THE FISHERY AND BIOLOGY OF THE ROCK LOBSTER *JASUS TRISTANI* AT THE TRISTAN DA CUNHA ISLAND GROUP

by

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DECLARATION

I, James Glass, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed

Date

ABSTRACT

The Tristan lobster *Jasus tristani* is distributed among several isolated islands and submerged seamounts in the South East Atlantic Ocean. This species occurs only at the Tristan da Cunha group, a British Overseas Territory and the World's most remote inhabited island, and in international waters at Vema Seamount 1680 km ENE of Tristan. All these populations are exploited commercially. The catch, processing and export of *J. tristani* is the most important economic activity for the inhabitants of Tristan da Cunha, providing the livelihood of many families and accounting for approximately 80% of the Island's revenue.

Sustainable harvesting of this valuable resource requires accurate long-term data on catch and effort, as well as information on the most important biological parameters such as growth, recruitment, moulting and reproductive cycles. This information is critical for robust assessments and management strategies. This thesis describes the history of the lobster fishery at the Tristan da Cunha island group, reporting on catches and trends in Catch Per Unit Effort between 1967 and 2010. A total of 247,014 lobster samples, both sexes combined, was sampled for size composition and sex ratios, as well as 1,526 lobsters for length/weight relationships, between 1997 and 2010. This confirms earlier findings that females have broader and heavier tails than males for the same carapace length (CL).

Results show that males dominate catches at all islands, and their average size was larger than that of females (83.5 ± 14.46 versus 73.4 ± 8.64 mm CL, respectively). Inter-island differences in lobster population structure appear to be caused by differences of food availability as well as in density-dependent growth and survival of young lobsters. The largest lobsters were found at Gough Island (87.2 ± 15.13 mm CL), and the smallest at Inaccessible island (73.2 ± 11.39 mm). Tristan was the next largest to Gough Island (84.0 ± 12.56 mm) followed by Nightingale island (78.2 ± 11.33 mm). Lobsters caught inshore were larger than those caught offshore, although this may be related in part to differences in catches between fishing gear types.

This study showed that fecundity increases in a linear manner with CL, and although larger lobsters clearly produce more eggs than smaller ones, the gain in fecundity is not as great as in some lobster species where fecundity is more closely associated with weight. The study showed no significant differences in egg size between islands, or between large and small females at one island. The egg production per gram of body weight and mean egg diameter both seem to be less than reported in an earlier study in the 1990s. While it seems likely that this is due to differences in the way in which samples were collected (with only stage 2 ova

collected and measured in this study), the possibility of a decline in fecundity needs to be investigated further.

A range of management measures have been developed over the history of the fishery, and important current measures include an annual total allowable catch (TAC) for each island, minimum size limits, and a closed season timed to protect egg-bearing females. The fishery has recently been awarded certification by the Marine Stewardship Council. The study has confirmed that current conversion factors are broadly correct and that different size limits established for each island are justified. Concern is raised, however, by the fall in catch per unit effort and the mean size of lobsters at the three northern islands over the past 7 years. These trends will need to be closely monitored.

There are still many uncertainties over key parameters such as growth and recruitment and the intention is to increase the knowledge base and our understanding of the dynamics of the lobster stock. A research plan has been developed, so that progress can be monitored through the gradual implementation of scientifically defendable fisheries management procedures and increased research and monitoring capacity.

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Finally to my wife Felicity and family, who has been my pillar, through testing times, Thank you!

DEDICATION

I would like to dedicate this Thesis to my family, my wife Felicity, children Norman and Sarah and my two grandchildren Kieran and Connor.

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GLOSSARY

ACAP	Agreement on the Conservation of Albatrosses and Petrels
ANRD	Agriculture and Natural Resources Department
CL	Carapace Length
CPUE	Catch Per Unit Effort
DAFF	Department of Agriculture, Forestry and Fisheries
DFID	Department for International Development
FAO	Food and Agriculture Organisation (of United Nations)
FCO	Foreign and Commonwealth Office
FD	Fisheries Department
GLM	Generalized Linear model
GRT	Gross Register Tonnes
HCR	Harvest Control Rules
LPBD	Large Power Boat Day
MARAM	Marine Research and Assessment Group
MCM	Marine and Coastal Management
MLS	Minimum Legal Size
MRAG	Marine Resources Assessment Group
MSC	Marine Stewardship Council
mt	metric tonnes
MT	Monster Trap
NRD	Natural Resources Department
OMP	Operational Management Procedures
SFO	Sea Fishery Officer
TAC	Total Allowable Catch
TDCDC	Tristan da Cunha Development Company

TDCFD Tristan da Cunha Fisheries Department

TDCG Tristan da Cunha Government

UCT University of Cape Town

Chapter 1

Introduction

1.1 Description of *Jasus tristani* – Discovery and taxonomic importance

The spiny lobster *Jasus tristani* at the Tristan da Cunha island group was first discovered by a scientific expedition by the *HMS Challenger* to Nightingale Island on the 17th October 1873 (Bate, 1888). A Norwegian expedition to Tristan da Cunha during 1937-38 undertook a comprehensive taxonomic study of the Tristan lobster and some years later *J. tristani* was recorded as a separate species from other *Jasus* species by Holthuis and Silvertsen (1967). *Jasus tristani* is one of six extant species in the genus *Jasus* (Holthuis, 1991). All six species are of commercial interest and live in restricted zones in the temperate waters of the southern hemisphere (Holthuis, 1991). The English name for the species is Tristan rock lobster, referring to the islands where the male holotype originates from (Holthuis, 1963).

Recent studies based on mitochonaial DNA have shown an apparent lack of barriers to dispersal and gene flow over thousands of kilometres of the Southern Indian and Atlantic Oceans, and suggest that *Jasus paulensis* and *Jasus tristani* should be synonymized as *Jasus paulensis* (Groeneveld *et al*., 2012).

J. tristani in the Atlantic occurs only around the islands of Tristan da Cunha, Nightingale, Inaccessible, and Gough, and at the Vema Seamount, roughly 2000 km to the north-east of the Tristan da Cunha archipelago (Holthuis, 1991). These islands are volcanic and rise from abyssal depths to the surface, thus separating benthic populations associated with each island. The geography of the Islands, and the distribution and habitat of *J. tristani* is described in detail in Chapter 2.

1.2 Global importance of Spiny Lobsters

Over 90 countries fish or market spiny lobsters. However,more than 70% of the global commercial catch comes from countries bordering on the Caribbean Sea, south-eastern

Atlantic Ocean, the Pacific and the eastern Indian Ocean. The largest producers, by country, are Australia, New Zealand, South Africa, Cuba, Brazil, Mexico and the United States of America (Phillips & Kittaka, 2000; FAO, 2005).

The most convenient means of marketing lobster products is generally as whole frozen lobsters or as frozen lobster tails, although much higher prices can be achieved for live lobster. In 2006 prices were up to US $100 per kilogram for some species of live lobster in Japan (Phillips & Kittaka 2006).

International markets for spiny lobsters are highly variable and dependent on the global economic climate. As an example from the Asian markets, Japanese demand for spiny lobster has declined over the past decade, whereas in China, the demand for imported lobster between 2001 to 2006 increased in value from approximately US $850,000 in 2001 to more than US $5.8 million in 2006 (http://www.globefish.org).

The Food and Agriculture Organization of the United Nations (FAO), in their capture production figures report that the global production of fish, molluscs, and crustaceans was 140 million tonnes in 2007. Of this total production only 228,930 mt were described as lobsters. Similar catches were made over the previous six years (FAO, 2007), although slightly down from the previously year (2006) when 250,558mt were landed. In 2010 lobster catches had increased and the FAO, reported catches of 280,000 mt of lobster, of which 188,000 mt (67%) was of the clawed lobster (family *Nephropidae*), 80,000 mt (28%) of spiny lobsters (*Palinuridae*) and about 10,000 mt (4%) of slipper lobsters (*Scyllaridae*) (FAO, 2012).

In 2011 a limit of 2807.3 mt was in place in New Zealand under the Quota Management System (QMS), of which 2806.8 mt were for the rock lobster *Jasus edwardsii*. However the fishing fleet were unable to catch this quota and the total catch was 2539.9 mt of which 2539.5 mt was *J. edwardsii*. Other major landings of *Jasus* species reported in 2010 were for the Cape rock lobster *Jasus lalandii* 3418 mt, the St. Paul rock lobster *Jasus paulensis* 390 mt and Tristan da Cunha lobster *Jasus tristani* 383 mt.

The South African south and west coast rock lobsters *Palinurus gilchristi* and *Jasus lalandii,* respectively, have an approximate export value of US $14.1 and US $24.5 million per annum respectively (DAFF, 2012).

For *Jasus tristani* there are three main markets: USA, Japan and Australia. The USA market is generally for frozen lobster tails and during the 2011/12 season an average market price of US $24.89 per pound (US $54.76 per kg) was recorded. In Japan, despite poor economic performance during the 2011/12 season, prices for whole cooked and whole raw frozen lobster have remained remarkably resilient at around 2580 Yen per/kg (equivalent to approximately US $27 per kg). The attractiveness of this market has to some extent been influenced by the strong Yen: US $ exchange rate. The market in Australia during the 2011/12 season returned an average of AUD 31.50/kg (approximately US $30 per kg) for whole cooked frozen and whole raw sashimi lobster. The buyers have been showing strong interest in the sashimi grade product which will once again be used by the Hog's Breath Steakhouse chain for its nationwide lobster promotion in 2013. Since the Tristan da Cunha lobster received Marine Stewardship Council (MSC) certification in 2011, the fishing company has received trade enquires from EU based importers. To date, no *J. tristani* has been sold to buyers in the EU (Ovenstone Agencies, 2012).

1.3 Distribution and life history characteristics of *Jasus* lobsters

Six *Jasus* species occur in the mid-latitudes (between 20˚S and 50˚S) in the southern Atlantic, Indian and Pacific Oceans. Their geographic distribution is shown in Table 1.1. *Jasus* lobsters are not only found on the continental shelves of large landmasses, but also occur on offshore ridges, banks and sea-mounts (Holthuis, 1991; Booth, 2006). Several species live around small island groups including the most remote inhabited island in the world, Tristan da Cunha. Other islands at which *Jasus* lobsters are found include St Paul and Amsterdam (South West Indian Ocean), Desventuradas Island (South East Pacific) and New Zealand. The only large landmasses which support populations of *Jasus* in their coastal waters are Australia, and the southern coast of Africa (Phillips, 2006).

Table 1.1: Geographical distribution of the *Jasus* species of lobster

Species	**Geographical distribution**
Jasus lalandii	Southern Africa (central Namibia to Algoa Bay, South Africa)
Jasus edwardsii	Southern Australia (Victoria, South Australia & Tasmania) New Zealand
Jasus frontalis	South Pacific, around Juan Fernandez Islands, Islas Desventuradas
*Jasus paulensis**	Southern Indian Ocean, around St Paul and Amsterdam Islands
Jasus caveorum	Eastern parts of the South Pacific Ocean
*Jasus tristani**	Tristan da Cunha archipelago; Gough Island; Vema seamount

* *Synonymized (*Groeneveld *et al*., 2012).

Jasus tristani inhabits similar environments to the other *Jasus* species, living mainly on rocky reefs and rough ground,from the intertidal zone to depths of 200 m (Holthuis, 1991; Booth, 2006).As with other species, the waters around Tristan are described as cool temperate.

Juvenile *Jasus* lobsters usually inhabit rocky environments in shallow waters, and as they grow larger they become increasingly communal and often aggregate in dens, which protect them from predators (Butler *et al*., 2006; Holthuis, 1991). *Jasus* lobsters are mainly nocturnal foragers, feeding on a range of benthic and non-benthic organisms ranging from kelp (Butler *et al*., 2006), other crustaceans, molluscs and echinoids (Fielder, 1965; Barkai *et al*., 1996; Booth, 2006). Cannibalism may occur during moulting (Heydorn, 1969).

Female *Jasus* lobsters reach sexual maturity at sizes ranging between 56 – 120 mm carapace length (CL), depending on species and environmental conditions (Booth, 2006). Eggs are fertilized externally and after extrusion they attach to the hairs of the pleopods on the ventral abdomen of females (Phillips & Kittaka, 2000). Most of the *Jasus* species bear eggs during winter or spring for a period of between 2 and 6 months. After hatching, the phylosoma larvae are pelagic and drift in ocean currents for between 4 and 22 months (Booth, 2006), whereafter they moult into a puerulus stage. The puerulus is a transparent settlement phase, which swims inshore where they settle to begin a benthic existence. The puerulus moults into the first juvenile stage a few days after settlement. Juveniles moult several times per year and grow relatively fast up to the size at which sexual maturity is reached. Female age-at-maturity ranges between 3 and 7 years, depending on species (Booth, 2006). After reaching maturity, most *Jasus* species moult annually.

However, much shorter seasonal inshore and offshore movements of lobsters are associated with moulting and breeding (Booth, 1997; Atkinson & Branch, 2003; Gardner *et al*., 2003) and are more common in this genus.

1.4 Biology and fisheries of *Jasus tristani*

Scientific interest in the biology and fisheries of *J. tristani* at the Tristan Island group peaked between 1960 and 1990, and several published studies (Pollock & Roscoe, 1977; Roscoe, 1979; Pollock, 1981; 1986; 1991) date from that period. Heydorn (1969) provided good ecological and stock status reference points from the 1960’s, based on a brief survey undertaken in 1967. Further research included tagging programmes, and studies of size at maturity, fisheries performance, growth and population structure determined from DNA (Pollock & Roscoe, 1977; Roscoe, 1979; Pollock, 1981; 1986; 1991; Von der Heyden *et al*., 2007; Groeneveld *et al*., 2012).

Pollock and Roscoe (1977) studied growth between moultsof tagged lobsters, and found that moult increments of adult lobsters were, on average 5 mm for males and 1 mm for females. These growth rates were similar to those recorded for *Jasus lalandii* at some sites off South Africa. Moult increments measured at Inaccessible Island were smaller than at Tristan da Cunha and Nightingale Island, and at all sites the moult increments declined with increasing lobster size.

Pollock (1991) investigated inter-island variations in growth and population structures. He suggested that slower growth rates at Inaccessible island, compared to Tristan da Cunha and Nightingale Island, was as a result of higher survival rates and a greater abundance of juveniles at Inaccessible Island, and therefore greater competition for food and other resources. The higher densities of lobsters result in slower individual growth rates. Pollock (1991) attributed the higher juvenile survival rate at Inaccessible Island to a rougher bottom topography with better shelter from predators in the shallow sub-tidal zone (where pueruli settle), compared to Tristan da Cunha and Nightingale Island.

The tagging results showed that most animals were recaptured 1-2 km from the release point, and no movement was recorded between islands. The steep drop-offs to greater depths between islands probably limit the movements of juvenile and adult lobsters to the individual island shelf areas (Pollock, 1981).

Roscoe (1979) reported that spawning starts in the austral autumn (May) and that females are egg-bearing throughout winter. Females move to shallow waters and cease foraging during daylight while the eggs are at an early stage. Most female *J. tristani* have shed their eggs by October. The smallest egg-bearing females were in the 60-64mm CL size class at Inaccessible Island and in the 70-74 CL class at Tristan da Cunha (Roscoe, 1979), this author postulated that females may mature later at Gough Island because of the water being cooler, although this has not been further investigated. However, observations from the fishermen have reported that females shed their eggs later at Gough (Glass, H. *pers.comm.*).

Von der Heyden *et al*. (2007) compared the mitochondrial DNA of *J. tristani* among the four islands and Vema Seamount. The analysis found no evidence of separate population structure among lobsters at Tristan da Cunha, Nightingale, Inaccessible and Gough Islands, suggesting that it was a panmictic population with free larval dispersal between the four islands. A slight genetic difference between these populations and those at the Vema Seamount (approximately 1,680 km to the ENE of the Tristan group at 31°.37.92S - 008°.21.54E, chart SAN2) suggested that larvae from the Tristan da Cunha group do not regularly reach Vema, and that the population at the seamount is self-recruiting.

Research on the *COI* gene analysed in a study carried out by Groeneveld *et al.,* (2012*),* stated that they fail to identify any significant differences between *Jasus tristani* and *Jasus paulensis* sampled over 6000 km apart. This species, *Jasus paulensis,* is found in the French territories of St. Paul and Amsterdam Islands and Seamount 150, in the Southern Indian Ocean and fished by the French. Groeneveld *et al*., (2012) concluded identical haplotypes in *Jasus paulensis* in the southern Indian Ocean from *Jasus tristani* in the South Atlantic and a Bayesian phylogenetic analysis strongly support the monophyly of the individuals sampled, which separates them from other *Jasus* species. The results reveal the lack of barriers to larval distribution and gene flow in the southern hemisphere waters over thousands of kilometres and that *Jasus paulensis* and *Jasus tristani should be synonymised as Jasus paulensis (Heller, 1862)*

1.5 Economic significance of the *Jasus tristani* fishery

The catch, processing and export of *Jasus tristani* is the most important economic activity of the inhabitants of Tristan da Cunha, providing the livelihood of many families and accounting for some 80% of government revenue (Tristan da Cunha Government (TDCG) Finance Dept unpublished report). The Tristan Government (a British Overseas Territory [OT], whose security and management is broadly overseen by the UK Foreign and Commonwealth Office [FCO]) depends entirely on the revenue generated from the fishing industry (mainly lobster), and it is therefore imperative to conserve stocks and avoid over-exploitation, so as to sustain the fishery over a long term (Hently, 2006). The financial value to the island's GDP, derived from the lobster concession holder cannot be disclosed due to commercial confidentiality as the fishery is operated bya single company.

1.6 Present status of the fishery and its management

The fishery is considered to be exploited sustainably although it has been predicted that, if current Total Allowable Catches are maintained, they could lead to reduction in catch rate (CPUE) of some 10 to 20%, over the next two decades (Johnson & Butterworth, 2012) Even if the stock remains sustainable, this could result in a decrease in revenue for the Tristan da Cunha Government. However, there is presently a strong drive by Island authorities and the concession holder to maintain the stock at sustainable levels. This includes periodic numerical assessments of the lobster stocks by the Marine Resources Assessment Group (MRAG) in UK. In addition MARAM, at the University of Cape Town, South Africa, in conjunction with the Tristan da Cunha Fisheries Department is developing fisheries management measures, for the lobster fishery, including Harvest Control Rules (HCR) and Operational Management Procedures (OMP). These will help the Tristan da Cunha Government to decide Total Allowable Catches (TAC's) of lobsters at the Tristan da Cunha group.

The fishery has undergone a Marine Stewardship Council (MSC) assessment, and was certified in 2011, passing its first audit in 2012. Marine Stewardship Council certification of a fishery can only be achieved after an independent assessment of the target stock, management of the fishery, and impact of the fishery on the environment, including bycatch (http://www.msc.org/track-a-fishery/south-atlantic/tristan-da-cunha-rock-lobster). Certified products carrying the MSC label have access to specific markets, and can provide a price premium for environmentally responsible fishing.

1.7 Information gaps and significance of the present study

The following information gaps in the biology and fishery of *J. tristani* have been identified and will form the rationale for the work undertaken in this thesis:

a) Although several earlier studies on the biology of *J. tristani* exist (see above), there is a paucity of recent biological information with which to assess temporal & spatial changes in population size structures, reproductive potential, growth rates and abundance;

b) There have been several changes in fishing strategy, including the types of gear used, changes to closed and open fishing seasons, introduction of a Total Allowable Catch (TAC) in 1991, vessel replacements, changes to the minimum legal size, and a change in the concession holder in 1997. The impacts of these changes on the fished populations, or on the data that have been collected, have not been quantitatively explored;

c) From 2006 - 2010 a fisheries-independent survey was initiated and these data need to be assessed;

d) Data collection procedures to support regular stock assessments have been formalized and the capacity of islanders to assist with data collection and processing needs to be further developed.

1.8 Aims of the study

Most of the data on *J. tristani* on which this study is based have been collected by the Natural Resource Department (NRD, now Fisheries Department, FD) at Tristan da Cunha between 1991 (when the TAC was first introduced) and 2010. Based on the gaps identified in Section 1.7, the aims of this thesis are:

a) To provide historical information on the fishery, including the fishing areas and habitats around the four Islands, changes in fishing gear and vessels used, long-term trends in fishing effort, catch and catch-per-unit-effort (CPUE) and past fisheries management (Chapter 2);
b) To analyse length and weight relationships essential in fisheries management for catch conversions (Chapter 3);
c) To analyse inter-island variability in population size structure, and long-term trends in lobster size at each island (Chapter 4);
d) To analyse the fecundity and egg-size of females at the four islands (Chapter 5);
e) To recommend management initiatives likely to result in a sustainable and well-managed fishery based on the biological and population characteristics of the species (Chapter 6).

Chapter 2

Study area and history of the fishery, with long term trends in gear use, fishing effort, catches and catch rates

2.1 Introduction - Discovery and settlement of Tristan da Cunha

The uninhabited islands of Tristan da Cunha, Nightingale Island and Inaccessible Island were first sighted in 1506 during a voyage to India by the Portuguese admiral Tristão da Cunha, who named the main island after himself. Although he was unable to land, his discovery appeared on nautical maps from 1509 and on Mercator's world map of 1569 (Brander, 1940).

Tristan da Cunha is the largest and only permanently inhabited island in the group. The island has been inhabited since 1816 when Corporal William Glass came to the island with his family as part of a British garrison. The garrison was sent from the Cape Colony (South Africa) to ensure that Napoleon, then incarcerated on St Helena Island 1370 nm to the north of Tristan da Cunha, would not escape via this route (Brandon, 1940). When the garrison withdrew in 1817, Glass remained behind and a small community developed under his leadership. The Island population fluctuated with the arrival of shipwrecked folk and sailors through the 19th century and the first quarter of the 20th century, and the present community of 263 (2012 census) all live in one village, Edinburgh of the Seven Seas, situated on the north-westerly coastal plain of the island, and only seven family surnames remain (Glass, Green, Swain, Repetto, Lavarello, Hagan and Rogers).

2.2 Island governance

Tristan da Cunha is a British Overseas Territory (OT), and its security and management is overseen by the UK Government. It has its own constitution although it does share a Governor with St Helena Island. In practice, the Governor has little input into the day-to-day running of the Tristan community and rarely visits the islands (for practical reasons). The Governor appoints an Administrator to represent him or her on Tristan. The Administrator is resident in Edinburgh of the Seven Seas, and is head of Tristan government and chair of the

Island Council. The Council, composed of eight elected and three appointed members, advises on Island decisions, which are formally taken by the Administrator. The fishery is managed within the legal framework of the Tristan da Cunha Fishery Limits Ordinance, which allows the Tristan Government to control fisheries within the Tristan EEZ.

2.3. Study area

Chapter 2 is subdivided into sections to: a) describe the geographic location, geology and benthic environment of the Tristan da Cunha Group of islands and Gough Island: b) describe the history of the island and fishery, including descriptions of the gear types and vessels used: and c) explain historical trends in fishing effort, catches per island and Catch-Per-Unit-Effort (CPUE).

The study area comprises four volcanic islands located on the outer slope of the Mid-Atlantic Ridge in the South Atlantic Ocean. Tristan da Cunha, Nightingale, Inaccessible and Gough Islands (Stramme & Peterson, 1990). Three of the four islands are grouped closely together to form the Tristan Group – these are Tristan da Cunha Island, with the smaller Nightingale and Inaccessible islands located roughly 20 nautical miles (nm) to the west and southwest respectively. The Tristan da Cunha Group lies roughly midway between southern Africa and South America, at 37°05'S, 12°17'W, about 1660 nm west from Cape Town in South Africa (Fig. 2.1). Gough Island lies 223 miles SSE of Tristan, at 40°19'S, 9°56'W.

All four islands are situated on the edge of the "Roaring Forties" and are summits of large volcanic cones that rise up from the abyssal depths (more than 3,000 m deep) from the outer slopes of the mid – Atlantic Ridge. Tristan da Cunha, Nightingale Island and Gough Island have narrow shelf areas which drop off into abyssal depths. Only Inaccessible has a discrete bank to the west of the island which extends to 7 nm. The planar areas of the sea-bed as estimated by Roscoe (1979) around each island to the 183m depth isobaths is calculated as; Inaccessible 124 km^2, Gough 96 km^2, Tristan 71 km^2 and Nightingale 38 km^2. However, the shelf topography of the islands differ considerably.

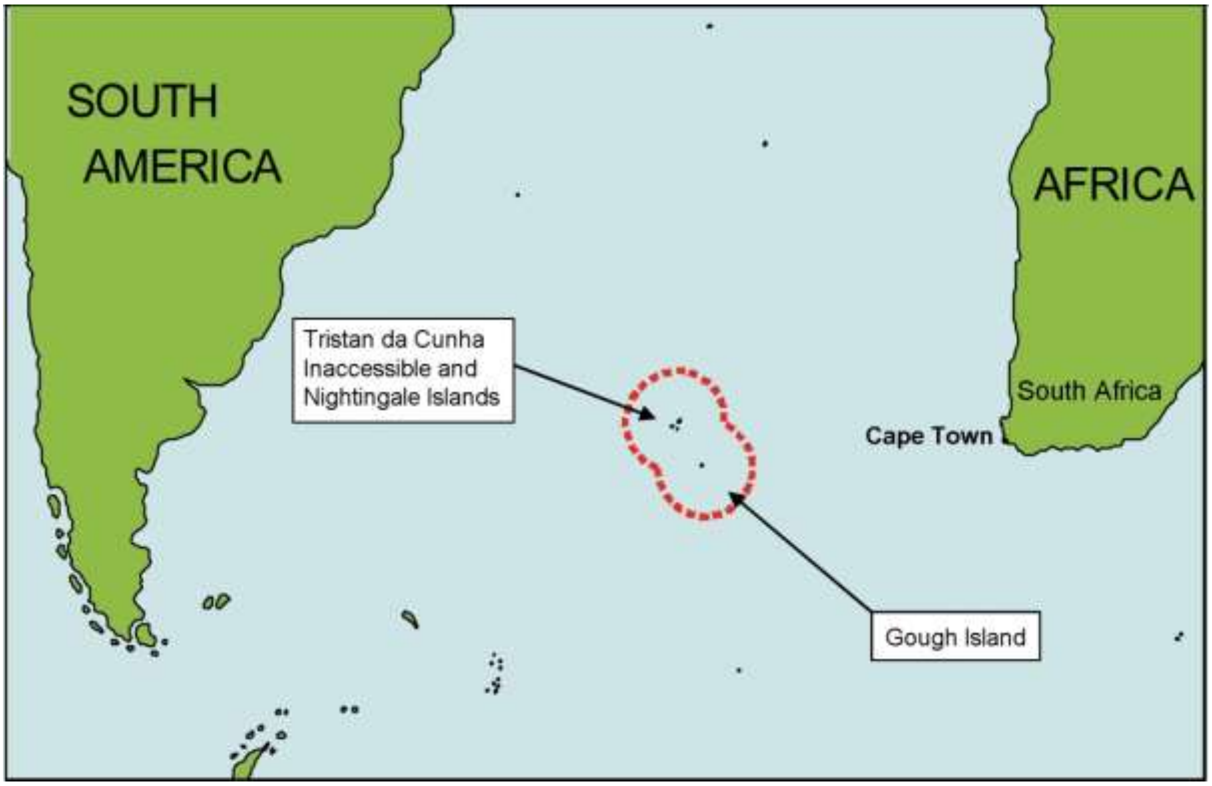


Fig. 2.1: Location of the Tristan da Cunha group of islands and Gough Island in the South Atlantic, midway between southern Africa and South America (Figure source: Peter Ryan)

2.3.1 Topography of the four islands

a) Tristan da Cunha Island

Tristan da Cunha is the largest island of the group (96 km^2), and is roughly circular in shape with a diameter of about 12 km across (Fig. 2.2). The highest point on the island is Queen Mary's Peak (2060 m), and the island is estimated to be around 200,000 years old (Ryan & Glass, 2007). The most recent volcano eruption was in 1961. Being volcanic the island has a classic conical shape, with steep cliffs and gullies radiating downwards from the highest point. The shallow subtidal shelf-slope at Tristan da Cunha is relatively gentle, compared to Gough and Nightingale islands.

b) Inaccessible Island

Inaccessible Island is of an intermediate size (14 km^2), with a rhomboidal shape measuring roughly 4×5 km (Fig. 2.2). The highest point is to the west, known as Swale's Fell (approx. 600 m), with a plateau sloping down to the east. The island is estimated to be 3-4 million years old (Ryan & Glass, 2007), the most recent volcanic eruption occurred 50,000 years ago at Round Hill. This island has the largest shelf area, particularly noticeable to the west, where it extends approximately 7 nm from the shore to the drop-off. The shelf of Inaccessible Island slopes relatively gently, similarly to the Tristan da Cunha shelf, with few deeply incised features.

c) Nightingale Island

Nightingale is the smallest island in the group (4 km^2) with the highest point at High Ridge (approx. 400 m) and two large adjacent islets, Stoltenhoff Island and Middle Island (Fig. 2.2). Nightingale Island is covered in dense vegetation, and is highly eroded with remaining trachyte rocks forming low cliffs with sea caves. There are a number of ponds which have developed into shallow depressions on the western plateau. The estimated age of the island is 18 million years old, and the most recent volcanic eruption occurred < 200 000 years ago at Ned's Cave (Ryan & Glass, 2007). The drop-off from the shore is almost vertical down to a depth of 10 m.

d) Gough Island

Gough is the second largest island (65 km^2), situated 223 nm to the SSE of Tristan da Cunha, and it measures 13×5 km (Fig. 2.2, Ryan & Glass, 2007). The highest point on the island is Edinburgh Peak (910 m). The age of Gough Island has been estimated at 3-5 million years old. The western aspect of the island is characterised by curved slopes, whereas the northern and eastern aspects feature a number of deeply incised valleys or 'glens', and a number of sea-stacks and peaks. Similar to Nightingale Island, the drop-off from the shore is almost vertical down to a depth of 10 m.

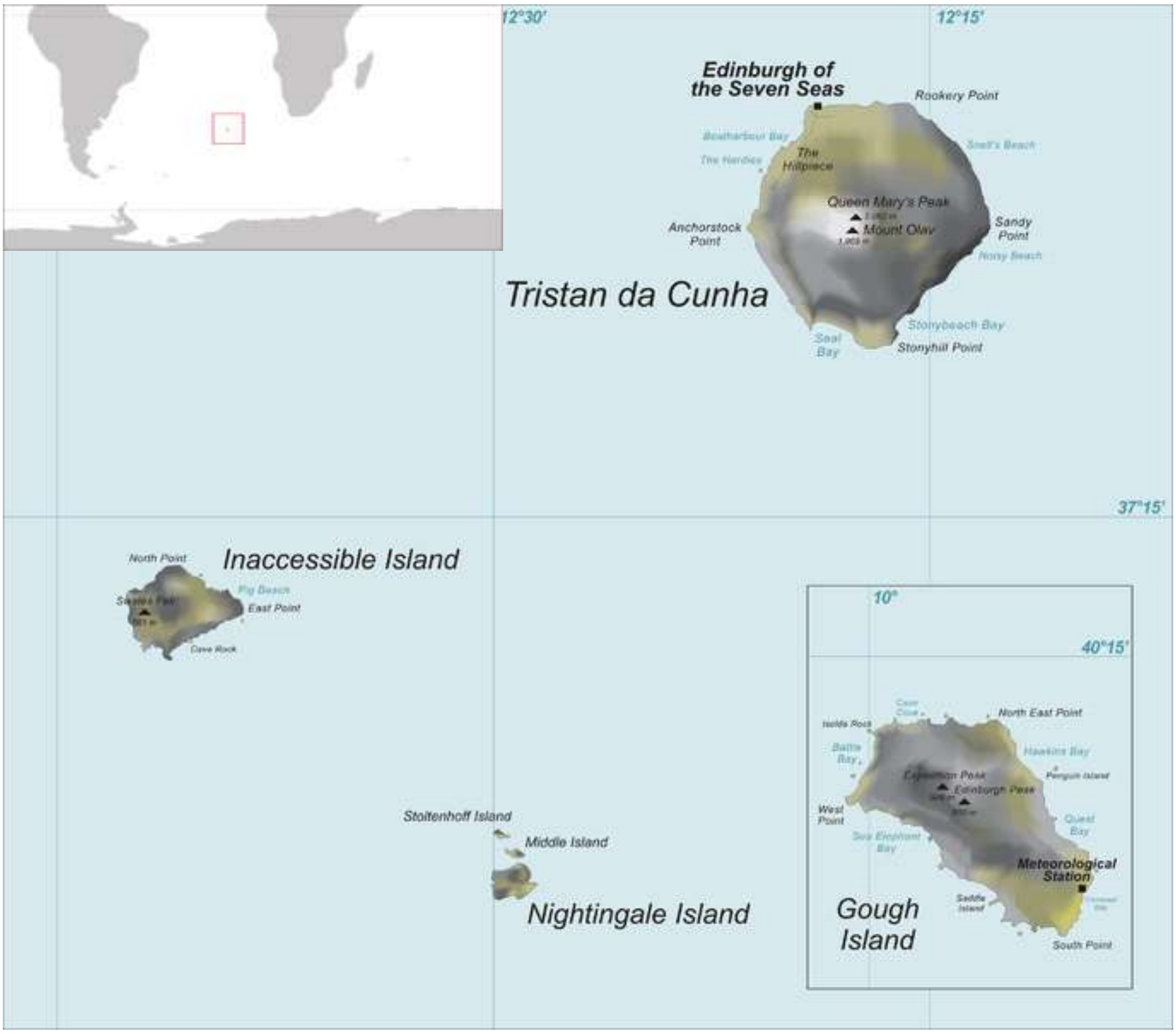


Fig. 2.2: Map showing the relative locations, sizes and main features of Tristan da Cunha, Inaccessible Island and Nightingale Island. The latter two islands lie approximately 20 nm to the SW of Tristan da Cunha Island. Inserted bottom right shows the main features of Gough Island, which lies approximately 223 nm SSE of the Tristan Group. (McAlister Elliott and Partners Ltd, 2012)

2.3.2 Ocean Environment

All four islands fall within the West Wind Belt, and also in the path of the eastwards flowing Atlantic Gyre current system. The South Atlantic Current, envelopes the islands from the west and lies adjacent to the Subtropical Convergence (STC) (Stramme & Peterson, 1990; Andrew *et al.*, 1995; Swythe–Wright *et al.*, 1998). The STC is a circumpolar oceanic front located at approximately 42˚S where the surface temperature of the seawater drops sharply from approximately 18°C to 10°C. Average sea surface temperatures at Tristan da Cunha in the austral summer range from 15 - 19°C, and in winter it declines to 13 - 15°C. At Gough

Island sea surface temperatures are on average 3°C cooler than Tristan da Cunha, Nightingale Island and Inaccessible Island during all months (Pollock, 1991 & Andrew *et al.*, 1995).

2.3.3 Inter- and shallow subtidal biota

Pollock (1991) described the inter- and subtidal benthic environment at the Tristan da Cunha group based on a diving survey. Despite several bays and offshore pinnacles, a steep profile, small tidal range, and exposed coastline limit the rocky intertidal area and only at Tristan da Cunha are there significant intertidal rock pools. The fauna that do occur around the islands generally have low species diversity (Roscoe, 1979; Pollock, 1991). Most common taxa are decapod crustaceans (mostly *Jasus tristani*), gastropod mollusks, soft corals, starfish and urchins. The urchin *Arbacia crassispina* dominates the subtidal ecosystem, and this urchin is in turn a common prey of rock lobsters (Pollock 1991). There is only one common whelk *Argobuccinum sp*, which is often caught in the lobster pots, especially when the traps are set on barren ground.

In the shallow subtidal zone the rocks are usually covered with turfs of short seaweed consisting of species of *Cladophora, Plocamium, Epymenia, Halopteris, Polysiphonium, Gigartina* and *Dictyota* (Pollock, 1991; Scott & Andrews, 2007; Scott, 2010). This seaweed in the subtidal zone is replaced by the pale kelp *Laminaria pallida* at around 10 m, and is then replaced in deeper waters by the giant kelp *Macrocystus pyrifera,* which surrounds all the islands with a kelp fringe at depths ranging from 10 – 40 m.

More than 50 species of fish have been recorded from the inshore waters of Tristan and Gough, mainly bony fish (Andrew *et al*. 1995). Most fish have an extended pelagic or open ocean stage (eggs, larvae or pelagic juveniles), and are widely distributed around the islands. The only endemic fish is the intertidal klipfish *Bovichthus diacanthus* (Andrew *et al*., 1995; Scott & Andrews, 2007; Scott, 2010).

2.4. History of the Lobster Fishery

2.4.1 Fishing sectors

Two distinct lobster fishing sectors have developed at the islands: a vessel-based fishery and an island-based fishery. The two sectors are closely linked as they share the same resource and markets.However, they differ in many key aspects and are treated separately throughout this study. Key characteristics of the two sectors are:

a) Vessel-based fishery - A fishery operated by concession that employs large ocean-going fishing vessels from Cape Town in South Africa that targets fishing grounds around all the islands (i.e. Tristan da Cunha, Inaccessible, Nightingale and Gough Islands) using several gear types (dinghies with hoop-nets, long-lines, monster traps). Catches are processed and frozen on-board fishing vessels; and

b) Island-based fishery - A fishery operated solely by island fishermen that is restricted to Tristan da Cunha Island, using dinghies/power-boats operating with hoop-nets/powerboat traps, that deliver its catches to a factory on the island for processing.

2.4.2 Establishment of the vessel-based fishery

The first attempt to establish a trade with lobster from Tristan da Cunha on a commercial basis was made by Rev. H. M. Rogers in 1925, when he tried to interest the manager of the Union Whaling Company in Durban S.A. to develop an industry in whaling and crawfishing at Tristan da Cunha. However, the project was not deemed profitable at the time (Munch, 1971).

Constant changes in fishing vessels since the inception of the fishery in 1949 have resulted in varying fishing capacity over time. A summary of the vessels with general information on their flag-status, size (Gross Register Tonnes, GRT), fishing and processing capacity, and the year in which they started operating in the Tristan da Cunha lobster fishery are shown in Table 2.1.

Table 2.1: Summary of vessels used by concession to catch lobsters at the Tristan Group and at Gough Island. The table shows the years of activity, GRT (tonnes) and gear types used

YEAR SAILED TO TRISTAN	VESSEL	GRT (TONNES)	GEAR AND METHOD
1948	*Pequena*	184	12 dinghies
1951	*Isolda* renamed *Tristania*	628	26 dinghies
1953	*Voorbok*	316	20 dinghies
1954	*Voorbok* renamed *Frances Repetto*	316	20 dinghies 25 dinghies
1965	*Gillian Gaggins*	793	20 dinghies 2 powerboats
1971	*M.F.V. Hilary*	303	Long-lines with traps
1971	*M.F.V. Melodie*	303	Long-lines with traps
1973	*M.F.V. Tristania II*	603	Long-lines with traps 2 powerboats
1984	*M.V. Hekla*	708	Long-lines with traps 2-5 powerboats
1997 – Present	*M.V. Hekla* renamed *M.V. Edinburgh*	1085	Long-lines with traps 2-5 powerboats
1997 – 2009	*Kelso*	1678	Long-lines with traps 2-6 powerboats

**M. V. Edinburgh* increased in GRT from 708 – 1085, when renamed and fitted with extra processing equipment (Glass, *pers. obs*)

Commercial lobster fishing at Tristan da Cunha started in 1949 following a scientific survey for lobster by the *Pequena* in 1948 (Appendix A,1). The *Pequena* was a South African flagged, 70 foot wooden vessel. The vessel was purchased by Tristan da Cunha Development Company (TDCDC) in 1948, for the initial surveys to establish the viability of a commercial fishery. The vessel fished with dinghies, and catches of processed lobster tails were rough-packed, frozen on board, and repacked for export in Cape Town. The survey coincided with a period of very high catches of the closely related *Jasus lalandii* along the western coast of South Africa (Melville–Smith & van Sittert 2005). The survey was commissioned by the Lamberts Bay Canning Company (LBCC), in association with South

African Sea Products, South West Africa Fishing Industries, Vitamin Oils, and Ocean Products (Munch, 1971). The survey was led by Mr. C. H. Gaggins (then MD of LBCC) and Rev. P. C. Lawrence, the first naval chaplain stationed on Tristan during the Second World War. The survey was also supported by the Union Government of South Africa and the Colonial Office in London. The *Pequena* spent a month at Tristan in February and March 1948 and returned to Cape Town with favourable reports (Munch, 1971). The South Atlantic Islands Development Corporation (SAIDC) was formed and granted sole rights to export lobsters. The construction of a canning plant on Tristan da Cunha started in 1949, and it was operational by the end of 1950.

In 1949, the *Pequena* fished with 12 dinghies using hoop nets, and returned to Cape Town in October with 60,000 frozen tails (approx 2,000 cases) and 20,000 penguin eggs. A second vessel *Tristania* (Appendix A, 2) was commissioned in 1950 and fitted with a larger freezer. The *Tristania* was a steel vessel, South African flagged, and 120 foot, she was purchased by TDCDC in 1951 and fished at Tristan until 1972. It fished with 26 dinghies but changed to longline fishing in 1969/70, fishing mainly at Gough Island.

The *Tristania* remained the company's main fishing and processing vessel until she was replaced by the larger *M.F.V. Tristania II* (Appendix A, 3) in June 1973. The *M.F.V. Tristania II* was a Bermudan flagged, 160 foot steel vessel powered by a Burmiester and Wain 1000 hp engine. Purchased by Tristan Investments in 1972, and converted in Cape Town for long-line operations and packing for export, she fished at Tristan up to 1996. The *Pequena* was found not suitable for operating in the South Atlantic gales and was replaced in 1953 with the *Voorbok,* a 300 mt coaster later renamed *Frances Repetto* (Appendix A,4). The *Frances Repetto* was a South African flagged, 100-foot wooden vessel. Built during the Second World War in Halifax, Nova Scotia. Purchased by TDCDC in 1953 she operated around the Tristan group until 1965. During that period the vessel fished with 20 dinghies.

A refrigerated vessel, the South African flagged, 162-foot steel vessel *Gillian Gaggins* (Appendix A,5)*,* was built in Durban by Barship, and purchase in 1965. This vessel initially carried 20 dinghies, but later a number of these were replaced by motorboats. In 1969 *Gillian Gaggins* was converted to fishing with plastic top entry traps on longlines. The *Gillian Gaggins* was converted to a mother ship in 1971, to process catches made by other vessels for export, up until she was withdrawn from service in 1973. In 1974 the fleet was reorganized by decommissioning the *Gillian Gaggins*, and refitting two new long-lining vessels, the *M.F.V. Melodie* (Appendix A,6) and *M.F.V. Hilary* (Appendix A,7), so that their catch could be frozen and tailed on board. The *M.F.V. Melodie* and *M.F.V. Hilary* wereSouth African flagged, 123 foot steel sister-ships with similar design. The vessels were powered by Deutz 930 hp engines, and were built by Globe Engineering in Cape Town in 1971. Both vessels were fitted with refrigerated holds in 1973. The two vessels catches were processed for export on board, with products including whole raw and whole cooked lobsters and lobster tails. The *M.F.V. Melodie* was withdrawn in 1976 and the *M.F.V. Hilary* in 1984.

Initially catches were packed in rough cartons and repacked at a factory in Hout Bay, South Africa, but later they were repacked at Tristan to save cost. In 1974 rectangular steel frame traps were introduced, as these proved to be more efficient. During the mid 1970's until the early 1980's each vessel would deploy 4 - 6 longlines each with 35 - 65 traps and hauled twice every 24 hours, weather permitting (Roscoe 1979). The *M.F.V. Melodie* and *M.F.V. Hilary* were replaced in January 1984 by the *M.V. Hekla* (Appendix A,8), which used both longlines and powerboats. The *M.V. Hekla* was a Belize flagged 68 m steel vessel, of 1085 GRT, and powered by a Deutz 1600 hp engine. The *M.V. Hekla* purchased by Tristan Investments in 1983, was converted from a cargo vessel, for long-line fishing operations, processing and packing for export. The initial concession was revoked at the end of 1996 due to breach of regulations, and a new concession was granted in 1997, including a suite of regulations to govern the fishery. The *M.V.Hekla* was renamed *M.V. Edinburgh*, and the *M.F.V. Tristania II* was replaced by the *Kelso* (Appendix A, 9). The Belize flagged vessel Kelso, was built in Japan in 1971 as a fisheries patrol vessel. The length of the vessel was 71 m, 1678 GRT, and powered by 8000hp. The Kelso was purchased by Premier Fishing in 1996 and converted for lobster trap fishing and onboard processing operations. The vessel was named *Kelso* after a town in Scotland, where Tristan da Cunha's founder came from in 1816. The vessel ceased fishing in May 2009 and was sold to White Star Limited (registered St. Kitts & Nevis).

2.4.3 Establishment of the island-based fishery

From 1949 to1961 all fishing was done by hoop-nets from dinghies launched from the shore. The hoop-nets are similar to those used in the inshore lobster fishery in South Africa (Schoeman *et al.*, 2002a); Fishing was initially restricted to the northern areas of Tristan da

Cunha Island, near the settlement, until a motorboat was purchase in the mid 1950's to tow the dinghies around the island.

From 1955 to 1958 islanders fished an average of 32 days per year. In 1960 the canning plant was closed, and extra freezing capacity installed. This led to an increase in production from 60,000 crayfish tails (no weight known, 1949 unpublished records) to 52.5 mt of tails in 1960/61. The lava flow from a volcanic eruption in October 1961 obliterated the factory and the island was evacuated. The islanders returned in 1963 and rebuilt the factory, which reopened on 23rd May 1966 (Crawford, 1982). In the interim, island fishermen continued to fish with dinghies and hoop nets, and delivered their catch directly to the large vessels. Larger motorboats gradually replaced the Tristan da Cunha fleet of dinghies from 1965 onwards, and steel traps covered with chicken mesh wire were added to the gear in 1968. The traps were then changed to nylon mesh netting in the 1980's.

There have been a number of changes in the fishery since 1997, including a reduction in fishing gear and the number of motorboats from 20 to nine (Table 2.2). This has been due to an increase in CPUE, and the demand for a superior quality product. On the 13th February 2008 the island received a setback in fishing operations, when the present Fish Factory caught fire and burnt to the ground (Tristandc, n.d.; Tristantimes, n.d.). It has been rebuilt to EU specifications, and was officially reopened on 17th July 2009.

Table 2.2: Summary of the numbers and types of boats and fishing gear used by local fishers around Tristan da Cunha Island to catch lobsters for delivery to the onshore factory

Year	Boats	No. of Boats	Gear used
1949 – 1961	13 ft Dinghies	20 Dinghies	Hoop nets
1965 – 1979	13 ft Dinghies and 5-7 m Power boats	20 Dinghies and powerboats	Hoop nets & traps
1980 – 1999	5-7 m Power boats	20 Powerboats	Hoop nets & traps
1999 – 2000	5-7 m Power boats	19 Powerboats	Hoop nets & traps
2001 – 2003	5-7 m Power boats	18 Powerboats	Hoop nets & traps
2004 – Present	7 m Power boats	9 Powerboats	Hoop nets & traps

2.4.4 Importance of management

Roscoe (1979) provided a summary of catch statistics between 1949 and 1976. He noted that the size composition of populations surrounding the islands had changed since the introduction of fishing, and that catches from the commercial fishery had declined particularly at Tristan da Cunha. He recommended that a quota system be implemented, and that a Minimum Legal Size (MLS) be introduced. Pollock (1981, 1986, & 1991) produced yield-per-recruit curves from which size limits were derived. The first (MLS) were introduce during the 1981/82 fishing season, and in 1983/84 at Tristan da Cunha. The size limit requires that all lobsters smaller than 70 mm CL must be returned to the sea. A side-effect of the implementation of this measure was a reduction in CPUE compared to years before (Pollock, 1982). Total catches from all islands combined (Appendix B) continued to decrease and Total Allowable Catches (TAC's) were recommended by the Tristan da Cunha Government.

Total Allowable Catches (TAC's) were first introduced in 1991 (Island Council minutes 26th February 1991). In 1993, the Natural Resources Department (NRD) of the Tristan Island group was established (renamed Agriculture and Natural Resources Department, (ANRD) in 2008, and since 2009 the Fisheries Department (FD). The FD recommends a TAC to the Island Council on an annual basis (Appendix C).

The license fishing season is from the 25th August – 31st May for the outer islands of Nightingale, Inaccessible and Gough. The season is closed from June until the 25th August. The vessels usually depart Cape Town for the start of the season mid-August to do independent biomass lobster surveys for the FD, before commercial fishing starts around the 1st September.

The fishing season for the Tristan local boats starts on the 1st July, until the TAC is caught. There is no closed season at Tristan as there is no overnight fishing (when most berried animals are caught), although the fishermen tend to cease fishing on the 30th April to have two months to service the fishing boats and gear. Since the new concession holders started in 1997, there have been a number of changes to the start of the season, gear used etc, although the FD department has always used the historic season, which runs from the 1st May until the 30th April for management purposes.

A minimum size limit of 70 mm (CL) carapace length was introduced by the Tristan da Cunha Government at all four island islands in the 1983/84 season. This was increased to 75 mm in the 2003/04 season at Gough Island, due to the lack of undersize lobsters being discarded and, at the same time, decreased from 70 mm to 68 mm at Inaccessible Island, due to the high percentage of undersized lobsters being discarded ± 40% <70 mm CL (Glass, 2003).This was followed by another reduction at Inaccessible Island in the 2012/13 season from 68 mm to 66 mm CL (Johnson & Butterworth, 2012).

2.5 Gear types

Data on the types and efficiency of fishing gear and boats used in a fishery are critical in any attempt to determine trends in fishing effort, and hence trends in catch rates and stock status. The fishery for *Jasus tristani* has been characterised by frequent changes in the types of traps used, as well as a succession of fishing vessels with varying capacity. These two factors complicate any attempt towards standardising fishing effort across years. Information on gear types and fishing vessels held by the Department of Agriculture Forestry and Fisheries (DAFF, Cape Town, South Africa) for the period 1973 to 1996 and by the Natural

Resources Department (currently the FD) on Tristan da Cunha since 1993, is described in section 2.5.1.

2.5.1 Gear types used

a) Hoop nets

Hoop nets (Appendix E, 1) consist of a steel hoop (12 mm steel, 0.7 m diameter) with 50 mm (knot to knot) mesh netting attached (Roscoe, 1979; Pollock, 1991). The mesh extends for 1 m. Bait is attached in the centre of the hoop using cross strings. Hoop-nets are set on individual buoys. They are not used by the powerboats operating from the lobster vessel at the outer islands, although they are still used by the local fleet at Tristan.

b) Beehive traps (Ink well)

Beehive traps consisted of a frame of 16 mm steel covered with 70 mm mesh netting (Appendix E, 2). These traps were introduced by the new concession holders in 1997-1999 whereafter they reverted to using monster traps (Glass, *pers obs*).

c) Monster traps

Monster traps were introduced in 1974 (Roscoe, 1979), and replaced the plastic top-entry kavel traps and the French oval traps in the early 1980s. The monster traps are cuboidal steel-framed traps measuring 120 x 80 x 50 cm, with two entries and a bagged end (Appendix E, 3). Bait is placed into a pocket in the middle of the trap blocked by two square pieces of sponge on either side. Monster traps are the only trap-type presently used in the longline fishery (Glass, *pers obs*).

d) Willow traps

Willow traps are barrel shaped traps built of French willow, with a weight inside to keep them on the bottom (Appendix E, 4). They were used at the beginning of the fishery in 1949 and they were set singly and used until the eruption of the volcano in 1961.

e) Plastic traps (top-entry kavel traps and oval-shaped traps)

Plastic top-entry kavel traps were introduced in the 1970s and set attached to longlines (Appendix E, 5) A similar collapsible oval-shaped plastic traps which were manufactured in France were also used in the fishery from the mid-1970s to early 1980s (Roscoe, 1979).

f) Steel traps / Powerboat traps (also called pots)

Steel traps otherwise known as Powerboat traps are wire-covered, top-entry traps with a semi-cylindrical shape. Traps are one metre long with escape bars approximately 50 mm apart. The traps were used during the 1970s and 1980s (Roscoe, 1979; Pollock, 1991), and were modified in the 1980s by covering them with a 60 mm mesh netting, including two bait boxes (one tied on either side of the opening) and by removing the escape bars (Appendix E, 6). The mesh size was increased from 60 mm to 75 mm in 1997, and finally reduced to 70 mm in 2011, due to the tails of the lobsters getting caught in the mesh. Steel Traps (Otherwise known as Powerboat traps) are still in use in the island-based fishery, and from the small five metre powerboats operating from the *M.V. Edinburgh,* whilst fishing at the outer islands of Nightingale, Inaccessible and Gough.

2.6 Collection of fisheries data for management purposes

Although fishing for *Jasus tristani* began in 1949, data collection only started when a marine biologist, M.J. Roscoe, visited the islands between 1971 and 1973. Roscoe (1979) provided a summary of catch statistics between 1967 and 1976. He noted that the size composition of populations surrounding the islands had changed since the introduction of fishing, and that catches from the commercial fishery had declined particularly at Tristan da Cunha. He recommended that a quota system be implemented, and that a Minimum Legal Size (MLS) be introduced. Pollock (1981, 1986, & 1991) produced yield-per-recruit curves from which size limits were derived.

Historical data on catches are available from the 1967/68 season (Appendix B), although other biological data such as morphometrics, size composition, sex ratios, reproduction, and growth only started being collected from 1971 by observers and fishers on board vessels and by the fish factory staff at Tristan da Cunha. However, over the years due to a number of people handling the lobster data, the FD have discovered that some log sheets have been lost or misplaced (Edwards & Glass, 2007).

In 1993 the Natural Resources Department (now the FD) was established on Tristan and has been responsible for the collection of fishing effort and catch information. Despite changes in the start of the fishing seasons since 1997 (for market reasons) the FD has always used the historical year, to be consistent with historic data.

The interpretation of the fishing effort for the fishery remains challenging given the many changes in gear, method, and vessels, and also shifts in fishing seasons (see sections 2.4 to 2.5). This affects the trends in catch rates or CPUE, which can be used as indicators of the abundance of a fished population. Although nominal CPUE indices are not always good estimates of abundance, if seasonal factors are not taken into account, they do give an indication of fisheries performance over time.

Prior to 1970, catch and effort data were not separated by island, but only reported as total values for all islands combined. The following sections describe the trends in fishing effort, catches and nominal (unstandardized) CPUE for each island, focusing on the period since 1970.

2.7 Total historical catches at all Islands

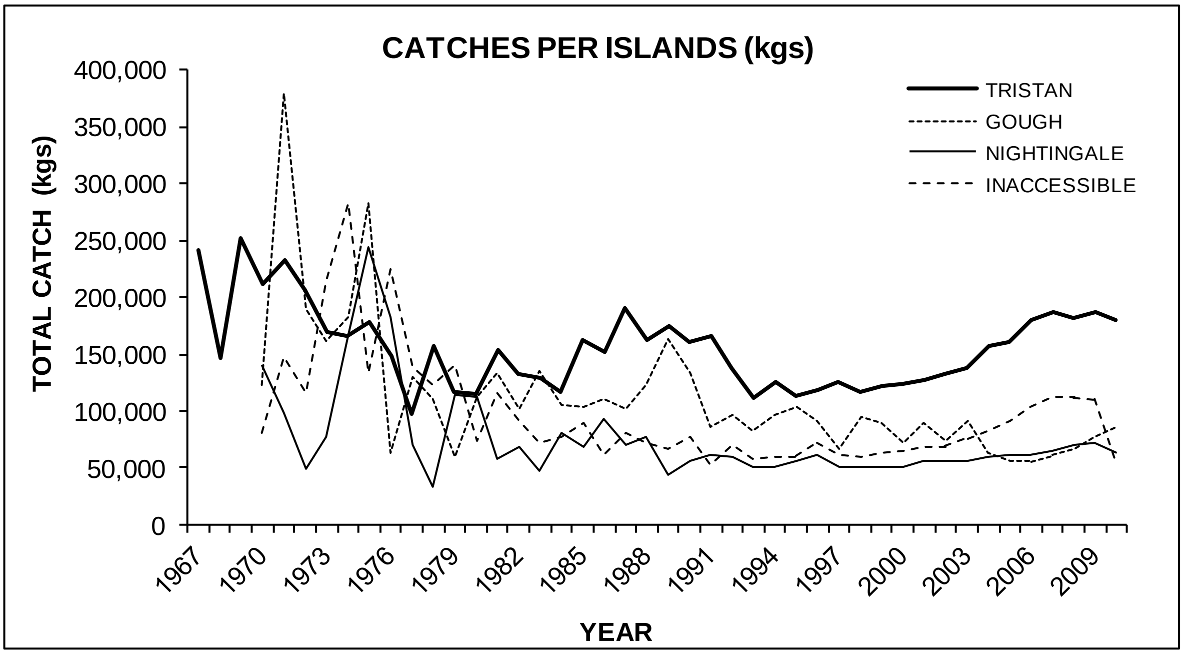


Fig. 2.3: Total annual catches of *Jasus tristani* per island from 1967 to 2010 for Tristan da Cunha, and from 1973 to 2010 for the outer islands of Nightingale, Inaccessible and Gough. Split-year fishing seasons are as follows: 1st May of Year 1 to 30th April of Year 2

The total reported catch per island since 1967 is shown in Fig. 2. 3, for Island-based and vessel-based fisheries combined (Appendix B). The Fig 2. 3, shows that catches peaked in the 1971/72 and 1975/76 seasons at Gough Island where 380 mt and 283 mt were landed respectively. Catches also peaked at Inaccessible Island during the 1974/75 and 1976/77 seasons, which landed 282 mt and 224 mt respectively. These exceptionally large catches made at Gough and Inaccessible between 1971 and 1977 coincides with the entry of two new longline vessels in the fishery (*M.F.V. Hilary & M.F.V. Melodie, 1971)* and the replacement of the *Tristania*, which only used dinghies, with the larger *Tristania II*, which used both longlines with traps and traps set from powerboats. Another event that affected catch rates was the introduction of steel monster traps in 1974. These traps replaced the less efficient small kavel plastic traps, which is thought to be approximately 1.8 more efficient (Pollock, 1981) and immediately increase catch rates. Over the past three decades, Tristan da Cunha has consistently yielded larger catches, than Nightingale, Inaccessible and Gough.

2.8 Total Allowable Catches (TAC's)

Catches made since 1991 have been influenced by a TAC set by the FD. Some over and under-catches have been recorded, and are shown in Appendix C, for each island and fishing season, from 1991 - 2011/12. From the change of the concession holder in 1997, when stricter regulations were brought in, TAC's were rarely exceeded. Catches for the outer islands, taken from the vessels pack data and calculated to live weight using a conversion factor, are tabled in Appendix B, as well as catches for Tristan da Cunha from the local powerboats.

For the 2010/11 fishing season, the fisheries at Inaccessible and Nightingale were closed when the wreck of the *Oliva* occurred, and for the 2011/12 Fishing Season the quota at Inaccessible was set at 95 mt but was reduced to 53 mt due to the *Oliva* effect (spillage of oil and soya), the fishery at Nightingale, remained closed during the 2011/12 fishing season.

2.9 Tristan Island

2.9.1 Fishing Effort

Roscoe (1979) introduced the Large Power Boat Day (LPBD) as the unit of fishing effort at Tristan da Cunha, and this was used until 1996. The LPBD was the unit used when dinghies operating with hoop-nets were replaced in the early 1970's by powerboats of 5.5 m and 7.5 m length, and when traps were added to the fishing gear. To reflect the shorter range and less gear carried by the smaller powerboats, their unit of effort was set a 0.5 * LPBD (Roscoe, 1979; Pollock, 1981). The LPBD method was used until December 1996, when there was a change of concession holders.

Time and landing restrictions placed on the powerboat fleet at Tristan da Cunha after 1997 biased the catches that could be made per LPBD, and the FD converted to measuring fishing effort as the number of traps or hoop nets set per hour fished. To make the data compatible, one trap or two hoop nets were set at 1 unit * hrs fished (CPUE Fig 2.6, Table 2.2). All the powerboats used both traps and hoop nets.

Fishing effort (number of boats or traps hauled) has decreased since 1997, since the new lobster concession holders (EUREX) replaced the previous company. Initially there were 20 local boats comprising seven large and 13 small powerboats. An increase in CPUE allowed a reduction in the fishing fleet to reduce the tonnage entering the factory daily and increase the quality of the product. At the start of the 2004 fishing season, the fishing effort was restricted to nine large powerboats (36 fishermen) per day. This level of effort has been maintained since then. Four fishers share a boat, two fishing on alternative days.

2.9.2 Catches

Data from the local fishery at Tristan da Cunha Island is collected from factory records of the weights landed by each boat on each fishing day. The trend in total catches shows a gradual decline between 1970 and 1991, when the TAC was introduced (Appendix B). Despite the downward trend, a status report by Pollock (1991) suggested that the levels of fishing effort and catches at the time were sustainable at all the islands and that the TAC would prove to be conservative, with the exception of Gough Island. A major change in the fishery followed with the change in the concession holder in 1997, when restrictions on gear, TAC's, and closed seasons were enforced. The new concession holder has abided by the regulations imposed by the Tristan da Cunha Government (TDCG), and a steady increase in catches has been reported between 1997 and 2010 (Fig. 2.4, Appendix B). A minimum legal size (MLS) of 70 mm CL was introduced at the outer islands during the 1981/82 fishing season and in 1983/84 at Tristan Island. A side-effect of the implementation of this measure was a reduction in the CPUE compared to the previous years (Pollock, 1991)

a) Total catches of lobster at Tristan da Cunha

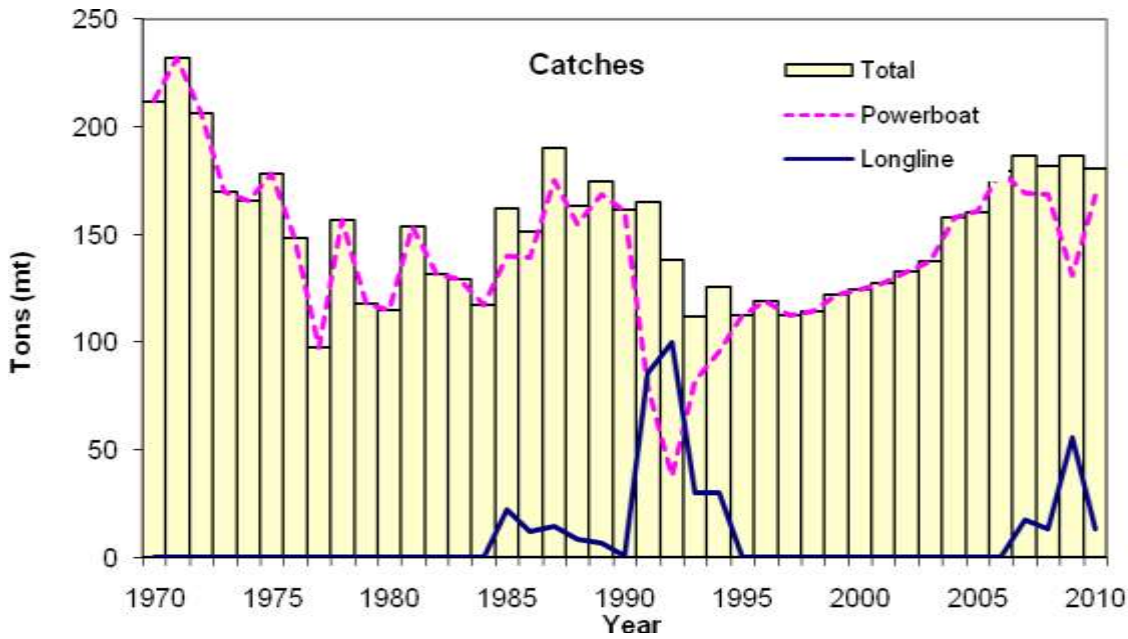


Figure 2.4: Historic catches of *Jasus tristani* in metric tonnes made by powerboats and long-line traps separately and combined, at Tristan da Cunha between 1970 and 2010

2.9.3 CPUE

The downward trend in CPUE prior to the changes in the concession holders in 1997 (Fig. 2.5) reflected changes in the status of the stocks (Glass, *pers obs*). It is possible that the lower CPUE values (and more days fished) after 1992 were a result of depletion caused by a longliner (*M.V. Hekla*) that operated around Tristan in 1992, when the harbour was closed for restoration (Fig. 2.4). This was the first time that a vessel operating with longlines and power-boats had fished around Tristan Island for an extended period. The sharp increase in CPUE measured between 1995 and 2005 reflect either a recovery in the lobster populations around the island or improved fishing efficiency.

b) Trends in CPUE of lobsters at Tristan da Cunha

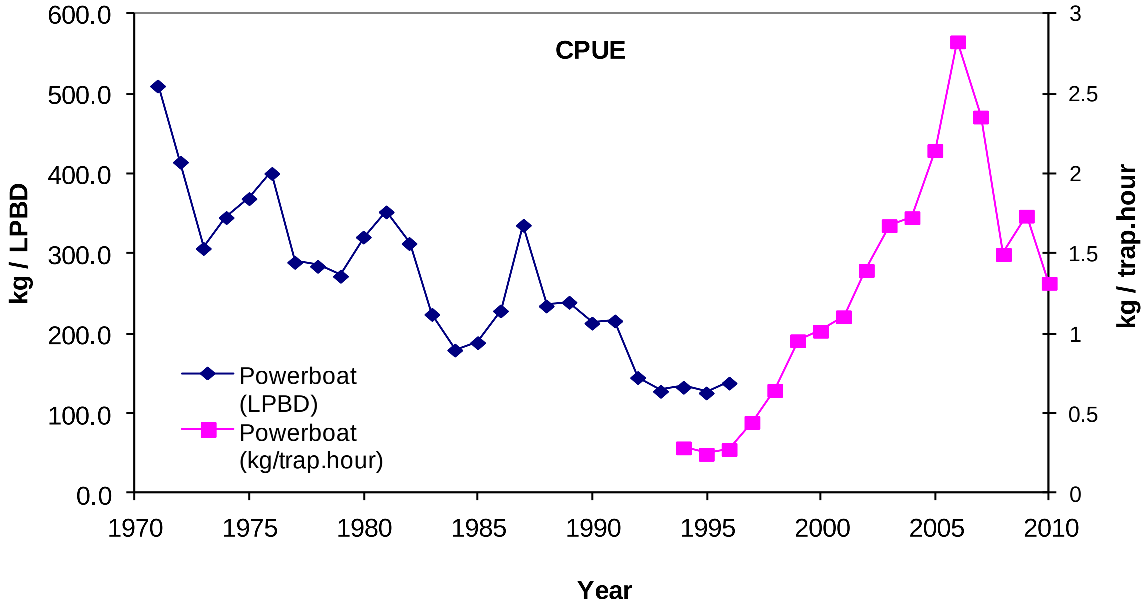


Figure 2.5: Catch Per Unit Effort (CPUE) of *Jasus tristani* from powerboats at Tristan da Cunha between 1970 and 2010. CPUE was initially measured as catch per LPBD (i.e. kg/ Large Power-Boat Day) and this was replaced in 1994 by a more accurate unit of catch per trap hour (kg/trap-hour). Three years of overlap are shown (1994-1996)

2.9.4 Seasonality

Fishing effort by power boats at Tristan is affected by the weather and sea-conditions. The harbour mouth is on the windward side of the island and adverse sea conditions often prevent boats from leaving the harbour (Fig 2.4, Appendix D). Large monthly and interannual variations in fishing effort occur, with most fishing occurring in October (14%) and November (16%), when weather conditions are good and catch rates high (due to both lobster sexes being available to the fishery). September is when the females shed their berry (eggs), and in December the fish factory is only operational for two weeks, before closing for the festive season.

In January and February the weather is often good enough for fishing, but the CPUE of lobster is reduced (due to females moulting and not feeding). No fishing was done by the local boats during the 1992/93 season, due to repairs being made to the harbour. The lower than average numbers of days fished between 1999 and 2004 occurred as fewer months were actively fished during that time (i.e. only in September to November in 1999, Appendix

D), catches were good and there were no restrictions on landings. The high number of days fished in 2008 (Appendix D) is explained by a change in fishing strategy, caused by the fire at the lobster factory. During that year, fishing at Tristan was conducted using five powerboats from the fishing vessel *Kelso;* these required more days to catch the quota than the nine boats that operated from the island in other years.

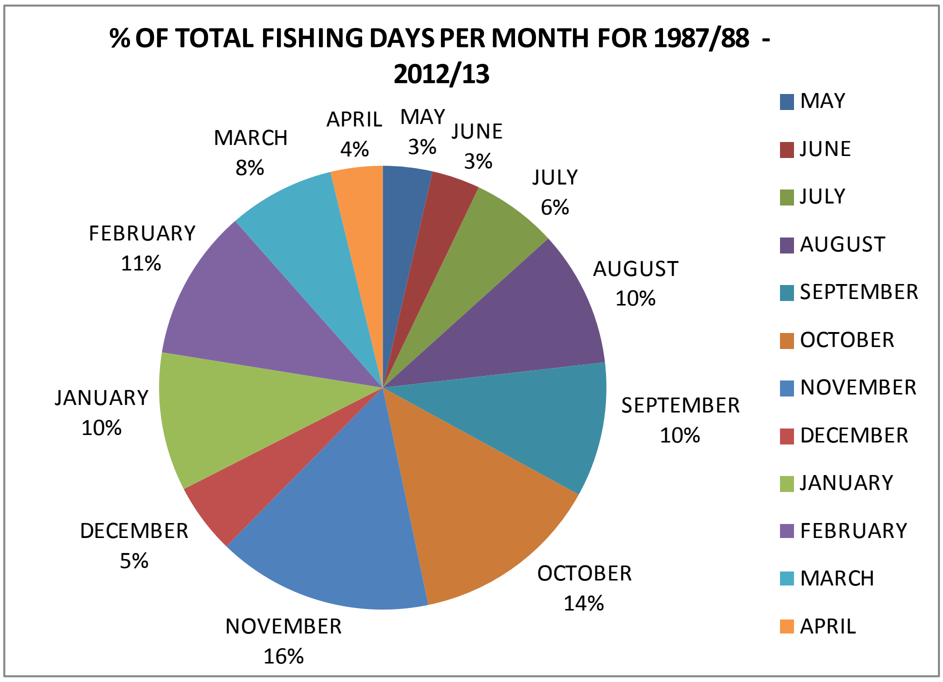


Fig. 2.6: The percentage of days per month (between 1987 and 2012) that fishing was conducted at Tristan from Island-based powerboats. Annual data are shown in Appendix D

2.10 Nightingale Island

2.10.1 Fishing effort

For the outer islands (i.e. Nightingale, Inaccessible and Gough Islands), large fishing vessels operating from Cape Town first operating with dinghies with a two man crew, but these were gradually replaced by the longline fishing method (20-40 traps attached to a line, Table 2.1, Fig 2.7) from 1969 onwards. Longliners first used plastic traps, but replaced these with large steel monster traps after 1974. Beehive traps were used for a short period by the new concession holders in 1997, although these proved unsuccessful and the Monster traps have subsequently remained the dominant choice and is the only trap used in the longline fishery at present (Glass, *pers. obs*).

The vessels operating with Monster traps attached to long-lines are based in Cape Town and make fishing trips to the Tristan group for two to three months duration, throughout the fishing season. The large fishing vessels use powerboats in addition to longline sets. These powerboats are similar to the small Tristan da Cunha powerboats, but use different fishing methods. They deploy up to 80 traps singly of a semi-cylindrical design (similar to the Tristan boats), but may use two sets of gear, left overnight, and work seven days a week. Powerboats are not deployed in poor weather conditions. Powerboats haul their gear twice per day (morning and afternoon) when the weather allows it. The variability in fishing methods used by the powerboats makes the outer island effort data difficult to interpret (Edwards & Glass 2007).

a) Fishing effort at Nightingale Island

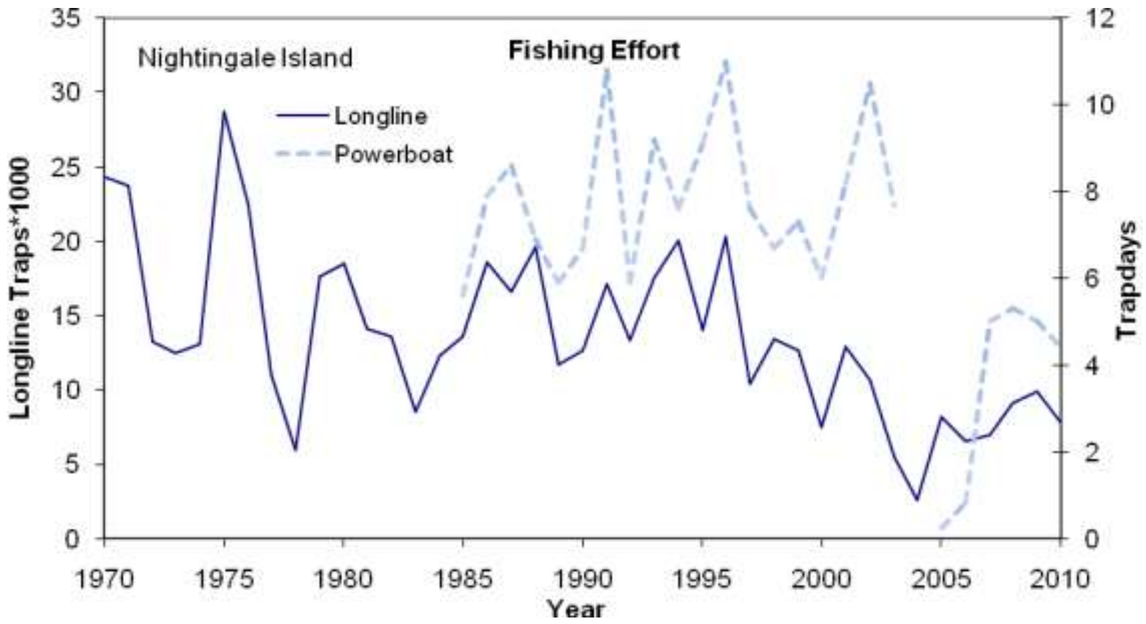


Fig 2.7: Fishing effort of long-lines and powerboats at Nightingale Island between 1970 and 2010

2.10.2 Catches

According to Pollock (1979) the downward trend in catches of lobster between 1974/75 and 1978/79 reflected a decline in abundance at Nightingale (Fig 2.8). On the 16th March 2011 a bulk carrier the *Olivia* ran aground at Nightingale Island and spilled 65,000 metric tonnes of soya beans, 1400 metric tonnes of heavy fuel oil and 75 metric tonnes of diesel. The island was closed to fishing, affecting the total catch landed at Nightingale for the 2010/11 season (Fig 8, Appendix B) and will remain so, until after a fisheries workshop in Cape Town South Africa, where scientist will meet to analyse the lobster data collected from Nightingale, and make recommendations. Test fishing at Nightingale was to allow for a re-evaluation of the impact of the *Oliva* incident on the resource.

b) Total catches of lobster at Nightingale Island

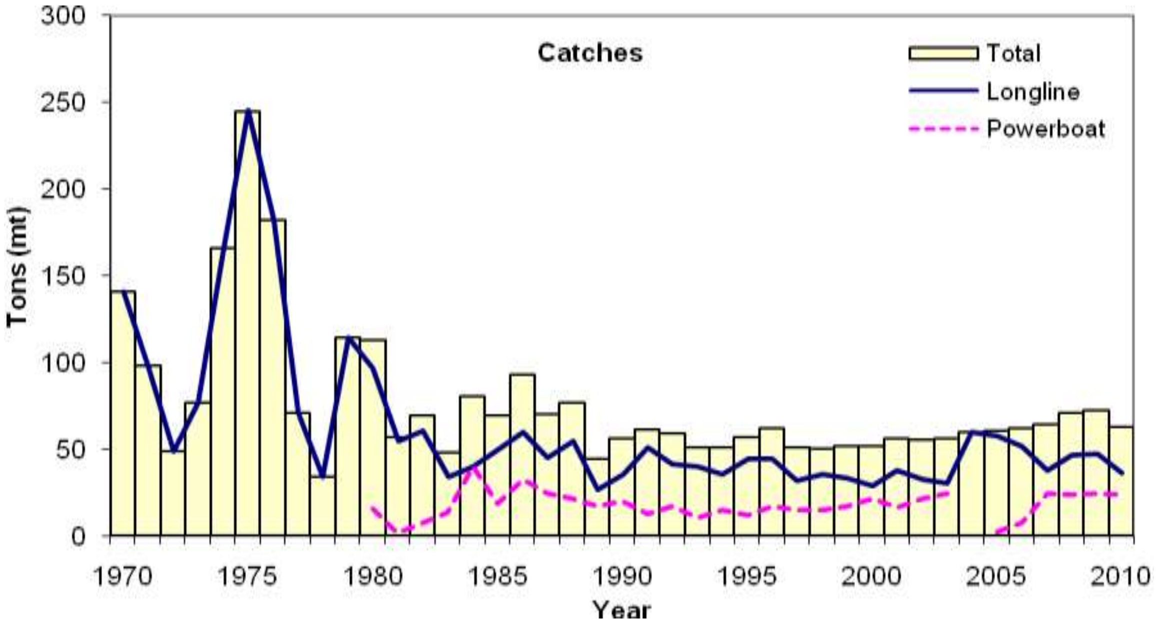


Fig 2.8: Historic catches of *Jasus tristani* in metric tonnes per fishing season, made at Nightingale Island by long-lines and powerboats separately and combined, for the period between 1970 and 2010

2.10.3 CPUE

The CPUE for the longline fishery is calculated as total catch over total effort. In 1974, Monster traps replaced the Plastic kavel top entry trap, and as a result the CPUE trends before and after 1974 should be treated separately due to the two different fishing gear types used (Fig. 2.9). The Monster traps led to a marked increase in the efficiency of the gear unit, and thus CPUE, which is reflected in Fig. 2.9 as a large increase in CPUE between 1974 and 1975. The CPUE trend at Nightingale Island showed another steady increase since the late 1990s to 2007, possibly related to the change in the concession holder in 1997 when stricter management measures were enforced.

c) Trends in CPUE at Nightingale Island

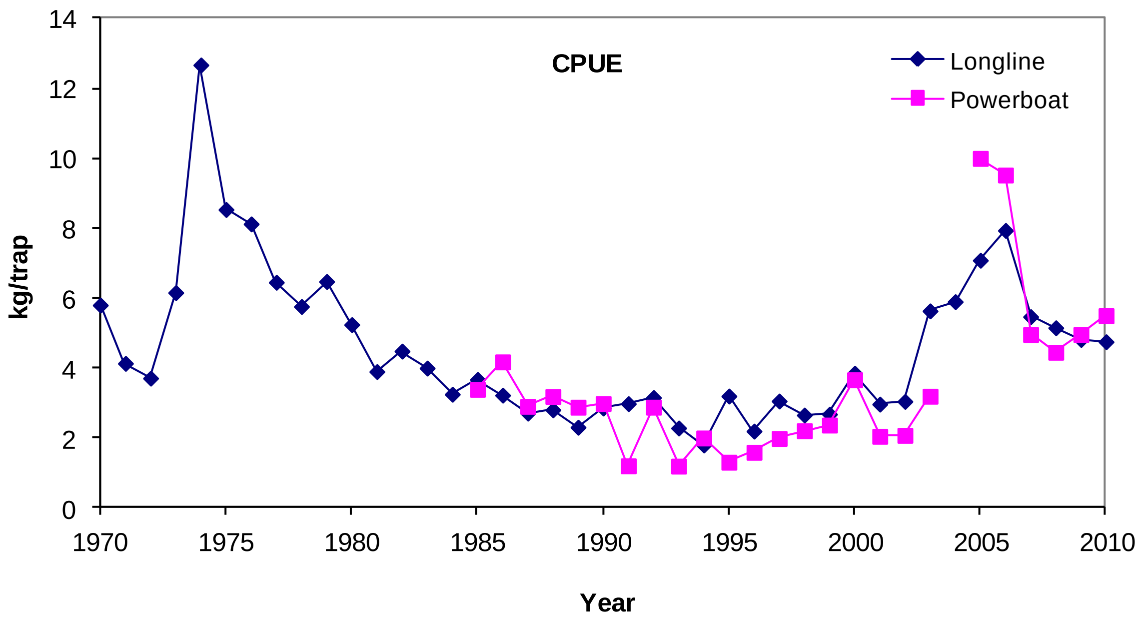


Fig 2.9: Catch Per Unit Effort (CPUE) of *Jasus tristani* using long-lines and power-boats at Inaccessible Island between 1970 and 2010

2.11 Inaccessible Island

2.11.1 Fishing Effort

At Inaccessible island longline fishing effort was high at the start of the fishery and declined through the 1970s through to the mid-1980s after which it stabilised (2.10). A large decrease in fishing effort (40.8 to 16.9 longline trap*1000 hauled) followed the change in concession holders, which occurred in 1997. To allow for the rebuilding of the lobster stock, after several years with a lower TAC the fishing improved and no powerboats were used in the 2005/2006 fishing season because long-line effort was sufficient to make the required catches.

a) Fishing effort at Inaccessible Island

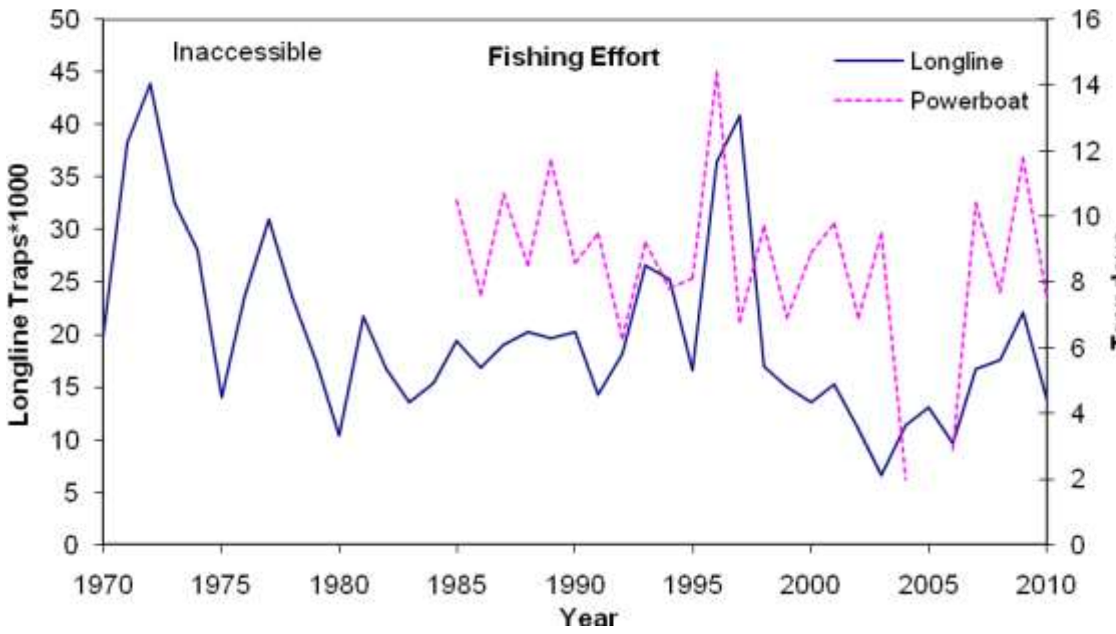


Fig 2.10: Fishing effort of long-lines and power-boats at Inaccessible Island between 1970 and 2010

2.11.2 Catches

At Inaccessible island a larger proportion of catches were made by longlines compared to power-boats in each year. Catches using longlines peaked at 282 mt in 1974 (Fig 11, Appendix B), when monster traps were first introduced, and then declined rapidly to a minimum of 34 mt in 1980 for longlines (74 mt with powerboats). Catches remained relatively stable at 70-100 mt per year between 1980 and 1997, but has steadily increased to > 100 t per year after 2005. Fishing was also stopped in the 2010/11 season following the wreck of the *Oliva* (on the 16^{th} March 2011) nine miles from the South East of Nightingale Island.

b) Total catches of lobster at Inaccessible Island

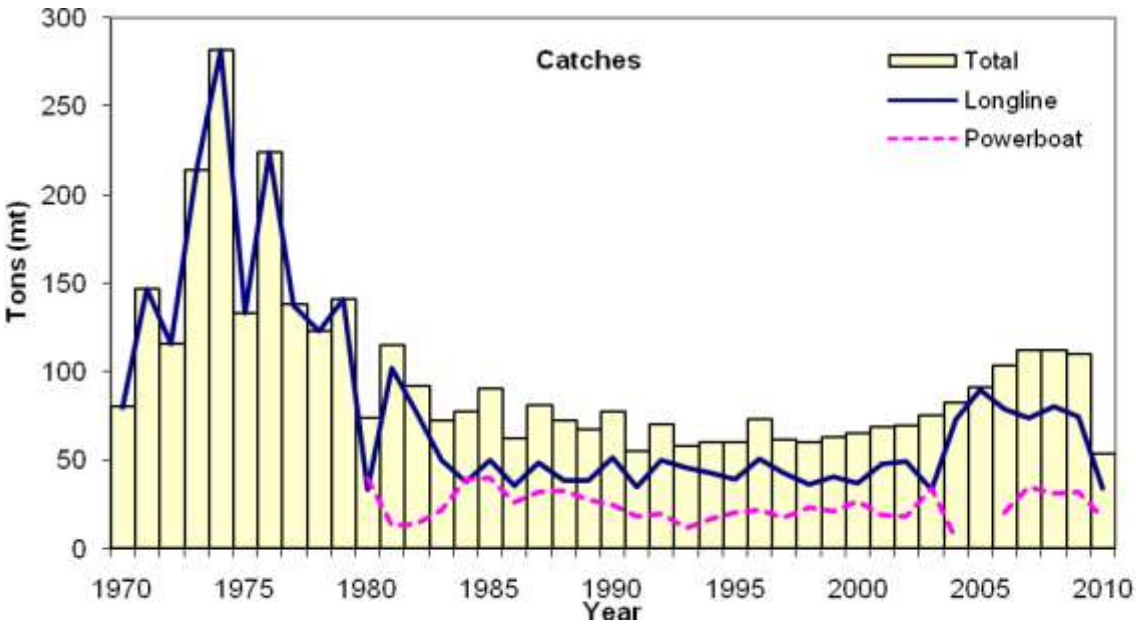


Fig 2.11: Total catches of *Jasus tristani* in metric tonnes per fishing season made at Inaccessible Island by long-lines and powerboats separately and combined for the period between 1970 and 2010

2.11.3 CPUE

Since the introduction of the steel monster trap in 1974, when the longline CPUE peaked at ca 10kg/trap, there has been a gradually declined to a low of 1.1kg/trap in 1997 (Fig. 2.12) despite 40,800 Monster traps being hauled (Fig 2.10). The CPUE of powerboats declined from approximately 4kg/trap.day in 1985, when they were first introduced, to 1kg/trap.day in 1996.

In the 2003/04 season the minimum legal size (MLS) was reduced from 70 mm to 68 mm (CL) at Inaccessible Island. Although no adjustments have been made to the CPUE, stock response has been detected in an assessment undertaken by the Department of Mathematics and Applied Mathematics at the University of Cape Town (Johnson & Butterworth, 2012) suggested that CPUE values should be adjusted downwards by 2% at Inaccessible Island from the 2003/04 season onwards (Johnston & Butterworth, 2009).

The CPUE trends of both gear-types increased gradually from 1997 and peaked to 8.2kg/trap for longlines, 6.9kg/trap for powerboat traps in 2006. However, since 2007/08 the CPUE for both longlines and powerboats at Inaccessible Island has showed some declines 2.5kg/trap and 2.3kg/trap respectively. No power-boats were used at Inaccessible Island in 2005.

c) Trends in CPUE at Inaccessible Island

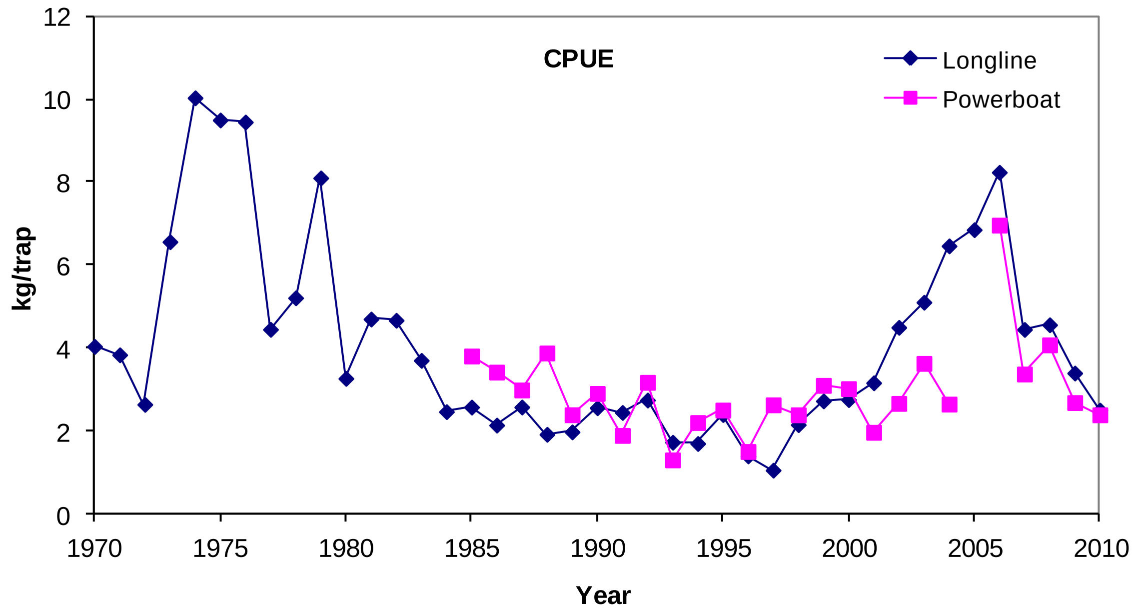


Fig 2.12: Catch Per Unit Effort (CPUE) of *Jasus tristani* using long-lines and power-boats at Inaccessible Island between 1970 and 2010

2.12 Gough Island

2.12.1 Fishing Effort

Longlines using plastic kavel traps and steel monster traps, were exclusively used at Gough Island until the mid 1970's, whereafter powerboats using small traps were also introduced. Catches made by the two gear-types were only recorded separately from 1985 onwards (Fig. 2.13). Fishing effort using both gear types increased gradually between 1985 and 2001, whereafter it decreased until 2008. Fishing effort declined by 50.2% for longlines and 39.4% for powerboat days between 2001 and 2008. Even with the substantially reduced longline effort of 8 331 traps hauled in 2008, landing 66 mt (longlines & powerboats). It was considerably higher than in 2001 where 41 692 traps hauled only landed 88.6 mt from both longlines and powerboats (Fig. 2.14, Appendix B) at Gough Island.

a) Fishing effort at Gough Island

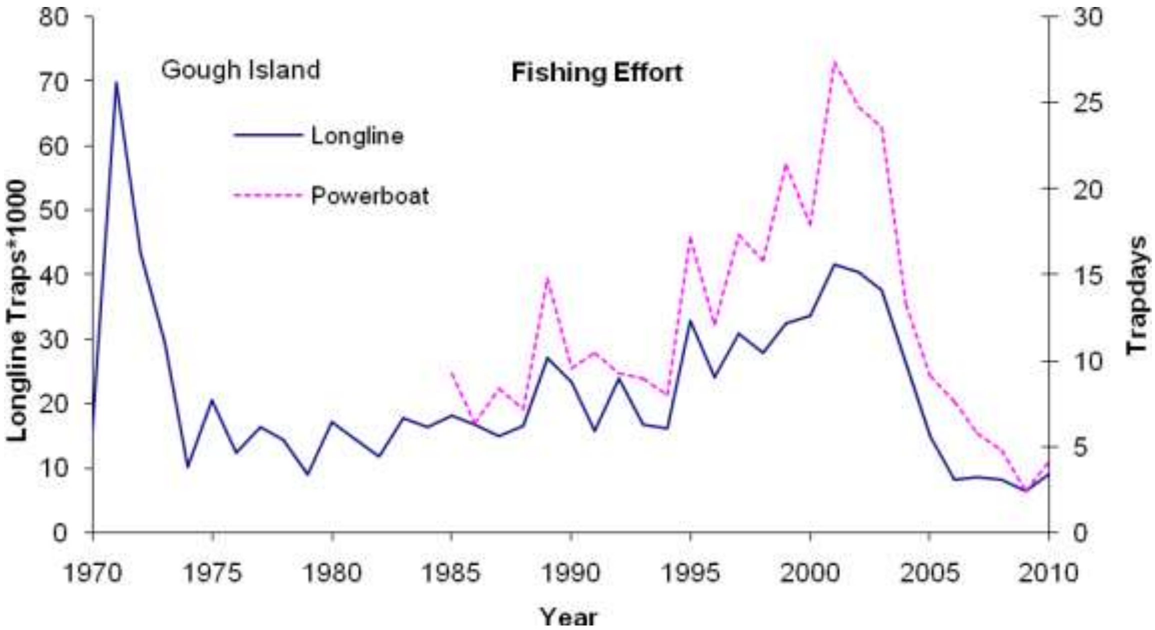


Fig 2.13: Fishing effort of long-lines and power-boat traps set at Gough Island between 1970 and 2010

2.12.2 Catches

With a single exception, the largest proportion of the annual catch at Gough Island is brought in by longline vessels. Catches at Gough Island peaked at 380 mt in 1971 (Fig. 2.14). Over the following five years, annual catches decreased to 64 mt in 1976. Between 1977 to the introduction of TAC's in 1991 there were only two years when the catches were below 100 mt. Since 1991 to 2010 only once in 1995 (103.5 mt) have more than a 100 mt been caught, although catches have steadily increase from 2006 (Appendix B).

b) Total catches of lobster at Gough Island

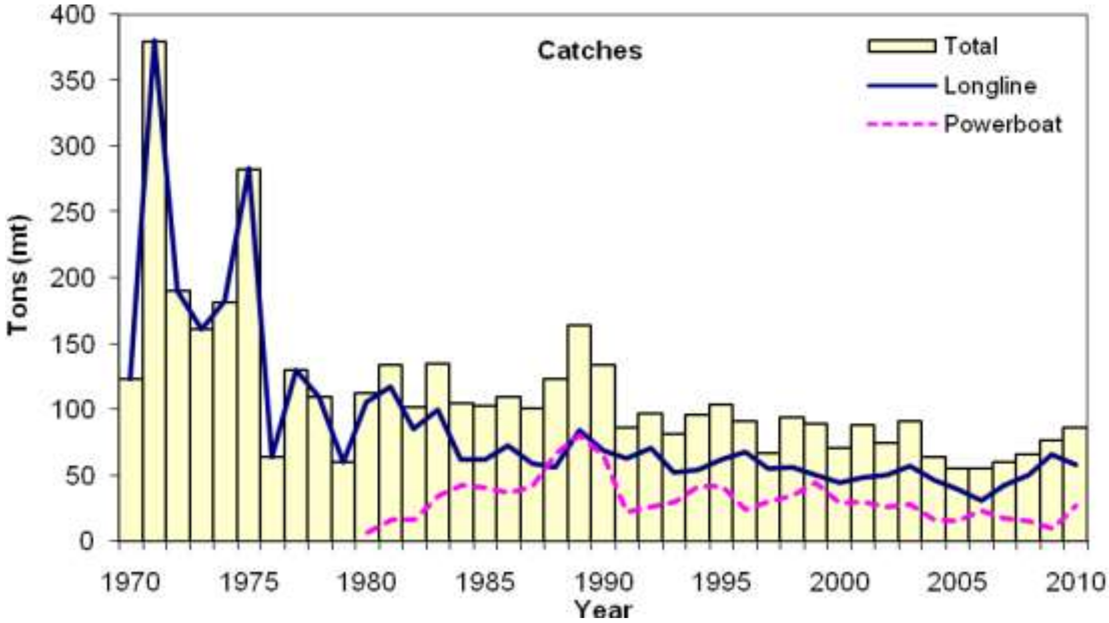


Fig 2.14: Total catches of *Jasus tristani* in metric tonnes per fishing season made at Gough Island by long-lines and powerboats separately and combined for the period between 1970 and 2010

2.12.3 CPUE

The large increase of lobsters at Gough Island in CPUE 17.8kg/trap in 1974 was as a result of the introduction of monster traps, to replace the less efficient barrel-shaped kavel traps. The CPUE of longlines thereafter declined gradually from 1975 to 1.2kg/trap in 2002 (Fig 2.15).

In the 2003/04 season the MLS was increased from 70 mm to 75 mm (CL) at Gough Island. Although no adjustments have been made to the CPUE, stock response has been detected in an assessment undertaken by the Department of Mathematics and Applied Mathematics at the University of Cape Town (Johnston & Butterworth, 2012) suggesting that CPUE values should be adjusted upwards by 5% at Gough Island, from the 2003/04 season onwards (Johnston & Butterworth, 2009).

Between 1995 and 2005, vessels fishing at Gough Island have struggled to achieve the TAC set for the island (Appendix C), and during the winter months it became uneconomic for them to operate because of a low CPUE, which is not evident in Fig. 2.15, because the seasons effort has been combined.

The concession holders were changed in 1997, and the TAC was reduced by 30 mt in 2004/2005. These management interventions appear to have led to a recovery of the fishery as the CPUEs of both longlines and powerboats have increased. According to MARAM Johnston and Butterworth (2009) (James *per obs*) the increase in the CPUE at Gough was likely a result of the management interventions (reduced TAC, increase in MLS) in 2004.

c) Trends in CPUE at Gough Island

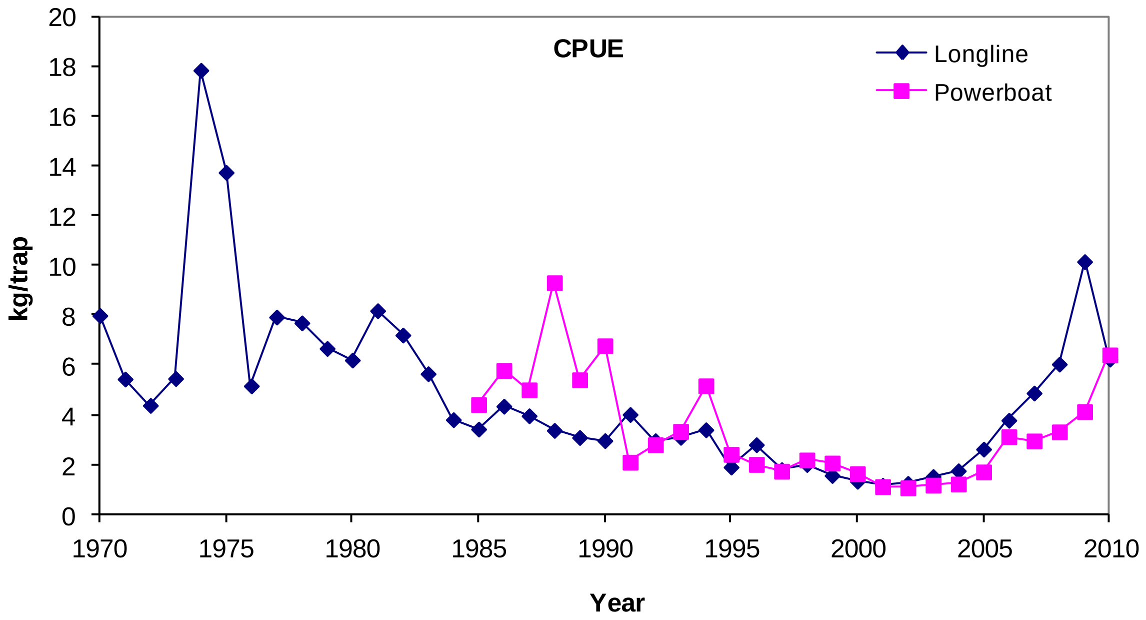


Fig 2.15: Catch Per Unit Effort (CPUE) of *Jasus tristani* using longlines and powerboats at Gough Island between 1970 and 2010

2.14 Conclusion

Since the fishery started for *Jasus tristani* at the Tristan da Cunha group in 1949, it has been characterised by a series of changes in boats, and fishing gear used. For the outer islands of Nightingale, Inaccessible and Gough, wooden vessels and dinghy's were replaced by steel vessels operating longlines with traps and 5-7m powerboats operating with both hoop nets and steel powerboat traps.

For the local fishery at Tristan da Cunha, dinghy's were replace by 5 m powerboats which was later replace by 7 m powerboats, operating with hoop nets and powerboat traps. This change in fishing techniques has seen catches increase and decrease over the past 60 years of operation. For the first 10 years of historic lobster catch records from 1967 to 1976, (at the time when the steel monster tarps were introduced in 1974) catches were 549 mt on average, all islands combined, but catches soon decline to an average of 416 mt for the next ten years. The following 10 years (1986 to 1996) up until the Tristan da Cunha Government (TDCG) changed the concession holders, the average had fallen to 380 mt.

Since the new concession holders were awarded the lobster concession in 1997 there has been some recovery, and catches have remained between 312 to 447 mt per fishing season for all islands combined. The lobster fishery at Tristan da Cunha has remained the most stable as the Tristan islanders are acutely aware that they have to look after their resources, as it is the main source of revenue and employment for future generations.

Three lobster processing factories have been built, the first one was destroyed by the 1961 volcano eruption, the second one was destroyed by fire in 2008, and the third one opened in 2009, and was built to European Union (EU) standards. The fishery for *J. tristani* was certified by the Marine Stewardship Council (MSC) in 2011, implying that it passed a stringent assessment of stock status, management efficiency, and environmental impact.

Appendix A

Fishing vessels used in the Tristan da Cunha group fishery (1949 – 2010)

***PEQUENA (A.1)*:** (Photo Penny Day)

***TRISTANIA (A.2)*:** (Photo Penny Day)

***TRISTANIA II (A.3)*:** (Photo Penny Day)

***FRANCES REPETTO (A.4)*:** (Photo John H Marsh Maritime Collection, Iziko Museums of South Africa)

***GILLIAN GAGGINS (A.5)*:** (Photo Penny Day)

M.F.V. HILARY (A.6): (Photo Michael Edwards)

M.F.V. MELODIE (A.7): (Photo James Glass)

M.V. HEKLA / M.V. EDINBURGH (A.8)**:** (Photo Norman Glass)

***KELSO (A.9)*:** (Photo Norman Glass)

Appendix B

Historic Catch Records of *Jasus tristani* caught at the Tristan da Cunha group in whole weight, metric tons. Split-year fishing seasons are as follows: 1st May of Year 1 to 30th April of Year 2

HISTORIC FISHING SEASON	TRISTAN TOTAL CATCH KGS	GOUGH TOTAL CATCH KGS	NIGHTINGALE TOTAL CATCH KGS	INACCESSIBLE TOTAL CATCH KGS	ALL ISLANDS GRAND TOTAL KGS
1967	241,700				241,700
1968	145,800				145,800
1969	252,800				252,800
1970	211,900	123,000	141,000	80,000	555,900
1971	231,900	380,000	98,000	147,000	856,900
1972	206,500	190,000	49,000	116,000	561,500
1973	169,760	161,000	77,000	214,000	621,760
1974	165,845	182,000	166,000	282,000	795,845
1975	178,300	283,000	245,000	133,000	839,300
1976	148,512	64,000	182,000	224,000	618,512
1977	97,500	130,000	71,000	138,000	436,500
1978	156,580	110,000	34,000	123,000	423,580
1979	117,556	60,000	114,000	141,000	432,556
1976	114,882	113,000	113,000	74,000	414,882
1981	153,673	134,000	57,000	115,000	459,673
1982	131,770	102,000	69,000	92,000	394,770
1983	128,934	135,000	48,000	72,000	383,934
1984	117,446	105,000	80,000	77,000	379,446
1985	161,947	103,000	69,000	90,000	423,947
1986	151,325	110,000	93,000	62,000	416,325
1987	189,937	101,000	70,000	81,000	441,937
1988	163,276	123,000	77,000	72,000	435,276
1989	174,682	164,000	44,000	67,000	449,682
1990	161,431	134,000	56,000	77,000	428,431
1991	165,347	86,020	61,387	55,274	368,028
1992	137,987	96,909	59,314	70,006	364,216
1993	112,060	82,043	50,861	58,532	303,496
1994	125,342	95,972	51,182	60,194	332,690
1995	112,540	103,508	56,660	60,080	332,788
1996	119,028	91,570	62,050	72,760	345,408
1997	125,765	66,994	51,288	61,108	305,155
1998	117,172	94,652	50,444	60,102	322,370
1999	122,019	89,678	51,433	62,725	325,855
2000	124,391	71,127	51,348	65,131	311,997
2001	127,274	88,666	55,748	68,918	340,606
2002	132,550	74,540	55,334	69,175	331,599
2003	137,698	91,665	56,173	75,536	361,072
2004	157,824	63,978	59,981	82,574	364,357
2005	160,555	55,780	60,868	90,844	368,047
2006	179,594	55,361	62,071	103,073	400,099
2007	186,755	60,659	64,104	111,985	423,503
2008	181,703	66,011	70,627	111,888	430,229
2009	186,830	77,090	72,631	109,947	446,498
2010	180,751	86,849	62,745	53,350	383,695

Appendix C

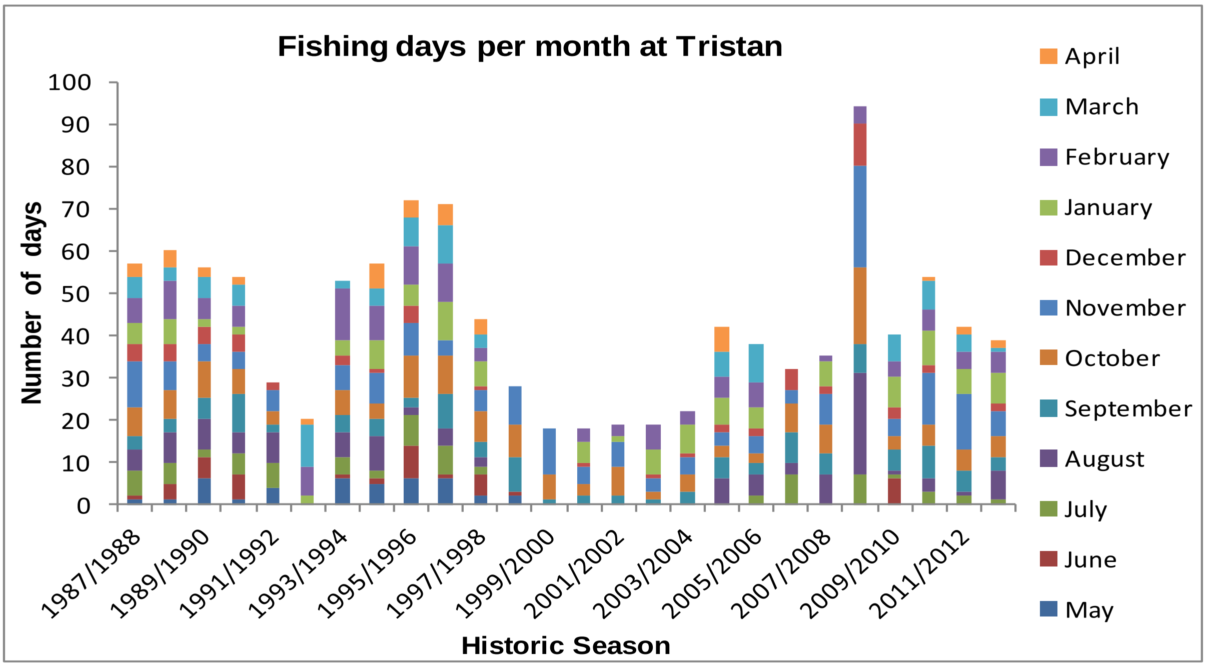
Total Allowable Catches (TAC's) set by the Fisheries Department and catches landed since the introduction of TAC's in 1991. Note difference in totals reflects new companies fishing season

FISHING SEASON	TRISTAN		GOUGH		NIGHTINGALE		INACCESSIBLE	
	TAC (KGS)	ACTUAL CAUGHT (KGS)	TAC (KGS)	ACTUAL CAUGHT (KGS)	TAC (KGS)	ACTUAL CAUGHT (KGS)	TAC (KGS)	ACTUAL CAUGHT (KGS)
1990/91 (MAY-APR)	147,000	160,768 + Hekla 663 = 161,431	90,000	134,000	60,000	56,000	75,000	77,000
1991/92 (MAY-APR)	160,000	79,372 + Hekla 85,975 = 165,347	97,000	86,020	60,000	61,387	70,000	55,274
1992/93 (MAY-APR)	149,000	37,811 + Hekla 100,176 = 137,987	82,000	96,909	51,000	59,314	60,000	70,006
1993/94 (MAY-APR)	145,000	82,180 + Hekla 29,880 = 112,060	82,000	82,043	51,000	50,861	60,000	58,532
1994/95 (MAY-APR)	145,000	95,596 + Hekla 29,746 = 125,342	96,000	95,972	51,000	51,182	60,000	60,194
1995/96 (MAY-APR)	112,000	112,540	119,000	103,508	51,000	51,127	60,000	60,075
1996 (MAY-DEC)	73,000	74,740	90,000	90,214	43,000	41,724	48,000	47,586
Change of Concession holder on 1st January 1997								
1997 (JAN-AUG)	59,000	60,582	48,000	11,543	20,000	20,315	24,000	24,063
1997/98 (SEPT-AUG)	112,000	112,254	100,000	86,304	51,000	51,288	60,000	61,108
1998/99 (SEPT-AUG)	112,000	114,388	100,000	87,850	51,000	50,444	60,000	60,102
1999/00 (SEPT-AUG)	120,000	122,019	100,000	93,359	51,000	51,433	60,000	62,725
2000/01 (SEPT-AUG)	125,000	124,391	90,000	74,941	51,000	51,348	65,000	65,131
2001/02 (SEPT-AUG)	128,000	127,274	80,000	79,876	55,000	55,748	68,000	68,918
2002/03 (SEPT-AUG)	133,000	132,550	80,000	78,558	55,000	55,334	68,000	69,175
2003/04 (SEPT-AUG)	138,000	137,698	88,000	83,704	55,000	56,173	75,000	75,536
2004/05 (AUG-JULY)	158,000	157,824	55,000	56,708	60,000	59,981	85,000	82,574
2005/06 TDC - (JULY-JUNE) OUT ISL. - (AUG-JULY)	160,000	160,555	55,000	55,780	60,000	60,868	90,000	90,844
2006/07 TDC - (JULY-JUNE) OUT ISL. - (AUG-JULY)	180,000	179,594	55,000	55,361	60,000	62,071	100,000	103,073
2007/08 TDC - (JULY-JUNE) OUT ISL. - (AUG-JULY)	185,000	169,386 + Edin. 17,369 = 186,755	60,000	60,659	63,000	64,104	110,000	111,985
2008/09 TDC - (JULY-AUG) OUT ISL. - (AUG-JULY)	190,000	168,522 + Edin. 17,498 = 186,020	65,000	66,011	72,000	70,627	110,000	111,888
2009/10 TDC - (JULY-JUNE) OUT ISL. - (AUG-JULY)	185,000	126,651 + Edin. 55,862 = 182,513	75,000	77,090	72,000	72,631	110,000	109,947
2010/11 TDC - (JULY-JUNE) OUT ISL. - (AUG-JULY)	180,000	167,778 + Edin. 12,973 = 180,751	85,000	86,849	72,000	62,745	105,000	53,350
2011/12 TDC - (JULY-JUNE) OUT ISL. - (AUG-JULY)	174,000	149,714 + Edin. 25,085 = 174,799	95,000	95,814	0	0	53,000	53,697

Appendix D

Fishing days per month at Tristan, for the historic season. Note: From July '08 – February '09 local boats were fishing from vessel *Kelso* as the Tristan Factory had been destroyed by fire

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	TOTAL SEASON
1987/1988	1	1	6	5	3	7	11	4	5	6	5	3	57
1988/1989	1	4	5	7	3	7	7	4	6	9	3	4	60
1989/1990	6	5	2	7	5	9	4	4	2	5	5	2	56
1990/1991	1	6	5	5	9	6	4	4	2	5	5	2	54
1991/1992	4	0	6	7	2	3	5	2	No Fishing -				29
1992/1993	Harbour Project								2	7	10	1	20
1993/1994	6	1	4	6	4	6	6	2	4	12	2	0	53
1994/1995	5	1	2	8	4	4	7	1	7	8	4	6	57
1995/1996	6	8	7	2	2	10	8	4	5	9	7	4	72
1996/1997	6	1	7	4	8	9	4	0	9	9	9	5	71
1997/1998	2	5	2	2	4	7	5	1	6	3	3	4	44
1998/1999	2	1	0	0	8	8	9	0	0	0	0	0	28
1999/2000	0	0	0	0	1	6	11	0	0	0	0	0	18
2000/2001	0	0	0	0	2	3	4	1	5	3	0	0	18
2001/2002	0	0	0	0	2	7	6	0	1	3	0	0	19
2002/2003	0	0	0	0	1	2	3	1	6	6	0	0	19
2003/2004	0	0	0	0	3	4	4	1	7	3	0	0	22
2004/2005	0	0	0	6	5	3	3	2	6	5	6	6	42
2005/2006	0	0	2	5	3	2	4	2	5	6	9	0	38
2006/2007	0	0	7	3	7	7	3	5	0	0	0	0	32
2007/2008	0	0	0	7	5	7	7	2	6	1	0	0	35
2008/2009	0	0	7	24	7	18	24	10	0	4	0	0	94
2009/2010	0	6	1	1	5	3	4	3	7	4	6	0	40
2010/2011	0	0	3	3	8	5	12	2	8	5	7	1	54
2011/2012	0	0	2	1	5	5	13	0	6	4	4	2	42
2012/2013	0	0	1	7	3	5	6	2	7	5	1	2	39



Appendix E

The various types of fishing gear used in the Tristan da Cunha fishery between 1949 and 2010

Hoop net (E.1), Bee hive or Ink well (E.2), Monster trap (E.3), Willow trap (E.4), Plastic trap or Kavel trap (E.5), Powerboat trap or pot (E.6)

Chapter 3

Length and weight relationships of *Jasus tristani*

3.1 Introduction

Length and weight relationships are essential to understand the biological parameters of fishes and crustaceans. These relationships are essential in fisheries management and stock assessments, where they are used to convert measurements of length or weight from different sources into comparable units (Human & Al-Busaidi, 2008). Length measurements from samples are normally used to characterize the size distribution of the population (the length frequency distribution), as they can often be collected more quickly and accurately than weight measurements and are less subject to temporary changes in the condition of individuals (Pollock & Augustyn, 1982). The relationship between length and weight is important to determine whether growth is isometric, or whether growth changes with age, and also for identifying sexual dimorphism (Le Cren, 1951).

As length-weight relationships are important morphometric parameters, there are numerous studies on these for crustaceans (Fielder, 1964; Berry, 1971; Beyers, 1979; Pollock & Augustyn, 1982; Grobler & Noll-Peard, 1997; Brinca & Palha de Sousa, 1983; Groeneveld & Goosen, 1996; Arana & Olate, 2000). If any part of the animal is discarded during primary processing then a measurement of the retained parts must be available to be converted to measurements useful for management purposes, such as the legally defined size limit. This is the case for *Jasus tristani*, for which the minimum size limit is defined in carapace length, but part of the catch is processed to frozen lobster tails on board the fishing vessel. Other management measures like quotas are typically based on the total weight of animals harvested, but again this may be difficult to measure if parts of animals are discarded before inspection. *Jasus tristani* is landed live, or as whole frozen or tailed lobster products (Pollock, 1981). To convert these product types into a total weight for management purposes, accurate conversion factors from tail weight to whole weight are required to monitor compliance with the total allowable catch.

Length and weight regressions for *Jasus tristani* were previously provided by Roscoe (1979). These regressions showed that the tailed weight represented 30% of the whole weight of rock lobster, and that tails from females were heavier than males of the same length. For the closely related Cape rock lobster *Jasus lalandii,* length and weight regressions were estimated by Heydorn (1969) and these showed that females of the same carapace length also had a higher tail weight than males, regardless of the time of year the lobsters were caught. Heydorn found that there was a quantifable increase in relative tail weight with size in females, whereas in larger males there was a decrease in tail weight relative to whole weight.

The aims of this chapter were to update the length-weight relationship of *Jasus tristani* from previous studies and to assess the relationships between a) carapace length (CL) and whole weight, b) CL and tail weight, c) whole and tail weight, and d) CL and the width of the 2^{nd} abdominal segment. These lobster measurements are all used for fisheries management purposes. An additional aim was to assess whether the conversion factor from tail weight to whole weight used in the factory at present (3.0) is correct, considering the size and sex ratio of lobsters captured in the fishery. Currently, trays of tails weighing 4.54 kg are converted to represent a weight of 13.63 kg of whole lobster. Finally, the chapter examines the trends in mean weight of retained lobster catches from Tristan da Cunha, Nightingale, Inaccessible and Gough Islands, contrasts these with the estimated weight of samples of the total catch, and examines possible impacts of the fishery on these parameters.

3.2 Materials and methods

3.2.1 Study Area

Refer to Chapter 2, section 2.3 for a full description of the study area.

3.2.2 Biological measurements (size and sex)

Carapace length (CL ± 0.1 mm) is used as a unit of measure for the Tristan lobster fishery, and other lobster fisheries (Pollock & Augustyn, 1982), because CL is easy to record when measuring large numbers of samples at sea. A large quantity of length and weight samples of *Jasus tristani* (1526 lobsters) from this study were collected by the Tristan da Cunha Fisheries Department between 1994 and 2007 (Sea Fisheries Observers reports). These data covered both sexes at Tristan da Cunha, Nightingale, Inaccessible and Gough Islands. All of these measurements were taken on freshly captured specimens. The widest possible CL range (58 to 141 mm CL) was covered, and only lobsters with no missing appendages were selected. Egg-bearing females were excluded from the samples.

CL was measured mid-dorsally from the anterior tip of the rostrum to the posterior edge of carapace using a Vernier calliper. Sex was determined externally by inspecting the position of the gonophores (genital pore). In males, the genital pore is located at the base of the fifth pair of walking legs while in the female rock lobster it is found at the base of the third pair of walking legs, where the eggs are released. In addition sex was determined by the number/position of the pleopodal exopodites (swimmers) located ventrally on the abdomen.

Whole weight (WW ± 1 g) was determined on an electronic scale after shaking excess water from the gill chambers and tail weight (TW ± 1 g) was determined from tails that were removed in a commercial manner, i.e. by removing the abdominal musculature which extends into the carapace with the tail (see Heydorn, 1969;, Groeneveld & Goosen, 1996). The width of the second abdominal segment (AS ± 1 mm) was also measured. All lobsters used for length weight samples were weighed onshore (using analytical balances - AS 220/C/2) by the Fisheries Department Officials to prevent inaccuracies associated with using electronic scales at sea.

3.2.3 Statistical treatment of data

Regressions were fitted to male and female data for lobsters from each island, using the least-squares method (Zar, 1984). All data were log-transformed prior to model fitting. Linear regressions ($y = ax + b$) were fitted to log – transformed CL versus WW and for CL versus TW data. All regression equations were fitted using Microsoft Excel.

Comparisons between the regression slopes and elevations (Zar, 1984), of length and weight relationships of the two sexes at each island, were tested using Student's t-tests for significant differences between slopes ($P < 0.05$).

A one-way analysis of variance (ANOVA) was utilized to test for significant differences in the mean size of lobster, (i.e. mean WW, CL, TW) between the four islands. Following this analysis a post hoc test, the Tukey's Honestly Significant Difference (HSD) test, was applied to analyse paired comparisons (Zar, 1984).

The relationship between WW and TW was examined using the least squares method to fit a linear regressions, again separating males and females. To compare CL and TW relationships, of male versus female lobsters, 150 male and 150 female lobsters between 63 mm and 78 mm CL were selected. This size range was selected as it included samples below and above the minimum legal size (MLS) at each island (i.e.Tristan da Cunha and Nightingale 70 mm CL, Inaccessible 68 mm CL, Gough 75 mm CL). Due to the limited number of samples, the relationship between CL and TW width for males and females was examined as a simple linear relationship.

Finally, trends in the mean weight of lobster in the retained catch at each island were computed from the number of cases of lobsters in each commercial size category for whole lobster and tails, using the computed mean weight of whole lobster in each size class, the mean number of animals per carton and the number of cases. Because individual lobsters were not measured, a standard deviation could not be estimated, therefore it is not possible to ascribe confidence limits to these estimates, but they represent the most comprehensive estimate of the size of harvested lobsters at each island. They are provided for comparison with the mean weight of samples (which comprise retained and released undersized lobster) estimated from the CL measurements and length/weight conversion regression.

3.3 Results

3.3.1 Length/weight relationships

From March 2006 to May 2007 a total of 1526 lobsters was measured at all islands combined (Table 3.1), of these 1253 (83.1%) were male and 273 (17.9%) were female. The CL ranged from 58 mm to 141 mm and 60 mm to 108 mm for males and females respectively.

Three sets of results are presented in this section: the relationship between CL and WW, the relationship between CL and TW, and the relationship between WW and TW. Data have been presented for all Islands combined, for each island separately and for male and female lobsters, as well as for both sexes combined (Table 3.1). Regression analysis of each of these data sets are presented in Table 3.1 and all show strong correlation with r^2 values > 0.9 in all cases, (Table 3.1) indicating that the equation fits the data well. Results of the Students t-tests, comparing slopes and elevations of linear regressions of male and female *J.tristani* are presented in Table 3.2. These data show that the relationship between CL and TW as well as TW and WW are significantly different for males and females from some of the islands.

3.3.2 Carapace length versus Whole weight

CL versus TW is for all Islands combined is shown in Fig 3.1 and for each island separately (Tristan Fig 3.2, Nightingale Fig 3.3, Inaccessible Fig 3.4 and Gough Islands Fig 3.5). Visual examination of the plots suggests a logarithmic relationship for both males and females. There was no significant difference between male and female CL and WW for all islands combined (Table 3.2). The same result was shown for Tristan Island and Nightingale, however, results shown a highly significant difference between males and females for lobsters at both Inaccessible and Gough Islands ($P < 0.001$) (Table 3.2).

3.3.3 Carapace length versus Tail weight

The CL versus TW relationship of lobsters show an apparent divergence between males and females. As lobsters increased in size, the TW of females became proportionally heavier than that of males, and this trend was highly significant for all islands combined and for Tristan Island (Table 3.2)

3.3.4 Whole weight verses Tail weight

The WW versus TW relationship of lobsters showed a difference between males and females at all islands except Nightingale Island (Table 3.2). For all islands the results for the pooled male and female data showed a highly significant difference between WW versus TW. The same result was seen at Tristan (Fig 3.10) and Gough (Fig 3.13) ($P < 0.001$) respectively, Nightingale (Fig 3.11) showed a significant difference between males and females ($P < 0.05$), while Inaccessible (Fig 3.12) which has the smallest lobster within the Tristan da Cunha group showed no significant difference. The current regression used to estimate WW from TW in the commercial fishery is shown in Fig 1a for males and Fig 1b for females, and compared to the results found here the current conversion factor is underestimated for larger males and overestimated for females.

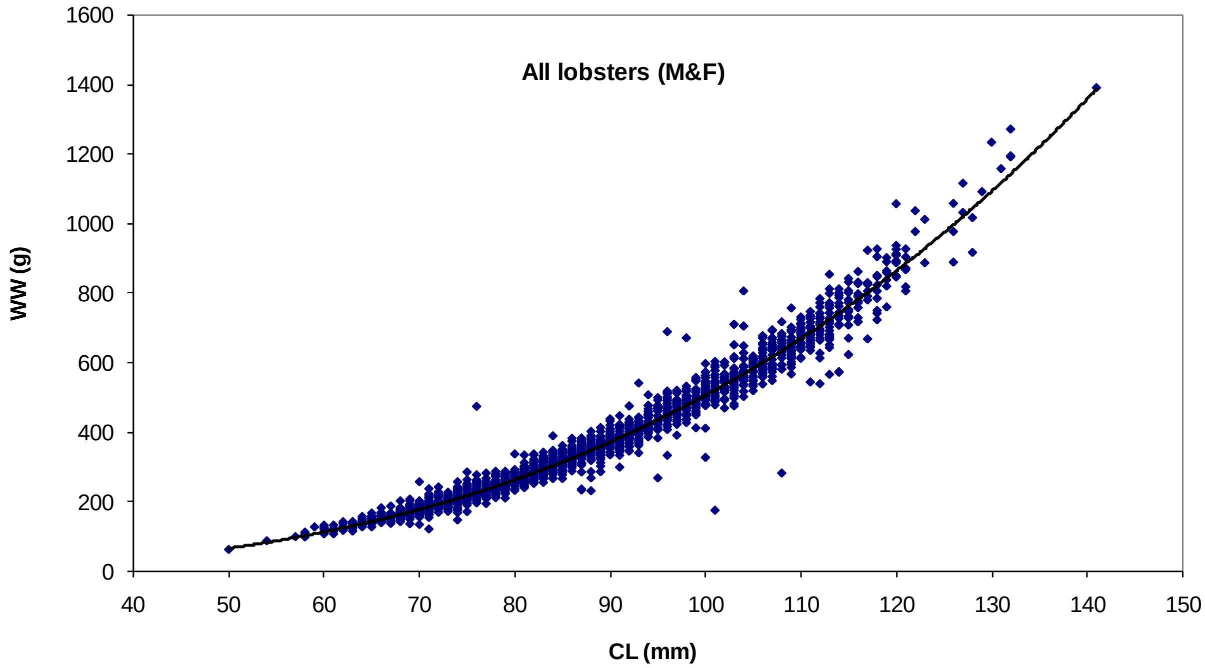


Figure 3.1: Carapace length (CL, mm) against whole weight (WW, g) for all *Jasus tristani* for all islands pooled and both sexes combined. Regression equation WW = 0.000726 x $CL^{2.9215}$ R^2 = 0.9704 (n = 1,526)

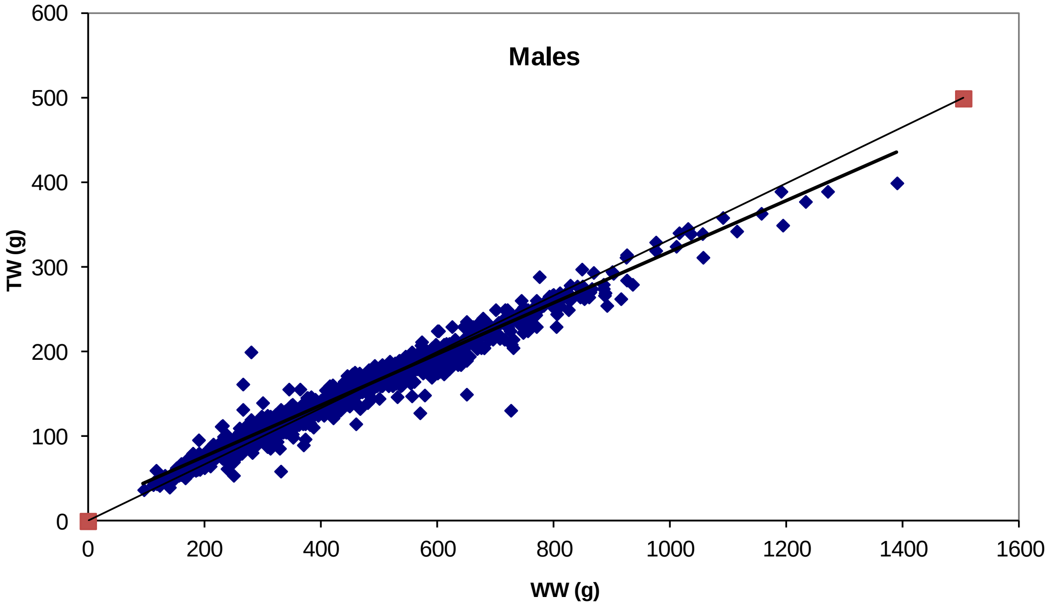


Figure 3.1a: Tail weight (TW g) against whole weight (WW g) for all male *Jasus tristani* sampled (all islands pooled). The current regression used to estimate whole weight from tail weight in the commercial fishery is shown by the line joining the two red cubes. Regression equation for males: TW = 0.3032 WW + 14.16, R^2 = 0.9658 (n = 1253)

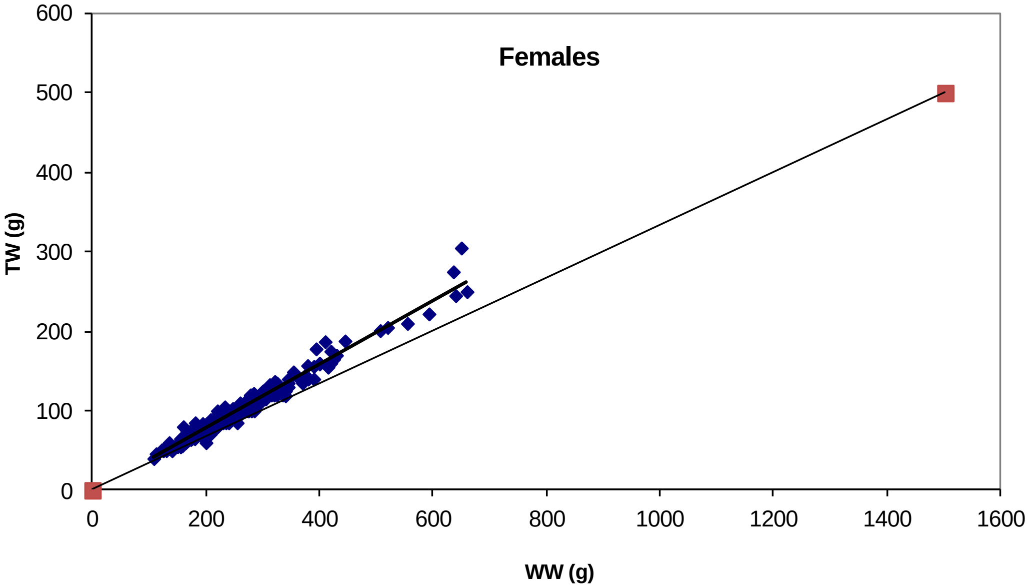


Figure 3.1b: Tail weight (TW g) against whole weight (WW g) for all female *Jasus tristani* sampled, irrespective of island. The current commercial regression used to estimate whole weight from tail weight is shown by the line joining the two red cubes. Regression equation for females: TW = 0.3987 WW – 0.9754 R^2 = 0.9678 (n = 273)

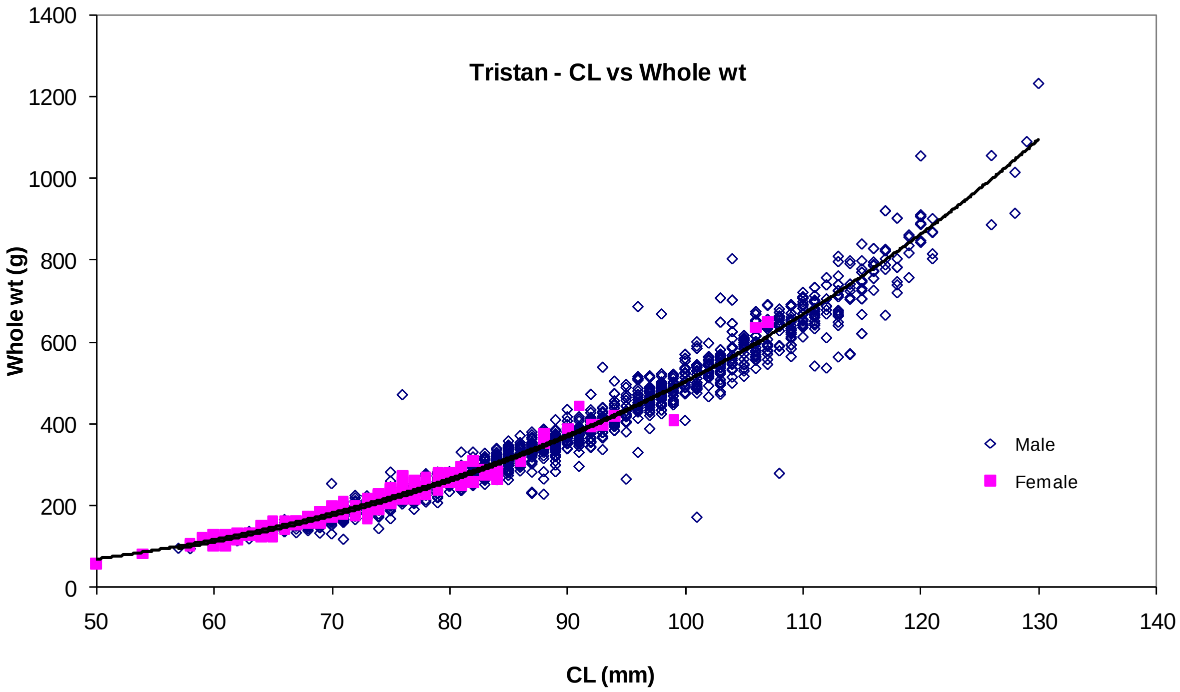


Figure 3.2: CL versus WW regressions for male and female *Jasus tristani* sampled at Tristan Island

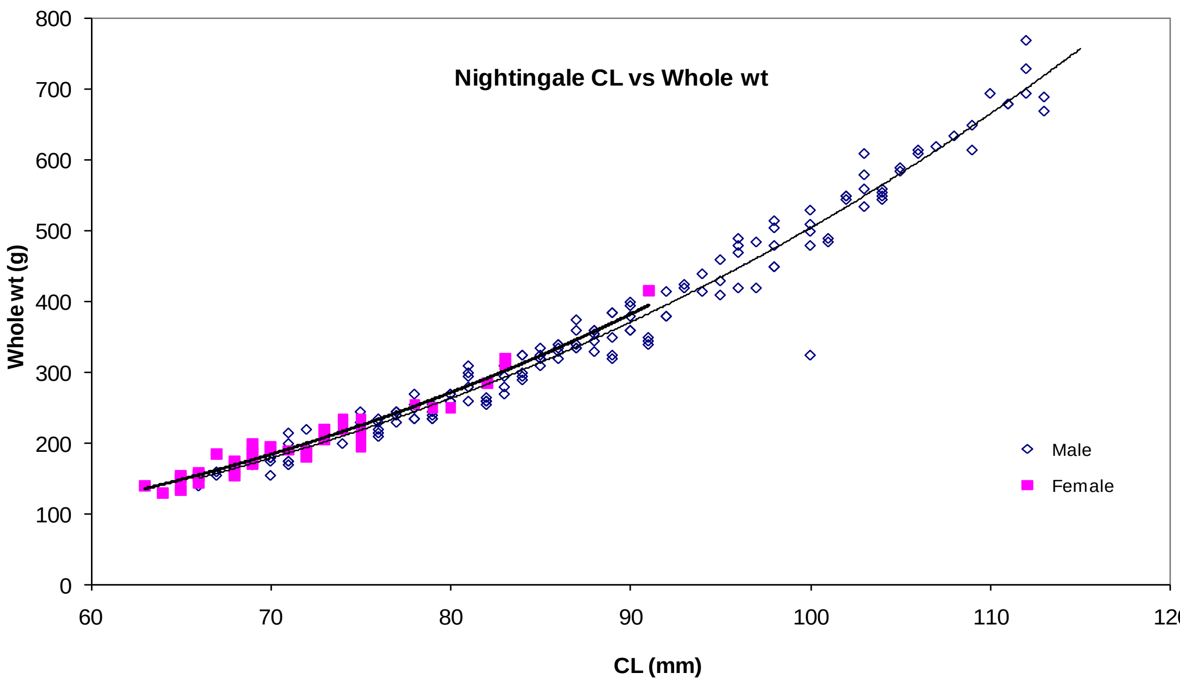


Figure 3.3: CL versus WW regressions for male and female *Jasus tristani* sampled at Nightingale Island

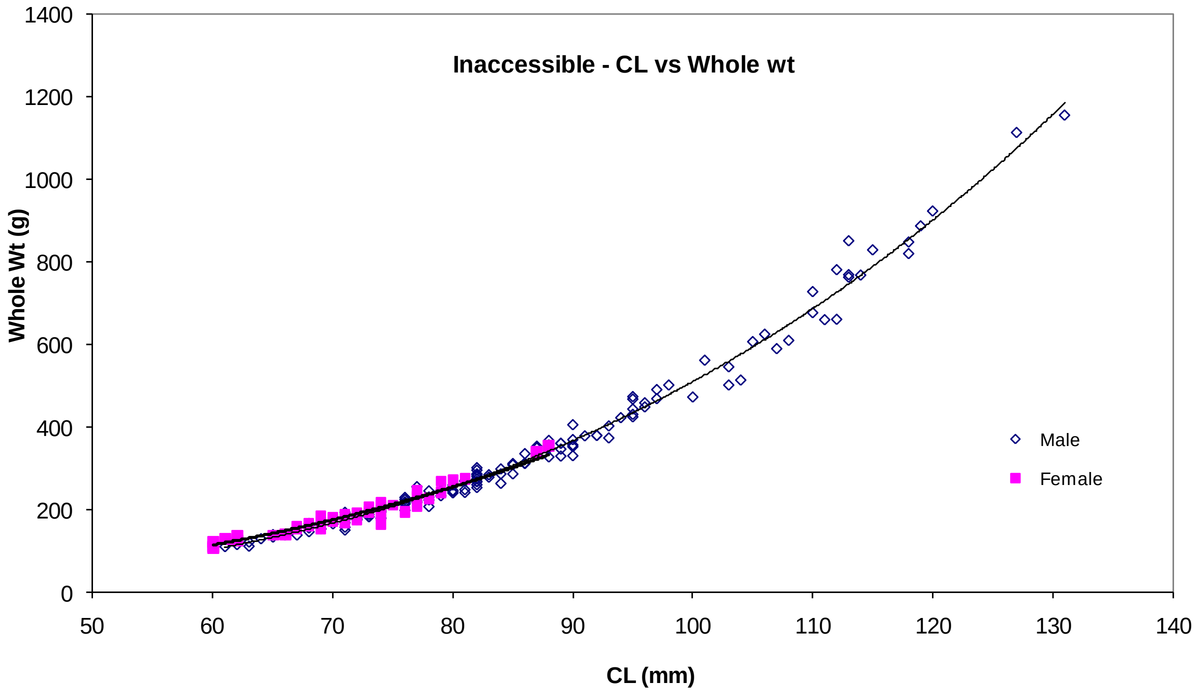


Figure 3.4: CL versus WW regressions for male and female *Jasus tristani* sampled at Inaccessible Island

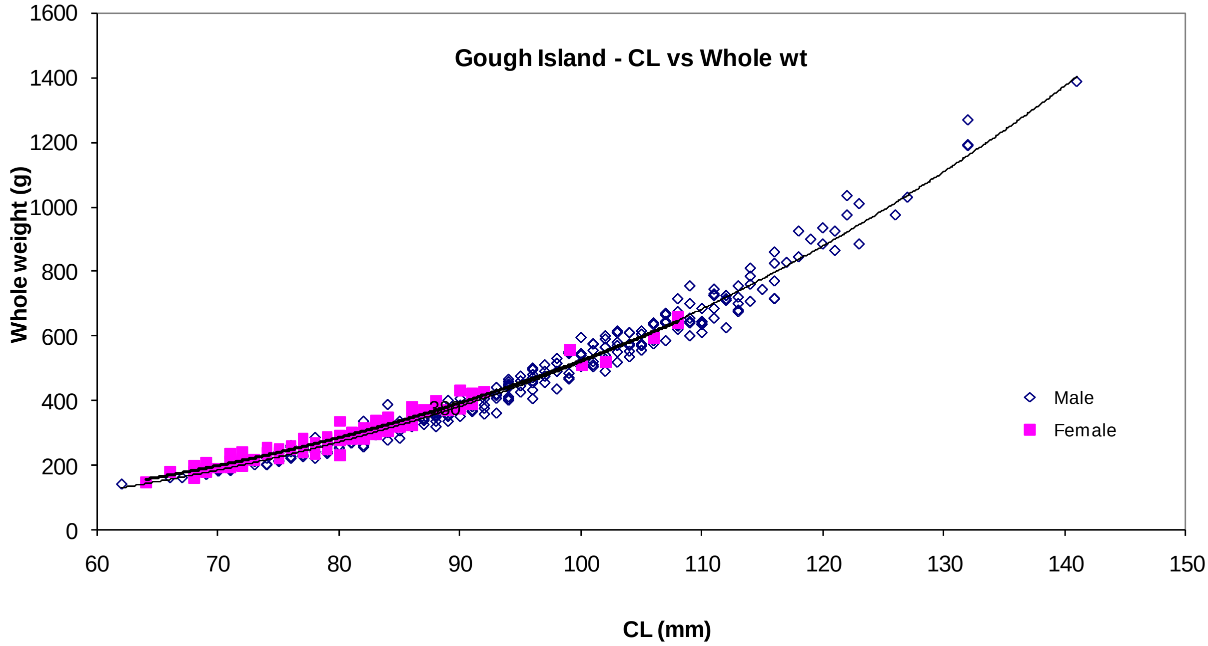


Figure 3.5: CL versus WW regressions for male and female *Jasus tristani* sampled at Gough Island

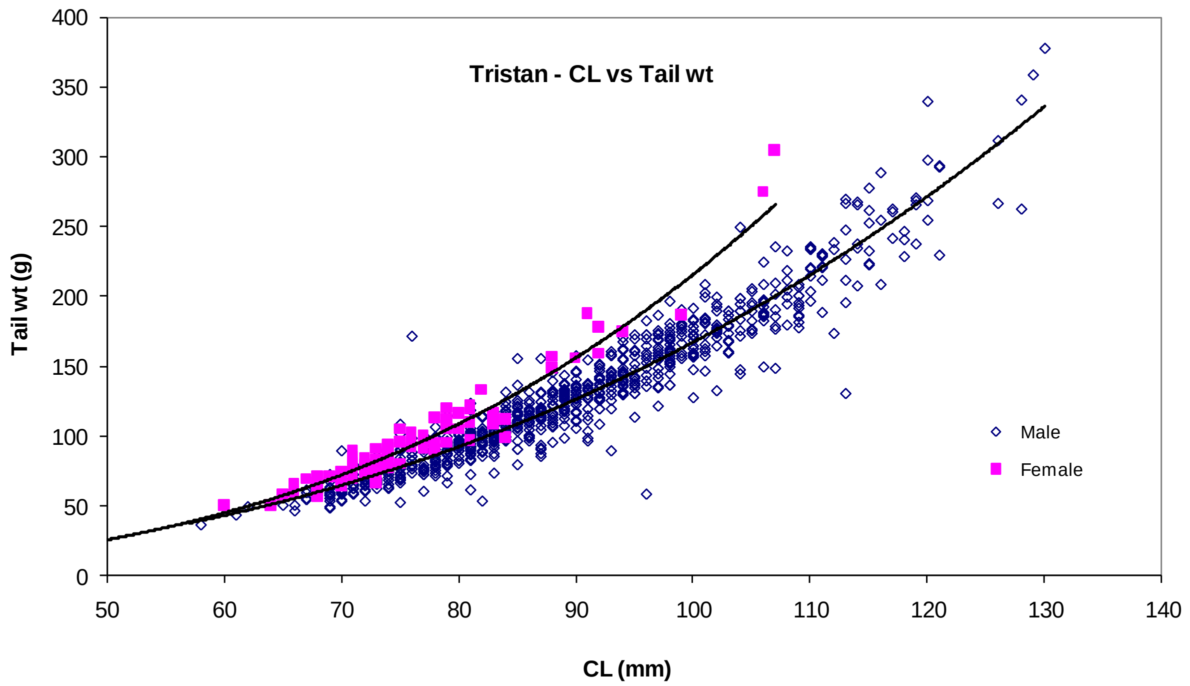


Figure 3.6: CL versus TW regressions for male and female *Jasus tristani* sampled at Tristan Island

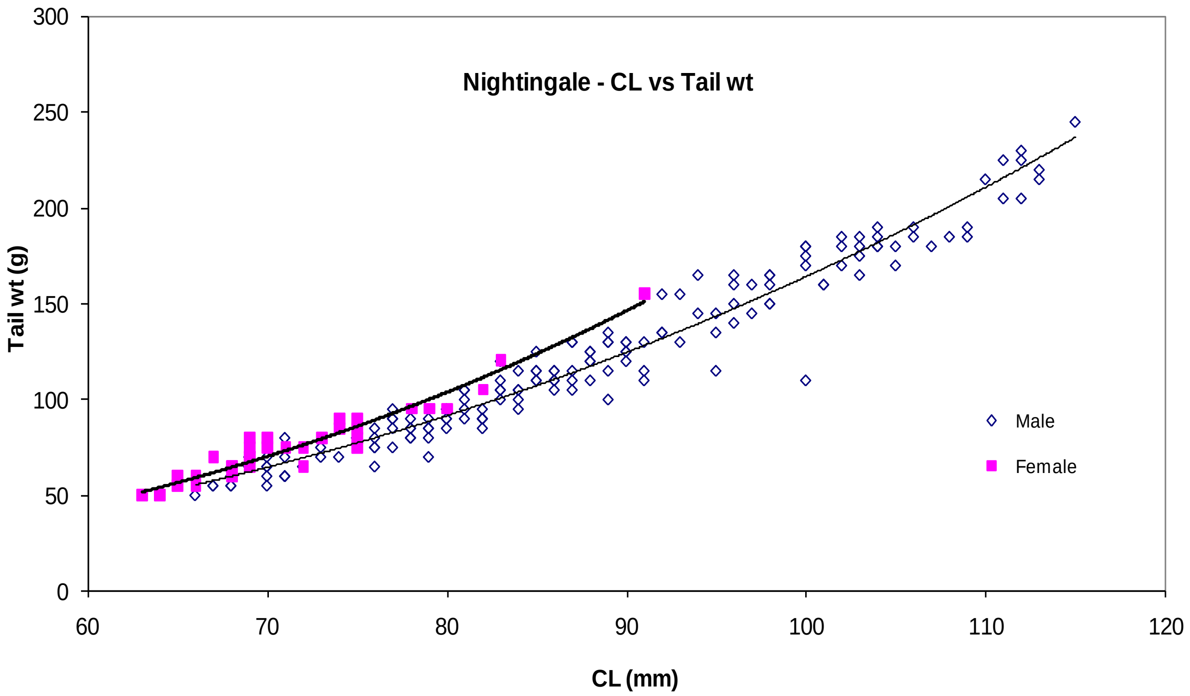


Figure 3.7: CL versus TW regressions for male and female *Jasus tristani* sampled at Nightingale Island

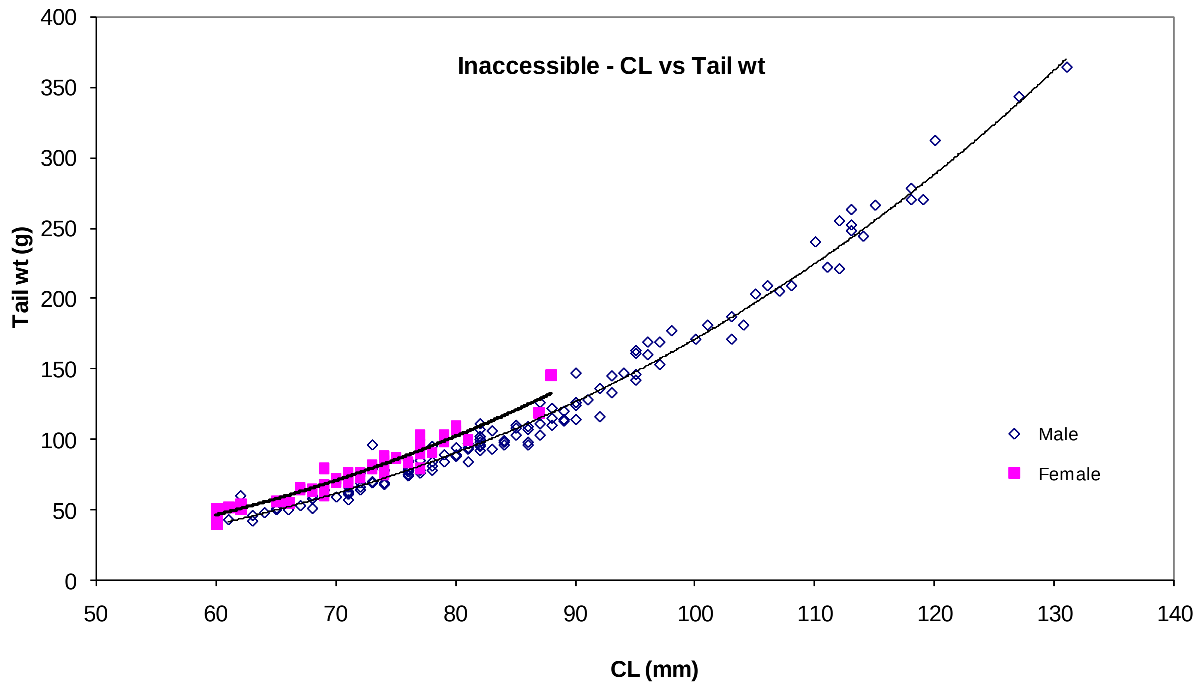


Figure 3.8: CL versus TW regressions for male and female *Jasus tristani* sampled at Inaccessible Island

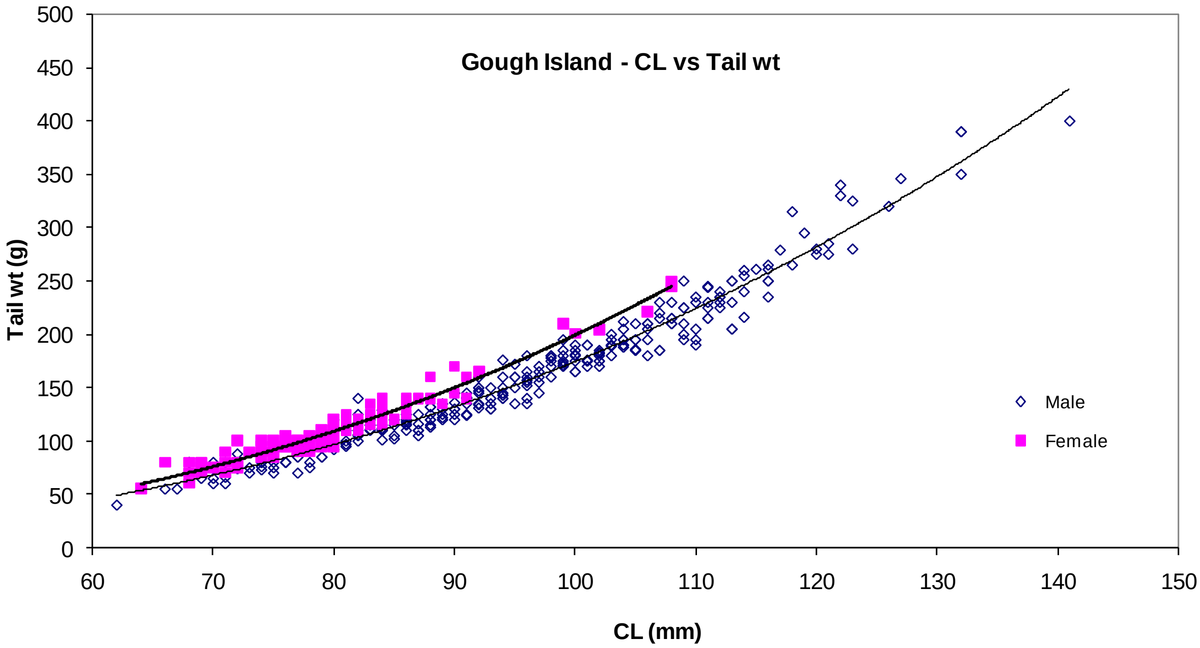


Figure 3.9: CL versus TW regressions for male and female *Jasus tristani* sampled at Gough Island

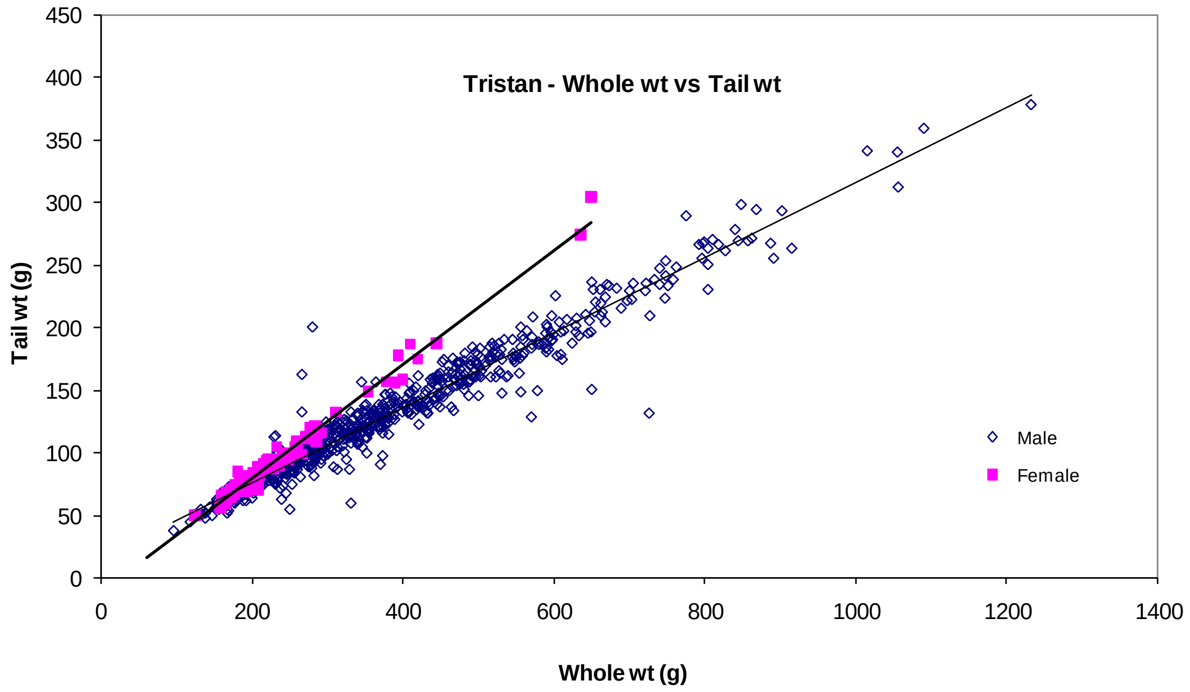


Figure 3.10: CL versus TW regressions for male and female *Jasus tristani* sampled at Tristan Island

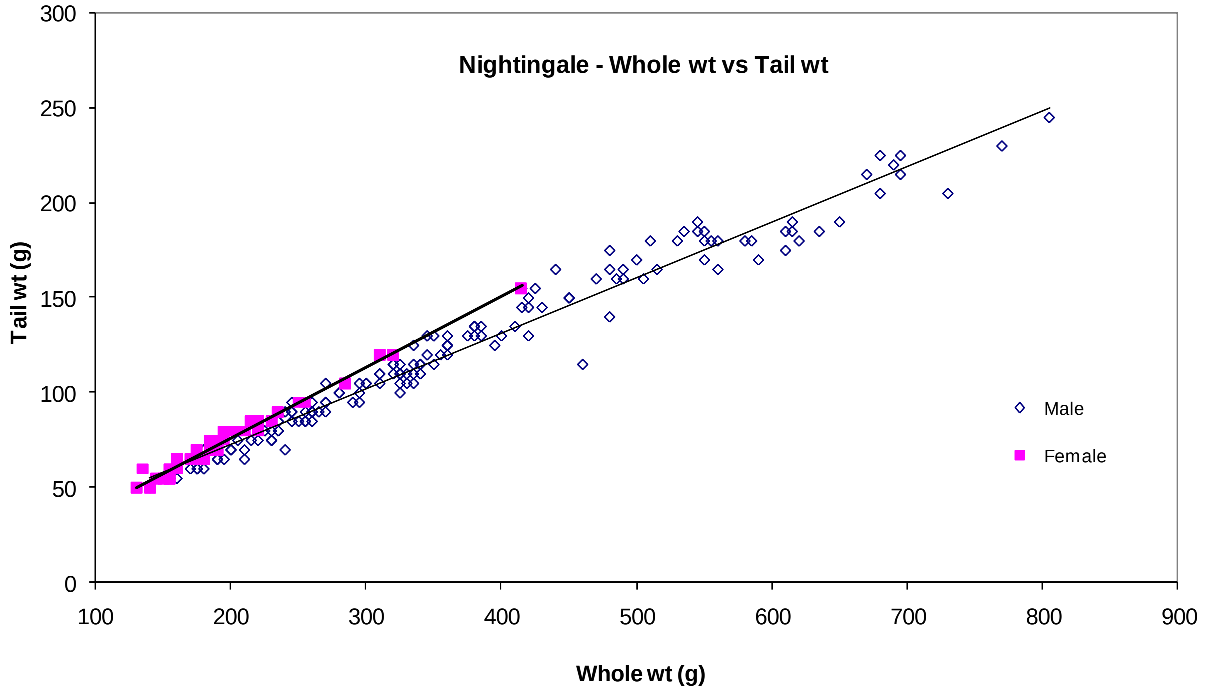


Figure 3.11: WW versus TW regressions for male and female *Jasus tristani* sampled at Nightingale Island

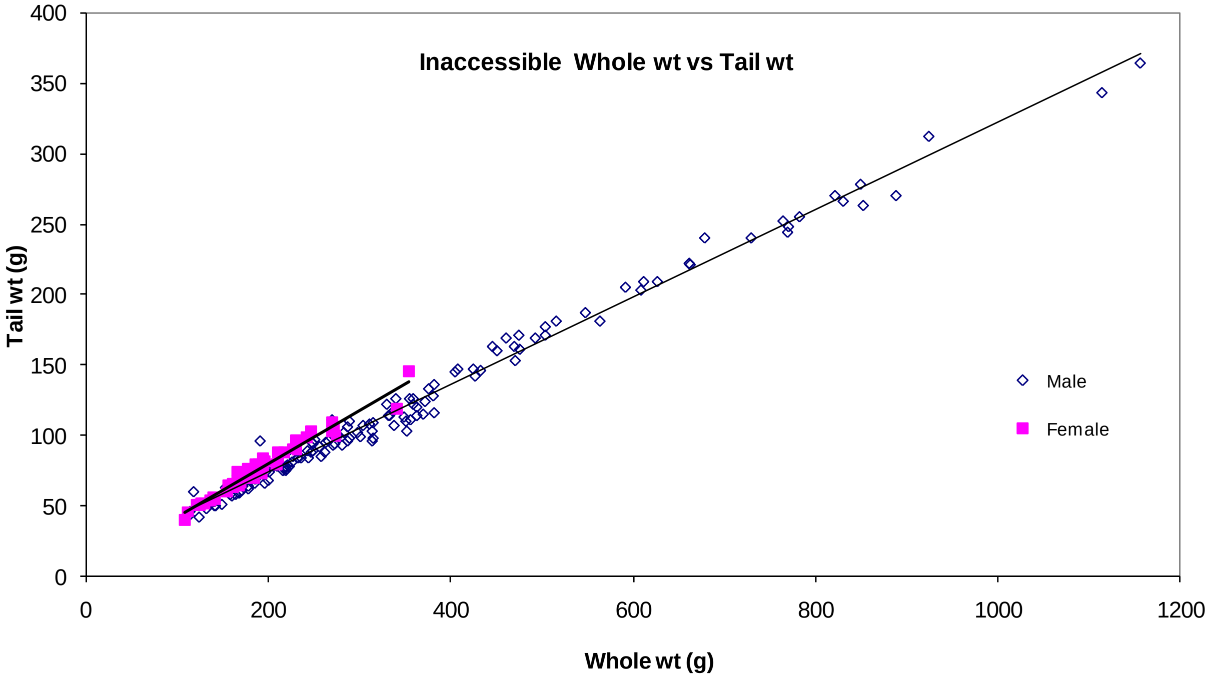


Figure 3.12: WW versus TW regressions for male and female *Jasus tristani* sampled at Inaccessible Island

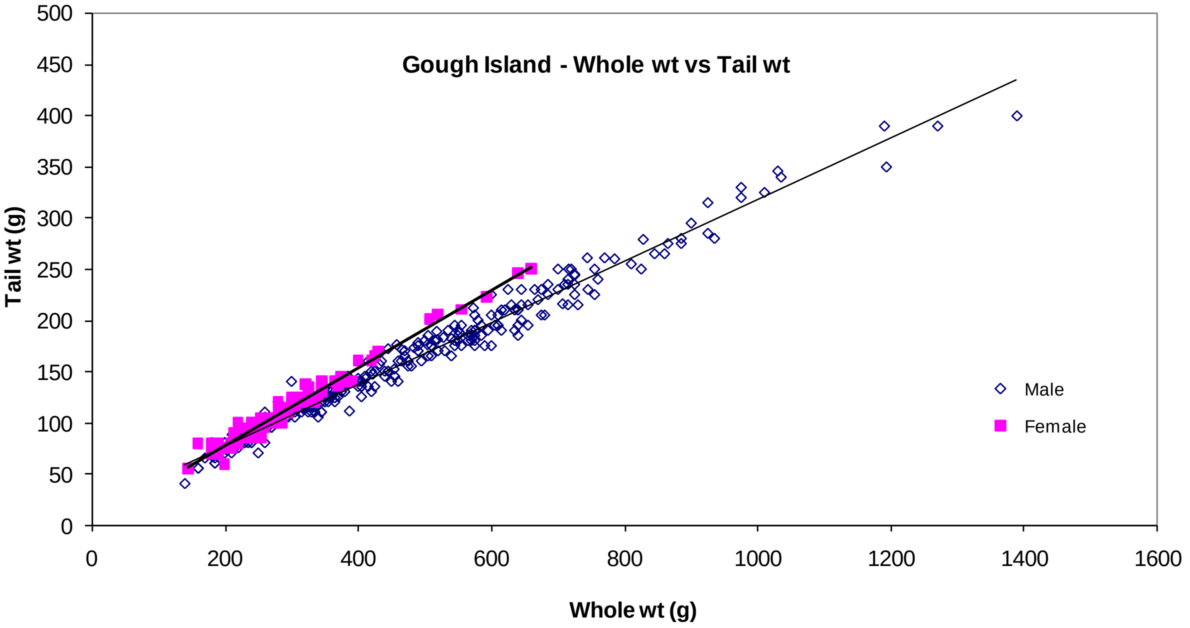


Figure 3.13: WW versus TW regressions for male and female *Jasus tristani* sampled at Gough Island

Table 3.1: Summary of statistics for male and female *Jasus tristani* at Tristan, Nightingale, Inaccessible and Gough Islands. Regressions are all linear using log transformed variables: log y = a(log x) +b. The following abbreviations were used: CL = Carapace length (mm); WW = Whole weight (g); and TW = Tail weight (g)

Island	independent (X) variable	dependent (Y) variable	Sex	a (slope)	b (intercept)	r2	N	t (slope)	p (** = <0.01)		minimum CL (mm)	maximum CL (mm)
All islands	log(CL)	log(WW)	M & F	2.922	-3.139	0.97	1526	224	0.00000E+00	**	58	141
All islands	log(CL)	log(WW)	M	2.967	-3.230	0.97	1253	199	0.00000E+00	**	58	141
All islands	log(CL)	log(WW)	F	2.938	-3.156	0.95	273	71	3.90131E-177	**	60	108
All islands	log(CL)	log(TW)	M	2.685	-3.144	0.94	1253	136	0.00000E+00	**	58	141
All islands	log(CL)	log(TW)	F	2.953	-3.59	0.94	273	65	2.55757E-167	**	60	108
All islands	log(WW)	log(TW)	M & F	0.884	-0.161	0.96	1526	187	0.00000E+00		58	141
All islands	log(WW)	log(TW)	M	0.903	-0.215	0.96	1253	178	0.00000E+00	**	58	141
All islands	log(WW)	log(TW)	F	0.993	-0.387	0.97	273	86	9.84917E-199	**	60	108
Tristan	log(CL)	log(WW)	M & F	2.910	-3.122	0.96	757	133	0.00000E+00	**	58	130
Tristan	log(CL)	log(WW)	M	2.932	-3.167	0.96	668	120	0.00000E+00	**	58	130
Tristan	log(CL)	log(WW)	F	2.882	-3.060	0.95	89	40.6	2.49738E-58	**	60	107
Tristan	log(CL)	log(TW)	M	2.632	-3.044	0.91	668	80.8	0.00000E+00	**	58	130
Tristan	log(CL)	log(TW)	F	3.080	-3.826	0.92	89	32.4	2.48493E-50	**	60	107
Tristan	log(WW)	log(TW)	M	0.895	-0.195	0.94	668	106	0.00000E+00	**	58	130
Tristan	log(WW)	log(TW)	F	1.069	-0.556	0.97	89	56	4.97168E-70	**	60	107
Nightingale	log(CL)	log(WW)	M & F	2.869	-3.036	0.98	208	97.7	1.59956E-174	**	63	115
Nightingale	log(CL)	log(WW)	M	2.913	-3.124	0.98	165	81.9	2.39058E-134	**	66	115
Nightingale	log(CL)	log(WW)	F	2.907	-3.099	0.94	43	25.3	1.22212E-26	**	63	91
Nightingale	log(CL)	log(TW)	M & F	*2.517*	-2.821	0.95	208	63.5	3.04298E-137	**	63	115
Nightingale	log(CL)	log(TW)	M	2.628	-3.041	0.95	165	57.8	1.65321E-110	**	66	115
Nightingale	log(CL)	log(TW)	F	2.916	-3.535	0.93	43	22.8	6.59875E-25	**	63	91
Nightingale	log(WW)	log(TW)	M	0.902	-0.223	0.98	165	81.9	2.39058E-134	**	66	115
Nightingale	log(WW)	log(TW)	F	0.994	-0.406	0.97	43	35.5	2.07586E-32	**	63	91

Table 3.1 (continued)

Island	independent (X) variable	dependent (Y) variable	Sex	a (slope)	b (intercept)	r2	N	t (slope)	p (** = <0.01)		minimum CL (mm)	maximum CL (mm)
Inaccessible	log(CL)	log(WW)	M	3.124	-3.541	0.99	139	117.4	2.29873E-139	**	61	131
Inaccessible	log(CL)	log(WW)	F	2.807	-2.935	0.95	50	29.6	1.74591E-32	**	60	88
Inaccessible	log(CL)	log(TW)	M & F	2.687	-3.139	0.97	189	72.7	4.69123E-139	**	60	131
Inaccessible	log(CL)	log(TW)	M	2.849	-3.463	0.98	139	78.8	5.36412E-116	**	61	131
Inaccessible	log(CL)	log(TW)	F	2.746	-3.216	0.93	50	27.2	8.08022E-31	**	60	88
Inaccessible	log(WW)	log(TW)	M & F	0.880	-0.148	0.98	189	88.6	1.15240E-154	**	60	131
Inaccessible	log(WW)	log(TW)	M	0.909	-0.228	0.98	139	87	8.99908E-122	**	61	131
Inaccessible	log(WW)	log(TW)	F	0.968	-0.322	0.97	50	38.9	5.91945E-38	**	60	88
Gough	log(CL)	log(WW)	M	2.900	-3.085	0.98	281	125.4	2.25860E-247	**	62	141
Gough	log(CL)	log(WW)	F	2.720	-2.722	0.96	91	44.8	7.59994E-63	**	64	108
Gough	log(CL)	log(TW)	M & F	2.490	-2.732	0.95	372	85.8	2.60138E-246	**	62	141
Gough	log(CL)	log(TW)	M	2.620	-2.999	0.96	281	86.8	6.28675E-204	**	62	141
Gough	log(CL)	log(TW)	F	2.687	-3.074	0.94	91	37.2	5.06041E-56	**	64	108
Gough	log(WW)	log(TW)	M & F	0.882	-0.146	0.97	372	107.3	7.55800E-281	**	62	141
Gough	log(WW)	log(TW)	M	0.901	-0.203	0.98	281	104.2	2.10764E-225	**	62	141
Gough	log(WW)	log(TW)	F	0.973	-0.349	0.95	91	42.1	1.50075E-60	**	64	108

Table 3.2: Results of the Students t-tests comparing slopes and elevations of linear regressions of male versus female *J. tristani.* (Significant difference levels are* Significant difference = P<0.05); **Highly Significant difference = P< 0.001)

Island	Regression	Slopes t-value	Slopes Significance (P)	Elevations t-value	Elevations Significance (P)	Degrees of freedom (df)
All Islands	Log CL vs Log WW	0.062	0.536	0.840	0.401	1523
All Islands	Log CL vs Log TW	4.438	< 0.001**	-3.914	< 0.001**	1523
All Islands	Log WW vs Log TW	126.462	< 0.001**	2.651	< 0.008**	1523
Tristan	Log CL vs Log WW	-0.523	0.601	0.588	0.557	754
Tristan	Log CL vs Log TW	3.488	< 0.001**	-3.225	< 0.001**	754
Tristan	Log WW vs Log TW	5.226	< 0.001**	-4.556	< 0.001**	754
Nightingale	Log CL vs Log WW	-0.050	0.960	0.112	0.911	208
Nightingale	Log CL vs Log TW	1.852	0.065	-1.703	0.090	208
Nightingale	Log WW vs Log TW	2.520	< 0.013*	-2.161	< 0.032*	208
Inaccessible	Log CL vs Log WW	-3.514-	< 0.001**	3.610	< 0.001**	186
Inaccessible	Log CL vs Log TW	0.895	0.372	1.157	0.249	186
Inaccessible	Log WW vs Log TW	1.708	0.089	-1.193	0.235	186
Gough	Log CL vs Log WW	2.803	< 0.005**	2.969	< 0.003**	369
Gough	Log CL vs Log TW	0.816-	0.415	-0.480	0.631	369
Gough	Log WW vs Log TW	2.915	< 0.004**	-2.375	< 0.018*	369

While male and female growth can differ samples from all islands were pooled to provide overall best estimates of the regression equations for CL against WW (males and females combined), for management purposes and for TW against WW for males and females (separately). These data are presented graphically in Figures 3.1, 3.1a and 3.1b.

3.4 Differences between the size of lobsters based on samples from each island

The characteristics of lobsters (sexes combined) sampled at each island (CL, WW and TW) have been compared through a series of pair wise comparisons are shown in Table 3.3.

Table 3.3: Inter-island comparisons of lobsters *J. tristani* for (WW), (CL), and (TW), sexes combined, using one way (single factor) analysis of variance (ANOVA), followed by a Tukey honestly significant difference (HSD) test, where appropriate (Zar 1984). G = Gough Island, I = Inaccessible Island, N = Nightingale Island, T = Tristan. * * Highly Significant difference (P<0.001)

Whole weight (WW) differences between islands				
Comparison	Difference (g)	SE	F statistic	Significance (P)
G vs I	0.16	0.013	12.656	< 0.001**
G vs N	0.119	0.012	9.719	< 0.001**
G vs T	0.067	0.009	7.495	< 0.001**
T vs I	0.093	0.012	8.067	< 0.001**
T vs N	0.052	0.011	4.686	< 0.001**
N vs I	0.041	0.014	2.877	0.055
Carapace Length (CL) differences between islands				
Comparison	Difference (g)	SE	F statistic	Significance (P)
G vs I	0.046	0.004	10.67	< 0.001**
G vs N	0.036	0.004	8.617	< 0.001**
G vs T	0.015	0.003	5.026	< 0.001**
T vs I	0.031	0.004	7.808	< 0.001**
T vs N	0.021	0.004	5.464	< 0.001**
N vs I	0.01	0.005	2.061	0.161
Tail weight (TW) differences between islands				
Comparison	Difference (g)	SE	F statistic	Significance (P)
G vs I	0.146	0.011	12.824	< 0.001**
G vs N	0.126	0.011	11.435	< 0.001**
G vs T	0.069	0.008	8.496	< 0.001**
T vs I	0.077	0.01	7.472	< 0.001**
T vs N	0.058	0.01	5.775	< 0.001**
N vs I	0.02	0.013	1.547	0.296

These inter-island comparisons of lobsters *J. tristani* for (WW), (CL), and (TW), sexes combined, show no significant difference between the samples from Nightingale and Inaccessible. All the other islands showed a significant difference (P<0.001) between them.

3.5 Comparison of carapace length and tail width

The results of comparison of carapace length and tail width for lobsters sampled are shown in figure 3.14.

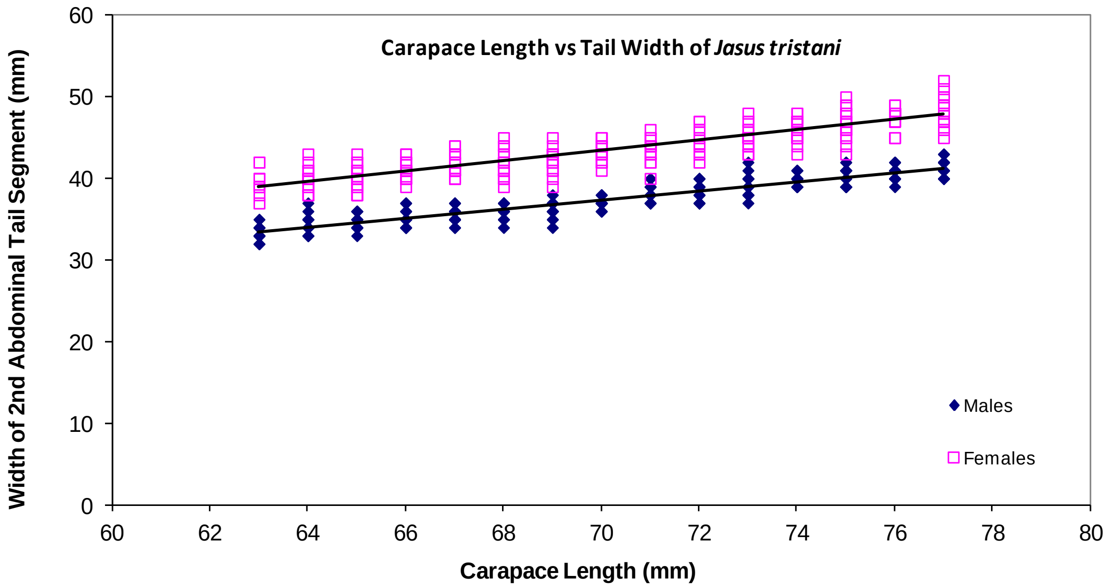


Figure 3.14: Carapace length (CL, mm) versus the width of the 2nd abdominal tail segment (AS, mm) for male and female *Jasus tristani,* respectively. Data from all islands have been pooled Females: y = 0.6307x - 0.7767, R^2 = 0.7961 and Males: y = 0.5559x - 1.5325 R^2 = 0.8693

There is some individual variability between tail width for lobsters of a given carapace length, and that the difference between the sexes is marked, with females having a wider tail than males over all sizes (Figure 3.14). In Table 3.4 below, the estimated mean tail width for lobsters with a carapace length corresponding to the current size limit is shown. This is used as management measure in the commercial fishery.

Table 3.4: Results of the three minimum legal sizes (MLS) used in the Tristan da Cunha fishery, Inaccessible (68 mm), Tristan & Nightingale (70 mm) and Gough (75 mm)

CL	Male (Tail width)	Female (Tail width)	Difference in Male and Female tail width
68	36.3 mm	42.1 mm	5.84 mm
70	37.4 mm	43.4 mm	5.99 mm
75	40.2 mm	46.5 mm	6.36 mm

3.6 Discussion

Sampling of the commercial catch of rock lobster has been carried out in Tristan da Cunha since the start of the commercial fishery in 1949. In the early 1970's Roscoe (1979) collected information on many of the characteristics of the population from commercial catches, including length weight samples. This study provides the necessary updates of this analyses, and provides information relevant for current management measures in the fishery.

3.6.1 Length weight relationships

The relationship between CL and TW has been estimated for males and females separately, but statistical analysis suggests that the differences are not significant. These are contrasted with a range of other lobster species in Table 3.9. All species display isometric growth.

Table 3.5: Relationships, between whole and tail weights, and carapace length for spiny lobsters, from this and other studies

Relationship	Species	Source
W(g) M & F vs. CL (mm) = 0.0015CL^2.7663	Jasus lalandii	Beyers (1979)
W(g) M & F vs. CL (mm) = 0.0011CL^2.8214	Jasus lalandii	Grobler & Noli-Peard (1997)
WW M & F vs CL (mm) = 0.0017 CL^2,5930	Palinurus delagoae	Brinca & Palha de Sousa (1983)
WM M & F vs CL (mm) = 0.0018 CL^2,7704	Palinurus delagoae	Groeneveld & Goosen (1996)
TM M & F vs CL (mm) = 0.0052 CL^2,3129	Palinurus delagoae	Groeneveld & Goosen (1996)
WW M & F vs CL (mm) = 0.0044 CL^2,5748	Palinurus gilchristi	Pollock & Augustyn (1982)
TM M & F vs CL (mm) = 0.0007 CL^2,8460	Palinurus gilchristi	Groeneveld & Goosen (1996)
WM M & F vs CL (mm) = 0.0013 CL^2,8701	Palinurus gilchristi	Groeneveld & Goosen (1996)
WM M & F vs CL (mm) = 0.0004 CL^3,0151	Scyllarides elisabethae	Groeneveld & Goosen (1996)
TM M & F vs CL (mm) = 0.0008 CL^3,1779	Scyllarides elisabethae	Groeneveld & Goosen (1996)
WW Males CL (mm) = 0.0017 CL^2.7830	Jasus frontalis	Arana & Olate (2000)
WW Fem CL (mm) = 0.0034 CL^2.6597	Jasus frontalis	Arana & Olate (2000)
WW M & F vs CL (mm) = 0.00073 CL^2.9215	Jasus tristani	This study
WW M vs CL (mm) = 0.00059 CL^2.9667	Jasus tristani	This study
WW F vs CL (mm) = 0.00070 CL^2,9377	Jasus tristani	This study

The relationship between WW and TW shows significant differences between the sexes particularly with increasing lobster size. The *J. tristani* female lobsters' tail weight accounts for a higher proportion of the total weight than for males, as the lobsters increase in size. This finding is similar to that of Heydorn (1969) who reported that *Jasus lalandii* and *J.tristani* were morphologically very similar, and like *J. tristani, J. lalandii* females of the same CL had a considerably higher TW than males. He suggested that the female lobster tail is wider to enable the female to carry its eggs. In other lobster species, there were no significant differences in TW between male and female *Scyllarides elisabethae* (Groeneveld & Goosen 1996) although there were differences between males and females for *Palinurus delagoae* and *Palinurus gilchristi,* with females becoming progressively heavier with size (Groeneveld & Goosen 1996). The implications of this for enforcement of size limits are discussed in section 3.4.3 below.

The relationship between WW and TW is important for monitoring compliance with the total allowable catch. Commercial catches of *J. tristani* that are processed into tails are converted into whole weight using fixed conversion factors. Roscoe (1979) estimated the percentage tail yield at 30%. The present yield estimate is around 33% using the commercial the conversion formula: Live Wt in Kgs = No. of 10 lb cartons of tails X 13.636363. As shown by the results in section 3.3.1 this formula provides a reasonable approximation but it:

- tends to overestimate the total weight of females from the tail weight; and

- tends to underestimate the total weight of large males.

Estimation of the total catch from tail weight is thus sensitive to both the sex ratio of the catch and the size threshold at which the fishing company decides to start processing whole lobster to tails. In general, the practice has been to tail the larger lobster for the US market, while small lobster are packed as a whole product for the Japanese market (James, pers. comm.) This tendency to tail large lobster (which the samples suggest are predominantly male) may have led to underestimation of the total catch and exceeding of the TAC.

Solving the simultaneous equations for the observed regression of tail weight against whole weight for both sexes (sex ratio as per samples) and the formula used commercially to estimate yield of tails gives the result that, for male lobster with a total weight of over 760 g (tail weight of over 254 g) the commercial conversion factor will underestimate the catch against the TAC. The average tail weight of tailed lobster shown in the tables of packed lobster show that it is predominantly larger lobster that have been tailed. It can be concluded that the TAC has probably been exceeded through the application of the commercial conversion factor.

3.6.2 Tail width and carapace length

As discussed above it is clear that tail width of males and females is different for lobster of the same carapace length (Table 3.4). For each sex there is a clear correlation between tail width and CL, however there is also within sex variability. This would make it difficult to establish with certainty whether the tail from a lobster close to the size limit had actually come from an undersized lobster or not. At present this may not be much of an issue. The great majority of lobsters processed to tails are the larger specimens, and lobsters close to the size limit are packed whole. In the event that market trends change, and smaller lobster are processed to tails, it may be necessary to change the legislation and impose a limit on tail width, as is the case in the New Zealand lobster fishery for example (Anon, 2011).

3.7 Conclusion

It is known in many fisheries that when the level of exploitation become too high, a decrease in the CPUE and average size of the exploited stock may be observed (Rounsefell & Everhart, 1953). This may be the case in the Tristan fishery and the need for additional management measures, such as a proposal for a tail width size limit and a conversion factor based on lobsters of that size and larger as a proposal, especially if market demand started to cause tailing of smaller lobster. This will enable Sea Fishery Officers to check those lobsters already process and packed close to the size limit, as it is likely that the use of the current conversion factor is allowing more lobster to be harvested than should be taken under the quota.

Chapter 4

Size composition and sex ratios of *Jasus tristani*

4.1 Introduction

Size composition is an important variable in the analysis of fished stocks, because it can be used as a direct indicator of demographic changes caused by fishing or environmental factors (Cockcroft *et al.,* 1995). Trends in size composition are used in several classes of models of population structure / dynamics, including age / size structured production models, determination of mortality and growth rates, and recruitment in yield models (Hilborn & Walters, 1992; Miller & Fryer, 1999). Size composition data can be collected from commercial fisheries using a variety of methods, including direct length measurements by observers at sea, port-measurements when fish are landed, or analysis of pack-categories, weights and counts of lobsters (Hilborn & Walters, 1992).

The interpretation of size composition samples can be highly complex because samples may be influenced by large number of factors such as geographical location of capture (Groeneveld & Branch, 2002), year, month or season of data collection (Pollock, 1981; Cruywagen, 1997), gear type used (Pollock & Beyers, 1979; Pollock & Beyers, 1981; Groeneveld, 2002; Schoeman *et al.,* 2002), depth of capture (Cockcroft *et al.,* 1995), and soak-time of fishing gear (Miller, 1990).

Geographic variations in size composition are often associated with highly variable growth rates in spiny lobsters (Herrnkind, 1980; Kanciruk, 1980; Pollock, 1992; MacDiarmid, 1991). Growth rates are influenced not only by intrinsic factors such as genetic factors and sex (Roscoe, 1979; Pollock, 1991) but also by environmental conditions, such temperature (Pollock, 1981), benthic habitat (Schoeman, 1997), food and other resources (Newman & Pollock, 1974), density dependence (Pollock, 1981) and other anthropogenic influences (fishing pressure, pollution) (Roscoe, 1979; Pollock, 1991).

Variability in sex ratios of catches in turn reflects catchability of male and female lobsters which may be linked to moulting (Goosen & Cockcroft, 1995) or reproduction (when lobsters may not feed for a period, and therefore do not enter traps) or migrations when certain life-history stages move out of fishing areas (Groeneveld & Branch, 2002). Male lobsters often grow faster, due to a larger increment when moulting, than females after attaining maturity, so that a preponderance of males is often present in the largest size classes (Pollock, 1991).

The size composition of *J. tristani* have previously been analysed by Rowan (1949), Heydorn (1969), Roscoe (1979), Pollock (1981, 1991), and their results showed a general decline in average size since the start of commercial fishing in 1949. According to Pollock (1991), there is a marked inter-island variability (largest lobsters at Gough Island and smallest at Inaccessible), and the average size (mean) of males is larger than that of females. Pollock (1991) further suggested that the inter-island variations in population structure was linked to reduced growth rates at Inaccessible Island, as a result of high lobster densities there.

All previous studies on *Jasus tristani* size composition were based on data collected from the commercial fishery and included the use of a variety of gear-types, and fishing methods. Using several gear types and collecting samples from a broad depth range from different islands at different times of year may cause sampling bias. Sampling bias can be reduced by using fisheries independent data, where similar gear and methods are used to repeatedly collect samples at chosen locations and seasons.

Over the past decade (1997 to 2010), size composition at Tristan and the outer Islands were collected from two sources. Firstly, the commercial fishery was used to randomly collect data at all four islands, using a variety of methods and gears. Secondly a fisheries independent survey was introduced in 2006 and conducted every year. Monster traps are set at given depths and positions around each island during September (start of fishing season) and February (completion of fishing season each year). The size composition of lobsters collected by commercial fishing may differ from those collected during the structured survey, and therefore the data from these two sources are treated separately.

The aims of this chapter were to determine:

- The size of male and female lobsters captured by the fishery (commercial data);

- Inter-island variability in population size structure between Tristan, Inaccessible, Nightingale and Gough islands (commercial data);
- The influence of gear-type on size of lobsters caught (commercial data);
- The influence of depth-of-capture on size composition (survey data);
- Long-term trends in size composition at each island (commercial data);
- Sex ratios (commercial data).

4.2 Material and Methods

4.2.1 Study Area

Refer to Chapter two, section 2.3 for a full description of the study area.

4.2.2 Biological measurements (size and sex)

Refer to Chapter three, 3.2.2. for a detailed description of the biological measurement method.

4.2.3 Commercial data

Commercial data were collected during commercial lobster fishing operations between 1997 and 2010. Data were collected from a variety of fishing gears (hoop-nets and cylindrical lobster pots at Tristan and monster traps (MT) with a 75 mm mesh size on longlines at the outer islands, using the *M.V. Edinburgh*. The *M.V. Edinburgh* also deployed powerboats (when weather permitted) that used lobster pots only; both the *M.V. Edinburgh* and her powerboats used overnight sets. Data on depth of catches were absent. Data are available only in summarized 5 mm length-categories. The 5 mm length category precluded statistical analysis at the level that can be done for the survey data. Nevertheless, the commercial data allowed for comparisons of lobster size (mm) relative to the gear-type used (i.e. hoop-nets versus cylindrical pots), and for comparison of the average size of lobsters captured in each year from 1997 to 2010 at each island.

For the longline fishery at Nightingale, Inaccessible and Gough Islands, Sea Fishery Observers (SFO) randomly sampled lobsters for size composition and sex ratio. Data was collected by measuring the first two baskets or a minimum of 100 unsorted lobsters caught per individual long-line with strings of 20 monster traps. SFO are present throughout the fishing season onboard the *M.V. Edinburgh.*

For the hoop-net and pot fisheries operated from the local powerboats at Tristan Island, SFO accompany the fleet (whenever possible) to collect unsorted lobster samples (approximately 5000 lobsters per fishing season). The lobster samples are usually taken from one haul of hoop nets, or a few traps depending on catches, from two to four boats per day.

The size composition data from Nightingale, Inaccessible and Gough, are collected in the same manner from commercial vessels fishing the same shelf area of that particular island. Using baited monster traps on longlines throughout the season so fluctuations were restricted to a minimum each year to reduce basis.

4.2.4 Survey data

Size composition data of *Jasus tristani* was collected during fisheries-independent surveys using the *M.V. Edinburgh*. Nine monster traps with 50 mm mesh size were set along long-lines (2,400 m) in transects perpendicular to each island (e.g. Tristan has eight transects, Nightingale has four transects, Inaccessible has five transects and Gough Island has eight). Two surveys per year were conducted from 2006 to 2009. For each season there is a Leg 1 survey conducted in September, prior to the start of the fishing season and a Leg 2 at its conclusion in February. Traps were set inshore (Average = 46 m depth) and offshore (Average = 78 m depth). The total number of lobsters caught from each trap was recorded by SFO to allow for comparison of lobster size by season (February versus September), depth stratum, sex, and island.

4.2.5 Statistical treatment of data

Student's two-sample t-tests were used to compare means of two groups of data (Depth, sexes, inshore versus offshore and gear types. ANOVA was used to compare means of more than two groups of data (islands) (α=0.05; Zar 1984). Variance of data reflected by standard deviation (SD) (mean ± SD).

4.3 Results

4.3.1 Males versus females

A total of 247 014 lobsters of both sexes between 45 - 140 mm CL were measured from the commercial lobster fishery at Tristan, Nightingale, Inaccessible and Gough Island combined. Between 1997 and 2010, and the mean CL 80.52 ± 13.82 mm, (Fig. 4.1a). The average length of males 83.45 ± 14.46 mm CL, (n = 175 192) was 10.08 mm CL larger than females 73.37 ± 8.64 mm, (n = 71 822) (Fig. 4.1b). Results showed that there was a highly significant difference $P < 0.001$ between males and females. Male lobsters dominated length classes > 80 mm CL. The percentage of males in all commercial samples combined was 71%.

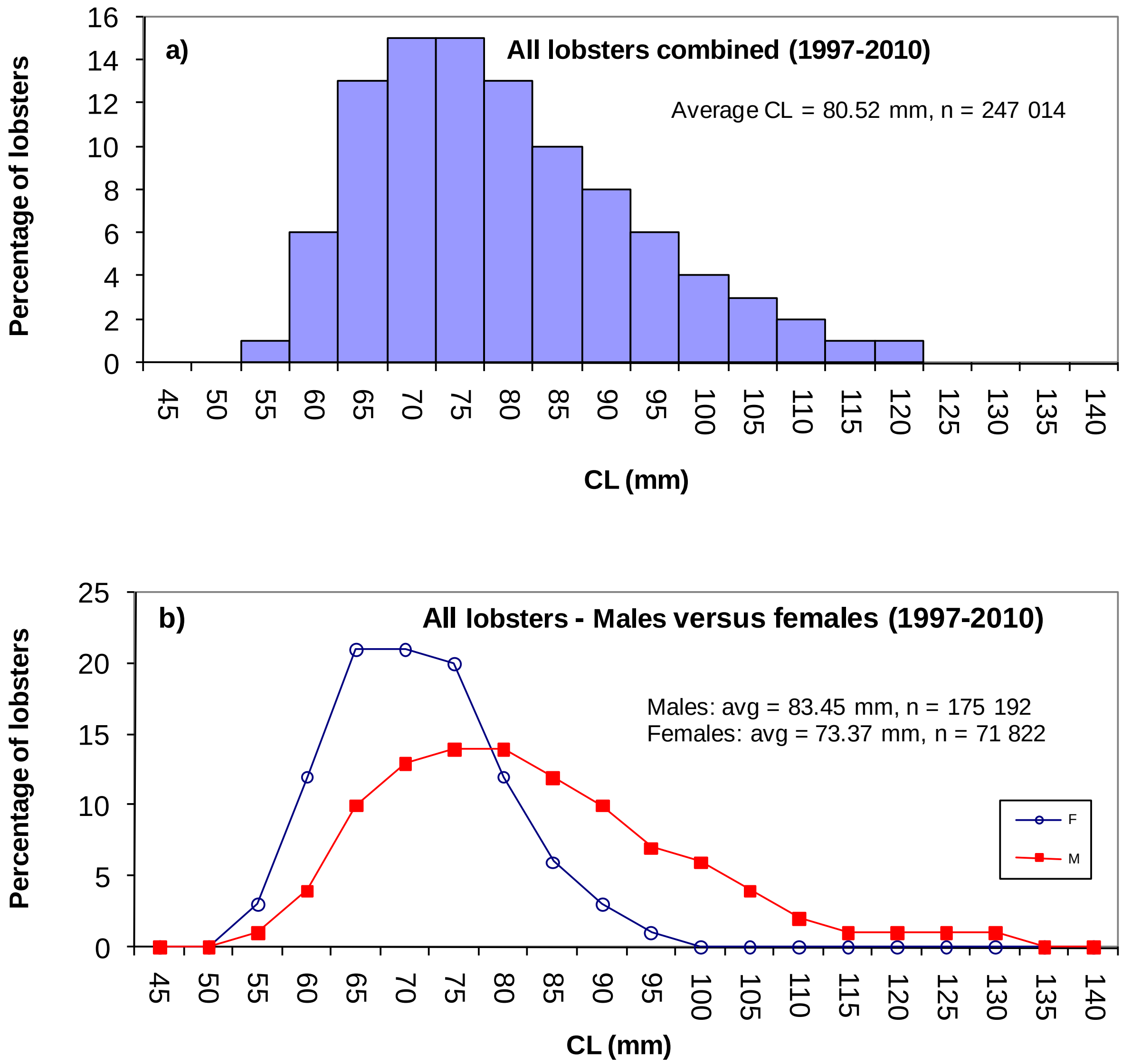


Figure 4.1: Size composition of all *Jasus tristani* from the commercial fishery measured between 1997 and 2010, for all islands pooled and both sexes combined (a) and of males and females respectively (b)

4.3.2 Inter-island comparisons

The average CL of lobsters at Gough Island (87.21 ± 14.41 mm CL, n = 76,345), was larger than those collected at Tristan (83.98 ± 12.56 mm CL, n = 42,096), Nightingale (78.18 ± 11.33 mm CL, n = 57 046) and Inaccessible (73.21 ± 11.39 mm CL, n = 71 527), (Fig. 4.2).

This trend in size reduction of lobsters occurred in both males and females. Females at Inaccessible Island were smaller than at any other Island (average of 66.21 ± 6.12 mm CL, n

= 18 218), and those at Gough Island (78.98 ± 8.03 mm CL, n = 25 345) were larger than the females from the other three islands of Tristan, Nightingale and Inaccessible.

The average CL of females was smaller than that of males at each island, with a difference in size between males and females of 12.32 mm CL at Gough, 12.55 mm CL at Tristan, 8.65 mm CL at Nightingale and 9.39 mm CL at Inaccessible. Females below 90 mm CL were rarely caught except at Gough, where 10.75% of the 25 345 females measured were above 90 mm CL.

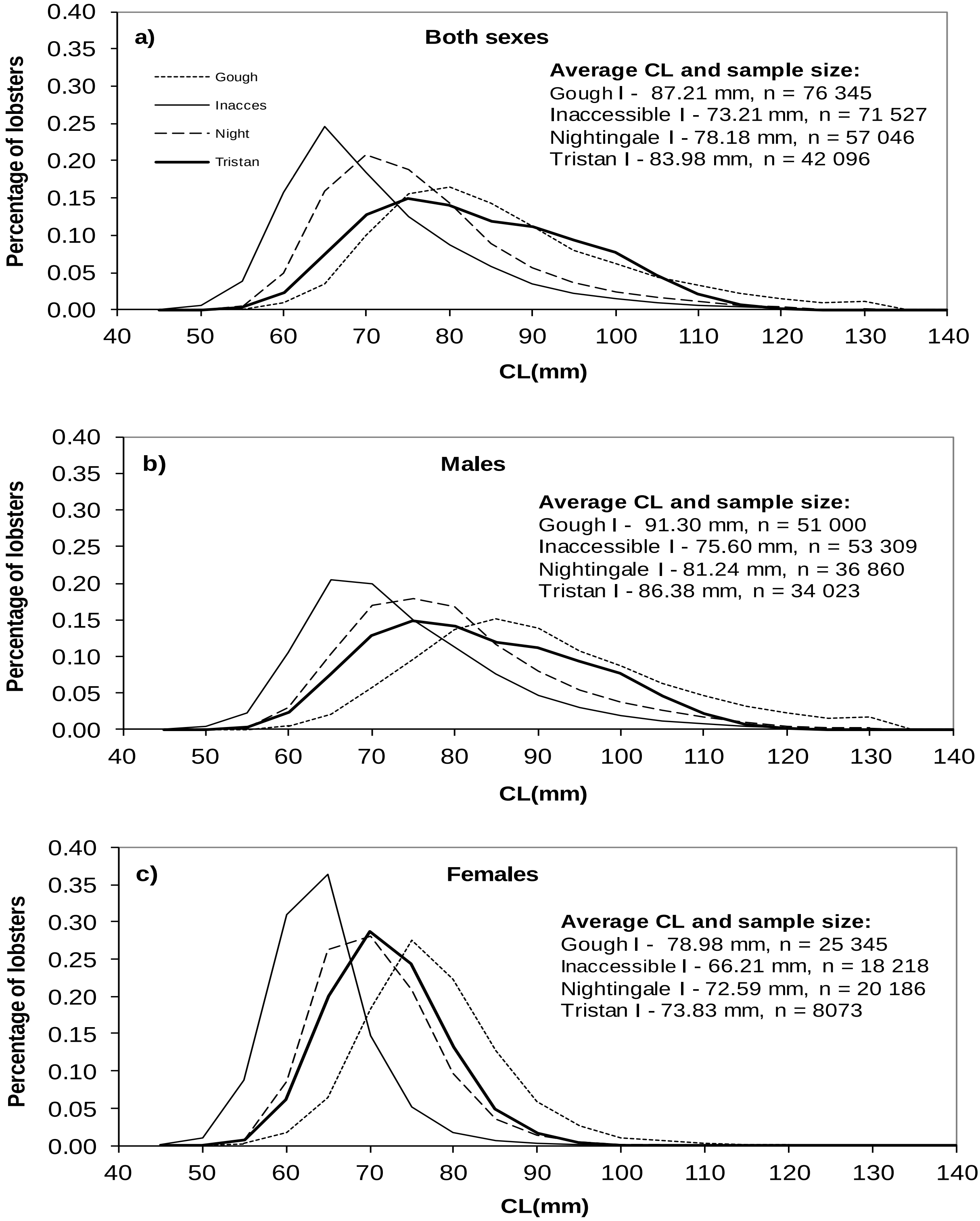


Figure 4.2: Size composition of a) both sexes combined, b) male and c) female lobsters caught between 1997 and 2010 by commercial fisheries at Tristan, Gough, Nightingale and Inaccessible Islands, respectively. The abbreviation Gough I = Gough Island and is the same with the other islands

4.3.3 Long-term trends in size composition

The average size 90.59 ± 6.13 mm CL of lobsters caught at Gough Island was larger than at any of the other islands between 1997 and 2002 (Fig 4.3). However, from 2003 to 2007, there was a small difference between the average lobster size at Gough Island 86.53 ± 3.12 mm CL and at Tristan 86.94 ± 4.20 mm CL. At Gough Island the average CL increased from 83.12 mm CL to 90.36 mm CL between 2005 and 2010. At Tristan Island the average CL has decreased from 91.83 mm CL to 81.00 mm CL between 2007 and 2010.The average CL (75.59 ± 2.07 mm CL) at Inaccessible remained relatively constant from 1997 to 2005 but decreased to 66.99 mm CL in 2010. The average size of lobsters, caught at Inaccessible Island were smaller than other islands. A gradual increase in average lobster size to 80.72 mm CL from 78.09 mm CL was reported at Nightingale Island between 2001and 2007, then it declined to 74.93 mm CL in 2010 (Fig 4.3).

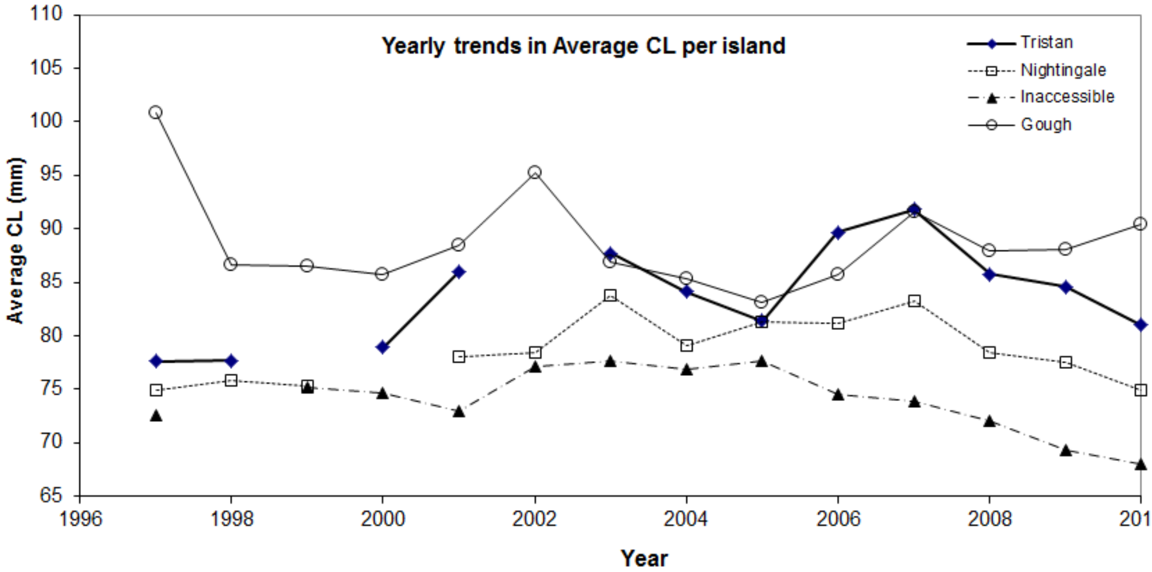


Figure 4.3: Interannual trends in the average size of *Jasus tristani* (sexes combined) caught at Tristan, Nightingale, Inaccessible and Gough Islands by commercial fisheries between 1997 and 2010

4.3.4 Trends in the mean weight of lobster harvested at each island

Tables 4.1 – 4.4 show the mean weights of lobster *J. tristani*, for tails and whole processed product based on the total retained catch and for random samples taken by fishery observers.

Table 4.1: Mean weights of lobster at Tristan da Cunha per fishing season

Season	Tails (kg)	Whole (kg)	Tails/Whole (kg)	C.L Samples (kg)
1997/98	0.32	0.23	0.28	~
1998/99	0.36	0.21	0.29	0.27
1999/00	0.36	0.21	0.29	~
2000/01	0.39	0.24	0.32	0.26
2001/02	0.40	0.24	0.32	0.35
2002/03	0.41	0.25	0.33	~
2003/04	0.40	0.23	0.32	0.37
2004/05	0.39	0.25	0.32	0.31
2005/06	0.37	0.28	0.33	0.31
2006/07	0.40	0.29	0.36	0.41
2007/08	0.41	0.30	0.36	0.43
2008/09	0.42	0.26	0.33	0.36
2009/10	0.35	0.29	0.34	0.35
2010/11	0.32	0.31	0.32	0.30

Table 4.2: Mean weights of lobster at Nightingale Island per fishing season

Season	Tails (kg)	Whole (kg)	Tails/Whole (kg)	C.L Samples (kg)
1997/98	0.41	0.21	0.31	0.29
1998/99	0.34	0.20	0.27	0.26
1999/00	0.35	0.19	0.27	0.23
2000/01	0.44	0.24	0.34	~
2001/02	0.41	0.22	0.32	0.26
2002/03	0.36	0.23	0.30	0.26
2003/04	0.40	0.21	0.31	0.32
2004/05	0.44	0.22	0.33	0.27
2005/06	0.45	0.23	0.34	0.29
2006/07	0.53	0.27	0.34	0.29
2007/08	0.47	0.26	0.35	0.33
2008/09	0.40	0.24	0.31	0.26
2009/10	0.40	0.24	0.28	0.26
2010/11	0.34	0.24	0.27	0.23

Table 4.3: Mean weights of lobster at Inaccessible Island per fishing season

Season	Tails (kg)	Whole (kg)	Tails/Whole (kg)	C.L Samples (kg)
1997/98	0.40	0.21	0.31	0.30
1998/99	0.36	0.19	0.28	~
1999/00	0.33	0.19	0.26	0.23
2000/01	0.43	0.21	0.32	0.23
2001/02	0.40	0.22	0.31	0.21
2002/03	0.38	0.21	0.30	0.25
2003/04	0.39	0.21	0.30	0.26
2004/05	0.43	0.21	0.32	0.25
2005/06	0.41	0.21	0.31	0.25
2006/07	0.39	0.23	0.27	0.23
2007/08	0.36	0.22	0.27	0.22
2008/09	0.31	0.20	0.24	0.21
2009/10	0.32	0.20	0.23	0.18
2010/11	0.28	0.20	0.23	0.17

Table 4.4: Mean weights of lobster at Gough Island per fishing season

Season	Tails (kg)	Whole (kg)	Tails/Whole (kg)	C.L Samples (kg)
1997/98	0.65	0.25	0.45	0.48
1998/99	0.48	0.21	0.35	0.35
1999/00	0.46	0.24	0.35	0.35
2000/01	0.51	0.28	0.40	0.36
2001/02	0.47	0.26	0.37	0.40
2002/03	0.50	0.28	0.39	0.47
2003/04	0.45	0.23	0.34	0.36
2004/05	0.50	0.25	0.38	0.34
2005/06	0.52	0.27	0.40	0.34
2006/07	0.61	0.30	0.38	0.35
2007/08	0.60	0.28	0.40	0.43
2008/09	0.55	0.29	0.41	0.37
2009/10	0.53	0.29	0.37	0.38
2010/11	0.56	0.32	0.39	0.41

4.3.5 Size differences at different islands

There was a significant difference between mean size of lobsters sampled, as measured by carapace length and weight, between islands, with the exception of Nightingale and Inaccessible which showed no significant difference (Chapter 3, Table 3.3). This agrees with past studies which have found inherent differences between the populations at each island. Pollock (1981) found that growth rates at Inaccessible were the lowest, while male lobsters at Nightingale and Gough were considerably larger than at the other islands. This was also confirmed by earlier results by Roscoe and Pollock (1977). It is also further by these results that show Inaccessible as having the smallest lobster and Gough the largest. Over time, however, there appear to have been changes induced by fishing (see below).

4.3.6 Trends in the mean weight of lobster harvested at each island

Two factors are important in analyzing changes in the mean weights of retained lobster:

- Fishing pressure, which removes larger individuals and may also contribute to increased mortality of undersized lobster that are returned to the sea. Barkai and Berg (1988) have shown that models of *Jasus lalandi* populations can only explain the population structure if there is high mortality of undersized lobster and lobsters caught several times and released are known to suffer from stress and injury, which in return can affect their size when molting (Brown, 1957; Chittleborough, 1975; Brown & Caputi, 1985; Brouwer *et al.,* 2006).
- Changes in the size limit – which allow the retention of smaller lobster, thus reducing the mean weight of the retained catch.

As can be seen there has been a general increase in the mean weights at Tristan (Table 4.1) during the ten years from 1997 to 2006. Tristan is believed to have been affected by uncontrolled fishing during the construction of the new harbour in the mid-1990s, and since then conservative TACs have allowed the stock to rebuild. The mean size harvested has fallen slightly in recent years. This decrease seems to have affected the population at large, with the mean size of lobsters sampled also decreasing and merits close monitoring.

At Nightingale Island (Table 4.2) the mean size of lobsters harvested has been relatively stable up until 2007. Again the mean weight of retained lobsters and the mean weight of random samples has decreased in recent years. Lobsters at both these islands (Nightingale and Tristan) increased in mean weight in correlation with CPUE, when mean weights decreased so did the catches (Fig 4.3).

Inaccessible Island lobsters (Table 4.3) with the exception of one season (2004/05) showed a gradual decline since 1997. The extensive fishing grounds at this island, perhaps combined with a perception that they harbor naturally small lobster, have led to substantial fishing effort over the years. The reduction of the size limit to the smallest of any in the Tristan group in the 2003/04 season has further driven down mean sizes in retained lobster and random samples.

The population at Gough Island was in decline until the TAC was reduced by 30 mt (in 2004/5), followed by an increased in the MLS from 70 mm CL to 75 mm CL (2003/04 season). This not only increased the CPUE but also the average mean weight of lobsters for the season (Table 4.4). This suggests that fishing pressure may have a direct impact on lobster size and weight.

4.3.7 Effects of gear-types on size

The length frequency data between the local powerboat trap and hoop net at Tristan indicates that larger lobsters are caught in hoop nets (Fig. 4.4). The average CL of lobsters for both sexes combined in the hoop nets was 88.63 ± 11.05 mm CL, and in the traps was 86.60 ± 11.67 mm CL. The results showed a highly significant difference $P < 0.001$ between the two gear types. The average size of males was 88.6 ± 10.63 mm CL, n = 2 194 in the hoop nets compared to 85.8 ± 11.32 mm CL, n = 2160 in the traps. Female lobsters for the hoop nets were also larger 76.47 ± 6.18 mm CL, n = 430 in the nets than 72.8 ± 6.12 mm CL, n = 210 in the traps.

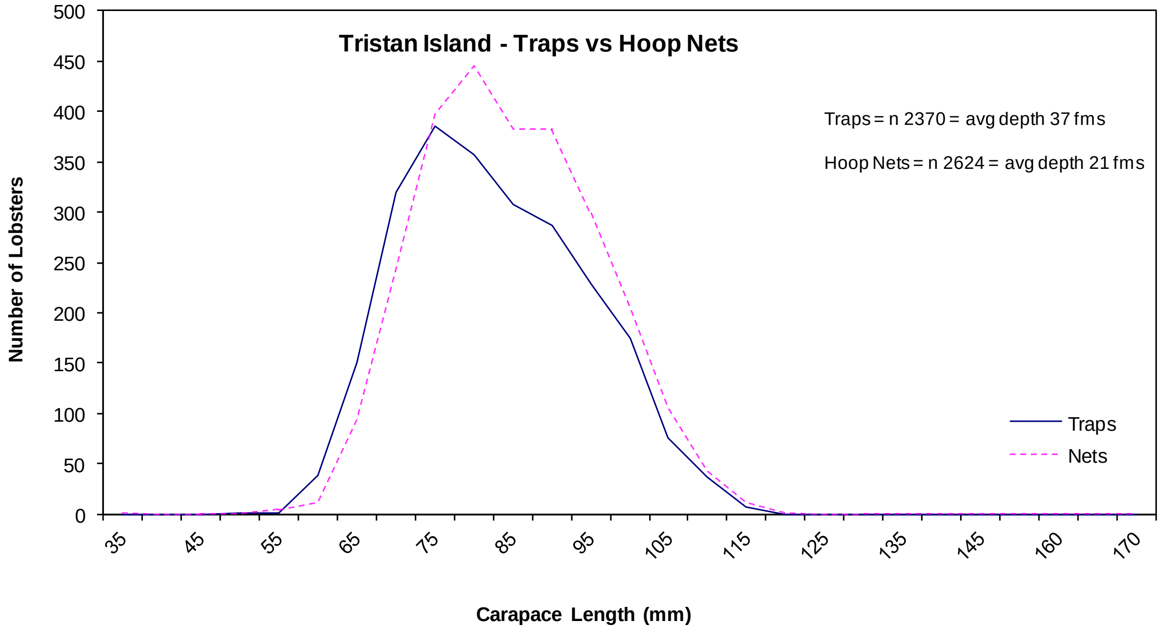


Figure 4.4: *Jasus tristani* both sexes combined caught in the two different gear types, powerboat traps versus hoop nets operated by the local fishing fleet at Tristan Island

4.3.8 Effects of depth on size

Lobster size composition data collected during the fisheries-independent surveys were categorized according to Island, year and season. From the eight transects deployed at Tristan three MT inshore, were compared with three MT offshore on each transect (Table 4.5).

For the purpose of a comparison of lobster size across depth, data collected at Tristan Island were selected, because the average depth of inshore stations (40 – 60 m) differed substantially from the depth measured at the offshore stations (109 – 144 m). The difference between inshore and offshore depth ranges measured at the other three islands (Nightingale 41 – 46 m inshore to 41 – 66 m offshore, Inaccessible 33 – 37 m inshore to 44 – 48 m offshore, Gough 56 – 62 m inshore to 84 – 93 m offshore) was far less, and these data were therefore not used for the comparison of lobster size across depth.

Table 4.5: Average CL (mm) of lobster samples caught Inshore and Offshore during fisheries independent surveys using 50 mm mesh traps at Tristan, Nightingale, Inaccessible and Gough Island. L1 = September leg 1 and L2 = February leg 2 per split-year fishing season

Island	Year	Month	Depth (m)	n	Avg CL (mm)	Depth (m)	n	Avg CL (mm)
Tristan	2006	Sep - L1	60	1821	88.2	138	1189	86.2
Tristan	2007	Feb - L2	49	1659	91	144	1481	91.5
Tristan	2007	Sep - L1	53	2498	83.5	109	1782	83.5
Tristan	2008	Feb - L2	40	1125	83.5	112	1076	87.2
Tristan	2009	Feb - L2	41	168	88.9	109	159	96.7
All Tristan samples			49		87.02	122		89.02
Nightingale	2006	Sep - L1	46	380	87.7	66	393	83.5
Nightingale	2007	Feb - L2	44	384	86.6	60	200	90.1
Nightingale	2007	Sep - L1	46	689	86	41	570	84.7
Nightingale	2008	Feb - L2	41	204	81.6	55	219	77.4
Nightingale	2009	Feb - L2	41	485	76.3	58	166	83.8
All Nigtingale samples			44		83.6	56		83.9
Inaccessible	2006	Sep - L1	37	2473	76.1	48	649	76.7
Inaccessible	2007	Feb - L2	34	437	78.1	44	246	74.6
Inaccessible	2007	Sep - L1	33	927	76.5	45	892	68.8
Inaccessible	2008	Feb - L2	33	328	79.4	44	452	71.3
Inaccessible	2009	Feb - L2	33	425	72.3	45	977	69.1
All Inaccessible samples			34		76.5	45		72.1
Gough	2006	Sep - L1	62	587	88.3	90	411	93.9
Gough	2007	Feb - L2	57	258	97.4	93	193	94.4
Gough	2007	Sep - L1	56	722	91.8	86	518	86.7
Gough	2008	Feb - L2	56	257	100.6	84	192	101.5
Gough	2009	Feb - L2	56	235	102.3	85	178	99.5
All Gough samples			57		96.1	88		95.2

The average size male and female combined from the first three traps inshore from 2006 to 2010 were 81.63 ± 6.93 mm CL compared with the last three traps on the offshore being 82.55 ± 7.83 mm CL (Table 4.2). In September 2007 there was a highly significant difference P< 0.001 for males and again in September 2009 there was a significant difference P<0.05. A similar pattern followed for the females, in February 2009 there was a significant difference P<0.05, and again in March 2010 there was a highly significant difference P< 0.001 (Table 4.6).

Table 4.6: Statistical comparison of lobster sizes caught during surveys at inshore stations versus those caught at offshore stations at Tristan da Cunha Island. Students t-test assuming unequal variances were used for males, females and both sexes combined, respectively. * indicates Significant difference = P<0.05, * * Highly Significant difference (P<0.001). SD is the Standard deviation

Year	Month	Category	Inshore AvgCL	SD	Offshore AvgCL	SD	df	t-value	P
2006	Sep	Males	89.01	13.23	88.77	13.26	1995	0.46	0.32
		Females	73.63	7.83	75.14	7.98	186	-1.58	0.06
		Both sexes	88.2	13.45	86.22	13.53	2527	3.93	4.42
2007	Feb	Males	92.19	12.25	92.38	12.8	2905	-0.41	0.33
		Females	71.84	6.09	73.28	8.55	121	-1.22	0.11
		Both sexes	90.97	12.91	91.45	13.28	3138	-1.02	0.15
2007	Sep	Males	84.61	12.27	85.72	13.26	3005	-2.61	< 0.00**
		Females	71.81	7.63	71.99	7.72	453	-0.26	0.39
		Both sexes	83.53	12.47	83.45	13.51	3638	0.11	0.46
2008	Feb	Males	87.55	13.37	90.54	13.63	1693	-4.56	2.68
		Females	72.42	6.36	71.57	7.29	372	1.34	0.09
		Both sexes	83.44	13.65	87.1	14.68	2170	-6.06	7.83
2008	Sep	Transects for Sep '08 were not done due to factory fire							
2009	Feb	Males	86.34	11.48	91.53	12.32	2607	-11.24	5.83
		Females	73.83	6.3	72.65	6.65	271	1.62	< 0.05*
		Both sexes	84.74	11.72	89.75	13.11	2851	-11.00	6.53
2009	Sep	Males	83.02	11.52	82.01	12.89	2356	2.22	< 0.01*
		Females	70.86	8.98	70.8	7.94	192	0.06	0.48
		Both sexes	82.42	11.7	80.72	12.93	2736	3.93	4.31
2010	Mar	Males	85.28	12.37	88.79	14.05	2716	-6.94	2.49
		Females	75.02	6.75	72.63	7.51	308	3.38	< 0.00**
		Both sexes	83.44	12.22	87.08	14.39	3054	-7.70	9.26

Figure 4.5 indicates lobster samples collected from eight transects using MT at Tristan during two fishing seasons (2006/2007 and 2008/2009). Carapace length measurements of lobsters between 35 mm CL to 155 mm CL (n =12 958) were taken from three inshore MT (average depth = 46 m) and compared with three offshore MT (average = 78 m).

The size composition data of inshore lobsters (males and females combined) was 84.53 ± 13.44 mm CL, n = 7271 compared to offshore lobsters (males and females combined) being 85.20 ± 14.25 mm CL, n = 5687.The results showed a Highly Significant difference P< 0.001 (Fig 4.5). Although the size class for lobsters were similar inshore as they were offshore, the frequencies of lobsters were more in the offshore traps than inshore traps.

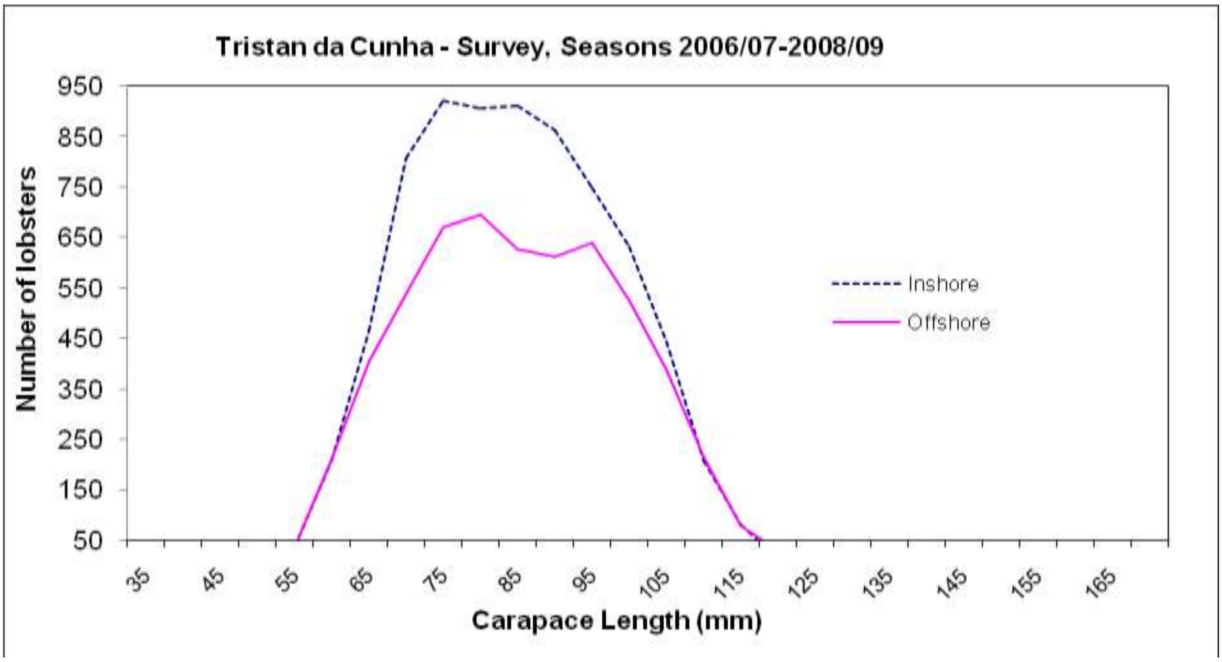


Figure 4.5: Male and female *Jasus tristani* combined, from three inshore MT versus three out-shore MT, from eight transects at Tristan Island over two fishing seasons

4.3.9 Sex Ratios

Sex ratios from random lobster measurements collected by SFO between 1997 and 2010 (Fig 4.6) were male-dominated at each of the four islands, ranging from 66% and 68% males in samples at Nightingale and Gough Islands respectively, to 77% and 80% males at Inaccessible and Tristan Islands.

The percentage of males taken from commercial samples, in the months the SFO were on the vessel is shown graphically in Fig 4.6. At Tristan Island where only daylight fishing takes place during the fishing season, between June and September 98 to 100% of the commercial catches were male lobsters only. The vessels fishing at the outer islands that left their fishing gear over night caught a mixture of males and females throughout the year (Fig 4.6).

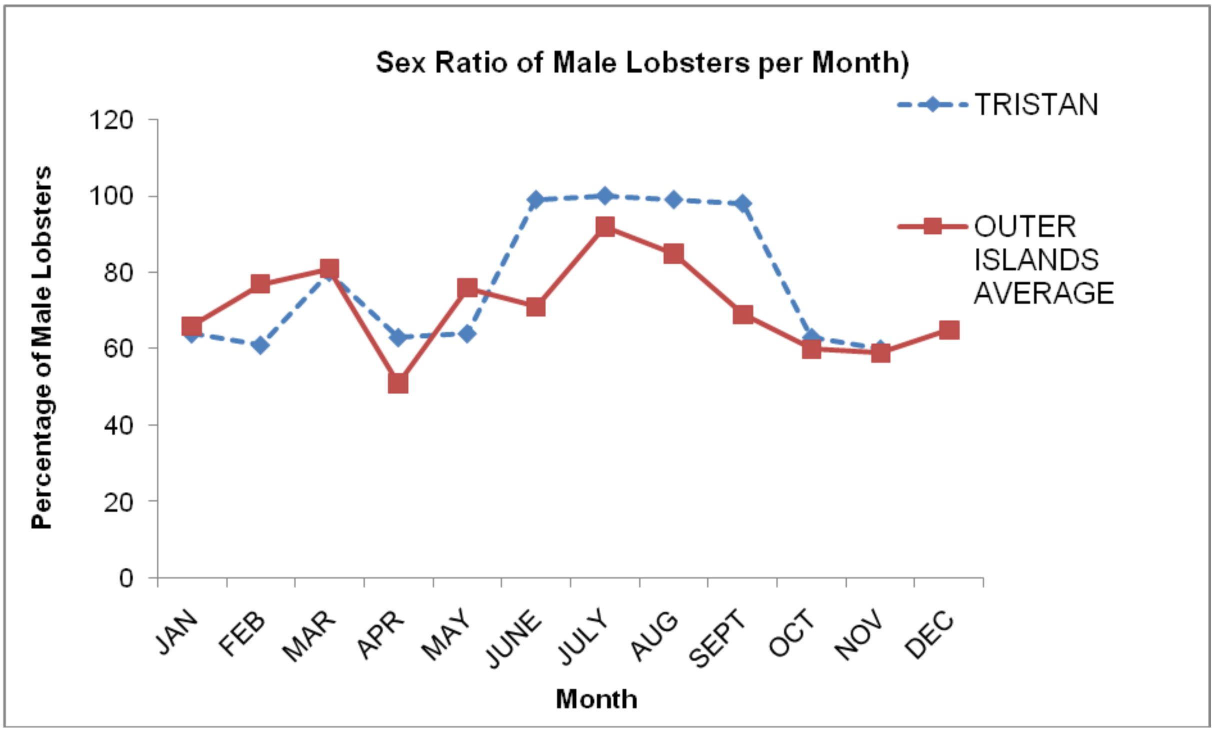


Figure 4.6: Sex ratio of male lobsters *Jasus tristani* taken from the Sea Fisheries Observers commercial samples

The high percentage of males in catches was also evident in Figure 4.7 which showed the percentage of males in each 5 mm CL size class, from the 247,014 lobster samples taken by Sea Fishery Observers between 1997 and 2010. Figure 4.7 indicates the percentage of males from all islands combined and for each island separately. It is evident that males are dominate in the catches, Islands Tristan (80.82 % males) and Inaccessible (74.5 % males) show a similar pattern is size classes below 65 mm CL, as do Gough (66.8 % males) and Nightingale (64.61 %) below 75 mm CL. At Inaccessible which has the smallest lobsters in the TDC group, 33.7 % were below the MLS, compared with Gough which has the largest lobsters in the TDC group having only 8.3% below the MLS.

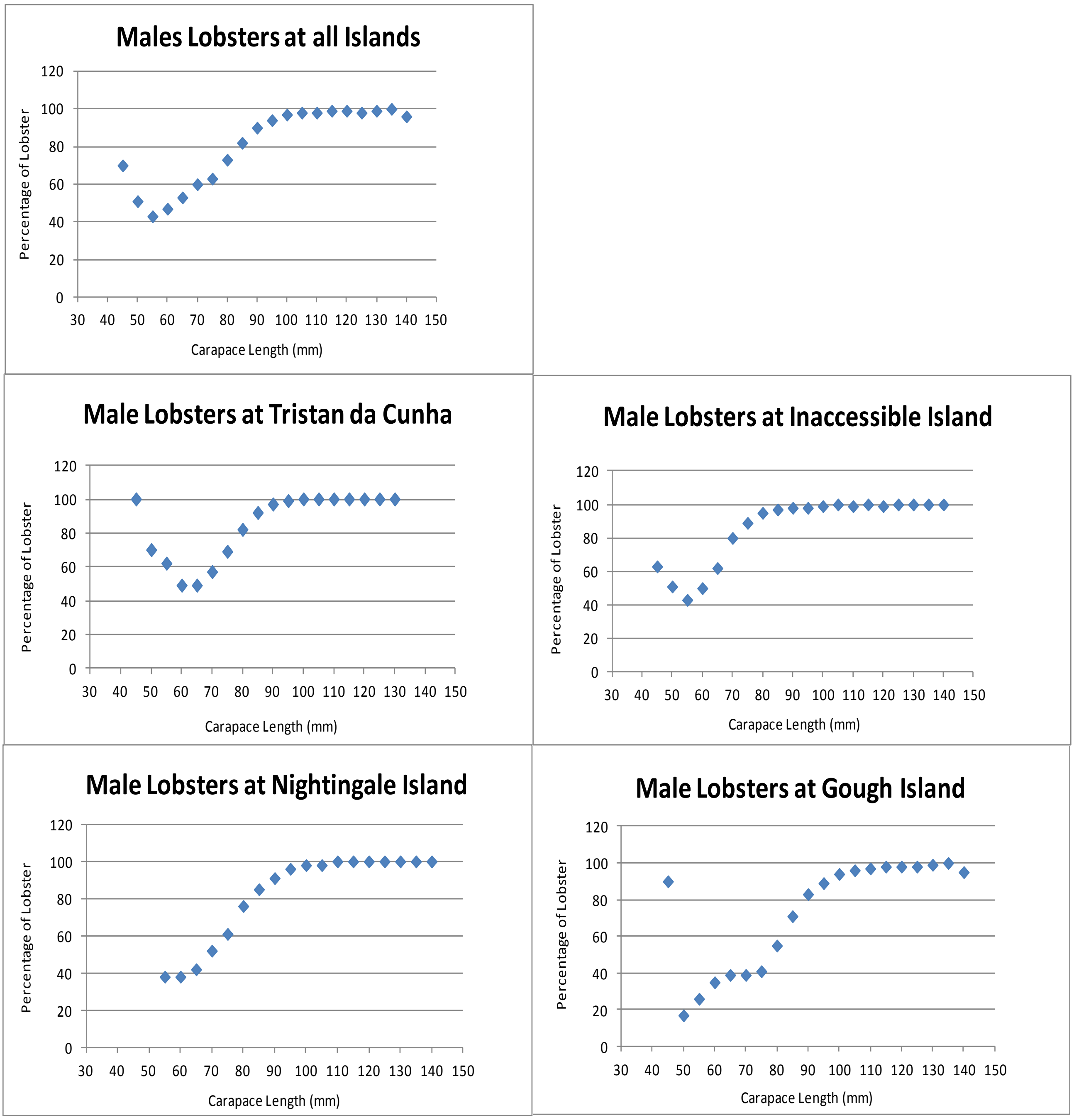


Figure 4.7: The percentage of male lobsters in each 5 mm CL size class, from the 247 014 lobsters sampled by Sea Fishery Observers during commercial fishing between 1997 and 2010. Both sexes combined and at Tristan, Inaccessible, Nightingale and Gough separately

4.4 Discussion

4.4.1 Males versus Females

The average size of the males were 83.45±14.46 mm CL, n = 175 192 compared with the females 73.37±8.64 mm CL, n = 71 822, the trend was the same for Tristan, Inaccessible Nightingale and Gough. Roscoe reported that the growth increments of *J. tristani* at moult varied with sex in the size class 73-109 mm CL. Male increments were 5 mm CL at Tristan and Nightingale whereas females was 1 mm CL. Males were therefore larger than females. Although the mean increment at Inaccessible was slightly lower at 4 mm CL. Pollock (1991) also reported that *J. tristani* female lobsters were smaller than males. Other studies show that males grow more than females, in *Jasus lalandii* (Roscoe & Pollock, 1977) and *Palinurus delagoae* (Groeneveld, 2000).

4.4.2 Inter-Island comparisons

The differences in average size composition of *J. tristani* at each island (Figure 4.2) confirms the observations of Roscoe (1979) and Pollock (1981 & 1991), indicating that the smallest lobsters are at Inaccessible Island and the largest at Gough.

At Gough 14.5% of lobsters were below the MLS of 75 mm CL, compared with 63.2% at Inaccessible. Nightingale Island despite a similar growth rate (Pollock, 1991) as Gough Island is considerably smaller at 78. 18 ±11.33 mm CL, n = 57 046 and this could be due to the smaller fishable area at Nightingale (Pollock, 1981). Of the 30,000 lobsters tagged in 1976/77 between the four islands no lobsters released at a specific island has ever been found at another, which strengthens the argument that there is no movement between stocks at any of the islands (James & Pollock, *pers comms*).   This is plausible given that the depth is more that 3,000 m between islands, however the reasons for the differences in size composition at the different Islands, have not yet been proven by any study. Gough Island is further South and the water temperature is generally 3°C cooler (Andrew *et al.*, 1995), Roscoe (1979) reported that the larger size of lobsters at Gough is ascribed partly to environmental differences. Inaccessible is thought to produced the highest amount of juveniles due to the habitat, which restricts the food availability for the lobsters and thus produces stunt growth (Pollock, 1981). The differences in size composition of lobsters between the three northern islands of Tristan, Inaccessible and Nightingale is not clear, as all three islands are situated only a few kilometres from each other and are not known to have significantly different benthos (Roscoe, 1979; Pollock, 1981; 1991; Andrew *et al.*, 1995; Scott, 2010).

4.4.3 Long-term trends in size composition (average carapace length)

Minimum legal size limits (MLS) for *Jasus tristani* fished at the Tristan group was first recommended by Roscoe (1979), although it was not until 1983 when an MLS of 70 mm CL was approved by the Tristan Island Council for implementation at Tristan, Nightingale, Inaccessible and Gough. This was altered in 2003, to 75 mm CL at Gough, 68 mm CL at Inaccessible, while Tristan and Nightingale remained at 70 mm CL (Glass, 2003). Inaccessible was altered again in the 2012/13 season (November) although this is not covered here (Johnson & Butterworth , 2012). The change in size (MLS) limits will influence the average size of lobsters processed (pack categories) data immediately, but it will not necessarily affect the sampled size of lobsters as these are taken by Sea Fishery Observers from unsorted lobsters. Each island is discussed separately below.

4.4.3.1 Tristan

The average size of lobster *Jasus tristani* found at Tristan Island during this study was 83.98 ± 12.56 mm CL, n = 42 096, and had increased to become the second largest average size of lobsters in the Tristan da Cunha group. Roscoe (1979) refers to the collection of length frequency data from Tristan in 1949, carried out by Mrs. Rowan (1949) that the lobsters sampled came from hoop nets at Tristan, gave a modal size between 120-129 mm CL to which less than 1% were smaller than 80 mm CL. By 1971/72 this mode had decrease to between 80-89 mm CL with about 20% being smaller than 80 mm CL. The females had also decreased between 1949 and 1971 although less pronounced.

Samples collected at the start of this study in 1997 gave the average lobster size at Tristan combined as 77.64 mm CL. It was at this time that the island made a change of the concession holder, bringing in a new fishing company and implemented strict controls on the landings of undersized lobster, gear restrictions, and mesh sizes. Sizes immediately started to increase and in 2007 had reached a CL of 91.8 mm CL. However, as shown in this study this started to decline and in 2010 was currently at 81.0 mm CL (Fig. 4.3). From the data it is evident that as the CPUE of lobsters increases, so does the size composition, when CPUE falls so does the size. This has happen at Tristan which could suggested that the TAC at this island was too high, and need to be reduced. Although, it is predicted that the CPUE and average size will always be lower when catching the maximum sustainable yield (MSY) than when harvesting less.

4.4.3.2 Nightingale

Results from this study found that the lobsters *Jasus tristani* at Nightingale island was the third largest 78.18 ± 11.33 mm CL, n = 57 046 in the group (Fig. 4.2) next to those found at

Tristan island. The size at Nightingale has decreased since Roscoe (1979) reported that male lobster *Jasus tristani* from Nightingale Island was slightly larger than Tristan, but that both Nightingale and Tristan were larger than Inaccessible, with a modal size between 75-79 mm CL.

The average sizes of lobsters at Nightingale were always larger than Tristan up until the 1980's, when two vessels decided to fish at Nightingale at the same time. However, there was a change of Captains on the vessel *Tristania II* and both Captains chose to fish at Nightingale, as the lobsters were larger than Inaccessible and there was less work for their crew sorting the undersize catch. Previously from the two vessels, one Captain would choose to fish at Nightingale and the other at Inaccessible. This imeadially put pressure on the lobster stocks at Nightingale, as this island had the smallest fishable/shelf area within the Tristan da Cunha group, and the average size decreased (James *per obs*, Pollock, 1991; 1992)

Catch size composition data for Nightingale illustrate that size composition has changed more obviously than at the other islands, as a result of fishing pressure. This pressure on the stock at Nightingale forced the size composition of lobster to decline (James *pers obs*), and supports the contention that fishing has had a large impact on the lobster stock at this island, and the attempts made to restrict fishing there were fully justified in the early 1990's (Pollock, 1992).

It was only after the change of the concession holders in 1997, when strict controls were implemented (such as only one ship fishing at any one island at any one time) did the stock show signs of recovery moving from 74.9 mm CL in 1997 increasing to 83.2 mm CL in 2007. Since then there has been a steady decline and in 2010 was back down to 74.9 mm CL. (Fig. 4.3).

The decline in size composition at Nightingale may be linked to the TAC. Between 1997 and 2012 the TAC was approximately 55 mt and the size was constantly between 70 - 83 mm CL. However, as soon as the TAC increased to between 60 -72 mt (Figure 4.3, year 2007) the size composition decreased from 83.2 mm CL to 74.9 mm CL. This leans towards the argument that fishing pressure on a population reduces the size composition, as it removes more of the older animals (Pollock, 1981; Glass, *per obs*).

4.4.3.3 Inaccessible

The results from this study provided similar findings to that of Roscoe and Pollock 1977 and Roscoe, 1979; That smallest lobsters occur at Inaccessible island (Fig. 4.2). Roscoe (1979) collected data from all islands between 1971 and 1973) from all the islands and reported on the larger modal and mean size of males from samples taken inshore at the islands of Nightingale and Inaccessible, and commented especially on the different size distributions recorded from different fishing areas around Inaccessible (Roscoe 1979). He reported that the modal size composition from the longling fishery was 75-79 for males and 70-74 for females, although the males caught inshore were much larger at between 80-89 mm CL. This size distribution is also supported by Pollock, (1981, 1991) and MARAM (Johnson & Butterworth, 2012).

When the new concession holders took over in 1997, the average size lobster at Inaccessible Island was 72.51 mm CL and increased to 77.69 mm CL in 2005. Since then it has decreased more than any of the other islands to 67.99 mm CL in the 2010 season (Figure 4.3). It is understandable that the average CL would have decreased at Inaccessible in 2003/04 as this was the year the MLS was reduced from 70 mm CL to 68 mm CL. The reduction in the MLS increased the number of smaller packed grades (Counts of lobster per 10kg carton, especially counts 68 and 72) from 1 - 2.5 % pre 2003/04 to 5 - 7 % post the reduction in the size limit. However, the company's strategy (bar the 2002/03 season when the Japanese market price collapsed) has been focused on increasing whole production. Therefore one would expect to see an increasing trend in the smaller sizes, as these are the premium value grades. However, this would not have affected the Sea Fishery Observers samples (lobster measurements) which are taken from unsorted lobsters, therefore one can say with certainty that they has been a decline in size composition.

Other factors controlling size composition and size reduction could be environmental factors, Pollock (1991) relates the inter-island differences to food availability *per capita* to lobsters at the different islands and a function of lobster densities. Fishing pressure, or the fishing area concentrated by the vessels, for an extended period, has also shown size reductions in the past, such as Nightingale in the late 1980’s (Glass, J, *pers. obs*.)

Another factor which may be affecting the size composition is the amount of handling and releasing of undersize lobster, as these procedures are known to have an effect and reduces productivity of the stock (Brouwer, *et al.,* 2006). This is especially noticeable at Inaccessible Island, where there was between 33.29 – 54.25 % of undersized (68 mm) discarded daily (Johnson & Butterworth, 2013). It is also evident that, like Tristan, the CL size has decreased with a decreasing CPUE and this may suggest that the TAC at Inaccessible Island is too high (See chapter 2, section 4.1).

4.4.3.4 Gough

The average size of lobster *Jasus tristani* at Gough Island during this study was 87. 21 ± 14.42 mm CL, n = 76 345. At the start of this study in 1997 the average was 100.89 mm CL. In 2010 this had decreased to 90.36 mm CL both sexes combined. This reduction suggest that the decreased is size is a result of increased fishing pressure in the 1989/90 and 1990/91 seasons.

Although Roscoe (1979) reported lobsters at Gough attained a greater maximum size of 175-179 mm CL for males and 115-119 mm CL for females, than Tristan, Nightingale and Inaccessible. One of the reasons could be when the previous fishing company knew they had lost the option to renew the fishing concession with the Tristan Government. A second reason could be that this was also when TAC's were introduced although not recognized by the previous concession holders (Chapter 2. Appendix C), who exceeded the TAC's for the first year of implementation (1990/91). Thereafter the TAC could not be caught, until it was drastically reduce in the 2004/05 season by 32 mt.

From 1960 to the 1990's, illegal fishing took place at Gough Island because of its distance from the other islands. The lack of fishery monitoring (within Tristan da Cunha's EEZ) and the likelihood of poaching taking place, may have resulted in a negative impact on the lobster stocks within the area (James *per obs*). Although the average CL of lobsters at this island since 1997, have not shown the fluctuations in size, compare with the other islands.

In the 2003/04 season the MLS increased from 70 mm CL to 75 mm CL at Gough Island, which helped levelled off the decline in the average CL. At this time it was 86.89 mm CL and may even helped contributed to the increase slightly to 90.36 mm CL in 2010. It would seem that the reduction of 32 mt in the TAC has also helped the population at Gough to recover, showing increases in both the CPUE and the average CL Figure. 4.3.

4.4.4 Effects of gear-types on size (Powerboat trap verses hoop net)

From this study where 4,994 samples of size composition data of lobsters *Jasus tristani* were collected, between the local powerboat trap and hoop net at Tristan Island. The conclusion was that larger lobsters are caught in the hoop nets (Fig. 4.4). Despite the depth or area fished larger lobsters are still caught in the hoop nets. For the hoop nets both sexes combined the lobsters were 88.63 mm CL, compared with in the traps 86.60 mm CL. males were 88.6 mm CL and females 76.47 mm CL, and this could be due to the fact that the larger animals are chasing the smaller ones away when approaching the bait (Rowan, 1949). However, this still remains the case for lobsters of both sexes in the traps males 85.8 mm CL and females 72.8 mm CL. (James *per obs*).

Previous studies report the same findings for *Jasus tristani*. Rowan (1949) observed lobsters being caught by hoop nets at Tristan and reported that larger lobsters entered first, and only after the majority of the larger lobsters had disperse, would the smaller lobsters enter. Both Roscoe (1979) and Pollock (1981 & 1991) as well in previous reports (unpublished) for the concession holder, have reported similar differences, between the hoop nets and traps. Other fisheries using different gear types (Groeneveld, 2000) have also seen differences in the sizes of lobsters caught. Design traps used to catch lobsters, can be modified to target a certain species and size range (Miller, 1990). It can also increase catch rates of legal size lobsters and reduce sorting time (Everson et al., 1992; Rosa-Pacheco and Ramirez-Rodriguez, 1996).

4.4.5 Effects of depth on size (Inshore versus offshore, Survey data)

Size composition of lobsters over depth was collected during fisheries independent surveys between 2006 and 2010 using the *M.V. Edinburgh* at Tristan, Nightingale, Inaccessible and Gough. (Table 4.5). During this period there were four occasions (Table 4.6) when the results showed significant differences (Males Sep-2007, $P<0.001$ and Males Sep-2009, $P<0.05$) and for females (Females Feb-2009, $P<0.05$ and Females Mar-2010, $P<0.00$) in the size of lobsters captured in the Inshore and Offshore stations during the surveys undertaken at Tristan between 2006 and 2010 (Table 4.6). However, it is possible that these differences may be due to the males moulting in September and the females moulting in February and March.

Lobster samples taken at Tristan during the (07/08 & 08/09) seasons survey (Fig 4.5), the offshore traps produced a greater amount of larger lobsters average 85.20 mm CL, and the inshore traps producing a higher frequency of lobster of the average size 84.53 mm CL. showing a highly significant difference $P < 0.001$ in size over depth, as the same gear type (MT) was used. It is evident in Fig 4.5 that you are getting the same range of sizes in both locations, but fewer medium sized fish offshore. The increase in lobsters offshore could be that the lobsters offshore are not as easy prey to predators (such as Octopus) as those lobsters inshore. At the present moment the fisheries independent surveys have not been running long enough to produce sound statistical evidence that shows any clear differences, in size of lobster over depth.

4.4.6 Sex ratios

During this study male lobsters in the Tristan fishery dominate catches for much of the year (Fig 4.6 & 4.7), although females are more predominant when they were out of berry, and while the males were moulting from October through to March (Fig 4.6). It is at this time that catch rates are at their highest, due to both sexes being on the bite, and again in March - April after moulting (Roscoe 1979, James *pers obs*). Seasonal changes in sex ratio is likely to be cause by variations in catchability related to reproduction, moulting and migration (Roscoe, 1979, Pollock, 1981).

At Tristan only daylight fishing occurs inshore, whereas the samples from the outer islands are taken from longlines offshore, for Tristan this will have an impact on the sex ratio and average size for females during breeding (June to September, Fig. 4.6), when the majority are thought to cease foraging during daylight (Roscoe, 1979). Therefore male lobsters dominate the retained catch for most of the year, and when the greater mean weight of males is taken into account, their contribution to the commercial catch by weight is even greater. This is further demonstrated in Fig 4.7 which shows between 64.61 % and 80.82 % were males from the Sea Fishery Observer samples and as can be seen while the females are the majority in the smaller size classes all the larger lobsters is males. The contribution of females to the retained catch is further reduced because of their smaller size, due to lesser growth rates (Pollock, 1991), and the requirement by law to return berried lobster.

Estimating the sex ratio of a population from trap caught lobster can be difficult to quantify due to seasonal variations in availability due to moulting and reproduction (Morgan, 1980).

The variation, and contribution to the commercial catch of each sex, is in itself interesting, the composition of lobsters caught by different gear types, is influenced by the animals behavior towards the fishing gear (Hancock & Simpson, 1962; Arana & Ziller, 1994; Green *et al.*, 2009).

4.5 Conclusion

A number of conclusions can be drawn from this study 1) The average size of male lobsters tend to be larger than females, despite area fished or gear type used. 2) Males dominate catches. 3) Hoop nets catch larger lobsters than the powerboat traps despite the depth fished. 4) It is evident from the results that that fishing pressure does effect size composition. If the fishery continues to be heavily fished beyond a sustainable level, the size composition is expected to continue to shift to smaller sizes, indicating that the level of fishing is not compatible with the level of fishing.

Chapter 5

Fecundity of *Jasus tristani* at Tristan, Nightingale, Inaccessible and Gough

5.1 Introduction

The number of eggs produced by lobsters during their lifetime is often large in order to offset high mortality rates that are characteristic of early life history stages (Pollock, 1997). Species that produce fewer, but larger eggs may rely on stronger larvae with a lower mortality, in contrast to species that rely on larger quantities of smaller eggs and larvae with higher mortality (Pollock & Melville-Smith, 1993). In general, eggs carried by the members of the *Jasus* genus are smaller and more numerous than those carried by *Palinurus* and *Panulirus* spiny lobsters (Pollock & Melville-Smith, 1993).

Jasus species spawn annually although the number of spawnings per season varies in other gerera . Multiple spawning occurrs in *Panulirus japonicus* and *P. argus* (Creaser, 1950; Ino, 1950), and *P. omatus* is reported to spawn three times (McFarlane & Moore, 1986). Briones & Lozano, (1992) reported that *P.inflatus* and *P. gracilis* can spawn as many as four times in a season.

Spatial and temporal (interannual) variations in fecundity and reproductive potential have been shown for rock and spiny lobsters (Beyers & Goosen, 1987; Melville-Smith *et al.,* 1995; Groeneveld, 2005) and clawed lobsters (Estrella & Cadrin, 1995; Tully *et al.,* 2001). Spatial variation in fecundity have been attributed to differences in growth rates, size at maturity and body size ((Pollock & Goosen, 1991; Melville-Smith et al., 1995; Groeneveld, 2005).

It is important to know the seasonal cycle of reproduction and the size of maturity as these are critical factors in determining a minimum legal size (MLS) and managing exploited spiny lobster populations (Heydorn, 1965; Annala *et al.,* 1980; Booth, 1984). When deciding a MLS, the principle is that most of the female lobsters should have had the opportunity to breed at least once before being landed by the commercial fishery (Annala *et al.,* 1980). Nevertheless, fecundity of large females can be more than an order of magnitude larger than fecundity of smaller individuals (Jeffs *et al.,* 2013) Closed seasons for lobsters during the egg bearing season can also be applied, timed to prevent damage to those females carrying eggs.

Fecundity-size relationships of spiny lobsters have often been determined for fished populations because they can be used together with size frequency data to assessthe effects of changes of minimum legal size and exploitation rate on egg production (Annala & Bycroft, 1987; Beyers & Goosen, 1987; Goñi *et al*., 2003; Groeneveld, 2005).

Female *Jasus tristani* are known to reach maturity before they are 60 mm at Tristan and Inaccessible, and it is assumed that rock lobsters mature at Nightingale at a similar size (Roscoe 1979).

The behavior of female *J. tristani* is similar to that of other *Jasus* species, in that they produce a single brood of eggs annually (Jeffs *et al.,* 2013). Mating is usually in autumn, and peaks around April when most of the females have shed their old exoskeletons. It is while the bodies of the females are soft that mating occurrs (Phillips & Kittaka, 2000) with egg laying taking place a month later. Eggs are externally fertilized and attach to the hairs of the pleopods of the female (Phillips & Kittaka, 2000), where they are carried over the austral winter (May to October). At this stage females are said to be in berry, (Roscoe, 1979; Pollock, 1981, 1991; MacDiarmid & Booth, 2003).

The females tend to migrate in shallower water at this time and cease foraging during daylight, while the eggs are at an early stage (Pollock, 1981). Most females in berry are caught in fishing gear that has been left down over night. Most female *J. tristani* have shed their eggs by the end of October.

Silberbauer (1971) states that most hatching takes place at night for *Jasus lalandii* and has been recorded to take place over a period of 3 - 5 days. This is thought to be similar for *J. tristani,* however, it has not been proven.

By comparison with the 20-30 day larval life of *Homarus*, the larval life of the spiny lobster is a long 4 - 22 months (Johnson, 1960; Lazarus, 1967; Chittleborough & Thomas, 1969; Berry, 1974; Lesser, 1978). After this stage the juveniles continue to grow, moulting several times a year. Adult lobsters, moult on average once per year. *Jasus lalandii* reaches sexual maturity at a carapace length between 65 - 70mm for males and females respectively (Heydron, 1966). The assumption made by Pollock (1981) is that recruitment of *J. tristani* is complete for both sexes at 60 mm carapace length. Adult males are known to grow faster than females (see earlier chapters of this thesis).

Around 75% of *J. tristani* female lobsters captured in traps at Tristan Island during the period June - August in berry. This drops towards the end of the year, and by October only the smaller adult females, which have mated/moulted late, are in berry (James Glass *pers obs*). The peak of the egg bearing period is around three months (June – August) for *J. tristani* (although for all *Jasus* species it depends on environmental/temperature conditions (Bruce, 2007). Lobsters in berry are not found in catches at Tristan between December and March (Fisheries Dept, Glass, J., *pers. obs*).

Pollock (1991) speculated that the phyllosoma larvae of *J. tristani* are carried right around the South Atlantic by the gyre system, which would take about three years (Shannon *et al.,* 1973), and would require an improbably long larval life span. It seems more likely that the larvae from the Tristan lobsters are being carried by the currents that are driven by prevailing westerly (SW) winds away from the islands and returned to the islands by a local current system. It is considered likely that surface currents around the islands vary, but seem to work in a SW - NE cycle (Glass, J., *pers obs*). When the wind is in one direction, often the current is in the other (kelp tailing into the opposite direction of the wind, often known as a boiling pot or whale's weight by the Tristan islanders).

DNA showed gene flow between Tristan islands/seamounts in the SW Indian ocean. This implies that at least some larvae must reach there from Tristan (Groeneveld *et al.,* 2012).

The overall objective of this chapter was to assess female trends in female fecundity at the Tristan da Cunha group islands, with the following specific objectives;

- To determine and compare the fecundity-size relationships of *J. tristani* females sampled at Tristan da Cunha, Nightingale, Inaccessible and Gough Islands.

- To determine egg-size, and to compare fecundity-size relationships with earlier studies of *J. tristani* and with information available for other *Palinuridae* (particularly *Jasus* spp.).

5.2 Materials and methods

5.2.1 Study Area

Refer to Chapter two, section 2.3 for a full description of the study area.

5.2.2 Biological measurements (size and sex)

A total of 176 random samples, of egg-bearing (berried) female lobsters were collected during the breeding season (July to September) by Sea Fisheries Observers (SFO). These were collected from traps set during a fishing survey at Tristan da Cunha, Nightingale, Inaccessible and Gough Islands, between 2006 and 2008. The carapace length (CL ± 0.1 mm) was measured mid-dorsally from the posterior edge of carapace to the anterior tip of the rostrum spine using vernier calipers.

The females were selected so that they spanned a wide size range (57 mm to 115 mm CL), and they were then frozen intact at sea and transported to a laboratory, where the egg-masses were excised and frozen until they could be processed further. The egg diameters of three replicate eggs per female were measured using a binocular microscope. Eggs were staged as per the description of Groeneveld (2005) as follows: Stage 1 egg - masses (no eyespots; eggs uniformly bright orange); Stage 2 (small eyespots); and Stage 3 eggs (eyespots large; eggs discoloured). Stage 2 eggs were used in this study, as the start of the fishing season (25th August) was late into the breeding season and lobster sizes of stage 1 would have been difficult to collect.

Egg mass was weighed and oven-dried at 70ºC for 24 h. Extraneous material (small remains of the pleopods and cetae) was removed manually and the total dried egg mass per female was weighed in grams (g). Subsamples of dried eggs (0.1 g) were taken from egg masses and counted, and fecundity was estimated according to the equation:

$F = (Wt / Ws) Es$,

where Wt is the total dry weight of the egg sample, Ws the subsample weight, and Es the egg count of the subsample.

5.2.3 Statistical treatment of data

Linear regressions of fecundity and dry mass as a function of CL were calculated using least-squares fit for the years 2006 to 2008 for each island. Comparison of the regression equations for CL versus fecundity were carried out using a series of paired comparisons between islands with a dummy variable for island and the Excel regression tool which undertakes an analysis of variance and t-test to compare the probability of the intersect and slope of the two lines being the same. Egg diameters were compared among islands using a single factor ANOVA. A comparison of egg diameter for large (CL>80 mm) and small (CL<80 mm) lobsters was also undertaken using a single factor analysis of variance.

5.3 Results

5.3.1 Fecundity-size relationships

During the egg-bearing season a total of 176 lobsters were collected and measured sizes ranged from 57 mm to 115 mm CL. All eggs which were a stage two (small eyespots) were removed and data reported on for all islands separately and combined.

Two sets of results are presented in this section: the relationship between carapace length (CL) and dry mass (DM) of lobster eggs and the relationship between CL and fecundity (Egg Number). Data have been presented graphically for Tristan, Nightingale, Inaccessible and Gough Islands separately in Appendices F and G.

The results for each island (Table 5.1) show similar regression equations for carapace length versus the dry mass and the carapace length versus fecundity (egg number). The results show a strong correlation between egg mass and carapace length, as well as egg number with carapace length ($r^2 > 0.7$ in all cases). In all cases the relationship was found to be linear.

Table 5.1: Linear regression statistics (y = ax - b) of CL (mm) versus dry mass (DM, g) and CL verses number of eggs (Fec), carried by female *J.tristani* captured at Tristan, Nightingale, Inaccessible and Gough.								
Island	**Year**	**Egg stage**	**Regression**	**a**	**b**	**r2**	**n**	**Size range**
Tristan	2006 - 2008	2	CL - DM	0.2279	11.333	0.7932	54	57 - 95
Tristan	2006 - 2008	2	CL - Fec	1703.7	79258	0.7384	54	57 - 95
Nightingale	2006 - 2008	2	CL - DM	0.3095	17.067	0.8678	39	63 - 112
Nightingale	2006 - 2008	2	CL - Fec	2128.4	107048	0.7974	39	63 - 112
Inaccessible	2006 - 2008	2	CL - DM	0.2113	10.082	0.8022	52	56 - 87
Inaccessible	2006 - 2008	2	CL - Fec	1747.4	78067	0.7495	52	56 - 87
Gough	2006 - 2008	2	CL - DM	0.3047	16.752	0.7664	31	69 - 115
Gough	2006 - 2008	2	CL - Fec	1920.4	102092	0.7156	31	69 - 115

The difference relationship between CL and. fecundity between islands is are shown in Fig 5.1.

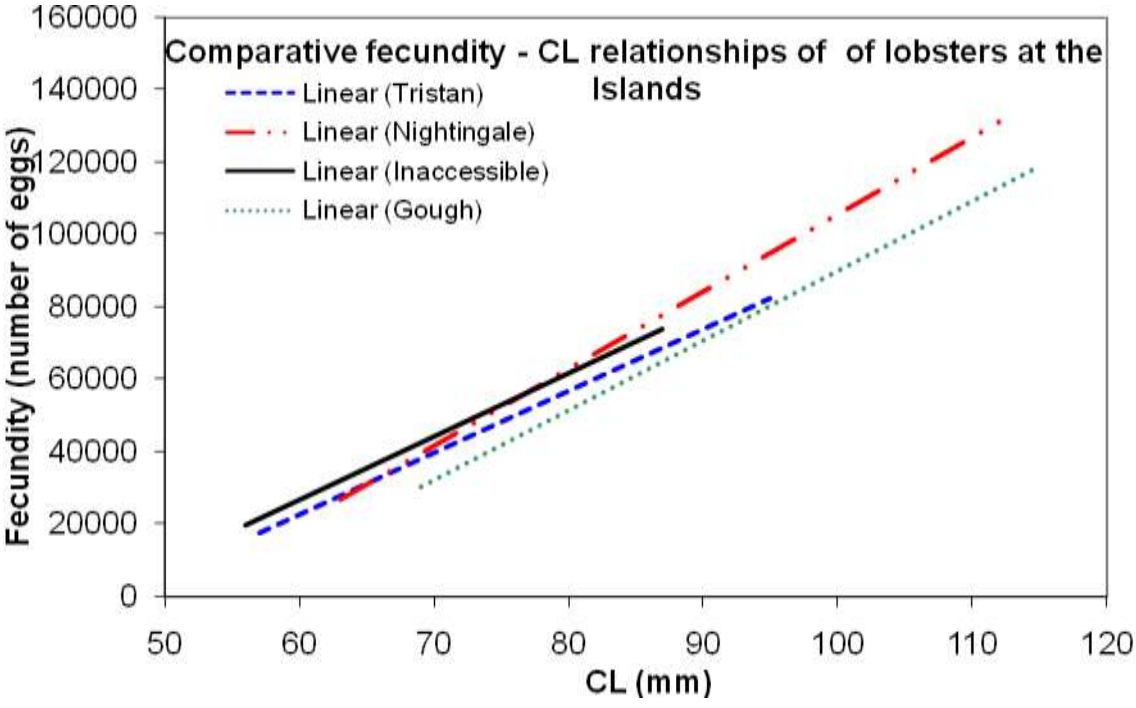


Figure 5.1: Comparative Carapace Length versus fecundity regressions of lobsters *Jasus tristani* from Tristan Nightingale Inaccessible and Gough Islands

An inter-island comparison of the CL fecundity relationship is presented in Table 2. Differences between the slope and intersect of regression lines appear to be significant in all cases ($P<0.05$) but as noted above some caution needs to be exercised in making a series of paired comparisons.

Table 5.2: Paired comparison of regressions of CL vs Egg Number for female lobster collected from different islands.

Inter-island comparison	Regression	Slopes t-value	Slopes Significance	Elevations t-value	Elevations significance	Degrees of freedom
Inaccessible & Gough	CL vs Egg Number	-2.7614	P = 0.00716	3.8836	P = 0.0002125	82
Inaccessible & Nightingale	CL vs Egg Number	-2.1156	P = 0.03725	2.4908	P = 0.01465	90
Inaccessible & Tristan	CL vs Egg Number	-6.0066	P = 2.9 E-08	6.7933	P = 7.5 E-10	105
Nightingale & Gough	CL vs Egg Number	-4.2984	P = 5.8 E-05	5.1485	P = 2.6 E-06	69
Nightingale & Tristan	CL vs Egg Number	-8.2521	P = 1.3 E-12	8.6523	P = 2 E-13	92
Tristan & Gough	CL vs Egg Number	-2.2795	P = 0.02527	2.8064	P = 00627	84

In this study whole weight of the female lobsters was not recorded, so egg number was not compared with whole weight of the female lobsters. This makes it difficult to compare fecundity with previous studies that have used this metric. In addition, previous studies have not distinguished between the lobsters from different islands. Length was converted to weight using:

$WW = 0.007 \times CL^{2.9377}$ (chapter 3 - regression for females all islands)

To allow for comparison with other studies, the WW vs. Egg number relationship was calculated as follows:

Egg Number = 1704 x CL – 77660 (combined data from all islands, Annex H)

Applying these two best fit relationships provides the estimated whole weight and egg number for a range of carapace lengths (Table 5.3). Analysis of egg mass carapace length relationship was also examined for lobsters from each island the results are presented in Figure 5.2.

Table 5.3: Estimated egg number per g. of whole weight for a range of sizes of female lobsters

CL mm	WW g.	Egg no	Egg No per g. WW
60	117	24580	210
65	148	33100	223
70	184	41620	226
75	226	50140	222
80	273	58660	215
85	326	67180	206
90	386	75700	196
95	452	84220	186
100	525	92740	177
105	606	101260	167
110	695	109780	158
115	792	118300	149
120	898	126820	141

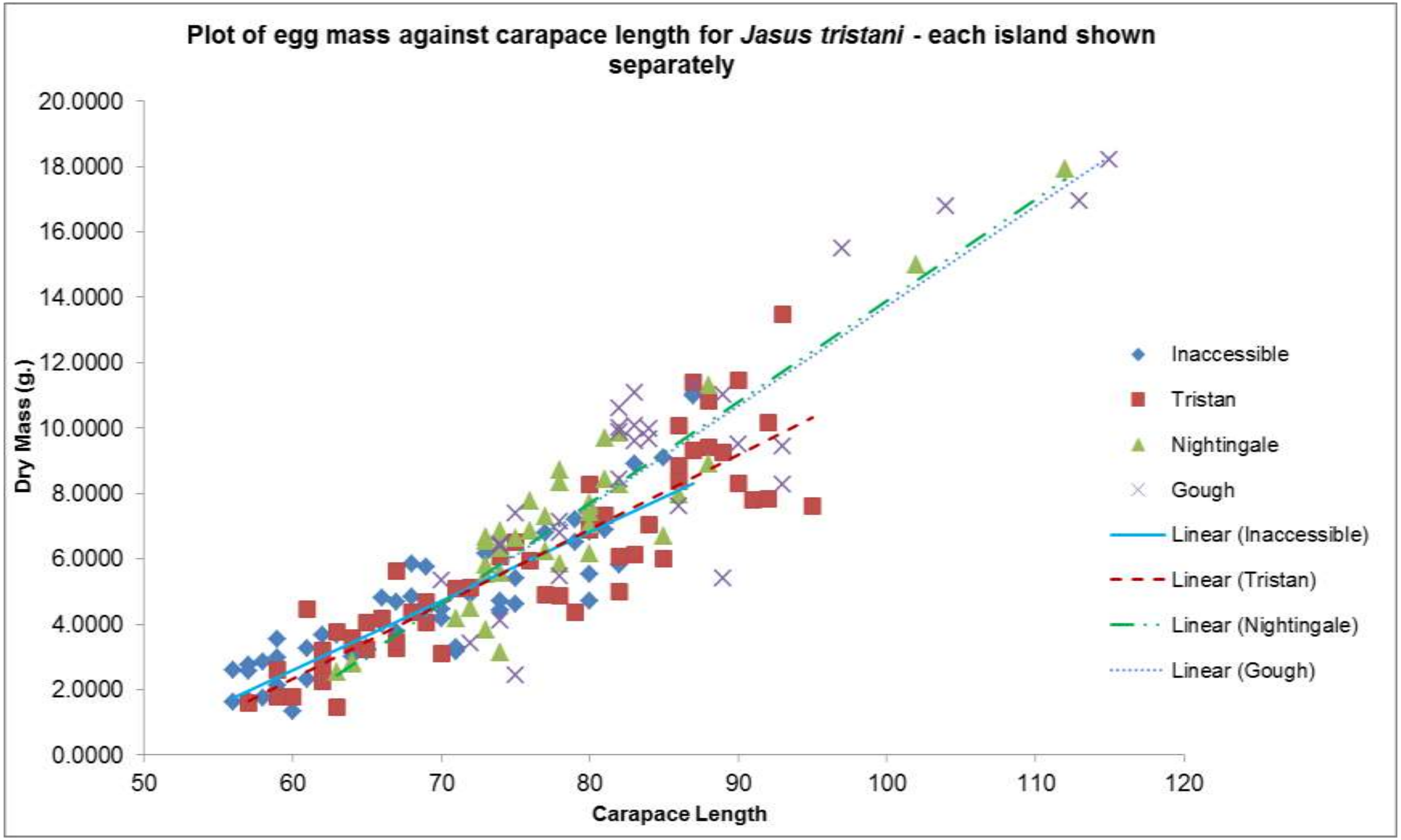


Fig. 5.2: Plot of egg mass against carapace length for female lobsters of each island with regression lines fitted.

5.3.2 Egg-size relationships

The egg diameters of from Nightingale, Inaccessible and Gough were measured (Table 5.4) and no significant differences were found between islands. Female lobsters at Gough Island were tested to see if there were any differences in the diameter of eggs collected from small (CL < 80 mm) and large (CL > 80 mm) females, and no significant difference was found P = < 0.53, n = 33.

Table 5.4: Comparison of egg size (diameter) of eggs collected from lobsters at Gough, Inaccessible and Nightingale Islands

	Island			
	Gough	**Inaccessible**	**Nightingale**	**Grand Total**
Number of eggs (n)	33	12	12	57
Average diameter (mm)	0.66	0.62	0.62	0.64
Standard deviation (mm)	0.06	0.06	0.06	0.06
Minimum diameter (mm)	0.53	0.52	0.53	0.52
Maximum diameter(mm)	0.75	0.73	0.69	0.75

5.4 Discussion

5.4.1 Fecundity-size relationships

The results show that the relationship between CL length and fecundity was linear. In many finfish species, although fecundity is highly variable, body weight is the main factor influencing it (Rideout & Morgan, 2010). Studies of the lobster *Jasus edwardsii* suggest a power relationship, with fecundity increasing with approximately the cube of the carapace length (Linnane *et al.*, 2008), suggesting a similar relationship between fecundity and body weight. However many studies of rock lobster show a linear relationship between CL and fecundity. Morgan (1972) found a linear relationship between fecundity and CL for *Panulirus longipes* and based on a review of literature stated that this was the same as many rock lobsters of the family *Palinuridae.*

The result of this study suggests that there are significant differences in the relationship between size (as measured by carapace length) and fecundity for *Jasus tristani* between the four islands of Tristan, Nightingale, Inaccessible and Gough Islands. In general, lobsters at Tristan and Inaccessible have a larger number of eggs at small sizes, but the fecundity increases more rapidly with size at Gough and Nightingale.

The onset of sexual maturity in female *Jasus tristani* has been commented on in three papers. Heydorn (1969) reported that the smallest ovigerous female found had a carapace length of 55 mm. Roscoe (1979), found all the small females sampled to be sexually mature (judged by the presence of ovigerous setae), but his sample included only three individuals with carapace lengths of less than 60 mm. Pollock (1991) examined several thousand females at Nightingale and Inaccessible, and concluded that the size at 50% maturity is 56 mm at Inaccessible and 59 mm at Nightingale. Again this was based on the presence of ovigerous setae: work on other *Jasus* species suggests that this will underestimate the size at which 50% of females are actually berried (Chubb, 1991; Groeneveld & Rossouw, 1995).

Variation in size at maturity in different areas has also been observed for other *Jasus* species (Gardner *et al.,* 2006). Although this study did not attempt to establish the size at maturity, simply taking a range of egg-bearing lobster of different sizes, it is consistent that the smallest egg-bearing females were collected at Inaccessible (56 mm CL) and Tristan (57 mm

CL). It is also consistent with the observation of Pollock (1991) that growth rates at Nightingale and Gough are greater. In many species, slow growth rates are associated with the onset of maturity at a smaller size; while the conditions that favour faster growth rates (optimum temperatures and/or availability of feed – Hazell *et al.*, 2001) may be expected to lead to greater fecundity once individuals have matured. Beyers and Goosen (1987) reported that fecundity was higher for mature *Jasus lalandi* in areas where growth rates are higher.

The comparison of fecundity from this study with an earlier assessment provides a point of difference for other studies. Pollock and Goosen (1991) recorded a fecundity of 300 eggs per gramme of body weight as a general mean from different islands and sizes. In this study, estimated egg production per gramme of body weight ranged from 141 - 226 depending on the size of the parent. One possible explanation is that this study only examined eggs at the second stage of development. It is not clear from publications that the earlier study followed the same protocol.

5.4.2 Egg-size relationships

This study found that stage 2 ova had a mean diameter of 0.64 mm with a range of 0.52 - 0.75 mm. There were no significant differences between egg size from the three islands sampled. This contrasts with an earlier study where Pollock and Goosen (1991) found the mean egg diameter for *J. tristani* as 0.83 mm. Even the maximum diameter in this study (0.75 mm) was still smaller than the mean found by Pollock and Goosen. They also reported that eggs of *Jasus tristani* were some 20% larger than those of *Jasus lalandi.* Again it is not clear whether the difference with the results of this study represent evidence of a reduction of the mean size of ova from earlier years, or whether the previous study included more developed and thus larger egg sizes.

5.5 Conclusion

In conclusion this study provides the range of fecundity for the *Jasus tristani* at the four islands of Tristan, Nightingale, Inaccessible and Gough Islands. Fecundity increases in a linear manner with carapace length – so although larger lobster clearly produce more eggs than small ones, the gain in fecundity is not as great as in some lobster species where the mass-fecundity relationship is exponential.

The samples collected showed a wide range of female sizes, and egg-bearing females that were below the current minimum size limits at each island. Female lobster benefit from regulations and practices in the fishery that tend to protect them:

- the minimum size limits (66 mm CL at Inaccessible, 70 mm CL at Tristan and Nightingale and 75 mm CL at Gough) set above the size of egg-bearing lobsters (56 mm CL Inaccessible, 57 mm CL at Tristan), combined with slow growth rates after the onset of maturity, should protect females for more than one year after the inset of spawning;
- the requirement to return all berried lobster if captured is likely to reduce female mortality; and
- the practice of setting gear only during the daytime at Tristan, when berried females forage mainly at night also tends to protect females during the spawning season.

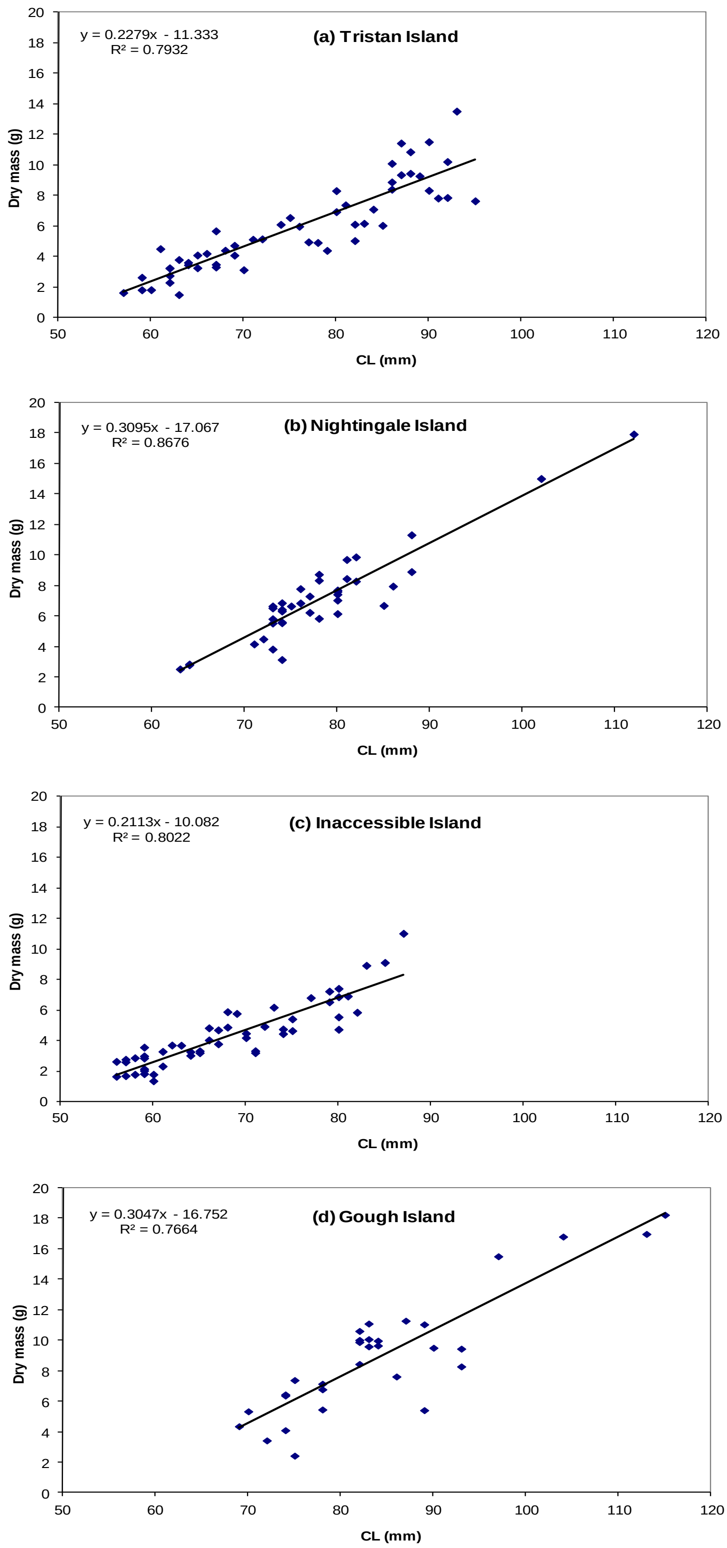
There seem to be differences in the fecundity/CL relationship between the islands, although some caution is needed in interpreting the statistical treatment of these results, and it is possible that fecundity may have been affected by other factors. Observations were consistent with lobster maturing at a smaller size at Inaccessible and Tristan, but developing greater fecundity at length for larger females at Nightingale and Gough. Linnane *et al.,* (2008) found similar difference between populations *of Jasus edwardsii* in Australia and, based on modeling, concluded that reproductive potential could be maximized by using different size limits in different areas. Recent measures in the Tristan da Cunha fishery have included reducing the MSL at Inaccessible, while increasing it at Gough, and this approach seems to be supported by these findings.

The study found no significant differences in egg size between islands, or between large and small females at one island. In finfish, greater egg size is often associated with parental size and/or condition and can be an indicator of improved survival of larvae (Buckley *et al.,* 1991). On the other hand, Melville-Smith *et al.,* (2008) found no differences in egg size among populations of the Australian western Rock Lobster *Panulirus cygnus*, and found that only analysis of the fatty acid composition of the eggs was useful in predicting larval survival.

One point of concern coming from this study is that egg production per gramme of body weight and mean egg diameter both seem to be less than reported in an earlier study in the 1990s. While it seems likely that this is due to differences in the way in which samples were taken (with only stage 2 ova collected and measured in this study), the possibility of a decline in fecundity needs to be investigated further. In Australia Linnane *et al.*, (2010) found evidence of widespread declines of rock lobster recruitment that is apparently linked to climate change.

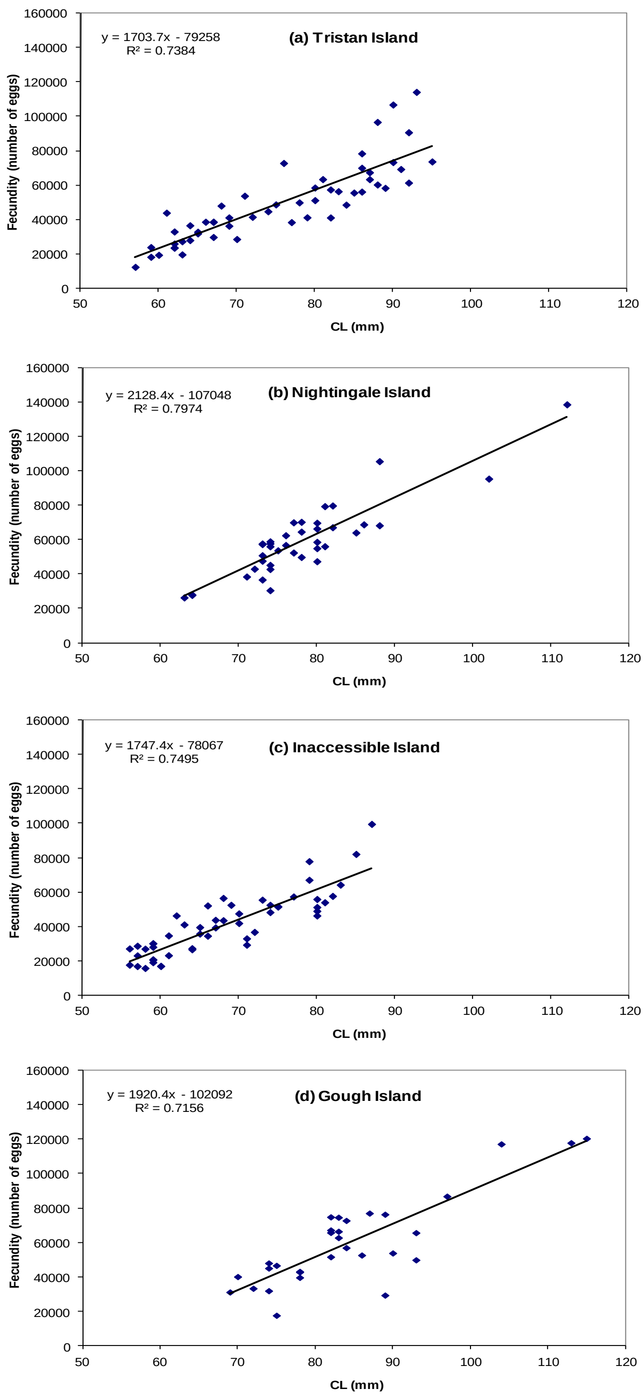
Appendix F

The relationship of *Jasus tristani* between egg mass and Carapace Length (CL) at Tristan, Nightingale, Inaccessible and Gough



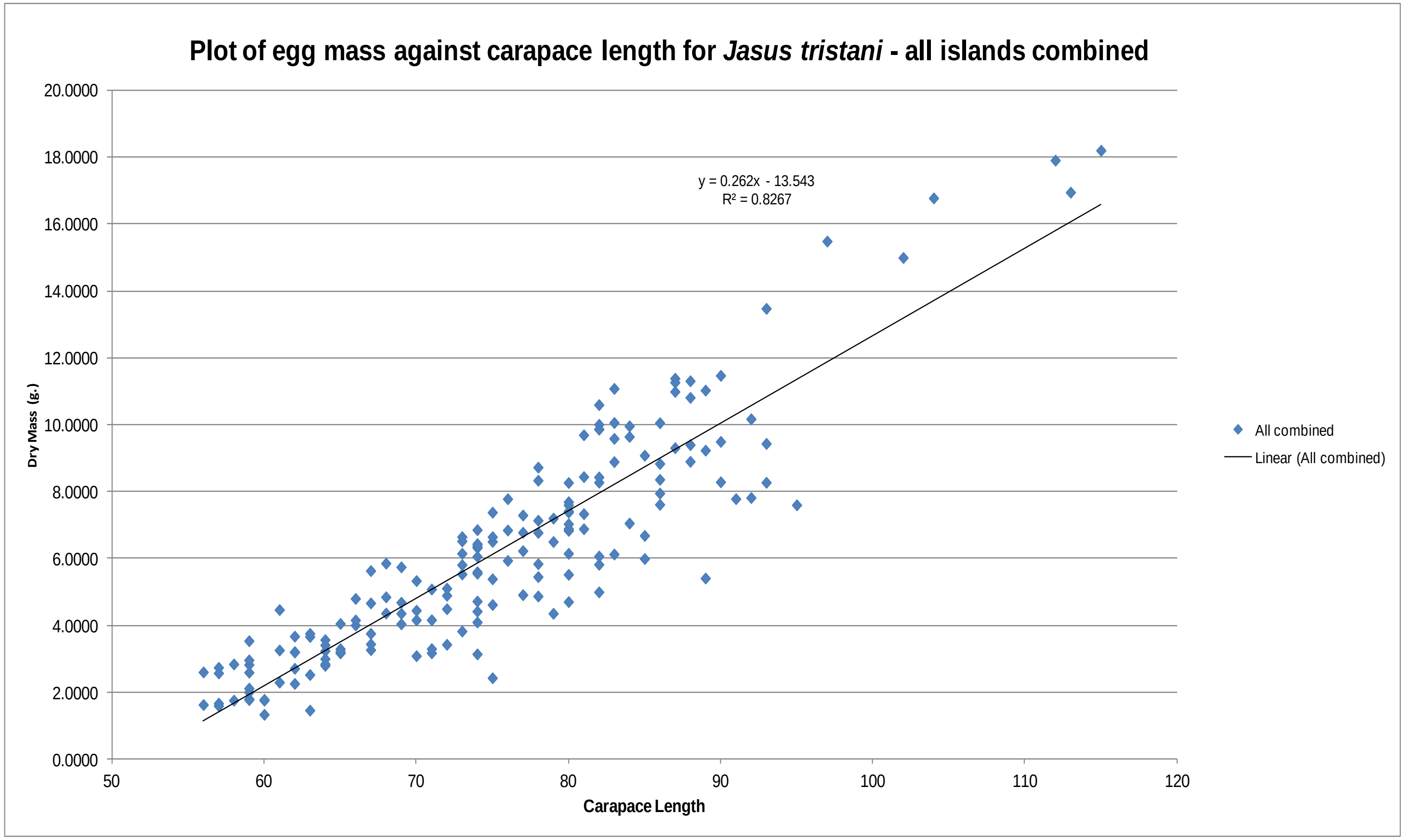
Appendix G

The relationship of *Jasus tristani* between Carapace Length (CL, mm) and the fecundity (number of eggs) at Tristan, Nightingale, Inaccessible and Gough



Appendix H

Plot of egg number against CL for lobster from all islands combined



Chapter 6

Management

6.1 Introduction

Fisheries management allows exploitation of a stock for economic and social benefit whilst maintaining its capacity to sustain future catches through sustainable recruitment into the fishery. This is achieved through controls on fishing effort; catch (in the form of total allowable catches (TAC's) allocated on an annual basis); and other regulatory conditions such as area closures, gear restrictions and size limits. To assess the state of the stock of rock lobster and develop appropriate management measures it is necessary to have a good understanding of various biological characteristics, for example growth (Pollock & Roscoe 1977; Phillips, *et. al.* 1992), recruitment, moult season (Isaacs *et al.* 2000) and reproductive cycles (Groeneveld 2005).

The main aim of this thesis was to improve the understanding of the *Jasus tristani* lobster fishery at the Tristan Island group, and to recommend management initiatives which will work towards a well-managed fishery based on the biological and population characteristics of the species,in order to maintain the resource and optimise the benefits for Tristanians. The fishery provides full or part time employment for more than half of the community, and generates the majority of the islands' revenue.

6.2 History of Management Measures

The uniqueness of the Tristan fishery is in the way it is managed, the structure as shown in Figure 6.1. For many years, the island has had an agreement with a single user, to ensure that the licensee has a strong incentive to invest in the long-term sustainability of the resource. The Tristan islanders are acutely aware that the lobster fishery is the lifeline of the island's economy. In many ways it can be seen as a pioneer of rights-based management.

Although an exclusive concession should provide adequate incentives for good management, over the years it has been supplemented by adding a minimum size (CL), seasonal closures, boat and trap restrictions, a ban on taking egg-bearing females and catch quotas.

Fishing started in 1949 although it was not until freezer shipments to South Africa in the late 60's and the introduction of steel traps on longlines in 1974 that commercial exploitation began in earnest. Declines in the CPUE and size composition led to the introduction of a size limit (70mm in 1983). Catches continued to decline and, following an independent analysis of the stock status TAC's were introduced in 1991. The previous concession holder contested the right of the Government to impose TACs and subsequently lost the concession when it was put up for tender, at the end of 1996. At that time new restrictions were written into the agreement and enforced, and as a result the fishery started its recovery.

6.2.1 TAC/TAE

The most important management measure for the Tristan Fishery has been the imposition of TACs for each island, introduced in 1991. The TACs are reviewed annually after analyses carried out by the staff of the Tristan Fisheries Department and MARAM, who take into account a variety of factors, such as the trends in CPUE at each island, size composition, influence of the weather on the previous year's catches (accessibility to the entrance of the harbour) and the performance of the fishermen in each area, and fishing days lost to discharging cargo. Despite not being recognised as ideal fisheries management, because a statistical package was not used, the fishery turned around from a declining fishery, to steady increases in CPUE between 1996 and 2006.

Since 2004 all data collected during the previous season is passed to MARAM for stock assessment modelling, which in return makes a number of TAC recommendations, previously based on an estimate of the replacement yield for each island (Johnston & Butterworth 2009). The recommendations are then submitted to the Director of Fisheries, who formally presents a suggested TAC to the Island Council, where it is debated and the following seasons TAC is approved by the Island Administrator and Council (Glass, 2009).

The Fisheries Department has always taken a precautionary approach, because the fishery accounts for 80% of the islands revenue and employment on the island. The basic ruling has been as follows:

CPUE increases, year 1, TAC maintained

CPUE increases, year 2, TAC increased 5 tonnes

CPUE decreases, year 1, TAC frozen

CPUE decreases, year 2, TAC reduced by minimum of 5 tonnes

The Tristan da Cunha group of islands received MSC certification for the lobster fishery in June 2011 (Fishing News International July 2011, www. tristandc.com, www.tristantimes.com). The Tristan Fisheries Department and the Marine Research and Assessment Group (MARAM) are working together to produce a harvest control rule (HCR), and operation management procedure (OMP) as part of a requirement for MSC certification. An OMP has been develop for Tristan and OMP's are currently under development for Nightingale, Inaccessible and Gough Island (Johnston & Butterworth 2013). The OMP will not only be designed to ensure sustainability, but to also try and maintain the previous three years average CPUE, at that particular island (or improve it at Tristan) so that the fishery remains economically viable.

6.2.2 Gear Restrictions

At present the main gear restriction applies to the local fleet on the island of Tristan. The *M.V. Edinburgh* fishing the outer islands is limited to the amount of gear that can be hauled in a single day. As a safety measure (to prevent overloading of the small boats) the islanders have always had some self-imposed restriction on the amount of gear used in the fishery.

Prior to 1994 there were no effective regulations. In 1995 strict controls came into force: small powerboats were restricted to a maximum of 12 traps; the large powerboats were limited to 19 traps; hoop nets were not limited. Due to landings at the factory during 2009 exceeding the capacity to process the catch on a timely basis, the gear was reduced to 10 traps, and 26 hoop nets per boat. More recently (2012), following a reduction in catch rates, the local boats have been limited to 14 traps and 32 hoopnets. The boats are inspected on a regular basis by the Fisheries Department, and if found over the limit, first a written warning is given, then a penalty. The amount of gear carried per season can be changed under licence (Glass, *pers. obs*).

In 2003/04 due to an increase in CPUE and thus landings at the Tristan factory, the fishing company (Ovenstone), in conjunction with the Fisheries Department, jointly decided to reduce the number of the local powerboats boats from 20 to 9. The main reason was to restrict landings delivered to the factory to manageable levels of around 5mt per day. All thirty-six fishermen were retained but now four fishermen share a boat on a rotational basis.

There has been a reduction in the fleet of the larger vessels fishing on the outer islands. Prior to the 2003/4 season, two factory ships fished the three islands, now only one vessel the *M.V. Edinburgh* operates on a rotational basis. This is more of an economic measure taken by the company (who find that they can catch the TAC with one vessel) than as a result of management restrictions.

There is a practice of using ‘open funnel’ traps which allow lobster to escape if traps are not hauled for some time or are lost. Personal observation has shown that traps left down after the bait has been finished soon empty of lobsters. Similarly Groeneveld *et al.* (2005) observed that the *Jasus lalandi* have a high rate of escapement from open funnel traps. Plastic traps are not permitted in the fishery, due to their prolonged survival if lost. There is thus little risk of ‘ghost fishing’ by lost traps.

6.2.3 Closed Season

Since the new concession holders took over the lobster fishery in 1997, a closed season has been introduced, which originally covered June and July (the time at which the largest catches of berried females are made). This decision was made by the Fisheries Department as the requirement to release berried lobsters is a notoriously difficult measure to enforce, and there have been various, mainly anonymous reports, of scrubbing berry and the clipping off of the pleopods on female lobster by the previous concession holder. In addition to this there was an informal agreement between Ovenstones and the island, that fishing for the large vessel *M.V. Edinburgh* would not start before August 20th, effectively extending the closed season from 2 to 3 months. Since the 2012/13 season the closed season has been fixed under licence from 1st June – 25th August. Both the *M.V. Edinburgh* and her powerboats leave gear down overnight. This is the time at which berried females are more active, so delaying the start of fishing by the large vessel reduces the number of berried animals caught.

While the closing of the season is a worthwhile measure, the absence of licensed vessels on the grounds, may make the Tristan da Cunha group a target for poaching at this time of year.

6.2.4 Minimum Legal Size (MLS)

Prior to 1983 there was no MLS at Tristan. A MLS of 70mm was implemented at all four islands as from July 1983.

The size at maturity appeared to vary between the four islands (Roscoe, 1979; Pollock, 1991) and it was decided by the Tristan authorities to have one size limit of 70 mm carapace length, so that lobster caught from a particular island could not be recorded as coming from another. All discarded rock lobster must be returned to the sea as soon as practicable and as close as possible to the place where caught.

In recent years, due to good compliance with the licence conditions by the present company (Ovenstones), and an increase in observer coverage on the vessel, the Tristan Fisheries Department adjusted the MLS at the start of the 2003/04 season in August 2003 to the following:

Gough Island increased from 70 mm to 75 mm

Inaccessible Island reduced from 70 mm to 68 mm.

The MLS at Nightingale and Tristan remained unchanged at 70 mm.

The decision to change the MLS between islands (Inaccessible and Gough), was a result of monitoring undersize throwbacks in relation to the catch. At Inaccessible as much as 45% of the catch was being discarded as undersized, whereas at Gough just over 1% below the MLS was being discarded. At Inaccessible both Roscoe (1979) and Pollock (1981, 1991) have reported on the high densities of juvenile lobster, reducing growth and as a result causing stunted growth. On that basis, lobsters of a given age are smaller, and median size at maturity is smaller than the other islands (Pollock 1991, James *per obs*). Thus a lower size limit at Inaccessible, where the lobster mature at a smaller size, seemed justified.

In South Africa the MLS for *Jasus lalandii*, was also reduced (from 89 to 75 mm CL) because of a reduction in lobster growth rates in the late 1980's and early 1990's and research that suggested the high discard rate was resulting in serious impacts on the stock (Barkai *et al.,* 1996). Without this reduction in MLS, the South African fishery would not be in the situation it currently is (Holloway, S., *per comms*).

The Monitoring, Control and Surveillance of the fishery is the responsibility of the Fisheries Department, with five fulltime staff and five part-time Sea Fishery Officers (SFO).

6.3 Current issues and implications of this study

Many years of study and experience of the Tristan lobster resource have led to the development of management arrangements that have been recognised by the Marine Stewardship Council as a model of sustainable fisheries management. The key elements of management have been the conservative application of limits on annual catches (TAC) which are closely monitored; an exclusive concession, which has tended to reduce fishing effort towards an economic optimum in recent years; a size limit that protects several year classes of sexually mature females; and the avoidance of significant catches of females in berry.

The study of length-weight relationships has shown that the conversion factor used to estimate whole weight from tail weight – while not perfect for lobsters of all sizes and both sexes – provide a generally good working estimate for management purposes. To maintain consistency with historical data and to avoid the need to retrospective conversion, it is not recommended that this is changed. It has also been shown that identifying undersized lobsters from tail width is unlikely to be reliable; but given that current marketing arrangements favour tailing of the larger size classes and the familiarity of the fishermen with the current method of measuring carapace length, there would again seem to be little reason to change.

The study has confirmed previous observations that the mean size of lobsters at the different islands differs, and in particular that lobsters at Inaccessible Island tend to be smaller, while those at Gough tend to be larger. Given the high rate of discards of undersized lobster at Inaccessible (some of which will not survive); the fact that a smaller MSL will still protect immature females; and the increased presence of Sea Fisheries Officers to monitor catches and verify that the size limits at each island are being observed, the reduction of the MSL at Inaccessible Island seems reasonable.

Some findings from this study give cause for concern, however. The CPUE at the three northern islands has declined since 1996, especially at Tristan and Inaccessible Island. The average size has also shown a decline in recent years and both the number and size of eggs carried by female lobsters appears to be lower than reported in previous studies, although additional work is required to determine if this is true for all egg stages. A decline in CPUE must always be taken seriously, as it impacts on the profitability of the fishery, even if some authorities question its value as a measure of stock abundance (Ye & Dennis, 2009). Taken together, these changes could imply some reduction in the productivity of the lobster stock, perhaps due to long-term oceanographic changes or cycles or fisheries impacts.

Finally, Tristan da Cunha, like other small island territories of the UK, is being encouraged to establish marine protected areas. It is often claimed that such areas can enhance fisheries, by protecting large adults which contribute to recruitment.

6.4 Conclusions and Recommendations

The Tristan Government has always had the opinion that if the islands were to enter into a long-term exclusive concession, that it would result in the optimal management of the fishery resource, giving the concession holder the opportunity to maximise financial benefits by adjusting fishing performance, so as to yield the best balance between catches and operating costs.

Prior to 1997 the fishery had fallen to its lowest level since commercial fishing began in 1949, despite receiving regular advice from fishery scientists.

Most of the recommendations and estimates of sustainable yields have been shown to be over-optimistic, and targets were rarely reached. This is evident where TACs did not show any improvement in the CPUE.

Since 1997, the new concession holders have co-operated fully with efforts to rebuild stocks, and there has been improvements at all the islands since 1997. The stocks responded by an increase of CPUE, where there has been a reduction in fishing effort, and stocks of *J. tristani* are in a much healthier state than those of many other commercially important crustacean fisheries. However declines in CPUE at the northern islands since 2006 will need to be carefully monitored and TAC's reduced if this continues.

The final decision on the setting of TAC's at the Tristan group must always remain the responsibility of the Tristan da Cunha Government, as the livelihoods of the Tristanians depend on the revenue generated from it, for future generations.

A Draft Research Plan is currently in place (Appendix I) to be further developed for Tristan da Cunha Fisheries Department (TDCFD) in conjunction with an international fishery scientist.

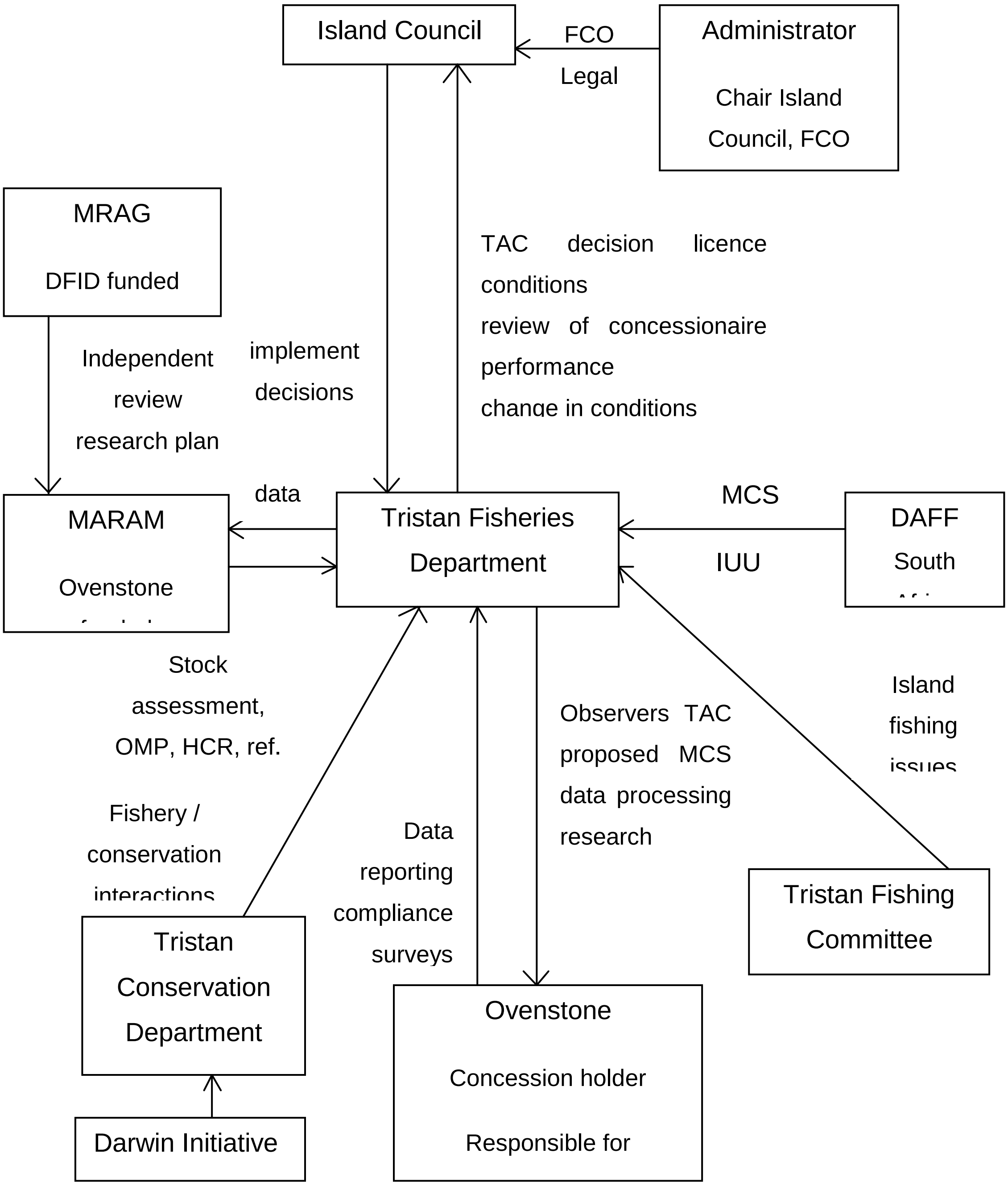


Fig 6.1: The structure of the Tristan fishery and the way it is managed.

Appendix I

<u>Tristan lobster fishery research plan</u>

Research conducted and Data Collected

<u>Fisheries- independent surveys:</u> Annual biomass surveys are carried out from the *M.V. Edinburgh* at each island. These surveys are carried out twice per season, fishing 4 transects at Nightingale, 5 transects at Inaccessible and 8 transects at each of Gough and Tristan with each round of fishing. The *M.V. Edinburgh* sets 9 small mesh (50mm) traps per line at selected depths along transects perpendicular to the coast at each island. The catch rate information resulting from these transects will shortly be incorporated into assessments as an additional index of abundance, as well as the size distribution of the catches which, because of the smaller lobsters taken by the small-meshed traps will also give an improved indication of incoming recruitment. At a later stage, the planned Management Procedure for the resource may be refined to include these data as well as CPUE as indices of abundance.

<u>Catch monitoring:</u> Commercial CPUE is constantly monitored and all catch and effort data are submitted to MARAM for GLM standardisation before input to assessment models. Future work will attempt stratification at a smaller spatial scale. Approximately 5000 random samples are collected at each island every season to monitor sex ratios and size at maturity with the aim of improving the biological information base on which management is based. These data also provide size composition data which are used as input to the assessment model. In combination these data also provide information on the volume and size composition of discards, which is also taken into account in the assessment model.

<u>Tagging:</u> As part of the remedial action to manage the impact of the *M.V. Oliva* casualty, a tagging program was implemented at Nightingale, Inaccessible and Tristan in January 2012 (Tagging report 2012/13 season), and tagging will continue during the 2013/14 season. The objective is to collect growth data (currently limited) which will improve the age structured assessment model presently being refined by MARAM. It is the intention to conduct further tagging on a regular basis at all islands in the future. Over time this information will also be input to the assessment model as the recaptures will provide independent information on the magnitude of fishing mortality.

Test Fishing: Following the grounding of the *M.V. Oliva* on 16 March 2011 and the subsequent closure of fishing at Nightingale a series of test fishing has been carried out at Nightingale during the 2012/2013 season. At the November (2012) workshop it was agreed that a period of 5 days commercial fishing should take place to test catch rates, compared with catches from the survey and test fishing. This took place and catches were the highest on record (1997 – 2013) for Ovenstones.

It was decided that a ceiling on the total catch at Nightingale for the 2012/13 season, was to be set at 40 mt, and after all fishing and surveys were completed the *M.V. Edinburgh* had landed 40,435kgs. Given that catches were excellent, the Fisheries Department consider it is safe to reopen the fishery at Nightingale, but to adopt a precautionary approach when deciding what the TAC should be. The same should apply to Inaccessible.

Juvenile lobster assessment program:

Independent juvenile count studies were carried out at Nightingale in January (Juvenile Report 2013), and it is the intention to carry on for another year. The biologist (Darwin Project) station on the island in consultation with the Fisheries Department will determine the viability of such surveys and establish whether a continued juvenile survey program should be carried out to obtain a better understanding of juvenile abundance and trends at these islands both in terms of measuring the impact of the *M.V. Oliva* on the larval and juvenile life stages at Nightingale and Inaccessible, and providing insight into the longer term recruitment dynamics in this fishery. If the results are positive it will be incorporated into the Marine Management Plan. No experimental trap fishing with smaller mesh <50 were carried out, this year.

Data collection ETP species:

The Tristan Fisheries Department participates in the ACAP process, including on-going collection of data on seabirds and seabird interactions with the fishery (Paper -Seabird night strikes and mortality in the Tristan rock lobster fishery, 2010/11-2012/13)

Objectives

To continue to collect fisheries dependent and independent data for incorporation into the age structured assessment model.

To review and revise target and limit reference points based on on-going scientific assessment and management procedure analyses.

To review the Tristan Lobster management system and the scientific work and resource management advice provided by MARAM, based on recommendations from MRAG's review of this work.

To formulate a Strategic Development Plan approved by the Island Council that recognises the need for a long term strategy for the management of the lobster resource (to be effected through the development and implementation of Management Procedures) to ensure that optimal social and economic benefits continue to be derived from the fishery.

To implement new electronic fishing logbooks at the start of the 2013-2014 season, also to remain with the printed logbooks until further notice.

Research Priorities

Research priorities have been set based upon an analysis of data requirements to fill gaps in the knowledge and management of the fishery. However, given the results of the test fishing at Nightingale the impacts of the *M.V. Oliva* is not as critical as previously thought, but should still be monitored. Key areas that have been identified are:

The casualty on the larval and juvenile life stages at Nightingale and Inaccessible;

The impact of the Oliva casualty on the adult population at Nightingale;

Tagging and Data collection by way of a biological sampling program to improve lobster growth rate assessment, a key input function for the resource modelling work;

Data collection to improve knowledge of larval settlement and juvenile recruitment.

Based on the above, the research priorities are set out below:

To cease test fishing, and resume commercial fishing operations at Nightingale with caution;

To assess the feasibility of conducting regular juvenile surveys at Nightingale, Inaccessible and Tristan and the usefulness of the data collected, (Darwin Marine Project);

To conduct further tagging at Nightingale, Gough and Tristan for the 2013/14 season;

To develop and implement appropriate Management Procedure for Tristan, this season in consultation with stakeholders with the objective of maintaining the Tristan Lobster stocks close to the agreed target reference points, agreed by the Tristan Island Council and other stakeholders.

The program for the implementation of the first OMP's for each of the 4 Islands in the Tristan fishery is:

2013/14 season	Tristan
2014/15 season	Inaccessible, Gough
2015/16 season (latest)	Nightingale

The delay in the implementation of the Nightingale OMP is due to the assessment of the impacts of the *M.V. Oliva* casualty.

The Biomass Surveys data will be included in the assessment models and OMPs from the 2014/15 season.

A Recruitment Index based on the analysis of the catch length data from the Biomass Surveys will be considered for inclusion in the models from the 2014/15 season.

Updated somatic growth data from the Tagging Program will be incorporated into the models and OMPs as it become usefully available.

To continue with work related to the monitoring of the stock.

Future research/monitoring by the Fisheries Department may become easier, as the Fisheries Department has just learnt that they have been successful in a Darwin Marine bid (Sustainable management of the marine environment and resources of Tristan da Cunha) that will run over two years. Having a biologist resident on Tristan is going to help training of islanders in species recognition, dive surveys and monitoring techniques, so building capacity to be better able to respond to any future events which may threaten the marine environment.

Chapter 7

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