each year during the breeding season from September to April. They forage by day and night, feeding on cephalopods and fish which they take from the surface. The Indian Yellow-nosed Albatross is also able to make shallow plunges after prey and often feeds on discards from fishing vessels (Cooper and Ryan 2002).

The Atlantic Yellow-nosed Albatross *(Thalassarche chlororhychos)* exhibits the same diet and foraging behaviour as the Indian Yellow-nosed Albatross. This species is distributed across the south Atlantic, southern Indian and Australasian waters and is common along South American and southern African continental shelves. Breeding locations include islands of southern Indian and Atlantic Oceans such as Tristan da Cunha, Gough, Prince Edward, Crozet, Kerguelen, Amsterdam and St Paul. The breeding season is from August to March with a single egg laid and attended to by both sexes (Cooper and Ryan 2002).

The Sooty Albatross *(Phoebetria fusca)* is found throughout the South Atlantic and southern India Oceans off the coasts of South America, South Africa and Australia. Sooty Albatross have not been recorded in the Pacific Ocean between Australia and South America. Breeding occurs between July and early September on small, isolated subantarctic islands including Prince Edward, Crozet, Amsterdam, Kerguelen, St Paul, Gough and Tristan da Cunha Islands. The Sooty Albatross is solitary when at sea and breeding pairs bond for life with both parents incubating and rearing the chick. They feed on fish, cephalopods, krill and carrion, taking their prey from the surface and also making shallow dives. Sooty Albatross may also forage at night in flocks and are known to follow ships and fishing vessels.

The Light-mantled Sooty Albatross *(Phoebetria palpebrate)* are distributed throughout Antarctica during summer and extends to subantarctic and subtropical waters during winter. They are biennial breeders, breeding between October and May on South Georgia, Marion, Prince Edward, Heard, Macquarie, Auckland, Campbell, Antipodes, Crozet and Kerguelen

Islands. The Light-mantled Sooty Albatross forages by surface-seizing, surface-diving and plunging, feeding mostly on cephalopods and crustaceans, but also taking fish and carrion such as seabird and seal remains.

The Southern Royal Albatross *(Diomedea epomophora)* is distributed throughout subantarctic and subtropical waters, and is occasionally found in Antarctic waters. They are most commonly found in New Zealand and South American waters. Breeding locations include Campbell, Auckland and Chatham Islands and Taiaroa Head, New Zealand with the breeding season beginning in October and extending to February. Like most albatross species, incubation and feeding of the chick is shared by both parents who form life-long monogamous bonds. The diet of the Southern Royal Albatross consists of mostly cephalopods, some fish, crustaceans and salps and is taken by surface-seizing.

The distribution of the Campbell Island Albatross *(Thalassarche impavida)* is confined to southern Australian waters, Tasman Sea and South Pacific Ocean. This species of albatross breeds only on the northern and western coastlines of Campbell Island and the tiny islet of Jeanette Marie off New Zealand. It feeds on fish, cephalopods, crustaceans and carrion (Birdlife International 2005).

The Chatham Albatross *(Thalassarche eremite)* is dispersed within the South Pacific Ocean from Tasmania, east to Chile and Peru. During the non-breeding season, birds migrate to the south-west coast of South America and then travel northwards into the coastal waters of Peru. The Chatham Albatross breeds only on The Pyramid – a large rock stack in the Chatham Islands of New Zealand. The breeding season is from August to March. This species of albatross feeds on cephalopods and fish (Birdlife International 2005).

2.3 Family *Procellariidae* (Petrels and shearwaters)

The White-chinned Petrel *(Procellaria aequinoctialis)* is widespread in the Southern Ocean inhabiting subantarctic, Antarctic and subtropical waters. White-chinned Petrels are highly dispersed during summer and most populations move to continental shelf waters off Australia, New Zealand, Africa and South America during winter. Breeding locations include South Georgia, Prince Edward, Crozet, Kerguelen, Antipodes, Auckland and Campbell Islands with the breeding season broadly between September and May. The diet varies between breeding and non-breeding birds. Breeding birds feed mainly on cephalopods with some crustaceans and few fish compared to non-breeding birds with a diet comprised of fish and offal with few crustaceans and some cephalopods when available. White-chinned petrels forage mainly at night by surface-seizing or surface-diving, occasionally pursuit-plunging.

The Northern Giant Petrel *(Macronectes halli)* is found throughout the Southern Ocean, mainly in subantarctic waters but is often found in Antarctic waters in the south-western Indian Ocean. Breeding occurs between August and February on a number of islands including South Georgia, Prince Edward, Crozet, Kerguelen, Macquarie, Antipodes, Auckland, Chatham and Campbell. Both sexes incubate and feed the chick, however males undertake a larger part of the incubation and guarding duties. Adults usually stay near breeding colonies throughout the year, but immature birds may undertake long journeys. There are marked differences in the diets between males and females with males scavenging on carcasses of penguins and seals while females prefer to take live prey at sea. Generally the Northern Giant Petrel’s diet consists of penguins, crustaceans, fish, cephalopods and mammals. Northern Giant Petrels are active predators, feeding at sea and on land. Prey is taken by surface-seizing, shallow diving, pursuit-plunging and scavenging with females feeding more at sea than males.

The Southern Giant Petrel *(Macronectes giganteus)* is also found throughout the Southern Ocean, mostly in Antarctic waters during summer. They are partially migratory, with immature birds and some adults dispersing widely and possibly circumnavigating Antarctica. Breeding occurs on the Antarctic continent and islands including South Georgia, Gough, Prince Edward, Crozet, Kerguelen, Heard and Macquarie. The breeding season varies between localities but generally extends between July and April. Southern Giant Petrels scavenge primarily on penguin carcasses but also feed on cephalopods, fish, crustaceans and seal carcasses. Like the Northern Giant Petrel, Southern Giant Petrels are active predators, feeding both on land and at sea and taking their prey by surface-seizing, shallow-diving and scavenging.

The Grey Petrel *(Procellaria cinera)* is distributed throughout much of the Southern Ocean, mainly in subantarctic waters. They are dispersive, possibly migratory birds, extending into subtropical waters during winter. The Grey Petrel breeds on cool-temperate, subantarctic islands including Tristan da Cunha, Gough, Prince Edward, Crozet, Kerguelen, Amsterdam, Macquarie, Antipodes and Campbell Islands. The breeding season extends from February to September. The Grey Petrel’s diet consists primarily of fish, cephalopods and crustaceans. Foraging behaviour consists of surface-seizing and some pursuit-diving. They are also known to scavenge behind fishing vessels.

Great-winged Petrels *(Pterodoma macroptera)* are found in subtropical and subantarctic islands throughout the mid South Atlantic, southern Indian and south-west Pacific Oceans as well as the Tasman Sea. The distribution extends farther north in winter. Great-winged Petrels are seen near breeding locations throughout the year which include Prince Edward, Kerguelen and Crozet Islands, as well as a number of islands off Australia and New Zealand. The breeding season is from late January to November with both sexes incubating and feeding the chick. They form sustained or long term monogamous bonds with their mate. The Great-winged Petrels diet comprises of mostly cephalopods, with some fish and crustaceans, taken by surface-seizing and dipping. These petrels are usually solitary when at sea.

The Flesh-footed Shearwater *(Puffinus carneipes)* is widely distributed across the southern Indian Ocean and south-west Pacific Oceans, particularly during the breeding season. During the non-breeding season, New Zealand and Tasman Sea populations migrate to the east coast of Korea while populations from south-western Australia move to the northern Indian Ocean. Flesh-footed Shearwaters breed on islands within the Australasian region and Indian Ocean, for example Lord Howe Island. The breeding season extends from September to May, with both parents incubating the egg and rearing the chick. The Flesh-footed Shearwater feeds primarily on fish and cephalopods and takes its prey by surface-seizing, surface-plunging and pursuit-diving to a depth of four metres. They usually feed during the day but have been recorded taking live prey under the light of fishing vessels at night.

The Short-tailed Shearwater *(Puffinus tenuirostris)* is distributed throughout the Pacific Ocean, and is a trans-equatorial migrant, undertaking extensive movement throughout the Pacific and moving to the northern hemisphere during the non-breeding season. Breeding occurs between September and April on islands located off south-eastern Australia. Both sexes incubate the egg and birds remain with the same breeding partner for life. The diet of the Short-tailed Shearwater consists of krill, cephalopods and fish. Foraging behaviour exhibited by this species includes surface-diving and pursuit-plunging with some surface-seizing, deep-plunging, pursuit-diving and scavenging.

The Wedge-tailed Shearwater *(Puffinus pacificus)* is found in tropical and subtropical waters within the Pacific and Indian Oceans. Populations at the northern and southern extremities of the distribution may migrate, while the tropical populations stay near breeding colonies. The species breeds throughout its distribution including the Hawaiian Islands, Lord Howe and Norfolk Islands, eastern Australia, islands off Western Australia, and countries such as Vanuatu, Samoa and New Caledonia among others. The breeding season ranges from August to April, with both parents incubating and feeding the chick. These birds also form life-long monogamous bonds. The Wedge-tailed Shearwater feeds mostly on fish, with some cephalopods, insects and jellyfish. The species forages by dipping and surface-seizing its prey, rarely deep plunging.

Sooty Shearwaters *(Puffinus griseus)* are found in subtropical, subantarctic and Antarctic waters of the Southern, Pacific and Atlantic Oceans. They are trans-equatorial migrants, moving to the north Pacific and Atlantic oceans during the non-breeding season. Breeding colonies can be found on subtropical and subantarctic islands within the Australasian region and mainland New Zealand between September and April. The diet is comprised of cephalopods, fish and crustaceans which are taken by pursuit-plunging, pursuit-diving and surface-diving. Sooty Shearwaters may also forage by shallow-plunging and surface-seizing.

2.4 Family *Sulidae* (Gannets and boobies)

The Australian Gannet *(Morus serrator)* is found along the southern and south-eastern coasts of Australia to New Zealand. Breeding takes place on islands off southern Australia and the north island of New Zealand between October and March. The Australian Gannet feeds on fish, taken by diving into the water (Australian Museum).

2.5 Family *Laridae* (Skuas, jaegers, gulls and terns)

The Subantarctic Skua *(Catharacta Antarctica)* is widely distributed throughout the Southern Ocean and breeds on most subantarctic and southern cool-temperate islands as well as the Antarctic continent during the summer months. The skua feeds on land and at sea, scavenging on eggs, chicks and carrion as well as eating crustaceans, molluscs and small mammals. Foraging behaviour includes surface-seizing at sea, scavenging and kleptoparasitism on live prey (Australian Antarctic Division).

3. Review of mitigation research in longline fisheries

3.1 Introduction

The following chapter provides a brief review of past research into mitigation methods used to reduce seabird bycatch in longline fisheries. This will serve to place ETBF research in context and allow for comparison with research undertaken previously in this fishery and also elsewhere around the world.

3.2 Longline fishing

Longline fishing is one of the world's major methods of catching fish. Longline vessels range in size and operation from small-scale artisanal fishing boats operating in coastal waters to large, modern and mechanized fleets fishing the high seas. Excluding the issue of seabird mortality, longline fishing is considered an environmentally friendly method of fishing as it has no destructive effects on bottom habitats (Brothers *et al.* 1999a). Longlining can be pelagic (lines are suspended from floats on the surface), demersal (lines are placed on the seabed) or semipelagic (lines are floated off the seabed).

Longline gear generally consists of four parts, the mainline (also referred to as the groundline), branchlines (also called snoods or gangions), hooks and baits. The mainline can measure up to 60nm in length but is typically between 20 – 35nm in the ETBF. It is suspended from the surface by buoy lines attached to floats. Branchlines, each with a single baited hook, are attached along each section of mainline suspended between the floats. Mainlines and branchlines are commonly made from nylon and polyester with both monofilament and multifilament lines used. Monofilament lines are preferred for pelagic and semipelagic longlining. The type of gear used, particularly the length of the monofilament mainline, buoy lines and branchlines, as well as the type of bait and hook used and the use of weights, swivels and wire traces can all vary depending on the species being targeted. The three main types of hooks used in the ETBF are Circle, J and tuna hooks, each being available in a range of sizes.

Longlines can be baited manually or with a baiting machine and are usually deployed from the stern of the vessel. The depth of the mainline can be varied by changing the speed of the hydraulic feeder and the vessel speed. The depth at which the mainline is set will depend on the species to be targeted. The constant rate at which the branchlines and buoy lines are attached is maintained with the use of a timer which sends a signal across a loudspeaker, indicating attachment of a line (generally every 5.5 – 6 seconds). A different signal is used to signify the attachment of a buoy line. The number of branchlines attached between each buoy is constant (usually between 5 and 7) and an accurate record is kept of the number of buoys deployed. Radio buoys are attached to the line every 35-40 buoys, and are used to locate the line at the start of hauling. Each buoy has a unique Morse signal and can be located using a radio detection finder. During hauling, the mainline is threaded over roller guides and through the hydraulic mainline feeder with the speed of recovery controlled by a crew member. The mainline coils from the hauler onto a conveyer belt which carries it across deck of the vessel. The vessel slows and often turns to starboard to allow the fish to be brought alongside the vessel where it is landed using a gaff or a harpoon. Very large fish are winched aboard after being secured with a noose, grappling tongs or a large gaff. Bycatch species and bait are removed from the hooks while the line is being coiled or after being brought aboard (Baron 1996).

3.3 Mitigation measures

Brothers *et al.* (1999) define a seabird mitigation measure as “a modification to fishing practices and/or equipment that reduces the likelihood of seabird incidental catch”. To encourage the use of mitigation measures, they must be economically and operationally neutral or advantageous to the fishers. Specifically, fishers will be willing to adopt mitigation measures to reduce the amount of bait loss to birds, subsequently reducing seabird catch rates, if the measures do not have a negative impact on catch rates. It is possible of course that fishery managers may impose mitigation measures regardless of whether they are advantageous to the fishers target catch rates or not.

Strategies used to reduce the incidental capture of seabirds can be divided into four categories: reducing the visibility of baited hooks to birds, preventing the birds from accessing the hooks, reducing the likelihood of a bird being killed if it does access a hook and discouraging birds from following longline vessels (Brothers *et al.* 1999).

3.4 Night setting

Although often unpopular with fishers, setting longlines at night can be a simple and effective technique, reducing seabird catch rates between 60-96% (Murray *et al*,. 1993; Klaer & Polacheck, 1995; Cherel *et al.*, 1996; Gales *et al.*, 1998). McNamara *et al.* (1999) reviewed night setting as a mitigation technique and found that mortalities per unit effort (MPUE) during night setting were much lower than during daylight portions of sets. Likewise, Brothers *et al.* (1999b) found an 85% reduction in seabird catch when lines were set at night.

The effectiveness of the technique however, varies between fisheries and seasonally within a fishery as some birds (e.g. White-chinned Petrels) are more active at night compared to other species. Night setting has been shown to be less effective during full moons (Brothers *et al.* 1999b) and at higher latitudes when hours of darkness are reduced. McNamara *et al.* (1999) also observed albatrosses landing close to the bright, buoyant chemical light sticks attached to branchlines on longlines targeting swordfish and noted the importance of reducing a vessel's aft-facing deck lighting in order to reduce the visibility of baited hooks at night. Weather and sea conditions do not appear to influence the effectiveness of this mitigation method (McNamara *et al.* 1999).

There is little information available on the effect of night setting on target species. Despite this, many fishers have used night setting successfully to catch target species and avoid incidental capture of seabirds (Brothers *et al.* 1999a). McNamara *et al.* (1999) found that night setting may reduce CPUE when targeting swordfish if sets do not begin before dark.

3.4 Underwater setting

A number of underwater setting devices have been designed and developed (chutes, funnels, capsules) to set baited hooks underwater, out of sight and beyond the diving range of most seabirds.

The underwater setting funnel is an attachment to the vessel's stern for use in single-line demersal longline fisheries. The funnel delivers baits 1 – 2m below the surface in calm seas (Brothers *et al.*, 1999; Melvin, 2000; Ryan and Watkins, 2002) which unfortunately is within the diving range of some seabird species. Melvin (2000) found setting baited hooks with the tube reduced seabird bycatch by 79%, similar to that achieved by adding weight to longlines while Ryan and Watkins (2002) found that bycatch rate was three times lower when using the funnel by both day and night.

Although the funnel successfully delivers bait below the surface, Melvin (2000) found that the line returned to the surface approximately 40-60m astern of the vessel. It was also noted that the line often jumped out of the setting tube. When this occurs, the line cannot be returned to the tube, subsequently rendering the mitigation measure useless for the remainder of the set. Although this happened rarely (~10% of sets) Melvin noted that in order to be effective, an experienced crew is required to operate the setting funnel.

The underwater setting chute is similar to the underwater setting funnel but can be applied to both demersal and pelagic longline fishing operations. Several studies have examined the effectiveness of the underwater setting chute and have found that setting longlines with the underwater chute has the potential to significantly reduce seabird bycatch (Gilman *et al.*, 2002; Brothers *et al.* 2000; O'Toole & Molloy, 2000). In fact, one study found that setting with the chute reduced seabird contacts with baited hooks by 95% compared to a control (Gilman *et al.* 2002). The same study found that the mean sink rate of baited hooks set through the chute were faster than those set under the control treatment, but the difference was not statistically significant. Similarly, the difference between the average depth of setting between the two treatments was also not significant. In contrast, O'Toole and Molloy (2000) found a significant difference in the mean depth between the two methods at 100m stern of the vessel. The mean depth at which TDRs attached to branchlines left the chute was 6.5m (range 2.5 – 10m), which is outside the maximum diving range of a number of seabird species. Bait retention was 90.1% when set with the chute compared to 69.5% when set under the control (Gilman *et al.*, 2002). This mitigation method could potentially have a positive effect on CPUE due to minimised bait loss.

Unlike the previous underwater setting methods, the underwater setting capsule is an active system, delivering baited hooks to a predetermined depth within a retrievable capsule (Smith and Bentley 1997). This method is suitable only for pelagic operations.

Evaluations of the underwater setting capsule to date have demonstrated the method's ability to reduce the incidental bycatch of seabirds (Brothers *et al.* 2000; Brothers & Molloy, 2001). During performance testing of the capsule, baits were delivered to a depth of 8m in ~2 seconds while it took 6 seconds to complete a full cycle (Brothers and Molloy 2001). Brothers *et al.* found that setting depth varied with the length of line attached to the capsule. During performance testing of the capsule by Brothers and Molloy (2001), there was no evidence that seabirds were capable of interacting with the baits set by the capsule and observations of bird behaviour suggested that seabirds were not aware of the baits being set and therefore lost interest in following the vessel. Brothers and Molloy (2001) observed no tangling or fouling in the mainline when setting baited hooks with the capsule and suggested that use of the capsule may assist in obtaining better line performance. Similarly, all baits set with the capsule were returned, suggesting that setting with the capsule will provide optimal fishing effort. Bait setting time was slightly slower than normal setting on the study vessel but this was partly due to the crew being unfamiliar with the use of the capsule (Brothers and Molloy 2001).Further development and assessment of the underwater setting capsule is required, particularly the reliability and effectiveness of the capsule should be investigated over time and in varying sea conditions.

3.5 Line weighting

The sink rate of a baited hook and the amount of time that it remains available to foraging seabirds will determine the likelihood of it being taken. Adding weight to longline gear aims to increase the sink rate of baited hooks, thereby reducing the amount of time it is available (either on the surface or within diving range) to seabirds. Numerous studies have shown that the addition of weight to either the mainline or branchlines increases the sink rate of baited hooks thereby reducing the availability of the hooks to seabirds (Melvin, 2000; Molloy *et al.*, 2000; Robertson, 2000; Brothers *et al.* 2001; Anderson and McArdle, 2002). A number of factors that may influence the sink rate of baited hooks have been suggested and include line hook-ups, weight pull-backs, propeller wash, weather, bait thaw, bait size, variability in the tension of the backbone, setting speed of the vessel, swell height and the amount of weight added to the line (Blackwell *et al.*, 2000; Robertson 2000; Brothers *et al.*, 2001). Seabird bycatch may be further reduced by using an appropriate line weighting regime in conjunction with a bird scaring line (Melvin, 2000; Robertson 2000; Brothers *et al.* 2001). Some fishers have suggested that target species CPUE may be affected as line weighting alters the line setting characteristics, however, this has yet to be proven (Brothers *et al.* 2001) in fact, Melvin (2000) found that weighted gear had no effect on the target catch in the Alaskan sablefish and Pacific Cod fisheries. Line weighting might have the potential to increase CPUE by reducing bait loss to birds.

3.6 Bait condition

There are two bait conditions that can affect the sink rate of the bait and therefore, the availability of the bait to seabirds. Firstly, frozen bait will sink more slowly than partially or fully thawed bait and secondly, air in the swim bladder of a fish will affect its ability to sink (Brothers *et al.* 1995). Brothers *et al.* (1999b) found that the use of thawed baits lowered seabird mortality in summer with 0.27 birds/1000 hooks caught using well thawed bait compared to 1.13 birds/1000 hooks captured when using frozen bait. Similarly, Klaer and Polacheck (1998) found that the level of bait thawing was significant in determining seabird catch rate during the day in summer. The effect of bait condition on CPUE of target species has not yet been examined. Differences between seabird catch rates on live or dead baits has also not yet been tested.

3.7 Bird scaring lines (BSL)

Brothers *et al.* (1999a) describe a bird scaring line (often referred to as a tori pole) as “any device that when deployed astern during line setting deters birds from taking baited hooks”. Bird scaring lines consist of a line (backbone) with suspended streamers attached to a pole on the vessel’s stern. The higher the line is mounted on the pole, the greater the distance of bait protection.

Studies have shown bird scaring lines can reduce seabird catch rates by 30-70% in pelagic tuna longline fisheries (Brothers 1991, Klaer and Polacheck 1995). Melvin (2000) found that paired streamer lines successfully reduced seabird catch rates by 88-100% compared to single streamer lines which reduced catch rates between 71-96%. The difference between paired and single streamer lines was not significant however; behavioural evidence suggested that single streamer lines allowed significantly more bait attacks than paired streamer lines in the US demersal sablefish fishery (Melvin 2000).

The characteristics of a bird scaring line will have some influence on the effectiveness of the line as a seabird bycatch mitigation measure and it is more difficult for a bird scaring line to be as effective in pelagic longline fisheries compared to demersal (Brothers *et al.* 1999). Keith (2000) evaluated a number of different tori designs and recommends tori lines be constructed using white nylon monofilament as the backbone, as white is the most visible colour in lowlight conditions, and the monofilament reduces the chances of the line being caught or entangled with stray hooks or floats. Keith (2000) also noted that the minimum height of attachment of 4.5m (set out under NZ legislation) provides an aerial coverage of around 35m. Based on the information collected by New Zealand fishery observers from 1992 on tori line specifications, Murray *et al.* (1993) suggest that tori lines be constructed of kuralon, measure 150m in length with seven pairs of streamers attached by swivels (each streamer to be long enough to reach the water) and the line must be rigged so that it is above the baits when thrown.

A number of other factors may also influence the effectiveness of bird scaring lines, particularly the sink rate of the longline gear. For example, Smith (2001) found that some sections of longline had not reached a depth of 5m or more by the end of the aerial section of the tori line (this is within the diving range of some seabird species) and suggested this may be due to propeller wash, turbulence or vessel movement caused by swell. Melvin (2000) hypothesized that the combination of weighted longline gear and paired streamer lines would result in seabird catch rates close to zero. Keith (2000) also noted that variation in sink rates may be attributed to weather effects and bait casting performance. Weather conditions, particularly wind speed and direction will influence the effectiveness of a bird scaring line

(Brothers *et al.* 1999a) as will the vessel's setting speed which affects the drag on the in-water section of the line and determines the length of the aerial section (Keith 1999).

3.8 Bait casting machine (BCM)

Bait casting machines are used in pelagic longline fisheries to throw baits clear of propeller wash and to ensure baits fall under the protection of a bird scaring line. Brothers (1993) indicated that bait loss to seabirds can be reduced by half with the use of a BCM, however the influence of bait condition on the results of this study are uncertain. In addition, bait loss rates may not relate directly to bird catch rates.

Results of the effectiveness of BCM to reduce seabird catch rates are mixed (Duckworth, 1995; Klaer & Polacheck 1995; Brothers *et al.* 1999b). Both Duckworth (1995) and Klaer and Polacheck (1995) found BCM to be an effective mitigation measure however Brothers *et al.* (1999) found the evidence for a reduction in bird catch rates with BCM unclear and noted that care and thought is needed if this method is to be used effectively.

Using a BCM has the potential to increase catch rates of target species as well as bycatch fish as more baits are kept on the hooks (Brothers *et al.* 1999a). No studies have examined the effect of BCM on CPUE.

3.9 Offal and bycatch discharge

While discharging offal and bycatch species can distract some seabirds from baited hooks during line setting and hauling (Cherel *et al.* 1995; McNamara *et al.* 1999), it can also have a "chumming effect", attracting seabirds to the area where baits are either sinking or being hauled and increasing seabird interactions with the gear (McNamara *et al.* 1999; Melvin, 2000). McNamara *et al.* (1999) tested the effectiveness of both no offal discards, with the intention that by not feeding seabirds while hooks are in the water, they will lose interest in following the vessel (Brothers 1995) and strategic offal discards to distract birds away from baited hooks. The data collected showed that seabird interactions and attempts to take bait significantly increased when no offal was discarded while strategic offal discards did reduce the number of seabird interactions with the vessel. A condition of the license to fish in the Antarctic Toothfish Fishery in the Ross Sea is that no offal is to be discharged and all waste must be frozen or turned into fish meal (NZ Ministry of Foreign Affairs and Trade). Interestingly, no seabirds have been caught in this area under these permit conditions (Robertson *et al.* 2003).

Discarding offal and bycatch species at any time may attract fish to the vessel and fishing gear and reduce bait loss to birds, subsequently increasing CPUE (McNamara *et al.* 1999).

3.10 Other mitigation measures

There are a suite of other mitigation measures that have been suggested as a means of reducing the incidental capture of seabirds in longline fisheries.

The Mustad line shooter, designed to prevent tension in the mainline and allow faster sinking rates of baited hooks, was tested by Melvin (2000) and found to significantly increase the rate of seabird bycatch. Melvin (2000) suggested that setting the line slack may set the baits into turbulence behind the vessel, keeping them closer to the surface and available to birds.

Brothers *et al.* (1999b) examined the effectiveness of a commercially available magnetic deterrent and found that it did not significantly affect the catch rate of seabirds. The device was also tested near a Shy Albatross breeding colony and there were no apparent effects on the bird's behaviour. In the same study, Brothers *et al.* (1999b) found that certain types of mainline affected seabird mortality, with highest catch rates observed on nylon monofilament lines. Seabird mortality was also found to be lower when the longline was set in a straight line, compared to a zigzag pattern (Brothers *et al.* 1999b).

Smith (2001) suggests that the colour of snoods, lines and baits may be altered so that they are less obvious to birds. Similarly, the use of blue-dyed bait has been shown to reduce seabird contacts with baited hooks (Anon*; McNamara *et al.* 1999). Artificial baits and synthetic lures have been suggested as a potential mitigation method and could be developed to be more effective and less expensive than natural baits. To date there are no records of birds being caught on synthetic lures in longline fisheries (Brothers *et al.* 1999a). Anecdotal reports suggest that seabird bycatch is reduced when live baits are used, as the hooks descend rapidly due to the fish swimming down, however no formal assessments of the effectiveness of live bait have been undertaken. Hook size and design, water cannons, acoustic and smoke deterrents have also been mentioned as possible mitigation measures (Brothers *et al.* 1999a).

4. Assessment of total allowable incidental catch numbers

4.1 Introduction

The objective of the 1998 Threat Abatement Plan (TAP) is to reduce seabird bycatch to below 0.05 seabirds per thousand hooks. A number of TAP mitigation trials have been conducted to date but none have achieved nominal rates below the 0.05 level. As such it has been recognised that a method is required by which trial results can be assessed during trial progression to determine if the trial is likely to achieve a catch level lower than the 0.05 rate. This would allow an unsuccessful trial to be terminated early (hence saving time and resources and allowing consideration of other trial designs).

In mitigation trials carried out by AFMA the number of hooks to be observed is usually specified. This chapter presents a method by which one can determine the number of seabirds caught in a trial (of given size, or observed hook number) that ensures that the rate remains below the 0.05 seabirds per thousand hooks. To ensure that the values provided can be used in future trials of varying sizes, the calculations have been conducted for a range of hook numbers (total hooks set). However, it is critical that the objective of each individual trial is considered in conjunction with the methodology employed.

4.2 Methods

In determining the catch rates beyond which a trial should be terminated, it is important that some variation be taken into account (i.e. confidence intervals calculated) rather than simply ending a trial once the number of captures exceeds 0.05 x Total hooks set. The reason for this is that we would expect that if the trial was replicated a number of times, this number of captures (0.05 x Total hooks set) would be reached at differing stages throughout the trials (and in some trials, not reached at all) due to the large number of factors affecting seabird bycatch.

As there is little empirical data available to provide a detailed understanding of the distribution of bycatch, the calculations that follow are based on the assumption of the poisson distribution. The poisson distribution assumes that the rate of catch and the variance of that catch are equivalent. Using this assumption, the 95% confidence intervals for seabird bycatch were calculated for a base case scenario assuming there was equal chance of catching seabirds across each shot and vessel in the trial. An alternative scenario was also investigated in an attempt to provide an indication on the effect on the confidence interval bounds when catch rates vary across shots and vessels.

Base case scenario

This scenario assumes that each hook has an equal chance of catching a seabird across each shot and vessel; i.e. that the distribution of seabird bycatch is poisson with rate parameter (and hence mean and variance) of 0.05 seabirds/1000 hooks. The poisson probability distribution was chosen as it usually provides a good model for the probability distribution of the number Y of rare events that occur in time, where the rate parameter is the average value of Y (Wackerly *et al.*19896).

The confidence intervals were calculated using: $\lambda \pm z_{\alpha/2}\sigma/\sqrt{N}$

Where λ is the TAP rate i.e. 0.05

$Z_{\alpha/2}$ is the approximation to the standard normal distribution at the significance level i.e 1.96

σ is the standard deviation of the assumed poisson distribution i.e.

N is the total number of shots i.e. number of boats x shots/boat (assuming 1000 hooks/shot)

Alternative scenario

It can be expected that the bycatch of seabirds will vary across vessels and shots. To incorporate the uncertainty associated with a variable population, a simple scenario was considered where the overall rate of 0.05 seabirds/1000 hooks was maintained. However, it was assumed that the number of vessels that catch seabirds is binomially distributed with a mean of 50% and that the distribution of seabird bycatch for those vessels that do catch some seabirds is poisson with mean and variance of 0.1 seabirds/1000 hooks i.e. half the vessels catch 0 seabirds and half 0.1/1000 hooks. Note that a range of other scenarios could also have been considered, each changing the uncertainty associated with the distribution of bycatch.

The variance term used in the calculation of the confidence intervals was calculated by

$$\mathrm{Var}(Y) = E[\mathrm{Var}(Y|X)] + \mathrm{Var}[E(Y|X)]$$

where Y is the number of seabirds caught across all shots
X is an indicator for the type (either catches seabirds or does not catch seabirds) of vessel
k is the number of shots
n is the number of vessels

Thus $\mathrm{Var}(Y) = (0.1)^2\, k^2\, n(0.5)^2 + 0.1k\ 0.5n$

where $E(Y|X) = 0.1kX$
$\mathrm{Var}[E(Y|X)] = (0.1)^2\, k^2\, n(0.5)^2$

$$\mathrm{Var}(Y|X) = 0.1kX$$
$$E[\mathrm{Var}(Y|X)] = 0.1k\ 0.5n$$

4.3 Results

The 95% confidence intervals for seabird bycatch were calculated for a base case scenario assuming there was equal chance of catching seabirds across each shot and vessel are presented in Table 1.1. An alternative scenario attempted to account for variation in catch rates across 10 vessels using 1000 hooks per shots (Table 1.2). Assuming 700,000 hooks are to be used, then under the base case scenario, the lower and upper 95% confidence bounds are 23 and 47 respectively, and under the alternative scenario, the lower and upper bounds are 10 and 60.

4.4 Discussion

Previous seabird mitigation trials used 350 000 hooks and the 95% confidence interval was 9 to 26 seabirds (Table 1,1). This confidence interval is interpreted as “if more than 9 and less than 26 seabirds are taken as bycatch, then one would not reject that the bycatch rate of seabirds is 0.05 per thousand hooks, at the 95% confidence level” (Wackerly et al.).

This implies that at the end of the trial, if less birds than the lower bound (9) are caught, then there is a 2.5% probability that the bycatch rate was 0.05 per thousand or more. If the upper bound (26) is used, then at the end of the trial there is a 97.5% probability that the bycatch rate of seabirds is more than 0.05 seabirds per thousand hooks.

If 700,000 hooks are to be used, then under the base case scenario, the lower and upper 95% confidence bounds become 23 and 47 respectively, and under scenario 2, the lower and upper bounds become 10 and 60 and their interpretation is exactly the same as that outlined above.

As the TAP states that the catch rate should remain *below* 0.05 seabirds per thousand hooks, a trial should be terminated once the lower confidence interval has been reached. It should be noted that the lower bounds calculated using the base case scenario are the least conservative in terms of seabird capture as all other cases will increase the confidence bounds as a result of increased variation. It should be noted that the actual variation associated with seabird captures could be incorporated in the calculation of the confidence intervals if adequate data were available.

Table 4.1. 95% confidence intervals for seabird bycatch under base case scenario.

Number of Hooks	Lower Bound (Seabirds per 1000 hooks)	Upper Bound (Seabirds per 1000 hooks)	Lower Bound (Number of seabirds)	Upper Bound (Number of seabirds)
100,000	0.00617	0.09383	1	9
150,000	0.01422	0.08578	2	13
200,000	0.01901	0.08099	4	16
250,000	0.02228	0.07772	6	19
300,000	0.02470	0.07530	7	23

350,000	0.02657	0.07343	9	26
400,000	0.02809	0.07191	11	29
450,000	0.02934	0.07066	13	32
500,000	0.03040	0.06960	15	35
550,000	0.03131	0.06869	17	38
600,000	0.03211	0.06789	19	41
650,000	0.03281	0.06719	21	44
700,000	**0.03343**	**0.06657**	**23**	**47**
750,000	0.03400	0.06600	25	50
800,000	0.03450	0.06550	28	52
850,000	0.03497	0.06503	30	55
900,000	0.03539	0.06461	32	58
950,000	0.03578	0.06422	34	61
1,000,000	0.03614	0.06386	36	64

Table 4.2. 95% confidence intervals for seabird bycatch under an alternative scenario, assuming 10 vessels using 1000 hooks per shot in the trial.

Number of shots	Number of Hooks	Lower Bound (Seabirds per 1000 hooks)	Upper Bound (Seabirds per 1000 hooks)	Lower Bound (Number of seabirds)	Upper Bound (Number of seabirds)
10	100,000	-0.00368	0.10368	0	10
15	150,000	0.00266	0.09734	0	15
20	200,000	0.00617	0.09383	1	19
25	250,000	0.00842	0.09158	2	23
30	300,000	0.00999	0.09001	3	27
35	350,000	0.01115	0.08885	4	31
40	400,000	0.01204	0.08796	5	35
45	450,000	0.01275	0.08725	6	39
50	500,000	0.01333	0.08667	7	43
55	550,000	0.01381	0.08619	8	47
60	600,000	0.01422	0.08578	9	51
65	650,000	0.01456	0.08544	9	56
70	**700,000**	**0.01486**	**0.08514**	**10**	**60**
75	750,000	0.01512	0.08488	11	64
80	800,000	0.01535	0.08465	12	68
85	850,000	0.01556	0.08444	13	72
90	900,000	0.01574	0.08426	14	76
95	950,000	0.01590	0.08410	15	80
100	1,000,000	0.01605	0.08395	16	84

5. Assessment of factors effecting bycatch mitigation

5.1 Introduction

This chapter presents analyses of data from the AFMA observer program operating in the Eastern Tuna and Billfish Fishery (ETBF). The analyses used statistical models to determine those factors which significantly increased the capture of seabirds, or conversely, to reduced captures of seabirds. Numerous factors were considered in the models including spatial, temporal, gear related and environmental variables.

As 77% of seabird captured were flesh-footed shearwaters, analyses of the AFMA observer program information was carried out for all birds captured and then separately for flesh-footed shearwaters. In addition, analyses were carried out separately for daytime and night fishing operations. There were some restrictions on which data could be used and how it was used, as described in the following section.

5.2 Data and methods

5.2.1 Data sources

Data pertaining to three seabird bycatch mitigation trials in the longline sector of the ETBF were sourced from the AFMA observer program. These trials are referred to as the:

- ***Longline chute trial*** (from here on referred to as the “chute trial”) carried out between October 2001 and April 2004
- ***Double tori lines with 60 gram swivels trial*** (from here on referred to as the “Double tori-60g trial”) carried out between April 2002 and November 2003
- ***Longline tori pole trial*** (from here on referred to as the “tori line trial”) carried out between February 2003 and April 2004.

The information from an ongoing generic observer program in the ETBF, which commenced in January 2004, was not used in this analysis as too little data had been collected when this study was initiated.

5.2.1 Data used in analyses

For the purposes of the analyses contained within this report, the observer data contained two types of data of interest, being information that quantified seabird presence, and information that described the gear, vessel and environmental conditions at each observation.

Seabird presence was recorded at three levels:

- ***Abundance*** around the vessel recorded as counts over a number of separated period during setting, soak time or hauling per set. The abundance was calculated as average counts per hour for setting, soak time or hauling in each set
- ***Interactions*** with gear were recorded as each interaction occurred during setting or hauling per set. The interaction was calculated as total number of interactions for setting or hauling in each set

• ***Capture of individuals*** calculated as total number of seabirds captured in each set (with the catch rate calculated as the number of seabirds caught per 1000 hooks).

Additional information collected by the observer program included spatial, temporal, gear, vessel and environmental data. Each of these categories contains a number of different types of collected data, as follows:

- ***Spatial factors*** – Latitude and longitude of capture

- ***Temporal*** – Date of capture (from which year, season and month can be derived) and time of setting/soaking of hooks

- ***Gear related factors*** – information pertaining to many gear and vessel related factors are collected by observers, however, for some factors data is still being entered into the database and was not available to this study. There may also be some instances where sea conditions or other factors prevented data recording. Therefore some factors could not be included in statistical models. Table 5.1 lists those factors considered in the statistical models (i.e. which had sufficient data to support analyses).

- ***Vessel related factors*** – factors identifying the vessel and vessel size were included in case these explained any of the variation in seabird catch rates or interactions with the fishing gear

In addition to data which could be used directly in the analyses, some observer data fields were assessed to contain errors, which upon advice from AFMA observer program, were corrected. Changes were made in instances where:

- Swivel weights were recorded as greater than 150gms
- Where “No” was listed in the Tori pole used field and NA listed in the Number of tori poles used, the number of tori poles was changed to 0 to allow inclusion of those records.
- The branchline lengths, bouyline lengths, distance between hook and weight, and leader length variables were checked for inconsistencies in measurement units and edited accordingly.
- The hauling time was recorded as prior to the start of setting or more than two days after the start of setting, these were assessed individually (for example, it was clear in many instances that the date had been recorded incorrectly) and dates/times corrected.
- Some of the abundance and interaction counts recorded as being NA in the observer database were changed to 0’s on advice from AFMA observer program
- Where vessel and gear attributes were recorded for a voyage but not for subsequent voyages, the attributes were assumed to remain the same for a given observer until the observer programme sheets indicated some change. In some cases the attributes were also back cast on advice from AFMA.

Derived variables

In addition to data used directly in analyses, a number of additional variables were derived from those recorded by observers and subsequently used in the analysis:

- Bird position relative to vessel: The mean vessel course was subtracted from the mean wind direction to determine a variable appropriate for indicating a bird’s likely location relative to the boat. When the difference between the two values is closest to 180 then birds are likely to be hovering off the stern above line deployment.
- Percentage hooks set during daylight: This was derived using the time of setting start and finish, time of nautical sunrise and sunset and the total number of hooks set.

- Soak time: Difference between the start of setting times and the end of hauling
- Lightstick use: If any colour lightstick was recorded the value of this variable is ‘Y’, otherwise ‘N’.
- Bait life status: Type of bait used (live/mixed/dead)
- Season: The season the shot took place in (Summer/Autumn/Winter/Spring)

5.2.3 Data not used in analyses

In addition to the variables listed in Table 5.1, there were a number of other factors considered for inclusion but which could not included in the models, for a variety of reasons. These included:

- ***Hook type and size*** – while domestic longliners have been known to use a variety of hook types and sizes, almost all of the observed trials were conducted using small J hooks, eliminating the need to include these variables in the model.
- ***Hook position in bait*** – over half of the shots recorded multiple classifications for hook position in bait, thus making it infeasible to include this variable at the shot level. However, autopsy data may be available in future and could be utilised in future analyses to determine the effect of hook position on seabird capture.
- ***Number of hooks set with tori line deployed*** – in some cases this was greater than the total number of hooks set. There were also a large number of missing observations.
- ***Lead weight use*** – a lead weight was used in the majority of instances. However, in 12 cases lead weight was recorded as ‘N’ with a positive value for weight size. Given the very small proportion of ‘N’ values this variable was not included in the model with the assumption that the weight size variable would be adequate.

5.2.2 Models

Generalised linear mixed models were used to assess the following:

1. Factors related to seabird capture during daytime sets
2. Factors related to seabird capture during night time sets
3. Factors related to seabird interactions during daytime sets
4. Factors relating to flesh footed shearwater captures during daytime sets

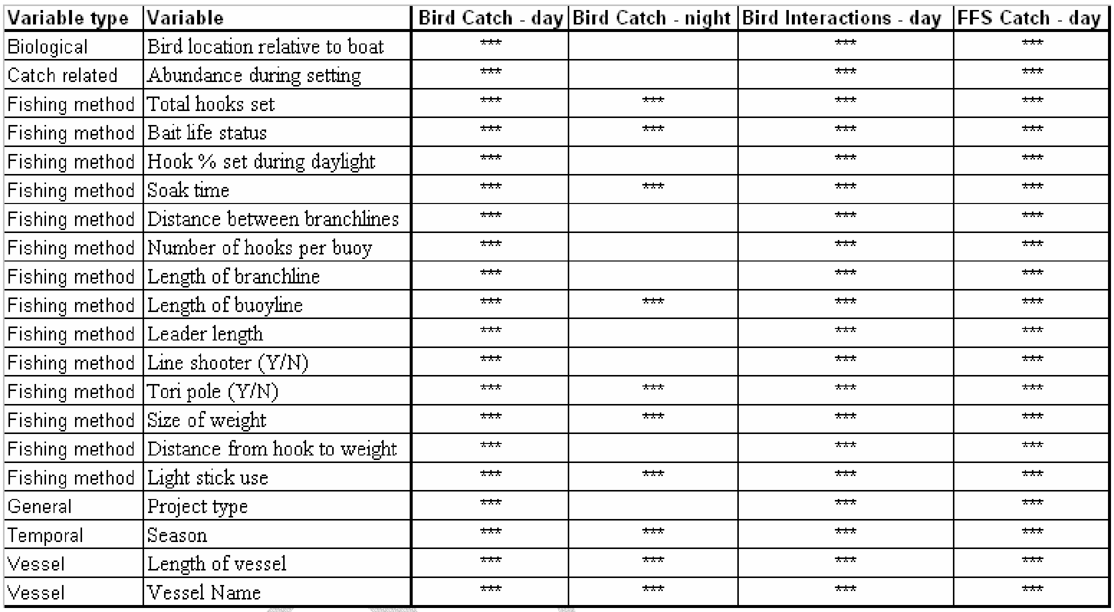
In addition, generalised additive models were used to identify regions of high seabird catch and high seabird abundance. The following provides a brief outline of GLMMs and GAMs and why they were used.

Generalised linear mixed models are…….. *ADD BRIEF EXPLANATORY TEXT*

…

GAMs are a flexible class of models that can be used either as the main analysis tool (Kleiber and Bartoo 1998 and Fewster *et al*. 2000) or as an exploratory tool (Wise *et al*. 2002) before constructing more formal analysis using, for example, GLMs. The GAM technique allows numerical independent variables to have nonlinear effects on the dependent variable as determined by a smoothing algorithm (Cleveland 1979). Thus the effect of an independent variable is only constrained by the smoothing algorithm and is the major difference between the GAM and GLM. In this case GAMS have been used to look at interacting location factors (latitude and longitude) to identify regions where there is a higher probability of seabird capture and where seabird abundance is higher.

Table 5.1 – List of variable considered in each of the four generalised linear models used to determine the relationship between gear, vessel, environmental and other factors and catch rates of seabirds by longliners in the Eastern Tuna and Billfish Fishery. The four models are Bird Catch – Day (model for all seabird captures in daytime sets), Bird Catch – Night (model for all seabird captures in night time sets), Bird Interactions – Day (a model assessing factors significantly related to seabird interactions with longline gear during daytime sets), and FFS Catch – Day (a model assessing factors significantly related to capture of fleshfooted shearwaters in daytime sets)



Variable type	Variable	Bird Catch - day	Bird Catch - night	Bird Interactions - day	FFS Catch - day
Biological	Bird location relative to boat	***		***	***
Catch related	Abundance during setting	***		***	***
Fishing method	Total hooks set	***	***	***	***
Fishing method	Bait life status	***	***	***	***
Fishing method	Hook % set during daylight	***		***	***
Fishing method	Soak time	***	***	***	***
Fishing method	Distance between branchlines	***		***	***
Fishing method	Number of hooks per buoy	***		***	***
Fishing method	Length of branchline	***		***	***
Fishing method	Length of buoyline	***	***	***	***
Fishing method	Leader length	***		***	***
Fishing method	Line shooter (Y/N)	***		***	***
Fishing method	Tori pole (Y/N)	***	***	***	***
Fishing method	Size of weight	***	***	***	***
Fishing method	Distance from hook to weight	***		***	***
Fishing method	Light stick use	***	***	***	***
General	Project type	***		***	***
Temporal	Season	***	***	***	***
Vessel	Length of vessel	***	***	***	***
Vessel	Vessel Name	***	***	***	***

* Total hooks set is Included as an offset in the model to account for the number of hooks set.

5.3 Results

5.3.1 Data characterisation – catch, effort and CPUE

Catch data: Catch data pertaining to bycatch of seabirds in the ETBF is zero inflated, meaning that the majority of fishing operations do not catch any seabirds (Figure 5.1). When only the positive catch data records are considered it is clear that most fishing operations have taken only one bird. A few operations have taken between 2 and 12 birds and a single operation took 44 birds (mostly flesh footed shearwaters).

A.

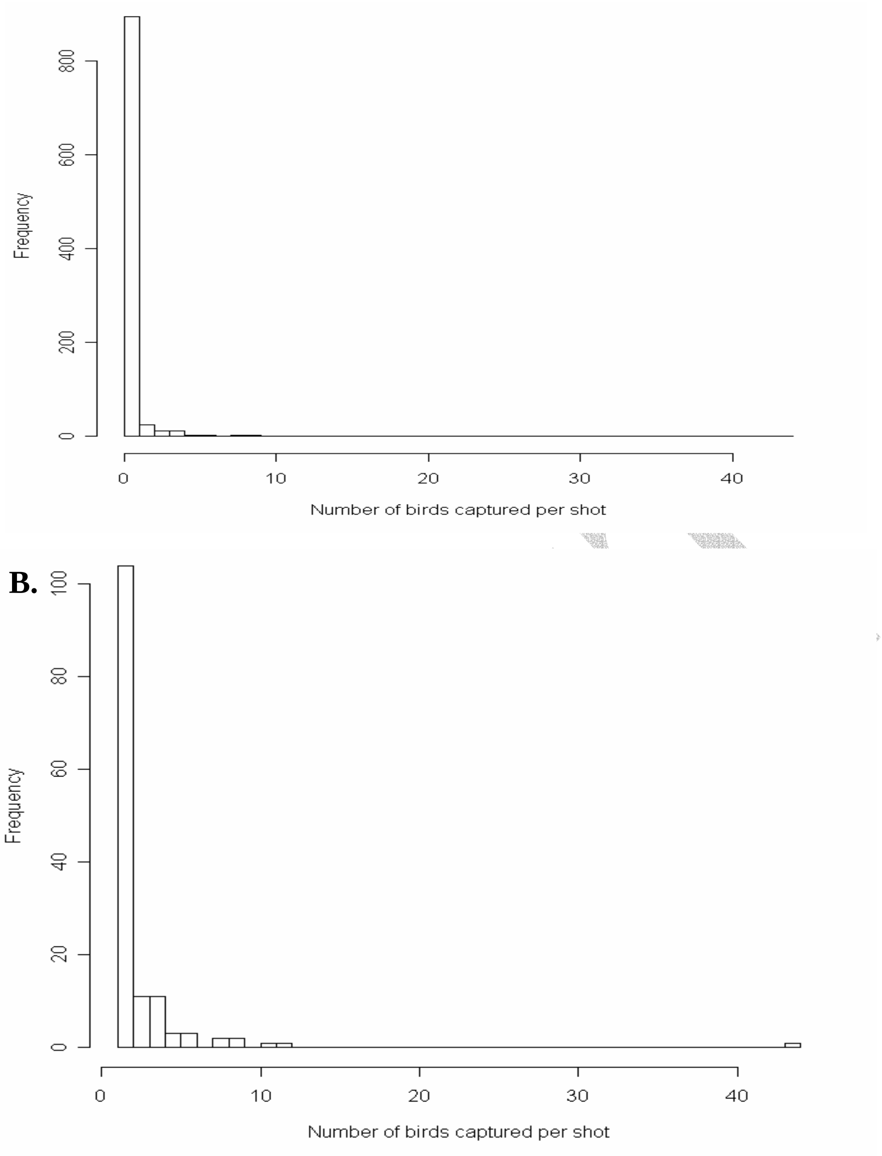


Figure 5.1 –Frequency histograms of, A) the number of birds captured per shot for all data, and B) the number of birds captured per shot for shots which took at least one seabird, across three seabird bycatch mitigation trials run in the Eastern Tuna and Billfish Fishery since 2001.

Data from three separate mitigation trials have been combined in the current model based analyses, due to each trial not having sufficient data across all data fields to be analysed separately.

All trials: Nearly 815 000 hooks were observed (Table 5.2) across all three trials, between 2001 and 2004, with 347 seabird captures observed. Observed effort was highest in winter months and lowest in summer. The majority of birds caught were fleshfooted shearwaters (263), with 12 black browed albatross and 11 great winged petrals also taken. Ten other species of seabird were caught in lower numbers. Six species of albatross, 4 species of shearwater, 2 species of petrel and 1 species of skua were identified in the bycatch. Despite high observed effort in Winter months in all three trials (~264 000 hooks total), only 7 seabirds were observed caught in that season. In contrast, 66 birds were caught in Summer, 133 in Autumn and 121 in Spring. Overall, observed seabird catch rate was 0.401 birds/1000 hooks. The highest catch rate for any single species was 0.323 for flesh footed shearwaters, with black browed albatross (0.015) and great winged petrel (0.013) the next highest. Across all observed fishing operations catch rates for daytime sets were more than four times higher (0.411/1000 hooks) than for night-time sets (0.096/1000 hooks).

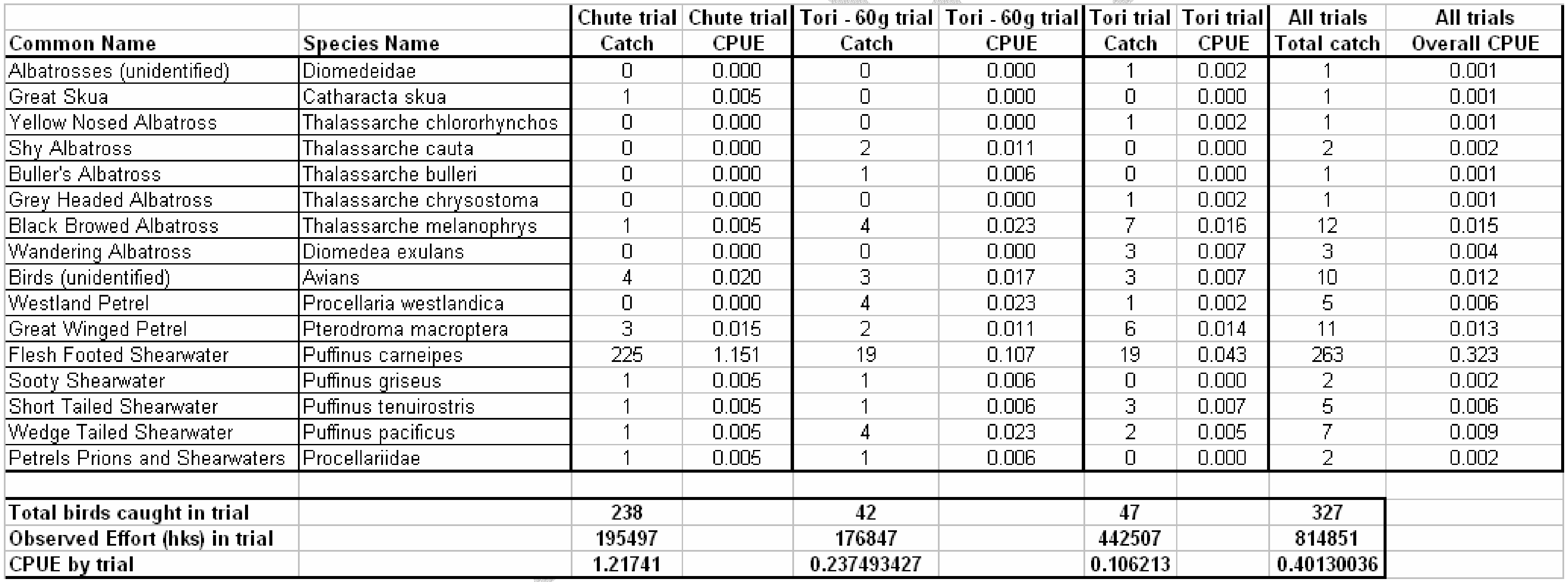
Tori pole trial: Over half (442 507 hooks) of the observed effort occurred in the tori-line trial, in which 47 birds were caught, at a catch rate of 0.11 birds/1000 hooks (Figure 5.2, Table 5.2). These included 19 fleshfooted shearwaters (catch rate 0.043/1000 hooks), 7 black browed albatross (0.016), 6 great winged petrals (0.014), 3 wandering albatross (0.007) and 3 short tailed shearwaters (0.007). Between 120 000 and 160 000 hooks were observed in Autumn, Winter and Spring periods of the trial, but just under 50 000 hooks in the Summer period. Seabird bycatch numbers were relatively low in Summer, Autumn and Winter periods (<10) but peaked at 32 for Spring period.

Double Tori-60g trial: Just over 176 000 hooks were observed in the Double toriline-60g trial, in which 42 birds were caught, at a catch rate of 0.237 birds/1000 hooks (Figure 5.2, Table 5.2). These included 19 fleshfooted shearwaters (catch rate 0.107/1000 hooks), 4 black browed albatross (0.023), 2 great winged petrals (0.011), 2 shy albatross (0.011) and 4 wedge tailed shearwaters (0.023). Just over 65000 hooks were observed in Winter months, with 54615 hooks observed in Autumn periods and nearly 37 000 in Spring periods. Only 19630 hooks were observed in the summer months. Only 2 seabirds were caught in the winter periods, while between 11-16 seabirds were caught in each of the other seasons.

Chute trial: Just over 195 000 hooks were observed in the chute trial, in which 238 birds were caught, at a catch rate of 1.217 birds/1000 hooks (Figure 5.2, Table 5.2). These included 225 fleshfooted shearwaters (catch rate 1.151/1000 hooks), 1 black browed albatross (0.005), 3 great winged petrals (0.015), 1 great skua (0.005). Relatively few hooks were observed in Spring (~28 000), compared to winter (42 726 hooks), summer (47 301 hooks) and autumn (77 052 hooks). Of the 238 birds caught, only 1 was caught in winter, while 50 were observed caught in summer, 109 in Autumn and 78 in spring (Figure 5.2). Most of the birds caught in each season were flesh footed shearwaters.

Species seasonal trends: Some species showed trends in season of capture (Figure 5.4), with the majority of albatross species captures in spring, westland petrel (summer/autumn), Great winged petrel (autumn/spring), fleshfooted shearwater (all seasons except winter), short tailed shearwater (summer/autumn), wedge tailed shearwater (autumn).

Table 5.2 – Total catch by seabird species for each mitigation trial undertaken in the Eastern Tuna and Billfish Fishery since 2001.



Common Name	Species Name	Chute trial Catch	Chute trial CPUE	Tori - 60g trial Catch	Tori - 60g trial CPUE	Tori trial Catch	Tori trial CPUE	All trials Total catch	All trials Overall CPUE
Albatrosses (unidentified)	Diomedeidae	0	0.000	0	0.000	1	0.002	1	0.001
Great Skua	Catharacta skua	1	0.005	0	0.000	0	0.000	1	0.001
Yellow Nosed Albatross	Thalassarche chlororhynchos	0	0.000	0	0.000	1	0.002	1	0.001
Shy Albatross	Thalassarche cauta	0	0.000	2	0.011	0	0.000	2	0.002
Buller's Albatross	Thalassarche bulleri	0	0.000	1	0.006	0	0.000	1	0.001
Grey Headed Albatross	Thalassarche chrysostoma	0	0.000	0	0.000	1	0.002	1	0.001
Black Browed Albatross	Thalassarche melanophrys	1	0.005	4	0.023	7	0.016	12	0.015
Wandering Albatross	Diomedea exulans	0	0.000	0	0.000	3	0.007	3	0.004
Birds (unidentified)	Avians	4	0.020	3	0.017	3	0.007	10	0.012
Westland Petrel	Procellaria westlandica	0	0.000	4	0.023	1	0.002	5	0.006
Great Winged Petrel	Pterodroma macroptera	3	0.015	2	0.011	6	0.014	11	0.013
Flesh Footed Shearwater	Puffinus carneipes	225	1.151	19	0.107	19	0.043	263	0.323
Sooty Shearwater	Puffinus griseus	1	0.005	1	0.006	0	0.000	2	0.002
Short Tailed Shearwater	Puffinus tenuirostris	1	0.005	1	0.006	3	0.007	5	0.006
Wedge Tailed Shearwater	Puffinus pacificus	1	0.005	4	0.023	2	0.005	7	0.009
Petrels Prions and Shearwaters	Procellariidae	1	0.005	1	0.006	0	0.000	2	0.002
Total birds caught in trial		238		42		47		327	
Observed Effort (hks) in trial		195497		176847		442507		814851	
CPUE by trial		1.21741		0.237493427		0.106213		0.40130036	

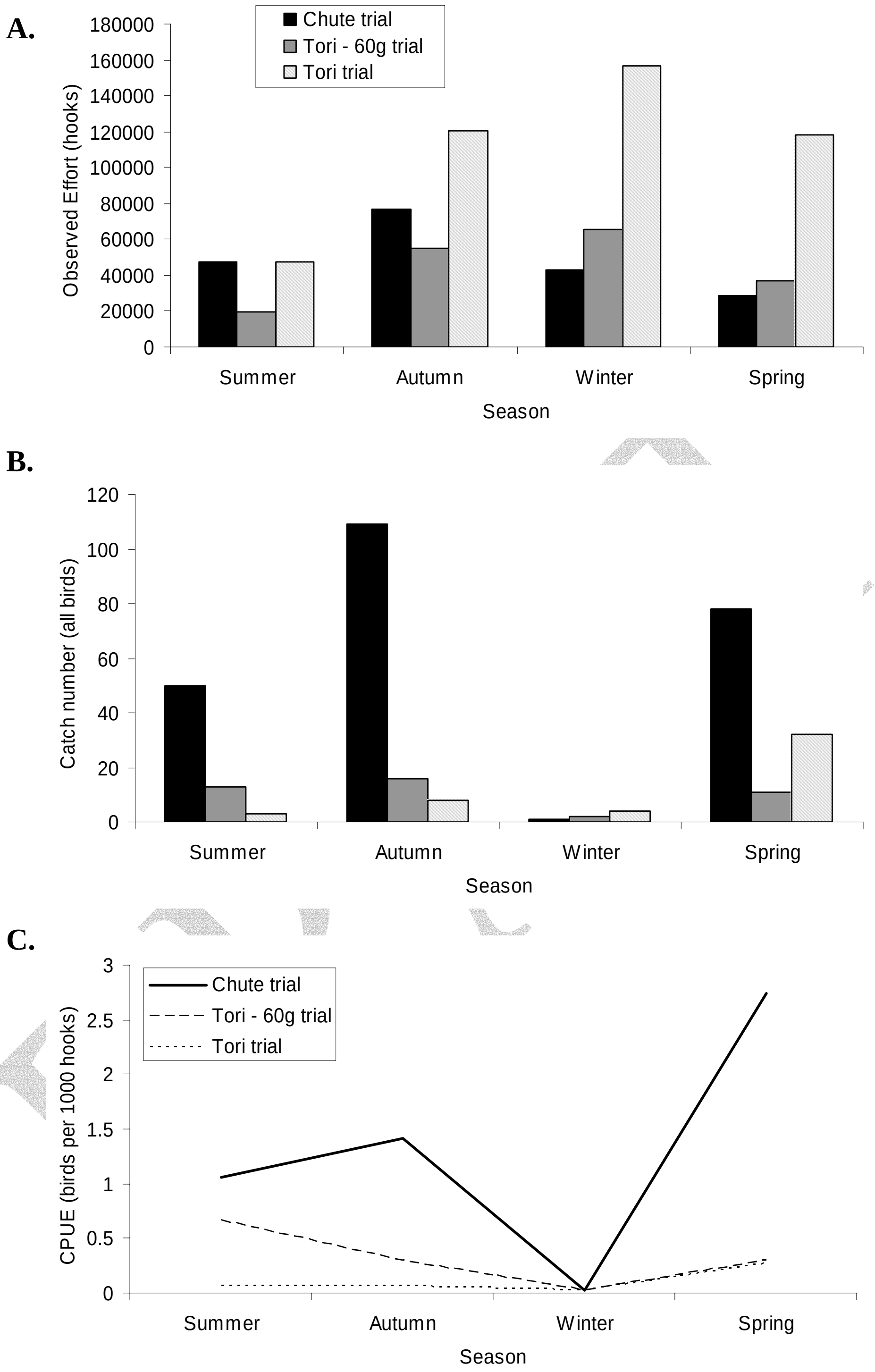


Figure 5.2 – A) Accumulated observed effort, B) Total number of birds caught, and C) Catch per unit effort, across seasons for each of the three seabird bycatch mitigation trials conducted in the Eastern Tuna and Billfish Fishery since 2000.

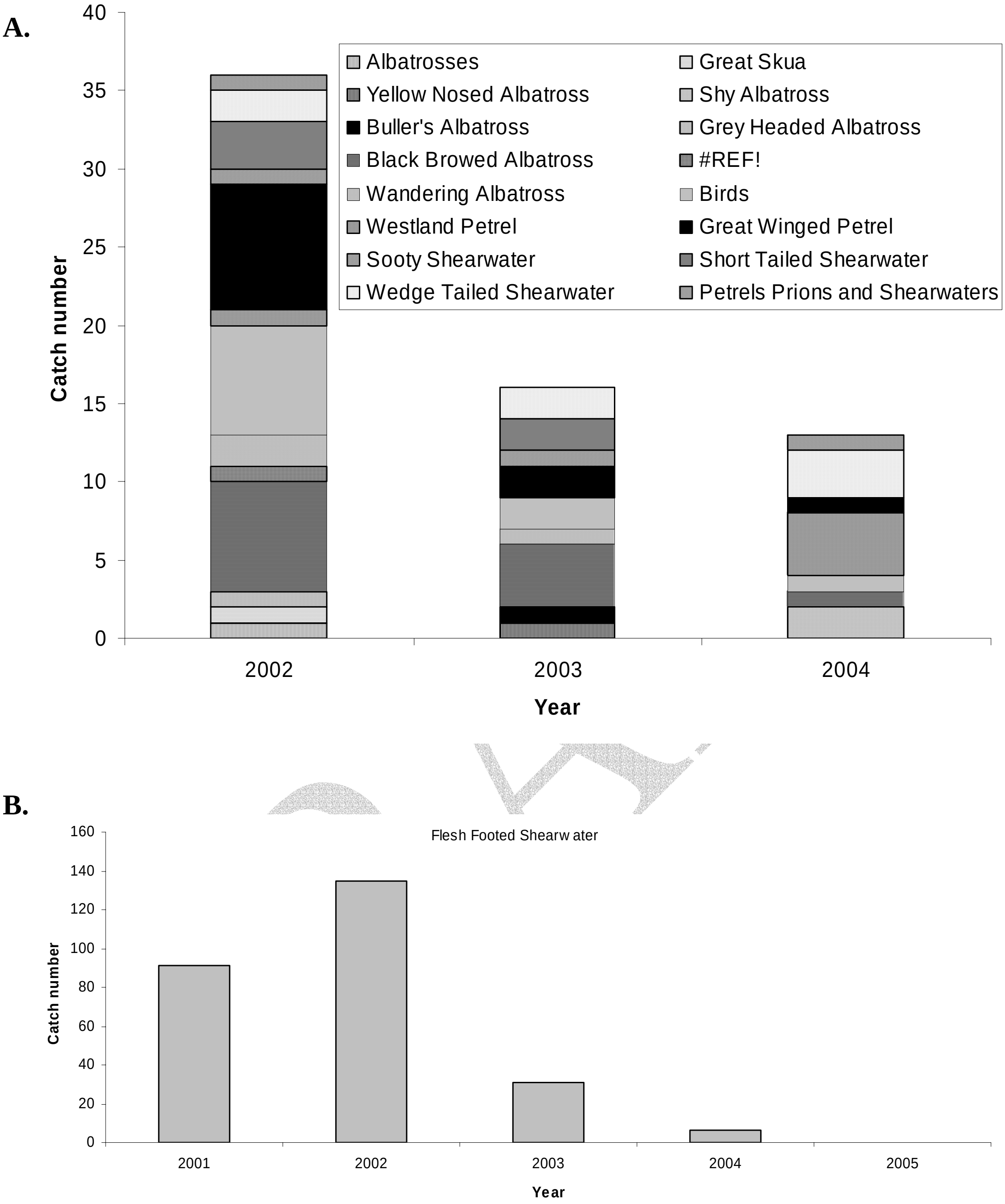


Figure 5.3 – Total annual observed catch of seabirds by species in the ETBF for A) All species excepting, B) Flesh footed shearwaters.

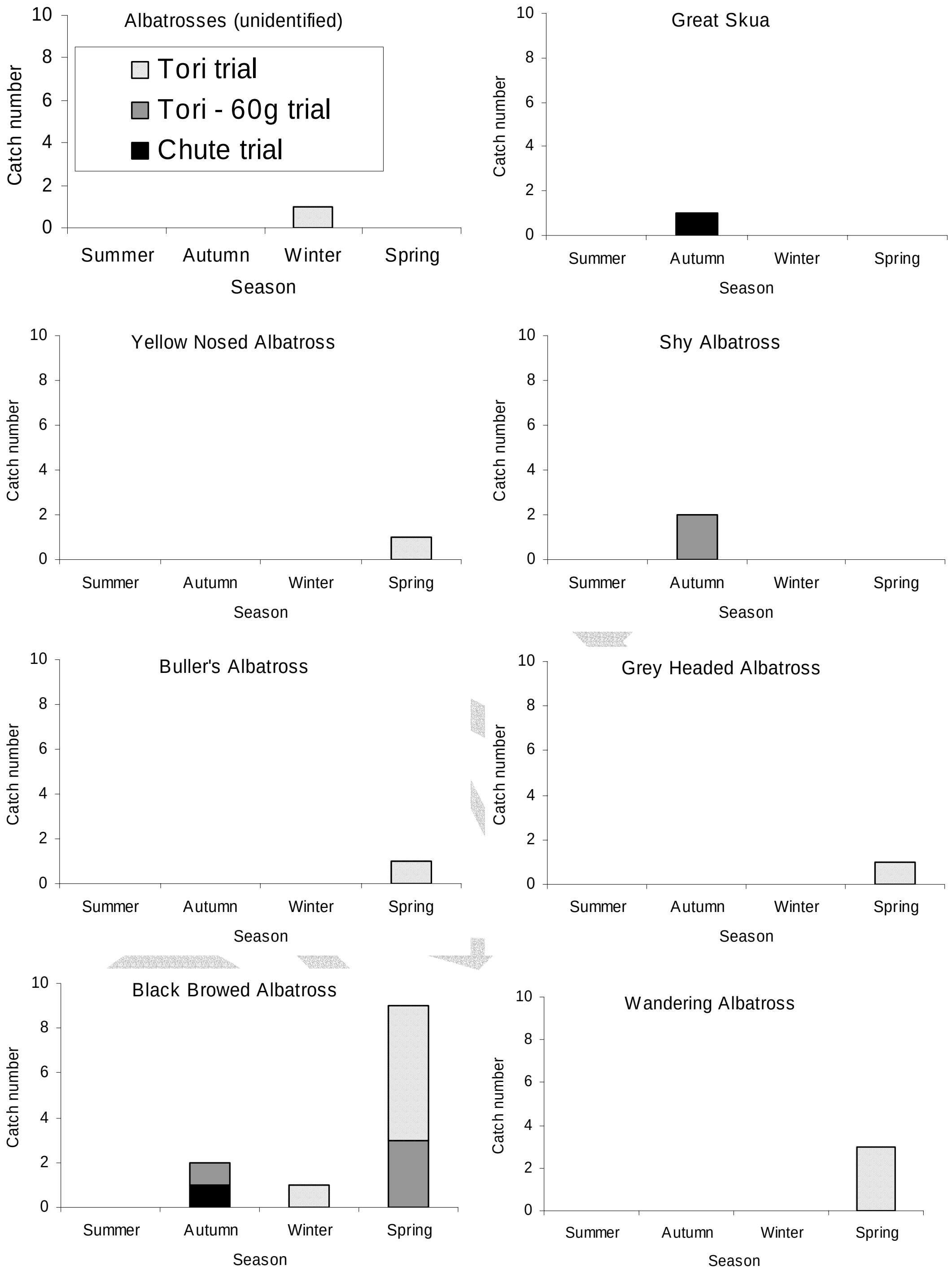


Figure 5.4 – Total observed catch by species across seasons for each of the three seabird bycatch mitigation trials conducted in the Eastern Tuna and Billfish Fishery since 2000.

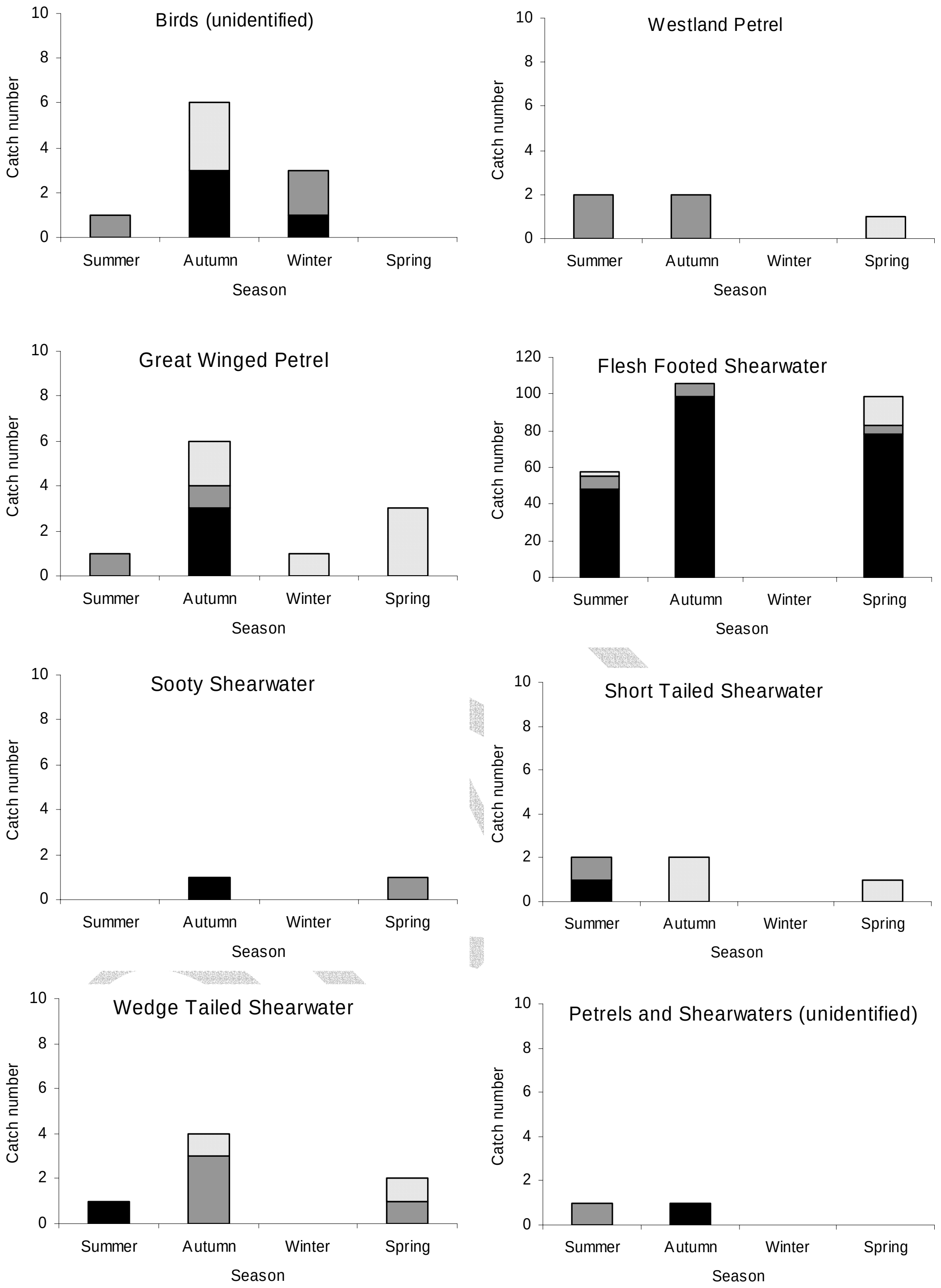


Figure 5.4 (continued) – Total observed catch by species across seasons for each of the three seabird bycatch mitigation trials conducted in the Eastern Tuna and Billfish Fishery since 2000.

5.3.2 Spatial resolution of high catch and abundance regions

Unfortunately, spatial mapping of seabird captures can not be presented due to the limited number of vessels that have partaken in observer trials and the “5-boat” restrictions on data representation. However, GAM based analyses of localities of high seabird capture and high seabird abundance can be represented as they represent an output based on all vessels involved in the trials.

A GAM was fitted to the catch data to model the distribution of seabird deaths based on latitude and longitude. Figure 5.5 presents a graphical representation of the model output. The results indicate that the greatest likelihood of capture occurs further away from the coast at approximately -30-33’S, 155-158’E. However, this is also an area of lower observer coverage, hence the actual observed number of birds caught is highest in coastal waters where observer effort was much higher

To provide an indication of locations of high seabird abundance, a generalized additive model was fit to the abundance data (Figure 5.5). Those lines marked with the highest values indicate the areas of greatest seabird abundance. These areas appear to be concentrated around the 156-160’E areas, although the data is sparse in these areas (due to low observer coverage) and would thus be associated with large standard errors.

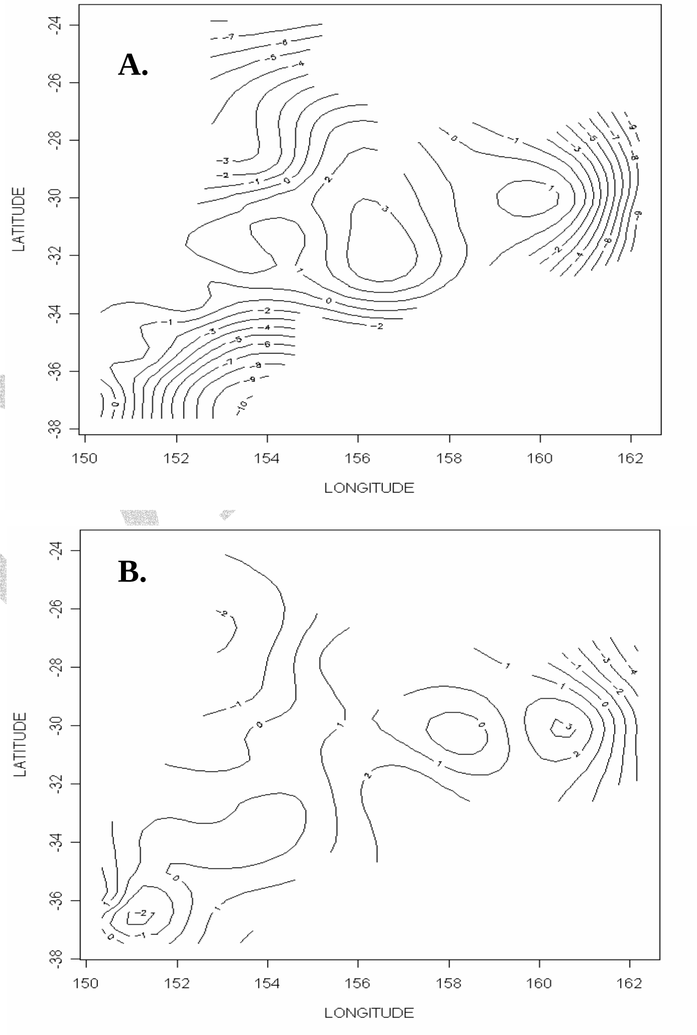


Figure 5.5 – GAM based representation of A) Regions of higher probability of bird capture/mortality, and B) Regions of higher bird abundance, in the region between 24-38S off eastern Australia, as based on observer reports of seabird catch and abundance between 2001-2004.

5.3.3 Factors Affecting Seabird Capture

In order to determine the factors affecting seabird capture a number of models have been considered. Due to data limitations (i.e. large amounts of missing data in many of the observer logbook data fields), these models have had to be conducted using a reduced set of the available data. The inability to distinguish between "NA" and zero values in particular has reduced the number of records available for modelling purposes as it was considered to be inappropriate to make assumptions about the collection of the data in many instances. For this reason only those variables that have been collected for the majority of observations have been included in the analyses. Therefore a number of factors that were considered to be possible drivers of seabird capture have not been incorporated in the overall models.

To determine the factors affecting seabird bycatch, separate models have been constructed for day and night setting, where night setting is defined as all hooks for a given shot set between nautical dusk and nautical dawn and day setting refers to all other shots. Preliminary analyses indicated that abundance is an important factor affecting the capture of seabirds and it has been determined from previous research that abundance counts calculated during dark are inaccurate. Therefore the model for seabird capture during daylight contains an abundance term while the night setting model does not. It should be noted that the model for daylight setting also contains a term for the proportion of hooks set during daylight hours (to account for not all hooks being set during daylight within a shot classified as a 'day' shot). Due to the incorporation of the abundance term in the model, only those environmental factors considered to influence seabird capture independently of abundance were included in the model i.e. it is thought that most of the environmental factors drive seabird abundance rather than captures. This assumption should be tested further in future analyses.

5.3.4 Factors effecting seabird capture during daytime sets

The number of bird captures for shots conducted during daylight was modelled at the shot level using a generalized linear mixed model based on a poisson distribution. Given the lack of control sample (sample of observations conducted using the same vessels and locations where no seabird mitigation measures were used), the trials have been compared to each other rather than comparison to instances where mitigation methods were not employed. However, the vessel, gear, shot and environmental factors affecting the rate of seabird bycatch have been determined wherever possible.

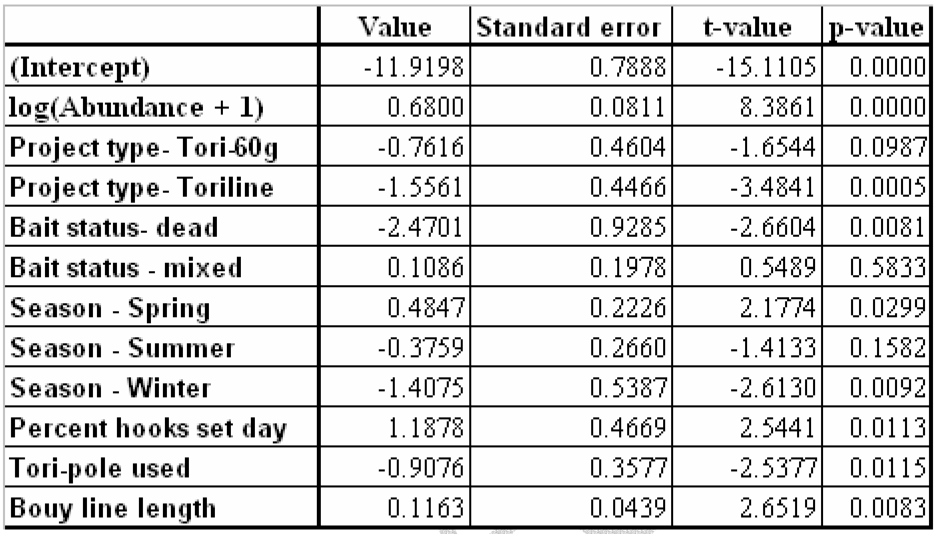
A number of factors that were acknowledged as possibly contributing to the capture of seabirds were not included in this part of the analysis due to the data limitations. The model was chosen on a reduced set of the data (417 observations) where all the variables considered for inclusion were recorded. A model containing all factors determined to be significant was then applied to an increased data set (548 observations) based on the presence of data for a smaller number of variables, to calculate more accurate model parameters. The variables considered in the model are listed in Table 5.2.

A random term "vessel" (factor indicating the vessel a shot was conducted by) was included in all of the models considered. This was to cater for the correlation between the shots recorded for each vessel i.e. the vessel and gear factors are highly correlated within vessel. The final model was:

> **Captures** ~ offset(log(Total hooks set)) + log(Abundance+1) + Trial type + Bait life status + Season + Percentage hooks set during daylight + Tori pole use + bouyline length

Note that the log was taken of the abundance term in the model as this factor was shown to be linearly related to seabird capture after fitting a generalized additive model to the data.

Table 5.3 – Generalised linear mixed model statistics identifying significant relationships between seabird captures and gear, temporal and trial related factors, for observed fishing operations conducted during daylight in the ETBF longline fishery



	Value	Standard error	t-value	p-value
(Intercept)	-11.9198	0.7888	-15.1105	0.0000
log(Abundance + 1)	0.6800	0.0811	8.3861	0.0000
Project type- Tori-60g	-0.7616	0.4604	-1.6544	0.0987
Project type- Toriline	-1.5561	0.4466	-3.4841	0.0005
Bait status- dead	-2.4701	0.9285	-2.6604	0.0081
Bait status - mixed	0.1086	0.1978	0.5489	0.5833
Season - Spring	0.4847	0.2226	2.1774	0.0299
Season - Summer	-0.3759	0.2660	-1.4133	0.1582
Season - Winter	-1.4075	0.5387	-2.6130	0.0092
Percent hooks set day	1.1878	0.4669	2.5441	0.0113
Tori-pole used	-0.9076	0.3577	-2.5377	0.0115
Bouy line length	0.1163	0.0439	2.6519	0.0083

The results (Table 5.3) indicate that:

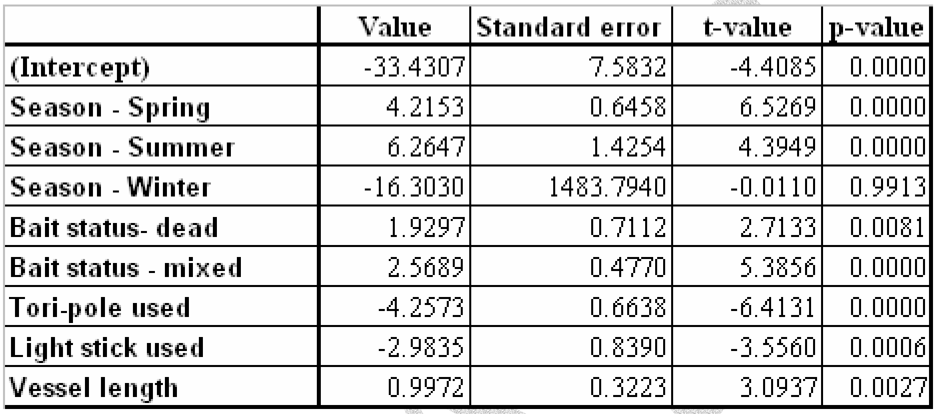
- As abundance during setting increased, the capture of seabirds increased
- There was a significant difference in seabird catch between the chute and tori pole trials, but not the chute and Double tori-60g trials. The number of seabird captures was the greatest for the chute trial. Note: further models revealed that significantly more birds were caught during the Double tori-60g trial compared to the tori pole trial.
- There were significantly less seabirds caught using dead bait than live bait (no significant difference between mixed bait and live bait, however the standard error is large).
- There were significantly more birds caught in Spring than in Autumn, no significant difference between Summer and Autumn and significantly less birds caught in Winter compared to Autumn.
- The number of seabirds captured increased as the percentage of hooks set during daylight hours increased.
- Significantly less birds were captured when tori poles were used as a mitigation measure.
- The number of seabirds captured increased as the length of the buoyline increased.
- There was variation in the capture of seabirds between vessels i.e. after accounting for the significant factors in the model, part of the variation remaining is not random but due to a ‘vessel’ effect (as indicated by the random effects term).

5.3.5 Analyses of factors relating to seabird captures at night

The number of bird captures for shots with the start and finish of setting occurring during the night was modelled at the shot level using a generalized linear mixed model based on a poisson distribution. As one of the trials in particular (Double tori-60g trial) had a very small number of shots conducted during the night, a trial type term was not incorporated and thus the model can be used to determine the significance of some of the factors across all trials. Due to the number of shots conducted during the night being significantly smaller than in the day, a much smaller number of variables could be considered in the model (126 observations). The variables initially considered in the model are listed in Table 5.2. The final model was:

> **Captures** ~ offset(log(Total hooks set)) + Season + Bait life status + Tori pole use + lightstick use + vessel length

Table 5.4 - Generalised linear mixed model statistics identifying significant relationships between seabird captures and gear, temporal and trial related factors, for observed fishing operations conducted at night in the ETBF longline fishery



	Value	Standard error	t-value	p-value
(Intercept)	-33.4307	7.5832	-4.4085	0.0000
Season - Spring	4.2153	0.6458	6.5269	0.0000
Season - Summer	6.2647	1.4254	4.3949	0.0000
Season - Winter	-16.3030	1483.7940	-0.0110	0.9913
Bait status- dead	1.9297	0.7112	2.7133	0.0081
Bait status - mixed	2.5689	0.4770	5.3856	0.0000
Tori-pole used	-4.2573	0.6638	-6.4131	0.0000
Light stick used	-2.9835	0.8390	-3.5560	0.0006
Vessel length	0.9972	0.3223	3.0937	0.0027

The results (Table 5.4) indicate that:

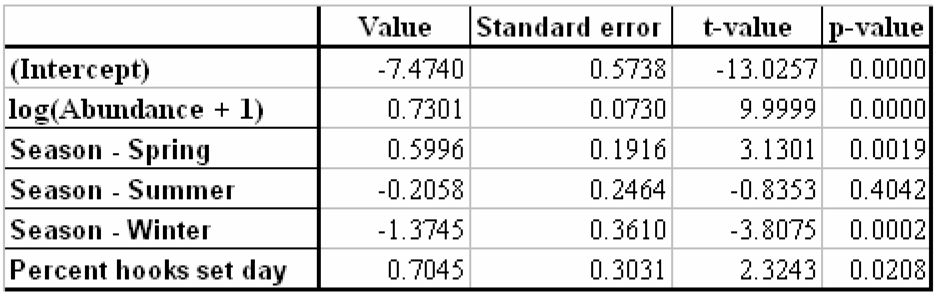
- Significantly more birds were caught during Spring and Summer compared to Autumn. There was no significant difference between captures during Winter and Autumn (note: this is most likely due to a very small number of observations for Winter)
- Significantly less birds were captured when a tori pole was used
- Significantly less birds were captured when lightsticks were used
- As vessel length increased, the number of seabirds captured also increased

5.6.3 Factors affecting Seabird Interactions During Daylight

It is assumed that seabird capture would increase as the number of seabirds interacting with the gear increases. The purpose of the analysis that follows was to determine the factors that effect seabird interactions. A generalized linear mixed model was fit to the data (n= 354) to determine the factors that affect bird interactions during daylight hours. Interactions were recorded during setting (405 shots) and hauling (41 shots). As it was not possible to distinguish between interactions which were not recorded and zero values, the total data set was effectively reduced to 405 shots and then further reduced based on the available data. For this reduced set of data, the factors considered were the same as for the model for bird captures during daylight setting. The final model was:

> **Interactions** ~ offset(log(Total hooks set)) + log(Abundance + 1) + Season + percentage hooks set during daylight

Table 5.5 - GLMM statistics identifying significant relationships between seabird interactions and included factors, for observed fishing operations conducted at during the day in the ETBF



	Value	Standard error	t-value	p-value
(Intercept)	-7.4740	0.5738	-13.0257	0.0000
log(Abundance + 1)	0.7301	0.0730	9.9999	0.0000
Season - Spring	0.5996	0.1916	3.1301	0.0019
Season - Summer	-0.2058	0.2464	-0.8353	0.4042
Season - Winter	-1.3745	0.3610	-3.8075	0.0002
Percent hooks set day	0.7045	0.3031	2.3243	0.0208

The results (Table 5.5) indicate that:

- As abundance during setting increased, the number of seabird interactions increased.
- There was a significant difference in the number of interactions between Spring and Autumn, with the most occurring during Spring. There was no significant difference between Summer and Autumn and there were significantly less interactions in Winter than in Autumn.
- As the percentage of hooks set during the day increased the number of interactions increased.
- There was little vessel to vessel variation in the number of seabird interactions as exhibited by the random effect.

5.3.7 Factors affecting flesh footed shearwater captures during daytime sets

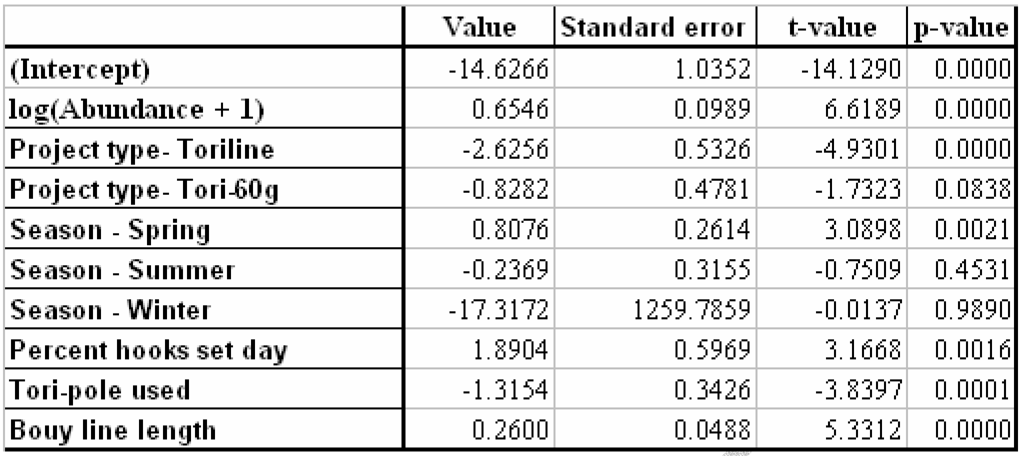
As the Flesh Footed shearwater made up 77% of all birds captured during the three trials, the distribution of captures for these species was also examined separately. Over all of the trials the mean rate of Flesh Footed Shearwater captures was 0.323 birds/1000 hooks. On a trial by trial basis, the catch rates were as follows:

Trial	*Rate*
LLCHUTE	1.151
LLTORI60	0.107
LLTORIPL	0.043

A model was fitted for the capture of Flesh Footed Shearwaters considering the same factors as for the overall capture of birds (Table 5.1). The reason for fitting this model separately was to determine whether there are any factors that effect the capture of this species in particular (given it represented the majority of bird captures). Due to the large number of NA's for the abundance of FFS including instances where captures were recorded, the abundance of all birds was used as a proxy (remembering FFS make up 77% of all captures). The final model was:

> **Captures** ~ offset(log(total hooks set)) + log(Abundance + 1) + trial type + Season + percentage hooks set per day + tori pole use + bouyline length

Table 5.6 - Generalised linear mixed model statistics identifying significant relationships between flesh foot shearwater captures and gear, temporal and trial related factors, for observed fishing operations conducted during daylight in the ETBF longline fishery



	Value	Standard error	t-value	p-value
(Intercept)	-14.6266	1.0352	-14.1290	0.0000
log(Abundance + 1)	0.6546	0.0989	6.6189	0.0000
Project type- Toriline	-2.6256	0.5326	-4.9301	0.0000
Project type- Tori-60g	-0.8282	0.4781	-1.7323	0.0838
Season - Spring	0.8076	0.2614	3.0898	0.0021
Season - Summer	-0.2369	0.3155	-0.7509	0.4531
Season - Winter	-17.3172	1259.7859	-0.0137	0.9890
Percent hooks set day	1.8904	0.5969	3.1668	0.0016
Tori-pole used	-1.3154	0.3426	-3.8397	0.0001
Bouy line length	0.2600	0.0488	5.3312	0.0000

The results (Table 5.6) indicate that:

- As abundance during setting increased, the capture of FFS increased
- There was a significant difference between the Chute and Tori pole trials, but not the Chute and Double Tori-60g trials. The number of FFS captures was the greatest for the Chute trial. Note: further models revealed that significantly more FFS were caught during the Double Tori-60g trial compared to the Tori pole trial.
- There were significantly more FFS caught in Spring than in Autumn, no significant difference between Summer and Autumn or Winter compared to Autumn. Note: The lack of significant difference between Winter and Autumn is most likely due to a lack of observations in Winter (as highlighted by the large standard error).
- The number of FFS captured increased as the percentage of hooks set during daylight hours increased.
- Significantly less FFS were captured when tori poles were used as a mitigation measure.
- The number of FFS captured increased as the length of the buoyline increased.
- There was little variation in the capture of FFS between vessels i.e. most of the remaining variation in the model is random.

5.4 Summary and discussion

Introduction: An understanding of those factors which effect seabird bycatch rates in the longline sector of the Eastern Tuna and Billfish sector is required if fishers and managers are to implement measures to reduce seabird bycatch and subsequently reduce the risk of partial fishery closures being enforced. The analyses presented in this chapter are based on observer data collected for three seabird bycatch mitigation trials in the fishery between 2001 and 2004. The results will be of use to future mitigation trial design and consideration of management options to address seabird bycatch. However, a number of issues pertaining to data recording by observers will need to be addressed to ensure that future analyses are not limited by inconsistencies in the data being analysed. Both the significance of the current results for fishery management and the problems associated with data collection are discussed here.

Seabird catches and catch rates in the ETBF longline sector: It is apparent from the analyses of observer collected data that the capture of seabirds in the ETBF longline sector is a relatively infrequent event. Of the more than 955 fishing operations observed across 3 trials and 4 years, 136 operations (14%) captured one or more seabirds. However, nearly 60 of these operations caught between 2 and 12 birds each, while one operation caught 44 birds. In total 327 seabirds were observed caught, at a catch rate of 0.401/1000 hooks.

Three points need be noted in regard to this trend. The impact of the mitigation measures being trialled on the relative frequency of seabird bycatch is uncertain, due to the fact that control vessels (vessels fishing without mitigation measures, but in the same time and area) were not used any of the trials. One critical assumption behind these trials is that if seabird catch rates reduce to less than 0.05 per 1000 hooks, then the mitigation measure(s) is having a significant mitigation effect. However, it should be kept in mind that other factors can reduce catch rates over time (population declines for example). Secondly, while relatively few fishing operations might capture seabirds, it is evident that any individual operation has the potential to catch numerous birds. The capture of 44 birds in a single fishing operation is of some concern to fishery managers and highlights the importance of trying to determine what factors influence these events. Finally, infrequent capture of seabirds also needs to be placed in the context of individual species population status. Many seabirds species have relatively low reproductive capacity and some have had noted declines in population numbers, hence small catches taken in longline fisheries might still have a significant impact for some species. The initial target TAP level of 0.05 birds/1000 hooks groups all seabirds and is considered a conservative target rate that would protect more vulnerable species such as albatross. Ultimately, the desired catch rates would be brought close to zero.

Both the overall nominal catch rate (0.401) and the nominal catch rates for the Chute Trial (1.217), the Double Tori-60g Trial (0.237) and the Tori pole Trial (0.106), exceed the target TAP rate of 0.05. Therefore none of the combinations of mitigation measures have successfully achieved the trial objectives. Clearly further trials need to be undertaken until a measure or combination of measures can be identified that reduce the catch rates below the target level. The analyses presented in this chapter have identified many of the factors effecting seabird bycatch rates and these analyses are discussed below. Analyses were run to identify factors related to seabird catch rates both at night and during the day, factors related to seabird interactions with fishing gear, and then factors relating to flesh footed shearwater captures only. Of all the seabirds caught, fleshfooted shearwaters are the most abundant and have the greatest diving and foraging ability.

The current analyses are unable to compare mitigation operations to control operations, but can compare across observed fishing operations (all of which were using some type of mitigation measure) and determine within that set of operations, what factors were significantly related to seabird catch rate.

Factors effecting seabird interactions with and capture by ETBF longline gear:

The effect of different vessel, gear, environmental and seasonal factors on seabird interactions with and captures by longline gear was assessed using 4 separate models. Two of the models analysed seabird (all species) captures for daytime and night time operations separately. A third model analysed fleshfooted shearwater catch rates and the final model assessed factors related to the number of interactions between seabirds (all species) and longline gear.

Most of the models assessed 20 different factors for their relationship to catch rates or interactions, however the model for bird captures at night could only consider 10 of these factors due to a lack of data (Table 5.1). The following discusses the relationship between each of the factors and seabird captures or interactions for all model types to highlight commonalities and disparities between models.

Seabird abundance (number of birds counted in vicinity of the vessel during fishing) during daytime operations was positively related to both interactions with and captures of all seabirds, and to captures of fleshfooted shearwaters (when analysed separately). In other words, captures or interactions will be more frequent if there are more birds in the vicinity of the vessel. This is not unexpected. Abundance was not considered in the night time models. These results suggest that fisheries managers could consider abundance triggered mitigation measures as potential management options, such as for example, a "move on" condition, by which fishers determine local seabird abundance via simple counts, and if these exceed a determined level, they must move on and fish in an area that does not exceed that level.

Night setting: While data restrictions (i.e. restricted use of abundance terms for day sets only when abundance counts can be accurately estimated) did not allow inclusion of a day/night term in any of the models, night set nominal catch rates of seabirds were 77% lower than those of the mean day time catch rates (for all birds). This supports previous studies results which have shown setting longlines at night can be a simple and effective technique, reducing seabird catch rates between 60-96% (Murray *et al*,. 1993; Klaer & Polacheck, 1995; Cherel *et al.*, 1996; Gales *et al.*, 1998; McNamara *et al.* 1999; Brothers *et al.* 1999b), although these studies were not always employing other mitigation measures also. While in the current study the data did not support analyses of the relative effect of night setting on different species catch rates, other studies have demonstrated that the effectiveness varies between fisheries and seasonally within a fishery as some species are more active at night than others. Night setting has been shown to be less effective during full moons (Brothers *et al.* 1999b) and at higher latitudes when hours of darkness are reduced. McNamara *et al.* (1999) also observed albatrosses landing close to the bright, buoyant chemical light sticks attached to branchlines on longlines targeting swordfish and noted the importance of reducing a vessel's aft-facing deck lighting in order to reduce the visibility of baited hooks at night. There is little information available on the effect of night setting on target species, but a BRS proposal to assess the impacts of mitigation measures (for both seabirds, turtles and sharks) on target catch is currently under consideration by funding bodies.

For daytime fishing operations, the ***percentage of hooks set during daylight hours*** is positively related to seabird interactions and catches, and to fleshfooted shearwater captures. This might be expected given that the period during which the birds are most likely to detect and attempt to take baited hooks, and when the baited hooks are within a range that can be accessed by the birds, will be during setting, and the likelihood of detection is higher when there is light. This finding in some way confirms that setting at night will result in lower catch rates, despite a model including day and night terms not being used here.

Trial type (being chute, double tori-60g and tori line trials) was significantly related to both seabird catch and to flesh footed shearwater catches. Catches of both were significantly higher in the chute trial when compared to trials using tori lines, with the single tori line trial having the lowest catch rates. In contrast, the number of daytime interactions between seabirds and longline gear did not vary by trial, suggesting that different mitigation measures had more effect on catch rates than they did on seabird interactions. In other words, seabirds made similar numbers of attempts at eating baits on hooks across the different trials, but fewer were caught at a result of these attempts during the tori line trial. Similarly, while a trial type term could not be included in the night time model for seabird captures, a tori pole use term was included and indicated that tori pole use was associated with lowered seabird catch rates at night.

Bait life status appears to hold a different relationship to catches of seabirds depending on whether fishers are operating at night or during the day. During the day, catch rates on live baited hooks are higher than on dead baited hooks, but the opposite holds true for catches of seabirds at night. An explanation for such a difference in the relationship is not clearly apparent, particularly when one considers that there was no significant effect of bait life status on seabird interactions nor on capture of fleshfooted shearwaters only. It may be possible that live bait react differently to placement in the water at night when compared to day and that this differential behaviour affects their likelihood of capturing the attention of seabirds or seabird ability to capture the bait. It is possible the difference is due to the comparatively small amount of data available for analyses of night sets, and the possibility that the data is consequently not representative of night setting operations in general.

The ***season*** in which a fishing operation occurs appears to be significantly related to both interactions with and captures of seabirds by longline gear. Across all models, spring had significantly higher catches or interactions (for all seabirds and for fleshfooted shearwaters only) relative to other seasons in most instances, with winter being associated with the lowest catch rates. There are a number of reasons why this trend may occur. The abundance of seabirds within the southern and central fishery zones is highest in spring and lowest in winter. Spring is the breeding season for a number of species and the breeding grounds occur within or on the periphery of the fishery area. For example, flesh-footed shearwaters, which comprised nearly 80% of the total observed seabird catch, have breeding populations in the Tasman Sea region in the breeding season, which extends through Spring, Summer and Autumn. They migrate to the northern hemisphere in the non-breeding season (winter), explaining the lack on incidental catch in the ETBF in that season. Black browed albatross, a relatively common incidental catch, have a breeding season also in spring within the fishery region.

As mentioned earlier, the ***use of tori lines*** was associated with significantly reduced catch rates for seabirds, both for daytime sets (x% reduction in nominal catch rates) and nigh-time sets (x% reduction). The latter finding suggests a visual deterrent is still effective for night setting, possibly due to light emitted by boat and by the moon being sufficient to allow bait detection by seabirds, but also be deterred by the tori lines. The same relationship between tori line and catch rates was found when only flesh footed shearwater catches were assessed. It is more difficult to explain why the use of tori lines would not show a similar relationship to the number of seabird interactions. In theory, tori-lines act as a visual deterrent to seabirds and should reduce both interactions and catches. It may be that some records excluded as “NAs” (ie interactions not recorded), were in fact zero interactions, so the number of zero interaction records in the model could be reduced. AFMA will be checking these records.

Other studies have shown bird scaring lines can reduce seabird catch rates by 30-70% in pelagic tuna longline fisheries (Brothers 1991, Klaer and Polacheck 1995). The two current tori pole type trials both had lower catch rates when compared to the chute trial. That said, data was not collected from control vessels hence we can not draw firm conclusions regarding the effectiveness of tori lines relative to normal fishing operations.

Melvin (2000) found that paired streamer lines successfully reduced seabird catch rates by 88-100% compared to single streamer lines which reduced catch rates between 71-96% (in demersal longline fishery). The characteristics of a bird scaring line will have some influence on the effectiveness of the line as a seabird bycatch mitigation measure and it is more difficult for a bird scaring line to be as effective in pelagic longline fisheries compared to demersal (Brothers *et al.* 1999). A number of other factors may also influence the effectiveness of bird scaring lines, particularly the sink rate of the longline gear. For example, Smith (2001) found that some sections of longline had not reached a depth of 5m or more by the end of the aerial section of the tori line (this is within the diving range of some seabird species) and suggested this may be due to propeller wash, turbulence or vessel movement caused by swell. Melvin (2000) hypothesized that the combination of weighted longline gear and paired streamer lines would result in seabird catch rates close to zero (for demersal longline fishery), but this was not the case for the Double tori-60g trial which did catch seabirds at above the target level. As stated previously, many of the factors which might influence the success of such trials could not be included in the current models.

Bouyline length was found to be positively related to seabird captures and to fleshfooted shearwater captures, for daytime sets, but not related to catches for night sets and not related to seabird interactions. It is possible that greater lengths of bouy line have a greater positive buoyancy to counteract the weight of the hooks, baits and swivels, hence keeping the baits within the foraging/diving range of the birds for longer. Alternately, bouyline length may be closely correlated with other fishing method factors for which information was not collected, but which might actually be the factors influencing catch rates.

Lightstick use was associated with significantly lower seabird catches for night sets. It is possible that the birds are more attracted to the lightsticks than to the baited hooks and therefore catch rates on hooks are lower. McNamara *et al.* (1999) observed albatrosses landing close to the bright, buoyant chemical light sticks attached to branchlines on longlines targeting swordfish. Alternately, the lightsticks may act as a deterrent at night. Unfortunately, interactions with longline gear can not be assessed at night by observers due to restricted visual range.

Vessel size was another factor found to have a significant effect on catches of seabirds for night-time sets only. Larger vessels were associated with higher catch rates. It is possible that larger vessels are more detectable by seabirds at night, possibly if they have more onboard lights, or make greater noise (allowing detection and homing by seabirds over greater distances). Larger vessels are generally capable of longer trips and therefore might associate greater numbers of seabirds over that time than smaller vessels. If this was the case, it would explain why vessel size was not a significant factor for any of the models based on daytime fishing operations, as those models have an “abundance” term that would account for such an effect of vessel size. The length of trip by vessels is a term that might be worth including in future models, based on observer observations that increasing numbers of seabirds associate to vessels on successive days of a trip.

A ***vessel*** term was also included in the models as a random effect and it was found that vessel explained some variation in catch rates of all seabirds during day time, after variation due to other factors was accounted for, but did not explain significant variation in catches or interactions for the other models.

A number of other factors were considered within each of these models but not included after they were found not to explain any of the variation in interactions or catches of seabirds by longline. These factors included whether a line shooter was used or not, the location of the birds relative to the boat (e.g. above line setter, off bow etc), soak time, distance between branchlines, hooks per basket, length of branchlines, leader length, size of swivel weights and the distance between the hook and the weight.

These findings have potential relevance to management options that might be considered to further mitigate against seabird captures in the general fishery:

1. Seabird catches and interactions are higher where seabird abundance is higher, suggesting that spatial restrictions on fishing might be considered to reduce the likelihood on vessels encountering high abundance times and areas.

2. The use of tori poles results in significantly reduced catch rates of seabirds compared to fishing operations not using tori poles.

3. Catch rates and interaction rates for flesh footed shearwater and for seabirds (as grouped in one model) are significantly higher in spring than in most other seasons, for most of the models, adding a potential temporal element to possible spatial based management options that might be considered.

4. The catch and interaction levels of seabirds (including flesh footed shearwaters) increases as the proportion of hooks set in daylight increases. This supports the idea that catch and interactions are lower for night time sets and that night setting is an effective mitigation measure. It backs up current regulations requiring fishers in some areas to set at night.

5. The use of lightsticks at night appears to be related to lower catches of seabirds at night. This is a relatively new finding and should be tested in further trials, to ensure it is not simply correlated to another influencing factor not considered here.

6. The relationship between vessel size, bouyline length and catches of seabirds needs to be further investigated to gain a better understanding of why these might be related to one another.

While most of these results should be reflective of the true relationships between catch rates and the different factors, a number of restrictions were placed on the analyses which meant the results should be treated with appropriate caution.

Restrictions on data analyses and interpretation:

1. ***Data holes*** – According to the AFMA, observer recording of data is fairly comprehensive and consistent. However, the entry of observer data into the AFMA database (soon to be completed) was not finished in time to allow inclusion of all data in the current analyses. A lack of data for potential key factors can mean that such factors have not been considered in the current models nor subsequent advice provision, and other factors (correlated in fishing operations) might be incorrectly identified as influencing catch and interaction levels.

2. ***Lack of controls*** – while it was possible to test the relative effectiveness of different mitigation measures against one another within the models, a lack of observation on control vessels (vessels fishing the same time and areas but without mitigation measures being employed) meant that the mitigation measures could not be assessed against a general fishing vessel (i.e. one not using mitigation). Implementing controls in such trials is difficult but should be considered if relative effects of mitigation measures are to be assessed. That said, if the ultimate goal is simply zero seabird catch, then the use of controls has less importance.

3. ***Lack of data on species other than flesh footed shearwaters*** – the relationship between different factors and the catch of seabirds is likely to vary on a species to species basis, due to difference in the species biology and behaviour as might relate to their abilities to detect fishing vessels, and to forage/dive for baited hooks. The models presented in this chapter are either for all seabirds grouped, or for flesh footed shearwaters. This is because there was too little catch data for species other than flesh footed shearwaters to allow species based models. Subsequently it needs be kept in mind that the "all seabirds" model is likely driven by the relationships between

fleshfooted shearwater captures and different factors. Flesh footed shearwaters make up 77% of the total seabird catch. However as noted earlier, different species populations will be impacted differently by small or large longline catches.

6. Determining seabird bycatch rates under different mitigation scenarios

6.1 Introduction

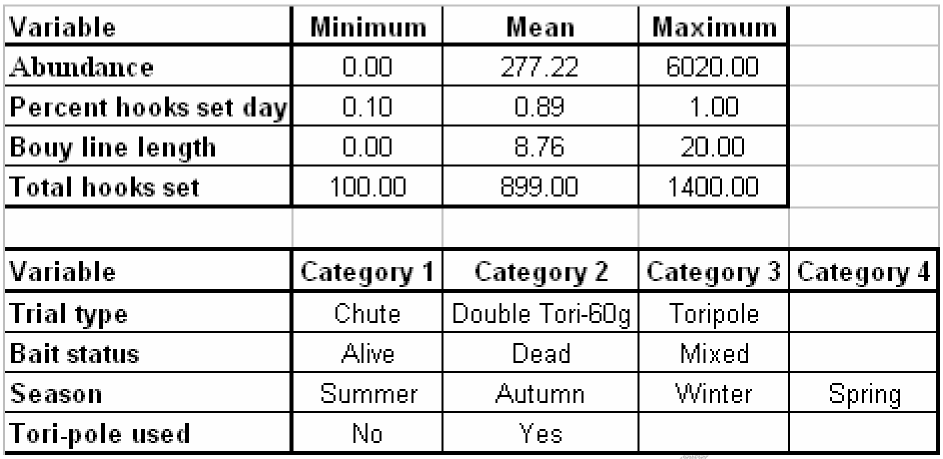
In order to provide more information about the frequency of bycatch and associated uncertainty under certain scenarios (based on the data available), model predictions were generated using the model for the overall capture of seabirds. It is intended that such scenario predictions might assist in future mitigation trial design and in general management decision making with regard to incidental catches of seabirds by longline. The standard errors of the model predictions were then calculated based on bootstrapping using 500 replicates. The predictions have been produced for each combination of categorical variable and the minimum, mean and maximum for numeric variables.

6.2 Methods

The original model for seabird captures during the day identified 8 factors as being significantly related to catches of seabirds, these factors being the trial type, abundance, bait status, season, percentage of hooks set in daylight, whether a tori pole was used, buoyline length, and total hooks set. In order to predict catches of seabirds under different scenarios (i.e. different combinations of factors that relate to seabird capture) each of these factors was assigned levels at which predictions were made. For categorical variables, the levels were simply each of the categories observed. For continuous variable, predictions were made at the minimum, maximum and mean levels observed for that variable (Table 6.1). Predictions were then made based on every possible combination of the different variables and associated levels (i.e. scenarios).

This approach generates a very large number of predictions (>200), and discussing each individually would be of limited use for providing advice to decision makers and industry. The utility of this approach is that the predictions can be sorted to look for patterns in the combinations of factors producing low catch predictions. In addition, predictions using factors identified as being associated with higher catches of seabird (sea chapter 5) can be extracted from the

Table 6.1 – Variables and their associated prediction levels used to estimate seabirds catches under different combinations of factors. Each of the variable selected was found to be significantly related to seabird catch levels for daytime longline operations in the ETBF.



Variable	Minimum	Mean	Maximum
Abundance	0.00	277.22	6020.00
Percent hooks set day	0.10	0.89	1.00
Bouy line length	0.00	8.76	20.00
Total hooks set	100.00	899.00	1400.00

Variable	Category 1	Category 2	Category 3	Category 4
Trial type	Chute	Double Tori-60g	Toripole	
Bait status	Alive	Dead	Mixed	
Season	Summer	Autumn	Winter	Spring
Tori-pole used	No	Yes		

prediction set, and examined to determine what factor combinations produce the lower catch rates when the factor of interest is held constant. For example, catches were identified as being higher in spring. Management may not wish to ban fishing in an entire season, but may wish to look at what combination of factors, during spring, produce the lowest catches, and then impose management measures to ensure those combinations are replicated by fishers during that season. Subsequently, the following results section will discuss the predictions in the context of the following questions:

1. Which combinations of factors produce predictions of zero seabird bycatch rates?
2. Which combinations of factors produce the lowest predictions of seabird bycatch when each of the following factors (identified in chapter 5 as being associated with high catch rates) are held constant:
    a. Season = Spring
    b. Bait use = Alive
    c. Abundance = 6000
    d. Percent hooks set in daylight = 100

6.3 Results

The full table of predictions for all scenarios is presented in Appendix 1. The following present excerpts from that table to highlight the key results. Please note that the high standard errors associated with many of the predictions are due to the limited amount of data available for modelling purposes.

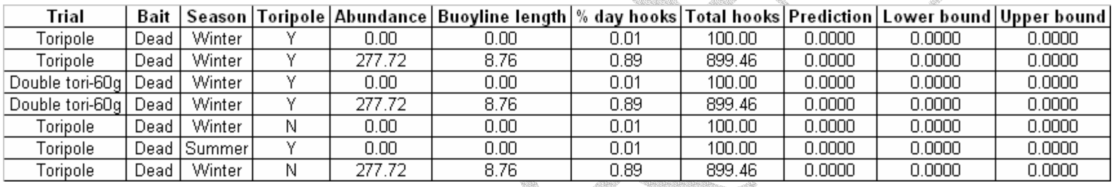
6.3.1 Zero seabird catch scenarios

When the set of predictions and associated scenarios are sorted according to the upper confidence limit for each prediction, it is apparent that certain combinations of factors predominate in association with zero catch rate predictions (Table 6.2). The scenarios listed in Table 6.2 are those whose predicted mean catch and upper confidence limit were zero. The common factors for these scenarios are trials using tori poles, with dead baits, in winter, with minimum or mean values for percentage hooks set during day and bouyline length and total hooks. None of the predictions are based on scenarios including 100% day set hooks, or maximal bouyline line, or maximum abundance, or spring time operations, live bait or chute trial operations.

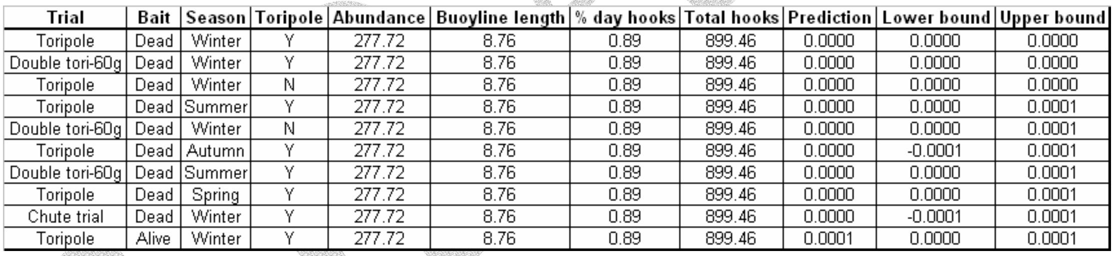
If scenarios in which the "mean" continuous variable values are used are considered (Table 6.2B), it is apparent that nearly all scenarios use dead bait and tori poles to achieve zero or near zero catches. Three scenarios predict an upper catch limit of zero, but all three are for winter, using tori poles and dead bait. The single scenario using live bait is winter based and uses a tori pole. The two scenarios not using tori poles are winter based and use dead baits.

The scenarios described in 6.3.1 are the "best case" scenarios (as can be assessed on the available data, but see discussion). However, under the assumption that managers may wish to explore other options, (for example, options that do not restrict fishers to only fishing in the winter season), we can look at whether any of the predictions of zero or minimal catch occur when certain high catch associated factors are included (e.g. What combination of factors results in lower catches for operations during spring).

Table 6.2 – A) Predicted seabird catch rates with upper confidence limits of zero, and B) Predicted seabird catch rates for predictions using mean continuous variable values.



Trial	Bait	Season	Toripole	Abundance	Buoyline length	% day hooks	Total hooks	Prediction	Lower bound	Upper bound
Toripole	Dead	Winter	Y	0.00	0.00	0.01	100.00	0.0000	0.0000	0.0000
Toripole	Dead	Winter	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0000
Double tori-60g	Dead	Winter	Y	0.00	0.00	0.01	100.00	0.0000	0.0000	0.0000
Double tori-60g	Dead	Winter	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0000
Toripole	Dead	Winter	N	0.00	0.00	0.01	100.00	0.0000	0.0000	0.0000
Toripole	Dead	Summer	Y	0.00	0.00	0.01	100.00	0.0000	0.0000	0.0000
Toripole	Dead	Winter	N	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0000

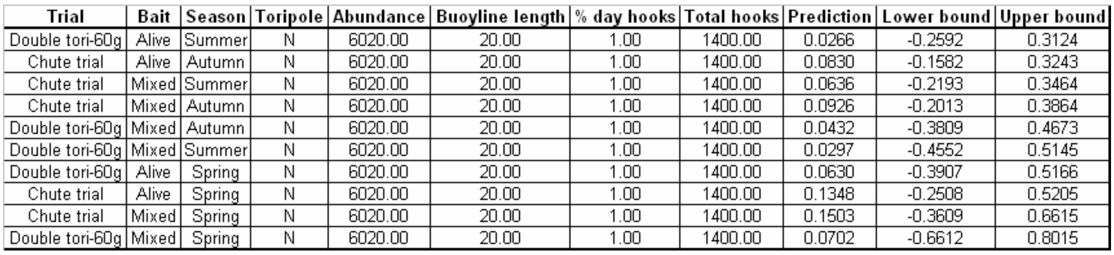


Trial	Bait	Season	Toripole	Abundance	Buoyline length	% day hooks	Total hooks	Prediction	Lower bound	Upper bound
Toripole	Dead	Winter	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0000
Double tori-60g	Dead	Winter	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0000
Toripole	Dead	Winter	N	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0000
Toripole	Dead	Summer	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
Double tori-60g	Dead	Winter	N	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
Toripole	Dead	Autumn	Y	277.72	8.76	0.89	899.46	0.0000	-0.0001	0.0001
Double tori-60g	Dead	Summer	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
Toripole	Dead	Spring	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
Chute trial	Dead	Winter	Y	277.72	8.76	0.89	899.46	0.0000	-0.0001	0.0001
Toripole	Alive	Winter	Y	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0001

6.3.2 Maximal seabird catch scenarios

In contrast to the results presented in 6.3.1, when predictions are sorted according to highest upper bounds on the predictions, then a number of factors commonly occur in the scenarios, being live or mixed baits, no use of tori poles, summer/spring or autumn seasons, high abundance, long bouylines, and all hooks set in daylight (Table 6.5).

Table 6.5 - A) Predicted seabird catch rates sorted and selected according to the 10 predictions with the highest upper confidence limits

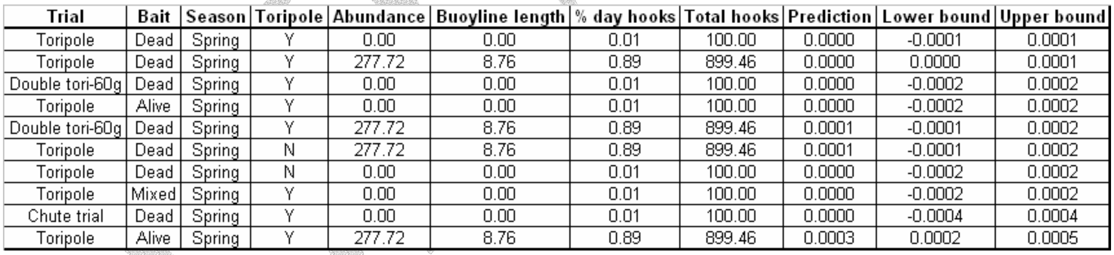


Trial	Bait	Season	Toripole	Abundance	Buoyline length	% day hooks	Total hooks	Prediction	Lower bound	Upper bound
Double tori-60g	Alive	Summer	N	6020.00	20.00	1.00	1400.00	0.0266	-0.2592	0.3124
Chute trial	Alive	Autumn	N	6020.00	20.00	1.00	1400.00	0.0830	-0.1582	0.3243
Chute trial	Mixed	Summer	N	6020.00	20.00	1.00	1400.00	0.0636	-0.2193	0.3464
Chute trial	Mixed	Autumn	N	6020.00	20.00	1.00	1400.00	0.0926	-0.2013	0.3864
Double tori-60g	Mixed	Autumn	N	6020.00	20.00	1.00	1400.00	0.0432	-0.3809	0.4673
Double tori-60g	Mixed	Summer	N	6020.00	20.00	1.00	1400.00	0.0297	-0.4552	0.5145
Double tori-60g	Alive	Spring	N	6020.00	20.00	1.00	1400.00	0.0630	-0.3907	0.5166
Chute trial	Alive	Spring	N	6020.00	20.00	1.00	1400.00	0.1348	-0.2508	0.5205
Chute trial	Mixed	Spring	N	6020.00	20.00	1.00	1400.00	0.1503	-0.3609	0.6615
Double tori-60g	Mixed	Spring	N	6020.00	20.00	1.00	1400.00	0.0702	-0.6612	0.8015

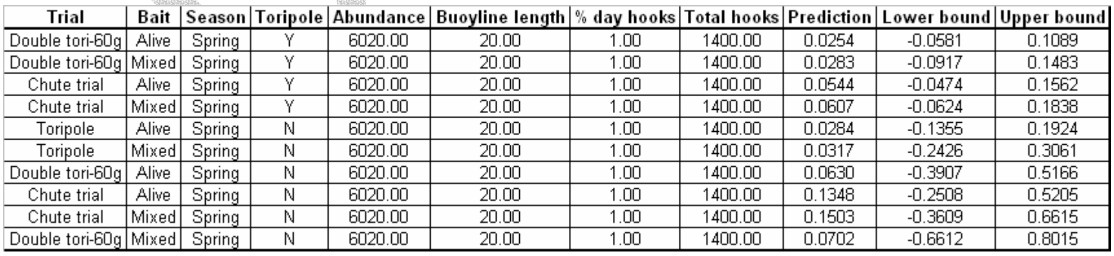
6.3.3 Spring catch scenarios

Analyses presented in chapter 5 indicated that interactions with and catches of seabirds by longline gear in the ETBF are highest in spring. As indicated in Table 6.3, the 10 scenarios with the lowest predicted upper confidence limit, for operations occurring in spring, show some commonalities in factors combinations. All but one are for tori pole associated trials, and the one chute trial scenario has tori poles being used anyway. Most of the scenarios involve the use of dead baits, tori poles, zero bouyline length, and few hooks set during the day. Many assume zero abundance, but given in reality that abundance tends to be higher during spring, and is beyond the control of fishers or managers, scenarios associated with higher abundance but low predicted catch levels are also presented. In the cases where abundance is set at 277, dead baits and tori poles are used. In other word, during spring when abundance is high, vessels might expect lower catch rates using tori poles and dead baits. Appendix 1 presents the full range of predictions and allows for consideration of other options not considered here. In contrast, the 10 scenarios with the highest predicted upper confidence limits (all of which are greater than the 0.05 target level), for operations occurring in spring, predominantly use live or mixed baits, no tori poles, long buoylines, large sets, with all hooks deployed in

Table 6.3 – Predicted seabird catch rates where Season=spring, sorted and selected according to the 10 predictions with the A) lowest upper confidence limits, and B) highest upper confidence limits



Trial	Bait	Season	Toripole	Abundance	Buoyline length	% day hooks	Total hooks	Prediction	Lower bound	Upper bound
Toripole	Dead	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
Toripole	Dead	Spring	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
Double tori-60g	Dead	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
Toripole	Alive	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
Double tori-60g	Dead	Spring	Y	277.72	8.76	0.89	899.46	0.0001	-0.0001	0.0002
Toripole	Dead	Spring	N	277.72	8.76	0.89	899.46	0.0001	-0.0001	0.0002
Toripole	Dead	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
Toripole	Mixed	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
Chute trial	Dead	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0004	0.0004
Toripole	Alive	Spring	Y	277.72	8.76	0.89	899.46	0.0003	0.0002	0.0005



Trial	Bait	Season	Toripole	Abundance	Buoyline length	% day hooks	Total hooks	Prediction	Lower bound	Upper bound
Double tori-60g	Alive	Spring	Y	6020.00	20.00	1.00	1400.00	0.0254	-0.0581	0.1089
Double tori-60g	Mixed	Spring	Y	6020.00	20.00	1.00	1400.00	0.0283	-0.0917	0.1483
Chute trial	Alive	Spring	Y	6020.00	20.00	1.00	1400.00	0.0544	-0.0474	0.1562
Chute trial	Mixed	Spring	Y	6020.00	20.00	1.00	1400.00	0.0607	-0.0624	0.1838
Toripole	Alive	Spring	N	6020.00	20.00	1.00	1400.00	0.0284	-0.1355	0.1924
Toripole	Mixed	Spring	N	6020.00	20.00	1.00	1400.00	0.0317	-0.2426	0.3061
Double tori-60g	Alive	Spring	N	6020.00	20.00	1.00	1400.00	0.0630	-0.3907	0.5166
Chute trial	Alive	Spring	N	6020.00	20.00	1.00	1400.00	0.1348	-0.2508	0.5205
Chute trial	Mixed	Spring	N	6020.00	20.00	1.00	1400.00	0.1503	-0.3609	0.6615
Double tori-60g	Mixed	Spring	N	6020.00	20.00	1.00	1400.00	0.0702	-0.6612	0.8015

daylight. They also predict for when abundance is at the maximum observed level. This is unlikely to represent a realistic abundance for the majority of fishing operations in spring.

6.3.3 Live bait scenarios

Another management option that has been considered is the restriction on the use of live bait. Given the higher catch rates of some target species on live bait, this management option is not an optimal one for fishers. Table 6.4 details the 10 scenarios with the lowest predicted upper confidence limit, for operations using live bait. Many of the scenarios assume an abundance of zero, however the key objective in mitigation studies is to reduce seabird capture when there are seabirds present in the vicinity of the boat. In addition, many of the scenarios are for operations in Winter, when abundance and catches of seabirds (in all trials) is very low, regardless of mitigation measures. All but one scenario involves the use of tori pole (and the one that doesn't assumes an abundance of zero in the area). Only one scenario assumes season is spring but again abundance is assumed to be zero.

Table 6.4 - Predicted seabird catch rates where Bait=alive, sorted and selected according to the 10 predictions with the lowest upper confidence limits.

Trial	Bait	Season	Toripole	Abundance	Buoyline length	% day hooks	Total hooks	Prediction	Lower bound	Upper bound
Toripole	Alive	Winter	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
Double tori-60g	Alive	Winter	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
Toripole	Alive	Winter	Y	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0001
Toripole	Alive	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
Toripole	Alive	Winter	N	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
Toripole	Alive	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
Toripole	Alive	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
Double tori-60g	Alive	Winter	Y	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0002
Double tori-60g	Alive	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0003	0.0003
Toripole	Alive	Summer	Y	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0003

6.3.4 Maximum abundance and daylight sets scenarios

One of the key objective in mitigation research is to determine ways in which seabird catches can be reduced or eliminated in situations where local abundance around the vessel is very high, and hook deployment is occurring in daylight when birds can easily detect the baits. Table 6.5 details the 10 scenarios with the highest upper bounds on the predicted catches. These scenarios predominantly use dead baits and tori poles. The one instance of live bait use is for a winter scenario, when catches are typically very low anyway. The one scenario in which tori poles were not used was also in winter. Interestingly, there is one spring time scenario present which suggests that dead baits and tori pole use might be sufficient to hold seabird bycatch rates at very low levels. It is worth noting that in none of the "best case" scenarios where there is high abundance and all hooks are set in daylight, are catches predicted to be zero.

Table 6.5 - Predicted seabird catch rates where Abundance and percentage hooks set during day are maximal, with predictions sorted and selected according to the 10 with the lowest upper confidence limits.

Trial	Bait	Season	Toripole	Abundance	Buoyline length	% day hooks	Total hooks	Prediction	Lower bound	Upper bound
Toripole	Dead	Winter	Y	6020.00	20.00	1.00	1400.00	0.0001	-0.0007	0.0010
Double tori-60g	Dead	Winter	Y	6020.00	20.00	1.00	1400.00	0.0003	-0.0015	0.0022
Toripole	Dead	Summer	Y	6020.00	20.00	1.00	1400.00	0.0004	-0.0017	0.0026
Chute trial	Dead	Winter	Y	6020.00	20.00	1.00	1400.00	0.0007	-0.0018	0.0032
Toripole	Dead	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0006	-0.0023	0.0035
Toripole	Dead	Winter	N	6020.00	20.00	1.00	1400.00	0.0004	-0.0036	0.0044
Toripole	Dead	Spring	Y	6020.00	20.00	1.00	1400.00	0.0010	-0.0036	0.0055
Double tori-60g	Dead	Summer	Y	6020.00	20.00	1.00	1400.00	0.0009	-0.0043	0.0061
Toripole	Alive	Winter	Y	6020.00	20.00	1.00	1400.00	0.0017	-0.0042	0.0076
Double tori-60g	Dead	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0013	-0.0053	0.0080

6.4 Discussion

It is clear from the analyses of available data as presented in this chapter that there are a number of key factors that are consistently associated with low predicted catch rates for seabirds. Clearly winter is the lowest catch season, but this information is only of use if managers were to consider restricting fishing on a seasonal basis. During the highest catch and interaction season, spring, the use of tori poles and dead bait is generally associated with very low catch rates of seabirds, but none of the scenarios predict a zero catch for spring under any combination of factors. Zero catch predictions however should be interpreted with caution, as they may be driven by a lack of data in a given category.

Scenarios in which live bait is used can achieve very low predicted catch rates if tori poles are used and/or local abundance is low with night setting. Again, none of the live bait scenarios predict a zero catch (using upper confidence limits).

All of the best case scenarios predicted for the use of live bait, or fishing in spring, or fishing when local abundance is high and hooks are set in daylight, have predicted upper confidence limits less than the 0.05 TAP target level. This might suggest that any of these combinations of factors will represent options for consideration by management to impose regulations to reduce captures of seabirds. However, in reality this is unlikely to be so, for the following reasons.

As has been highlighted previously in this report, many of the key factors which scientists, fishers and observers believe might influence seabird catches by longline, could not be considered in the models because far too little data was recorded in the observer logbooks for many of those data types to be included. Including such “low data” factors reduces the dataset that can be analysed and consequently increases the uncertainty around the predictions to a level where the results become meaningless. At the other end of the scale, when critical factors can not be included in analyses, then there will be significant deviance between the models and the real data, in other words the explanatory power of the models is limited.

None of the scenarios generate model based predictions of catch that approach either the 1.21 nominal catch rate for the chute trial, even for scenarios in which the hook number is maximal (1400), greater than the per 1000 comparison point. This is likely due to the fact that a number of records with the highest catch (e.g. 44 birds in one shot) did not have key associated data recorded and could not be included in the models.

In summary, the results presented in Chapter 5 and in this chapter provide an indication of the relative importance of some factors to seabird bycatch mitigation. However, it is likely that information pertaining to key factors was not included in the models (because not enough data on these factors was available), and as a result the scenario based predictions presented in this chapter are likely to underestimate seabird bycatch levels. It will be important to ensure prior to future analyses that all data for all shots are available for analyses. Otherwise, analyses such as those conducted here will have reduced value.

7. Recommendations

This report has attempted to address three key issues relating to seabird bycatch in the ETBF, so as to assist managers and industry in dealing with this difficult issue. These are:

4. Provide a method by which mitigation trials can be monitored to determine when they are exceeding the TAP target rate of 0.05 and should be terminated (Chapter 4).

5. Determine what factors (biological, gear, vessel related etc) contribute to seabird bycatch mitigation (Chapter 5).

6. Predict which combinations of these factors (and levels of factors) are likely to produce the lowest seabird bycatch rates (Chapter 6).

These objectives were aimed at providing managers and industry some guidance as to how to proceed with strategies to reduce seabird bycatch levels below the target 0.05 level. None of the mitigation trials to date have achieved this aim.

Discussions of the results of each of these analyses are presented in the relevant chapters. As a result of these analyses, we are putting forward four key recommendations to management,:

6. Data collection by observers must be, if the data is to be of any use in assessments of trial success/failure, more targeted and consistent. It is recognised that observers have a prioritised list of tasks to perform on board, not all of which pertains to seabird bycatch recording. In addition, conditions are not always favourable for the collection of large amounts of detailed data. However, the issue of seabird bycatch is a very serious one for the fishery (i.e. could result in area closures) and analyses such as those presented in this report have the potential to offer very significant insights into what constitutes an effective mitigation regime, providing there is sufficient and consistent data collection occurring pertaining to identified key factors.

7. Despite uncertainty in the analyses due to data limitations, the analyses did indicate that night setting, use of tori poles and dead baits (during the day) significantly reduced catch rates of seabirds and the use of these mitigation measures should be seriously considered as standard.

8. It was also very clear that there is a seasonal effect, with spring being the period of highest catches and winter the lowest. The value of conducting mitigation trials in winter may be limited, and not particularly cost effective, given that few birds of any species were observed caught in the fishery. A more detailed spatial, seasonal analyses of captures could offer fishery managers some spatio-temporal management options (i.e. in the form of closed time-areas).

9. The determination of a mitigation regime that will reduce seabird bycatch rates below the target level is of critical importance to the ETBF. The current analyses have set up models and an assessment framework which can be used to analyse observer data on a more regular basis (e.g. 12 monthly). It is recommended that new data (i.e. 2005/06) be incorporated into the models as soon as possible, with the aim of boosting sample size and allowing additional key factors to be included in the models. Furthermore, the model based consideration of factors relating to seabird abundance (by species)

would provide valuable information towards the consideration of management options.

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Still to be finalised

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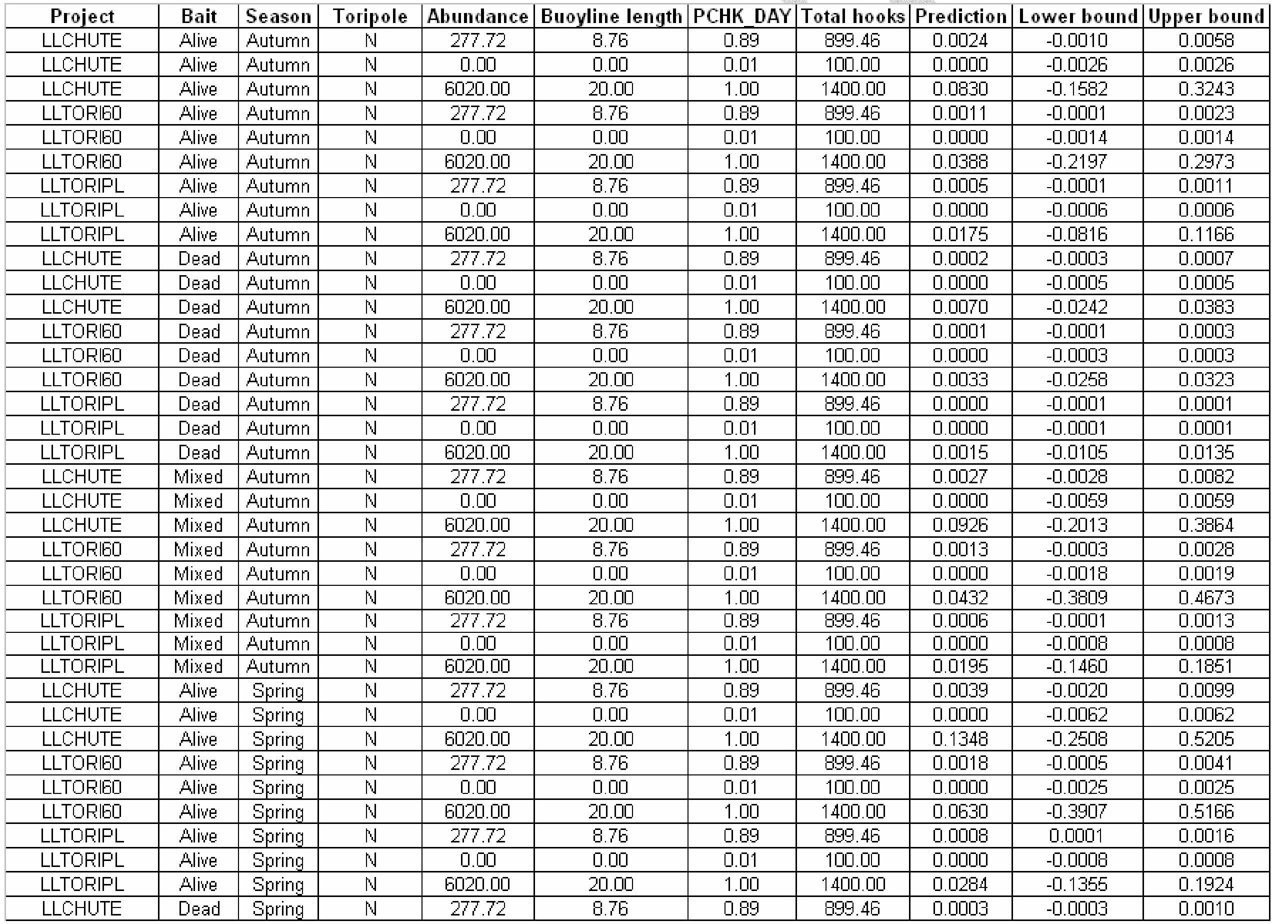
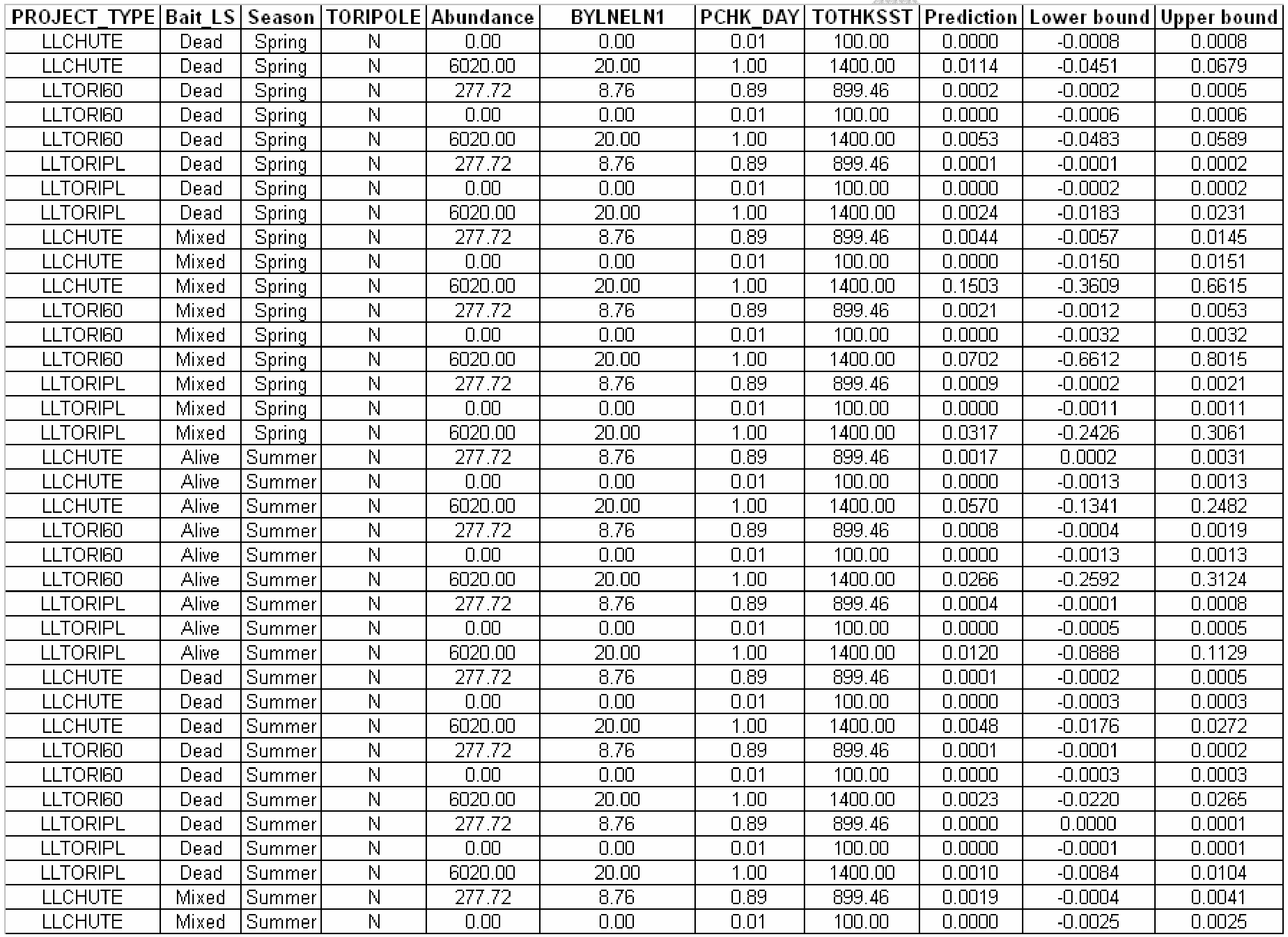
APPENDIX 1

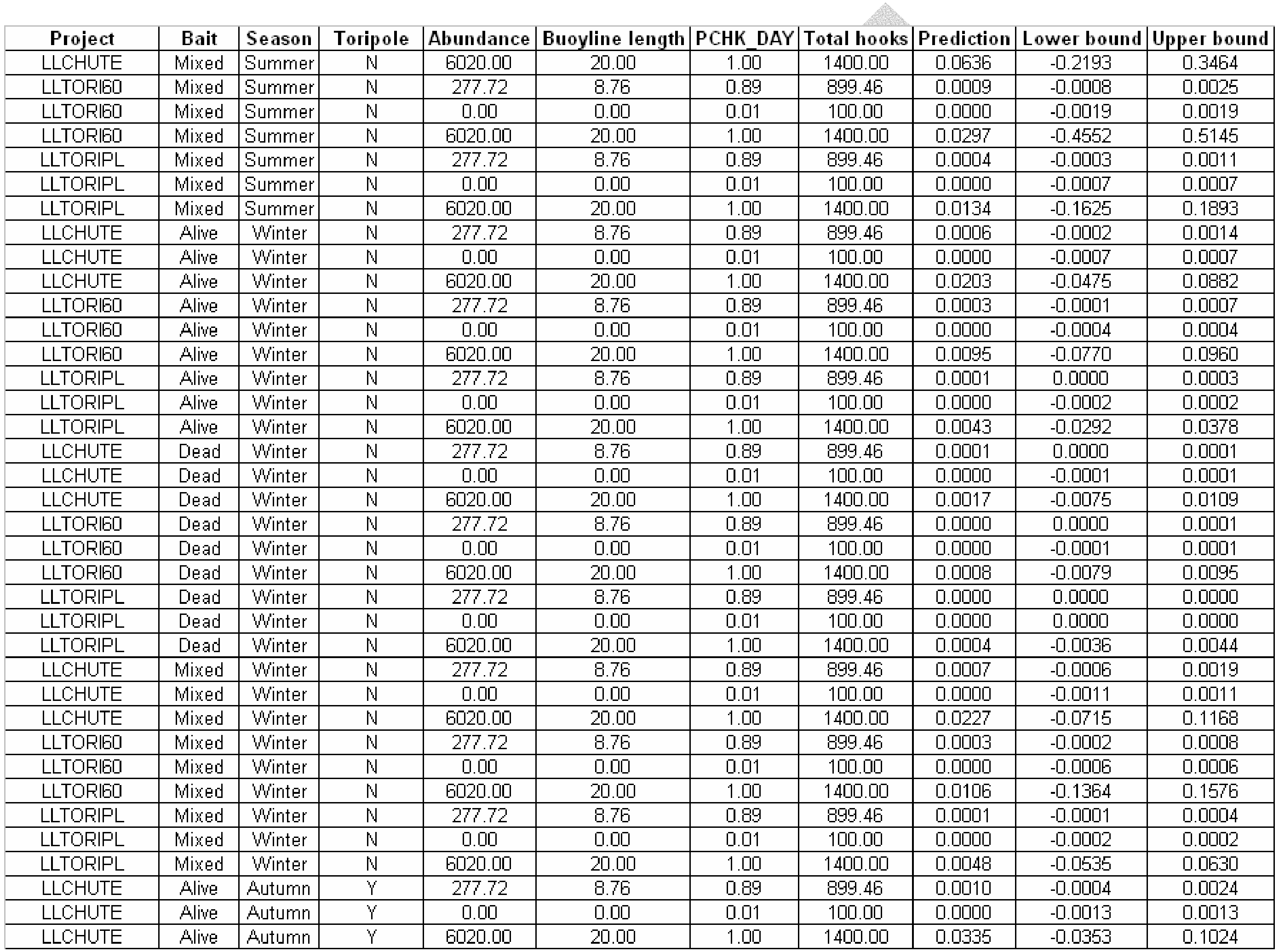
Predicted catch rates for ETBF longliners operating under various mitigation scenarios



Project	Bait	Season	Toripole	Abundance	Buoyline length	PCHK_DAY	Total hooks	Prediction	Lower bound	Upper bound
LLCHUTE	Alive	Autumn	N	277.72	8.76	0.89	899.46	0.0024	-0.0010	0.0058
LLCHUTE	Alive	Autumn	N	0.00	0.00	0.01	100.00	0.0000	-0.0026	0.0026
LLCHUTE	Alive	Autumn	N	6020.00	20.00	1.00	1400.00	0.0830	-0.1582	0.3243
LLTORI60	Alive	Autumn	N	277.72	8.76	0.89	899.46	0.0011	-0.0001	0.0023
LLTORI60	Alive	Autumn	N	0.00	0.00	0.01	100.00	0.0000	-0.0014	0.0014
LLTORI60	Alive	Autumn	N	6020.00	20.00	1.00	1400.00	0.0388	-0.2197	0.2973
LLTORIPL	Alive	Autumn	N	277.72	8.76	0.89	899.46	0.0005	-0.0001	0.0011
LLTORIPL	Alive	Autumn	N	0.00	0.00	0.01	100.00	0.0000	-0.0006	0.0006
LLTORIPL	Alive	Autumn	N	6020.00	20.00	1.00	1400.00	0.0175	-0.0816	0.1166
LLCHUTE	Dead	Autumn	N	277.72	8.76	0.89	899.46	0.0002	-0.0003	0.0007
LLCHUTE	Dead	Autumn	N	0.00	0.00	0.01	100.00	0.0000	-0.0005	0.0005
LLCHUTE	Dead	Autumn	N	6020.00	20.00	1.00	1400.00	0.0070	-0.0242	0.0383
LLTORI60	Dead	Autumn	N	277.72	8.76	0.89	899.46	0.0001	-0.0001	0.0003
LLTORI60	Dead	Autumn	N	0.00	0.00	0.01	100.00	0.0000	-0.0003	0.0003
LLTORI60	Dead	Autumn	N	6020.00	20.00	1.00	1400.00	0.0033	-0.0258	0.0323
LLTORIPL	Dead	Autumn	N	277.72	8.76	0.89	899.46	0.0000	-0.0001	0.0001
LLTORIPL	Dead	Autumn	N	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORIPL	Dead	Autumn	N	6020.00	20.00	1.00	1400.00	0.0015	-0.0105	0.0135
LLCHUTE	Mixed	Autumn	N	277.72	8.76	0.89	899.46	0.0027	-0.0028	0.0082
LLCHUTE	Mixed	Autumn	N	0.00	0.00	0.01	100.00	0.0000	-0.0059	0.0059
LLCHUTE	Mixed	Autumn	N	6020.00	20.00	1.00	1400.00	0.0926	-0.2013	0.3864
LLTORI60	Mixed	Autumn	N	277.72	8.76	0.89	899.46	0.0013	-0.0003	0.0028
LLTORI60	Mixed	Autumn	N	0.00	0.00	0.01	100.00	0.0000	-0.0018	0.0019
LLTORI60	Mixed	Autumn	N	6020.00	20.00	1.00	1400.00	0.0432	-0.3809	0.4673
LLTORIPL	Mixed	Autumn	N	277.72	8.76	0.89	899.46	0.0006	-0.0001	0.0013
LLTORIPL	Mixed	Autumn	N	0.00	0.00	0.01	100.00	0.0000	-0.0008	0.0008
LLTORIPL	Mixed	Autumn	N	6020.00	20.00	1.00	1400.00	0.0195	-0.1460	0.1851
LLCHUTE	Alive	Spring	N	277.72	8.76	0.89	899.46	0.0039	-0.0020	0.0099
LLCHUTE	Alive	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0062	0.0062
LLCHUTE	Alive	Spring	N	6020.00	20.00	1.00	1400.00	0.1348	-0.2508	0.5205
LLTORI60	Alive	Spring	N	277.72	8.76	0.89	899.46	0.0018	-0.0005	0.0041
LLTORI60	Alive	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0025	0.0025
LLTORI60	Alive	Spring	N	6020.00	20.00	1.00	1400.00	0.0630	-0.3907	0.5166
LLTORIPL	Alive	Spring	N	277.72	8.76	0.89	899.46	0.0008	0.0001	0.0016
LLTORIPL	Alive	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0008	0.0008
LLTORIPL	Alive	Spring	N	6020.00	20.00	1.00	1400.00	0.0284	-0.1355	0.1924
LLCHUTE	Dead	Spring	N	277.72	8.76	0.89	899.46	0.0003	-0.0003	0.0010

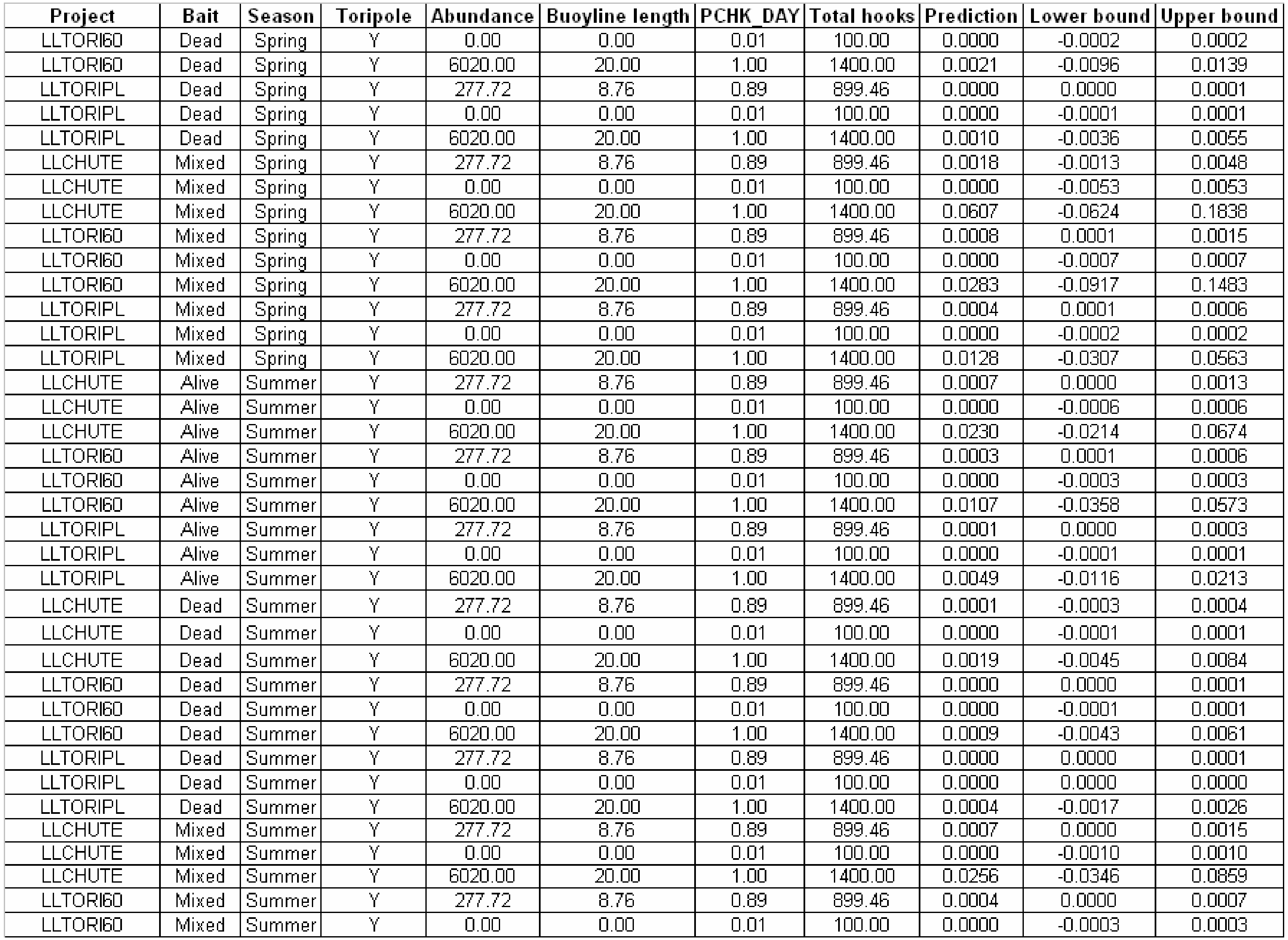


PROJECT_TYPE	Bait_LS	Season	TORIPOLE	Abundance	BYLNELN1	PCHK_DAY	TOTHKSST	Prediction	Lower bound	Upper bound
LLCHUTE	Dead	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0008	0.0008
LLCHUTE	Dead	Spring	N	6020.00	20.00	1.00	1400.00	0.0114	-0.0451	0.0679
LLTORI60	Dead	Spring	N	277.72	8.76	0.89	899.46	0.0002	-0.0002	0.0005
LLTORI60	Dead	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0006	0.0006
LLTORI60	Dead	Spring	N	6020.00	20.00	1.00	1400.00	0.0053	-0.0483	0.0589
LLTORIPL	Dead	Spring	N	277.72	8.76	0.89	899.46	0.0001	-0.0001	0.0002
LLTORIPL	Dead	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLTORIPL	Dead	Spring	N	6020.00	20.00	1.00	1400.00	0.0024	-0.0183	0.0231
LLCHUTE	Mixed	Spring	N	277.72	8.76	0.89	899.46	0.0044	-0.0057	0.0145
LLCHUTE	Mixed	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0150	0.0151
LLCHUTE	Mixed	Spring	N	6020.00	20.00	1.00	1400.00	0.1503	-0.3609	0.6615
LLTORI60	Mixed	Spring	N	277.72	8.76	0.89	899.46	0.0021	-0.0012	0.0053
LLTORI60	Mixed	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0032	0.0032
LLTORI60	Mixed	Spring	N	6020.00	20.00	1.00	1400.00	0.0702	-0.6612	0.8015
LLTORIPL	Mixed	Spring	N	277.72	8.76	0.89	899.46	0.0009	-0.0002	0.0021
LLTORIPL	Mixed	Spring	N	0.00	0.00	0.01	100.00	0.0000	-0.0011	0.0011
LLTORIPL	Mixed	Spring	N	6020.00	20.00	1.00	1400.00	0.0317	-0.2426	0.3061
LLCHUTE	Alive	Summer	N	277.72	8.76	0.89	899.46	0.0017	0.0002	0.0031
LLCHUTE	Alive	Summer	N	0.00	0.00	0.01	100.00	0.0000	-0.0013	0.0013
LLCHUTE	Alive	Summer	N	6020.00	20.00	1.00	1400.00	0.0570	-0.1341	0.2482
LLTORI60	Alive	Summer	N	277.72	8.76	0.89	899.46	0.0008	-0.0004	0.0019
LLTORI60	Alive	Summer	N	0.00	0.00	0.01	100.00	0.0000	-0.0013	0.0013
LLTORI60	Alive	Summer	N	6020.00	20.00	1.00	1400.00	0.0266	-0.2592	0.3124
LLTORIPL	Alive	Summer	N	277.72	8.76	0.89	899.46	0.0004	-0.0001	0.0008
LLTORIPL	Alive	Summer	N	0.00	0.00	0.01	100.00	0.0000	-0.0005	0.0005
LLTORIPL	Alive	Summer	N	6020.00	20.00	1.00	1400.00	0.0120	-0.0888	0.1129
LLCHUTE	Dead	Summer	N	277.72	8.76	0.89	899.46	0.0001	-0.0002	0.0005
LLCHUTE	Dead	Summer	N	0.00	0.00	0.01	100.00	0.0000	-0.0003	0.0003
LLCHUTE	Dead	Summer	N	6020.00	20.00	1.00	1400.00	0.0048	-0.0176	0.0272
LLTORI60	Dead	Summer	N	277.72	8.76	0.89	899.46	0.0001	-0.0001	0.0002
LLTORI60	Dead	Summer	N	0.00	0.00	0.01	100.00	0.0000	-0.0003	0.0003
LLTORI60	Dead	Summer	N	6020.00	20.00	1.00	1400.00	0.0023	-0.0220	0.0265
LLTORIPL	Dead	Summer	N	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
LLTORIPL	Dead	Summer	N	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORIPL	Dead	Summer	N	6020.00	20.00	1.00	1400.00	0.0010	-0.0084	0.0104
LLCHUTE	Mixed	Summer	N	277.72	8.76	0.89	899.46	0.0019	-0.0004	0.0041
LLCHUTE	Mixed	Summer	N	0.00	0.00	0.01	100.00	0.0000	-0.0025	0.0025

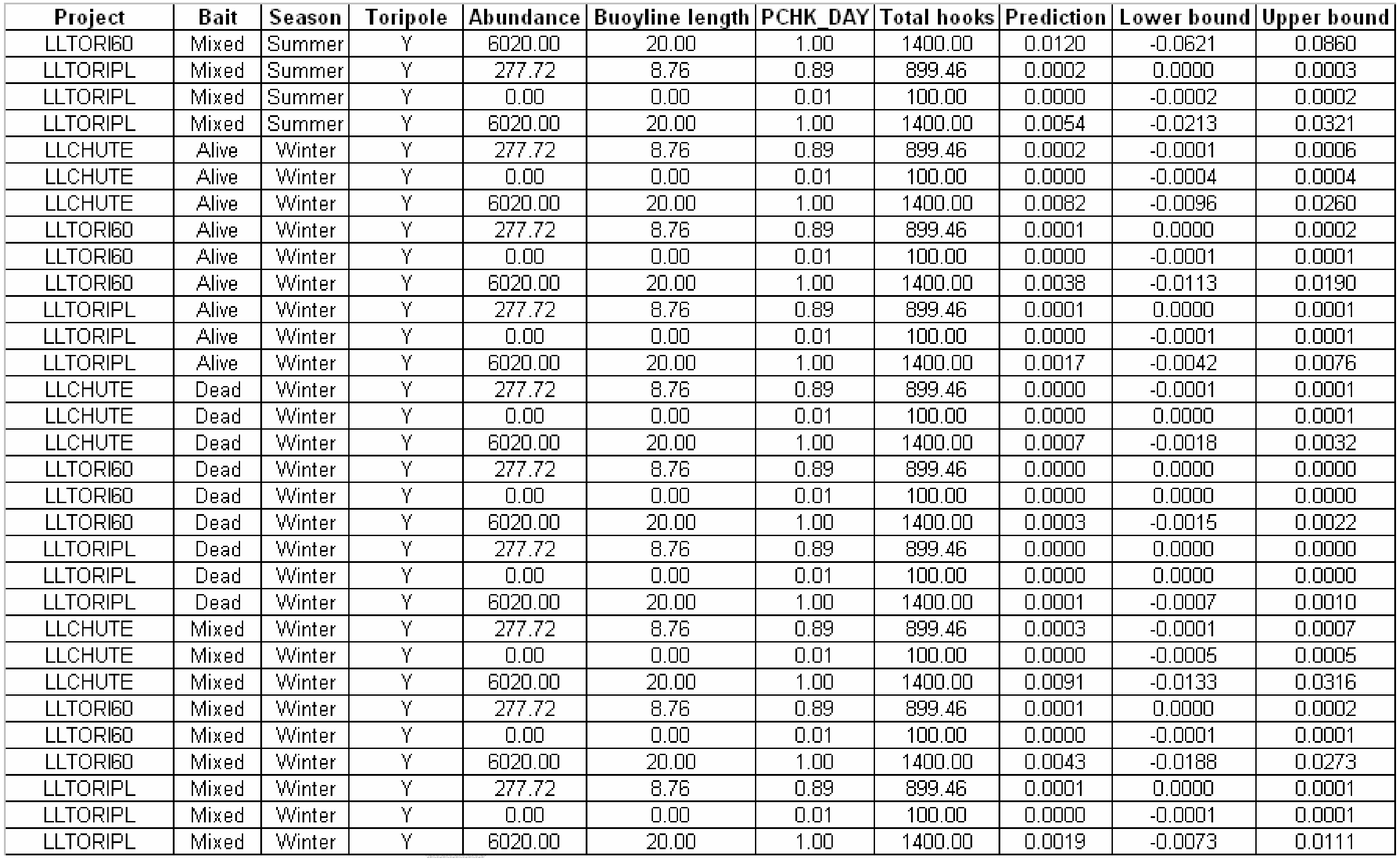


Project	Bait	Season	Toripole	Abundance	Buoyline length	PCHK_DAY	Total hooks	Prediction	Lower bound	Upper bound
LLCHUTE	Mixed	Summer	N	6020.00	20.00	1.00	1400.00	0.0636	-0.2193	0.3464
LLTORI60	Mixed	Summer	N	277.72	8.76	0.89	899.46	0.0009	-0.0008	0.0025
LLTORI60	Mixed	Summer	N	0.00	0.00	0.01	100.00	0.0000	-0.0019	0.0019
LLTORI60	Mixed	Summer	N	6020.00	20.00	1.00	1400.00	0.0297	-0.4552	0.5145
LLTORIPL	Mixed	Summer	N	277.72	8.76	0.89	899.46	0.0004	-0.0003	0.0011
LLTORIPL	Mixed	Summer	N	0.00	0.00	0.01	100.00	0.0000	-0.0007	0.0007
LLTORIPL	Mixed	Summer	N	6020.00	20.00	1.00	1400.00	0.0134	-0.1625	0.1893
LLCHUTE	Alive	Winter	N	277.72	8.76	0.89	899.46	0.0006	-0.0002	0.0014
LLCHUTE	Alive	Winter	N	0.00	0.00	0.01	100.00	0.0000	-0.0007	0.0007
LLCHUTE	Alive	Winter	N	6020.00	20.00	1.00	1400.00	0.0203	-0.0475	0.0882
LLTORI60	Alive	Winter	N	277.72	8.76	0.89	899.46	0.0003	-0.0001	0.0007
LLTORI60	Alive	Winter	N	0.00	0.00	0.01	100.00	0.0000	-0.0004	0.0004
LLTORI60	Alive	Winter	N	6020.00	20.00	1.00	1400.00	0.0095	-0.0770	0.0960
LLTORIPL	Alive	Winter	N	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0003
LLTORIPL	Alive	Winter	N	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLTORIPL	Alive	Winter	N	6020.00	20.00	1.00	1400.00	0.0043	-0.0292	0.0378
LLCHUTE	Dead	Winter	N	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0001
LLCHUTE	Dead	Winter	N	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLCHUTE	Dead	Winter	N	6020.00	20.00	1.00	1400.00	0.0017	-0.0075	0.0109
LLTORI60	Dead	Winter	N	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
LLTORI60	Dead	Winter	N	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORI60	Dead	Winter	N	6020.00	20.00	1.00	1400.00	0.0008	-0.0079	0.0095
LLTORIPL	Dead	Winter	N	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0000
LLTORIPL	Dead	Winter	N	0.00	0.00	0.01	100.00	0.0000	0.0000	0.0000
LLTORIPL	Dead	Winter	N	6020.00	20.00	1.00	1400.00	0.0004	-0.0036	0.0044
LLCHUTE	Mixed	Winter	N	277.72	8.76	0.89	899.46	0.0007	-0.0006	0.0019
LLCHUTE	Mixed	Winter	N	0.00	0.00	0.01	100.00	0.0000	-0.0011	0.0011
LLCHUTE	Mixed	Winter	N	6020.00	20.00	1.00	1400.00	0.0227	-0.0715	0.1168
LLTORI60	Mixed	Winter	N	277.72	8.76	0.89	899.46	0.0003	-0.0002	0.0008
LLTORI60	Mixed	Winter	N	0.00	0.00	0.01	100.00	0.0000	-0.0006	0.0006
LLTORI60	Mixed	Winter	N	6020.00	20.00	1.00	1400.00	0.0106	-0.1364	0.1576
LLTORIPL	Mixed	Winter	N	277.72	8.76	0.89	899.46	0.0001	-0.0001	0.0004
LLTORIPL	Mixed	Winter	N	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLTORIPL	Mixed	Winter	N	6020.00	20.00	1.00	1400.00	0.0048	-0.0535	0.0630
LLCHUTE	Alive	Autumn	Y	277.72	8.76	0.89	899.46	0.0010	-0.0004	0.0024
LLCHUTE	Alive	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0013	0.0013
LLCHUTE	Alive	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0335	-0.0353	0.1024

Project	Bait	Season	Toripole	Abundance	Buoyline length	PCHK_DAY	Total hooks	Prediction	Lower bound	Upper bound
LLTORI60	Alive	Autumn	Y	277.72	8.76	0.89	899.46	0.0005	0.0002	0.0008
LLTORI60	Alive	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0003	0.0003
LLTORI60	Alive	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0156	-0.0316	0.0629
LLTORIPL	Alive	Autumn	Y	277.72	8.76	0.89	899.46	0.0002	0.0000	0.0004
LLTORIPL	Alive	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLTORIPL	Alive	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0071	-0.0109	0.0250
LLCHUTE	Dead	Autumn	Y	277.72	8.76	0.89	899.46	0.0001	-0.0004	0.0006
LLCHUTE	Dead	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLCHUTE	Dead	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0028	-0.0069	0.0126
LLTORI60	Dead	Autumn	Y	277.72	8.76	0.89	899.46	0.0000	-0.0001	0.0001
LLTORI60	Dead	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORI60	Dead	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0013	-0.0053	0.0080
LLTORIPL	Dead	Autumn	Y	277.72	8.76	0.89	899.46	0.0000	-0.0001	0.0001
LLTORIPL	Dead	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORIPL	Dead	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0006	-0.0023	0.0035
LLCHUTE	Mixed	Autumn	Y	277.72	8.76	0.89	899.46	0.0011	-0.0007	0.0029
LLCHUTE	Mixed	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0023	0.0023
LLCHUTE	Mixed	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0374	-0.0378	0.1125
LLTORI60	Mixed	Autumn	Y	277.72	8.76	0.89	899.46	0.0005	0.0002	0.0008
LLTORI60	Mixed	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0003	0.0003
LLTORI60	Mixed	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0174	-0.0512	0.0861
LLTORIPL	Mixed	Autumn	Y	277.72	8.76	0.89	899.46	0.0002	0.0000	0.0004
LLTORIPL	Mixed	Autumn	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLTORIPL	Mixed	Autumn	Y	6020.00	20.00	1.00	1400.00	0.0079	-0.0186	0.0344
LLCHUTE	Alive	Spring	Y	277.72	8.76	0.89	899.46	0.0016	-0.0005	0.0037
LLCHUTE	Alive	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0024	0.0024
LLCHUTE	Alive	Spring	Y	6020.00	20.00	1.00	1400.00	0.0544	-0.0474	0.1562
LLTORI60	Alive	Spring	Y	277.72	8.76	0.89	899.46	0.0007	0.0002	0.0013
LLTORI60	Alive	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0006	0.0006
LLTORI60	Alive	Spring	Y	6020.00	20.00	1.00	1400.00	0.0254	-0.0581	0.1089
LLTORIPL	Alive	Spring	Y	277.72	8.76	0.89	899.46	0.0003	0.0002	0.0005
LLTORIPL	Alive	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLTORIPL	Alive	Spring	Y	6020.00	20.00	1.00	1400.00	0.0115	-0.0173	0.0402
LLCHUTE	Dead	Spring	Y	277.72	8.76	0.89	899.46	0.0001	-0.0003	0.0006
LLCHUTE	Dead	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0004	0.0004
LLCHUTE	Dead	Spring	Y	6020.00	20.00	1.00	1400.00	0.0046	-0.0121	0.0213
LLTORI60	Dead	Spring	Y	277.72	8.76	0.89	899.46	0.0001	-0.0001	0.0002



Project	Bait	Season	Toripole	Abundance	Buoyline length	PCHK_DAY	Total hooks	Prediction	Lower bound	Upper bound
LLTORI60	Dead	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLTORI60	Dead	Spring	Y	6020.00	20.00	1.00	1400.00	0.0021	-0.0096	0.0139
LLTORIPL	Dead	Spring	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
LLTORIPL	Dead	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORIPL	Dead	Spring	Y	6020.00	20.00	1.00	1400.00	0.0010	-0.0036	0.0055
LLCHUTE	Mixed	Spring	Y	277.72	8.76	0.89	899.46	0.0018	-0.0013	0.0048
LLCHUTE	Mixed	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0053	0.0053
LLCHUTE	Mixed	Spring	Y	6020.00	20.00	1.00	1400.00	0.0607	-0.0624	0.1838
LLTORI60	Mixed	Spring	Y	277.72	8.76	0.89	899.46	0.0008	0.0001	0.0015
LLTORI60	Mixed	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0007	0.0007
LLTORI60	Mixed	Spring	Y	6020.00	20.00	1.00	1400.00	0.0283	-0.0917	0.1483
LLTORIPL	Mixed	Spring	Y	277.72	8.76	0.89	899.46	0.0004	0.0001	0.0006
LLTORIPL	Mixed	Spring	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLTORIPL	Mixed	Spring	Y	6020.00	20.00	1.00	1400.00	0.0128	-0.0307	0.0563
LLCHUTE	Alive	Summer	Y	277.72	8.76	0.89	899.46	0.0007	0.0000	0.0013
LLCHUTE	Alive	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0006	0.0006
LLCHUTE	Alive	Summer	Y	6020.00	20.00	1.00	1400.00	0.0230	-0.0214	0.0674
LLTORI60	Alive	Summer	Y	277.72	8.76	0.89	899.46	0.0003	0.0001	0.0006
LLTORI60	Alive	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0003	0.0003
LLTORI60	Alive	Summer	Y	6020.00	20.00	1.00	1400.00	0.0107	-0.0358	0.0573
LLTORIPL	Alive	Summer	Y	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0003
LLTORIPL	Alive	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORIPL	Alive	Summer	Y	6020.00	20.00	1.00	1400.00	0.0049	-0.0116	0.0213
LLCHUTE	Dead	Summer	Y	277.72	8.76	0.89	899.46	0.0001	-0.0003	0.0004
LLCHUTE	Dead	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLCHUTE	Dead	Summer	Y	6020.00	20.00	1.00	1400.00	0.0019	-0.0045	0.0084
LLTORI60	Dead	Summer	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
LLTORI60	Dead	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORI60	Dead	Summer	Y	6020.00	20.00	1.00	1400.00	0.0009	-0.0043	0.0061
LLTORIPL	Dead	Summer	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0001
LLTORIPL	Dead	Summer	Y	0.00	0.00	0.01	100.00	0.0000	0.0000	0.0000
LLTORIPL	Dead	Summer	Y	6020.00	20.00	1.00	1400.00	0.0004	-0.0017	0.0026
LLCHUTE	Mixed	Summer	Y	277.72	8.76	0.89	899.46	0.0007	0.0000	0.0015
LLCHUTE	Mixed	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0010	0.0010
LLCHUTE	Mixed	Summer	Y	6020.00	20.00	1.00	1400.00	0.0256	-0.0346	0.0859
LLTORI60	Mixed	Summer	Y	277.72	8.76	0.89	899.46	0.0004	0.0000	0.0007
LLTORI60	Mixed	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0003	0.0003



Project	Bait	Season	Toripole	Abundance	Buoyline length	PCHK_DAY	Total hooks	Prediction	Lower bound	Upper bound
LLTORI60	Mixed	Summer	Y	6020.00	20.00	1.00	1400.00	0.0120	-0.0621	0.0860
LLTORIPL	Mixed	Summer	Y	277.72	8.76	0.89	899.46	0.0002	0.0000	0.0003
LLTORIPL	Mixed	Summer	Y	0.00	0.00	0.01	100.00	0.0000	-0.0002	0.0002
LLTORIPL	Mixed	Summer	Y	6020.00	20.00	1.00	1400.00	0.0054	-0.0213	0.0321
LLCHUTE	Alive	Winter	Y	277.72	8.76	0.89	899.46	0.0002	-0.0001	0.0006
LLCHUTE	Alive	Winter	Y	0.00	0.00	0.01	100.00	0.0000	-0.0004	0.0004
LLCHUTE	Alive	Winter	Y	6020.00	20.00	1.00	1400.00	0.0082	-0.0096	0.0260
LLTORI60	Alive	Winter	Y	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0002
LLTORI60	Alive	Winter	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORI60	Alive	Winter	Y	6020.00	20.00	1.00	1400.00	0.0038	-0.0113	0.0190
LLTORIPL	Alive	Winter	Y	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0001
LLTORIPL	Alive	Winter	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORIPL	Alive	Winter	Y	6020.00	20.00	1.00	1400.00	0.0017	-0.0042	0.0076
LLCHUTE	Dead	Winter	Y	277.72	8.76	0.89	899.46	0.0000	-0.0001	0.0001
LLCHUTE	Dead	Winter	Y	0.00	0.00	0.01	100.00	0.0000	0.0000	0.0001
LLCHUTE	Dead	Winter	Y	6020.00	20.00	1.00	1400.00	0.0007	-0.0018	0.0032
LLTORI60	Dead	Winter	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0000
LLTORI60	Dead	Winter	Y	0.00	0.00	0.01	100.00	0.0000	0.0000	0.0000
LLTORI60	Dead	Winter	Y	6020.00	20.00	1.00	1400.00	0.0003	-0.0015	0.0022
LLTORIPL	Dead	Winter	Y	277.72	8.76	0.89	899.46	0.0000	0.0000	0.0000
LLTORIPL	Dead	Winter	Y	0.00	0.00	0.01	100.00	0.0000	0.0000	0.0000
LLTORIPL	Dead	Winter	Y	6020.00	20.00	1.00	1400.00	0.0001	-0.0007	0.0010
LLCHUTE	Mixed	Winter	Y	277.72	8.76	0.89	899.46	0.0003	-0.0001	0.0007
LLCHUTE	Mixed	Winter	Y	0.00	0.00	0.01	100.00	0.0000	-0.0005	0.0005
LLCHUTE	Mixed	Winter	Y	6020.00	20.00	1.00	1400.00	0.0091	-0.0133	0.0316
LLTORI60	Mixed	Winter	Y	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0002
LLTORI60	Mixed	Winter	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORI60	Mixed	Winter	Y	6020.00	20.00	1.00	1400.00	0.0043	-0.0188	0.0273
LLTORIPL	Mixed	Winter	Y	277.72	8.76	0.89	899.46	0.0001	0.0000	0.0001
LLTORIPL	Mixed	Winter	Y	0.00	0.00	0.01	100.00	0.0000	-0.0001	0.0001
LLTORIPL	Mixed	Winter	Y	6020.00	20.00	1.00	1400.00	0.0019	-0.0073	0.0111