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**THE FISHES OF TRISTAN DA CUNHA AND GOUGH ISLAND (SOUTH
ATLANTIC), AND THE EFFECTS OF ENVIRONMENTAL SEASONALITY ON
THE BIOLOGY OF SELECTED SPECIES**

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**by
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ABSTRACT

This study focuses on the taxonomy, biogeography and biological aspects of the fishes of Tristan da Cunha and Gough Island in the central South Atlantic Ocean.

Oceanographic measurements were undertaken to determine the position and nature of the Subtropical Convergence (STC) in the vicinity of the islands. The Tristan da Cunha group is thought to be situated on the northern edge of the STC while Gough Island is situated on the southern edge of the front. The seasonal environmental cycle at the islands is characterised by an annual sea surface temperature fluctuation of approximately 5 °C and an annual change in stratification of the water column. It is suggested that this increase in stratification at the STC, brought about in the summer by insolation warming the surface layers of the ocean, enhances primary production. The STC is identified as a unique habitat for fishes and as an important barrier to dispersal of species in the Southern Ocean.

The present study has produced 18 new distributional records from the shelf waters of Tristan da Cunha and Gough Island. The fish fauna known from the shelf waters of these islands is reviewed, and a diagnosis, synonymy, and in some cases an illustration are provided. For certain species, brief notes on their biology, relative abundance and seasonal distribution are included. An analysis of the ichthyofaunal relationships between shallow water areas in the vicinity of the STC has resulted in the identification of a characteristic neritic STC ichthyofauna. The circumglobal distribution of many of these species is thought to be a consequence of a dispersive pelagic phase in their life-cycles.

Biological processes in fishes at these islands are temporally and spatially affected by seasonal changes in oceanographic conditions. Seasonal sea temperature variation was identified as being an indicator of other oceanographic phenomena that may affect processes such as growth, reproduction and feeding in fishes at the islands. Most species have a summer spawning season and growth rate increased during the summer months. It was hypothesised that enhanced primary production and a related increase in food quality and availability during the summer were the major factors temporally regulating the growth and reproduction of fishes at the islands.

Twenty families of neritic fishes have been recorded in the shelf waters of Tristan da Cunha and Gough Island. Most families are represented by only one species. Because of this a wide range of life-history strategies are apparent in the fauna. Nevertheless, there are a number of common life-history characteristics shared by most of the neritic species. Firstly, the early life-history of many species included an extended pelagic phase which might have facilitated colonisation throughout the STC zone in the past, thereby regulating extant species diversity in this region. Secondly, the common occurrence of an extended summer breeding season and iteroparity suggested that these characters also contributed to survival in what is considered to be an unpredictable environment. It would appear that these common characteristics hold the key to the success of many fishes in the STC zone.

This study has contributed to our understanding of oceanic island ecosystems and has revealed distributional patterns of fishes that were unknown previously. By focusing on the biological processes of selected species the regulatory role played by local environmental conditions became apparent. The results of this study are also relevant to proposed conservation measures for Tristan da Cunha and Gough Island.

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CHAPTER 1 - GENERAL INTRODUCTION

"In every living being there are two powers, between which a silent but incessant battle is being carried on - life, which builds up, and death, which pulls asunder. At first, life is all powerful - it lords it over matter; but its reign is limited. Beyond a certain point its physical vigour becomes gradually impaired; with old age it feebly struggles; and it is finally extinguished with time, when the chemical and physical laws seize upon it, and its organisation is destroyed. But in turn the very elements, though inert at first, are soon reanimated and occupied with new life. Every plant, every animal is bound up with the past, and is part of the future, for every generation which starts into life is only the corollary upon that which expires, and the prelude of another which is about to be born. Life is the school of death; death is the foster-mother of life" (Louis Figuier, 1891).

Tristan da Cunha consists of the three relatively small volcanic islands of Tristan, Inaccessible and Nightingale. Gough Island lies about 200 nautical miles south of the Tristan da Cunha group (see Chap. 2). These islands are all situated on the mid-Atlantic Ridge in the South Atlantic Ocean and are extremely isolated from other areas of shallow water. Bouvet Island is closest, situated some 1110 nautical miles to the south of Tristan while South Africa and South America are about 1660 and 1830 nautical miles distant respectively. St Helena Island lies approximately 1370 nautical miles to the north of Tristan da Cunha. Tristan Island is acknowledged to be the most isolated permanently inhabited locality on the globe (McWhirter, 1986).

The islands are a dependency of St Helena, itself a United Kingdom Dependent Territory. Only the largest island of Tristan is permanently inhabited. The community of about 300 people all live in the village of Edinburgh on the northwestern coastal plain of the island. Corporal William Glass, regarded as the founder of the present community, came to the island in 1816 with his wife and family as part of a British garrison sent from the Cape to ensure that Napoleon did not escape from St Helena via Tristan. Glass remained behind when the garrison left in 1817. A small farming community developed, initially under the leadership of Corporal Glass. The community was supplemented by whalers, sailors and ship-wrecked folk from many

nations during the last century and the first half of the 20th century. Today, only eight family names remain (Crawford, 1982).

Although initially neglected by the British authorities, a priest and various government officials have been present on Tristan since the Second World War. Prior to this, priests were present periodically, and the British had a naval station there during the Second World War. Until 1961 Tristan was known to few outsiders. In that year a volcanic eruption occurred on the outskirts of the village and the islanders were evacuated to England. Most returned in 1963. Since then British involvement increased, with a number of expatriate officials taking up residence on the island (Crawford, 1982). During the 1980s the number of expatriates decreased and at present only an administrator, a medical doctor and a priest remain.

Before the 1940s the islanders survived almost exclusively from subsistence activities and occasional trading with passing ships. Since 1948 a lucrative rock lobster fishery has formed the basis of Tristan's cash economy. A single company (South Atlantic Islands Development Corporation) has held the concession to fish the shelf areas around the islands for rock lobster. It owns and maintains a processing plant and fleet of small powerboats which are used by islanders employed by the company to fish for lobster in the shelf waters of Tristan Island. The island women are employed to process the catch. In addition the company operates two ships around Nightingale, Inaccessible and Gough Islands. These are based in Cape Town and are used to transport their own catches and those of the islanders to the outside world. These ships, together with the **RMS ST HELENA** and **MV S.A. AGULHAS**, run cargo and passengers to and from Tristan.

Subsistence activities still play a major role in the lives of the islanders. Today, exploitation of natural animal resources is restricted to certain species of seabirds and their products, rock lobster and fish, with all marine mammals and most seabirds protected by ordinance (Cooper, *et al.*, in prep.). Only the Great Shearwater, *Puffinus gravis* and the Rockhopper Penguin, *Eudyptes chrysocome moseleyi* are exploited in any significant quantities; the former for its fat, meat, feathers and guano, and the latter for its eggs, feathers and guano. Exploitation is restricted almost entirely to Nightingale Island during the summer when islanders sail to the island in traditional longboats. The present level of exploitation on Nightingale Island is not considered to be a threat to the populations of these two seabird species (Cooper, *et al.*, in

prep.).

The islanders depend on the fish resource to a large extent for food and as bait for the local rock lobster industry. A detailed description of the history of exploitation of marine resources at the islands is presented in Chapter 7. The insular nature of the island ecosystem would theoretically render the stocks vulnerable to over-exploitation by commercial fishing operations. Most of the fish species are bound to the islands for the completion of their life-cycle; hence, the populations are more or less isolated and not supplemented by recruits from outside of the immediate island ecosystem. At present, only the palinurid lobster, *Jasus tristani*, is commercially exploited. The catch per unit of effort (CPUE) for this species has decreased considerably since exploitation began in 1948, from approximately 510 kg/boat-day in 1971 to approximately 300 kg/boat-day in 1976 (Roscoe, 1979). If this industry were to collapse, there would be a strong incentive to exploit the fish stocks commercially.

Because most of the commercially desirable fish species are bound to the limited shelf areas of the islands in the adult stage there is a great danger of exploiting the fish stocks to commercial extinction, unless suitable management strategies are implemented timeously. Case histories of the commercial exploitation of small or closed stocks have been widely reported in the literature. For example, the commercial fishery for soupfin shark in California collapsed after only eight years through over-exploitation. The CPUE for this fishery decreased from 55 sharks caught in gill nets in 20 hours in 1937 to only 2 sharks caught with the same effort in 1944 (Ripley, 1946). On the east coast of South Africa breeding aggregations of the seventyfour, *Polysteganus undulosus*, were targeted in the commercial linefishery during the 1950s and 1960s. By the 1970s the stock had collapsed. Only 3.5 tonnes were harvested in 1985 in comparison to 1550 tonnes in 1910 (Penney *et al.*, 1989).

On a larger scale, fisheries for pelagic species have collapsed when fishing effort has exceeded the capacity of the stock to ensure sustainable recruitment. Examples of this include the collapse of the Namibian pilchard fishery in the 1960s (Armstrong *et al.*, 1991) and the Peruvian anchovy fishery which collapsed in 1972 (Idyll, 1973). As part of the overall aim of the present study it was deemed essential to obtain some understanding of the composition and the dynamics of the fish fauna of the islands before any commercial exploitation commenced.

Tristan da Cunha and Gough Island have for a long time been of interest to naturalists and social scientists. The interest of naturalists has been stimulated by the comparative youth and geographic isolation of the islands which has invoked classical evolutionary and biogeographic questions, while social scientists have been fascinated by the traditions and culture of the community. At least eight volumes have been published about community life on Tristan (eg. Rogers, 1926; Gane, 1932; Watts, 1936; Crawford, 1982).

Studies on the natural history of the islands have considered many aspects although few have been more than baseline investigations. Carmichael (1819) made notes on various terrestrial and marine species during a brief voyage to the area. Impressive collections and observations were made by the Norwegian expedition to the islands in 1937/38 when a wide range of both terrestrial and marine plants and animals, including fish, were studied. Seabirds have probably been the most comprehensively studied group (Hagan, 1952; Collar & Stuart, 1985; Fraser *et al.*, 1988; Klages *et al.*, 1988; Ryan *et al.*, 1989, 1990; Cooper *et al.*, 1990; Ryan & Maloney, 1991a, 1991b; Ryan, 1992). Although most of these studies have addressed the taxonomy and general biology of the birds of Tristan da Cunha and Gough Island, Ryan (1992) has researched morphological variation in *Nesospiza* buntings at different islands of the Tristan Group. The phenomenon of intraspecific morphological variation in a fish species at different islands is considered in the present study (see Chap. 4).

Additional studies have been undertaken on the population trends of seals at Gough Island (Bester, 1990), the littoral ecology of Gough Island (Chamberlain *et al.*, 1985), algal diversity (Chamberlain, 1965; Scott, 1990), rock lobster population dynamics and biology (Roscoe, 1979; Pollock, 1981) and fish distribution, taxonomy and biology (Penrith, 1967; Krefft, 1974, 1978; Hulley, 1981). Although a wide range of basic studies have been undertaken at the islands the very isolation that has created interest has inhibited detailed studies of the indigenous fauna and flora. The neritic fish fauna of the islands was particularly poorly studied and understood.

Tristan da Cunha and Gough Island are situated in an interesting and poorly understood frontal region, the Subtropical Convergence Zone (STC). The STC was reported to be in close proximity to the islands (Knox, 1960; Miller, 1982; Whitworth & Nowlin, 1987), but data on the nature of the STC in the mid-Atlantic were scarce (Lutjeharms & Valentine, in press). The surface expression of the STC represents the boundary between Subtropical Surface Water of

the subtropical gyres of the southern hemisphere and Subantarctic Surface Water of the Southern Ocean to the south (Lutjeharms & Valentine, in press). The STC is the northernmost of the three major frontal systems in the Southern Ocean. The other two fronts, the Subantarctic Front and the Antarctic Polar Front, as well as the STC are characterised by rapid latitudinal changes in surface water temperatures and salinities (Lutjeharms, 1985; Whitworth & Nowlin, 1987) and have been identified as having major effects on the distribution of fauna and flora (Lutjeharms, 1987). Abrams (1985) reported that the distribution of seabirds in the Southern Ocean was affected by the STC. Seasonal changes in the structure (Lutjeharms & McQuaid, 1986), and a related increase in primary productivity expressed by peaks in phytoplankton concentrations (Allanson *et al.*, 1981) have been found to occur at the front south of Africa. Allanson *et al.* (1981) suggested that an increase in stratification in the water column during the summer, caused by insolation heating the surface layers of the ocean, was responsible for the seasonally increased primary production. Increased primary and secondary production has been noted in the vicinity of other fronts by Pingree *et al.* (1975), Fournier *et al.* (1979), Olson & Backus (1985) and Marra *et al.* (1990), amongst others. Harris *et al.* (1988) reported that different species of the rock lobster genus, *Jasus*, occur north and south of the STC off southern Australia, New Zealand and Tasmania. The effects of the STC on the distribution and biology of neritic fishes has been neglected although certain oceanic species have been noted to be associated with the front (Gibbs, 1968; Krefft, 1974, 1978; Backus *et al.*, 1977; Hulley, 1981; McGinnis, 1982; Backus, 1986). Harris *et al.* (1988) found that catches of southern bluefin tuna off Tasmania were correlated to annual temperature changes close to the STC.

Ever since Darwin's (1859) novel discoveries on isolated islands such as the Galapagos and Hawaii, the implications of isolation for the evolution of species has become increasingly apparent. The 14 species of finch recorded from the Galapagos Islands (Lack, 1947) can be regarded as evidence of speciation through geographic isolation. It is generally accepted (Ribbink, 1986; Greenwood, 1991) that allopatric speciation has resulted in the estimated 800 cichlid fish species in the East African Great Lakes through geographic isolation of populations. Isolating mechanisms in the Great Lakes were thought to include amongst other phenomena, past changes in water level, micro-habitat dependence and isolation by water depth (Ribbink, 1986). It has also been suggested that stenotypic fishes have poor dispersal capabilities which is conducive to ecological specialisation and to speciation of allopatric populations (Ribbink, 1986; 1988). Another classical example of speciation through geographic isolation is

demonstrated in the desert pupfishes of North America. Isolated populations have evolved into what are considered to be four different species. The wet sites in which these fish live can be regarded as evolutionary "islands" which are separated from each other by unfavourable terrain (Cox & Moore, 1980).

Given the recognised role that the isolation of populations has on the evolution of species it was deemed important to determine the extent to which the resident fishes at Tristan da Cunha and Gough Island were isolated from other areas of shallow water in the Southern Ocean. The similarity of the known ichthyofauna at these islands and the New Amsterdam Islands in the Indian Ocean was noted previously (Sivertsen, 1945; Penrith, 1967; Hureau, 1969; Angot, 1951; Duhamel, 1984; 1989; Collette & Parin, 1991). Although these authors have acknowledged that dispersal between the islands in the two oceans could have resulted in faunal similarities, the absence of information on the dispersal capabilities of many of the species has limited their analyses.

The low level of endemism at all the islands in the STC region (Sivertsen, 1945; Penrith 1967; Duhamel, 1989) and the similarities in the ichthyofauna at island groups in the Atlantic and Indian Oceans suggested that resident species may have complex mechanisms enabling dispersal between distant points. To determine the nature of these mechanisms it was necessary to gain an understanding of the long distance dispersal capabilities of species. This entailed investigating the biological peculiarities of a species and ascertaining if these, in conjunction with physical dispersal agents such as currents, allowed the dispersal of the species from one place to another during some stage of its ontogeny.

The importance of eggs, larvae and juveniles (pelagic phases) to the dispersal of fishes has been emphasised. Leis (1991), who worked on coral reef fishes suggested that the pelagic phases are likely to determine the geographical size of population units because adults are relatively sedentary. Sinclair (1988) emphasised the importance of currents and dispersal adaptations of species in regulating the population richness of a species. Both these authors acknowledged that the retention or dispersal of propagules was determined by a combination of life-history strategy and physical oceanographic processes.

Movement of propagules into the pelagia may have implications for genetic mixing, predator

avoidance and food accessibility. Genetic mixing could occur by pelagic stages of different populations settling and reproducing at sites other than their source area. Although this is difficult to prove conclusively, tagging experiments have shown extensive mixing of juveniles from different herring populations in the Gulf of Maine (Sinclair, 1988). Predators may be avoided by spending part of the life-cycle in the pelagic zone. Although the life of larval fishes has been characterised as "precarious" the mortality suffered by the pelagic phase must be outweighed by the advantages of including a pelagic phase in the life-history (Leis, 1991). The avoidance of predators by existing in the pelagic zone could be particularly important to species exhibiting pelagic juvenile stages that are active and able to avoid predation in the pelagic more successfully than on densely populated reef areas. Food availability may also be enhanced by entering the pelagic habitat during the early stages of the life-cycle to optimise on planktonic organisms (Sinclair, 1988). It is probable that the small size of larvae may necessitate a pelagic existence in order to procure food that is small enough to ingest. Leis (1991) stated that all the taxa of Indo-Pacific shore-fishes on which dietary information was available fed on zooplankton which were more abundant in the pelagia than on reefs. A pelagic phase might be of greater importance to populations that occur in habitats in which space is limiting such as the shelf areas of small oceanic islands. A pelagic phase allows additional resources to be utilised by the population and may reduce intraspecific competition for these resources in the source areas.

In the light of the above it is apparent that the geographic position of the Tristan da Cunha Group and Gough Island presented a unique opportunity to study a fish community at an isolated locality. Also, by comparing the level of similarity and endemism of the neritic fish fauna at these islands with those at other islands and seamounts in the temperate waters of the southern hemisphere it was theoretically possible to obtain an understanding as to the degree that the populations of fishes at these islands were isolated from one another. The geographic locality of the islands also allowed investigation of the life-history strategies that have evolved in the ichthyofauna to ensure survival in conditions close to the STC. In addition the islands provided a land-base from which the dynamics of the STC could be studied throughout the year in a region where very few physical and chemical measurements of the front had been undertaken.

To address some of the issues raised above the following broad objectives were identified for

this study:

- a) To examine the structure and dynamics of the Subtropical Convergence in the Tristan da Cunha and Gough Island region.
- b) To re-assess the fish fauna of the islands and to determine if the distribution of species was affected by prevailing oceanographic conditions.
- c) To investigate aspects of the biology of key species in order to determine to what extent biological processes have been adapted to local environmental conditions in general, and to environmental seasonality in particular.
- d) To assess the fishery at Tristan Island in order to obtain an understanding of the seasonal dynamics in fish population and community structure, and to propose recommendations for the future rational exploitation of the resource.

Eighteen months were spent on Tristan da Cunha (October 1988 to April 1990) in order to obtain the information necessary to address these objectives. Although the time in the field was limited it was believed that the above objectives could be at least partially met. It should be stressed that a long term study would be necessary to gain a full understanding of oceanographic and biological processes at the islands.

Environmental attributes of the islands and the region as a whole were examined first to enable biological processes to be placed in perspective. The oceanography of the region was considered particularly important in influencing the biology and ecology of the fishes of the islands. It was hypothesised that the STC has pronounced effects on the fishes of the region. A detailed study of this frontal zone was therefore undertaken; the results of which are described in Chapter 2. Information from this chapter was used in subsequent chapters, in which it will become apparent that the STC does indeed influence many aspects of fish ecology at the islands.

Chapter 3 examines the diversity of fish species in the shelf waters of Tristan da Cunha and Gough Island. Prior to this investigation the neritic fish fauna was poorly known, necessitating the collection of fishes from different habitats using a variety of collecting methods. The taxonomic status of individual species is addressed and notes on the biology of those species are presented where possible. The biogeography of the neritic fishes of the STC region on a

global scale is examined and suggestions concerning the dispersal of these species are presented.

Certain species were chosen for intensive study to determine the effects of the environment on biological processes in the fish community at the islands. It was decided to undertake a detailed investigation of the biology of the fivefinger, *Acantholatris monodactylus* (Family Cheilodactylidae) in an attempt to discover how aspects of its biology were adapted to local environmental conditions. It was hoped that an understanding of the biology of this species would shed light on the effects of the environment on biological processes in the community as a whole.

A. monodactylus was chosen for detailed study for a number of reasons. Firstly, it was an extremely successful species as manifested by its abundance in the shelf waters of all the islands. Also, the fivefinger only occurred in or near the STC in the Southern Ocean which suggested that it may display a life-history strategy specifically adapted for conditions present at Tristan da Cunha and Gough Island. Secondly, the species was common in the catch of the Tristan fleet throughout the year allowing biological processes to be followed in all seasons. Thirdly, it was possible to collect *A. monodactylus* from the shore and offshore with hook and line, and from rockpools and subtidally with rotenone ichthyocide. This was an important factor as even when poor weather prevented the fishing fleet from putting to sea, samples could be collected using the other methods. Finally, because the fivefinger occurred at all the islands it was possible to compare biological processes such as feeding under different environmental conditions present at various islands. The biology of this species is described in Chapter 4.

Further studies on the processes of reproduction and growth were undertaken. These included investigations of the reproductive biology of the concha, *Nelabrichthys ornatus* (Family Labridae) and growth of the soldier, *Sebastes capensis* (Family Scorpaenidae).

Early in the study it was noticed that *N. ornatus* displayed a complex behavioral and physiological mode of reproduction including the formation of leks, and protogynous hermaphroditism. This was considered to be the most advanced reproductive strategy displayed by any species at the islands. It was believed that an understanding of the reproductive biology of this seasonal spawning, temperate wrasse (phenomena which are the exception rather than

the rule in this family) would shed light on the effects of seasonal environmental fluctuations on the process of reproduction. *N. ornatus* was also readily available in rockpools throughout the year so the seasonal reproductive cycle could be followed throughout the year. The reproductive biology of the concha is presented and discussed in Chapter 5.

It was hypothesised that fish growth would be affected by temperature at the islands. It was expected that a study of growth in a species that occurred at two localities with different temperature regimes would provide the information upon which to accept this hypothesis. If growth rate differed under different temperature regimes, it could be concluded that seasonal temperature changes would influence growth rate in a species at any one locality. This would further clarify the effect of environmental seasonality on the fishes of the islands. *S. capensis* was chosen for the study of growth because of its abundance at all the islands and the relative ease with which it could be collected throughout the year. The growth study is presented in Chapter 6.

Chapter 7 focuses on fish as a resource at the islands and investigated the status some of the important species taken in the linefishery. This investigation also provided useful information enabling the seasonal changes in community structure at the islands to be better understood. The fishery is controlled by local environmental conditions which were reflected in the seasonality and composition of catches. The nature of the fishery is discussed in relation to the ecological aspects affecting the component species. This chapter is by nature more applied than the preceding ones and includes management recommendations for the rational exploitation of the resources.

Chapter 8 concludes the study and is a reflection of the results and discussions of the preceding chapters. The relevance of this research is emphasised and general conclusions are presented.

CHAPTER 2 - A DESCRIPTION OF THE STUDY AREA AND THE SUBTROPICAL CONVERGENCE

2.1 - INTRODUCTION

The Tristan da Cunha group and Gough Island were formed by volcanic activity which has resulted in massive cones thrusting up from the outer slopes of the Mid - Atlantic Ridge (Heydorn & Lutjeharms, 1980). The three northern islands, Tristan, Inaccessible and Nightingale, lie centrally in the South Atlantic at 37°05'S, 12°17'W, 1660 nautical miles west of Cape Town and about midway between South Africa and South America. Gough Island lies 200 nautical miles south-southeast of Tristan at 40°19'S, 9°56'W (see Fig. 2.1).

Being volcanic and situated on the Mid-Atlantic ridge, all the islands have relatively narrow shelf areas (stretching on average about 2 km to sea) which drop off into abyssal depths. Depths of up to 3000 m have been recorded between the northern islands during the present study. The planar areas down to the 183 m isobath have been estimated for each of the islands by Roscoe (1979). This depth was considered important in the present study as it is probably near to the edge of the shelf around the islands and was usually the maximum depth sampled. Roscoe's estimated shelf areas were: Tristan, 71 km²; Nightingale, 38 km²; Inaccessible, 124 km²; and Gough, 96 km² (Fig. 2.2). The waters around the islands can be considered oceanic, because they are virtually unaffected by processes derived from the islands, such as silt deposition and fresh water run-off. Some nutrient enrichment may occur in the waters close inshore due to leaching of guano from large seabird colonies.

The inshore features of the four islands differ considerably, although all are characterised by a rugged sea floor topography. Tristan has many boulder and sandy beaches, shallow reef areas and deeply incised intertidal rockpools. These features are not as common at the other islands. The slope of the littoral bottom at Tristan is also more gentle than at the other islands. At Gough and Nightingale the drop-off from the shore to about 10 m is almost vertical. Gough has no large intertidal rockpools. Gough and especially Nightingale have deeply incised coastlines, with many bays and offshore pinnacles. All the islands are surrounded by a kelp fringe (*Macrocystus pyrifera*) occurring in depths from about 10 m to 40 m. The coastline of

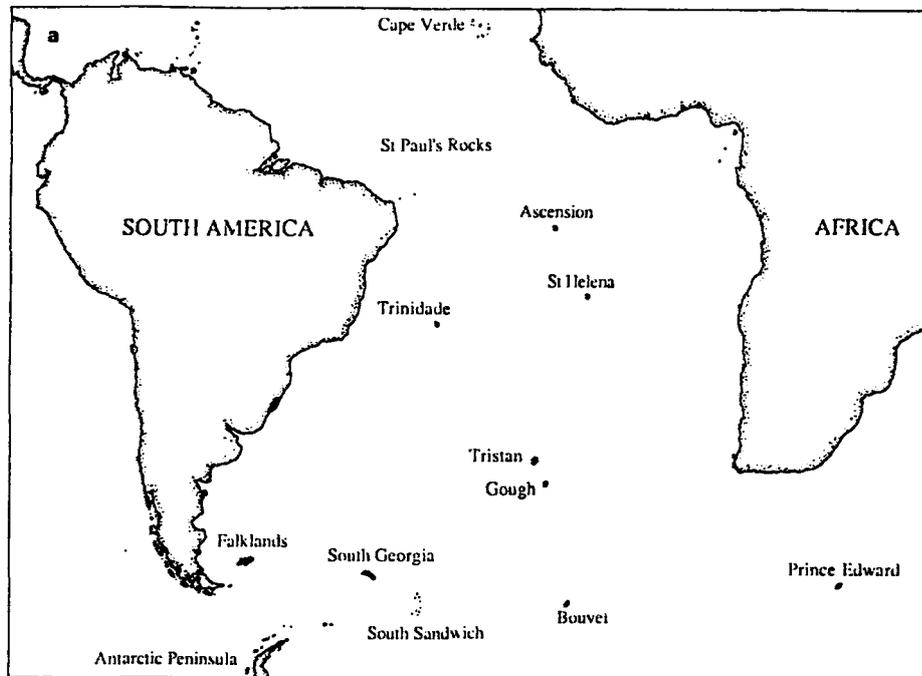


Figure 2.1. The position of Tristan da Cunha and Gough Island in the South Atlantic Ocean.

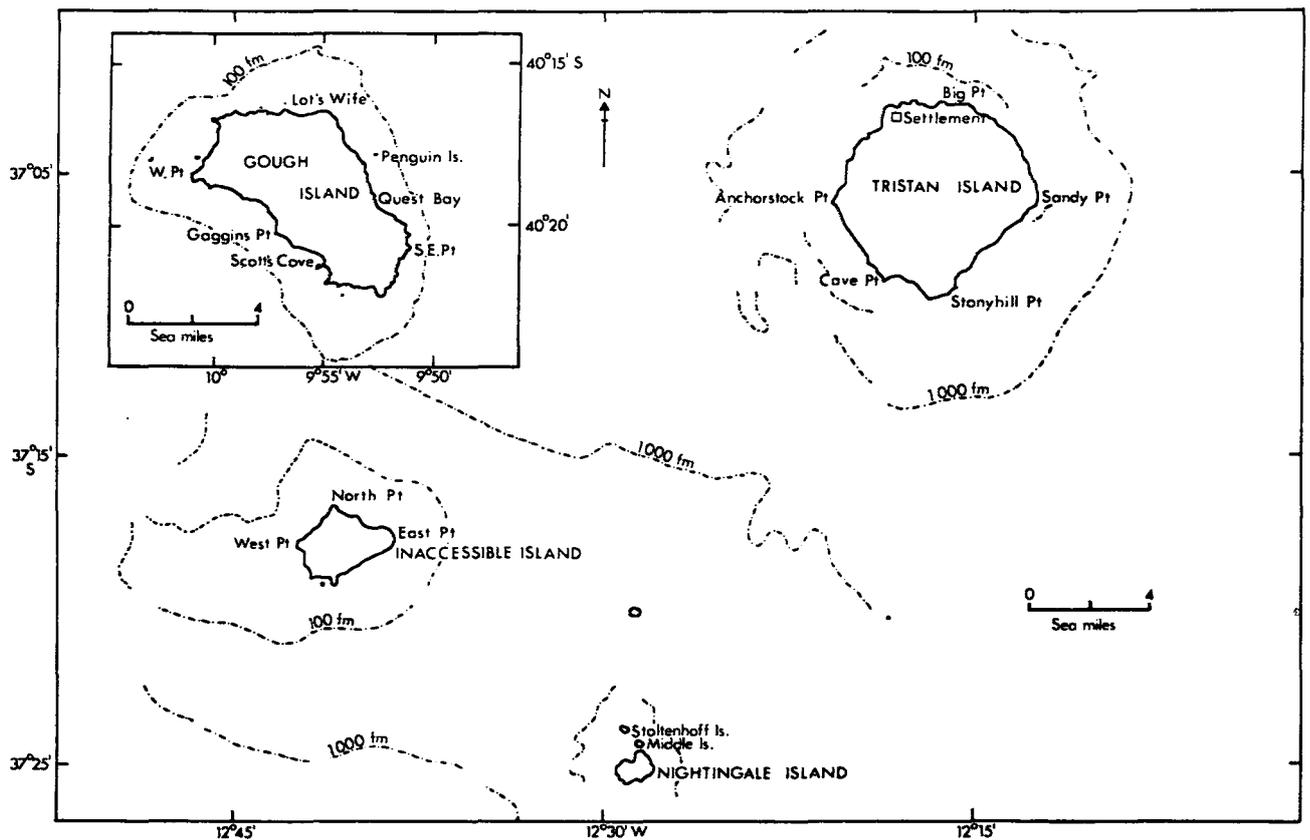


Figure 2.2. The Tristan da Cunha group with Gough Island inset showing the 180 m isobath around the islands (after Roscoe, 1979).

Inaccessible is more similar to that of Tristan than to the other islands, and it has few deeply incised features.

Potassium-argon dating techniques have shown that all the islands are relatively young. Nightingale has been estimated to be in the region of 18 ± 4 years old, Inaccessible, 6 ± 1.5 million years and Tristan only 1 million years old. Gough has been estimated to be 4 million years old (Miller, 1964).

All of the islands fall within the West Wind Belt. Tristan is also in the path of the South Atlantic Gyre, and in particular the South Atlantic Current which lies adjacent to the Subtropical Convergence (STC) (Stramma & Peterson, 1990). The islands are situated adjacent to, or within the STC (see Fig. 2.3) which is characterised amongst other criteria, by an abrupt meridional change in water temperature.



Figure 2.3. The Southern Ocean showing the approximate positions of the Subtropical Convergence (STC), the Subantarctic Front (SAF) and the Antarctic Polar Front (APF) (after Nakamura *et al.*, 1986).

Knox (1960) stated that the STC lies just north of Gough in summer and north of Tristan in winter. Relatively few physical and chemical measurements of this front have been undertaken in the central South Atlantic. Consequently the STC is poorly understood in this region. As mentioned in Chapter 1, it was hypothesised that the particular oceanographic conditions present in the vicinity of this frontal zone may influence the biology of organisms resident at the islands. Therefore, effort was directed towards obtaining a better understanding of the STC in the South Atlantic. Various oceanographic measurements in the inshore areas around the islands were undertaken during the period in the field, firstly to increase the range of data available from this region and secondly to ascertain if oceanographic conditions during the present study were representative of past patterns. The methods used during this part of the study are outlined below. This is followed by a general discussion of the STC in the South Atlantic based on the results obtained from the present study and information emanating from the input of Johan Lutjeharms (University of Cape Town) in Andrew *et al.* (in press).

2.2 - METHODS

Daily sea surface temperatures and salinities were measured from October 1988 to March 1990. Surface temperatures were measured using a Crawford bucket (Crawford, 1972) on the seaward side of the harbour breakwater at Tristan Island. Surface water samples were collected at the same locality. These samples were sent to Cape Town every three months where salinities were determined in parts per thousand (ppt) to an accuracy of 0.003 ppt, using a Beckman Model SR 9 salinometer.

Offshore temperature profiles were measured, on average, once a month off Tristan Island during the 18 month study period. Sampling periodicity was entirely dependent on sea conditions. A portable expendable bathythermograph (XBT) recorder and launcher were operated from an 8 m diesel powerboat or from the 35 m rock lobster vessel **MFV TRISTANIA II**. Care was taken to ensure that launching occurred in depths greater than 300 m as the XBT was capable of measuring a profile to this depth. The position, surface water temperature, salinity and weather conditions at each launch were recorded. These depths were usually obtained at a distance greater than 1 km from the shore.

Quality control of the temperature profile recordings were carried out in the manner described

in Lutjeharms (1985). In some cases traces were discarded due to spikes in the record, and in others only the trace above the spikes was used.

2.3 - THE SUBTROPICAL CONVERGENCE IN THE TRISTAN DA CUNHA REGION

The Subtropical Convergence forms the northern border of the Southern Ocean and the geographic limit to the influence of Subantarctic Surface Water. At and near the sea surface it consists of a strong horizontal gradient in temperature, salinity and a number of nutrients such as nitrate, nitrite and phosphate. These gradients are particularly well developed along the east coast of South America (Guretskiy, 1986) and south of the Brazil and the Agulhas Currents respectively (Peterson & Stramma, 1991).

According to Deacon (1933) the STC in the South Atlantic is marked by a surface temperature change of at least 4°C and a salinity change of at least 0.50 psu. Lutjeharms & Valentine (1984) have carried out a detailed analysis of the surface expression of the STC based on 70 crossings of the front, mostly south of Africa. They have established that the average width of the front here exceeds 200 km, that its temperatures span 11°C to 18°C on average at any one time and that it has a mean temperature, in the core of the front, of 14.2°C.

The STC has been noted to act as a substantive biogeographic barrier (Lutjeharms, 1987). In addition, it has been observed that the STC itself is an area of enhanced primary productivity and phytoplankton density (Allanson *et al.*, 1981) which might influence organisms in higher trophic levels through the food chain. Recent research (Stramma & Peterson, 1990) has furthermore shown that a strong current, the South Atlantic Current, flows along the full longitudinal extent of the STC and it is proposed that this current enhances the dispersal of pelagic phases of fishes in the STC region beyond that of the general eastward drift (see Chap. 3).

Up to the present the available physical and chemical data in the general vicinity of Tristan da Cunha and Gough Island have been insufficient to establish with certainty the relationship of these islands to the STC (Lutjeharms & Valentine, in press). However, evidence that the islands fall within the meridional range of the STC can be seen in Figure 2.4. These data are

derived from weekly products based on thermal infrared measurements made by satellite (Lutjeharms & Meeuwis, 1991). The locations of all distinct fronts for the period January to June 1988 are shown in Figure 2.4a. Figure 2.4b shows the locations of the 15°C surface isotherm which, according to Deacon (1933), represents the northern border of the STC in winter. Figure 2.4c shows the location of the 18°C isotherm in summer. All three diagrams indicate that Tristan da Cunha lies in the centre of the general meridional band in which the STC occurs.

Monthly average temperatures calculated for all the available sea surface temperature data from Tristan da Cunha and Gough Island also suggest that these islands lie within the STC (Fig. 2.5). Temperatures at Tristan in the warmer six months lie between 15°C and 19°C, and in the colder six months between 13°C and 15°C. Temperatures at Gough Island are on average 3°C lower than at Tristan during all months. If Deacon's (1933) definition of the STC is used, this would place the Tristan da Cunha group at the northern edge of the temperature range that the STC occupies and Gough Island at the southern border or entirely south of an STC influence. Monthly standard deviations are large, usually about 2°C (Fig. 2.5) from which it can be concluded that the seasonal temperature cycles at both Tristan da Cunha and Gough Island may be considerably different from year to year.

A comparison of temperatures measured during the present study and a climatic curve for all available data is shown in Figure 2.6. In general the sea surface temperatures at Tristan Island from the present study corresponded closely with the expected average. Both summers were slightly warmer than the average while the winter was slightly colder. The temperature cycle for this period was thus slightly more extreme than the average. It could therefore be concluded that the environmental conditions during this study, as represented by the sea surface temperatures, were characteristic of normal conditions.

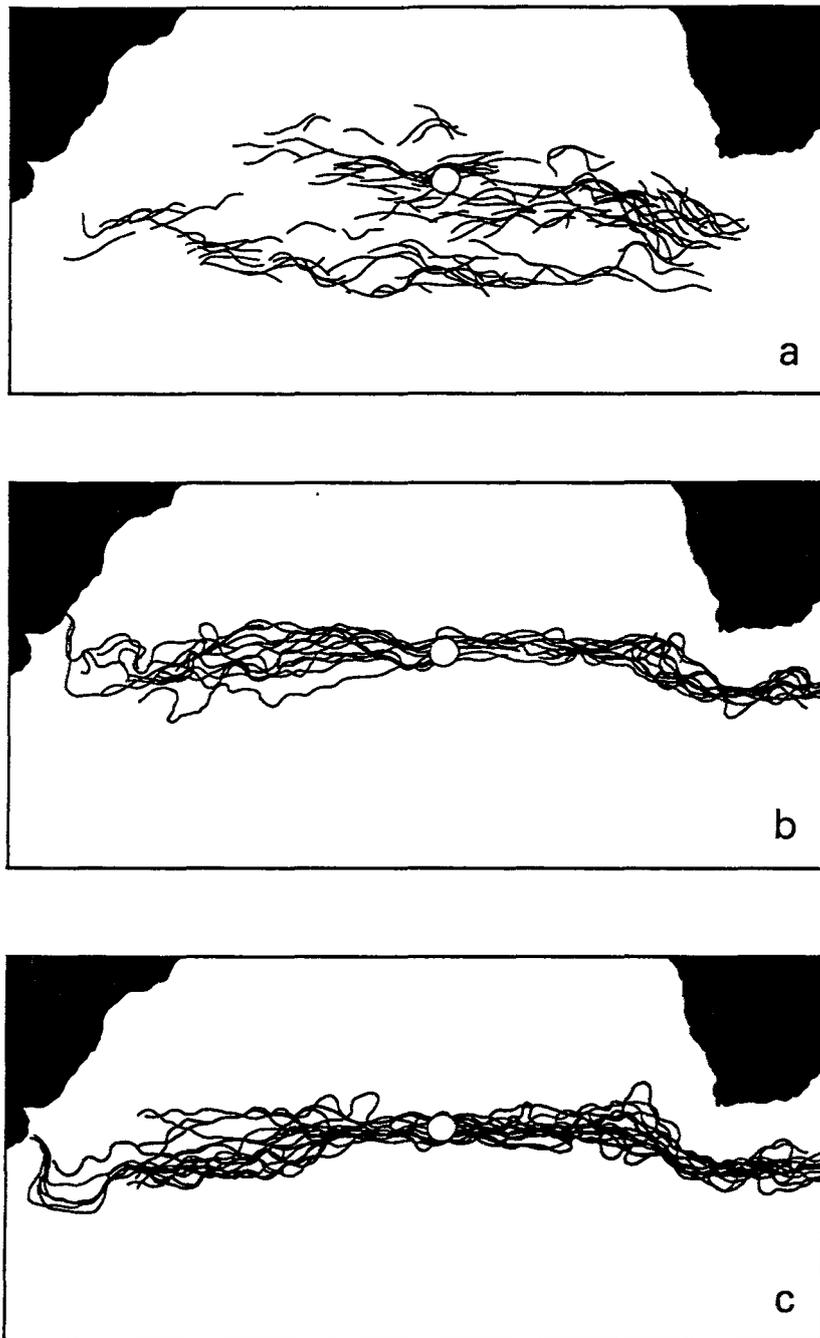


Figure 2.4. The location of the STC in the South Atlantic Ocean in 1988, according to satellite thermal infrared imagery. Panel (a) shows a compilation of all frontal expressions for a six month period, from January to June 1988. Panel (b) gives the locations of the 15°C surface isotherm for the months June to August. Panel (c) gives the same for the 18°C surface isotherm for the summer months December, January and February (after Andrew *et al.*, in press).

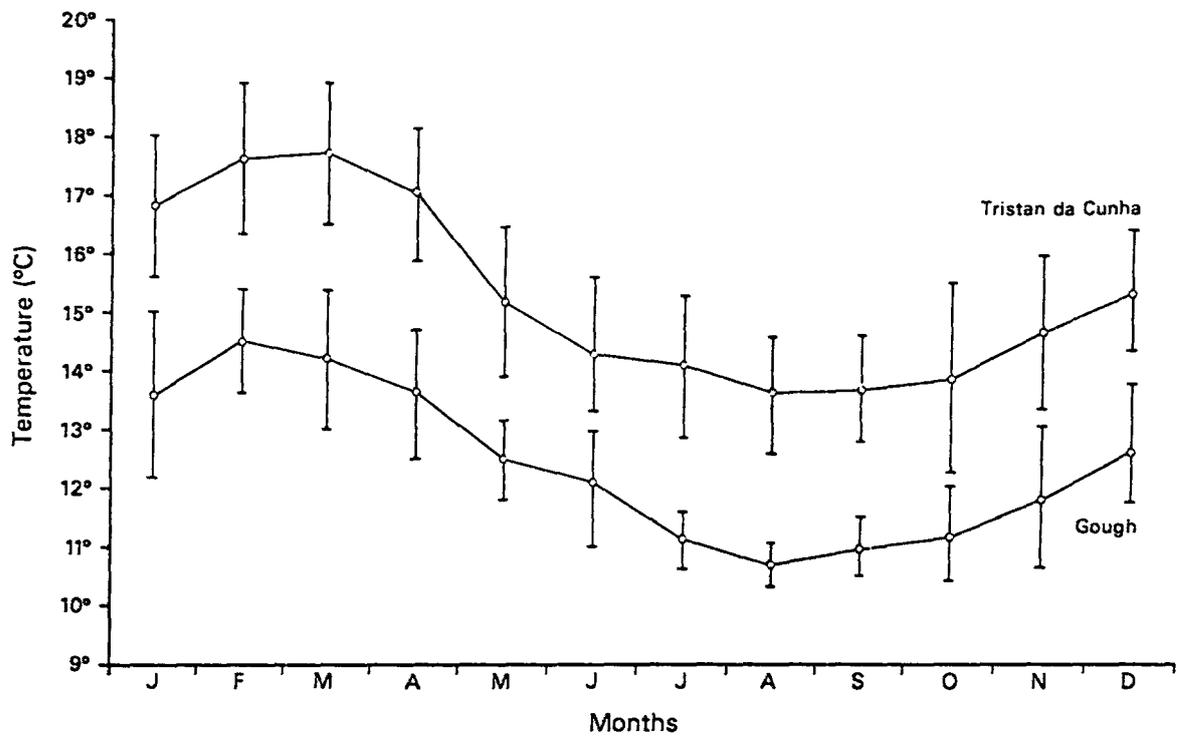


Figure 2.5. Mean monthly sea surface temperatures with standard deviations for each month for Tristan da Cunha and Gough Island. These calculations are based on all available data up to 1980 (after Andrew *et al.*, in press).

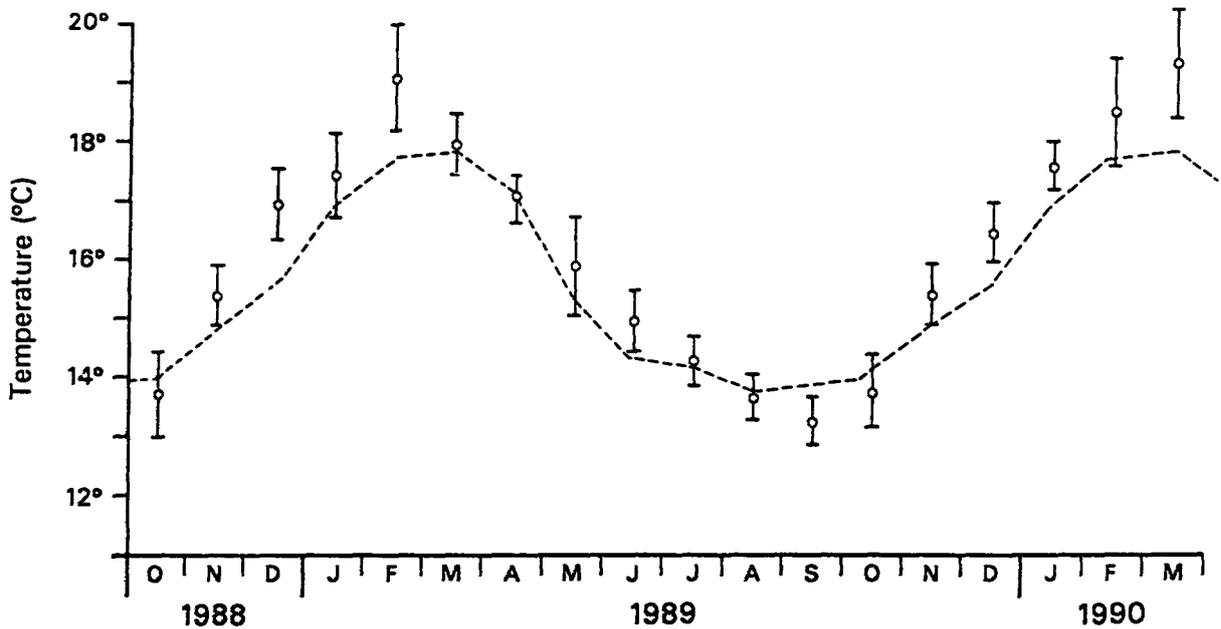


Figure 2.6. The average sea surface temperatures at Tristan da Cunha for each month for the period October 1988 to March 1990. Standard deviations are shown for each month. The broken line indicates the mean monthly sea surface temperatures for all available data up to 1980.

According to the range of salinities reported for the STC by Lutjeharms (1985) all the measurements taken during the present study indicate that the Tristan da Cunha group lies within the STC. Figure 2.7 shows salinity values from this study as compared to salinities at the STC given by Whitworth & Nowlin (1987). The mean salinity proposed by these authors at the northern edge of the STC is indicated by the broken line. Therefore, according to their definition all the samples taken at Tristan Island during this period were of Subtropical Surface Water, that is from north of the STC. The salinity measurements from this study do not clearly indicate any meridional movement of the STC on a seasonal basis. This is in contradiction of the view held by Knox (1960).

Figure 2.8 shows the results of the measurement of offshore temperature profiles over the 18 month period. Two distinctive processes may be inferred from this figure. Firstly, a seasonal warming of the upper 50 m is evident. This was particularly clear for station 8, taken on 13 February 1989 when the surface temperature was 21.0°C and the temperature at 50 m was 14.5°C. In winter the surface layer had cooled down to a uniform 13.3°C (station 15, Fig. 2.8). The second process is the event-controlled, vertical mixing of heat into the water column. This is evident from the step-like structure of a number of temperature traces (eg. stations 5, 9, 13, 14). All the heat absorbed in the upper 50 m in February is mixed to 100 m by March (station 9), to 200 m by August (station 14) and to 300 m by September (station 15). Whereas the temperature at 300 m had stayed more or less constant at 11°C, in August it suddenly increased to 12°C while the surface temperature had decreased to 13.2°C. By 17 October (station 17) the top 80 m was again 0.5°C warmer with a distinct step at that depth showing the vertical penetration of the mixing process. By 23 November (station 20) the top 40 m had again become warmer than 15°C.

Considered in conjunction with the findings of Lutjeharms & McQuaid (1986) who investigated changes in the thermal structure of Southern Ocean fronts with the onset of summer, the results presented here are quite significant. As summer progresses, surface water becomes increasingly warmer. This is due to insolation and not due to the overflow of warmer water from the north, in which case the salinity would also have risen. An increase in salinity was not evident from the present study (Fig. 2.7). Since the water masses below 100 m are not directly involved in this heating, they remain unchanged and a strong stratification between the upper 100 m and the water below is established. This has been observed previously (Lutjeharms &

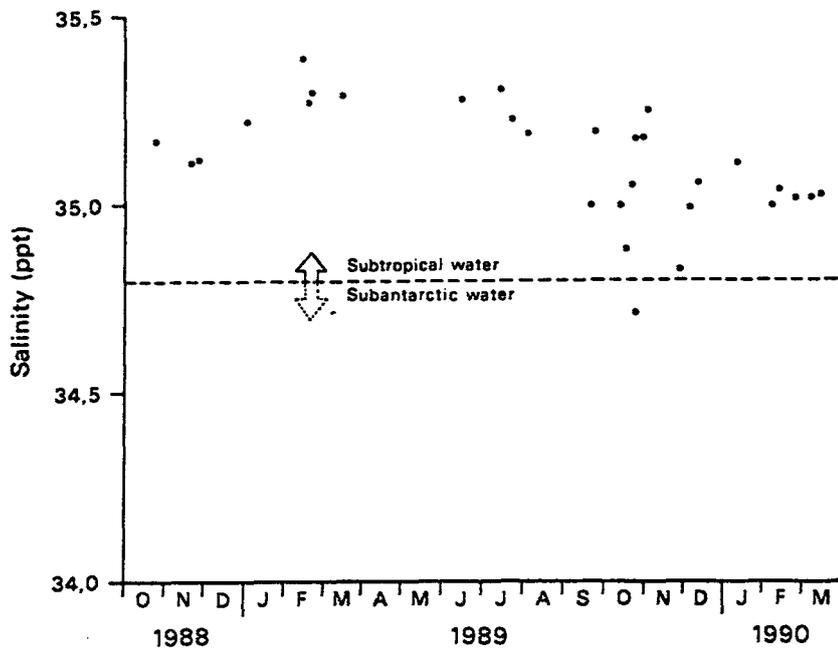


Figure 2.7. Offshore sea surface salinities measured in the vicinity of the Tristan da Cunha group from 1988 to 1990. The broken line denotes the saline limit of Subtropical Surface Water according to Whitworth & Nowlin (1987) (after Andrew *et al.*, in press).

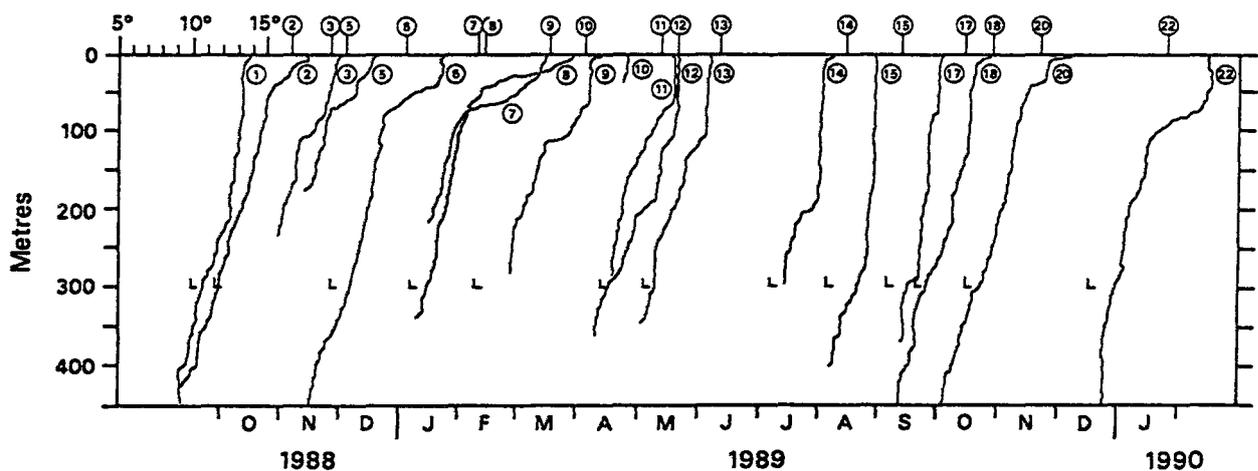


Figure 2.8. Profiles for ocean temperature to 400 m in the vicinity of the Tristan da Cunha group. The date when each profile was measured can be read off by comparing the numbered location on the top axis with the months on the bottom axis. Each numbered location corresponds to the 15°C isotherm on the temperature scale. The location of the 10°C isotherm at 300 m depth is shown as a step for each temperature trace that extended that deep (after Andrew *et al.*, in press).

McQuaid, 1986). With the onset of winter storms this upper, warmer layer is mixed out. Another possible mixing mechanism would be convective overturning as the sea surface cools.

The effect at the sea surface of this seasonal process might be an apparent southward shift of the STC during the summer months. In fact, the strongest horizontal thermal gradient might be found further south during the summer. The saline front will most probably not follow this thermal front, nor will the nutrient expression, or the major subsurface thermal expression of the front. For biological activity in the frontal zone this relative immobility of the major part of the STC itself is probably not as important as an increase in stratification at the front during the summer. Fournier *et al.* (1979) found that changes in the inclination of the Shelf-Break Front off Nova Scotia associated with varying degrees of mixing and stratification of the water column resulted in different phytoplankton standing stocks. They suggested that the steepness of the front influenced the depth to which phytoplankton were mixed which in turn controlled the amount of illumination received by a given cell. Therefore at times when the water column was well stratified (decreased frontal inclination) illumination available to phytoplankton would be at a maximum resulting in the highest production. Similarly, Marra *et al.* (1990) proposed that enhanced phytoplankton growth at the thermohaline Shelf-Break Front in the Middle Atlantic Bight could be explained by nutrient enrichment from turbid underlying water to organisms in clear well-lighted surface water. Allanson *et al.* (1981) hypothesised that increased primary productivity at the STC during the summer was mainly a result of an increase in stratification of the water column at this time. The layer of warm surface water resulting from this stratification in the summer probably extends south of the nutrient expression of the STC in the Tristan da Cunha region, and would therefore substantially increase the potential primary production of the frontal zone during summer by overlying an area of high nutrients which would otherwise be poorly accessible to organisms preferring warmer water.

This hypothetical mechanism would be in full agreement with all presently available data. It would also agree with the traditional perception of the fishermen of Tristan da Cunha that catches improve during the summer due to changes in the marine environment at this time. Increased primary production during this period may attract fish into the vicinity of the islands during the summer months as suggested by an increase in catch per unit of effort in the local linefishery (see Chap. 7). This hypothesis would not require the major subsurface expression of the STC to meander meridionally on a seasonal basis.

From a biogeographical perspective it may therefore be concluded that, although the STC is more diffuse in the mid-Atlantic than, for example south of Africa, the Tristan da Cunha group falls within its zone of influence. This may be through cast-off eddies (Lutjeharms & Valentine, 1988), filaments and other protrusions throughout the year. It is also likely that the surface expression of the STC retreats southward with the onset of summer and with increased vertical stratification in the water column at Tristan da Cunha. Such increased stratification may lead to increased primary productivity at this time of the year and therefore temporally affect the biology of the fishes at Tristan da Cunha and Gough Island. That this is indeed the case will be illustrated in the following chapters.

CHAPTER 3 - THE FISHES OF TRISTAN DA CUNHA AND GOUGH ISLAND AND A BIOGEOGRAPHIC REVIEW OF THE NERITIC ICHTHYOFAUNA

3.1 - INTRODUCTION

Little has been reported on the diversity and distribution of neritic fish species occurring at Tristan da Cunha and Gough Island. Publications concerning the fishes of this region have generally been descriptive in nature or have dealt with broad zoogeographical concepts. Many species descriptions have subsequently been revised and the number of species known to occur at the islands has increased. Carmichael (1819) published the first report on the fauna and flora of Tristan. He described four species of fish from Tristan and mentioned another five that occur there. Barnard (1923; 1925) listed five more species. Norman (1935a) described an additional species, and Sivertsen (1945) added seven species that were collected by the Norwegian expedition to the islands. Rowan & Rowan (1955) added three oceanic species to the fish fauna of Tristan. Penrith (1967) reviewed the fishes of Tristan da Cunha, Gough Island and the Vema Seamount northwest of Cape Town; he listed 23 species from Tristan, 8 from Gough and 13 from Vema, and compared the ichthyofauna of these localities with those from other areas of similar latitude. Various authors have listed oceanic midwater species collected near the islands. Krefft (1974, 1978) listed 16 species from the Tristan da Cunha and Gough Island region while Hulley (1981) figured an additional 24 species collected by the **FRV WALTHER HERWIG** in the vicinity of the islands during March 1971. Miller (1982) collected three additional oceanic species from the waters around Gough Island, and Gon & Heemstra (1987) added another neritic species from there. In total, 68 species have been reported in the literature from these southern mid-Atlantic islands.

In order to characterise the neritic fish fauna of the islands and to address broader questions concerning their biogeography it was necessary to undertake intensive collections using a variety of methods, which are outlined below. The list of fishes that is reported on in this chapter includes all known neritic species from the islands and those oceanic species either collected during the present study or that have not been reported from the islands previously. All sharks known from the islands are reported on (even though some species such as the blue

shark *Prionace glauca*, are regarded as oceanic) because of their important role as predators in the coastal waters of the islands. Records of oceanic species that are known to form important elements of the food chain in the shelf waters of the islands are also included. Records taken from the literature that are probable or doubtful are also discussed in this chapter.

Information on the neritic species from Tristan da Cunha and Gough Island is combined with records from other shallow water areas in the Southern Ocean to determine common features present in the neritic STC fish fauna. Brief biological notes are presented for individual species when possible. The biogeographical analysis considers only coastal or neritic species and excludes records of oceanic species in the vicinity of islands and seamounts in the STC region. This biogeographic analysis was undertaken firstly to determine if a neritic STC ichthyofauna could indeed be characterised, and secondly to ascertain to what extent populations of fishes at various localities were isolated from each other. P. C. Heemstra of the J.L.B. Smith Institute of Ichthyology provided significant input to the taxonomic status and description of many species through his contribution to Andrew *et al.* (in press).

3.2 - COLLECTION METHODS

This chapter is based mainly on fishes that were collected at Tristan da Cunha and Gough Island from October 1988 to March 1990. Collections at Tristan Island were made on each fishing day when the rock lobster fleet put to sea. Fish caught by the fishermen with hook and line were examined at the harbour and representative samples of different species were fixed and preserved. On average the fleet that put to sea consisted of 18-22 two-man powerboats. Fish were also collected with hook and line from the shore and with rotenone ichthyocide in the intertidal and shallow sub-tidal region (max. depth 10 m) on a monthly basis. Fish were also obtained in lobster traps set by the Tristan fishermen from depths ranging from 50 - 200 meters. Stranded specimens were also collected and one undigested specimen was collected after being dropped by an Antarctic tern (*Sterna vittata*). Underwater observations were carried out during 32 SCUBA dives when weather conditions were suitable. These were undertaken to assess habitat preference, fish abundance and behaviour, and also to determine if the sampling methods used were successful in capturing all species, at least down to a depth of 30 m.

The fish fauna of Nightingale, Inaccessible and Gough Islands were sampled with hook and

line and lobster traps from aboard the **MFV TRISTANIA II**, one of the two rock lobster vessels fishing at the islands. In addition, samples were collected from the shore at Nightingale by the author and at Gough by Robin Matthews, a member of the 1988/1989 South African Meteorological Team.

It is believed that the collections made using these methods has provided a relatively comprehensive list of neritic fish from 0 to 200 meters during both summer and winter. During the 18-month period in the field over 4000 specimens were examined in order to obtain biological information. Representative specimens of most species were preserved and are lodged in the collection of the J.L.B. Smith Institute of Ichthyology in Grahamstown, South Africa.

3.3 - THE FISHES OF TRISTAN DA CUNHA AND GOUGH ISLAND

The neritic fishes of the islands, and selected oceanic species, are listed below, with brief notes on the biology and ecology of some species. Photographs, and in some instances drawings, of specimens collected in this study are provided where possible. Many species have local common names that differ from those recognised elsewhere. In these cases the species name is followed by the internationally recognised common name and the Tristan common name (in parenthesis). The synonymies given here comprise the original nominal species and other synonyms or references that are pertinent to the taxonomy of these species. Total Length (TL) was generally measured, but Standard Length (SL) or Body Length (BL) are used in some cases. In all instances lengths are in millimetres. RUSI catalogue numbers are given for voucher specimens housed in the J.L.B. Smith Institute of Ichthyology. SAM catalogue numbers are given for specimens examined at the South African Museum in Cape Town. The list is divided into four categories. Firstly, those species that definitely occur at the islands. Secondly, those records based on sightings. Thirdly, records that are probable, and fourthly those that are doubtful.

CHONDRICHTHYES

Family Hexanchidae

Notorynchus cepedianus (Peron, 1807)

broadnose sevengill shark (rock shark)

Squalus cepedianus Peron, 1807: 337 (Tasmania).

Notorynchus cepedianus: Compagno, 1984; Bass *et al.*, 1986a.

DIAGNOSIS: One dorsal fin; 7 gill slits on each side of head; 6 rows of large teeth on each side of lower jaw; orbit length (horizontal eye diameter) much less than distance between nostrils and 1.6-3.0 times in least depth of caudal peduncle; snout length 1.1-1.3 times internostril distance and less than distance between lower ends of first gill slits.

Colour: Body pale grey dorsally, white below; dorsal surface of body and fins speckled with black spots.

MATERIAL: Tristan: RUSI 35991 (jaws) 1390 mm TL; RUSI 35992 (jaws) 1450 mm TL; RUSI 35995 (jaws) 1670 mm TL; RUSI 35997 (jaws) 1880 mm TL. In addition, 32 specimens were examined at the islands ranging from 1200 to 2250 mm TL.

REMARKS: Although it has not been reported from these waters before, the sevengill shark is the most common shark on the shelf areas of all the islands. *Notorynchus cepedianus* was almost certainly mistaken for *Hexanchus sp.* in Roscoe's (1979) record as the sixgill shark is extremely rare in the depths fished by the local fishermen. The broadnose sevengill shark is however commonly caught and used for bait. The local population is probably self sustaining, as all size ranges are found in the region (D. Ebert pers. comm.). Dietary items found in 10 guts examined included fish and cephalopods.

Distribution: *N. cepedianus* is found in all oceans except the North Atlantic and is restricted to relatively shallow coastal waters (Bass *et al.*, 1986a).

Family Carcharhinidae

Prionace glauca (Linnaeus, 1758)

blue shark (bottlenose shark)

Squalus glaucus Linnaeus, 1758: 235 ("European Ocean").

Prionace glauca: Compagno, 1984; Bass *et al.*, 1986b.

DIAGNOSIS: Two dorsal fins, the first dorsal just in front of pelvic fins; 5 gill slits on each side of head; pectoral fins long and falcate; no spiracles or ridge between dorsal fins; nictitating eyelid present; lip folds minute; teeth unicuspid, strongly serrated and broadly curved in upper jaw; lower jaw teeth narrower.

Colour: Brilliant dark blue above, white below; fades to grey after death.

MATERIAL: Tristan: RUSI 33584, 1200 mm TL. Inaccessible: RUSI 35996 (jaws) 2500 mm TL.

REMARKS: Sivertsen (1945) first reported the presence of this shark in Tristan waters. Blue sharks are caught all the year round at all the islands from the surface down to at least 150 meters. The two specimens (1200 mm and 2500 mm TL) collected in the present study were caught on the surface at Inaccessible and at 150 m at Tristan Island. This species is commonly caught, but only smaller specimens are landed and used as bait. The temperature regime at Gough would suggest that the shark reported by fishermen to be common there is in fact this species as temperatures there would be tolerated by the species (Bass *et al.*, 1986b).

Distribution: The blue shark is found in tropical and temperate waters of all the major oceans, but it prefers waters of 12° - 16°C (Bass *et al.*, 1986b).

Family Lamnidae

Isurus oxyrinchus Rafinesque, 1810

shortfin mako (bottlenose shark)

Isurus oxyrinchus Rafinesque, 1810: 12, Pl. 13 (Sicily). Compagno, 1984.

DIAGNOSIS: Two dorsal fins; caudal fin lunate, the lower lobe almost as big as the upper lobe; 5 large gill slits on each side of head; origin of first dorsal fin over or behind inner corner of pectoral fin; pectoral fins markedly shorter than distance from snout to pectoral fin origin; teeth lanceolate, without small basal denticles.

Colour: Dark blue above, white below.

MATERIAL: Tristan: RUSI 35994 (jaws) 2670 mm TL.

REMARKS: This is a new record for the islands and for any of the oceanic islands in the cold temperate waters of the Southern Hemisphere. A mako of 2670 mm TL was caught on a longline set at 100 m off Tristan Island. The species is said to be common in Tristan waters although seldom landed. Makos are occasionally seen leaping from the water and are known to display aggressive behaviour towards boats. A bluefish, *Hyperoglyphe perciforma*, of approximately 600 mm TL was found in the gut of RUSI 35994.

Distribution: The species is known from all warm-temperate oceans both inshore and in the open ocean (Bass, 1986).

Family Torpedinidae

Torpedo nobiliana Bonaparte, 1835

Atlantic electric ray

Fig. 3.1

Torpedo nobiliana Bonaparte, 1835: Fig. (pages not numbered; Italy); Compagno, 1986.

DIAGNOSIS: The head, body and pectoral fins forming a round soft flabby disc which is wider than long; tail short, with two moderate-sized dorsal fins (first distinctly larger than second) and a large triangular caudal fin (caudal fin height about equal to distance from upper origin of caudal to origin of first dorsal fin); no papillae on edge of spiracles.

Colour: Dorsal surface dark brown, with small irregular blackish spots and specks; underside white. In South African waters, *T. nobiliana* is described as "uniform shiny black or dark grey above, underside white" (Compagno *et al.*, 1989). Stehmann & Burkel (1984) described northeastern Atlantic specimens as "usually plain dark violet/brown above, sometimes

with indistinct darker dots and white spots; underside white to cream, often with dusky margins to disks and pelvic fins".

MATERIAL: Tristan: RUSI 35993, 890 mm TL.

REMARKS: This species is a new record for the islands. Another specimen of *Torpedo* (SAM 25245) was collected at Tristan in May 1969 and donated by the Division of Sea Fisheries to the South African Museum. Unfortunately, this specimen cannot now be located at the Museum. The specimen collected in the present study was collected by a Tristan fisherman with hook and line in about 150 m of water. It looks very similar to the specimen of *Torpedo macneilli* (Whitley, 1932) from St Paul Island that was illustrated by Duhamel (1989). *T. macneilli* (described originally from Australia) and *T. fairchildi* Hutton, 1872 (from New Zealand) may be synonyms of *T. nobiliana*.

Distribution: *T. nobiliana* is known from the Mediterranean and Eastern Atlantic Ocean (from Scotland to South Africa), the western North Atlantic (from Cuba to Nova Scotia) and along the south coast of South Africa to Algoa Bay. A specimen identified as *T. nobiliana* by B. Seret was reported from "bank Austral" (34° 54'S, 53° 14'E) by Duhamel (1989).

OSTEICHTHYES

Family Congridae

Bassanago nielseni (Karmovskaya, 1990)

hairy conger (eel)

Fig. 3.2

Pseudoxenomystax nielseni Karmovskaya, 1990: 8, Figs. 1c & 2d (Southeastern Pacific: Nazca Ridge, 22° 05'S, 81° 15'W).

DIAGNOSIS: Tail longer than head and trunk combined; skin covered with minute darkly-pigmented papillae, which are scattered and difficult to see in juveniles, but profuse in adults and give a distinctive "hairy" appearance to the body. Head length 15-19% TL; distance from tip of snout to anus 39-42% TL; predorsal distance 16-19% TL. Eye diameter 13-17% head length; snout fleshy, longer than eye and projecting in front of lower jaw; rear nostrils in front of middle of eye; front nostrils are short tubes directed forward at front of snout; gape extends to below pupil; a fleshy labial flange or lip on each side of lower jaw, but not continued across tip of jaw; no labial flange on upper jaw; cardiform teeth in several rows on jaws; intermaxillary tooth patch about as broad as long and not separated from maxillary or ethmovomerine teeth; vomer with a band of short conical teeth, the band extending posteriorly about to middle of maxillary tooth band. Lateral line a raised ridge running midlaterally along body, the pores opening via short, white, fleshy tubes along ventral edge of the ridge; 39-43 pores from head to vertical at front of anus; top and sides of head with numerous, short fleshy papillae (superficial neuromasts). Median fins continuous around tip of tail; pectoral fin rays 13-16. Preanal vertebrae (anterior to anus) 42-45 (n = 8); total vertebrae 150-159 (4 specimens with intact tail).

Colour: Brownish dorsally, pale ventrally; median fins pale with dark margin; some specimens distinctly darker than others.

MATERIAL: Tristan: RUSI 33577: 2, 580-600 mm TL; RUSI 33579, 840 mm; RUSI 33580 2, 570-630 mm. Nightingale: RUSI 33578 2, 580-600 mm; RUSI 33581, 660 mm. Inaccessible: RUSI 33604, 610 mm.

REMARKS: Although the hairy conger was found to be the most common eel at Tristan, it has not previously been reported from Tristan or Gough (Contrary to Duhamel, 1989, the species was not reported by Penrith, 1967.). All specimens from the present study were collected in traps set in waters deeper than 70 m. *B. nielseni* are often captured in traps overnight, suggesting that they are nocturnal feeders. An adult male specimen captured off Tristan Island in June 1989 was in a ripe running condition, indicating a winter spawning season for the species.

According to Smith (1989), "The species treated as *Pseudoxenomystax* by Castle....-*Congermuraens albescens* Barnard, 1923, *Bassanago bulbiceps* Whitley, 1948, and *Pseudomystax hirsutus* Castle, 1960 - seem quite different from *P. dubius* Breder and probably should be placed in *Bassanago* Whitley." Castle (1986) intimated that *P. hirsutus* (from New Zealand) may be a synonym of *B. albescens*; and P.C. Heemstra (J.L.B. Smith Institute of Ichthyology), having examined two specimens of *B. bulbiceps* from Australia, believes that this species should also be considered a synonym of *B. albescens* (Andrew *et al.*, in press). The supposed differences between *B. bulbiceps* and *B. hirsutus* in the numbers of dorsal and anal fin-rays and lateral line pores (as given by Castle, 1960) are subsumed in the counts given by Castle (1968) for *B. albescens* from South Africa.

Specimens of *Bassanago* from the Tristan Group have fewer vertebrae than *B. albescens* from South Africa (with 45-48 preanal vertebrae [n = 10] and 169-174 total vertebrae [7 specimens with intact tails]. Tentatively, the Tristan species is assigned to *B. nielseni*, which was recently described from the Nasca Ridge in the southeastern Pacific Ocean. According to Karmovskaya (1990), *B. nielseni* has a total vertebral count of 152-153, which falls within the range for Tristan specimens. The counts of 34-39 vertebrae before the anal fin reported by Karmovskaya (1990) in *B. nielseni* are lower than the counts of 42-45 for Tristan specimens. The taxonomic significance of this apparent difference in preanal vertebrae cannot be assessed with the material presently available.

B. albescens is common off Cape Point, South Africa, and has also been reported from southern Argentina and southern Chile (Nakamura *et al.*, 1986 [as "*Pseudoxenomystax albescens*"; Pequeno, 1989). If *B. bulbiceps* and *B. hirsutus* are synonyms of *B. albescens*, the species also occurs at Australia and New Zealand. *B. hirsutus* and *B. bulbiceps* were both

listed from Chatham Islands east of New Zealand by Roberts (1991), but he gave no vertebral counts for his specimens, so his identifications are dubious.

Distribution: *B. nielseni* is, at present, known only from the Tristan Group and the Nasca Ridge in the southeastern Pacific Ocean. Duhamel (1989) reported *Bassanago albescens* from Amsterdam Island, but the vertebral count for this specimen (148) indicates that it is probably *B. nielseni*.

Conger wilsoni (Bloch & Schneider, 1801)

conger eel

Fig. 3.3 + 3.4

Gymnothorax wilsoni Bloch & Schneider, 1801: 529 (Australia).

Conger wilsoni: Castle, 1986.

DIAGNOSIS (data from SAM specimen in parentheses): Tail longer than head and trunk combined; snout longer than eye; rear nostril in front of middle of eye; lips with well developed flange; teeth in 1 or 2 rows on jaws, the outer teeth longer, compressed, forming a continuous cutting edge; dorsal fin origin over or behind pectoral fin tip; a sensory pore behind and in line with corner of mouth; head 7.0-8.2 (8.0) times in SL; lateral-line with 37-40 (37) pores before anus; pectoral fin rays 13-17 (15); vertebrae 140-142 (144).

Colour: Dorsal two-thirds of head and body dark olive brown, ventral parts creamish white; dorsal and anal fins with black margin.

MATERIAL: Gough: SAM 29632, 488 mm TL.

REMARKS: This South African Museum specimen (collected in Transvaal Bay, Gough Island, with hook and line by T. Gosliner and B. Liltved) represents the first record of *Conger wilsoni* from any of the islands close to the STC.

Distribution: *C. wilsoni* is known from South Africa, Australasia, New Zealand and possibly Japan (if *C. jordani* Kanazawa, 1958 is a synonym). Castle (1986) estimated the larval life of *Conger* species as "about a year", and this would account for the wide distribution of *C. wilsoni*.

Gnathophis capensis (Kaup, 1856)

southern conger (eel)

Leptocephalus capensis Kaup, 1856: 153 (Cape of Good Hope; larva).

Congermuraena australis Barnard, 1923: 442 (False Bay, Tristan da Cunha).

Ariosoma australis: Penrith, 1967.

Gnathophis capensis: Castle, 1968; 1986; Duhamel, 1989.

DIAGNOSIS: Tail considerably longer than head and trunk combined; pectoral fins present; snout slightly longer than eye and projecting in front of lower jaw; lips not well developed; several rows of small teeth on jaws and roof of mouth, those on vomer blunt; no hair-like epidermal papillae on body; lateral-line pores and vertebrae 128-135.

Colour: Body olive brown above, paler below; head silvery; dorsal and anal fins with dusky margin.

MATERIAL: Tristan: RUSI 33627: 372 mm TL; SAM 12782: 186 mm TL; SAM 24551: 374 mm TL.

REMARKS: *G. capensis* appears to be rare in Tristan waters compared to *Bassanago nielsenii*; perhaps the southern conger prefers deeper waters and is therefore more difficult to collect. The single specimen from this study (RUSI 33627) was collected in a trap set overnight in 150 m.

Distribution: *G. capensis* is known from False Bay to Plettenberg Bay, South Africa (Castle, 1986) and from St. Paul and Amsterdam Islands (Duhamel, 1989). According to Castle (1968), the duration of larval life for *G. capensis* is 10-12 months. During this period, the larvae could easily drift from Tristan to South Africa or from South Africa to St. Paul Island.

Family Photichthyidae

Vinciguerria poweriae (Cocco, 1838)

Gonostoma poweriae Cocco, 1838: 167, Pl. 5, Fig. 2 (Messina).

Vinciguerria poweriae: Grey, 1964.

DIAGNOSIS: Small silvery fishes with photophores along ventral surface of head and body; head and body compressed; gill-rakers well developed, 14-16 total; eyes round; dorsal fin rays 13-15, the last ray above or behind anal fin origin; anal fin base equal to or shorter than dorsal fin base; anal fin rays 12-14; adipose fin over anal fin; pectoral rays 9-11; branchiostegal rays 8; 12-15 photophores from anal fin origin to ventral origin of caudal fin; no photophore at tip of lower jaw; one photophore in front of lower edge of eye and another behind lower edge of eye; premaxillary teeth uniserial, with 3 or 4 long teeth and a few smaller ones; lower jaw teeth biserial in front; vomer and palatines toothed; pterygoids and tongue toothless; maxilla with 2 supramaxillae; vertebrae 38-39 (Schaefer *et al.*, 1986).

Colour: Head and body dark dorsally, the flanks silvery; dark streak at tip of lower jaw and over premaxilla.

MATERIAL: Tristan: RUSI 33467: 49 mm TL.

REMARKS: The only specimen collected in this study was found floating dead on the surface near Tristan Island in December 1989, and represents a new record for the islands. During the day, this mesopelagic species is found at depths of 300-600 m, and at night it rises to 50-350m (Schaefer *et al.*, 1986).

Distribution: *V. poweriae* has a circumglobal, subtropical distribution (Schaefer *et al.*, 1986).

Family Sternoptychidae

Maurolicus muelleri (Gmelin, 1788)

Salmo mülleri Gmelin, 1788: 1378 (Sondmör, Norway).

Maurolicus muelleri: Weitzman, 1986.

DIAGNOSIS: Small silvery fishes with photophores along ventral surface of head and body; head and body compressed; long low dorsal adipose fin above rear end of anal fin; eyes large and round; teeth in jaws minute, uniserial or with a short outer row at front of lower jaw; dorsal fin base mostly in front of anal fin; dorsal rays 10-11; anal rays 19-23; pectoral rays 17-19; gill-rakers (17-21) + (4-7); 2 long groups of photophores along ventral edge of tail preceded by a single elevated light organ; a large light organ just behind symphysis of lower

jaw.

Colour: Brilliant silvery, the dorsal surface greenish blue.

MATERIAL: SAM 23950: 12 specimens; locality, "Tristan or Gough Island". None collected by the author.

REMARKS: This species was recorded from Tristan by Barnard (1925). Klages *et al.* (1988) recorded *M. muelleri* from the stomach contents of Rockhopper Penguins, *Eudyptes chrysocome moseleyi* at Gough Island.

Distribution: *M. muelleri* is found in tropical and temperate latitudes of all the oceans but it is more common in temperate waters (Weitzman, 1986).

Family Myctophidae

Lampadena dea Fraser-Brunner, 1949

Fig. 3.5

Lampadena dea Fraser-Brunner, 1949: 1097, fig., 1101, pl. 1A (48°27'S, 22°7-10'W); Hulley, 1981.

DIAGNOSIS: A charcoal black lantern fish with large mouth; maxilla not expanded posteriorly, extending well behind eye; anal fin base slightly shorter than dorsal fin base; dorsal fin origin above or slightly anterior to pelvic fin origin; a large, black-edged light organ on dorsal surface of caudal peduncle and another one on ventral surface of peduncle. Dorsal fin rays 13-15; anal fin rays 13-15; pectoral fin rays 13-16; gill-rakers (5-6)+(3-6).

MATERIAL: Inaccessible: RUSI 34036: 52 mm TL.

REMARKS: One specimen was collected with a net between 80 m and the surface. The species was recorded from the Tristan region by Hulley (1981). *L. dea* is a mesopelagic species of the open ocean; it is found at depths of 350-2390 m during the day and 150 m at night.

Distribution: Circumglobal in the vicinity of the STC (25° to 49° S latitude; Hulley, 1986).

Family Gadidae

Gaidropsarus novaezealandiae (Hector, 1874)

comb rockling

Fig. 3.6

Motella nova-zealandiae Hector, 1874: 107, Pl. 18, Fig. 76b (Cape Campbell, New Zealand); Svetovidov, 1986.

Gaidropsarus insularum Sivertsen, 1945: 8, Fig. 6 (Tristan da Cunha); Penrith, 1967; Cohen, 1986; Svetovidov, 1986; Duhamel, 1989).

Gaidropsarus parini Svetovidov, 1986: 122, Fig 2 (Nazca Ridge).

DIAGNOSIS: Body elongate, with long low dorsal and anal fins that reach posteriorly to the rounded caudal fin; the dorsal fin is preceded by a row of short filaments and a longer ray on the nape; pectoral fins large, with 20-21 rays; 2 barbels on snout (from anterior nostrils) and one on chin; pelvic fins with 7 rays; dorsal fin with 62-64 rays; anal fin with 50-54 rays; vertebrae 44-48; teeth in bands on jaws and vomer.

Colour: Head, body and fins dark reddish brown, purplish grey ventrally.

MATERIAL: Tristan: RUSI 31484: 142 mm TL; RUSI 33473: 3, 145- 160 mm; RUSI 33477: 3, 89-140 mm; RUSI 33482: 2, 130-180 mm; RUSI 33478: 6, 98-110 mm; SAM 24930: 147 mm SL. Gough: RUSI 31486: 193 mm; RUSI 13293: 300 mm; collected in 1978 by Gideon Rossouw; RUSI 33601: 3, 270-335 mm. Plus 25 additional RUSI specimens and 63 specimens (31-343 mm) examined at the islands but not preserved.

REMARKS: Juveniles and small specimens (less than 200 mm TL) are common in rockpools and in shallow subtidal areas at all the islands. Larger adults are found down to at least 50m. Prejuveniles (less than 30 mm TL) are silvery and are thought to be pelagic. This cryptic predator feeds on crustacea and small fishes.

The specific distinction of *G. insularum*, *G. novaezealandiae* and *G. parini* is dubious. According to Svetovidov's (1986) key to species of *Gaidropsarus*, these two species differ in the number of dorsal fin rays (*G. insularum* with 66-70 and *G. novaezealandiae* with 62-65), pectoral fin rays (*G. novaezealandiae* with 20-21 and *G. parini* with 23-24), length of first

dorsal fin base, and eye diameter. But these data are based on only 3 specimens of *G. insularum*, 10 *G. novaezelandiae*, and 2 *G. parini*. The dorsal fin-ray counts given in the text for *G. novaezelandiae* do not agree with those in his key and overlap the counts that he gives in the text for *G. insularum*. Furthermore, Duhamel (1989) has shown that the range in dorsal fin ray numbers of specimens from St. Paul and Amsterdam (62-76) includes the ranges for all three of these supposedly allopatric species.

Distribution: *G. novaezelandiae* is also known from the west coast of South Africa, St. Paul and Amsterdam Islands, Australia, New Zealand, Nasca Ridge, and the Bromley Plateau (31° S, 34° W).

Family Moridae

Physiculus karrerae Paulin, 1989

Fig. 3.7

Physiculus karrerae Paulin, 1989: 114, Fig. 10 (off Rio Grande, Brazil).

DIAGNOSIS (from Paulin, 1989; data from our specimens given in parentheses): Body elongate, cylindrical anteriorly, tapering to a narrow caudal peduncle and small separate caudal fin; snout rounded, mouth terminal; dorsal fin divided into a short anterior part of 7-8 (8) rays and a long posterior part of 68-76 (66-69) rays; anal fin with 73-78 (73-78) rays; pectoral fin rays 26-27 (25-27); about 150 vertical scale series from upper end of gill opening to caudal fin base; large light organ on belly, indicated by round black spot of naked (scaleless) skin in front of anus; diameter of light organ 16-18% of distance from anal fin origin to a interventral-line joining origins of pelvic fins; light organ closer to interventral-line than to anus; chin barbel present; no teeth on vomer; gill-rakers long and slender, 1-2 + 7-9; vertebrae 56 (58-59).

Colour: head and body mostly uniform reddish brown; abdomen dark bluish black; fins and lips dark brown.

MATERIAL: Nightingale: RUSI 33611: 2, 235-237 mm TL. Inaccessible: RUSI 33585: 11, 215-255 mm TL.

REMARKS: *Physiculus karrerae* has not been recorded from the islands previously. The species is common in the shelf waters from 50 m to at least 150 m at the northern islands, but it was not found at Gough. All specimens were collected in traps baited with fish.

Distribution: *P. karrerae* has a wide anti-tropical Atlantic distribution. The species was previously known from Bermuda, the Caribbean, southern Brazil and St Helena; depth range 250-800 m (Paulin, 1989). Specimens from the present study are the most southerly and the shallowest records for this species.

Family Exocoetidae

Cheilopogon pinnatibarbatus (Bennett, 1831)

smallhead flyingfish (flyingfish)

Fig. 3.8

?*Exocoetus exiliens* (non Linnaeus): Carmichael, 1819: 494.

Exocoetus pinnatibarbatus Bennett, 1831: 146 (Atlantic coast of North Africa).

Exocoetus lineatus Valenciennes, in Cuvier & Valenciennes, 1846: 92 (Gorée [Dakar] Sénégal).

Cypsilurus lineatus: Penrith, 1967.

Cypsilurus pinnatibarbatus: Gibbs & Staiger, 1970.

DIAGNOSIS: (from Gibbs & Staiger, 1970; data from the present study given in parentheses.)

Pectoral fins greatly enlarged, reaching past base of anal fin; pelvic fins also enlarged, reaching past origin of anal fin; pelvic fin origins closer to anal fin than to base of pectoral fins; anal fin origin under or behind base of 3rd dorsal fin ray; first pectoral fin ray unbranched, the rest branched; jaws subequal; teeth mostly unicuspid (conical); dorsal fin rays 11-14 (11-12); anal fin rays 9-12 (10); pectoral rays i,13-15 (i,13-14); vertebrae 49-51 (49); predorsal scales 39-47 (40, 45); head length contained 4.4-5.0 (4.4, 4.5) times in SL.

Colour: body dark iridescent blue dorsally, silvery white ventrally; pectoral fins dusky, with narrow pale transverse band and the rear margin pale.

MATERIAL: Tristan: RUSI 13015: 375 mm SL. Nightingale: RUSI 33597: 2, 460 mm TL.

REMARKS: These specimens represent the first record of this species from the islands. Flying fish are common in the waters around the northern islands in the warmer summer months

(November to April). Their presence coincides with sea surface temperatures of 15.5° to 20° C; according to Parin (1959), *C. pinnatibarbatus* comprises 6 subspecies, which are found circumglobally in waters of 15° to 25° C. At the Tristan group, flying fish are fed on extensively by the hammerhead shark, *Sphyrna mokarran*, and by the snoek, *Thyrsites atun*. Hammerhead sharks were seen feeding on flyingfish on the surface on a number of occasions. Two specimens of 460 mm TL were found after landing aboard ship at night. Carmichael (1819: 494) recorded a specimen of "*Exocoetus exiliens* that dropped on board a ship while at anchor, and which measured eighteen inches in length." He gave no descriptive details of the specimen, but judging from the large size, it is likely that this flying fish was *C. pinnatibarbatus*.

Distribution: Gibbs & Staiger (1970) mentioned that this species appears to be associated with islands or proximity to land and generally avoids tropical latitudes. It is known from the North Atlantic and the South Atlantic; specimens collected in this study represent the most southerly record for this species.

Hirundichthys rondeletii (Valenciennes, 1846)

subtropical flyingfish (flyingfish)

Exocoetus rondeletii Valenciennes, in Cuvier & Valenciennes, 1846: 115 (Mediterranean).

Hirundichthys rondeletii: Parin, 1984.

DIAGNOSIS: (Data from the present study given in parentheses.) Pectoral fins greatly enlarged, reaching past base of anal fin; pelvic fins also enlarged, reaching past origin of anal fin; pelvic fin origins closer to anal fin than to base of pectoral fins; anal fin origin under origin of dorsal fin; first 2 pectoral fin rays unbranched, the rest branched; jaws subequal; dorsal fin rays 10-12 (10); anal rays 11-12 (11); pectoral rays ii,15-18 (ii,16); predorsal scales 27-32 (29) [Heemstra & Parin, 1986].

Colour: body dark iridescent blue dorsally, silvery white ventrally; dorsal and caudal fins greyish; pectoral fins dark, with narrow pale margin along rear (ventral) edge of fin, other fins hyaline.

MATERIAL: Gough: RUSI 17709: 235 mm SL.

REMARKS: The single specimen reported on here was collected in 1972 by G. Basson and is a new record for the islands.

Distribution: *H. rondeletii* is a subtropical species of the upper epipelagic ecosystem (Parin, 1968). Gough Island is on the southern limit of the range for this species.

Family Scomberesocidae

Scomberesox saurus scomberoides (Richardson, 1842)

saury

Esox saurus Bloch & Schneider, 1801: 399 (part referring to J.R. Forster's ms. pertaining to New Zealand).

Sauris scomberoides Richardson, 1842: 26 (on *Esox saurus* above and G. Forster's illustration of New Zealand specimen).

Scomberesox saurus: Sivertsen, 1945.

Scomberesox saurus scomberoides: Hubbs & Wisner, 1980.

DIAGNOSIS: Body elongate, compressed, covered with small thin scales; dorsal and anal fins set on rear half of body with 4-6 finlets behind; jaw produced to form long slender beaks, with the lower jaw longest; dorsal fin rays (9-12) + 5 or 6 finlets; anal fin rays (11-14) + 6 or 7 finlets; pectoral fin rays 12-15; gill-rakers 39-51; vertebrae 64-70.

Colour: greenish brown to dark blue dorsally, separated by a silvery lateral stripe from the silvery-white ventral parts; fins hyaline.

MATERIAL: Tristan: SAM 28236: 186 mm BL. Inaccessible: RUSI 33473: 5, 23-25 cm TL.

REMARKS: Five fresh specimens of approximately 24 cm TL were removed from the gut of a snoek, *Thyrsites atun* off Inaccessible Island in February 1990. The saury was recorded from the region by Sivertsen (1945). It is likely that *S. saurus* is present in the surface waters of the region during the warmer summer months as none were observed at sea during the winter. Hagan (1952) reported that this species was found in the stomach contents of the Rockhopper Penguin, *Eudyptes chrysocome moseleyi*, the Yellow-nosed Albatross, *Diomedea chlororhynchos*, and the Brown Noddy, *Anous stolidus stolidus*, which were collected from

December 1937 to March 1938.

Distribution: The saury has a circumglobal distribution in the southern hemisphere (Hubbs & Wisner, 1980).

Family Lophotidae

Lophotus lacepede Giorna, 1809

crestfish

Lophotus lacepede Giorna, 1809: 179, Pl. II, Fig. 1 (type locality, probably Mediterranean Sea).

DIAGNOSIS: Body elongate, markedly compressed, tapering evenly to a minute caudal fin; dorsal fin origin on head in front of eyes, the anterior head profile vertical or inclined forward; dorsal fin rays 220-263, the first ray produced; anal fin with 12-20 short rays placed near the caudal fin; pectoral fin rays 14-17; pelvic fins rudimentary, situated below and behind pectoral fin base; no scales; swimbladder present; ink sack posterior to swimbladder, empties into cloaca (Heemstra, 1986).

Colour: Head and body silvery; fins red.

MATERIAL: Tristan: SAM 28234: 136 mm TL.

REMARKS: The specimen from Tristan was caught on a line in December 1977 and donated to the South African Museum by Mr E. Viljoen and Capt. Stofberg of the **MFV HEKLA**.

Distribution: The crestfish inhabits the lower epipelagic zone in tropical and subtropical waters of all oceans.

Family Berycidae

Beryx decadactylus Cuvier, 1829

beryx

Beryx decadactylus Cuvier, in Cuvier & Valenciennes, 1829: 222 (Lisbon?); Penrith, 1967; Heemstra, 1986a.

DIAGNOSIS: Body compressed and deep, the depth 44-50% SL; scales ctenoid; cheeks and

operculum scaly; preopercle serrate, but no single large spine; mouth large, the maxillae expanded posteriorly, with 2 supramaxillae; dorsal fin with 4 spines and 16-20 rays; anal fin with 4 spines and 25-29 rays; pelvic fins with 1 spine and 10 rays; pectoral fins with 15-17 rays; lateral-line scales 56-61; gill-rakers (6-7) + (17-19) [Heemstra, 1986a].

Colour: Head and body scarlet dorsally, silvery white below; fins scarlet.

MATERIAL: Tristan: SAM 21809: 362 mm SL.

REMARKS: Penrith (1967) received one specimen from Tristan.

Distribution: *B. decadactylus* is found in subtropical and temperate waters of all oceans; records include both sides of the North and South Atlantic, South Africa, Australia, New Zealand, Japan and Hawaii (Heemstra, 1986a).

Family Macrorhamphosidae

Centriscops obliquus Waite, 1911

banded snipefish (piper)

Fig. 3.9

Centriscops humerosus obliquus Waite, 1911: 170, Pl. 26 (New Zealand?); Menni & Miquelarena, 1979; Heemstra, 1986b.

DIAGNOSIS: Body very compressed; snout produced into a long tube at the end of which is the small toothless mouth; scales minute but visible to the naked eye, like shark denticles with sharp ridges and spines; orbit rim spiny; bony plates on body above pectoral fins and along ventral midline; pelvic fins small, with a spine-like ray and 4 branched rays; dorsal fin with 7 spines (2nd spine greatly enlarged and somewhat movable, the other spines fixed) and 16-18 segmented rays; anal fin with 17-21 rays; pectoral fin rays 15-17; snout length contained twice in body length; orbit diameter contained 3.0-3.2 times in snout length.

Colour: Males white or pale orange, with 6 oblique dark red bands on body; females with several horizontal, wavy dark stripes (see Fig. 3.9).

MATERIAL: Tristan: RUSI 33608: 145 mm TL. Gough: RUSI 33496: 2, 138-153 mm TL.

REMARKS: The specimens from the present study represent the first record of *C. obliquus* from the region. Although it is found at all the islands, *C. obliquus* is seldom encountered because it is caught only in lobster traps set at 50 m and deeper. One specimen was picked up on the beach after a storm. Males and females differ considerably in colour pattern, as described by Menni & Miquelarena (1979).

Distribution: *C. obliquus* is known from South Africa, Australia, New Zealand, Argentina (Heemstra, 1986b) and St Paul/Amsterdam Islands (Duhamel, 1989).

Notopogon lilliei Regan, 1914

round bellowsfish (piper)

Fig. 3.9

Notopogon lilliei Regan, 1914: 14 (New Zealand); Sivertsen, 1945; Heemstra, 1986b.

DIAGNOSIS: Body very compressed; snout produced into long tube at the end of which is a small toothless mouth; scales microscopic, laneolate and erect, giving the body a velvet feel; orbit rim not spiny, body depth (vertical at origin of pelvics) more than snout length and contained 1.6-1.9 times in distance from eye to end of caudal fin; distance from eye to origin of second dorsal spine distinctly less than distance from eye to caudal fin base; distance from base of second dorsal spine to first dorsal ray not more than length of soft dorsal fin base; eye diameter contained 2.7-4.0 times in snout length; snout length 1.6-1.9 times in body length (from rear edge of gill cavity to caudal fin base); dorsal fin with 7 spines (2nd spine greatly enlarged and somewhat moveable, the other spines fixed) and 14 to 15 segmented rays; anal fin rays 17-19; pectoral fin rays 16-17; pre-dorsal profile of body evenly convex; adults with a patch of short bristles above operculum.

Colour: Body orange, with silvery white patches anterior and posterior to pectoral fins; soft dorsal, caudal and anal fins with white bands.

MATERIAL: Tristan: RUSI 33490: 163 mm TL; SAM 26697: 86 mm BL. SAM 27479: 122 mm BL. Inaccessible: RUSI 33616: 2, both 167 mm TL. Nightingale: RUSI 33492: 226 mm TL; RUSI 33623: 222 mm TL. Gough: RUSI 33617: 200 mm TL.

REMARKS: *N. lilliei* is common in depths greater than 50 m at all the islands and is eaten by

Polyprion oxygeneios. All the specimens were collected in lobster traps set in depths from 40-200 m. *N. lilliei* is sometimes found washed up on beaches after storms. Hagan (1952) found this species in the stomach contents of the Blackbrowed Albatross, *Diomedea melanophris*, although it must be concluded that these specimens were scavenged after being washed up on the beach as the species lives in deeper waters.

Penrith (1967) suggested that the species originally recorded by Sivertsen (1945) as *N. lilliei* was *N. macrosolen* Barnard, 1925. However, the relatively large collection of specimens that are now available indicate that the species is indeed *N. lilliei*. According to Heemstra (1986b), *N. macrosolen* has a smaller eye (4.2-5.2 times in snout length), longer snout (1.3-1.5 times in body length), body depth 1.9-2.2 times in distance from eye to end of caudal fin, and the predorsal profile is straight (or nearly so) from the eye to the first dorsal spine.

Distribution: *N. lilliei* is also known from South Africa, New Zealand and South Australia (Heemstra, 1986b).

Family Scorpaenidae

Helicolenus mouchezi (Sauvage, 1875)

(soldier)

Fig. 3.10

Sebastes mouchezi Sauvage, 1875: 988 (St Paul Island).

Helicolenus tristanensis Sivertsen, 1945: 17-19, Pl.1, Fig. 12 & Pl. 6, Figs. 3-4 (Tristan da Cunha); Eschmeyer, 1969.

Helicolenus mouchezi: Eschmeyer & Hureau, 1971.

Helicolenus dactylopterus goughensis Barsukov, 1979: 12, Fig. 2 (Gough Island).

Helicolenus dactylopterus mouchezi: Duhamel, 1989.

DIAGNOSIS: Dorsal fin with 12 spines and 12-13 rays; anal fin with 3 strong spines and 5 or 6 rays; head spiny, but the suborbital ridge with or without a small spine below front edge of eye; pectoral fin rays 18-20; the upper part of fin truncate, the lower 8 rays unbranched and thickened with the tips free; lateral-line scales 27-30; gill-rakers 7-8 + 17-19, total 25-27; vertebrae 25 or 26. Head length (measured from front of upper jaw to tip of upper opercular spine) 37-39% SL; body depth 31-35% SL; orbit diameter 9.9-13.1% SL. Attains 420 mm

total length.

Colour: Ground colour variable, from brown to pale red; head, body and dorsal fin covered with conspicuous, small, dark brown spots; dark spots also on other fins; belly white; peritoneum and inside of operculum black; tongue and posterior part of buccal cavity dark grey.

MATERIAL: Tristan: RUSI 33619: 230 mm TL. Inaccessible: 33500: 3, 138-165 mm TL. Nightingale: RUSI 33590: 8, 159-253 mm TL. Gough: RUSI 7682: 293 mm SL; RUSI 18244: 2, 370-410 mm SL; RUSI 18248: 2, 310-340 mm SL. Plus 14 additional RUSI specimens and 96 fish of 128-420 mm TL examined at the islands.

REMARKS: At Tristan, the soldier inhabits deeper water (40 to at least 200 m) than the other scorpaenid (*Sebastes capensis*), and smaller size classes are not found close to shore. Because of its preference for deeper water, *H. mouchezi* is less common than *S. capensis* in the catch of local fishermen. *H. mouchezi* is a fecund live bearer (approximately 300 000 embryos counted in the ovary of a 400 mm TL specimen) spawning during the summer months from October through to April. The larvae are born at a size of 3.5-4.0 mm TL. Moser (1967) reports that *Sebastes paucispinis* in Southern California is ovoviviparous with large females producing up to two million larvae in one brood. *H. mouchezi* feeds almost exclusively on fish.

This species was thought to be endemic to the Tristan islands by Sivertsen (1945). Eschmeyer & Hureau (1971) suggested that *H. mouchezi* Sauvage, 1875, from Amsterdam and St Paul Islands is conspecific with *H. tristanensis*, and their suggestion is accepted. *H. mouchezi* differs from *H. dactylopterus* of South Africa in having a wider interorbital (13.8-15.6% HL, [n = 9, 179 - 278 mm SL] versus 11.2-13.9% HL [n = 8, 203 - 226 mm SL] in *H. dactylopterus*), shorter dorsal fin spines (3rd dorsal spine 13-16% SL, versus 16-18% SL in *H. dactylopterus*), fewer gill-rakers (lower-limb rakers 17-19 versus 20-22) and in colour pattern (head and body covered with conspicuous, small, close-set dark brown spots, versus dorsolateral parts of body with a few small, faint, irregular dark spots).

Barsukov (1979) described a new subspecies (*Helicolenus dactylopterus goughensis*) from Gough Island based on 5 specimens. Three of the four characters that Barsukov used to

differentiate *H. goughensis* from other species or subspecies of *Helicolenus*, namely body depth (28.7-30.8% SL), the number of anal fin rays (5 or 6) and the colour pattern do not differ significantly from the condition in *H. mouchezi* from Tristan and St Paul/Amsterdam islands (Duhamel, 1989). The fourth character, 26 vertebrae is also not useful to distinguish specimens from Gough Island; of 4 specimens from Tristan that were X-rayed in the present study, 1 has 26 vertebrae and the other 3 fish have 25 vertebrae.

Distribution: Tristan da Cunha group, Gough Island, St Paul and Amsterdam islands (Duhamel, 1989).

Sebastes capensis (Gmelin, 1788)

false jacobever (soldier)

Fig. 3.11

Scorpaena capensis Gmelin, in Linnaeus, 1788: 1219 (Cape of Good Hope); Carmichael, 1819.

Sebastichthys capensis: Sivertsen, 1945.

Sebastes capensis: Eschmeyer, 1969; Eschmeyer & Hureau, 1971; Eschmeyer, 1986.

DIAGNOSIS: Dorsal fin with 13 spines and 13-14 rays; anal fin with 3 strong spines and 6 rays; head spiny, but the suborbital ridge without a small spine below front edge of eye; pectoral fin rays 18-19, the lower 9-10 unbranched, the fin wedge-shaped; lateral-line scales 34-41; gill-rakers including rudiments 8-9 + 19-21; vertebrae 25 or 26. Head length 37.7-39.1% SL; body depth 32.9-36.0% SL.

Colour: variable, ranging from gold, through red, to orange with 5 or 6 pale spots on body at base of dorsal fin.

MATERIAL: Tristan: RUSI 33473: 148 mm TL; RUSI 33582: 318 mm TL; RUSI 33621: 255 mm TL; SAM 26696: 153 mm SL.. Inaccessible: RUSI 33489: 165 mm TL; RUSI 33589: 121 mm TL; RUSI 33592: 3, 125-233 mm TL. Nightingale: RUSI 33497: 3, 225-247 mm TL; RUSI 33589: 7, 153-264 mm TL. Gough: RUSI 33563: 330 mm TL; RUSI 33564: 435 mm TL. SAM 27489: 259 mm SL; SAM 29626-29631: 29, 117-398 mm SL; SAM 30444: 3, 150-258 mm SL; SAM 30445: 3, 195-266. Plus 30 additional RUSI specimens and 456 fish of 107-455 mm TL examined at the islands.

REMARKS: *S. capensis* occurs at all the islands from 2 to about 150 m, but it is apparently rare at depths greater than 100 m. Small individuals (less than 200 mm TL) are found in rockpools and shallow sub-tidal habitats to about 10 m. Adults are found in deeper water. This species is the second most abundant fish (after the five-finger) in the catch of the Tristan fishermen. It is used only as lobster bait. *S. capensis* is highly territorial, even as juveniles, with single individuals occupying caves and clefts. It is ovoviviparous and highly fecund (215 000 embryos counted in a 405 mm TL, 1070 g fish). The embryos hatch inside the mother's ovary and are released at a length of 0.3-0.4 mm TL) as free-swimming larvae. This ambush predator feeds mainly on fishes, but will also take benthic invertebrates.

Distribution: Chen (1971) considered the 11 nominal species that have been described from South America, Tristan da Cunha, Gough Island and South Africa as conspecific. According to Eschmeyer & Hureau (1971), who apparently were not aware of Chen's (1971) work, *S. capensis* may prove to be synonymous with *S. oculatus* Cuvier, 1833 of Chile and Argentina. The colour photo of the specimen from South America that was published by Nakamura (1986c) is very similar to *S. capensis*, but the count of 50-66 lateral-line scales given by Nakamura is much higher than in *S. capensis* or in the South American specimens examined by Chen (1971). Perhaps Nakamura was counting scale series above the lateral line, rather than pored lateral-line scales. Nakamura's count of "D XII, 12-14;" for the dorsal fin spines of *Sebastes oculatus* is also a mistake; this should have been written D XIII, 12-14 (i.e., 13 dorsal fin spines).

Family Polyprionidae

Polyprion oxygeneios (Bloch & Schneider, 1801)

wreckfish (steambras)

Fig. 3.12

Epinephelus oxygeneios Bloch & Schneider, 1801: 301 (New Zealand).

Polyprion oxygeneios: Roberts, 1989.

DIAGNOSIS: Body oblong, somewhat compressed, covered with small strongly ctenoid scales; body depth contained 3.3-3.8 times in SL (for fish larger than 25 cm SL); dorsal fin with 11 or 12 strong spines and 11 or 12 soft rays; anal fin with 3 spines and 8-10 rays; pectoral fins shorter than pelvics; caudal fin truncate; head, except for snout scaly; maxilla

exposed, scaly, with well-developed supramaxilla; rear edge of opercle with 2 spines, the lower one at the end of a distinct horizontal ridge; preopercle with large spines in juveniles, serrate in adults; teeth villiform, in bands on jaws, vomer and palatines and in a small oval patch on tongue; vertebrae 13+14.

Colour: Body distinctly bicoloured, the dorsal half dark bluish grey to green and ventral half abruptly pale.

MATERIAL: Tristan: SAM 28235, 1000 mm SL; 23 specimens 570-1450 mm TL examined at Tristan, but none preserved by the author. Gough: SAM 30450, 460 mm SL.

REMARKS: According to Roberts (1989) the genus *Polyprion* comprises two species, *P. oxygeneios* and *P. americanus* (Bloch & Schneider, 1801), both of which are widely distributed in the Southern Hemisphere. *P. americanus* also occurs in the North Atlantic; it differs from *oxygeneios* in having a deeper body (body depth 2.3-3.0 times in SL for fish larger than 250 mm SL) and a mottled or uniformly dark colour pattern (body not distinctly bicoloured).

Rowan and Rowan (1955) reported an 8-foot steambras from Tristan, and they identified this species as "*Polyprion americanus*". All of the *Polyprion* that were seen from Tristan (some 50 specimens) were *P. oxygeneios*, but *P. americanus* might also occur there, as it is known from Vema Seamount (Penrith, 1967; SAM 24300, 457 & 581 mm SL; SAM 31701, 530 mm SL) and is common off South Africa and the coast of Argentina.

P. oxygeneios occurs at all three of the northern islands and at Gough. It lives on high relief, rocky bottom at depths of 80 m to at least 200 m. It is not often caught by the local fishermen (about 100 individuals a year), and no juveniles smaller than 500 mm TL were seen. Juveniles are pelagic until at least 300 mm TL and often associate with floating objects (Roberts, 1989). An increase in gonad weight occurs towards the end of summer indicating that the species spawns at this time (February - April). *P. oxygeneios* feeds mainly on fish and rock lobster.

Distribution: The species has been reported from depths of 100 - 1000 m along continental coasts and off oceanic islands in most temperate and subtropical regions of the Southern Hemisphere (Roberts, 1989), including St Paul and Amsterdam Islands (Duhamel, 1989).

Family Serranidae

Lepidoperca coatsii (Regan, 1913)

Fig. 3.13

Caesioperca coatsii Regan, 1913: 237, Pl. 6, Fig. 1 (Gough Island).

Lepidoperca coatsii: Duhamel, 1989.

DIAGNOSIS: Dorsal fin with 10 spines and 16-18 rays, the interspinous membranes deeply incised; anal fin with 3 spines and 7-8 rays; pectoral fins with 16-17 rays; caudal fin truncate, with 15 branched rays; lateral-line scales 43-48; 2 or 3 rows of scales between lateral line and 5th dorsal fin spine; gill-rakers 9-12 + 22-25. Body depth contained 2.7-3.0 times in SL; head length 2.6-2.9 times in SL; eye diameter 2.4-3.0 times in head length (HL); bony interorbital width 4.0-5.2 times in HL; pectoral fins extend to between anus and base of 2nd anal fin ray, their length contained 1.1-1.2 times in HL; pelvic fins extend to between anus and anal fin origin. Head, including snout, maxilla, lower jaw and gular area scaly; maxilla with or without a splint-like supramaxilla; jaws with a row of small slender teeth and a pair of widely-spaced, exerted, small canines at front; 2 or 3 small canines at middle of each dentary; chevron-shaped band of small sharp teeth on vomer and 4 or 5 series of similar teeth on palatines; no teeth on tongue. Vertebrae 10+16; interneural bones 3

Colour: Head and body pinkish orange fading to white ventrally; 4 or 5 distinct purple lines running longitudinally along the body below pronounced lateral line. Fins yellowish, except spinous part of dorsal which has dark blotches on interspinous membranes.

MATERIAL: Nightingale: RUSI 31523: 3, 110-113 mm SL; RUSI 33606, 111 mm. Gough: BMNH 1912.7.172-6 (British Museum of Natural History): 4, 70-78 mm (syntypes of *Caesioperca coatsii* Regan); RUSI 13294: 82.5 mm; RUSI 33609: 138 mm.

REMARKS: *Lepidoperca coatsii* is a relatively rare reef species found at all the islands. The species was originally described from specimens collected at Gough Island in 100 fathoms by the *SCOTIA* (Regan, 1913). The 6 specimens collected in the present study were captured at Gough and Nightingale islands in lobster traps set in about 50 m of water.

The two specimens examined by P.C. Heemstra (J.L.B. Smith Institute of Ichthyology) from

the Indian Ocean Austral Seamount (MNHN 1984-82 & 1984-83 [National Museum of Natural History, Paris]) are indistinguishable from the Gough Island material.

Distribution: In addition to the Tristan Archipelago and Gough Island, *L. coatsii* has also been reported from St Paul and Amsterdam Islands (Duhamel, 1989) and the Austral Seamount (Duhamel, 1984).

Family Pentacerotidae

Pseudopentaceros richardsoni (Smith, 1844)

pelagic armourhead

Fig. 3.14

Pentaceros richardsoni Smith, 1844: 51 (pages not numbered), Pl. 21 (Cape of Good Hope); Smith, 1964; Penrith, 1967.

Pentaceros knerii Steindachner, 1866: 208, Pl. 1, Figs. 1 & 2 (off Cape Horn, Chile).

Griffinetta nelsonensis Whitley & Phillips, 1939: 233 (Nelson, New Zealand).

Pseudopentaceros richardsoni: Hardy, 1983; Heemstra, 1986c.

DIAGNOSIS: Body oblong, compressed; dorsal fin continuous, the spinous part much longer than soft-rayed part; dorsal fin spines 14 or 15, rays 8-10; anal fin spines 4 or 5, rays 7 or 8; pectoral fin rays 17-18; caudal fin truncate or slightly concave. Bones of head mostly exposed, rugose; mouth small, the maxilla not reaching past front edge of eye; lateral-line scales 74-86; gill-rakers (5-7) + (14-17).

Colour: Dark bluish dorsally, pale ventrally.

MATERIAL: Tristan: RUSI 33566, 465 mm TL; 33599, 455 mm TL; SAM 21791, 80 mm SL.

REMARKS: *P. richardsoni* was recorded from Tristan by Penrith (1967) who obtained a juvenile specimen from the Islands. Two adult specimens were collected with hook and line in 100 m during September 1989 and February 1990 respectively. The first was a 455 mm TL female with active gonads. The second was a 465 mm TL male with ripe testes. The species is therefore likely to be a summer spawner. It is thought that the species is common on the edges of the shelf surrounding the islands. Hardy (1983) described ontogenetic changes in the serrated ridges and spines on the head of small juveniles.

Distribution: *P. richardsoni* has been collected from depths of 50 - 600 m off South Africa, Australia, New Zealand and South America (Heemstra, 1986c; Penrith, 1967). Previous records from the North Pacific (Smith, 1964; Penrith, 1967) were reidentified as two new species by Hardy (1983). The absence of this species at the Amsterdam Islands (Duhamel, 1989) is puzzling.

Family Bramidae

Brama australis Valenciennes, 1840

pomfret

Fig. 3.15

Brama australis Valenciennes, 1840: Pl. 44, Fig 1 and unnumbered text (Valparaiso, Chile); Pavlov, 1991: 6-9.

Brama sp. Mead, 1972: 81, Pl. 4.

DIAGNOSIS (modified from Pavlov, 1991); data from specimen collected in the present study in parentheses): Body oblong, distinctly compressed; body depth 2.1 times in SL, the greatest body width 2.7-3.9 times in distance between snout and pelvic fin origin (cannot be measured on the specimen collected in this study because of missing epaxial muscles); dorsal profile of head distinctly convex, the distance between eye and nearest point on dorsal midline more than half eye diameter. Dorsal and anal fins scaly, dorsal fin rays 31-36 (dorsal fin damaged); anal fin rays 26-29 (28; last ray split to its base, which is contiguous with base of 27th ray); pectoral fin rays 20-22 (21); caudal fin lunate; lateral scale series 78-85 (about 79); total developed gill-rakers on one side of first gill arch 18-24 (5+13 = 18); vertebrae 14-25 = 39 (16+24 = 40).

Colour: Head and body mottled metallic silvery-black, darker dorsally; scaleless snout and tips of median fin rays also black; inside of mouth black.

MATERIAL: Tristan: RUSI 34593, 490 mm SL.

REMARKS: Only one specimen was collected; it was stranded on Halfway Beach on Tristan Island. This is a new distributional record for the species. According to the Islanders, this fish is washed up fairly regularly after storms. It is therefore probable that the species is common

in waters not fished with hook and line (i.e., deeper than 200 m).

The identification of this specimen is somewhat tentative. It was damaged before it was recovered, and most of the dorsal fin and epaxial muscles are missing. Except for the vertebral count, all of the meristic data fit the diagnosis given by Pavlov (1991) for "*Brama australis* and rule out other species that are known from the Atlantic Ocean. According to Mead (1972), *B. brama* has more vertebrae and more anal fin rays; *B. dussumieri* has more vertebrae and fewer gill-rakers; *B. caribbea* has fewer vertebrae, fewer gill-rakers and fewer lateral scale series; *B. orcini* has fewer lateral scale series and fewer gill-rakers; *B. myersi* has fewer pectoral fin rays and more vertebrae.

Mead (1972) described two specimens from South Africa (434 mm SL) and New Zealand (468 mm SL) which he assigned to an undescribed species (designated "*Brama sp.*"). According to Mead (1972: 81), *Brama sp.* differs from *B. brama* and *B. japonica* in that the "the gill filaments (not the rakers) appear to be much longer (longer than distance between anterior nostril and orbit, nearly as long as snout; while in *B. brama*, and in *B. japonica* of somewhat shorter length, these filaments are about equal to the distance from anterior nostril to orbit)". In RUSI 34593, the length of the longest gill filaments on the first arch are 26 mm and the distance from anterior nostril to eye is 17 mm; Mead (1972) did not record these measurements for the two specimens that he examined.

B. australis is very similar to *B. japonica*, which is known only from the North Pacific. Pavlov (1991) mentioned that the dorsal head profile of *B. japonica* is more steeply convex than in *B. australis*, and this is also shown on Mead's (1972: Pls. 3 & 4) illustrations.

Distribution: *Brama australis* (including *Brama sp.* Mead 1972) is known from the southeastern Pacific Ocean, New Zealand, South Africa and Tristan da Cunha. Duhamel (1989) listed "*Brama sp.* Mead, 1972" from Amsterdam Island, based on a photograph.

Family Emmelichthyidae

Emmelichthys nitidus Richardson, 1845

southern rover

Emmelichthys nitidus Richardson, 1845: 47, Pl. 29, Figs. 7 & 8 (west coast of Australia); Heemstra & Randall, 1977; Heemstra, 1986d.

DIAGNOSIS: Body elongate, subcylindrical; body depth 4.1-5.2 times in SL, and less than head length; spinous dorsal fin separated from soft dorsal fin by a gap with 2-4 isolated spines; soft dorsal and anal fins with scaly basal sheath; dorsal fin with 13 spines and 9-11 soft-rays; anal fin with 3 spines and 10 rays; pectoral fin rays 20-23; caudal fin forked; upper jaw very protrusile; maxilla scaly, not covered by preorbital bone when mouth is closed; supramaxilla long and slender; lateral-line scales 87-98; gill-rakers (10-12) + (27-31); vertebrae 10+14.

Colour: Dark bluish grey dorsally, silvery reddish on ventral parts.

MATERIAL: Tristan: RUSI 34592: 285 mm TL.

REMARKS: *E. nitidus* occurs near the bottom in waters deeper than 100 m. The only specimens collected came from the guts of the deep water predator *Polyprion oxygeneios*. This is a new record for the region.

Distribution: The southern rover is also recorded from South Africa, Australia, New Zealand, St Paul and Amsterdam Islands (Heemstra, 1986d).

Family Carangidae

Naucrates ductor (Linnaeus, 1758)

pilotfish

Gasterosteus ductor Linnaeus, 1758: 295 ("in Pelago").

Naucrates ductor: Smith-Vaniz, 1986.

DIAGNOSIS (modified from Smith-Vaniz, 1986): Body elongate, subcylindrical; caudal fin forked; first dorsal fin with 7 spines (first minute), second dorsal with 1 spine and 30-35 rays; anal fin with 2 small spines preceding fin, a slender spine closely bound to first ray, and

19-22 rays; pectoral fins shorter than pelvics; length of dorsal-fin lobe in adults not much longer than pectoral fin, 11-13% fork length; gill-rakers (7-10) + (15-20) = 22-29. Maxilla reaches about to vertical through anterior edge of pupil. Caudal peduncle with a low fleshy keel on each side.

Colour: Body silvery blue dorsally, with 6 broad dark bars, including one at base of caudal fin; caudal fin lobes with white tips.

MATERIAL: Tristan: SAM 28931: 2, 312 & 341 mm FL.

REMARKS: *N. ductor* is a member of the pelagic, open-ocean fauna, and juveniles are often associated with jellyfishes and flotsam of terrestrial origin. The pilotfish got this name from its habit of riding the bow wave of ships or large fishes. This commensal relationship is adopted with several species of sharks, rays and other large fishes.

Distribution: The pilotfish has a circumtropical (Smith-Vaniz, 1986) and temperate distribution in all the oceans.

Seriola lalandi Valenciennes, 1833

giant yellowtail (yellowtail)

Seriola lalandi Valenciennes, in Cuv. & Val., 1833: 208 (Brazil); Smith, 1961: 568; van der Elst, 1981: 131. *Lichia pappei* Castelnau, 1861: 40 (Cape Province). *Seriola pappei*: Smith, 1959: 256; Smith & Smith, 1966: 71. *Seriola banisteri* Smith, 1959: 256, Fig. 2 (Natal). *Seriola (Regificola) pappei*: Smith, 1961: 568. *Seriola (Regificola) banisteri*: Smith, 1961: 568.

DIAGNOSIS (modified from Smith-Vaniz, 1986): Caudal fin forked; first dorsal fin with 7 spines (first minute), second dorsal with 1 spine and 30-35 rays; anal fin with 2 small spines preceding fin, a slender spine closely bound to first ray, and 19-22 rays; pectoral fins shorter than pelvics; length of dorsal-fin lobe in adults not much longer than pectoral fin, 11-13% fork length; gill-rakers (7-10) + (15-20) = 22-29. Maxilla reaches about to vertical through anterior edge of pupil. Caudal peduncle with a low fleshy keel on each side.

Colour: Blue to olivaceous above, shading to silvery white below; sometimes with narrow bronze stripe along midside of body; caudal fin olivaceous yellow.

REMARKS: *Seriola lalandi* was first recorded by Rowan and Rowan (1955) from Tristan. It seems that this fish is extremely rare in Tristan waters. A specimen of 600 mm TL was caught with hook and line in February 1989; it was not kept. One other specimen was observed underwater at about 20 m during March 1989. This subtropical species probably enters Tristan waters (possibly a fringe area of the species' range) during the warmer summer months.

Distribution: The yellowtail is considered to be circumglobal and restricted to subtropical waters (Smith-Vaniz, 1986).

Trachurus longimanus (Norman, 1935)

southern horse mackerel (mackerel)

Fig. 3.16

Decapterus longimanus Norman, 1935b: 255 (Tristan da Cunha); Penrith, 1967.

Trachurus longimanus: Duhamel, 1989; Collette & Parin, 1991.

DIAGNOSIS (data from 6 specimens, 355-492 mm FL): Body depth 4.4-5.0 times in FL; head length 3.7-3.9 times in FL; greatest height of scales in curved part of lateral line 3.0-3.8% FL; greatest height of scales in straight part of lateral line 4.0-4.6% FL. Caudal fin forked; first dorsal fin with 8 spines, second dorsal with 1 spine and 31-34 rays; anal fin with 2 distinct spines preceding fin, a slender spine closely bound to first ray, and 26-29 rays; last ray of dorsal and anal fins enlarged, connected by membrane to penultimate ray but set about 50% farther apart than other rays; pectoral fins with 22-23 rays (2 dorsalmost rays unbranched); curved part of lateral line with 48-53 scales (these scales vertically elongate but mostly hidden by overlying skin and small accessory scales); straight part of lateral line with 44-50 scutes (including those on caudal fin); gill-rakers (15-17) + (40-42) = 56-59.

Colour: Body silvery-grey, dark bluish green dorsally, silvery white ventrally; a small black spot on upper rear margin of operculum.

MATERIAL: Tristan: RUSI 34594: 395 mm FL; RUSI 34595: 492 mm FL. Inaccessible: RUSI 33567: 355 mm FL. Nightingale: RUSI 33569: 460 mm FL. Gough: RUSI 11084: 448 mm FL; SAM 30443: 400 mm FL. Plus 135 specimens examined at the islands but not preserved.

REMARKS: *T. longimanus* shoals from the surface down to about 50m and is present at Gough as well as the northern islands. At Tristan, it spawns from October to March. As expected from the long numerous gill-rakers, planktonic organisms such as amphipods and small pelagic fishes are the major prey. Collette & Parin (1991) reported euphausiids (*Euphausia recurva*) as the primary food item in specimens from Walters Shoal.

Distribution: *T. longimanus* was once thought to be endemic to Tristan da Cunha (Sivertsen, 1945), but it has since been recorded from Vema Seamount (Penrith 1967), St Paul Island (Duhamel, 1989) and Walters Shoal (Collette & Parin, 1991).

Family Echeneidae

Remora remora (Linnaeus, 1758)

shark remora

Echeneis remora Linnaeus, 1758: 260 (Indian Ocean).

Remora remora: Heemstra, 1986e.

DIAGNOSIS: Body elongate; top of head covered by a long flat sucking disk; body depth contained 5-8 times in SL; dorsal and anal fin bases less than twice head length; disc with 14-20 ridges; dorsal fin rays 22-26; anal fin rays 22-24; pectoral fin rays 26-30; gill-rakers (5-6)+(26-28).

Colour: Dark brownish grey.

MATERIAL: Tristan: RUSI 7296: 2, 102 & 167 mm SL.

REMARKS: As the name implies, the shark remora is usually attached to sharks. The two RUSI specimens were collected in June 1977 by Peter Warren, captain of **MFV TRISTANIA II**, a lobster vessel operating at the islands.

Distribution: Worldwide except in polar seas.

Family Cheilodactylidae

Acantholatris monodactylus (Carmichael, 1819)

(fivefinger)

Fig. 3.17

Chaetodon monodactylus Carmichael, 1819: 500, PL. 24 (type locality, Tristan da Cunha).

Cheilodactylus Carmichaelis Cuvier, in Cuv. & Val., 1830: 360 (based on *Chaetodon monodactylus* Carmichael).

?*Cheilodactylus aspersus* Richardson, 1850: 64 (type locality: "Port Arthur, Van Diemen's Land" [= Tasmania], erroneous).

Acantholatris monodactylus: Gill, 1862; Sivertsen, 1945; Penrith, 1967; Duhamel, 1989; Collette & Parin, 1991.

Chilodactylus monodactylus: Sauvage, 1879; Regan, 1913; Norman, 1935a.

DIAGNOSIS: Caudal fin forked; dorsal fin with 16-18 spines and 24-27 rays; anal fin with 3 spines and 11 or 12 rays; pectoral fins with 14-15 rays, the upper 2 rays and the lower 5-6 rays unbranched, the other rays branched; lateral-line scales 50-54; gill-rakers 5-7 + 16-18. Measurements from 18 specimens, 226-323 mm SL: Body depth at pelvic fin origin 38-46% SL, head length 28-34% SL, and snout to dorsal fin origin 28-34% SL; orbit diameter 4.9-9.5% SL, interorbital 5.6-9.5% SL, caudal peduncle depth 7.8-8.9% SL, longest pectoral ray 33-43% SL.

Colour: Body usually bronze (but the colour varies from silver through bronze to orange) with 5-6 dark brown or black vertical bars on dorsal part of body, the first at dorsal fin origin and the last at base of caudal fin; dorsolateral parts of head and body with numerous small black spots.

MATERIAL: Tristan: RUSI 33570: 253 mm SL; RUSI 33603: 284 mm SL. Nightingale: RUSI 33575: 2, 200-218 mm SL. Inaccessible: RUSI 33586: 2, 282-290 mm SL; RUSI 33587: 4, 214-252 mm SL. Gough: RUSI 33573: 250 mm SL; RUSI 33568: 323 mm SL; RUSI 33576: 281 mm SL; RUSI 33583: 226 mm SL; RUSI 33593: 241 mm SL; RUSI 33600: 274 mm SL; RUSI 33602: 280 mm SL. Amsterdam: RUSI 35212: 230, 282 mm SL.

REMARKS: The fivefinger is the most dominant species in terms of biomass on the shelf

areas of the three northern islands, and it is also the most common species captured for food and bait. It occurs in all well-covered habitats (i.e., algal covered reefs and kelp stands) from 1.5 m to at least 150 m. The species is an opportunistic carnivore, feeding on benthic invertebrates, planktonic salps and amphipods, and other fishes. It is normally restricted to within 10 m of the seabed. Larval and paperfish stages of this species are pelagic, while juveniles are usually seen swimming in shoals of up to 15 individuals within 2 metres of the bottom. Tagging studies done at Tristan show that larger individuals are territorial, and have a relatively small home range. Adults are often seen resting on the bottom in caves or crevices. The species attains 650 cm TL and is relatively slow growing. Age and growth studies using otoliths show that large adults attain ages in excess of 25 years. The fivefinger spawns in summer from early February to late April.

Specimens from Gough Island appear to have a smaller head than the *A. monodactylus* from the Tristan group: head length 28-29% SL (7 fish of 226-323 mm SL) versus head length 30-34% SL (10 fish of 200-290 mm SL). The colour patterns of *A. monodactylus* from Gough do not differ significantly from those at Tristan (or those that have been examined from St Paul and Amsterdam islands). In view of the small sample of fish that are available from Gough and the absence of any other differences in the specimens examined, the Gough population is considered to be conspecific with the Tristan *monodactylus*. More detailed notes on the biology and morphological variation of this species are presented in Chapter 4.

Distribution: In addition to the Tristan da Cunha group and Gough Island, *A. monodactylus* has been recorded from St Paul and Amsterdam Islands (Sauvage, 1879; Kner, 1865; Hureau, 1969; and Duhamel, 1989), at an un-named seamount in the southwest Indian Ocean (Duhamel, 1984), Walters Shoal (400 miles south of Madagascar, Collette & Parin, 1991) and from Vema Seamount in the southeast Atlantic (Penrith, 1967).

Family Latridae

Latris lineata (Forster, 1801)

striped trumpeter (funnyfish)

Fig. 3.18

Cichla lineata Forster, in Bloch & Schneider, 1801: 342 (New Zealand).

Latris lineata: Penrith, 1967; Last *et al.*, 1983; Duhamel, 1989).

DIAGNOSIS: (data from the present study given in parentheses) Body elongate, compressed, the depth contained 2.9-3.1 times in SL; caudal fin forked; dorsal fin with 18 spines and 34-36 rays, the fin divided almost to the base between spiny and soft-rayed parts; anal fin with 3 spines and 25-27 (28) rays; pectoral fins with 18 (17) rays, the lower 8 or 9 rays unbranched, the middle rays longest; gill-rakers 6 + 16.

Colour: Head and body dark olive green dorsally, with 3 silvery bands from head to tail; belly silvery yellow; fins greenish yellow.

MATERIAL: Tristan: RUSI 33595: 745 mm TL. Gough: SAM 22623: (skin) 900 mm SL: SAM 22891: 900 mm SL.

REMARKS: One specimen was collected at Tristan Island in 80 m. This species is seldom hooked but is known from all the islands including Gough (Jimmy Glass, Tristan da Cunha, pers. comm.).

Distribution: *L. lineata* is also known from the Amsterdam Islands (Duhamel, 1989), Australia, New Zealand (Last *et al.*, 1983; Ayling & Cox, 1982) and the sub-Antarctic Auckland Islands (Kingsford *et al.*, 1989).

Mendosoma lineatum Guichenot, 1848

Fig. 3.19

Mendosoma lineatum Guichenot, 1848: 213 (Valparaiso, Chile); Gon & Heemstra, 1987; Duhamel, 1989.

DIAGNOSIS: Body elongate, moderately compressed, the depth contained 3.5-3.9 times in SL; caudal fin forked; dorsal fin with 22-24 spines and 24-27 rays, the fin divided between spinous and soft-rayed parts; anal fin with 3 spines and 17-21 rays; pectoral fin rays 16-18, the upper 2 and lower 6-8 rays unbranched, but not thicker or longer than other rays; mouth very protrusile, the upper jaw with 1 row of small conical teeth; no teeth on lower jaw, vomer or palatines; body covered with cycloid scales; lateral-line scales 69-77; lower-limb gill rakers 20-22.

Colour: Bluish green dorsally, fading to silver-yellow below lateral line; fins pale yellow, the caudal fin darker yellow.

MATERIAL: Tristan: RUSI 33471: 2, 83-86 mm TL; RUSI 33625: 225 mm TL. Nightingale: RUSI 33613: 218 mm TL. Gough: RUSI 26047, 175 mm SL; RUSI 33626: 4, 210-235 mm TL.

REMARKS: *M. lineatum* is common at all the islands and shoals in groups of similar-sized individuals. Adults are epibenthic from about 20 m, but juveniles and small fish shoal close to the surface where they are easy prey for birds. Klages *et al.* (1988) reported this species in the stomach contents of the Rockhopper Penguin, *Eudyptes chrysocome moseleyi* at Gough Island. Small shoals of juveniles occasionally become trapped in rockpools. *M. lineatum* is mainly planktivorous, but it will also feed on small pelagic fishes. The species forms an important prey item for the snoek, *Thyrsites atun*.

Distribution: Gon & Heemstra (1987) reported the first Atlantic record of this species from Gough Island. *M. lineatum* is also known from Chile, New Zealand, Tasmania, St. Paul and Amsterdam Islands (Gon & Heemstra, 1987; Duhamel, 1989) and the sub-Antarctic Auckland Islands (Kingsford *et al.*, 1989).

Family Labridae

Nelabrichthys ornatus (Carmichael, 1819)

Tristan wrasse (concha)

Fig. 3.20a+b

Labrus ornatus Carmichael, 1819: 502, Pl. 27 (Tristan da Cunha).

Labrichtys lantzii Sauvage, 1875: 988 (St. Paul Island).

Labrichtys isleanus Sauvage, 1875: 988 (St. Paul Island).

PlatyGLOSSUS robinsoni Gilchrist & Thompson, 1914: 86 ("Natal" [specimen evidently mislabelled]).

Nelabrichthys ornatus: Russell, 1983; Duhamel, 1989; Collette & Parin, 1991.

DIAGNOSIS: Body elongate, compressed; body depth contained 3.9-5.3 times in SL; head length 3.3-4.2 times in SL; snout 3.7-4.4, eye diameter 4.5-6.1, interorbital width 5.3-6.8 and suborbital depth 5.9-9.2 times in head. Caudal fin rounded; dorsal fin with 9 spines and 12-13 rays; anal fin with 3 slender spines and 11-12 rays; pectoral fin rays 12-14; lateral-line complete, with 26-27 scales; lateral line tubes branched; total gill-rakers 15-25; branchiostegal

rays 6; cheeks scaly; preopercle entire; vertebrae 9 + 17-18.

Colour: Sexually dichromatic; three colour phases are distinguished. Juveniles: predominantly yellow with indistinct markings of initial phase females. Initial (female) phase: head and body olive brownish with azure lateral stripes on body. Juveniles and females with 3 distinct black spots: one between first two dorsal fin spines, the second near base of dorsal fin between last 3 fin rays, and the third at middle of caudal fin base. Terminal (male) phase: Head and body brownish, the body scales marked with violet or red; lines on head and body violet or blue; dorsal fin purplish brown tinged with reddish, with 3 violet longitudinal stripes and a black spot between first and third spines (no black spot at rear end of dorsal fin or base of caudal fin); anal fin yellowish, violet edged; caudal fin reddish yellow, with concentric violet stripes; paired fins hyaline.

MATERIAL: Tristan: RUSI 33468: 2, 40-50 mm TL; RUSI 33483: 188 mm TL; RUSI 33607: 7, 90-175 mm TL; RUSI 33615: 6, 90-180 mm TL; SAM 10503 (5, not measured); SAM 10504 (6, not measured); SAM 24070 (1, not measured); SAM 25284 (1, not measured); SAM 23764 (1, not measured). Nightingale: RUSI 33481: 155 mm TL. Gough: SAM 29920 (9, 91-165 mm SL; SAM 29922: 6, 155-172 mm SL); SAM 29923: 4, 84-168 mm SL.

REMARKS: *N. ornatus* is numerically the most abundant species on the shelf areas of the three northern islands. It was not seen by the author at Gough Island, but there are three lots of specimens in the South African Museum (see above) that were collected at Gough Island with spearguns by W. Liltved and T. Gosliner in September 1981.

N. ornatus inhabits waters from 1.5 m to at least 50 m and is rarely seen more than 2 metres above the bottom. The species favours areas with plentiful cover, either in the form of reef or kelp beds. The diet of this fish consists of epiphytic organisms.

N. ornatus is a protogynous hermaphrodite with a lek mating system. All fish begin life as females, and some change to males at a size of 160-170 mm TL. The mechanism inducing this change is not clearly understood, but is thought to be related to size, as adult males establish temporary territories. Open areas surrounded by adequate cover are favoured for establishing territories, and larger males occupy more desirable sites that are close to cover and more sheltered. Secondary males of 170 mm TL and larger will set up territories about

2 m in diameter each evening throughout the spawning season (November to March). Vigorous displays are directed at any females moving into the territory of a particular male. If a female accepts the advances, the pair swim rapidly upwards and spawn in midwater. The mating system of this species is discussed in more detail in Chapter 5.

Distribution: *N. ornatus* is known from the Tristan da Cunha group, Gough Island, Vema Seamount (Duhamel, 1989), St. Paul and Amsterdam Islands (Duhamel, 1989) and Walters Shoal (Collette & Parin, 1991).

Family Bovichtidae

Bovichtus diacanthus (Carmichael, 1819)

(klipfish)

Fig. 3.21

Callionymus diacanthus Carmichael, 1819: 501, Pl. 26 (Tristan da Cunha).

Bovichthys diacanthus: Regan, 1913; Penrith, 1967.

DIAGNOSIS: Body elongate, subcylindrical, the depth contained about 5 times in SL; head length about 3 times in SL; Two dorsal fins joined at the base; first dorsal fin with 8-9 spines; second dorsal fin with 20-21 rays; anal fin rays 15-16; dorsal and anal fin-rays unbranched; pectoral fin rays 14-15; pelvic fins with 1 spine and 5 rays, the fin origin distinctly anterior to pectoral fin base; caudal fin truncate or slightly convex; head and body naked; a large spine on opercle.

Colour: Generally olive or blackish green with white blotches; belly silver white; lower border of paired fins, also anal and caudal fins edged with white. *B. diacanthus* is able to adopt a reddish brown or blackish colour in order to match the colour of its habitat.

MATERIAL: Tristan: RUSI 33484: 3, 135-162 mm TL; RUSI 33487: 6, 120-185 mm TL; RUSI 33488: 9, 115-152 mm TL; SAM 10505 (14); SAM 26991 (4); SAM 23951 (1). Gough: RUSI 33614: 190 mm TL; SAM 27478 (1); SAM 27481 (1); SAM 29925 (1); SAM 29926 (3). Plus 20 additional RUSI specimens and 160 fish of 50-250 mm TL examined at the islands.

REMARKS: *B. diacanthus* is extremely common in rockpools of 10 cm and deeper and in subtidal areas down to about 20 m. This species is able to tolerate a wide temperature range.

Sun-warmed rockpools where the species occurs reach summer midday temperatures of up to 27.4°C, and ocean winter temperatures can drop as low as 10°C at Gough Island.

The pelagic larva develops into a silvery postlarval stage, and at about 55 mm TL, the postlarvae move into shallow water where they transform to benthic olive-coloured juveniles. The pelagic postlarvae occur in large shoals and are important prey for predators such as *Thyrsites atun*. Adults become scarce or absent from the shallow subtidal region during February and March. Gonad development prior to this seaward movement suggests that it is a spawning related event. *B. diacanthus* feeds predominantly on epiphytic fauna and amphipods.

Distribution: *B. diacanthus* is endemic to the Tristan group and Gough Island. Other species of *Bovichtus* are known from St. Paul and Amsterdam Islands in the South Indian Ocean (Duhamel, 1989), the Antarctic Peninsula and the southern coasts of South America, Australia and New Zealand (Fischer & Hureau, 1985), and also the sub-Antarctic Auckland Islands (Kingsford *et al.*, 1989).

Family Gempylidae

Thyrsites atun (Euphrasen, 1791)

snoek

Scomber atun Euphrasen, 1791: 315 (Cape of Good Hope).

Thyrsites atun: Penrith, 1967; Nakamura, 1986a.

DIAGNOSIS: Body distinctly elongated and compressed, the greatest depth contained 7-9 times in SL; mouth large, with fearsome teeth; lateral line single, abruptly bent downwards below posterior dorsal fin spines; caudal fin forked; dorsal fin divided to the base before soft-rayed part, with 18-21 spines followed by a short fin of 10-12 rays and 5-7 separate finlets; anal fin of 2 or 3 minute spines, 8-11 rays and 5-7 finlets; pelvic fins small, with 1 spine and 5 rays; pectoral fin rays 14- 15; no fleshy keels on caudal peduncle or belly; 2 nostrils on each side of snout.

Colour: Silvery with purplish hue when fresh; fins dark grey.

MATERIAL: Tristan: RUSI 33480: 43 mm TL; SAM 10502 (3); SAM 28233 (2). Gough:

SAM 30439 (skull); SAM 30448 (1). Plus 60 specimens (maximum size 1260 mm TL) examined at the islands.

REMARKS: This mesopelagic predator occurs year round in the waters of all the islands, including Gough. The population at the islands appears to be self sustaining with larvae, juveniles and breeding adults present. Spawning occurs in shallow water throughout the summer months (October to April). Adult snoek feed primarily on fish, mainly pelagic juveniles of *Bovichtus diacanthus* and *Mendosoma lineatum*; during the summer months, exocoetids are also a common prey item.

Distribution: *T. atun* is found close to shore throughout the temperate waters of the southern hemisphere (Grant *et al.*, 1978). It was not previously known from Gough Island.

Family Trichiuridae

Lepidopus caudatus (Euphrasen, 1788)

buttersnoek

Trichiurus caudatus Euphrasen, 1788: 52, Pl. 9, Fig. 2 (Cape of Good Hope, South Africa).

Lepidopus caudatus: Nakamura, 1986b.

DIAGNOSIS: Body greatly elongated and compressed, the depth contained 11-15 times in SL; dorsal fin base runs entire length of body; no notch between dorsal fin spines and rays; dorsal fin with 9 slender spines and 88-100 rays; anal fin with 2 small spines and 61-64 rays, the first 40 or so rays embedded; pectoral fin rays 12; caudal fin small and forked; pelvic fins reduced to a scale-like spine inserted close behind pectoral fin base; a single nostril on each side of snout; lateral line single; scales absent.

Colour: Silvery; fins pale.

MATERIAL: Tristan: RUSI 33596: 1270 mm TL. Nightingale: RUSI 18251: 1500 mm TL.

REMARKS: Only one specimen of this benthopelagic species was collected off Tristan. This is a new record for the region. One other specimen was reported to have been caught by an islander in the past.

Distribution: The species has a wide distribution extending down the eastern Atlantic

from Iceland, Norway, to the Mediterranean, South Africa, an Indian Ocean seamount situated at 34°51'S, 53°14' E, Australia and New Zealand (Duhamel, 1984; Nakamura, 1986b).

Family Scombridae

Allothunnus fallai Serventy, 1948

slender tuna

Fig. 3.22

Allothunnus fallai Serventy, 1948: 132, Fig. 1 (South Island, New Zealand); Collette, 1986.

DIAGNOSIS: Body elongate, torpedo shaped, the depth contained 4.5-6.5 times in FL; head length 3.7-3.9 times in FL; first dorsal fin of 17-18 slender spines depressible into a groove; second dorsal fin with 12-13 rays followed by 6-8 little finlets; anal fin of 13-14 rays, followed by 6-7 finlets; caudal fin forked; pectoral fin rays 24-26; gill-rakers (21-25) + (49-53) = 71-78; vertebrae 20+19.

Colour: Bluish dorsally, white ventrally.

MATERIAL: Tristan: RUSI 31527, 265 mm TL.

REMARKS: One juvenile was collected on the surface at Tristan during February 1989. The slender tuna was not previously recorded from the region.

Distribution: Worldwide between 20° and 50°S (Collette, 1986).

Family Stromateidae

Hyperoglyphe perciforma (Mitchill, 1818)

barrelfish, Antarctic butterfish (bluefish)

Coryphaena perciformis Mitchill, 1818: 244 (New York harbour).

Perca antarctica Carmichael, 1819: 501, Pl. 25 (Tristan da Cunha).

Seriollella antarctica: Regan, 1913.

Seriollella antarctica: Sivertsen, 1945.

Palinurichthys porosus: Barnard, 1948, Smith, 1949.

Mopus perciformis: Smith, 1949.

Palinurichthys antarcticus: Penrith, 1967.

Hyperoglyphe antarctica: Haedrich, 1967, 1986; Duhamel, 1989.

DIAGNOSIS: Body stout, little compressed, the depth 2.5-3.4 times in SL; head length 2.8-3.2 times in SL; dorsal fin divided to the base, the front part low, with 7 or 8 short stout spines, not increasing in length posteriorly and less than half length of anterior soft-rays in second dorsal fin; dorsal fin origin on or slightly behind a vertical at upper end of pectoral fin base; second dorsal fin with 19-21 rays; anal fin with 3 spines (hidden at front margin of fin) and 14-16 rays; pectoral fin long and falcate, reaching vertical at anal fin origin, the rays 18-22; top of head naked except for a small patch of scales on each side above and behind eyes; lateral-line arched anteriorly, curving to mid-lateral position below middle dorsal fin rays, thence running straight to tail base; about 80-95 pored lateral-line scales; gill-rakers 6-7 + 16-18; vertebrae 25.

Colour: Body dark blue-grey fading to grey below; fins dusky.

MATERIAL: Tristan: RUSI 33565: 495 mm SL; RUSI 34597: 425 mm SL; RUSI 34598: 528 mm SL; RUSI 34599: 440 mm SL. Gough: RUSI 18246: 2, 385-420 mm SL; SAM 23311 (1); 30449 (1). Plus 178 specimens from Tristan, Nightingale, Inaccessible, and Gough examined in the field but not preserved.

REMARKS: The barrelfish occurs year round at depths of 40 to over 150 m. Fishes more than about 450 mm TL are epibenthic in shoals. Juveniles are pelagic and not captured by hook and line. In Tristan waters, barrelfish feed predominantly on cephalopods and colonial salps, but they will also take fish prey.

In New Zealand, "*H. antarctica*" reaches approximately 1000 mm TL and 14 kg in 9 years (Horn, 1988) and attains a maximum size of at least 1370 mm FL and a weight of 36 kg (McDowall, 1982). At Tristan, specimens of 800 mm TL are sexually mature, and spawning occurs during January and February.

According to Haedrich (1967), *H. antarctica* differs from all other species in its "low median finray counts, large mouth, and a characteristic patch of scales on the otherwise naked occiput ...". But the median finray counts reported by Haedrich are not lower than those reported for

H. perciforma, and Haedrich (1967) does not give measurements of either *H. antarctica* or *perciforma* to substantiate the supposed difference in mouth size. The presence/absence of a small patch of scales above and behind the eye in *H. perciforma* of the North Atlantic appears to be an ontogenetically variable character. Six juveniles that we examined from the western North Atlantic (MCZ 36624, 209 mm SL, from off Massachusetts, and MCZ 60816, 5, 115-131 mm SL [Museum of Comparative Zoology] from off New Jersey) did not have a patch of scales above and behind the eye; but according to Merriner *et al.*, 1970, there are "scales present posterior to the eye" in specimens of 345-819 mm TL from North Carolina. In view of the absence of significant differences between *H. perciforma* and *H. antarctica*, it is concluded that they represent a single widely distributed species.

Distribution: *H. perciforma* occurs widely in the North Atlantic and Mediterranean Sea (Karrer, 1986). If it is correct to synonymize *H. antarctica* with *H. perciforma*, then this species also has a wide Southern Hemisphere distribution. In addition to the Tristan da Cunha group, this species is known from Gough Island and Vema Seamount (Penrith, 1967), South Africa (Haedrich, 1986) St. Paul and Amsterdam Islands (Duhamel, 1989), southern Australia, New Zealand, Kermadec Islands (McDowall, 1982), and Chatham Islands east of New Zealand (Horn, 1988; Roberts, 1991). Although records of *H. perciforma* from the tropics are rare (perhaps non-existent), juveniles are often found in association with flotsam (hence the name "barrelfish"), a habit that is surely responsible for the wide distribution of this species and may provide a mechanism for mixing of populations from the North Atlantic and Southern Hemisphere.

Schedophilus velaini (Sauvage, 1879)

oval driftfish (stumpnose, snoutfish)

Fig. 3.23

Seriollella velaini Sauvage, 1879: 32, Pl. 1, Fig. 2 (St Paul Island).

Leirus moselli Cunningham, 1910: 95, Pl. 5 (St Helena Island).

Seriollella christophersenii Sivertsen, 1945: 23, Fig. 16, Pl. 1 (Tristan da Cunha).

Mupus imperialis (non Cocco, 1840): Smith, 1949; Penrith, 1967.

Schedophilus labyrinthicus McAllister & Randall, 1975: 1, Fig. 1 (Easter Island).

Schedophilus ovalis (non Cuvier, 1833): Barnard, 1948; Haedrich, 1967; 1986; Stehmann & Lenz, 1973; Edwards & Glass, 1987; Duhamel, 1989.

DIAGNOSIS: (from Haedrich, 1986; data from the present study in parenthesis): Body firm, depth 2.9-3.1 (2.9) times in SL; head length 3.2-3.6 (3.5) times in SL; single dorsal fin with 6-8 (7) weak spines graduating in length to the soft-rays and 27-29 (28) rays; anal fin with 3 spines (hidden at front margin of fin) and 19-21 (19) rays; pectoral fin elongate and pointed in adults, with 21-22 (22) rays; lateral-line scales 90-110 (90); gill-rakers 6-7 + 17 (7+17); vertebrae 10+15 (11+15); predorsal bone formula (of Ahlstrom *et al.*, 1976) 0/0/2+1+1/1+1/.

Colour: Olive green dorsally, silvery on sides and below.

MATERIAL: Tristan: RUSI 34596, 535 mm TL. Plus 60 specimens of 450-730 mm TL examined at the islands but not preserved.

REMARKS: *Schedophilus velaini* is relatively common at all the islands, and is often caught amongst bluefish. This species is generally epibenthic, but occasionally feeds higher up in the water column; stomach contents include planktonic salps, cephalopods and small fish. *S. velaini* is seldom caught in waters shallower than about 40 m. Spawning occurs in late summer. According to Haedrich (1986,) this species attains 1000 mm TL, but the largest specimen caught at the islands is only 730 mm TL.

McAllister & Randall (1975) pointed out that specimens of *S. ovalis* (Cuvier, 1833) from the North Atlantic Ocean have more anal fin-rays (21-23) compared with those from the Southern Hemisphere (18-20). But McAllister & Randall's distinction of their new species (*S. labyrinthicus*) from *S. christophersoni* and *S. velaini* based on a supposed difference in the number of anal fin-rays (18-19) in *labyrinthicus* [n=4], was 20 in the latter two species [n=2]) does not hold up in the light of data from the present study and those presented by Duhamel (1989) for additional specimens from St. Paul/Amsterdam Islands. It is concluded therefore, that *S. labyrinthicus* and *S. christophersoni* are synonyms of *S. velaini*.

Like *Hyperoglyphe perciforma* (and most other stromateioid fishes), the post larval and small juveniles of *Schedophilus velaini* are associated with flotsam and pelagic jellyfishes in the open ocean (Ahlstrom *et al.*, 1976). This habit accounts for the worldwide distribution of these species.

Distribution: *S. velaini* is known from St Helena, Vema Seamount, South Africa, St. Paul/Amsterdam Islands, Australia, Lord Howe, Rapa Island, Juan Fernandez Islands and Chile

(Haedrich, 1986, Duhamel, 1989).

SIGHT RECORDS

Family Sphyrnidae

Sphyrna mokarran (Ruppel, 1837)
great hammerhead (hammerhead shark)

Zygaena mokarran Ruppel, 1837: 66, Pl. 17 (Red Sea).

Sphyrna mokarran: Compagno, 1984.

DIAGNOSIS: Head flattened and greatly expanded laterally with the eyes on the ends of the lateral expansions; front of head with a median indentation; rear edge of pelvic fins markedly concave; second dorsal fin relatively large; its height greater than length of 3rd gill slit; teeth distinctly serrate.

REMARKS: This warm-water species occurs in Tristan waters only from November to April when water temperatures are at their highest (16 - 20° C). It has not been recorded from the islands before. During these months this shark is commonly seen feeding on the surface often in pursuit of exocoetids, which are also only present in the region during the warm-water months. No hammerhead was captured during this study. Identification was possible because *S. mokarran* has a high second dorsal fin that is easily visible when the shark swims at the surface. The other two *Sphyrna* species that are known from the South Atlantic have a much lower second dorsal fin that would not project much above the surface of the water (Compagno, 1984).

Distribution: *S. mokarran* is wide ranging in tropical seas close inshore and in the open ocean (Compagno, 1984).

Family Molidae

Mola sp.

Ocean sunfish were sighted on three occasions around the northern islands during the present study. The specimens were too large to capture. Ocean sunfish are found in all oceans but not

in polar seas (Heemstra, 1986f).

PROBABLE RECORDS

Family Hexanchidae

Hexanchus griseus (Bonnaterre, 1788)

sixgill shark

Squalus griseus Bonnaterre, 1788: 9 (Mediterranean).

Hexanchus griseus Compagno, 1984; Bass *et al.*, 1986a.

DIAGNOSIS: One dorsal fin; six gill slits on each side of head; lower jaw with a row of six large teeth on each side; mouth length contained 1.6-2.7 times in its width; snout length 4-7% TL, 2.0-2.8 times in mouth width; length of dorsal fin base contained 1.1-1.4 times in distance from dorsal base to origin of upper caudal fin lobe.

Colour: Grey.

REMARKS: A specimen that was caught in October 1989 in about 150 m off Gough Island represents the first record for the islands close to the STC. This shark was identified by David Ebert (formerly of the Department of Ichthyology and Fisheries Science, Rhodes University) when he was with the Shark Research Centre at the South African Museum. The specimen cannot now be located at either the South African Museum or the J.L.B. Smith Institute of Ichthyology. Roscoe (1979) mentioned a "*Hexanchus sp.*" as commonly caught and used for lobster bait by the Tristan fishermen, but this is probably *Notorynchus cepedianus* (see p. 24).

H. griseus is a benthic species that is found in depths of 100-1500 m in all oceans. It attains a length of 5+ m and a weight of 730+ kg.

Family Alepsauridae

?*Aleposaurus ferox* Lowe, 1833

lancetfish

?*Aleposaurus ferox* Lowe, 1833: 104 (seas off Madeira); Rowan & Rowan (1955); Heemstra

& Smith, 1986.

DIAGNOSIS: Body greatly elongated, compressed, without scales; fleshy keel along each side of caudal peduncle; dorsal fin high and long, with about 40 rays; anal fin much shorter, with 13-18 rays; dorsal adipose fin above posterior anal fin rays; caudal fin forked, mouth large, with fearsome teeth.

REMARKS: Rowan & Rowan (1955) reported "*Alepisaurus ferox*" from Tristan, but they gave no diagnostic information on their specimen. This fish could be either *A. ferox* or *A. brevirostris* Gibbs, 1960. The latter species is common at the sub-Antarctic islands (Gon, 1990), and both species belong to the lower epipelagic fauna of tropical and temperate waters of all oceans (Heemstra & Smith, 1986).

Family Myctophidae

?*Symbolophorus barnardi* (Tåning, 1932)

Myctophum humboldti: Brauer, 1906: 192 (in part); Barnard, 1925: 243 (in part); Sivertsen, 1945.

Myctophum humboldti barnardi Tåning, 1932: 128 (off Cape Point, South Africa).

Symbolophorus barnardi: Hulley, 1986.

DIAGNOSIS (from Hulley, 1986): Mouth subterminal, the maxilla moderately expanded posteriorly and reaching well past eye; anal fin base longer than dorsal fin base; pectoral fin unpigmented; dorsal fin rays 13-15; anal fin rays 21-23; pectoral fin rays 12-14; gill-rakers (4-6)+(12-14) = 17-20.

REMARKS: Sivertsen's (1945) record of "*Myctophum humboldti*" was based on a specimen dropped by a tern (*Sterna vittata*), which had been feeding close to Tristan Island. His identification was taken from descriptions by Barnard (1925) and Brauer (1906), and according to Hulley (1986), these descriptions apply (at least in part) to *Symbolophorus barnardi*. It is a high-oceanic mesopelagic species that comes to the surface at night.

Distribution: Circumglobal between 30° and 40°S.

Family Trachipteridae

?*Trachipterus trachipterus* (Gmelin, 1789)

perigrine ribbonfish

Cepola trachipterus Gmelin, 1789: 1187 (Adriatic Sea).

Trachipterus trachipterus: Heemstra & Kannemeyer, 1984.

DIAGNOSIS: (from Heemstra & Kannemeyer, 1986): Body extremely elongated and compressed, tapering evenly to a minute caudal fin that projects dorsally from the slender tip of the tail; dorsal fin with 145-184 rays, the fin base extends from head to caudal fin; anal fin absent; scales absent, but ventral edge of body with enlarged pointed tubercles; no membranous flaps on dorsal and pelvic fin rays of juveniles; pelvic fins absent in adults; pectoral fin with 13-14 rays; eye diameter 8.4-10% of distance from snout to anus and contained 1.4-1.6 times in length of lower jaw.

Colour: Head and body silvery; front of head, interorbital area, dorsal part of upper jaw and tip of lower jaw are black; young with 3-5 dark blotches on sides of body; dusky blotch usually visible on body at bases of 20-28th dorsal fin rays.

REMARKS: One specimen (length not given) was taken close to Gough Island in an RMT-2 midwater trawl in October 1980 (Miller, 1982). Efforts to obtain the specimen have been unsuccessful.

Distribution: This offshore epipelagic species is rare but widely distributed from the Mediterranean to South Africa, Japan and New Zealand (Heemstra & Kannemeyer, 1986).

DOUBTFUL RECORDS

Family Nototheniidae

Eleginops maclovinus (Cuvier, 1830)

REMARKS: *E. maclovinus* is known from Southern Chile, Argentina and the Falkland Islands (Nakamura, 1986c). It attains 60 cm SL and is a popular food fish at the Falkland Islands. One specimen, 231 mm SL, SAM 22892, was reported from Tristan by DeWitt *et al.* (1990: 285).

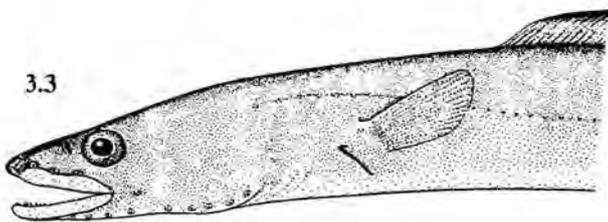
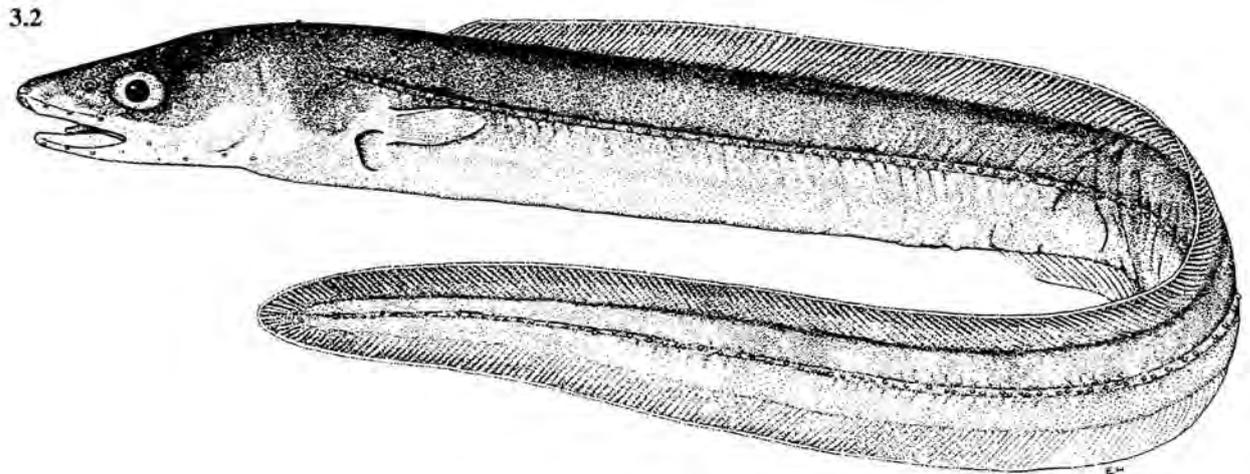
There is no collector or date of collection listed in the museum register for this specimen, and it is the only one known from the island. Some of the Tristan fishermen who have been to the Falkland Islands are familiar with *E. maclovinus*, and they say that this species does not occur at Tristan. The South African Museum specimen may have been mislabelled, and may have actually been caught at the Falkland Islands.

Notothenia coriiceps (Richardson, 1844)

REMARKS: A similar case to the previous species is the specimen of *Notothenia coriiceps* (SAM 22892) which is also listed in the Museum's register from Tristan, but without collector or date. *N. coriiceps* occurs at subantarctic islands all round the Southern Ocean (DeWitt *et al.*, 1990). It is a common shallow-water fish that is easy to see and to collect. This species was not observed at Tristan during the present study, and the fishermen there also have not seen this species.

Family Bothidae?

REMARKS: Two specimens were captured with a handnet in about 25 m at Nightingale Island in April 1989 by divers from the Sea Fisheries Research Institute in Cape Town. These flatfish were found in a patch of white sand, an unusual habitat in these waters as most sand is of volcanic origin and is black. These specimens are at present being identified by Dr D.A. Hensley, University of Puerto Rico.



Figures 3.1 to 3.4.: 3.1. *Torpedo nobiliana*, 890 mm TL (Tristan Island); 3.2. *Bassanago nielsenii*, 600 mm TL (Tristan Island); 3.3 + 3.4. *Conger wilsoni*, 490 mm TL (Gough Island).



Figures 3.5 to 3.12.: 3.5. *Lampadena dea*, 52 mm TL (Inaccessible Island); 3.6. *Gaidropsarus novaezelandiae*, 300 mm TL (Gough Island); 3.7. *Physiculus karrerae*, 237 mm TL (Nightingale Island); 3.8. *Cheilopogon pinnatibarbatus*, 460 mm TL (Nightingale Island); 3.9. *Notopogon lilliei* (top), 167 mm TL (Tristan Island), *Centriscops obliquus*, (middle, male; bottom, female), 145 mm and 130 mm TL respectively (Tristan Island); 3.10. *Helicolenus mouchezi*, 210 mm TL (Tristan Island); 3.11. *Sebastes capensis*, 320 mm TL (Tristan Island); 3.12. *Polyprion oxygeneios*, 610 mm TL (Tristan Island).



3.15

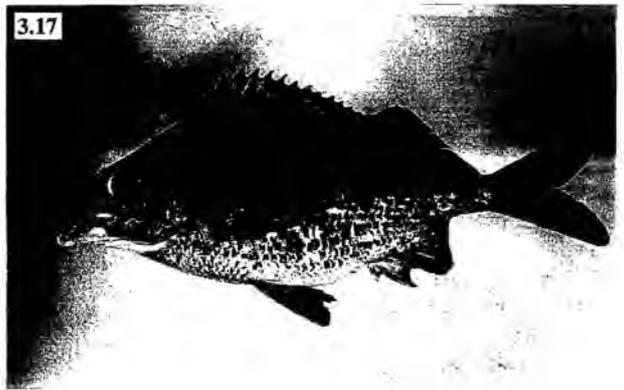
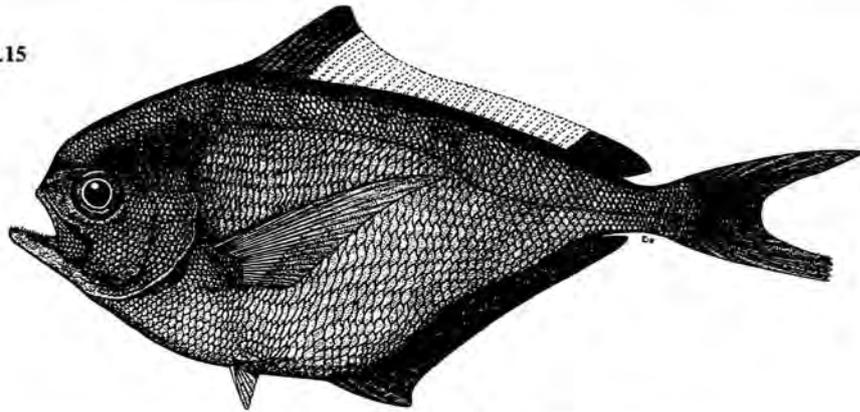
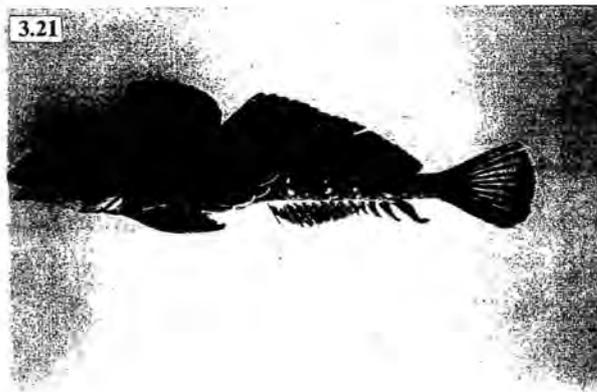
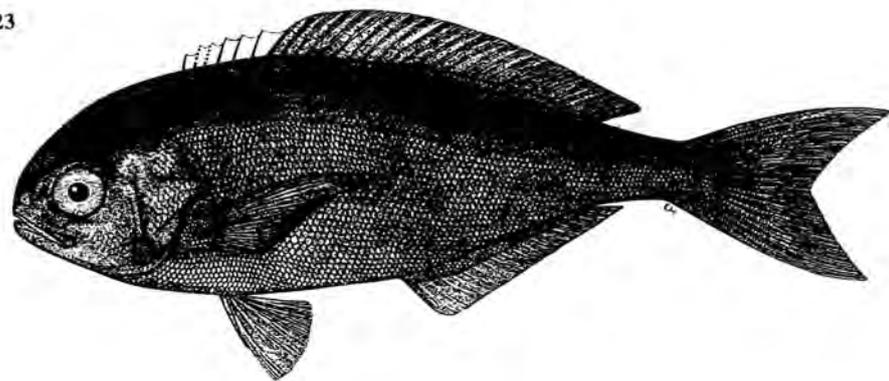


Figure 3.13 to 3.19.: 3.13. *Lepidoperca coatsii*, 110 mm TL (Nightingale Island); 3.14. *Pseudopentaceros richardsoni*, 455 mm TL (Tristan Island); 3.15. *Brama australis*, 490 mm SL (Tristan Island); 3.16. *Trachurus longimanus*, 290 mm TL (Tristan Island); 3.17. *Acantholatris monodactylus*, 200 mm TL (Tristan Island); 3.18. *Latris lineata*, 745 mm TL (Tristan Island); 3.19. *Mendosoma lineatum*, 225 mm TL (Tristan Island).



3.23



Figures 3.20 to 3.23.: 3.20a. *Nelabrichthys ornatus*, terminal male, 200 mm TL (Tristan Island); 3.20b. *Nelabrichthys ornatus*, juvenile, 55 mm TL (Tristan Island); 3.21. *Bovichtus diacanthus*, 120 mm TL (Tristan Island); 3.22. *Allothunnus fallai*, 265 mm TL (Tristan Island); 3.23. *Schedophilus velaini*, 430 mm SL (Tristan Island).

3.4 - DISCUSSION

There are several differences in the assemblage of neritic fish species collected at Tristan da Cunha and Gough Island further to the south. These differences are shown in Table 3.1. Fishes were split into a neritic (coastal) and an oceanic category. Penrith (1967) used the same categories although some of the species that he considered oceanic have been included in the neritic group due to biological information that is now available. The neritic group comprises those species that appear to be restricted to the islands during their adult stage. The oceanic group includes species that are wide ranging in the pelagic zone of the oceans. Once again it is stressed that although some oceanic species are included in the list presented in this chapter, only neritic species are used in the biogeographic analysis which follows.

Twenty seven of the 29 neritic species known from the region were recorded from the northern islands while only 18 were recorded at Gough.

Table 3.1. Species of fishes included in Chapter 3 from Tristan da Cunha and Gough Island, showing circumpolar affinities with the neritic ichthyofauna of other shallow water areas close to the STC. T = Tristan da Cunha group; G = Gough Island; V = Vema seamount; S = South Africa; N = New Amsterdam Islands; A = Australia and New Zealand; SA = South America. * = new record for Tristan da Cunha and Gough Island; + = species present; g = genus present.

NERITIC SPECIES	T	G	V	S	N	A	SA
<i>Notorynchus cepedianus</i> *	+	+		+		+	+
<i>Torpedo nobiliana</i> *	+		+		g		
<i>Hexanchus griseus</i> *		+		+	+	+	+
<i>Bassanago nielseni</i> *	+				g	g	+
<i>Conger wilsoni</i> *		+		+		+	
<i>Gnathopis capensis</i>	+			+	+		
<i>Gaidropsarus novaezelandiae</i>	+	+		+	+	+	+
<i>Physiculus karrerae</i> *	+			+		+	
<i>Beryx decadactylus</i>	+			+		+	g
<i>Centriscops obliquus</i> *	+	+		+	+	+	+
<i>Notopogon lilliei</i>	+	+		+	g	+	g
<i>Helicolenus mouchezi</i>	+	+		g	+	g	g
<i>Sebastes capensis</i>	+	+		+	g		+
<i>Polyprion oxygeneios</i> *	+	+	g	g	+	+	+
<i>Lepidoperca coatsii</i>	+	+			+		g
<i>Pseudopentaceros richardsoni</i>	+			+		+	+
<i>Emmelichthys nitidus</i> *	+			+	+	+	g
<i>Seriola lalandi</i>	+		+	+	+	+	
<i>Trachurus longimanus</i>	+	+	+	g	+	g	g
<i>Acantholatris monodactylus</i>	+	+	g		+		
<i>Latris lineata</i>	+	+			+	+	
<i>Mendosoma lineatum</i>	+	+			+	+	+
<i>Nelabrichthys ornatus</i>	+	+	+		+		

Table 3.1 cont.

NERITIC SPECIES	T	G	V	S	N	A	SA
<i>Bovichtus diacanthus</i>	+	+			g	g	g
<i>Thyrsites atun</i>	+	+		+	+	+	+
<i>Lepidopus caudatus</i> *	+			+	+	+	+
<i>Hyperoglyphe perciforma</i>	+	+	+	+	+	+	
<i>Schedophilus velaini</i>	+		+	+	+	+	+
<i>Brama australis</i> *	+			+	g	+	g
OCEANIC SPECIES							
? <i>Sphyrna mokarran</i> *	+						
<i>Prionace glauca</i>	+	+					
<i>Isurus oxyrinchus</i> *	+						
<i>Vinciguerria poweriae</i>	+						
<i>Maurolicus muelleri</i>	+	+					
<i>Lampadena dea</i>	+						
? <i>Symbolophorus barnardi</i>	+						
? <i>Alepisaurus ferox</i>	+						
<i>Cheilopogon pinnatibarbus</i>	+						
<i>Hirundichthys rondeletii</i> *		+					
<i>Scomberesox saurus scomberoides</i>	+						
<i>Lophotus lacepede</i> *	+						
<i>Trachipterus trachipterus</i>		+					
<i>Naucrates ductor</i> *	+						
<i>Remora remora</i> *	+						
<i>Allothunnus fallai</i> *	+						

Distributional records of neritic species occurring at Tristan da Cunha and Gough Island were compiled in order to characterise a shallow water Subtropical Convergence ichthyofauna. These records were taken from the present study, as well as from published checklists of fishes from other shallow water areas in the Southern Ocean. These included Vema Seamount (Penrith, 1967), South Africa (Smith & Heemstra, 1986), St. Paul and Amsterdam Islands (Angot, 1951;

Hureau, 1969; Beurois, 1976; Duhamel, 1989), Walters Shoal and an unnamed seamount south of Madagascar (Collette & Parin, 1991), South Australia (Maxwell, 1980; Last *et al.*, 1983), New Zealand (Ayling & Cox, 1982) and the southern parts of South America (Nakamura *et al.*, 1986). Based on these distributional records, neritic species occurring at Tristan da Cunha and Gough Island were broadly divided into three categories; those that occur widely to the north of the STC, those that occur only within or close to the STC, and those occurring south of the STC.

Five of the 29 neritic species that are common to the Tristan da Cunha group and/or Gough Island are found only within or close to the STC. Twenty two species are widely distributed in temperate and subtropical waters to the north of the STC, and only two species are known from sub-antarctic waters. Figure 3.24 illustrates the distributional composition of neritic fishes found in the Tristan region.

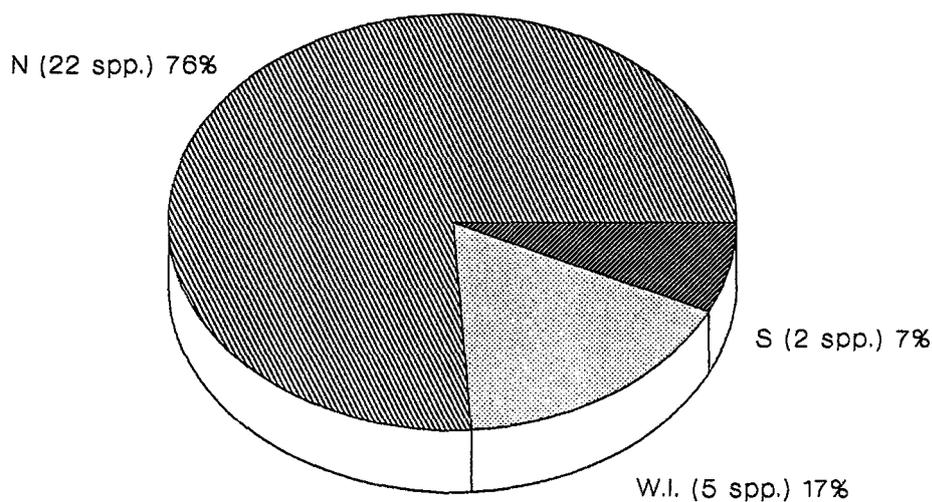


Figure 3.24. The distributional composition of neritic species occurring at Tristan da Cunha and Gough Island. N = species found only north of the STC; W.I. = species found only within or close to the STC; S = species found only south of the STC.

The circumpolar distribution of Tristan da Cunha and Gough Island neritic fishes at widely separated shallow water areas in the Southern Ocean indicates remarkably high levels of affinity. Table 3.1 shows the occurrence of neritic species recorded at Tristan da Cunha and Gough Island at these other localities. Table 3.2 summarises the affinities between these areas by indicating the number of common neritic species and genera. Vema Seamount in the south eastern Atlantic has only 21 % of the coastal species recorded from Tristan da Cunha and Gough Islands. South Africa has 62 %, St Paul and Amsterdam Islands 62 %, Australia and New Zealand 66 %, and South America 41 % of the coastal species recorded from the South Atlantic Islands respectively. At the generic level there are even greater circumpolar similarities. A more rigorous statistical comparison between the areas was not carried out as it was believed that this would not enhance understanding of ichthyofaunal affinities. Limited collections from areas such as Vema Seamount and the New Amsterdam Islands would lead to incorrect conclusions concerning the degree of affinity between the areas. The comparison by percentage shared species and genera presented in Table 3.2 simply indicates that many species and genera are widespread in the STC region.

Table 3.2. The number of species, and the percentage species and genera of Tristan/Gough neritic fishes at other shallow water areas close to the STC. T/G = Tristan/Gough; V = Vema seamount; S = South Africa; N = New Amsterdam Islands; A = Australia and New Zealand; SA = South America.

	T/G	V	S	N	A	SA
# sp.	29	6	18	18	19	12
% sp.		21	62	62	66	41
% genera		28	72	83	79	69

The fish assemblage from these isolated mid-Atlantic islands can be considered typical of a fauna from a transition zone. That is, there are sub-antarctic, temperate and subtropical elements present. A knowledge of the fish fauna from a frontal zone such as the STC yields valuable information about the factors affecting general dispersal and distribution of fishes in the oceans. Comparison of the fish fauna from the Tristan da Cunha group with that of Gough

Island is useful because of the different temperature regimes at the two localities. The close proximity of the two islands and the availability of reliable temperature data enables us to observe (in the field) how temperature affects the distribution of fishes in the oceanic region which, because of logistic constraints, is usually difficult to assess.

The differences between the fauna at Gough and Tristan are particularly apparent in the large, visible oceanic migrant species that move into the Tristan area from the north during the warmer summer months. At least four pelagic subtropical species (*S. mokarran*, *I. oxyrinchus*, *C. pinnatibarbatius*, *S. saurus scomberoides*) are found at the northern islands but not at Gough during this period (November to April). Although sampling at Gough was less intense than at Tristan during the present study it is apparent that at least two resident neritic species (eg. *Schedophilus velaini* and *Physiculus karrerae*) are only found at the northern islands. This indicates that there is a strong isolating factor preventing certain species from reaching Gough Island, only 200 miles to the south of Tristan. The subantarctic Prince Edward group and Crozet in the south Indian Ocean have no fishes in common with the areas close to the STC (Gon & Heemstra, 1990). The large percentage of species found only within or north of the STC indicates that the convergence zone is an effective barrier to the dispersal of animals in the Southern Ocean. As suggested by Sivertsen (1945) and Penrith (1967), water temperature appears to be the primary factor affecting the latitudinal distribution of fishes in the region.

The circumpolar distribution of neritic fishes occurring at Tristan and Gough is indicative of complex dispersal mechanisms. Species that are bound to shallow waters throughout their life cycle, or at least in the adult form, have evolved mechanisms to ensure dispersal to distant regions while maintaining a breeding population in the source region. It is hypothesised that dispersal via eggs, larvae and in some cases juveniles, has resulted in the ichthyofaunal similarities at widely separated localities. In the case of the Tristan da Cunha and Gough species this means long periods in the pelagic zone before metamorphosis into the benthic form occurs. It is known that at least 11 species of the wide-spread residents found at Tristan da Cunha and Gough Island have prolonged pelagic phases. The relatively large size that these species attain before adopting a benthic or epi-benthic life-style allows time for dispersal over considerable distances to take place.

The three congrid eels, *Bassanago nielsenii*, *Conger wilsoni* and *Gnathophis capensis*, the first recorded from Tristan and the Nasca Ridge, the second from Gough, South Africa and Australasia, and the third from Tristan and the New Amsterdam Islands, have relatively long lived leptocephalid larvae (Castle, 1986), which would facilitate dispersal within the ACC between these distant points. The widespread scorpaenid species, *Helicolenus mouchezi* and *Sebastes capensis* probably have long pelagic phases (Moser & Ahlstrom, 1978). *Polyprion oxygeneios*, another suprabenthic species, has juveniles which occur in the pelagia near floating objects until they grow to at least 300 mm TL (Roberts, 1989). This species is found off Tristan da Cunha and Gough Island, St Paul and Amsterdam Islands, Southern Australia, New Zealand and South America. The two extremely widely distributed stromateids *Hyperoglyphe perciforma* and *Schedophilus velaini* are pelagic until at least 300 mm TL (Haedrich, 1986; Horn, 1988). Relatively large pelagic stages of *Acantholatris monodactylus* (57 mm TL), *Mendosoma lineatum* (86 mm TL), and *Gaidropsarus novaezealandiae* (31 mm TL), species which are also widely distributed, were encountered during the present study. *Bovichtus diacanthus* has a pelagic juvenile stage which is terminated at a size of approximately 55 mm TL. Adults of all these species and congenetics of *B. diacanthus* occur at widely separated areas of shallow water in the Southern Ocean close to the STC.

Table 3.3 lists the known reproductive characteristics of Tristan da Cunha and Gough Island neritic species that have benthic or epi-benthic adults. The reproductive biology of only a few species is known in detail, therefore, common trends for the family or genus, taken from the literature, are listed where possible. These species display a wide range of reproductive strategies including live-bearing, protogynous hermaphroditism and pelagic broadcast spawning. Sinclair & Tremblay (1984) have shown that an increase in fecundity occurred with an increase in the duration of the larval phase in different populations of Atlantic herring. They suggested that an increase in fecundity is necessary to compensate for the higher population losses from the distributional area that occurs through a longer period in the pelagia, especially in poor retention areas. Therefore, observations from the present study were used to broadly categorise fecundity and egg size of the various species as being high or low, and small or large respectively. The presence or absence of an extended pelagic phase is listed in Table 3.3 from observations from the present study or from the literature.

Table 3.3. Reproductive characteristics of resident neritic Tristan da Cunha and Gough Island fishes.

Species	Known reproductive characteristics	Fecundity	Egg size	Long pelagic phase	Reference
<i>Notorynchus cepedianus</i>	live bearer	low	large	?	Ebert, 1990
<i>Torpedo nobiliana</i>	oviparous	low	large	?	Compagno, 1986; Heemstra & Smith, 1986
<i>Bassanago nielseni</i>	broadcast spawner	high	small	yes	Thresher, 1984
<i>Conger wilsoni</i>	broadcast spawner	high	small	yes	Castle, 1986
<i>Gnathophis capensis</i>	broadcast spawner	high	small	yes	Castle, 1968
<i>Gaidropsarus novaezelandiae</i>	?	?	?	yes	present study
<i>Physiculus karrerae</i>	?	?	small	?	present study
<i>Beryx decadactylus</i>	?	high	small	?	P.C. Heemstra, pers. comm.
<i>Centriscopus obliquus</i>	?	high	small	?	present study
<i>Notopogon lilliei</i>	?	high	small	?	present study
<i>Helicolenus mouchezi</i>	live bearer	high	small	yes	Thresher, 1984; present study
<i>Sebastes capensis</i>	live bearer	high	small	yes	Moser & Ahlstrom, 1978; present study
<i>Polyprion oxygeneios</i>	gonochorist	high	small	yes	Roberts, 1989
<i>Lepidoperca coatsii</i>	?	?	?	?	

Table 3.3 cont.

Species	Known reproductive characteristics	Fecundity	Egg size	Long pelagic phase	Reference
<i>Pseudopentaceros richardsoni</i>	?	high	small	?	present study
<i>Brama australis</i>	broadcast spawner	high	small	?	Mead, 1972
<i>Emmelichthys nitidus</i>	? protogynous	?	?	?	Thresher, 1984
<i>Acantholatris monodactylus</i>	broadcast spawner	high	small	yes	present study
<i>Latris lineata</i>	?	high	small	?	
<i>Mendosoma lineatum</i>	?	high	small	yes	present study
<i>Nelabrichthys ornatus</i>	protogynous	high	small	?	present study
<i>Bovichtus diacanthus</i>	? broadcast spawner	high	small	yes	present study
<i>Hyperoglyphe perciforma</i>	broadcast spawner	high	small	yes	Haedrich, 1986; present study
<i>Schedophilus velaini</i>	broadcast spawner	high	small	yes	Haedrich, 1986; present study

Forty one percent of the resident species collected have an extended pelagic phase. This is an extraordinarily high percentage given that the reproductive biology of most of the remaining 59 % of species is unknown. All the species with extended pelagic phases have a high fecundity and small egg size. Fifty eight percent of all resident species collected display this characteristic. Because high fecundity and small egg size is so common in species with extended pelagic phases the intuitive conclusion that was reached was that many of those species whose early life-history is unknown may display similar prolonged pelagic phases. It can be concluded that the common bond between many of the resident species at the Tristan and Gough is an extended pelagic phase and that this common trait is present in unrelated species displaying a wide range of reproductive modes. There is strong evidence, therefore, that an extended pelagic phase is important for the survival of the majority of the resident neritic species at the islands.

Given the common occurrence of the prolonged pelagic phase in these fishes a discussion of the possible mechanisms resulting in the wide distribution of these species is warranted. It is considered unlikely that the life-cycles of resident species at Tristan da Cunha and Gough Island includes a complete circumpolar cycle. That is, for spawning to take place at one point and settlement occurring at the same point after the pelagic stages have circled the southern ocean in the Antarctic Circumpolar Current (ACC). It is believed that at some point in history, chance events separated pelagic stage individuals as vagrants (*sensu* Sinclair, 1988) from a much more localised larval retention area closer to the source area. Enough vagrants must have reached suitable settling sites further on in the path of the ACC and South Atlantic Current (SAC) to facilitate the establishment of breeding populations at these new sites. It is probable that colonisation of suitable regions occurred sequentially in an easterly direction (from the source areas) under the influence of the ACC and the SAC.

It is also considered unlikely that the pelagic phases are retained in the oceanic gyres present in each of the major oceans and that they return to the area where they were spawned via these circulations. The limited chance that the offspring have of reaching the small islands where they were spawned after drifting in these extremely extensive gyres is not considered viable for the maintenance of breeding populations. The literature on dispersal mechanisms of oceanic island fish populations places more emphasis on the retention of propagules in the vicinity of spawning areas, rather than on dispersal. Authors such as Boden (1952), Boden & Kampa (1953) and Sale (1970) have concluded that physical oceanographic phenomena such as current eddies and upwellings often enhance retention in the source areas rather than dispersal. Leis (1982) stressed that diverse mechanisms are utilised by the pelagic phases themselves in conjunction with oceanographic phenomena to ensure retention in the source area. At present not enough information exists to define localised current patterns in the Tristan da Cunha and Gough Island region or to determine the capacity that pelagic phases have to actively utilise these currents to ensure retention. It is suggested, however, that the majority of propagules are able to remain in the source area and that dispersal to other distant shallow water areas has come about through occasional vagrants reaching such distant localities.

Sinclair (1988) cautioned against the use of surface oceanographic phenomena as explanations for pelagic phase dispersal and emphasised that movements of propagules within a current system may greatly effect the speed and hence distance that they may disperse. Even so, it

was believed that it would be useful to determine the distance that pelagic phases of Tristan/Gough species could theoretically disperse passively in the eastward moving current systems if they became separated from local retention areas. Drift card and FGGE drifting buoy experiments in the Southern Ocean have shown that the ACC has a mean surface velocity of between 10.3 (± 5.0) cm/s and 15.0 (± 3.9) cm/s in latitudes 35°S to 40°S (Shannon *et al.*, 1973; Patterson, 1985; Lutjeharms *et al.*, 1988). A mean velocity of 12.65 cm/s would allow pelagic stages to be transported passively up to 4000 km in one year. If these drift rates are considered in relation to the relatively long lived larval and juvenile stages of Tristan/Gough fishes it would appear that dispersal over the great distances between shallow water areas in the Southern Ocean could be possible if the species are tolerant of other physical oceanographic conditions, such as temperature.

Pollock (1990) suggested that the South Atlantic may have been the source area from which the palinurid lobster *Jasus paulensis* at Amsterdam and St Paul Islands originated. This species and *J. tristani* from Tristan, Gough and Vema Seamount are closely related and could perhaps still be regarded as conspecific (Pollock, 1990). He suggested that a northward latitudinal shift of from 2° to 4° of the STC combined with an increase in velocity of the ACC during recent glacial periods, as proposed by McIntyre *et al.* (1976) and Kennett (1982), would increase the chance of dispersal of long lived larvae in an easterly direction from the Atlantic into the Indian Ocean. This explanation might also be true for the wide distribution of STC fishes. A slight shift in the position of the STC to the north would effectively place fish propagules that are now virtually unaffected by the SAC and the ACC, in their path and facilitate a circumpolar dispersal in an easterly direction. St Paul and Amsterdam islands have been estimated to be in the order of 700 000 years old (Gunn & Abranson, 1971) while the Tristan group and Gough Island are more than one million years old (Miller, 1964). For this reason it would seem probable that the Indian Ocean Islands were colonised from the South Atlantic Islands and Southern Africa. Also, as Pollock (*op cit.*) suggests, a number of glacial periods have occurred during the last 700 000 years with the last drawing to an end as recently as 15 000 years ago. Therefore, the last colonisation of St Paul and Amsterdam by fish could have been relatively recent. It is probable that conspecific populations at the widely spread areas of shallow water in the STC region have now become reliant mainly on the retention of propagules rather than distant recruitment.

The original source areas of the widespread resident species at the oceanic islands must have been the three ancient continental land masses of Southern Africa, Australasia and South America to a greater or lesser degree. The volcanic islands of Tristan da Cunha, St Paul and Amsterdam and seamounts such as Vema and Walters Shoal were colonised from these areas and are thought to have acted as stepping stones for dispersal, once breeding populations had established themselves there. The relatively high affinities that all the areas have with each other in terms of common genera could be explained by subsequent speciation after the initial dispersal, perhaps followed by further dispersal between them. The systematic relationship that the various genera have to one another needs to be addressed in order to define source areas with certainty.

It is believed that the prolonged pelagic phases present in many of the species of the isolated oceanic islands close to the STC is not an adaptation to ensure dispersal to distant areas but exists simply because only those species exhibiting this specialisation could originally have reached these islands. However this adaptation has probably led to the low level of endemism at Tristan da Cunha, Gough Island and the New Amsterdam Islands in the Indian Ocean. Gough Island has no endemic fishes, while only one, *Bovichtus diacanthus* is shared between Gough and Tristan da Cunha. St Paul and Amsterdam Islands have perhaps one endemic species (Duhamel, 1989).

It is impossible to be sure of the mechanisms responsible for the widespread distribution of certain species without further information on the distribution of the early life-history stages of the species involved. The ideas on dispersal outlined above will hopefully serve as a starting point to which further early life-history information on the species of the STC region can be added when it becomes available. It is also apparent that further collecting is necessary at certain localities before the fauna of the areas of shallow water in the STC region can be compared with confidence.

Because a particular assemblage of neritic species has been found to be present at Tristan, da Cunha, Gough Island, and the New Amsterdam Islands, this study supports the views of Collette & Parin (1991) who argued that their so-called West Wind Drift (W.W.D.) Islands should be placed in a single zoogeographical province. The new information available from these areas has shown that Tristan da Cunha and Gough Island, and the New Amsterdam Islands are more

closely related in terms of their fish fauna than to those regions that Briggs (1974) indicated. Briggs included the Tristan-Gough Province in the southern South American Cold Temperate Region and the Amsterdam-St Paul Province in the Southern African Warm Temperate Region. Collette & Parin (1991) however, have grouped Walters Shoal and an un-named seamount on the Madagascar Ridge with the W.W.D. islands. It is apparent from the present study that these areas have greater affinities with Briggs's Western Indian Ocean Province. The presence of relatively few of the species found at the other W.W.D. islands is not sufficient reason to place these seamounts in the West Wind Drift Islands Province. Collette & Parin (1991) have not considered the effects of the STC on the seamount fauna and have thereby omitted what has here been considered as an important factor regulating the fauna in this region. Walters Shoal and the un-named seamount are influenced mainly by the tropical regions to the north. Also, because there is no evidence of cessation or major directional changes in the Antarctic Circumpolar Current in the last 700 000 years (Pollock, 1990) it seems unlikely that any species would be able to colonise in a westward direction in this region as these authors have suggested. It is proposed that dispersal of the fishes in this region occurred in a stepping stone fashion in an easterly direction.

CHAPTER 4 - THE EFFECTS OF ENVIRONMENTAL SEASONALITY ON THE BIOLOGY OF *ACANTHOLATRIS MONODACTYLUS*

4.1 - INTRODUCTION

This chapter focuses on various aspects of the biology of the fivefinger, *Acantholatris monodactylus*. As mentioned in Chapter 1 it was decided to study the biology of this species in detail in an attempt to gain an understanding of the effects of local environmental conditions on biological processes of fish at the islands as a whole. *A. monodactylus* can be regarded as being extremely successful at the islands. This is demonstrated by its abundance at both the Tristan da Cunha Group and Gough Island. Globally, the species occurs only at localities close to, or within the STC, which suggested that it may display biological characteristics important for survival in this frontal region.

This species has been recorded from the Tristan da Cunha group and Gough Island, as well as from the Vema Seamount in the South East Atlantic (Penrith, 1967) and from St Paul and Amsterdam Islands in the South Indian Ocean (Duhamel, 1989). *A. monodactylus* also occurs at various seamounts in the south and south west Indian Ocean (Duhamel, 1984; Collette & Parin, 1991).

The fivefinger is of great importance to the islanders of Tristan da Cunha as it is the most abundant species taken by fishermen throughout the year, both from the beach and from boats and is an esteemed table fish. In addition, the species is used extensively as bait for the rock lobster industry. An estimated 19 tonnes are taken each year from the shelf waters around Tristan Island (see Chapter 7). Significant quantities are also harvested around Inaccessible, Nightingale and Gough Islands by the two lobster vessels and their powerboats operating in the area. The availability of the species throughout the year was an important factor in choosing it for a detailed biological study.

This chapter is divided into four sections dealing with specific aspects of the biology of *A. monodactylus*. In the discussion an attempt is made to synthesize the information and illustrate

the effects that the environment has on biological processes. Firstly, age and growth is addressed, followed by accounts of the reproductive and feeding biology of the species. In the final section variation in the morphology of fivefinger at Tristan da Cunha and Gough Island further south, is examined. All these accounts are based on data collected during the 18 month period in the field.

Sivertsen (1945) aged *A. monodactylus* by reading growth rings on scales. Apart from this work, age and growth in the fivefinger has not been studied. He suggested that the species was slow growing reaching a maximum age of 20 years at a size of 470 mm TL. Given the relatively large proportion (16 %) of scales that were unreadable in his sample of 190 scales and the fact that he only used scales from fish collected in the summer months, it was considered important to age the fivefinger using otoliths collected throughout the year to either confirm his results or to obtain better age estimates. An initial comparison of the clarity of growth zones on scales and otoliths in the present study indicated that otoliths would provide better estimates of age as the clarity of growth zones was greater.

Opaque and hyalin (translucent) zones in the otoliths of fishes are related to temporal variation in growth rate (Ricker, 1975). The different appearance of the two zones is brought about by differential deposition of calcium carbonate and protein during the endogenous circadian rhythm (Campana & Neilson, 1985). Growth varies with temperature, food availability, reproductive output and any other physiological condition that lowers surplus energy (Newell, 1977). Because of this seasonality in growth zone deposition it was considered essential to determine the period of fast and slow growth in *A. monodactylus* and to compare this to changes in local oceanographic conditions and other aspects of the species biology such as reproduction and feeding. The aim of the ageing study was therefore firstly to determine the growth rate of the species, and secondly to determine how seasonality in local environmental conditions affected this process.

Nothing was known about the reproductive biology of the fivefinger prior to the present study. Temperature has been noted to temporally affect the timing of spawning in many fish families (Thresher, 1984). Because of this, it was relevant to the broader aims of this thesis to determine if this was apparent in the fivefinger, and if so, how temperature affected timing of reproduction. The relationship of temperature to the timing of spawning is probably the result

of the influence that temperature has on other biological ocean processes such as an increase in primary productivity and consequent enhanced food availability for offspring. This hypothesis was first suggested by Hjort (1914) and has since been added to and formalised by Cushing (1975) in his match/mismatch theory. Essentially this theory hypothesizes that fish spawn in relation to the timing of phytoplankton blooms which would increase food availability for pelagic larvae. The theory suggests that annual variability in the timing of phytoplankton blooms, due to stratification in the water column, creates variability in fish larval mortality. This theory has been criticised because of limited support available from field observations (Sinclair, 1988). However, a number of authors have found a relationship between larval development and larval food requirements (Jones, 1973; Laurence, 1977; Lasker, 1975; 1978) supporting the match/mismatch theory in part. These authors have not however been able to link the timing of spawning specifically to the timing of phytoplankton blooms. It was therefore attempted to relate the timing of spawning in the fivefinger to oceanographic occurrences at Tristan da Cunha and Gough Island.

No information has been published on the feeding biology of *A. monodactylus* at Tristan da Cunha or Gough Island. Beurois (1976) carried out a feeding study on the species at Amsterdam Island as part of an investigation on the marine resources of that island group. It has been suggested (Chap. 2) that seasonal changes in stratification in the ocean around the Tristan da Cunha Group and Gough Island lead to increased nutrient availability and therefore higher primary productivity during the summer months. It could therefore be hypothesized that seasonal and spatial temperature changes would affect the availability of food and thus the diet of the fish occurring at the islands. This study was aimed at investigating the diet of *A. monodactylus* and the possibility that the feeding biology of this species was closely linked to spatial and temporal changes in the oceanographic conditions of the region. The results of this feeding study are currently in press (Andrew & Hecht, 1992).

During the course of the study it was noticed that specimens of *A. monodactylus* from Tristan, Nightingale and Inaccessible had proportionately larger heads and shallower bodies than specimens collected at Gough Island. The Tristan islanders also recognised a difference in specimens collected at the two localities. Similarly, Penrith (1967) reported differences in the morphology of the one specimen of *A. monodactylus* that he examined from Gough Island (SAM 22890) when compared to specimens he collected at Tristan da Cunha.

It has often been assumed that narrow morphological adaptation with little phenotypic variation can occur within a single species (eg. van Oijen *et al.*, 1981; van Oijen, 1982). However, intraspecific changes in growth rate, body form, size at maturity and other physiological processes, under different environmental conditions, have been widely acknowledged. Reports of these effects have come especially from studies of freshwater fishes where environmental conditions can vary greatly within the geographical range of a species (eg. Iles, 1973; Hindar & Jonsson, 1982; Hecht & Zway, 1984; Balon, 1985; Meyer, 1987). Indeed, environmentally induced phenotypic plasticity has been reported in a wide variety of organisms ranging from plants to large mammals (eg. James, 1983; Sultan, 1987; Geist, 1989).

Evidence indicating that the fivefinger has dispersed over great distances (Chap. 3), suggested that the population at Tristan was not completely isolated from the one at Gough but was genetically connected via the long-lived pelagic phase. Because fivefingers from these two populations were considered to be conspecific, it was hypothesised that morphological variation had resulted from the noted differences in environmental conditions at the two localities. Morphological comparison of fivefingers from Tristan da Cunha and Gough Island was therefore carried out to determine the extent to which the two morphs differed and an attempt was made to ascertain the most probable causes of this morphological variation.

4.2 - AGE AND GROWTH

4.2.1 - METHODS

The catches of the local fishing fleet were sampled at the Tristan harbour on 70 occasions during the 18 month period on the Island. Fivefinger ranging in length from 150 mm to 647 mm TL were sampled from the fishermen's catch while smaller fishes (88 mm - 150 mm TL) were collected in tidal rockpools using rotenone ichthyocide or from the shore using rod, hook and line. All fish ($n = 374$) were measured for total length in millimetres and weighed to the nearest gram. Sagittal otoliths were removed for age and growth determination each month and stored dry in cross referenced envelopes. A total of 250 pairs of otoliths were collected.

In order to determine if a positive relationship existed between otolith length and total fish length, the longitudinal length of otoliths was measured and subjected to regression analysis. For ageing purposes it is important to determine the extent to which growth in fish length is

reflected by otolith growth (Bartlett *et al.*, 1984). After examining whole otoliths (burnt and unburnt), and cutting both transverse and longitudinal sections through the nucleus it was decided that transverse sections of unburnt otoliths allowed rings to be most easily read. Sections (0.2 - 0.4 mm thick) were cut with a double bladed diamond edged otolith saw (Rauck, 1976) and mounted on glass slides. The growth rings were then read under a microscope on three occasions at one week intervals. The validity of the ring counts was accepted if at least two of the three readings corresponded. Of the 250 otoliths examined only 75 % could be read successfully. To determine the periodicity of ring formation the outer margin of each section was examined and noted to be either opaque or hyalin. The seasonal changes of the otolith margin was plotted as percent frequency of occurrence (opaque or hyalin) against month of the year. Sexually immature fish (ca. < 200 mm TL - see Fig. 4.8, next section) were separated from sexually mature fish in this analysis as it was evident after an initial examination of otoliths that zone deposition varied in immature and mature fish.

Using a computer programme developed by Punt & Hughes (1989) the observed length-at-age data was analyzed to determine which of 11 growth equations currently in use best described the growth of the species. This programme tested individual observed length-at-age data for random residuals and homoscedasticity by performing a non-linear minimisation (using the simplex method) in order to determine a suitable growth model/error model combination. An absolute, rather than a relative error model was chosen when fitting a growth curve to the observed data as this model resulted in a fit that satisfied the runs test, thus indicating that the growth of the fivefinger was adequately modelled by the selected growth model (Draper & Smith, 1966). Variance analysis was performed by the conditioned bootstrap method to determine which of a number of suitable models best fitted the data (Butterworth, *et al.*, 1989).

4.2.2 - RESULTS

Figure 4.1 shows that otolith length (OL) increased with fish length. The curve is described by the equation, $OL = 0.0932 TL^{0.6975}$, ($n = 250$; $r^2 = 0.972$). This indicated that growth in fish length was closely reflected by growth in otolith dimension and suggested that otoliths were suitable for age determination. The power relationship provided a better correlation coefficient (r^2) compared to the linear, log or exponential relationships.

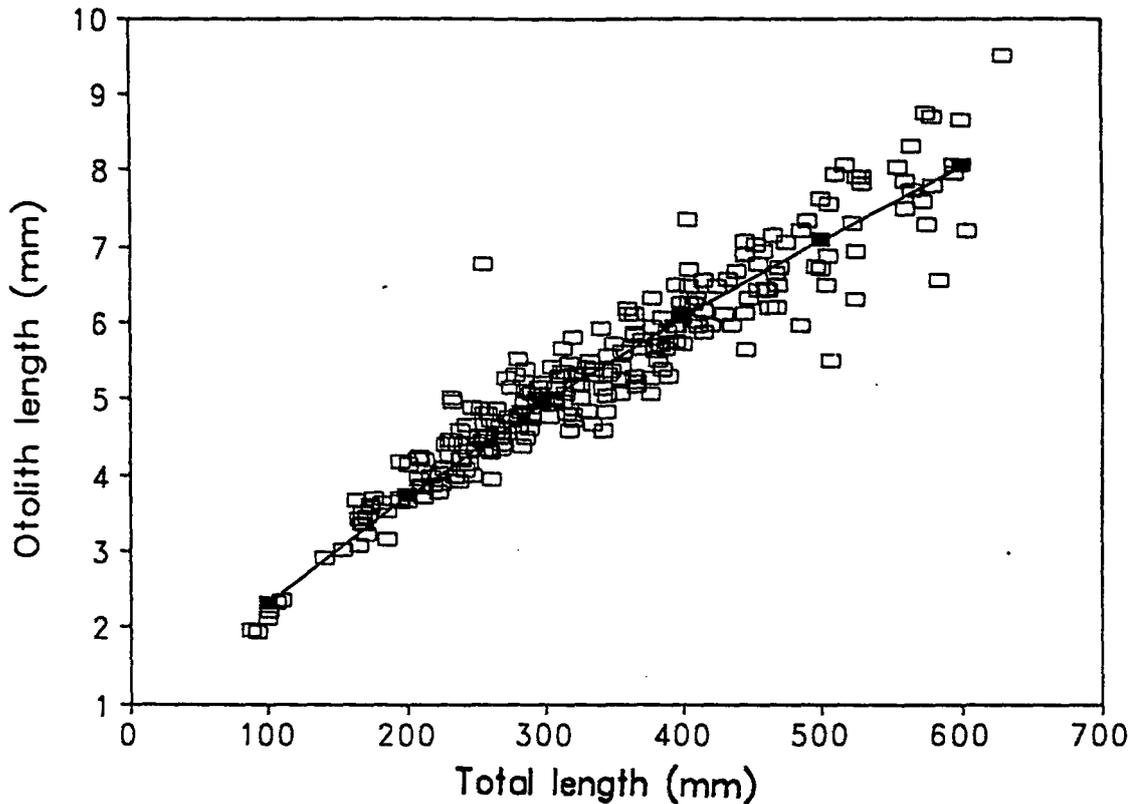


Figure 4.1. The relationship between otolith length and fish length in *A. monodactylus*. (n = 250; $r^2 = 0.972$).

An initial examination of the otolith edge of sexually immature fish showed that only one opaque/hyaline ring pair was deposited each year (Fig. 4.2a). Although only a small sample (n = 35) of immature fish was available it appeared as though the opaque zone was deposited from January to March (period of high water temperature). However, in sexually mature fish, two opaque/hyaline ring pairs were generally deposited each year (Figure 4.2b). After sexual maturity the opaque zones were deposited from February to May (period of high water temperature) and in July (after spawning - see Fig. 4.5, next section) respectively. Figure 4.3 shows a sectioned otolith from a seven year old fish of 350 mm TL and indicates how growth zones were interpreted in this study.

The possibility of a difference in growth rate between males and females was tested by means of a Student's t-test (Adler & Roessler, 1972). Table 4.1 shows that the mean observed length-at-age of males and females did not differ significantly at $P > 0.05$.

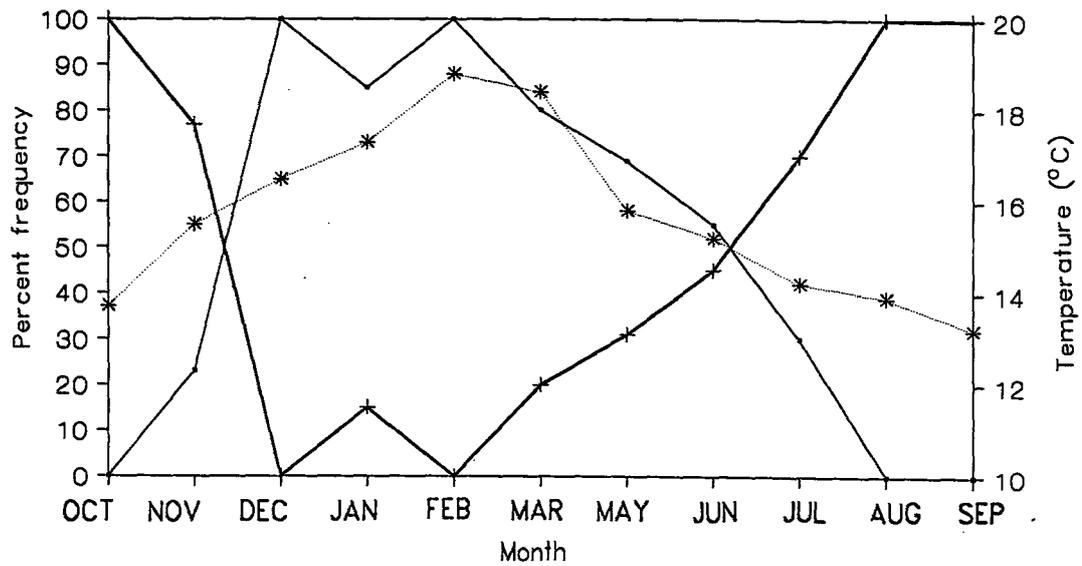


Figure 4.2a. Percentage frequency of occurrence of opaque (small squares) and hyalin (plusses) outer margin of otoliths from sexually immature *A. monodactylus* (n = 35). Mean monthly temperatures are also indicated (stars).

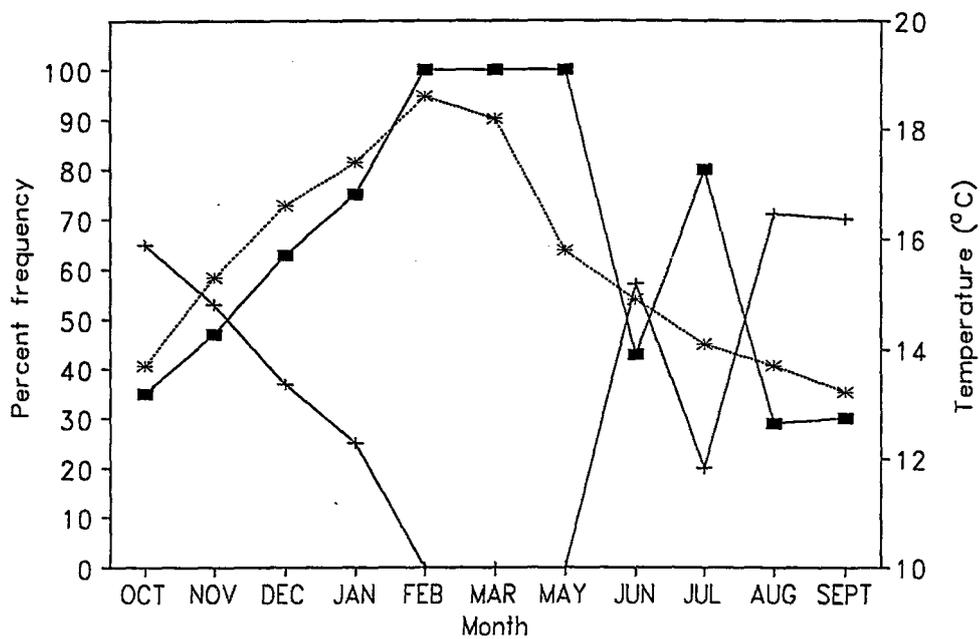


Figure 4.2b. Percentage frequency of occurrence of opaque (squares) and hyalin (plusses) outer margin of otoliths from sexually mature *A. monodactylus* (n = 207). Mean monthly temperatures are also indicated (stars).

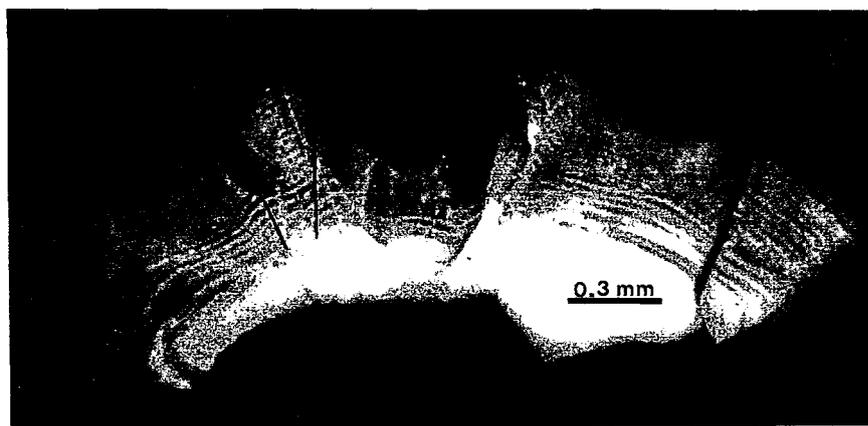


Figure 4.3. Thin section from the otolith of an 11 year old (400 mm TL) specimen of *A. monodactylus* indicating how growth zones were interpreted. The first three growth zones were regarded as annuli while two opaque/hyalin zones were considered to represent an annulus after the first three years (see text).

Table 4.1. Test for significant difference between mean observed length-at-age of male and female *A. monodactylus* from Tristan da Cunha. - = no significant difference at $P > 0.05$.

Age (years)	Mean TL (Females)	n	S.D.	Mean TL (Males)	n	SD	dF	t	Sig. Diff.
3	200.25	8	41.5	191.25	12	44.2	18	0.23	-
4	245.27	18	51.4	251.5	24	43.7	40	0.21	-
5	281.32	19	40.2	263.7	17	44.1	34	0.62	-
6	342.75	8	77.2	313.13	12	62.3	18	0.46	-
7	338.33	9	48.8	342.1	10	50.1	17	0.08	-
8	387.33	9	55.4	388.72	11	45.6	18	0.03	-
9	428.33	2	83.3	390.57	7	34.9	7	0.39	-
10	410.5	5	120.9	370.92	13	73.3	16	0.38	-
11	471.6	3	23.8	412.6	10	74.6	11	0.91	-
12	406.66	1		430.33	3	64.9	2	0.09	-
13	469	5	153.5	440.33	3	66.5	6	0.59	-
14	543.2	2	30.7	510	1		1	0.88	-
15	542.5	2	46	474	4	71.8	4	0.67	-
17	530	1		577.5	2	24.7	1	1.57	-
24	592	2	16.97	580	1		1	0.57	-

The growth of the fivefinger at Tristan da Cunha was best described by the special Von Bertalanffy growth equation, $L_t = 620.64(1 - e^{-0.11(t+0.419)})$ [$F = 2.658$; Sum of squares = 692208; $P < 0.025$]. Table 4.2 is an age/length key of the population. The mean observed and calculated length-at-age is also shown. Figure 4.4 describes the growth of the fivefinger at Tristan da Cunha.

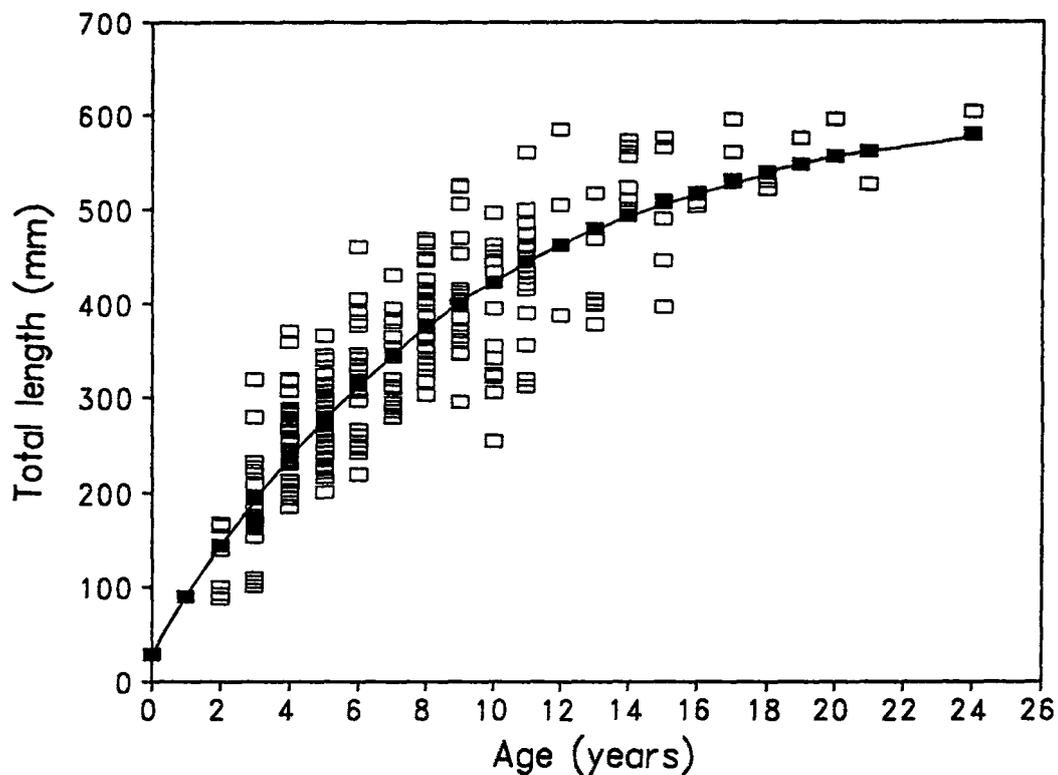


Figure 4.4. The relationship between total length (mm) and age (years) in *A. monodactylus* from Tristan da Cunha and the calculated Von Bertalanffy growth curve for the species ($n = 189$).

4.3 - REPRODUCTION

4.3.1 - METHODS

Gonads were removed each month (n = 262) and weighed to the nearest 0.1 gram in order to calculate a monthly gonadosomatic index (GSI) and to determine the breeding season of the fivefinger. No samples were collected during April 1989 due to the absence of the author from the islands at this time. The macroscopic condition of gonads was recorded during the monthly sampling periods by designating indices of seasonal maturity (Nikolsky, 1963). The indices used are shown in Table 4.3. Macroscopic observations were undertaken to establish the size at sexual maturity and to confirm the estimate of seasonal reproductive activity using the GSI technique.

Table 4.3. Description of the visual indices used to assess the macroscopic maturity stages in *A. monodactylus* gonads (adapted from Nikolsky, 1963).

Index	Maturity stage	Description
I	Quiescent	Gonads small. Testes thin and translucent. Ovaries cream, thin and elongated
II	Developing	Gonads increase in size slightly. Testes cream to white. Ovaries cream but thickened. Eggs not visible to the naked eye
III	Active	Gonads larger. Sperm visible if testis is cut and squeezed. Ovaries become yellow/orange with eggs visible to the naked eye
IV	Active/ripe	Gonads swollen. Testes whiter. Some eggs are unattached from the ovarian tissue
V	Ripe	Gonads swollen. Sperm flows freely if testis is cut. Many large, translucent eggs unattached from ovarian tissue
VI	Ripe running	Sperm and eggs flow from cloaca when abdomen is lightly squeezed
VII	Spent	Gonads flaccid, bloodshot and reduced in size

In order to estimate the size when 50 % of the population became sexually mature the macroscopic gonad condition of 217 fishes (ranging from 88 mm - 647 mm TL) was recorded during the peak of the breeding season. Fivefingers sampled at all three of the northern islands

were included in this analysis. Fishes with quiescent or undeveloped gonads (ie. stage I) during this period were assumed to be immature. All specimens with developing, developed or spent gonads (ie. from stage II to stage VII) were assumed to be mature and likely to spawn, or have spawned at some stage during the spawning period.

The ovaries of six mature fish varying in length from 215 mm - 647 mm TL in a ripe condition were removed to obtain an estimate of fecundity. To ensure that oocytes and ova were at a similar stage of development, these ovaries were collected in the middle of the spawning period during the same week (25 February - 5 March 1990). This limited the sample size but excluded possible bias caused by differential gonadal development during the spawning period (Bagenal, 1978). The ovaries were opened longitudinally shortly after removal and placed in Gilson's fluid. This treatment hardens the eggs and with periodic shaking releases them from the ovarian tissue (Bagenal, 1978). Eggs were counted after storage in Gilson's fluid for 12 months. Eggs were enumerated by volumetric subsampling. Four subsamples of 5 ml aliquots were taken after all the eggs had been diluted in 2000 ml of water. The mixture of water and eggs was stirred vigorously to ensure random distribution before taking the 5 ml aliquot sample. Only eggs greater than 0.4 mm in diameter were found to be yolked. These were regarded as likely to be spawned in that season and were included in the count. A fecundity index, 'F' (proposed by Garratt, 1985), was calculated for each of the size classes represented in the sample of six ovaries in order to determine which size class or classes of the population contributed the most ova during a spawning season.

$$'F' = \frac{\text{number of eggs counted in representative ovary}}{\text{examined from each size class}} \times \frac{\% \text{ of that size class in the overall}}{\text{breeding population}}$$

'F' is an index indicating the relative proportion of eggs produced by each size class. In order to convert 'F' to a percentage, each size class was divided by the sum of 'F' for each the six samples examined and multiplied by 100. This resulted in an estimate of the percentage eggs produced by each size class in the population.

Because of the small number of ovaries used in this analysis, the fecundity of the specimens examined was assumed to represent all fishes within the 50 mm size classes from which the sample specimens were taken. It must be stressed that this simple analysis was not intended

to give detailed information on the fecundity of the species but was undertaken to obtain some indication of the reproductive output of various size classes in the population.

4.3.2 RESULTS

Spawning took place in late summer from January through to the end of April. Both male and female GSI curves (Fig. 4.5) and the visual index of maturity (Fig. 4.6) indicated a clear spawning period at this time. Given the relatively protracted breeding season of *A. monodactylus* it is probable that the species releases more than one batch of eggs over several months.

Figure 4.7 shows that 50 % maturity was attained at a size of approximately 170 mm TL, at an age of between two and three years. Some fish became mature at a length of 120 mm while most (90 %) of the population reached maturity at a length of about 250 mm. One hundred percent maturity was reached at 400 mm at an age of about nine years.

Based on the fecundity analysis, it was apparent that the number of eggs in the ovary increased with fish size (Fig. 4.8). The instantaneous fecundity ranged from 15 425 to 310 500 in fishes ranging from 180 g (ca. 215 mm TL) to 3.96 kg (ca. 647 mm TL) respectively. Yolked eggs ranged in size from 0.4 to 0.7 mm in diameter. Figure 4.8 also shows the percentage contribution of ova per size class. It became evident that fish ranging in length from 200 to 300 mm TL were the principal contributors to absolute population fecundity. This size class was also the most abundant, making up 60.3 % of the adult population caught by the fishing fleet (see Chap. 7).

Some observations on the early development of fertilized eggs were made by W. Uys (Department of Ichthyology and Fisheries Science, Rhodes University) during a cruise of the **MV S.A. AGULHAS** to Gough Island in April 1983. Eggs and sperm were stripped from individuals in the ripe running condition. The eggs were fertilized on board ship and their development was followed until the larvae were lost during a Southern Ocean storm. Gastrulation occurred approximately 13 hours after fertilization. At hatching (about 40 hours after fertilization) the larvae were approximately 2 mm in length, were neutrally buoyant and

were suspended upside down in the water column by the oil droplet. After 60 hours the larvae turned right side up and swam actively. At this stage the larvae were lost during the storm.

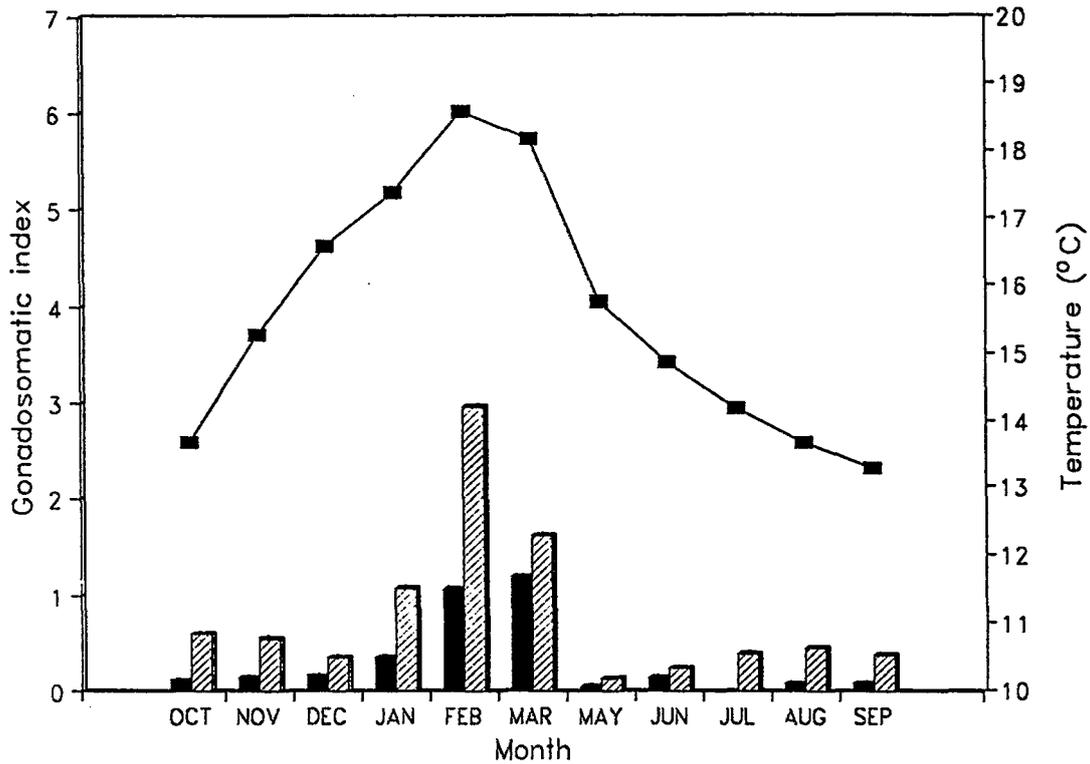


Figure 4.5. Mean monthly gonadosomatic indices of male (solid bars, n = 104) and female (hatched bars, n = 145) *A. monodactylus* from Tristan da Cunha, and mean monthly temperature.

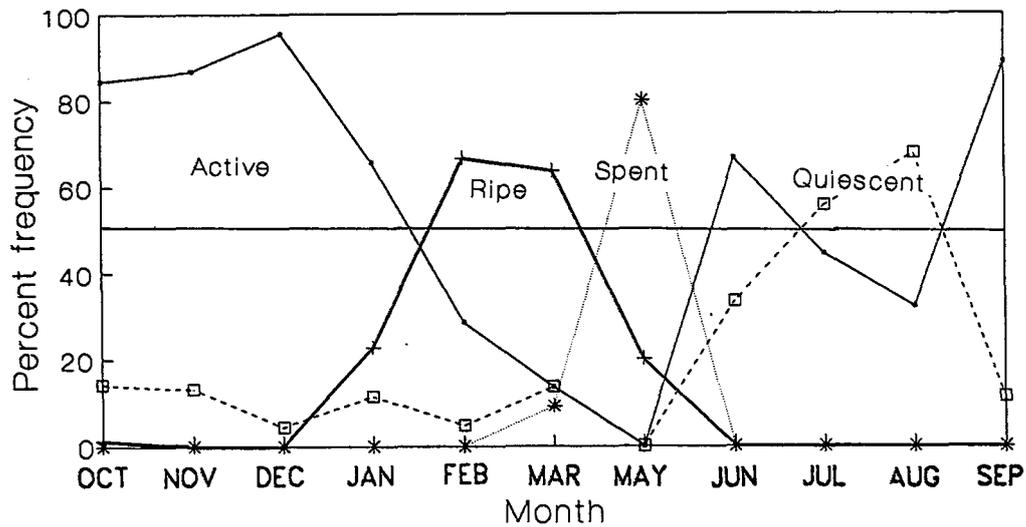


Figure 4.6. Seasonal changes in the condition of *A. monodactylus* ovaries from visual assessment.

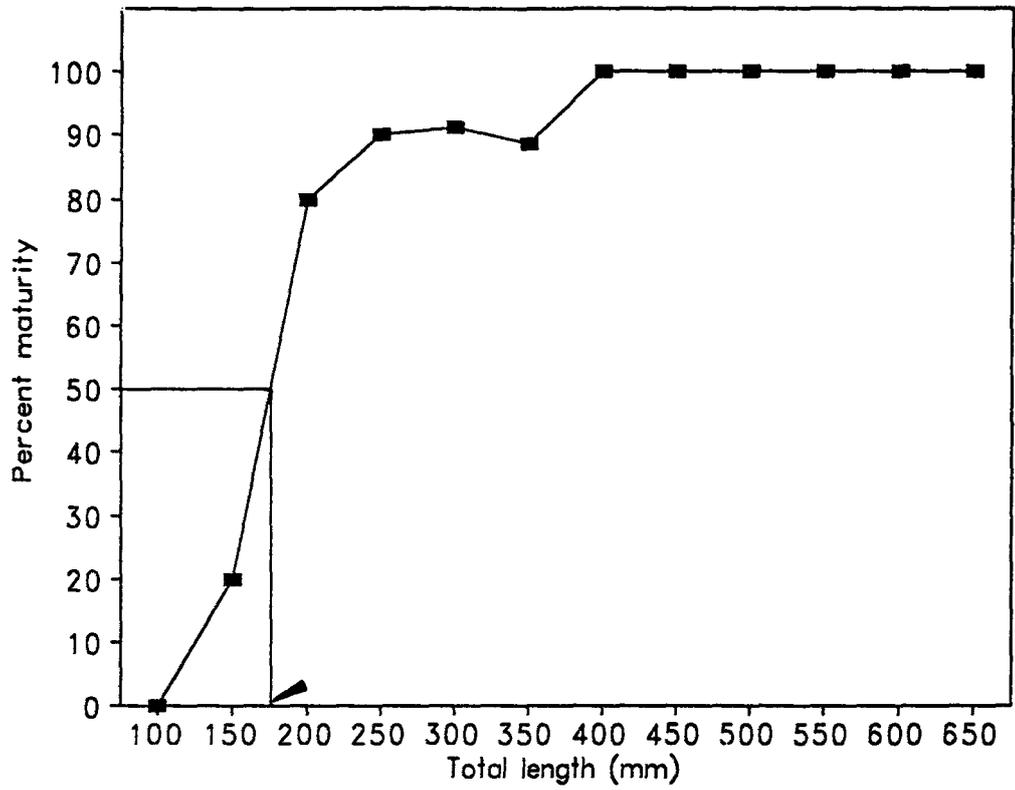


Figure 4.7. Percentage maturity in *A. monodactylus* based on visual assessment of gonads. Size at 50 % maturity is indicated by the arrow.

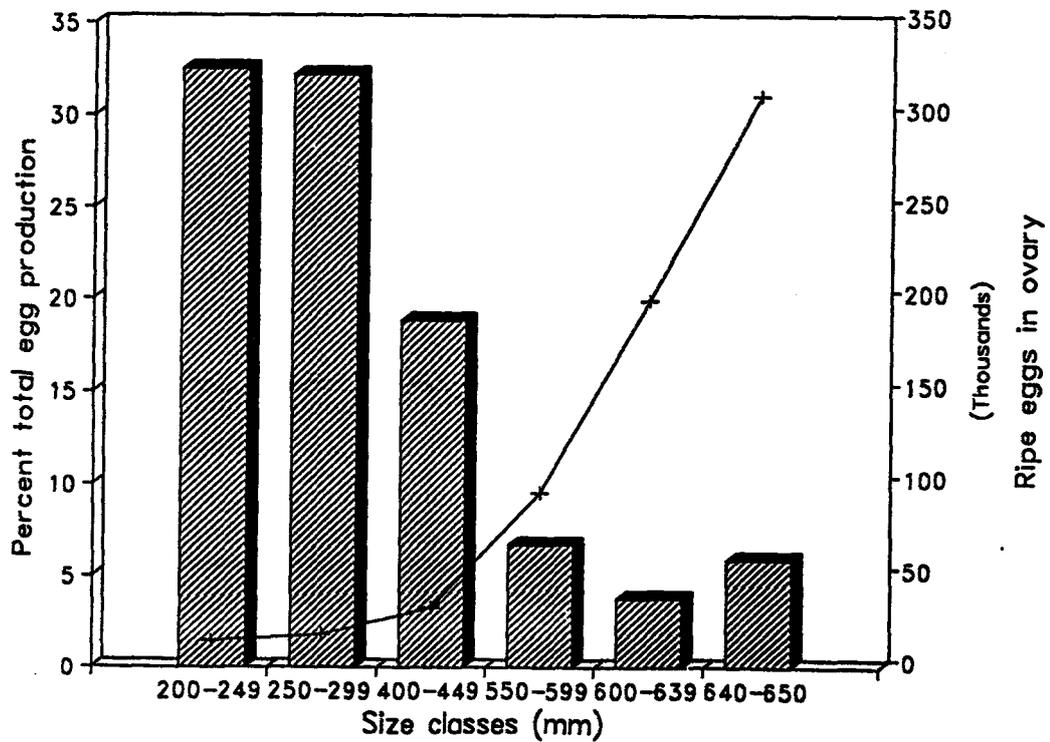


Figure 4.8. Instantaneous fecundity and percentage egg production per size class in *A. monodactylus*.

The absence of benthic juveniles of less than 70 mm TL in any of the habitats sampled and the fact that a pelagic paperfish of 57 mm TL was collected (Fig. 4.9) after having been dropped by an Antarctic tern, *Sterna vittata*, suggested that the pelagic phase of this species was relatively long. The smallest benthic phase *A. monodactylus* collected was one year old (88 mm TL) indicating that the pelagic phase may last for up to a year.

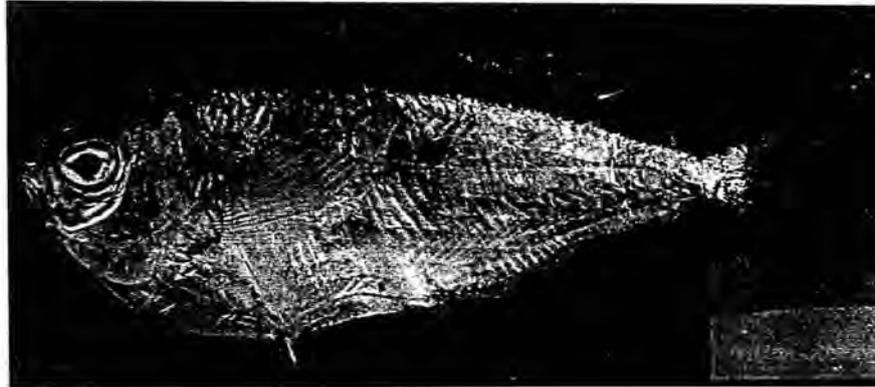


Figure 4.9. The pelagic paperfish of *A. monodactylus* (57 mm TL).

4.4 - FEEDING

4.4.1 - METHODS

Stomachs and hindguts were removed from fish from October 1988 to March 1990. Most of the fish sampled were obtained from the catch of the local rock lobster fleet although smaller specimens were collected at Tristan Island with hook and line from the shore and in rockpools using rotenone ichthyocide. Fishes were also collected with hook and line and in lobster traps at Nightingale and Inaccessible Islands; from the shore and from aboard **MFV TRISTANIA II**. Samples were obtained at Gough Island from the shore using handlines and also off-shore from lobster traps. Using these methods it was possible to collect gut samples of fish ranging from 182 mm to 575 mm TL from waters ranging from 1 m to over 200 m depth. A total of 375 fish were examined for gut contents. All the fish were measured for TL and mass to the nearest millimetre and gram respectively. Of the 375 fish, 102 specimens had food remains in their guts and were used in this study.

Stomachs and hindguts were removed from fresh specimens and preserved in buffered 10 %

formalin. After three months the material was transferred to 50 % propyl alcohol. Gut contents were identified to the lowest possible taxon and weighed to the nearest 0.01 g. The percentage contribution by mass of each food group in individual stomachs (Windell & Bowen, 1978) and the overall percentage frequency of occurrence (Hynes, 1950) was calculated. A ranking index for each food type was calculated by multiplying the percentage frequency of occurrence with the mean percentage mass of each food group and dividing the product by 100 (adapted from Hobson, 1974). Percentage contribution by mass and percentage frequency of occurrence were used as it was believed that these two measures would give the best indication of the relative importance of various food items. It was not possible to quantify all food items numerically, especially algal fragments which were common in the guts of fishes. Therefore percentage contribution by mass was used as this allowed all food types to be quantified even when disintegrated in the gut. Frequency of occurrence was used as this would indicate the proportion of the sample that actually fed on particular food items.

In order to determine if the contents of stomachs and hindguts differed, the contents of 63 stomachs and 44 hindguts of fishes ranging in size from 182 mm TL to 575 mm TL collected at Tristan Island were compared.

To determine if a shift in diet occurred with size in this species, fish from Tristan Island were separated into two size classes. Stomach contents of 30 fish ranging in size from 182 mm to 349 mm TL and 33 fish ranging in size from 352 mm to 575 mm TL were compared. The 350 mm separation was chosen as SCUBA observations indicated that fishes smaller than about 350 mm TL were supra-benthic and more mobile than larger fishes which were territorial and occurred close to the substrate.

The stomach contents of 14 specimens from Nightingale and Inaccessible Islands (180 mm - 420 mm TL) were compared with 63 stomachs taken from fish collected at Tristan Island (182 mm - 575 mm TL) to determine if there was a change in diet with locality at the northern islands.

To test if a shift in diet with season occurred the stomachs from 21 fish caught in winter (219 mm - 467 mm TL) and 42 fish caught in summer (182 mm - 575 mm TL) at Tristan Island were compared.

Finally, the contents of 25 stomachs from fish collected at Gough Island (256 mm - 435 mm TL) were compared with 63 stomachs from fish collected at Tristan da Cunha (182 mm - 575 mm TL). The last two comparisons were carried out to determine if diet was affected by seasonal and spatial differences in oceanographic conditions.

Spearman Rank Correlation Coefficients (r_s) and 't' values were calculated from the percent frequency of occurrence data in order to determine if the diets in the above comparisons were different from each other or not. One tailed 't' tests were carried out after an 'r_s' adapted for ties in the rank data had been calculated for each comparison using the methods described by Siegel (1956) and Fritz (1974).

4.4.2 - RESULTS

Table 4.4 shows that indigestible material was concentrated in the hindgut of *A. monodactylus*. Algae were highly ranked in both stomachs and hindguts indicating that virtually no digestion of the macrophytic material took place. Soft, easily digestible material such as fish, salps and sipunculids ranked much higher in stomachs than in hindguts while the relatively indigestible calcareous tubes of the polychaete *Spirorbis sp.*, the exoskeletons of amphipods and the shells of brachiopods were concentrated in the hindgut. The statistical comparison of the % frequency of occurrence of items found in the stomach and hindgut ($r_s = 0.625$; $t = 3.83$; $P < 0.01$) showed a significant correlation between the two (ie. stomach and hindgut prey items were similar). However, differences were apparent in mean % mass of particular ingested items. Because of the advanced stage of digestion of food in the hindgut, stomach contents gave a better representation of the food utilised by *A. monodactylus*. Contrary to the findings of Beurois (1976) at Amsterdam Island soft tissue prey was difficult to identify and hard exoskeletal and calcareous material accumulated in the hindgut of specimens collected during the present investigation; a phenomenon noted in other dietary studies (eg. Froggia, 1977; Buxton, 1984). It was therefore decided to use only stomach contents for subsequent analyses.

Table 4.5 shows that macroalgae were less important in the diet of smaller *A. monodactylus* than in larger specimens. It is also apparent that a greater variety of small benthic invertebrates were taken by smaller specimens. Invertebrates eaten by both small and large fivefingers generally ranked higher in the diet of small fishes. The diets of smaller and larger

specimens showed no significant correlation (ie. were not similar) at $P < 0.0005$ ($r_s = 0.603$; $t = 3.54$).

Table 4.6 indicates that algae formed the most important ingested item for *A. monodactylus* at Tristan Island as well as Nightingale Island. The major difference in the diets at the two islands was the greater importance of small rock lobster, *Jasus tristani*, in the diet at Nightingale Island as compared to Tristan Island. A statistical test was not carried out on this data because of the small size of the sample from Nightingale Island.

Table 4.7 shows that algae, fish and polychaetes were the most important items found in the stomachs of *A. monodactylus* during both summer and winter. A greater variety of invertebrates were taken during summer while *J. tristani* seemed to be preyed upon to a greater extent in winter. Amphipods ranked higher in the diet during the summer. The diets of specimens collected in summer and winter showed a significant correlation (ie. were similar) at $P < 0.01$ ($r_s = 0.725$; $t = 4.93$). However, once again differences in the mean % mass of particular ingested items were apparent.

A much greater variety of organisms were fed on by *A. monodactylus* at Gough Island than at Tristan Island. Table 4.8 shows that 22 food groups were found in the stomachs of fish collected at Gough Island while only 16 groups were found in the stomachs of fish from Tristan Island. Figure 4.10 illustrates that algae formed a relatively insignificant part of the stomach contents of fish from Gough Island while at Tristan Island this was the major component of the stomach contents. Sea urchins and amphipods were ranked higher in the diets of fish from Gough Island than from Tristan Island. *Spirorbis sp.* tubes were absent in the stomachs of specimens from Gough Island. No significant correlation ($P > 0.1$) was found between the diets of specimens from the two localities ($r_s = 0.084$; $t = 0.469$). That is, diets at the two localities were not similar.

Table 4.4. Comparison of food groups in 63 stomachs (S) and 44 hindguts (H) of *A. monodactylus* (182 - 575mm TL) collected at Tristan Island.

Prey species	% Frequency occurrence		Mean % mass		Rank	
	S	H	S	H	S	H
ALGAE	68.3	72.7	58	60.7	39.6	44.2
Phaeophyta	54	42.5	43.1	41.6		
<i>Ulva sp.</i>	19	22.7	11.3	16.6		
Remains	15.9	9.1	3.6	2.5		
PISCES	23.8	4.5	17	3.2	4	0.1
<i>Nelabrichthys ornatus</i>	1.6	2.3	1.6	0.9		
Remains	22.2	2.3	15.4	2.3		
POLYCHAETA	9.5	13.6	4.5	9	0.4	1.2
<i>Spirorbis sp.</i>	3.2	9.1	1.5	9		
Remains	6.3	4.5	3	0.03		
UNIDENTIFIED REMAINS	7.9	22.7	4.3	11.4	0.3	2.6
AMPHIPODA	9.5	20.5	2.2	3	0.2	0.6
MACRURA	4.8	4.5	3.4	1	0.2	0.05
<i>Jasus tristani</i>	4.8	4.5	3.4	1		
ECHINOIDEA	3.2	6.8	3.2	6.8	0.1	0.5
OPHIUROIDEA	4.8	2.3	1.7	0.05	0.08	T
BRACHYURA	4.8	4.5	1.2	0.5	0.06	0.02
SALPIDAE	1.6	-	1	-	0.02	-
SIPUNCULIDA	1.6	6.8	0.7	0.09	0.01	T
CIRRIPEDIA	1.6	-	0.9	-	0.01	-
BRACHIOPODA	1.6	4.5	0.01	4	T	0.2
OPISTHOBRANCHIA	1.6	-	0.2	-	T	-
ISOPODA	1.6	4.5	0.04	0.2	T	T
COPEPODA	1.6	-	0.04	-	T	-
POLYPLACOPHORA	-	4.5	-	0.09	-	T

T = Trace, i.e. items with a rank < 0.01

Table 4.5. Comparison of food groups in stomachs of *A. monodactylus* smaller (n = 30) and larger (n = 33) than 350 mm TL.

Prey Species	% Frequency occurrence		Mean % mass		Rank	
	<350 mm	>350 mm	<350 mm	>350 mm	<350 mm	>350 mm
ALGAE	66.6	75.8	53.5	62.2	35.6	47.1
Phaeophyta	50	57.6	41.4	44.7		
<i>Ulva sp.</i>	13.3	24.2	10.1	12.4		
Remains	16.7	15.2	2	5.1		
PISCES	26.7	21.2	18.5	15.5	4.9	3.3
<i>Nelabrichthys ornatus</i>	-	3	-	3		
Remains	26.7	18.2	18.5	12.5		
POLYCHAETA	16.7	3	6.8	2.3	1.1	0.07
<i>Spirorbis sp.</i>	6.7	-	3.1	-		
Remains	10	3	3.7	2.3		
UNIDENTIFIED REMAINS	6.7	9.1	6.2	2.5	0.4	0.2
AMPHIPODA	13.3	6.1	2.9	1.7	0.4	0.1
ISOPODA	6.7	-	3.1	-	0.2	-
ECHINOIDEA	3.3	3	3.3	3	0.1	0.09
OPHIUROIDEA	3.3	6.1	3.3	0.2	0.1	0.01
SIPUNCULIDA	3.3	-	1.5	-	0.1	-
CIRRIPEDIA	3.3	-	1.8	-	0.06	-
MACRURA	3.3	9.1	1.5	6.5	0.05	0.6
<i>Jasus tristani</i>	3.3	9.1	1.5	6.5		
BRACHYURA	3.3	6.1	1.5	1	0.05	0.06
SALPIDAE	-	3	-	2	-	0.06
BRACHIOPODA	-	3	-	0.02	-	T
OPISTHOBRANCHIA	3.3	-	0.3	-	T	-
COPEPODA	3.3	-	0.1	-	T	-

T = Trace, i.e. items with a rank < 0.01

Table 4.6. Comparison of food groups in the stomachs of *A. monodactylus* from Tristan Island T (n = 63), and Nightingale and Inaccessible Islands N (n = 14).

Prey species	% Frequency occurrence		Mean % mass		Rank	
	T	N	T	N	T	N
ALGAE	68.3	35.7	58	27.3	39.9	9.7
Phaeophyta	54	14.3	43.1	11.7		
<i>Ulva sp.</i>	19	-	11.3	-		
Remains	15.9	21.4	3.6	15.6		
PISCES	23.8	7.1	17	7.1	4	0.5
<i>Nelabrichthys ornatus</i>	1.6	-	1.6	-		
Remains	22.2	7.1	15.4	7.1		
POLYCHAETA	9.5	7.1	4.5	1.7	0.4	0.01
<i>Spirorbis sp.</i>	3.2	-	1.5	-		
Remains	6.3	7.1	3	1.7		
UNIDENTIFIED REMS.	7.9	21.4	4.3	17.8	0.3	3.8
AMPHIPODA	9.5	7.1	2.2	0.2	0.2	0.02
MACRURA	4.8	21.4	3.4	21.4	0.2	4.6
<i>Jasus tristani</i>	4.8	21.4	3.4	21.4		
ECHINOIDEA	3.2	-	3.2	-	0.1	-
OPHIUROIDEA	4.8	-	1.7	-	0.08	-
BRACHYURA	4.8	7.1	1.2	4	0.06	0.3
SALPIDAE	1.6	-	1	-	0.02	-
SIPUNCULIDA	1.6	-	0.7	-	0.01	-
CIRRIPEDIA	1.6	-	0.9	-	0.01	-
BRACHIOPODA	1.6	-	0.01	-	T	-
OPISTHOBRANCHIA	1.6	-	0.2	-	T	-
ISOPODA	1.6	-	0.04	-	T	-
COPEPODA	1.6	-	0.04	-	T	-
PROSOBRANCHIA	-	7.1	-	7.1	-	0.5
PORIFERA	-	21.4	-	14.7	-	3.1

T = Trace, i.e. items with a rank < 0.01

Table 4.7. Comparison of food groups in the stomachs of *A. monodactylus* collected during the summer S (n = 42) and winter W (n = 21) at Tristan Island.

Prey species	% Frequency occurrence		Mean % mass		Rank	
	S	W	S	W	S	W
ALGAE	76.2	71.4	58.5	57.2	44.6	40.8
Phaeophyta	52.3	57.1	41.7	46		
<i>Ulva sp.</i>	21.4	14.3	12.1	9.7		
Remains	16.8	14.3	4.7	1.5		
PISCES	21.4	28.6	14.7	21.6	3.1	6.2
<i>Nelabrichthys ornatus</i>	-	4.8	-	4.8		
Remains	21.4	23.8	14.7	16.8		
POLYCHAETA	9.5	9.5	5.3	5.1	0.5	0.5
<i>Spirorbis sp.</i>	4.8	-	2.2	-		
Remains	9.5	9.5	3.1	5.1		
UNIDENTIFIED REMAINS	7.1	9.5	4.4	4.1	0.3	0.4
AMPHIPODA	9.5	9.5	3.1	0.05	0.3	0.05
ECHINOIDEA	4.8	-	4.7	-	0.2	-
OPHIUROIDEA	4.8	4.8	2.5	0.2	0.1	T
BRACHYURA	7.1	-	1.9	-	0.09	-
SALPIDAE	2.4	-	1.6	-	0.04	-
SIPUNCULIDA	-	4.8	-	2.2	-	0.1
CIRRIPIEDIA	2.4	-	1.3	-	0.03	-
MACRURA	2.4	9.5	0.6	9.1	0.01	0.9
<i>Jasus tristani</i>	2.4	9.5	0.6	9.1		
BRACHIOPODA	-	4.8	-	0.03	-	T
OPISTHOBRANCHIA	2.4	-	0.2	-	T	-
ISOPODA	2.4	-	0.06	-	T	-
COPEPODA	2.4	-	0.06	-	T	-

T = Trace, i.e. items with a rank of < 0.01

Table 4.8. Comparison of food groups in the stomachs of *A. monodactylus* collected at Tristan Island T (n = 63) and Gough Island G (n = 25).

Prey species	% Frequency occurrence		Mean % mass		Rank	
	T	G	T	G	T	G
ALGAE	68.3	26.1	58	5	39.6	1.3
Phaeophyta	54	21.7	43.1	4.4		
<i>Ulva sp.</i>	19	-	11.3	-		
Remains	15.9	8.7	3.6	0.6		
PISCES	23.8	4.3	17	4.3	4	0.2
<i>Nelabrichthys ornatus</i>	1.6	-	1.6	-		
Remains	22.2	4.3	15.4	4.3		
POLYCHAETA	9.5	4.3	4.5	0.1	0.4	T
<i>Spirorbis sp.</i>	3.2	-	1.5	-		
Remains	6.3	4.3	3	0.1		
UNIDENTIFIED REMAINS	7.9	30.4	4.3	13.6	0.3	4.1
AMPHIPODA	9.5	30.4	2.2	10.1	0.2	3.1
MACRURA	4.8	4.3	3.4	0.08	0.2	T
<i>Jasus tristani</i>	4.8	4.3	3.4	0.08		
ECHINOIDEA	3.2	52.2	3.2	31.2	0.1	16.3
OPHIUROIDEA	4.8	4.3	1.7	1	0.08	0.04
BRACHYURA	4.8	4.3	1.2	0.04	0.06	T
SALPIDAE	1.6	4.3	1	0.9	0.02	0.04
SIPUNCULIDA	1.6	-	0.7	-	0.01	-
CIRRIPEDIA	1.6	-	0.9	-	0.01	-
BRACHIOPODA	1.6	4.3	0.01	0.1	T	T
OPISTHOBRANCHIA	1.6	4.3	0.2	0.05	T	T
ISOPODA	1.6	4.3	0.04	0.1	T	T
COPEPODA	1.6	-	0.04	-	T	-
PROSOBRANCHIA	-	8.7	-	3.7	-	0.3
GASTROPODA	-	4.3	-	0.02	-	T
POLYPLACOPHORA	-	13	-	12.2	-	1.6

Table 4.8 cont./...

Table 4.8 cont.

Prey species	% Frequency occurrence		Mean % mass		Rank	
	T	G	T	G	T	G
PYCNOGONIDA	-	17.4	-	0.5	-	0.09
HYDRAZOA	-	8.7	-	0.5	-	0.04
ZOANTHARIA	-	17.3	-	8.2	-	1.4
BIVALVIA	-	4.3	-	1.8	-	0.08
EUPHAUSIACEA	-	8.7	-	6.3	-	0.5
OSTRACODA	-	4.3	-	0.05	-	T

T = Trace, i.e. items with a rank < 0.01

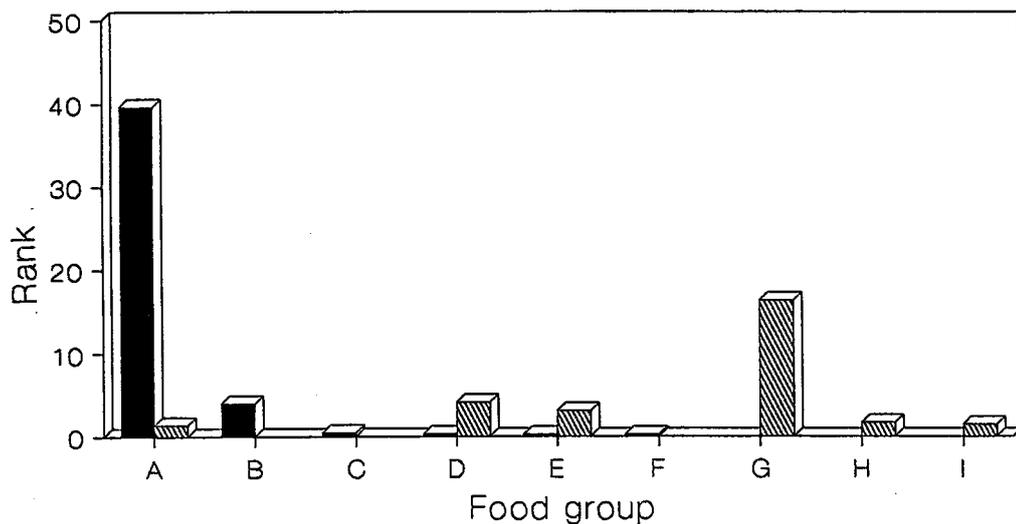


Figure 4.11. Ranks of the six most important food groups in the stomachs of *A. monodactylus* collected at Tristan da Cunha (solid bars) and Gough Island (hatched bars). A = Algae; B = Pisces; C = Polychaeta; D = Unidentified remains; E = Amphipoda; F = Macrura; G = Echinoidea; H = Polyplacophora; I = Zoantharia.

4.5 - MORPHOLOGICAL VARIATION IN *A. MONODACTYLUS*

4.5.1 - METHODS

Seven specimens collected at Gough Island and 10 from Tristan da Cunha of a similar size range were morphologically and anatomically compared to determine if the two forms differed from each other. In addition, two specimens from Amsterdam Island were examined to determine if these differed from the South Atlantic specimens in any way.

MATERIAL EXAMINED

Gough Island fishes

RUSI 33602, 280 mm SL; RUSI 33568, 308 mm SL, taken in a lobster trap set in 60 m during July 1989 by J. Glass. RUSI 33576, 268 mm SL; RUSI 33573, 230 mm SL; RUSI 33583, 208 mm SL; RUSI 33593, 225 mm SL; RUSI 33600, 262 mm SL, collected with hook and line in 10 m below the weather station by R. Matthews on 30 November 1988.

Tristan da Cunha fishes

RUSI 33587 A, 252 mm SL; RUSI 33587 B, 265 mm SL; RUSI 33587 C, 241 mm SL; RUSI 33587 D, 214 mm SL, RUSI 33586 B, 290 mm SL, Inaccessible Island. RUSI 33603, 284 mm SL; RUSI 33570, 253 mm SL, Tristan Island. RUSI 33586 A, 282 mm SL; RUSI 33575 A, 218 mm SL; RUSI 33575 B, 200 mm SL, Nightingale Island. All fish were collected by the author offshore in depths ranging from 25 m to 100 m from October 1988 to March 1990.

Amsterdam Island fishes

RUSI 35212, 2 specimens, 230 mm and 282 mm SL.

Morphometric characters were determined from specimens that were fixed in 10 % formalin for three months and then transferred to 50 % iso-propanol. Skeletal differences were determined by measurements taken from radiographs. Measurements were made to the nearest 0.1 mm. Standard length (SL) was from the tip of the snout (without including the upper jaw) to the end of the hypural bones. The body depth at pelvic fin origin included the scaly sheath

at the base of the dorsal fin. Head length and snout length excluded the upper jaw. Orbit diameter was the horizontal diameter of the orbit. The pectoral fin length was measured from the origin of the longest ray to its tip; caudal peduncle length was measured from the end of the hypural bones to the posterior base of the anal fin; caudal peduncle depth was measured at the narrowest part of the caudal peduncle. Spine and ray lengths and vertebral counts were taken from radiographs. Lateral-line (LL) scales did not include scales posterior to the base of the caudal fin. Gill-raker counts were given as upper + lower-limb rakers.

4.5.2 - RESULTS

Table 4.9 shows the morphometric measurements taken from seven specimens from Gough and the 10 specimens from Tristan. Measurements from the two specimens from Amsterdam Island that fell outside the range for Tristan and Gough specimens are given in parentheses in Table 4.9. The head of Gough Island specimens was smaller relative to the body than of the Tristan specimens. Gough fishes were generally but not always deeper bodied than Tristan specimens. Also, the first anal spine of Tristan fish was longer than that of Gough specimens. Figure 4.10 illustrates morphological differences between specimens of similar size collected at Tristan da Cunha and Gough Island. Figures 4.11, 4.12 and 4.13 show the differences in head, postorbital and first anal spine length as a percentage of standard length in specimens from Tristan da Cunha and Gough Island. Figure 4.14 illustrates the differences in the shape of the first predorsal bone between fishes collected at the two localities.

Temperature and salinity have been noted to influence the development of vertebrae in fish (Hubbs, 1922; Fowler, 1970; Fahy & O'Hara, 1977). Although temperature and possibly salinity differences are apparent between Tristan Da Cunha and Gough Island, radiographs of specimens from both localities showed that there was no difference in vertebral number.

Table: 4.9 Comparative morphometric measurements of specimens of *A. monodactylus* from Gough, Tristan da Cunha and Amsterdam Islands (in parenthesis).

Character	Gough (n=7) 226-323mm min. max.		Tristan (n=10) 200-290mm min. max.
Dorsal spines	16 - 17		16 - 18
Dorsal rays	25 - 27		24 - 27
Anal spines	3		3
Anal rays	11 - 12	(11 - 13)	11 - 12
Pect. fin			
Upper unbr. rays	2		2
Branched rays	7		7
Lower unbr. rays	5 - 6		5 - 6
L.L. scales	50 - 53		50 - 54
Upper G.R.	5 - 6		6 - 7
Lower G.R.	17 - 18		16 - 18
Total G.R.	22 - 24		23 - 25
Vertebrae	35		35
P2 0 body depth	39.6 - 45.5%	(32.2 - 37.2%)	37.6 - 42.4%
Depth at D1 0	27.8 - 38.4%		32.8 - 37.3%
Snout - D1 0	27.8 - 30.9%		29.7 - 33.8%
Snout - Anus	63.5 - 70%		62.2 - 68.7%
Snout - Anal fin	67.6 - 72.8%	(65 - 65.6%)	66.6 - 74.2%
Head length	27.9 - 29.1%	(26 - 27.8%)	29.9 - 33.8%
Snout length	8.8 - 10.7%		10.1 - 11.9%
Orbit diameter	5.7 - 7.2%		4.9 - 9.5%
Interorbital	7.5 - 8.6%		5.6 - 9.5%
Postorbital	12.7 - 13.4%	(11.2 - 12.1%)	13.5 - 15.9%
Preorbital	6.3 - 6.9%		6.3 - 7.7%
Length upper jaw	7.6 - 8.9%		6.4 - 10.5%
Length lower jaw	9.3 - 11.7%		10.4 - 12.9%
Soft D. fin base	28.8 - 32%		25.3 - 30.6%
Anal fin base	17.1 - 18.4%		14.9 - 18.8%
Pect. fin length	28.9 - 31.4%		29.9 - 37.7%
Pelv. fin length	19.9 - 21.4%		20.1 - 22.4%
Caud. ped. length	16.8 - 21.7%		19.3 - 22.6%

Table 4.9 cont.

Character	Gough (n=7) 226-323mm min. max.		Tristan (n=10) 200-290mm min. max.
Caud. ped. depth	8.3 - 9%	(5.3 - 5.4%)	7.9 - 8.9%
Upper caud. lobe	23.7 - 27.2%	(29.4 - 29.9%)	24 - 28.5%
Lower caud. lobe	21.7 - 24.4%		23.3 - 25.8%
Mid. caudal ray	9.4 - 10.8%		9.2 - 12.2%
First anal spine	4.4 - 5.3%		5.8 - 6.2%
Second anal spine	7.9 - 11.8%		9.6 - 12.1%
Third anal spine	8.1 - 17.7%		9.2 - 9.8%
Seventh dorsal spine	11.1 - 14.2%		11.5 - 14.2%
Last dorsal spine	4.0 - 7.5%		6.0 - 8.2%

A. monodactylus at both localities displayed a wide variation in colour pattern. The general body colour ranged from orange/brown through gold to silver, with 6 dark bars dorsally, the first at the dorsal fin origin, the last at the base of caudal fin; small irregular black spots were scattered over the dorsolateral parts of the head and body. The pelvic fin and gill cavity were blackish.

The two specimens from Amsterdam Island differed from both Tristan and Gough fivefingers. One of the specimens from Amsterdam Island had 13 anal rays as apposed to the 11 - 12 recorded in the South Atlantic specimens. In addition the Amsterdam Island fish had a smaller head and a more elongated body than those from the other two localities. These features were shown by the reduced body depth and caudal peduncle depth to SL ratio, and the increased upper caudal lobe to SL ratio. The shape of the predorsal bones in these two specimens resembled those in specimens from the Tristan da Cunha group. Because of the limited number of specimens available and the lack of comprehensive dietary data for the Amsterdam fishes, morphometric data from the two specimens are included only as a comparison to the South Atlantic specimens.



Figure 4.10. Two specimens of *A. monodactylus* from (a) Tristan da Cunha (200 mm SL) and (b) Gough Island (245 mm SL), illustrating differences in external morphology. The main differences apparent from the photographs are in the predorsal profile and relative head size.

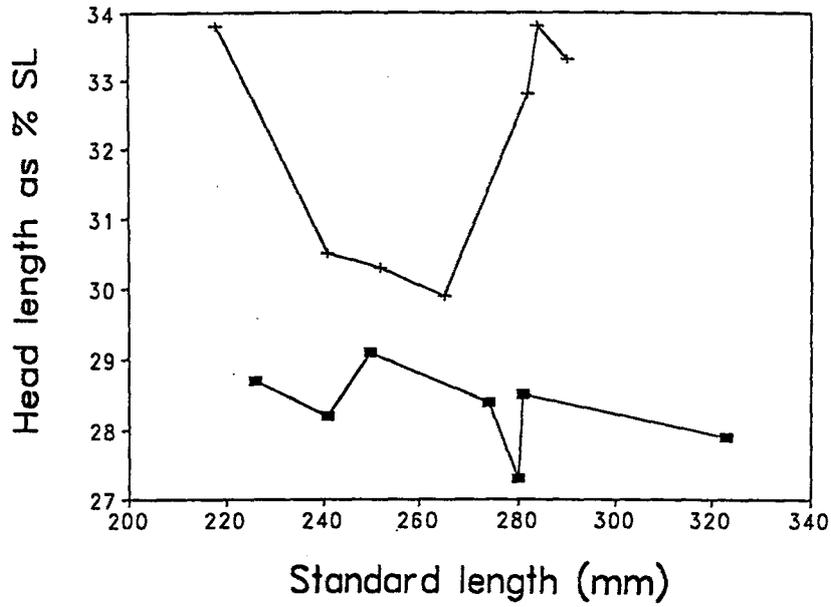


Figure 4.11. Head length as a percentage of SL plotted against SL in seven specimens of *A. monodactylus* from Tristan da Cunha (plusses) and seven specimens from Gough Island (squares).

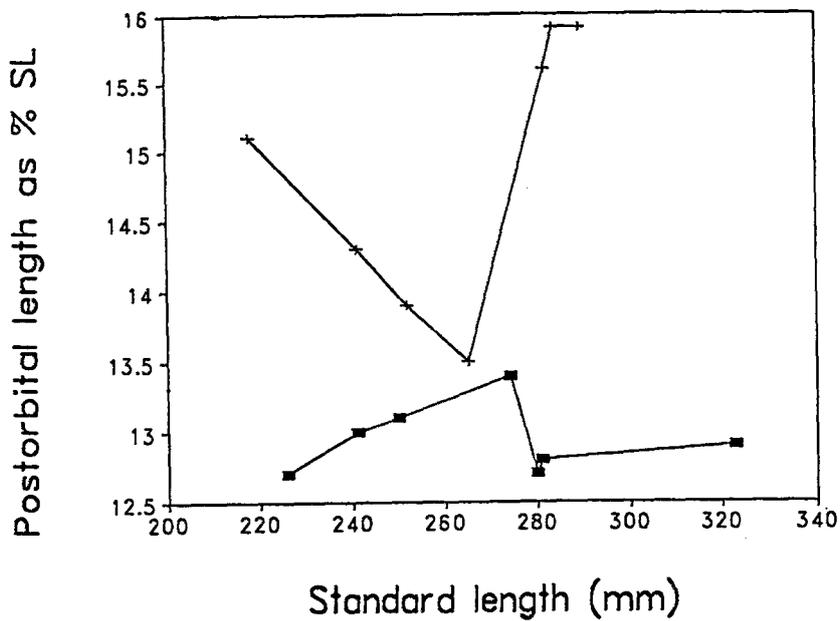


Figure 4.12. Postorbital length as a percentage of SL plotted against SL in seven specimens of *A. monodactylus* from Tristan da Cunha (plusses) and seven specimens from Gough Island (squares).

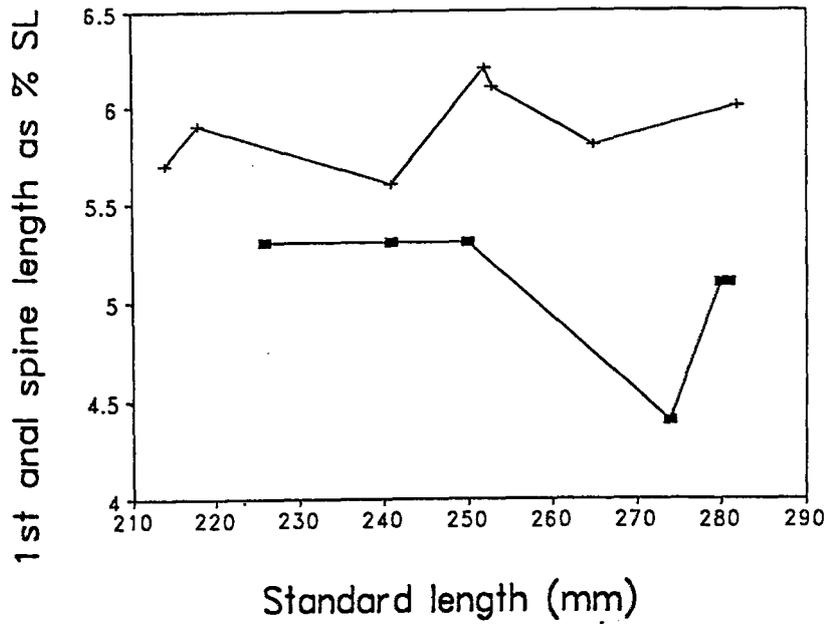


Figure 4.13. Length of first anal spine as a percentage of SL plotted against SL in seven specimens of *A. monodactylus* from Tristan da Cunha (plusses) and six specimens from Gough Island (squares).

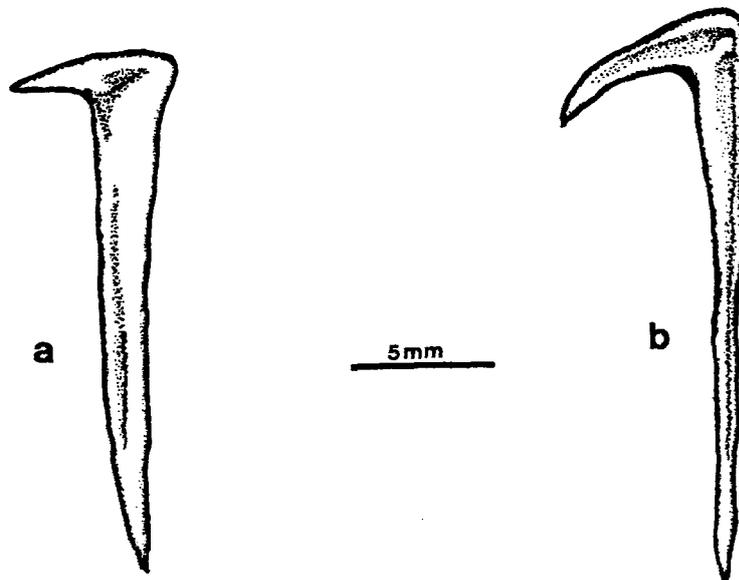


Figure 4.14. Diagrammatic representation of differences in the form of the first predorsal bone in specimens of *A. monodactylus* from (a) Tristan da Cunha and (b) Gough Island.

4.6 - DISCUSSION

A. monodactylus has been shown to be a slow growing and long lived species (Fig. 4.4). These results are consistent with Sivertsens' (1945) findings although larger and older fish were sampled in the present study in which a maximum age of 24 years at a length of 592 mm was recorded. Although larger fish were collected (max. 647 mm TL) these fish were not aged as otoliths were unreadable. It is evident therefore, that the species may attain ages in excess of 24 years.

The phenomenon of growth zone stacking was responsible for the high percentage (25 %) of unreadable otoliths. This has been a recurrent problem in age and growth studies of many long lived species (Blacker, 1974). Buxton (1987) reported that he was unable to read the otoliths of some of the largest specimens of the sparids *Chrysoblephus laticeps* and *C. cristiceps* due to stacking of growth zones near the outer margin of otoliths. Stacking of growth zones has been recorded in other long lived sparids including *Cymatoceps nasutus* (Buxton & Clarke, 1989) and *Sparodon durbanensis* (Buxton & Clarke, 1991). Similarly, Mann (1992) found larger specimens of the sparids, *Diplodus sargus* and *D. cervinus*, difficult to age because of stacking in the otolith.

A important aim of this study was to determine if growth varied seasonally. It is evident that opaque growth zones were deposited during the summer in otoliths of both sexually immature and mature fishes (Figs. 4.2a & b). Furthermore the single opaque zone laid down in immature fish and the two opaque zones in mature fish were temporally related to events known to affect growth rate in fishes. An opaque zone is deposited in all fish during the period when water temperatures are highest, while the second opaque zone in older fish is deposited after the breeding season.

Growth rate is known to be influenced by temperature (Newell, 1977; Bagenal, 1978). Numerous studies indicating that temperature positively influences growth within tolerated temperature ranges of fish species have been undertaken. Lasker (1964) reported increased growth rate at higher temperatures in the Pacific sardine, *Sardinops caerulea* while Brett (1976) found a positive relationship between temperature and growth rate in the sockeye salmon, *Oncorhynchus nerka*. Similarly Fonds (1979) and Tandler *et al.* (1989) found growth rate to

increase with temperature in *Solea solea* and the larvae of gilthead bream *Sparus orata* respectively. Smith (1989) states that body temperature in fishes rises with water temperature. As a result metabolic rate increases, appetite increases and consequently growth increases until the upper critical temperature for a particular species is reached. In the freshwater Mozambique Tilapia, *Oreochromis mossambicus*, which occurs naturally in subtropical systems with distinct seasonal temperature fluctuations, temperature was found to positively influence growth rate. Bruton & Allanson (1974) and Hecht (1980) suggested that the laying down of opaque zones in the hard tissues of the body of *O. mossambicus* was related to increased metabolic rate during the period of highest water temperatures.

The second opaque zone in mature fivefinger otoliths was deposited after spawning had ceased (Fig. 4.2b). This could represent increased growth rate associated with peak feeding after spawning. Botha (1971) stated that peak feeding occurred immediately after spawning in the Cape hake *Merluccius capensis*. Buxton (1987) found that the period of rapid growth in *Chrysoblephus laticeps* and *C. cristiceps* occurred after the breeding season. Bruton & Allanson (1974) and Hecht (1980) both found that a second opaque zone was laid down in *O. mossambicus* after spawning and suggested that this was a result of post spawning feeding in order to regain condition after the rigours of this activity.

Considerable controversy over the interpretation of the period of fast growth in otoliths has developed. Many authors have interpreted the opaque zone as the period of rapid growth while others have argued that increased growth rate is depicted by the hyaline zone. Buxton (1987) presented a synopsis of studies where opaque and hyalin zones were interpreted as faster or slower growth. Buxton (*op cit.*) presents a extensive body of evidence suggesting that the hyalin zone represents fast growth. He concluded that increased growth is likely to occur during periods when other energy demanding processes such as gonadal investment are low. In most temperate species this would suggest that rapid growth occurs in the winter as spawning generally occurs during summer in these species (Thresher, 1984). However, the evidence from the present study strongly suggests that rapid growth in the fivefinger occurs during the summer months and is represented by the formation of opaque zones in otoliths. The timing of opaque zone formation is consistent with other studies where this zone has been found to depict fast growth (Hecht & Baird, 1977; Buxton & Clarke, 1986; Thomas, 1983; 1985).

A. monodactylus has an extended breeding season that coincides with the four summer months with the highest water temperatures (Figs. 4.5 & 4.6). This suggests that spawning is closely related to water temperature in this species, perhaps indirectly. In Chapter 2 it was hypothesised that increased stratification of the water column during the summer months may lead to enhanced primary production at Tristan da Cunha and Gough Island at this time of the year. It was suggested that stratification was due to the heating of the sea surface in the STC region which increased the availability of nutrients from colder subantarctic water to phytoplankton in the surface waters. The occurrence of extensive phytoplankton blooms has been noted during the summer months in the Southern Ocean south of Africa (Allanson *et al.*, 1981). If food availability is enhanced during the summer months then it would seem plausible that this may be a factor influencing the timing of spawning in the fivefinger. If this were the case then it would lend support to Cushings' (1975) match/mismatch theory discussed earlier. Unfortunately evidence of phytoplankton blooms during the summer at these islands is lacking at present, probably as a result of the limited oceanographic research that has been carried out there.

The instantaneous fecundity of *A. monodactylus* was high (Fig. 4.8). This, together with a relatively low age at sexual maturity (2 - 3 years at 170 mm TL, see Figs. 4.4 & 4.7) and high maximum age (24 years) suggests that females have a high reproductive output during their lifespan. The species also appears to have a long-lived pelagic phase before settlement occurs. These biological characteristics obviously allow the species to survive successfully at the islands. Sinclair & Tremblay (1984) found that fecundity increased with the length of the pelagic phase in different populations of Atlantic herring in the Gulf of Maine. They suggested that this was an adaptation to compensate for the higher mortality suffered by an increased period in the pelagia. High fecundity could therefore be expected in *A. monodactylus* as a mechanism to compensate for the theoretical high mortality suffered during the extended pelagic phase. Observations during the present study on the fecundity of other species at the islands with a long lived pelagic phase indicated that high fecundity was the norm in these species (see Table 3.3, Chap. 3).

The neutral buoyancy of fivefinger eggs noted by Uys (1983) suggests that larvae hatch in the pelagia after which they grow into postlarval paperfish before metamorphosis into the benthic form occurs. As mentioned in Chapter 3, the wide distribution of *A. monodactylus* at localities close to the STC in the Southern Ocean is believed to be a consequence of this extended

pelagic phase. Although most offspring must be retained in the vicinity of the islands in order for the population to sustain itself, it is believed that pelagic phase vagrants that become separated from the retention area have the capability to disperse to distant localities.

Algae were found to pass from the stomach through the hindgut without any visible digestion taking place. Large amounts of algae are thought to be ingested in order to digest epiphytic organisms on the algal fronds. The three most common algal species ingested were the two Phaeophytes, *Laminaria pallida* and *Macrocystis pyrifera*, and the Chlorophyte *Ulva sp.*. These species were commonly covered with the sedentary polychaete *Spirorbis sp.*. The calcareous tubes of this polychaete were often found either mixed with undigested algal material in the stomach and hindgut or packed without algae in the hindgut. Beurois (1976) found that although algae occurred infrequently in stomachs of fivefinger at Amsterdam Island, fragments of *Macrocystis pyrifera* present in the intestine were often encrusted with the bryozoan *Cellepora hyalina*. This may suggest that the species selected particular fronds which supported large concentrations of encrusting invertebrates. These algae all have relatively broad, flattened fronds and hence an enlarged surface area which might in addition to encrusting invertebrates also support high concentrations of epiphytic diatoms which could be digested by the fish.

It has been found in other fish species such as *Rhabdosargus holubi* (Blaber, 1974), *Sarpa salpa* (Christensen, 1978) and *Diplodus sargus* (Joubert & Hanekom, 1980) that epiphytic diatoms are utilised, while no cellular digestion of the macroalgae occurs. In species such as the sparid *Pachymetopon grande*, where algae was found to contribute significantly to fish nutrition without cellular digestion taking place it was concluded that extracellular carbohydrates present in the mucus layer were digested (Clarke, 1988; Buxton & Clark, 1991). These authors suggested that the chemical nature of extracellular carbohydrates in the Rhodophyta, which were the principal group of algae fed on by *P. grande*, allowed these to be more easily digested than carbohydrates in the Chlorophyta or Phaeophyta (Montgomery & Gerkin, 1980; Horn *et al.*, 1982). Taking this into consideration it seems unlikely that *A. monodactylus* gained significant nutrition from algae ingested, which comprised principally Phaeophyta and Chlorophyta. Also, no cellular digestion of algae was noted in gut contents of fivefinger.

The energy expenditure associated with biting off and ingesting large quantities of macroalgae

was probably compensated for by the high concentrations of prey species such as *Spirorbis* sp.. Also, the densities of macrophytes in a given area was high and energy need not have been expended in searching for and capturing moving prey. The relatively depauperate invertebrate fauna at all the islands (Roscoe, 1979) could render the nutritional returns obtained from feeding on organisms on the surface of the algae important for the survival and success of *A. monodactylus* at these islands.

The comparison of the diets of small and large *A. monodactylus* from Tristan Island showed that small individuals fed on a greater variety of small invertebrates than the larger fish. This could result from enhanced hunting success in smaller fish achieved by foraging for food over a greater area. SCUBA observations showed that individuals smaller than 350 mm foraged in loose schools of up to 15 individuals while larger individuals were more often solitary and territorial, inhabiting clefts or caves (Andrew *et al.*, in press). The occurrence of this territorial behaviour was confirmed by the recapture of three specimens tagged in the present study up to four months later at the same locality where they were released.

Algae formed a smaller proportion of stomach contents in small individuals although macrophytes remained the most important in terms of ingested material. Also, small individuals ingested *Spirorbis* sp. covered algae more often than larger individuals. This too may be a result of the greater mobility of small individuals which enabled them to search for algal stands encrusted with polychaetes. In addition, smaller individuals occurred in larger numbers in shallow water where *Ulva* sp. was the dominant algal species, which had greater concentrations of encrusted *Spirorbis* sp. than the kelps in deeper water (pers. obs.).

Although only 14 stomachs were examined from Nightingale Island, it was apparent that the array of food items taken was similar to that taken at Tristan Island. Algae formed the most important item in the guts of fish at both localities although it was found in a smaller proportion of stomachs and in smaller quantities in the Nightingale Island specimens.

Whereas fish formed an important part of the diet of *A. monodactylus* at Tristan Island, juvenile rock lobster, *Jasus tristani*, were more important than fish at Nightingale Island. Diving observations at Nightingale Island showed that the nature of the inshore area differed from that at Tristan Island. Nightingale Island had very few tidal rockpools and an almost

vertical drop-off from the shore to about 10 m whereas the inshore region at Tristan Island consisted of many sheltered rockpools and a more gentle drop-off. The shallow rockpools (< 1.5 m) at Tristan Island afforded nursery areas for juvenile rock lobster while at Nightingale Island they occurred in deeper water. *A. monodactylus* which were large enough to feed on small rock lobster were seldom encountered in waters shallower than 2 m. This would effectively decrease the predation pressure on juvenile rock lobster by *A. monodactylus* at Tristan Island. Juvenile rock lobster had very little protection from predators at Nightingale Island. Pollock (Sea Fisheries Research Institute, Cape Town, pers. comm. April 1989) suggested that the topographical differences between the inshore areas of the two islands are so great that the lower abundance of adult rock lobster at Nightingale Island may be attributable to the greater predation of juveniles by fish. Studies on the West Australian rock lobster *Panulirus cygnus* (Howard, 1987) have shown that predation of juveniles by fish may be an important factor in regulating the abundance of adult rock lobsters. He found that predation was concentrated on newly settled lobsters and could account for a large proportion of juvenile mortality.

The comparisons of the diets of *A. monodactylus* caught in summer and in winter at Tristan Island, and the diets of fish caught at Gough and Tristan Islands were undertaken to determine if temperature changes in the oceanic environment had an effect on the availability of food and thus on diet. Only slight differences in the relative importance of various items in the stomachs of specimens collected in summer and winter were apparent. Algae and fish remained the most important items in stomachs during both seasons. It is interesting to note that no *Spirorbis sp.* was found in stomachs collected in winter at Tristan Island indicating an absence of this prey or a dietary shift towards other items during the winter. Rock lobster were more important in the diet during the winter months. It is possible that other invertebrates such as amphipods which have relatively short life cycles were scarce in winter. These data showed that amphipods were more important in the diet during summer than in winter. If this shift in diet was related to increased availability of this prey item on a seasonal basis it would strengthen the hypothesis that greater stratification of the water column would result in increased nutrient availability and thus productivity in the summer months (Allanson *et al.*, 1981). Beurois (1976) suggested that a seasonal shift in diet in *A. monodactylus* at Amsterdam Island was related to a change in the abundance of particular prey items caused by seasonal variation in oceanographic conditions. More data on the seasonal abundance of prey items such

as amphipods needs to be collected at Tristan da Cunha to further understand the effects of changes in oceanographic conditions on the diet of *A. monodactylus*.

A comparison of the diets of fish caught at Tristan Island and Gough Island throughout the year indicated that the feeding biology of *A. monodactylus* at the two localities differed greatly. A far larger range of invertebrate animals were ingested by the fish at Gough Island. Also, algae which formed the most important item in the stomachs of *A. monodactylus* from the northern islands, were of very little significance in the diets of fish from Gough Island. At this island small sea urchins formed the most important part of the diet while amphipods, anemones and chitons were all fed on extensively. The switch from utilising algal epiphytes as a major source of nutrition is thought to be due to a number of intrinsic differences in the marine environment at Gough Island.

Firstly, the kelp *Laminaria pallida* that is common at Tristan Island does not occur at Gough Island and is replaced by *Durvillea antarctica* (Chamberlain, 1965). It is possible that this brown alga does not support the rich epiphytic growth that *L. pallida* does at Tristan Island. Also, the polychaete *Spirorbis sp.*, so common on algae at Tristan Island, was not found in the guts of any of the fish sampled at Gough Island. It is likely, therefore, that this encrusting species does not occur at Gough Island. *Ulva sp.* was also absent from the stomachs of fish collected at this island. This alga was not observed whilst snorkelling at Gough Island. *Ulva sp.* is the most common substrate for *Spirorbis sp.* at Tristan da Cunha. The absence of *Ulva sp.* and *L. pallida* at Gough Island may explain the insignificant contribution that algae made to the diet of *A. monodactylus* at this island. This is regarded as further evidence that fivefinger at the northern islands selectively fed on *Spirorbis sp.* encrusted macroalgae.

The relatively close proximity of Gough Island to Tristan da Cunha would suggest that the two localities would have similar environments. However, the difference in mean annual sea temperatures of about 3°C at Tristan da Cunha and Gough Island (Fig. 2.5, Chap. 2) manifests itself in both the distribution and biology of species in the region. A number of fish species common to the Tristan da Cunha group are absent at Gough Island due to differing oceanographic conditions at the two localities (Chap. 3) Some species such as *A. monodactylus* are however able to survive at both localities.

It can be concluded that the fivefinger displays a highly opportunistic feeding strategy at Tristan da Cunha and Gough Island. Beurois (1976) found that *A. monodactylus* at Amsterdam Island also feeds opportunistically. Fish collected inshore and offshore fed on items that were abundant at the particular depths at which they were collected. This strengthens the opinion that the species is strongly adapted to survive successfully in conditions which offer different levels of food availability.

Although the fivefinger exists successfully at Gough island, the fish there are morphologically distinct from those at Tristan da Cunha. It has been shown that specimens of *A. monodactylus* from the Tristan da Cunha group and Gough Island differed significantly in some skeletal components and resulting body proportions. Because the populations at the two localities are not believed to be completely isolated, it is proposed that differing environmental conditions and resultant food availability has given rise to two eco-morphs in the South Atlantic. Ryan (1992) found intraspecific variation in male song, colouration and morphology in *Nesospiza* buntings at Nightingale and Inaccessible Islands. He concluded that these differences were evidence of the early stages of speciation as he considered the populations at the different islands to be reproductively isolated. These results suggest that intraspecific variation occurs in other vertebrate groups as well as fish at different islands within the Tristan da Cunha and Gough group.

Meyer (1987) has shown conclusively in the Neotropical cichlid species *Cichlosoma managuense* that body form can vary greatly depending on the food ingested by the animal. He conducted experiments in tanks where diet could be strictly controlled and morphological changes could be closely monitored. He fed two groups of full siblings two different diets for a period of 8 months. Thereafter both groups were fed a common diet. In this case phenotypes that differed significantly at 8.5 months converged almost completely after 16.5 months. He also found that if feeding continued on two different diets after 8.5 months the phenotypes remained distinct. Similarly, Jubb (1967) and Gaigher (1975) found considerable intraspecific variation in the head and mouth parts of southern African yellowfish species and related these differences to phenotypic plasticity induced by varying feeding strategies under different environmental conditions.

The results of Meyers' (1987) work suggested that there was no significant difference in

growth rate in his experimental animals fed different diets. Only morphological differences occurred, especially in the head length, cheek depth and eye diameter. It is interesting to note that the major difference between *A. monodactylus* at Tristan and Gough is in the proportion of head length to standard length. Rubin & Lanyon (1984) have demonstrated that even low frequencies of dynamic loads on bone can result in the remodelling of bone structure. In simple terms this means that bone is relatively plastic when external forces are applied to it. Based on this observation and the fact that diet in *A. monodactylus* differed significantly at Tristan and Gough Islands it seems reasonable to expect this remodelling to be manifested in the head of the animal; hence the differences in head proportions in fishes from the two localities.

The extensive documentation of evidence indicating that intraspecific epigenetic morphological variation does indeed occur under varying environmental pressures such as food availability, and hence diet (Iles, 1973; Hindar & Jonsson, 1982; Hecht & Zway, 1984; Balon, 1985; Meyer, 1987), suggests that this is a highly probable mechanism through which the fivefinger at Tristan da Cunha and Gough Island develop different morphological characteristics during their ontogeny. This is presented as further evidence of the effect of the environment on fishes at Tristan da Cunha and Gough Island.

The separation of shallow water habitats in the open ocean is particularly marked compared to most marine habitats in shallow continental waters because of the great depths between these in the open ocean. This has enabled the examination of two populations that are isolated in the adult phase, have different diets, and probably maintain some genetic mixing via dispersive pelagic phases. The differences that are apparent between *A. monodactylus* from Amsterdam Island in the Indian Ocean and those from the South Atlantic are further evidence that this species displays morphological differences under differing environmental conditions. In conclusion, although all evidence indicates the occurrence of trophic polymorphism in the fivefinger it would be desirable to test the hypotheses outlined above with controlled feeding experiments to verify the existence of this phenomenon in wild fish.

Having addressed age and growth, reproduction, feeding and environmentally induced phenotypic variation in *A. monodactylus*, more or less as individual entities, it is appropriate to consider the biology of this species in a broader perspective. The species can be briefly described as a long-lived, slow growing and fecund gonochorist. Many small eggs are produced

by females which hatch into the water column as eleutheroembryos (*sensu* Balon, 1985). No parental care is evident. Larvae develop into an active pelagic paperfish phase before settlement occurs. The species feeds opportunistically on a wide variety of prey items.

Resource partitioning, particularly of habitat and food, occurs between the different stages of the life cycle of the fivefinger. Fivefingers in different size classes prefer different habitat types thereby utilizing space to a maximum. Larvae and paperfish stages are restricted to the pelagic zone surrounding the islands. Fishes between about 70 mm and 150 mm TL prefer rockpools and shallow water (less than 3 m). Small fivefingers (less than 350 mm TL) live in loose shoals of up to 15 individuals near or in high relief areas covered by stands of either *Macrocystis pyrifera*, *Laminaria pallida* or both. Larger adults tend to be solitary and inhabit well defined territories around clefts and caves on high relief reef. Thus the fivefinger inhabits a wide variety of bottom types as well as a wide depth range.

Diet also varied in the different stages outlined above. Although diet of the pelagic phase was not studied it is highly probable that pelagic individuals would feed entirely on small organisms found in the pelagia. It was shown that fivefingers less than 350 mm fed on a greater variety of prey items than the larger, more sedentary fish and it was suggested that this was a result of smaller fishes being typical search-hunters (Hughes, 1980). Optimal foraging theory (Hughes, 1980) predicts that prey items will be actively selected if the relative value of prey items differ in terms of assimilated energy. The greater mobility of smaller fish suggests that they may be able to select food items to a greater extent than larger individuals, as indicated by the higher proportion of algal fronds with attached polychaetes ingested by smaller fishes.

The utilisation of different habitats and food by fivefinger in different stages of the life cycle is considered particularly important in the shelf waters of Tristan da Cunha and Gough Island where it is highly probable that these resources are limiting. In effect, the observed habitat separation must reduce intraspecific competition on the shelf. This strategy allows the species to optimise the resources of a number of habitats, thereby escaping the option of "placing all the eggs in one basket".

In order to further understand how the suite of biological characteristics outlined above have enabled the species to become so successful at the islands it is useful to consider how these

characteristics are viewed by modern life-history theory.

Various descriptive terms and theories have been proposed in an attempt to categorise organisms according to their biological characteristics. These generally attempt to describe alternative strategies that may be adopted by an organism in their development (Bruton, 1989). Species have been described as generalists or specialists (Holm, 1985), opportunist species or equilibrium species (Colinvaux, 1986), r- or k- strategists (MacArthur & Wilson, 1967), and most recently, as altricial or precocial species (Balon, 1988).

Ecological generalists are usually defined as species that occupy a wide multidimensional niche and are considered to be adaptable species. Specialists occupy a narrow multidimensional niche and are considered to be adapted (Holm, 1985). It has been argued however that generalists are "versatility specialists" (Lorenz, 1978, in Bruton, 1989). These two terms are extremely broad and are therefore not considered useful for categorising complex life-history styles in this study.

Similarly, the terms opportunist and equilibrium species are broad and not suited to describe the life-history of an organism satisfactorily. According to Colinvaux (1986), there are two extreme life-history strategies that are common in nature, one suited to marginal environments which are subject to un-predictable perturbations, the other suited to more equable environments in which perturbations are more predictable and organisms are likely to reach some sort of equilibrium. Unpredictable, or capricious, environments are typically inhabited by opportunist species while predictable, or benign, environments are typically inhabited by equilibrium species (Bruton, 1989).

The theory of r- and K- selection was first proposed by MacArthur & Wilson (1967) in an attempt to describe how species' life histories were adapted to the environment after different stages of colonisation of islands. They suggested that species with high rates of reproduction and rapid growth were more successful during the early, uncrowded stages of colonisation. Under more stable, climax conditions species equipped for competitive survival at high densities were selected for. They described these different strategies by invoking the r and K parameters used in population growth equations where r is the intrinsic rate of increase and K is the upper asymptote or equilibrium population size (Pianka, 1972).

MacArthur & Wilson (1967) showed that r- selection dominates in the early stages of colonisation while K- selection predominates under conditions of more intense competition, such as in stable, climax conditions. In the early stages of colonisation where competition for resources is less intense but where density-independent mortality is high, it would be favourable for a population to have a high intrinsic rate of increase in order resist decimation. Reproductive effort should therefore be relatively high (r- selection). Conversely, under conditions of intense competition for resources it would be favourable for a species to have fewer large parents than many small offspring. Reproductive effort would be lower (K- selection). It seems then that the separation of r- and k- strategists hinges on the relative proportion of the organism's total resources that are allocated to reproduction (Gadgil & Solbrig, 1972). According to Adams (1980) r- selected species are generalists, display early maturation, fast growth and a short life span. K- selected species are specialists, display a high age at first maturity, slow growth and a high maximum age. r- selected species are also generally regarded as suitable candidates for exploitation because their biological characteristics are aimed at production (Adams, 1980). Clearly, *A. monodactylus* is neither a strongly r- or K- selected species. Although this theory provides a relatively simple (ie. few parameters) means of comparing life-history styles it has been criticised for a number of reasons.

The major criticisms include its lack of explanatory power when dynamic reproductive strategists are considered. Failure to consider such dynamic strategists can result in misleading comparisons of populations (Bruton, 1989). The theory has also been criticized as being too inflexible (Mann *et al.*, 1984). These authors have suggested that environmental effects, such as the effects of temperature and productivity overshadow genetically determined life-history styles. In essence the theory does not consider the epigenetic processes underlying different life-history styles.

The concept of altricial/precocial homeorhetic states (Balon, 1989) is considered to be more appropriate for categorising life-history strategies as it takes the epigenetic and ecological processes resulting in a particular life-history strategy into account (Bruton, 1989). The importance of epigenetic and ecological processes in influencing the biology of the fish at Tristan da Cunha and Gough Island has been stressed in this study.

Altricial and precocial life-history strategies were first used by ornithologists to describe

differences in parental investment in birds (eg. Nice, 1962). In the traditional usage of the terms, altricial species invest less per individual young than precocial species and produce many poorly developed young as compared to the few, well developed young produced by precocial species (Bruton, 1989). These terms have been developed into the concept of altricial/precocial homeorhetic states (Balon, 1985; 1988; 1989). This concept reflects the processes behind the formation of patterns such as r- and K- selection described above (Bruton, 1989) and therefore enables more complete description of an organisms' life-history style. Table 4.10 lists the suite of characters typically associated with altricial and precocial life-history strategies in fishes (after Bruton, 1989).

With the large range of characters used in the concept of altricial/precocial life-history strategies it should theoretically be possible to place a species at some point in the continuum between the two extremes. However, to do this it is necessary to have a comprehensive knowledge of the species' biology and of the environment in which it lives. It is important to be able to compare findings with characteristics of other species in order to place the life history style of the species under study into perspective.

Known or probable characters of the biology and ecology of *A. monodactylus* are listed in Table 4.10. In terms of epigenetic and ecological characters the fivefinger shows strong altricial and precocial traits. Because of the difficulty in defining the particular position that the fivefinger occupies in the altricial/precocial continuum it is suggested that the species be treated as a unique biological entity when considering it in relation to conservation or fisheries management.

Table 4.10. The suites of characters typically associated with altricial and precocial life-strategies in fishes (after Bruton, 1989), and characters present in *A. monodactylus*.

	Altricial	Precocial	<i>A. monodactylus</i>
EPIGENETIC			
egg size	small	large	small
egg yolk	not dense	dense	not dense
egg number	large	small	large
larvae	usually present	usually absent	present
juvenile mortality	high	low	probably high
size at first feeding	small	large	small
size at first breeding	small	large	large
parental investment	low	high	low
fitness of young	low	high	high
reproductive rate	high	low	?
ECOLOGICAL			
trophic niche	wide	narrow	wide
species diversity	low	high	low
specialised	less	more	less
chromosome number	high	low	?
species interdependence	lower	higher	lower
adaptability	high	low	high
adaptedness	low	high	?low
typical environment	unstable	stable	unstable
environmental changes	unpredictable	predictable	unpredictable
surplus production	high	low	?
life style	generalist	specialist	generalist
community	pioneer	equilibrium	?equilibrium
mortality	density-independent	density-dependent	density-dependent and -independent
dormancy	common	uncommon	?

In fact, the danger of species being categorised as altricial or precocial based on only a few of the characters listed in Table 4.10 is considered by this author to be a threat to rational management of stocks. It is stressed that a thorough knowledge of a species' biology should be obtained before attempting to propose management procedures. Life-history theory should perhaps be used as an aid to understanding the natural world rather than as a practical tool for conservation or fisheries management, applications of the theory which Bruton (1989) suggested would be useful. It is useful, however, to compare the life-history characteristics of various species at the islands in an attempt to determine common factors contributing to their success. This will be carried out in Chapter 8.

The study of the biology of *A. monodactylus* has shown that the species is well adapted to survival at the islands. It is unlikely that the species has evolved these characteristics since colonising the islands. It is known that many species in the Family Cheilodactylidae have pelagic paperfish (Allen & Heemstra, 1976) and it is believed that the fivefinger reached the mid-Atlantic islands because of this adaptation. It survived because it was tolerant of, or was able to adapt to, local environmental conditions. An indication of this ability to adapt is evident from the dietary differences found in the species at Tristan da Cunha and Gough Island.

Growth, reproduction and feeding in the fivefinger have been shown to be influenced by temporal and spatial variation in environmental conditions. The extent to which these biological processes are affected by environmental fluctuations in other species at the islands will be considered in the following chapters.

CHAPTER 5 - THE REPRODUCTIVE BIOLOGY OF THE CONCHA WRASSE, *NELABRICHTHYS ORNATUS*

5.1 - INTRODUCTION

Little was known about the biology of the concha, *Nelabrichthys ornatus*, prior to this study. During the first month on Tristan it became apparent from SCUBA observations of colour and size dimorphism that the species might be hermaphroditic. As mentioned in Chapter 1, it was decided to study the reproductive biology of this species in detail because the hermaphroditic reproductive strategy was considered to be the most complex strategy displayed by any species at Tristan da Cunha and Gough Island. It was hoped that a knowledge of the reproductive biology of this species would contribute towards a further understanding of reproductive processes, and their seasonality, at the islands.

N. ornatus was first described from Tristan Island in the South Atlantic by Carmichael (1819) as *Labrus ornatus*, and later by Regan (1913) as *Labrichthys ornatus*. Regan found that the two species described by Sauvage (1875) from St Paul Island in the south Indian Ocean, *Labrichthys lantzii* and *L. isleanus*, were male and female of the same species. The three nominal species were synonymised by Russel (1983) under a new monotypic genus, as *Nelabrichthys ornatus*. This species has subsequently been found at Walters Shoal on the Madagascar Ridge (Collette & Parin, 1991) and at Amsterdam Island in the south Indian Ocean (Duhamel, 1989).

In the South Atlantic the concha inhabits the shelf waters of Tristan, Inaccessible, Nightingale and Gough Islands. The species occurs in intertidal and subtidal waters to a depth of over 50 m and up to 2 km from the shore. Numerically it is the dominant fish species from 2 m to at least 25 m depth. Their distribution is restricted by algal or rock cover and for this reason they are most commonly found within 2 m of the bottom.

Most work on hermaphroditism in the family Labridae has taken place on tropical or warm temperate species (eg. Moyer & Shepard, 1975; Meyer, 1977; Warner & Robertson, 1978; Bell, 1983; Warner & Lejeune, 1985; Kobayashi & Suzuki, 1990), although Jones (1980; 1981) has

described hermaphroditism in a cool temperate labrid off New Zealand. In this chapter the occurrence of protogynous hermaphroditism in *N. ornatus* is confirmed and the reproductive season, courtship and mating behaviour of the population at Tristan da Cunha is described. The advantages of this reproductive strategy for survival in the seasonal environment at the islands is discussed and common reproductive features with other species at the islands are outlined.

5.2 - METHODS

Observation and collection of *N. ornatus* was carried out in the intertidal and subtidal regions down to about 25 m depth at two localities close to the settlement of Edinburgh on the north west coast of Tristan Island (Fig. 5.1). The first study site (A) was situated off the harbour and covered the shallow subtidal down to about 15 m and extended a distance of approximately 75 m out to sea. The second intensively studied site (B) was situated at Flat Rocks and included intertidal rockpools ranging from 0.5 m to 2.5 m depth.

Rotenone collections were made on a monthly basis between October 1988 and March 1990 in the rockpools at site B. A total of 243 conchas were collected in 20 rotenone stations over this period. These animals were measured, weighed and sexed using visual criteria, and a sample of the gonads from each monthly collection were kept for histological examination. Gonads were fixed in a 10 % formalin for 3 days and then stored in 50 % propyl alcohol. Gonads were embedded in paraffin wax, sectioned at 6 to 8 μ m, stained with orange-G and haematoxylin, and viewed under a microscope at between 40 and 400 X magnification.

Observations on habitat preference, population density, social structure and spawning behaviour were done with SCUBA and snorkel diving. Monthly fixed width strip transects (30 m x 4 m) were done between 2.5 m and 8 m depth at site A. This was achieved by swimming along a 30 m line laid out on the bottom and counting all fish within 2 m either side of the line. A constant swimming speed was maintained as far as possible to prevent the recounting of fish. The strip transecting technique was chosen in preference of point transecting for a number of reasons. Firstly, strip transects cover a greater area than other techniques. This was important as the distribution of concha was patchy at site A and this technique allowed fish in a variety of habitat types to be counted. Secondly, concha were relatively sedentary therefore fish density in the fixed strip was not thought to change significantly during the 1 to 2 minutes taken to

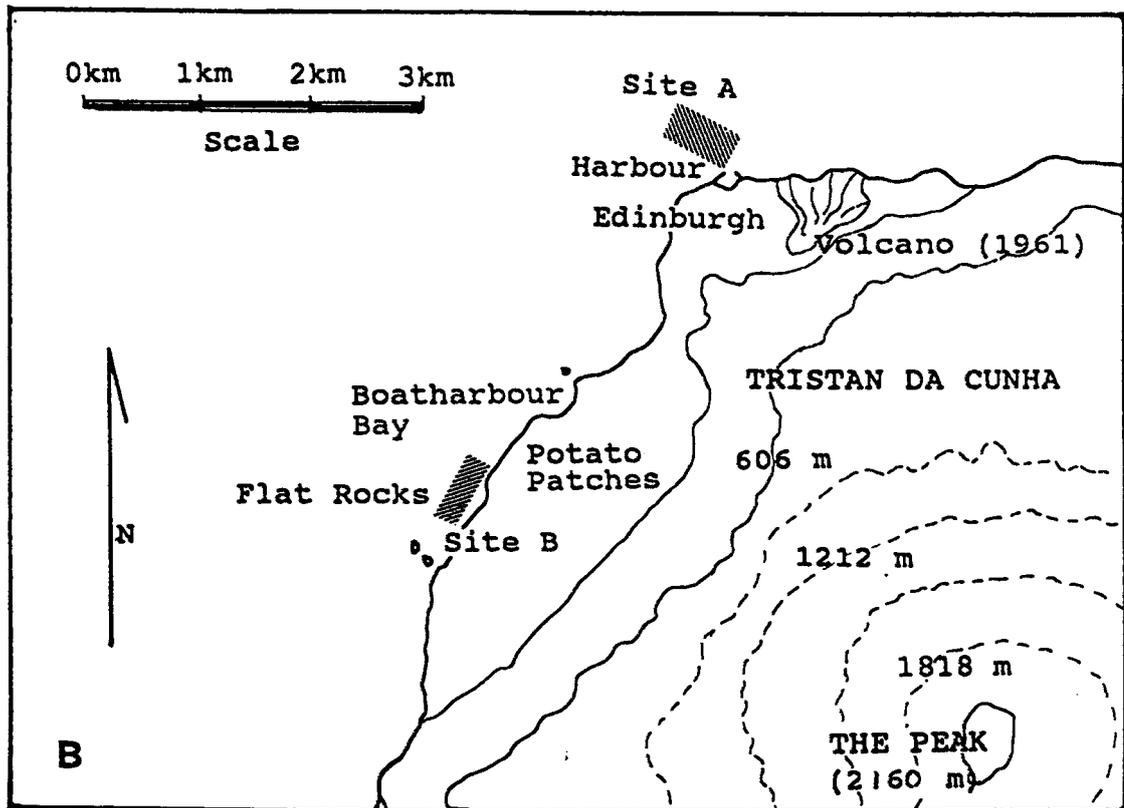
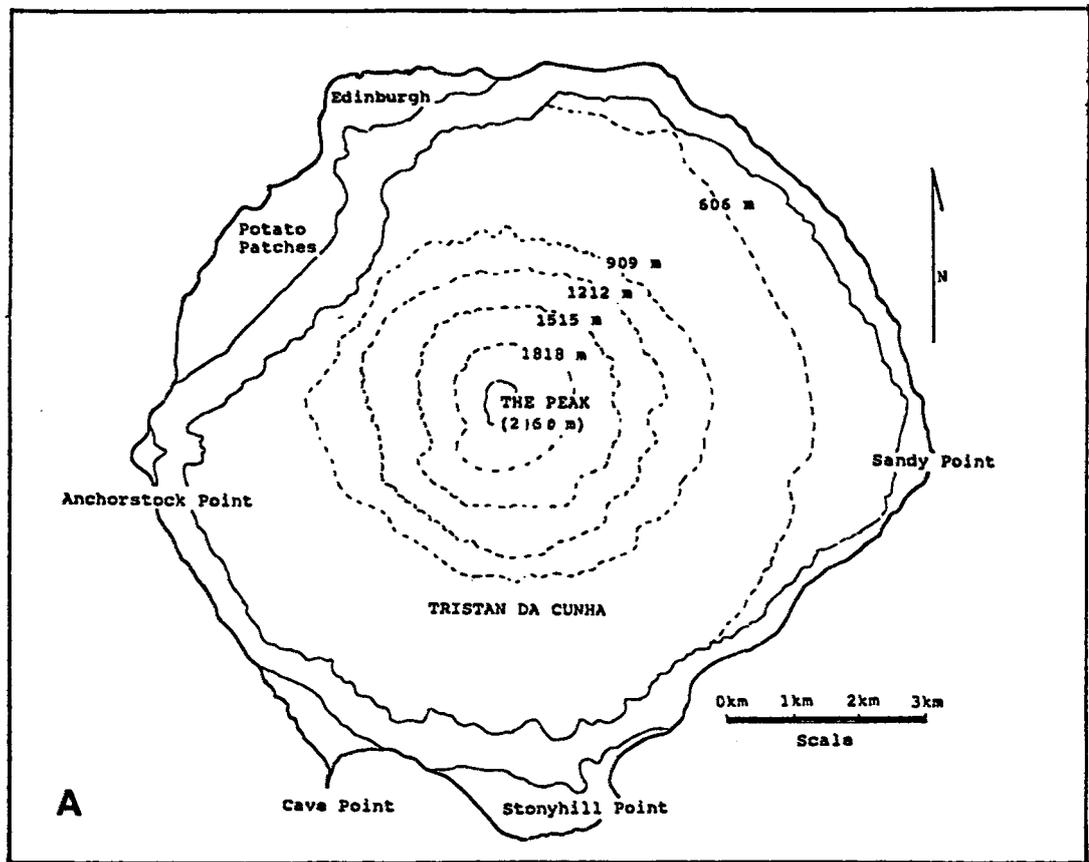


Figure 5.1. Tristan Island (A) and an enlargement of the northwest sector (B), showing the locations of site A and B (shaded)[adapted from Crawford, 1982].

swim the transect (Buxton, 1987). For these reasons strip transects have predominated over other techniques in reef fish surveys of a number of species, including labrids (eg. Jones, 1980; Leum & Choat, 1980; Kingett & Choat, 1981; Bell, 1983). Counts were done during daylight when fishes were feeding and therefore more visible. Sex ratios were estimated using colour dimorphism. Behavioral observations were conducted at site B by lying motionless on the bottom in the cover of kelp stands for periods ranging from 30 minutes to 2 hours.

The duration of the spawning season was determined by macroscopic observation of breeding condition throughout the year and by calculating mean monthly gonadosomatic indices (GSI). An intensive period of observation was undertaken during the summer spawning season of 1989/1990. SCUBA dives were undertaken at various times throughout the day from 11 December to 15 December 1989 and on other occasions through the summer to determine the timing and duration of spawning activities. In addition total fish counts and visual estimations of sex ratios were undertaken on four occasions during daylight hours at site B during the breeding season. A total of 15 hours observation were undertaken during the study period. The period in December coincided with a full moon, although this only rose after observation ended in the evening.

The pool at site B (Round Pool), chosen for observation of courtship and mating, was approximately circular with a diameter of 15 m (176.6 m²) and had not been subjected to rotenone collecting at any stage during the study. The sides of the pool were almost vertical and covered with dense algal growth. The rock of the sides of the pool was heavily fissured allowing adequate cover for conchas. The central area of the pool was devoid of the kelps *Macrocystis pyrifera* or *Laminaria pallida* and the bottom was littered with round boulders of a maximum of 20 cm diameter, covered with algal turf. The bottom of the pool sloped from 1.5 m at the southern shore to 2.5 m at the northern edge.

5.3 - RESULTS

5.3.1 - GONADAL STRUCTURE

The gonads of *N. ornatus* were suspended from the postero-dorsal mesentery of the body cavity. They were paired and fused posteriorly into a common gonoduct. In the resting phase ovaries and testes were thread-like, translucent and sexes were fairly difficult to distinguish.

With the onset of gonadal recrudescence ovaries increased in size almost filling the body cavity, were reddish-orange in colour and in ripe individuals translucent eggs were clearly visible. The testis was creamy-white in appearance but the increase in size was not as marked as in females. Figure 5.2 shows that mean GSI values for females increased from less than 1 to almost 7 (7 fold increase) from October to November, while male GSI values remained below 1 throughout the year. Males displayed a 4 fold increase in GSI during recrudescence. Based on the histological material available, oogenesis and vitellogenesis appeared to be very similar to reports in the literature (Wallace & Selman, 1981; Kobayashi & Suzuki, 1990). Oocytes were observed during all stages of development, including the primary growth, initiation of yolk vesicle (cortical alveoli), late yolk vesicle, early vitellogenic, maturation and atretic stages.

Two distinct egg sizes were present in ripe ovaries, small pre-vitellogenic oocytes (< 0.4 mm), and vitellogenic oocytes between 0.4 and 0.6 mm in diameter. Of the 18 153 yolked eggs counted in a single mature female (125 mm TL) collected in the middle of the breeding season, only 14.3 % were unattached from the connective tissue. This would suggest that *N. ornatus* was a multiple batch spawner, shedding small batches of eggs at each spawning event during

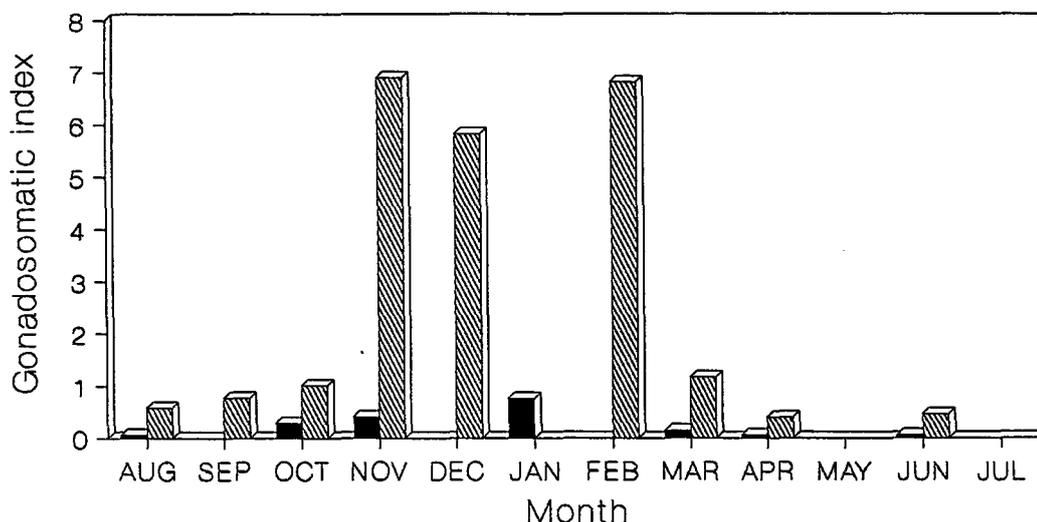


Figure 5.2. Mean monthly gonadosomatic indices for male (solid bars) and female (hatched bars) *N. ornatus* collected at Tristan da Cunha (n = 132).

the breeding season. Gonadosomatic indices showed that gonadal recrudescence began in October, spawning took place between November and February and gonadal regression occurred in March (Fig. 5.2).

The occurrence of protogynous hermaphroditism in *N. ornatus* was confirmed histologically. The transition from female to male, which was not evident from macroscopic examination of gonads, occurred through an invasion of the ovary by testicular tissue. Initially, spermatogenic cysts formed amongst oocytes. These then expanded into seminal lobules while oocytes degenerated, resulting in a mature testis displaying remnants of a female history, such as a rudimentary ovarian lumen (Figs. 5.3a to d). These stages of transition were also found in the protogynous labrid, *Cirrhilabrus temmincki* by Kobayashi & Suzuki (1990). Transitional gonads were observed in *N. ornatus* between 93 mm and 196 mm TL. In sex changing individuals either the ovary or the testis was mature, precluding possible self fertilisation.

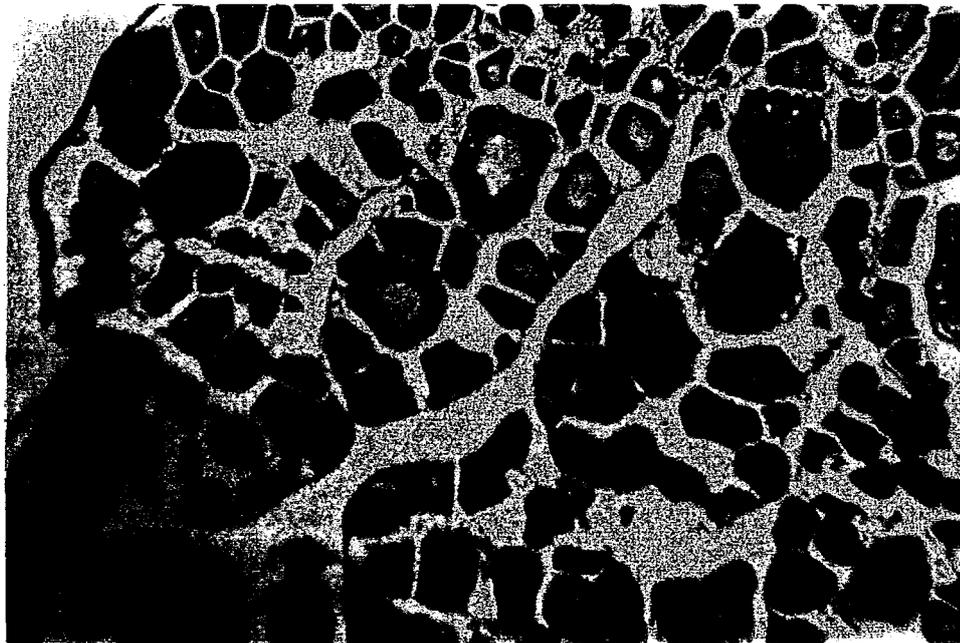


Figure 5.3a. Mature ovary of a 144 mm TL female *N. ornatus* (X 80) showing active vitellogenesis.



Figure 5.3b. Developing spermatogenic cysts (sc) in the mature ovary of a 178 mm TL female *N. ornatus* (X 80).



Figure 5.3c. Degenerating oocytes (do) in the mature testis of a 180 mm TL male *N. ornatus* (X 80).

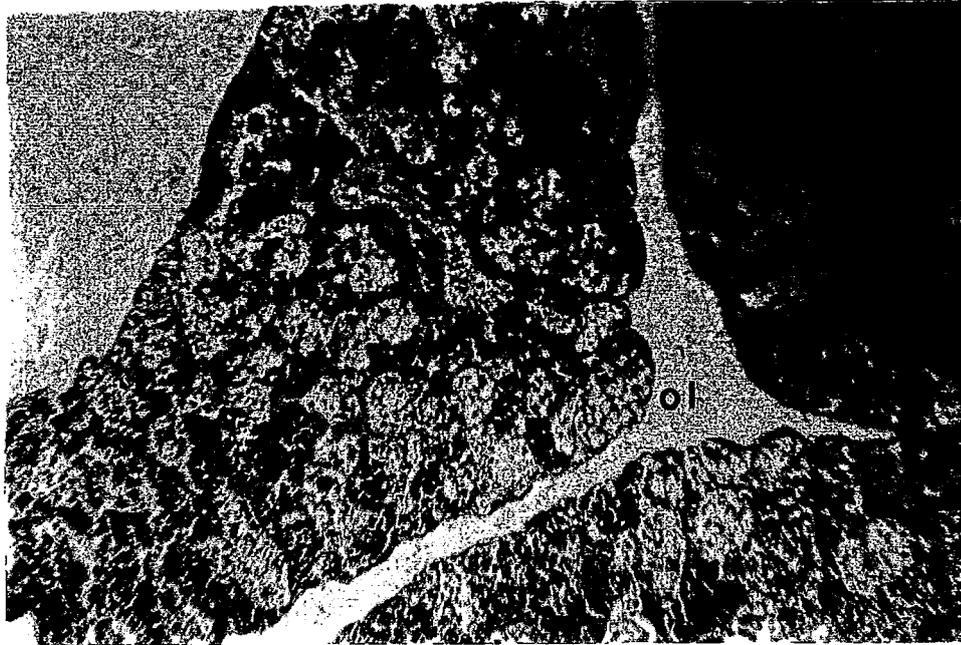


Figure 5.3d. Mature testis from a 202 mm TL male *N. ornatus* (X 80) showing active spermatogenesis and the rudimentary ovarian lumen (ol).

5.3.2 - COLOUR AND SIZE DIMORPHISM

Three different colour phases were recorded in *N. ornatus*. Juveniles were predominantly yellow with faint lateral stripes similar to the more obvious striping found in adult fish. Mature females were olive brown with azure striping on the head, body and caudal fin. Juveniles and females had black spots at the base of the anterior and posterior parts of the dorsal fin and on the upper part of the caudal peduncle, and the fins were transparent (initial phase). Males were also olive brown in colour, but the striping was more intense than in females. Only the spot at the anterior of the dorsal fin was present and the dorsal, anal and caudal fins were brightly patterned with azure stripes (terminal phase). The juvenile and terminal male phase are illustrated in Figure 3.20a and b, Chapter 3.

From behavioral observations, sexing fishes in the field and the histological studies it was clear that the species was monandric with all males found at the upper end of the size range. No initial phase males were recorded although smaller males tended to be less brightly coloured than larger ones. Fish undergoing sex change exhibited transitional colour patterns.

5.3.3 - POPULATION STRUCTURE

The length frequency distribution of fish sampled intertidally (site B), and the relationship between size and colour phase is shown in Figure 5.4. There was little overlap in the size distribution of the colour phases. During the breeding season (at the end of the study period) all of the fish in Round Pool (n = 139) were collected (Fig. 5.5).

The sex ratio in the Round Pool sample was 1 male : 3.9 females and the density of fish in this pool was 0.78 fish /m². Visual assessment of fish density and sex ratio conducted on four occasions during the breeding season in Round Pool showed that density ranged from 0.84 to 1.13 fish /m² and sex ratio ranged between 1 : 5 and 1 male : 6.48 females. By comparison, subtidal monthly transects at site A produced an average density of 0.24 (±0.13) fish /m². Visual assessment of sex ratio at site A was 1 male : 12.2 females on average. No observable changes in density or sex ratio was noticed at site A with the onset of the breeding season although the limited number of transects undertaken (as a result of poor weather conditions) prevented meaningful statistical comparison of monthly samples. In all of the localities sampled

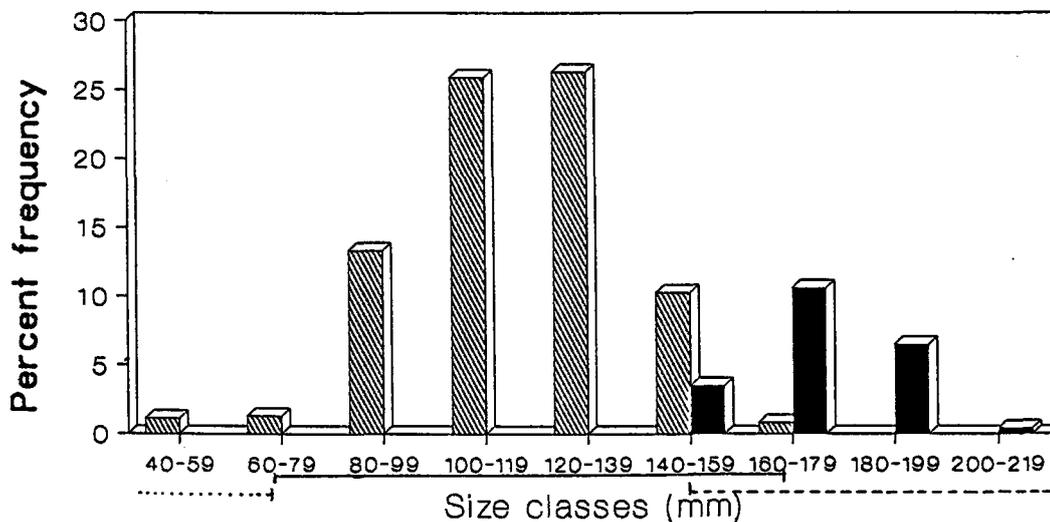


Figure 5.4. Length frequency distribution of all *N. ornatus* sampled from the intertidal zone from October 1988 to March 1990 (hatched bars = females, solid bars = males; n = 263). The relationship between size and colour phase is also shown (dotted line = juvenile, solid line = female, dashed line = male).

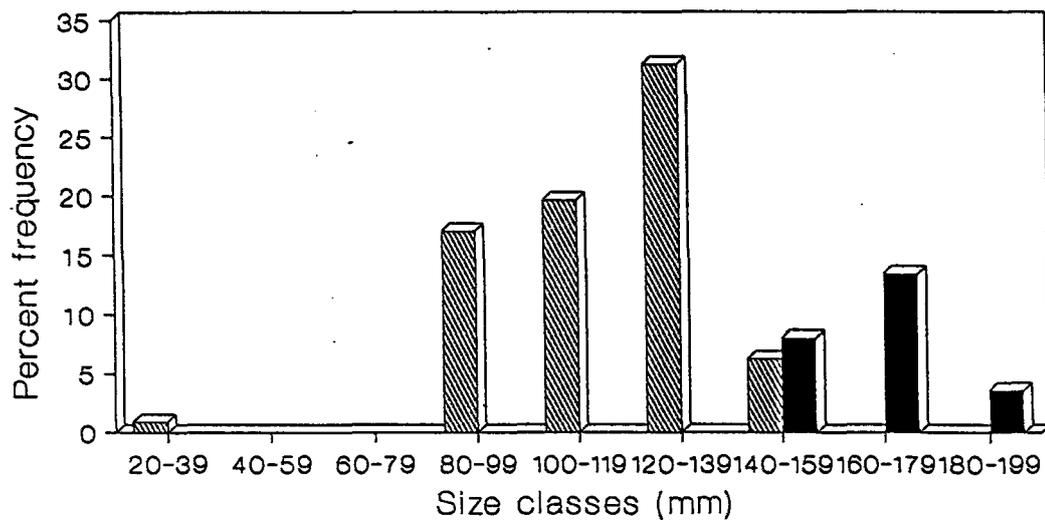


Figure 5.5. Length frequency distribution of all *N. ornatus* in Round Pool collected on 28 March 1990 at the end of the breeding season (hatched bars = females, solid bars = males; n = 139).

large and small fish occurred in separate habitats. Larger females and males (>90 mm TL) monopolized areas where macroalgal cover was good, while smaller females and juveniles were restricted to low relief areas made up of rounded boulders with little algal cover. This habitat partitioning was probably the result of the levels of protection that the different habitats afforded animals of different size. Juveniles and small females were able to utilise small boulders for cover by remaining between them, while larger females and males needed more prominent features such as those present on higher relief reef in order remain under cover. It should be remembered that even males in this species attain a relatively small maximum size and are therefore vulnerable to predation by other reef dwelling species.

The observed difference between sex ratios and densities at site A and B is thought to be a combination of the interspecific habitat partitioning described above, and a movement of adult conchas to preferred spawning sites during the breeding season. Site A was a habitat preferred by small females and juveniles while site B was a preferred spawning site. Irregular observations during the spawning season at other subtidal localities around the island showed a similar relationship between habitat, population density and sex ratio.

5.3.4 - COURTSHIP DISPLAYS AND MATING

During the day male and female fishes remained in areas that afforded reasonable cover. Males and females mingled freely in feeding groups containing fish of all sizes. There was little aggression shown by males at this time of day although irregular short bursts of aggressive display were observed.

As evening approached males would take up their positions in the central open areas of the pool, setting up roughly circular territories of up to 2 m diameter. Four sites close to the point of observation were occupied by the same individuals on each evening. Individuals were recognised by size and missing patches of scales presumably lost through fighting with other territorial males. In their territories males adopted a courtship coloration. The olive brown base colour turned a milky white while the azure stripes remained. Fishes in general are often capable of rapid and striking temporary colour changes (Thresher, 1984). The caudal, dorsal and anal fins were extended during the entire courtship period. The movement into territories was accompanied by increased aggression toward other males, and other species inhabiting the pool.

Although chasing males normally stopped at their territorial boundary they sometimes chased other males up to 5 m outside of this. The longer chases were normally a result of vigorous fighting which could last for up to 30 seconds. Fighting consisted of rapid chases with frequent confrontations where fishes appeared to nip each other. Females moved freely through the area without regard for territorial boundaries. The smallest female observed amongst these was approximately 50 mm TL.

Courtship began just before sunset each day during the spawning season. The onset of courtship appeared to be closely related to light intensity, always first beginning in the shaded areas of the pool followed by the sunlit areas. Courtship continued for approximately 70 minutes, ending when light intensity was reduced. This occurred between 30 and 40 minutes after sunset.

Courtship displays are illustrated in Figure 5.6. Males would attempt to attract females by swimming off the bottom at an angle of 45 degrees to a height of approximately 30 cm and then returning to the substrate. This upward arching swim lasted about 5 seconds and was

accompanied by continuous shaking of the body and fins. The arch was followed by a looping swim close to the substratum with a sharp turn at the furthest extreme. It extended a distance of about 50 cm and was also accompanied by continuous shaking. In four territories observed on four separate occasions, each male performed the display an average of 47 times. Males attempted to court any females close to their territories irrespective of female size. Females only joined the male at the end of his courtship display, ascending rapidly off the bottom to within 50 cm of the surface where spawning presumably took place. The release of gametes was not observed because of the poor light intensity during observations. Males and females parted after reaching the peak of the upward swim and returned to the bottom. The spawning swim took approximately 2 seconds to complete.

No evidence of sneaking or streaking (Krebs & Davies, 1981; Warner, 1984) by smaller males was observed at any time. Smaller males were present in the pool but occupied peripheral territories where mating success was not as high as in the more visible territories in the central areas of the pool. Bachelor males were absent and it appeared that the numbers of males in the pool were limited by available territories. Fighting between males assured that the largest males occupied the optimum sites in the middle of the courtship arena while the smallest would be chased out into adjoining pools.

Females began to leave the courtship arena 25 to 30 minutes after sunset. Following this the males left their territories for algal cover at the pool edge and reverted back to normal coloration.

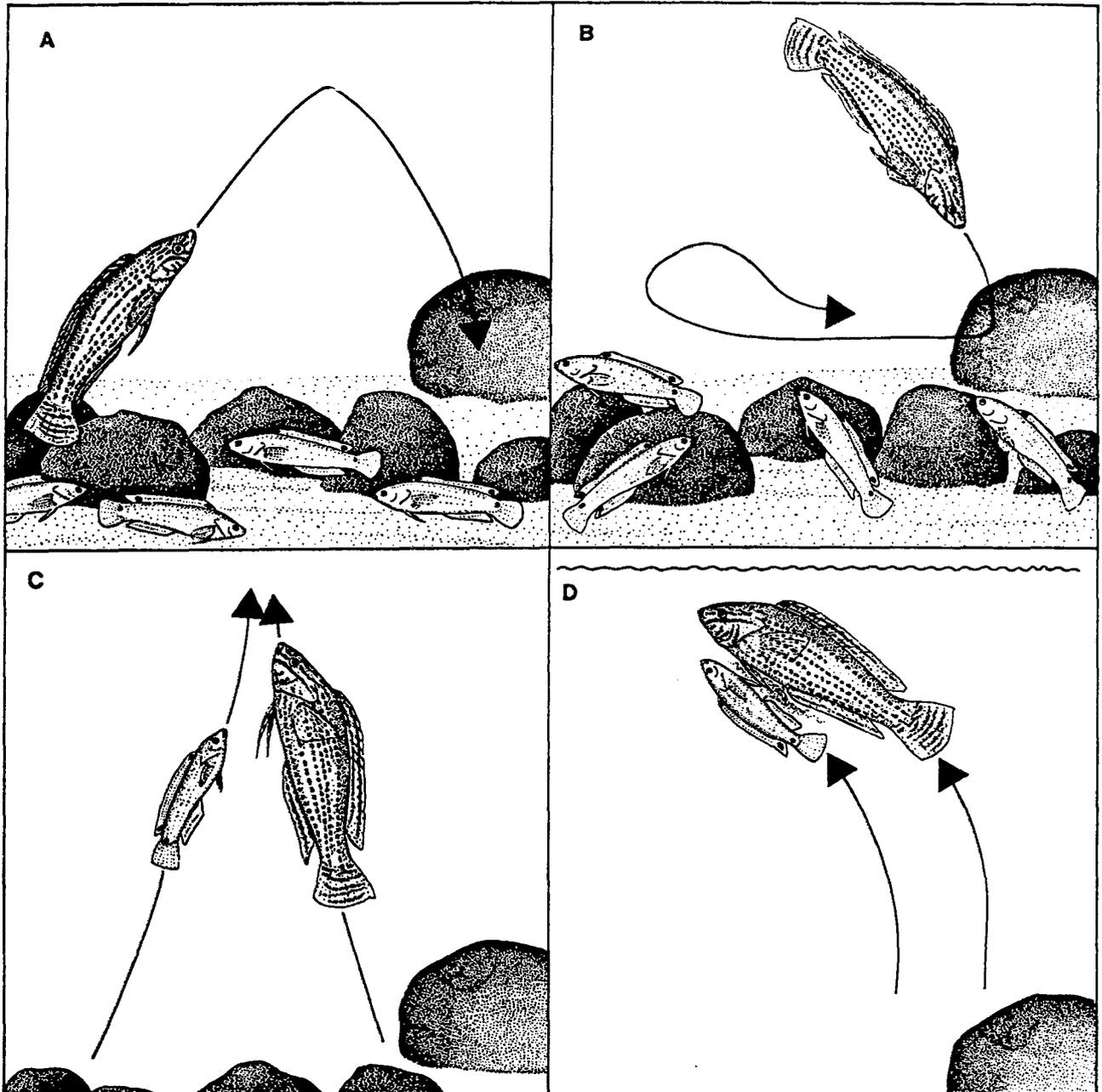


Figure 5.6. Courtship and spawning behaviour of *N. ornatus*. (a) and (b) show male display routine. (c) shows the spawning ascent. (d) shows the release of gametes. See text for a more detailed description.

5.4 - DISCUSSION

N. ornatus has been found to be a sequential protogynous hermaphrodite with all fishes starting life as functional females and a proportion of these females changing sex to become functional males. Protogyny has been recorded in at least 14 families including the wrasses (Labridae), parrotfishes (Scaridae), groupers (Serranidae), damselfishes (Pomacentridae), angelfishes (Pomacanthidae), sea breams (Sparidae) and gobies (Gobiidae), with new records of protogyny constantly appearing in the literature (Warner, 1984). Sex change obviously holds some advantages to species otherwise this strategy would never have been selected for. It has been suggested that the lifetime reproductive potential of an individual in a population may be increased by changing sex (Shapiro, 1984).

A reasonable explanation of sex change has been termed the size advantage model (Ghiselin, 1969; Robertson & Choat, 1974; Warner, 1978). The concept of this theory is based on the probability that an individual which changes sex at the right size or age will have more offspring than one that remains male or female, if the expected number of offspring differs with size between the sexes (Warner, 1984). Expected fertility is regulated by two factors. Firstly, the number of gametes that an individual actually produces can be determined by its size, especially in females which can hold only as many eggs (which are relatively large compared to sperm) as her size allows. Secondly, the mating behaviour of the species is important in that size can determine the spawning rate of individuals. This is seen in many reef fishes, such as the concha, where larger males monopolise the spawning of females through behavioral mechanisms. The spawning rate of small males is thus low, while equivalent sized females have little trouble finding a mate. In this scenario, an individual that functioned as a female when small and as a male after attaining a large size would have more offspring over its lifetime than one that remained either male or female. Natural selection would thus favour protogyny (Warner, 1975). If this were the case then size or age at sex change would be genetically determined.

Social control of sex change has been noted in several species of coral-reef fishes. Harem species have proved particularly suitable for study because of their tendency to exist as small, localised groups. Robertson (1972) found that in harems of the cleaner wrasse, *Labrides dimidiatus*, the largest female would change sex within a few hours if the male was removed.

In other harem species (Moyer & Nakazono, 1978; Coates, 1982) it was also found that the largest remaining females changed sex when the opportunity arose. Shapiro (1984) however, argued that size *per se* is not the important factor controlling change of sex. He regarded behavioral induction of sex change as a means through which improved reproductive success may be achieved. Sex change would occur at any point when circumstances were favourable regardless of the size or age of the individual. The relative size would therefore be more important than the absolute size of an individual. It appears therefore that mechanisms inducing sex change differ among species.

Regardless of the mechanisms responsible for inducing sex change it is apparent that most protogynous species exhibit some form of monopolisation by large males as was shown in *N. ornatus*. For example, Moyer & Nakazono (1978) found this in the angelfish, *Centropyge interruptus*, while Thresher & Moyer (1983) found this in three species of damselfish. Buxton (1989) reported that larger males monopolised mating through resource defence in the two temperate sparids, *Chrysolephus laticeps* and *C. cristiceps*. In the case of *N. ornatus* monopolization of female spawning by large males was achieved through the defence of territories in a communal spawning site. It is therefore evident that size is important in determining the success of reproduction in *N. ornatus*.

In addition to a sexual size difference *N. ornatus* was permanently sexually dichromatic and males were able to enhance colour differences during courtship by adopting a milky white base colour. Robertson & Hoffman (1977) suggested that male-specific colour patterns are primarily the result of intersexual selection by females. They based this hypothesis on the fact that some labrid species, such as *Halichoeres maculipinna*, maintain brilliant colours during courtship but lose them during aggressive inter-male activities. Secondly, they noted that strictly harem labrids, including *Labroides dimidiatus*, in which female mate choice and, consequently, intersexual selection is limited, are sexually monochromatic, while non-strictly harem species are sexually dichromatic. Thresher (1984) suggested that neither of these assertions were supportable as there were too many exceptions to this pattern, even in the labrids. Robertson (1981) added that the conspicuous male coloration of terminal phase males functioned in species recognition and long-distance attraction of females. Thresher (1984) suggested that intrasexual competition may be important in the evolution of sexual dichromatism as many labrid species intensify colour patterns during aggressive activities. He concluded that the female-choice

hypothesis and the intrasexual competition hypothesis are not mutually exclusive, and suggested that extant patterns of labrid dichromatism developed as a result of a combination of these two processes. Based on the above it seems plausible that the sexual colour differences in *N. ornatus* may play a role in both influencing female choice of mate, and aggressive display aimed at other males.

N. ornatus has a lek-like mating system. Emlen & Oring (1977, pp 219) define a lek as "a communal display area where males congregate for the sole purpose of attracting and courting females and to which females come for mating". The term 'lek' was first used to describe a mating system in birds (eg. Robel & Ballard, 1974). It has since been used to adequately describe mating systems in labrids found in both temperate (Bell, 1983) and tropical waters (Warner *et al.*, 1975; Warner & Robertson, 1978; Moyer & Yogo, 1982), and in other families (Loiselle & Barlow, 1978). Emlen & Oring (1977) suggest that lek mating systems in fish could be beneficial for a number of reasons. Firstly, the copulation success of high ranking males would increase, while that of lower ranking males would decrease in a male aggregation where communal display is carried out. The second advantage of aggregation in particular areas is that encounters with females would be increased if females predictably concentrated in those areas. Also, the display of males in this area is pooled, enhancing the effect of the courtship display. Male aggregations allow females to compare potential mates that have already sorted themselves into an order of dominance. That is, males show their status by being able to occupy more or less desirable territories.

Emlen & Oring (1977) proposed that species exhibiting a lek-like mating strategy are typified firstly by a relatively long breeding season and secondly by a heavily skewed operational sex ratio. Also, a species in which individual males are unable to economically control or monopolize the resources necessary for female acquisition is likely to have a lek-like mating system. Although *N. ornatus* has a fairly long breeding season for a temperate species, a heavily skewed sex ratio was not apparent in Round Pool, contrary to Emlen & Oring's (1977) prediction.

Two male origins have been recorded in wrasses, termed primary and secondary males. Only secondary males were apparent in *N. ornatus*. In monandric species only males derived from sex changing females are apparent, and are termed secondary males. In diandric species males

may be born as such (primary) or result from sex changing females (Buxton, 1987). The existence of primary males is usually associated with populations where a skewed sex ratio makes it difficult for a single male to protect and mate with a large number of females (Warner, 1978). For example, these males have been found in the protogynous wrasse, *Thalassoma bifasciatum* (Warner *et al.*, 1975). Population size has also been found to influence the existence of primary males. Warner (1978) suggested that large populations encourage the existence of a greater proportion of primary males because of the limited availability of suitable territory sites. In *N. ornatus* the relatively low sex ratio during the breeding season suggests that terminal males are able to accommodate all females and that there is no evolutionary pressure for the existence of primary males. Alternatively, monandry could have developed because terminal males are able to exclude smaller males from mating thereby removing the selective pressure for the existence of diandry. The absence of primary males has also been reported in populations of the temperate labrid, *Pseudolabrus celidotus*, which displays a low sex ratio of between 3.7 and 8.7 females per terminal male (Jones, 1980). The general theory that primary males will be present in species with loose social systems (Robertson & Choat 1974; Jones 1980) is supported by the absence of these males from the *N. ornatus* population. This species displays a relatively rigid social system, especially during the breeding season, as is evident from the observations in Round Pool during the breeding season where population densities remained between 0.84 and 1.13 fish /m² and sex ratio remained between 5 and 6.48 females per male over a four month period.

The relatively small testes size of male *N. ornatus*, evident from gonadosomatic indices (Fig. 5.2) could be expected given the observed spawning behaviour in this species. Sperm competition is probably reduced in polygynous species, such as the concha, where pair spawnings are the norm. Large testes, on the other hand, are probably indicative of intense sperm competition, such as would occur in group spawnings (Buxton, 1987).

The spawning ascent in *N. ornatus* is a common feature among coral-reef fishes (Thresher, 1984). Two hypotheses have been proposed to account for this widespread spawning event. Randall (1961) suggested that rapid spawning ascents may serve a mechanical function by causing a decrease in water pressure and a consequent expansion of the swim bladder thereby forcing gametes out of the body into the water column. This theory has been generally discounted for three reasons. Firstly many species without swim bladders display spawning

ascents. Secondly, the height of spawning ascents do not appear to vary with depth. To result in the same amount of swim bladder expansion, spawning ascents should be higher in deeper water than in shallow water. Thirdly, the height of spawning ascents is usually less than a meter, especially in smaller fishes, and the change in swim bladder volume over this change in depth is not thought to significantly influence gamete release (Thresher, 1984).

The alternative, more widely accepted, explanation of the spawning ascent was first suggested by Jones (1968). He considered that this behaviour was a result of two competing selective pressures. Firstly, free floating eggs are released away from the bottom which is considered adaptive because it reduces the risk of predation of fertilised eggs by benthic filter feeders and planktivorous fishes. Secondly, the height of the spawning ascent is thought to be regulated by the risks of predation incurred by the adults while spawning. They presumably run a high risk of being attacked by predators due to their increased visibility and vulnerability. Consequently, spawning ascents should be rapid and only high enough to ensure that gametes are partially protected from immediate predation (Thresher, 1984).

The timing of daily spawning in *N. ornatus* seems to be light dependent, beginning just before sunset and ending when visibility was reduced to a low level. This is believed to be advantageous in that it probably decreases immediate predation of fertilized eggs. It has been suggested (Johannes, 1978) that planktivore activity decreases at dusk. It could be argued that egg predation would be further reduced if spawning occurred at night when eggs would not be as visible to visual planktivores. However, in the concha, courtship and display are obviously important to the spawning process. For maximum effect these activities have to be carried out when sufficient light is available (Thresher, 1984). It is therefore believed that a compromise between decreasing the risk of egg predation, and ensuring successful courtship behaviour, has resulted in the dusk spawning period in *N. ornatus*.

Both male and female gonadosomatic indices (Fig. 5.2), and behavioral observations of *N. ornatus* showed that the breeding season lasted from November to March. This period coincided with the months of highest water temperature (Fig. 2.5, Chap. 2) and photoperiod at the islands. These environmental parameters appear to be the most important in influencing reproductive seasonality (de Vlaming, 1972). Differences in the length of the breeding season in conspecific sparids occurring in subtropical and temperate waters on the east coast of South Africa have

been noted (Buxton, 1987). While temperature regimes differed substantially between localities compared, photoperiod was relatively similar. This indicated that although photoperiod may be an important cue influencing the neuro-endocrine centres that control gonadotropin secretion (de Vlaming, 1972), temperature may be more important in determining the length of the breeding season (Buxton, 1987).

As discussed in Chapter 4, it may not be temperature, directly, that determines the breeding season of *N. ornatus* but the effect that this environmental parameter has on other oceanographic phenomena such as food availability, through increased primary productivity during warmer periods of the year. Cushing (1975) proposed the match/mismatch theory in which it is suggested that spawning is timed to allow pelagic larvae to optimise on enhanced food availability during phytoplankton blooms.

Spawning in the concha could occur during the summer months at Tristan da Cunha to coincide with stable inshore ocean conditions. Various authors have shown strong evidence suggesting that spawning seasonality is a function of selection for spawning during periods of minimal offshore directed currents so that larvae have the highest possibilities of developing and metamorphosing into juveniles without being carried away from suitable substrates (Johannes, 1978; Sale, 1970; Leis & Miller, 1976). Sea conditions during the winter months are generally highly variable at Tristan da Cunha, while summer conditions are more stable. It is reasonable to expect therefore, that offshore transport of larvae would increase in winter, a factor which could negatively effect larval settlement. In order for inshore retention of larvae to be successful the larval stage in the concha would have to be relatively short. Nothing is known about the larvae of this species at present. If the larval stage was relatively short it becomes difficult to explain the wide distribution of the species. In Chapter 3 it was suggested that the wide distribution of many Tristan species was a result of a protracted larval phase allowing time for dispersal to distant localities to take place.

In summary, *N. ornatus* is a monandric protogynous hermaphrodite. The species displays size monopolisation of spawning, is sexually dichromatic and has a lek-like mating system. A seasonal pattern of gonadal development and spawning is apparent suggesting that environmental parameters such as temperature, food availability and inshore retention of larvae may determine a summer breeding season in this species. *N. ornatus* is the only known

hermaphrodite at Tristan da Cunha and Gough Island emphasising that a variety of reproductive strategies allow different species to survive successfully at the islands.

CHAPTER 6 - GROWTH OF THE SOLDIER, *SEBASTES* *CAPENSIS*, UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

6.1 - INTRODUCTION

Earlier in this thesis (Chap. 4) it was pointed out that growth in many fishes had been found to be affected by ambient water temperature (Lasker, 1964; Brett, 1976; Fonds, 1979; Smith, 1989). It was decided to test if growth rate varied in a species occurring at two localities with different temperature regimes in order to assess the effect that this environmental parameter had on fish growth at the islands. The soldier, *Sebastes capensis*, was chosen for this study because a large enough sample of specimens was available to carry out such a comparison between fishes at Tristan da Cunha and Gough Island, which displayed different temperature regimes (see Chap. 2). If growth rate was indeed found to be influenced by temperature at these two localities, it would suggest that growth rate could vary on a seasonal basis at any one locality where significant seasonal temperature fluctuations occurred.

Age and growth in the genus *Sebastes* has received wide attention in the literature, especially in the northern hemisphere where a number of species are of commercial importance (Six & Horton, 1977; Beamish, 1979; Boehlert & Kappenman, 1980; Boehlert & Yoklavich, 1984; Wilson & Boehlert, 1990). Species in this genus display a wide range of longevity with some species such as the Puget Sound rockfish, *S. emphaeus* reaching a maximum age of only five years at a size of 179 mm SL (Moulton, 1975) and others such as the splitnose rockfish, *S. diploproa* attaining in excess of 80 years at a size of 360 mm (Bennett *et al.*, 1982; Wilson & Boehlert, 1990). The extremely high age recorded in the latter species should be accepted with caution given the small maximum size recorded in this species. In addition these authors did not attempt to validate annuli. Few studies on growth of *Sebastes* species in the southern hemisphere have been undertaken. Sivertsen (1945) counted growth rings on the scales from nine specimens of *S. capensis*, collected at Tristan da Cunha. Other than this no work has been published on age and growth in this species.

S. capensis has been recorded from the Tristan da Cunha group, Gough Island, the west coast

of southern Africa and possibly off southern and western South America (Eschmeyer, 1986). At Tristan da Cunha this species is used extensively for lobster bait and is a potential food fish for the islanders. At present only about four tonnes are harvested annually around Tristan Island (see Chap. 7). However, because the species commonly occurs only to about 50 m depth on a limited shelf area, this level of fishing is not insignificant.

The objective of this study was to investigate growth of *S. capensis* in an attempt to quantify environmental effects on fishes at Tristan da Cunha and Gough Island.

6.2 - METHODS

S. capensis were collected from October 1988 to March 1990 at the three northern islands of Tristan, Nightingale and Inaccessible, and from Gough Island. Specimens caught with hook and line for lobster bait by the Tristan fleet were sampled on 70 occasions throughout the study period. *S. capensis* were collected from the shore at Gough Island with hook and line by members of the South African Meteorological Team, and offshore from the lobster vessel **MFV TRISTANIA II** during two trips to that island. Fish were sexed, measured for total length (TL), and weighed. The sagittal otoliths were removed for ageing. Otoliths have been widely used for age determination in *Sebastes*, as growth rings in these structures have proved to be clearer than in other structures commonly used for ageing fishes, such as scales (Six & Horton, 1977; Wilson & Boehlert, 1990). Otoliths from 132 specimens from the northern islands (107 mm - 420 mm TL) and 52 from Gough Island (191 mm - 430 mm TL) were used in this study.

Otolith weight was plotted against fish length for both the populations to determine if a suitable relationship existed between these two parameters for ageing purposes. Otolith weight was used rather than otolith length in this case as many of the large, brittle otoliths from this species were broken during removal from the skull, and it was possible to weigh the broken pieces making up the whole otolith. Although other workers (Six & Horton, 1977; Beamish, 1979; Boehlert & Kappenman, 1980; Bennett *et al.*, 1982; Boehlert & Yoklavich, 1984; Wilson & Boehlert, 1990) who have aged *Sebastes* species have not used this technique, it was considered important to determine if a positive relationship existed between otolith weight and fish length in order to ascertain the degree to which growth in this species was reflected in otoliths (Bartlett *et al.*, 1984). As whole otoliths did not show clear opaque and hyaline rings

they were mounted in polyester resin and sectioned through the nucleus with a double bladed diamond edged saw (Rauck, 1976) at a thickness of between 0.2 and 0.4 mm.

The periodicity of growth ring deposition for annulus validation was difficult to determine from an examination of the otolith margins. Although it was not essential to validate annuli to show different growth rates in the two *Sebastes* populations, it was decided that it would be useful to obtain an idea of the longevity of this species in order to further understand its biology. Therefore, a preliminary investigation of daily rings was carried out as this technique had been used successfully by a number of authors to validate annuli (Victor & Brothers, 1982; Radtke & Targett, 1984; Campana & Neilson, 1985; Hecht & Smale, 1986). Victor & Brothers (1982) stated that daily rings were most obvious in younger fish, therefore daily rings on thin sections of five otoliths with three to five opaque/hyaline zone pairs were counted. Thin sections were polished with 5 μm lepigate alumina powder and etched for two to four minutes (depending on the thickness of the section) with 0.5 M hydrochloric acid. Daily rings were counted from the outer edge of the first opaque zone to the outer edge of the second opaque zone, using transmitted light from below at between 100 and 300 X magnification.

Annual rings were counted at low power under reflected light using a dissecting microscope on three separate occasions. Counts were considered valid only if two out of the three readings corresponded. Ninety eight and 94 percent of the otoliths from Tristan da Cunha and Gough Island respectively were read successfully.

The Student's t-test (Adler & Roessler, 1972) was used to determine if there was any difference between the mean lengths-at-age for male and female *S. capensis* from Tristan da Cunha. Only ages 5 to 11, and age 13 could be compared in this way as too few data sets were available for the other ages.

Growth curves for *S. capensis* collected at Tristan da Cunha and Gough Island were fitted by iteration using the software programme PCYIELD 2.11 (Punt & Hughes, 1989) as described in Chapter 4. The Student's t-test was used to test if a significant difference existed in lengths-at-age between fish collected from the northern islands and Gough Island. Although fish from age 3 upwards were recorded from Tristan da Cunha, only lengths from age 5 upwards could be compared because of the small sample size from Gough Island.

6.3 - RESULTS

Otolith weight (OW) increased with fish length (TL) in *S. capensis* collected at both Tristan da Cunha and Gough Island. For Tristan da Cunha specimens this was best described by the power relationship, $OW=6.65 \times 10^{-7} TL^{2.14}$ (n=107; $r^2=0.89$) and for Gough Island specimens $OW=2.68 \times 10^{-7} TL^{2.27}$ (n=48; $r^2=0.83$). This indicated that otoliths reflected growth in fish length in this species relatively closely, and could therefore be used for ageing purposes (Bartlett *et al.*, 1984).

Although daily growth increments were relatively obscure, counts from three of the clearest otoliths ranged between 310 and 372 daily rings in one hyalin/opaque zone pair (see Fig. 6.1). Victor & Brothers (1982) stated that by counting daily increments between probable successive annual marks, it was possible to verify both the number and position of these annuli. The results of the present daily growth increment analysis therefore suggested that one opaque and hyalin ring represented an annulus in this species.

Figure 6.2 shows the clear annual rings in the sectioned otolith from a 10 year old soldier of 360 mm TL collected at Tristan da Cunha and indicates how the growth zones were interpreted in this study.

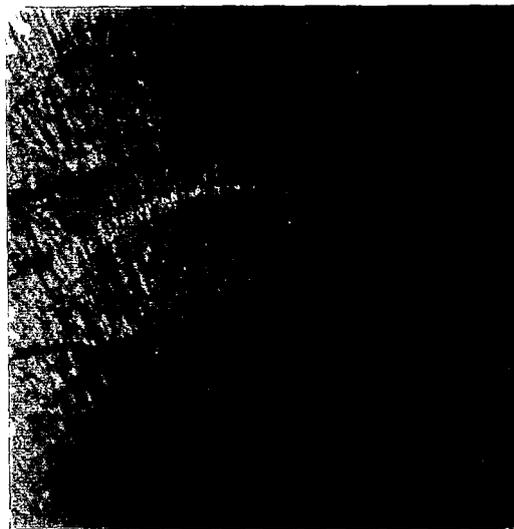


Figure 6.1. Daily rings in the sectioned otolith of a 145 mm TL *S. capensis* (X 129). In this photomicrograph some of the 375 daily rings counted in one hyalin/opaque ring pair are apparent.



Figure 6.2. Photomicrograph of the sectioned otolith of a 10 year old, 360 mm TL, *S. capensis* (X 40) indicating how annuli were interpreted.

No significant differences ($P > 0.05$), except for age-class 11, were found for the mean lengths-at-age of male and female *S. capensis* from Tristan da Cunha (Table 6.1). Too few data were available from Gough Island to carry out a similar comparison. It was therefore assumed that growth rates for male and female soldier at this island were also not significantly different. The data for males and females at both localities were therefore combined in the computation of the growth curves. Table 6.2 shows that the lengths-at-age in the two populations are significantly different at $P < 0.05$.

Table 6.1. Test for significant difference between the mean observed length-at-age of male and female *S. capensis* at Tristan da Cunha). * = significant difference at $P < 0.5$.

Age	Mean TL Males (mm)	n	SD	Mean TL Females (mm)	n	SD	dF	t	Sig. Diff.
5	140.6	3	4	138.3	3	2.9	4	-0.813	
6	142.5	2	7.8	183.1	8	31.9	8	1.713	
7	215.5	4	19.4	234.7	7	45	9	0.796	
8	251.5	4	22.1	227.3	11	35.2	13	-1.267	
9	274.7	8	28.4	269.3	13	28.5	19	-0.418	
10	292	7	28.3	289.1	11	27.4	16	-0.209	
11	259	4	37.4	311.9	10	34.5	12	2.535	*
13	323.4	9	38.9	325.7	8	37.5	15	0.124	

Table 6.2. Test for significant difference between mean observed length-at-age of *S. capensis* from Tristan da Cunha and Gough Island. * = significant difference at $P < 0.05$.

Age	Mean TL Tristan (mm)	n	SD	Mean TL Gough (mm)	n	SD	dF	t	Sig. Diff.
5	139.4	5	3.8	193	2	2.8	5	-17.741	*
6	181.7	7	34.2	284.6	5	42.7	10	-4.644	*
7	220.6	9	31	301.9	11	22.2	18	-6.82	*
8	230.5	16	34.7	329.4	5	27.6	19	-5.78	*
9	272.4	21	28.5	341.4	10	25.2	29	-6.515	*
10	290.3	18	26.9	369.6	10	13.3	26	-8.68	*
11	296.8	14	41.9	389	6	30.2	18	-4.83	*

The special Von Bertalanffy growth equation, $L_t = L_\infty (1 - e^{-k(t-t_0)})$, in combination with the absolute error model was used in all cases to describe the growth in this species as this growth model/error model combination satisfied the requirements for random residuals and homoscedasticity. Figure 6.3 shows the fitted growth curve for *S. capensis* at the Tristan da Cunha group ($F = 4.46$; Sum of squares = 144047; $P < 0.025$). Growth curves constructed for ages 5 to 11 for Tristan da Cunha and Gough Island (Fig. 6.4) show that *S. capensis* grows more rapidly at the latter locality (Tristan: $F = 2.002$; Sum of squares = 88516; $P < 0.025$, Gough: $F = 1.506$; Sum of squares = 31729; $P < 0.025$). Table 6.4 shows the Von Bertalanffy growth parameters for the entire sample from the northern islands, and for ages 5 - 11 at the northern islands and Gough Island. The growth coefficient 'k', indicative of the rate at which the growth curve approaches the asymptote (Beverton & Holt, 1959; Punt & Hughes, 1989), of the Gough Island fish is almost twice as large as that of the Tristan fish.

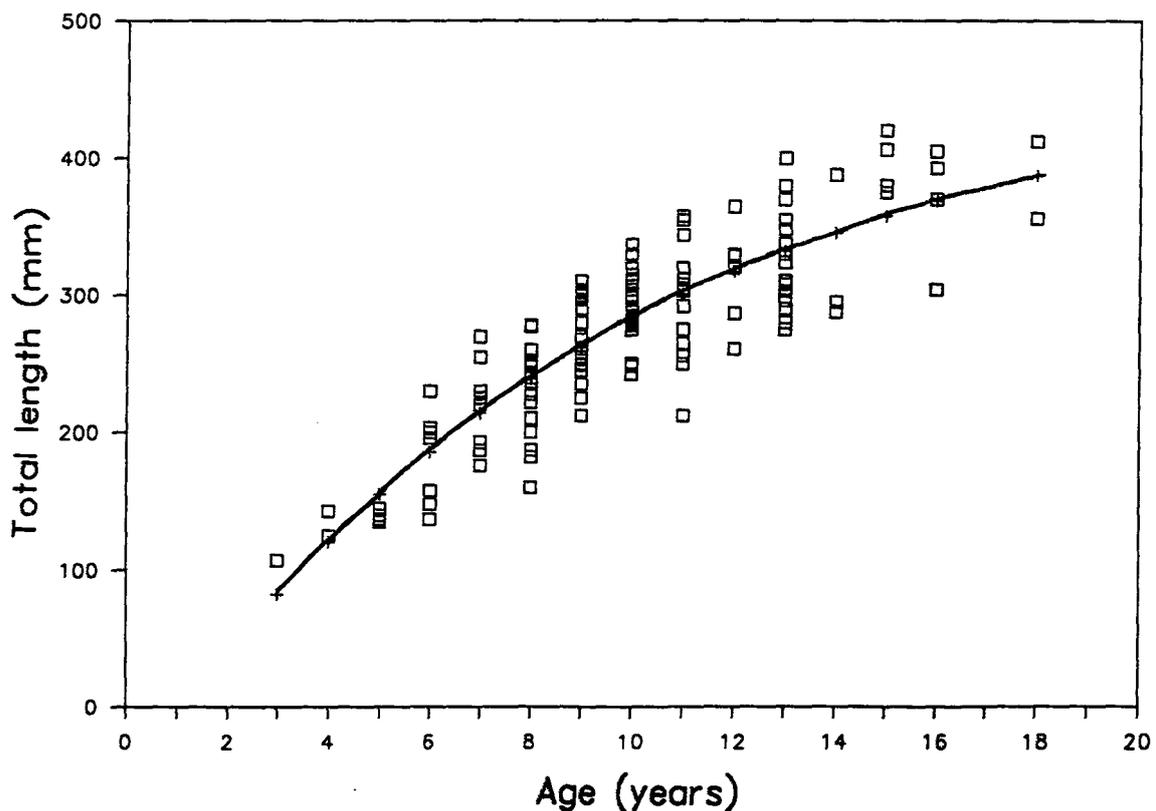


Figure 6.3. Observed length-at-age of *S. capensis* from Tristan da Cunha and the fitted Von Bertalanffy growth curve for this species (n = 129).

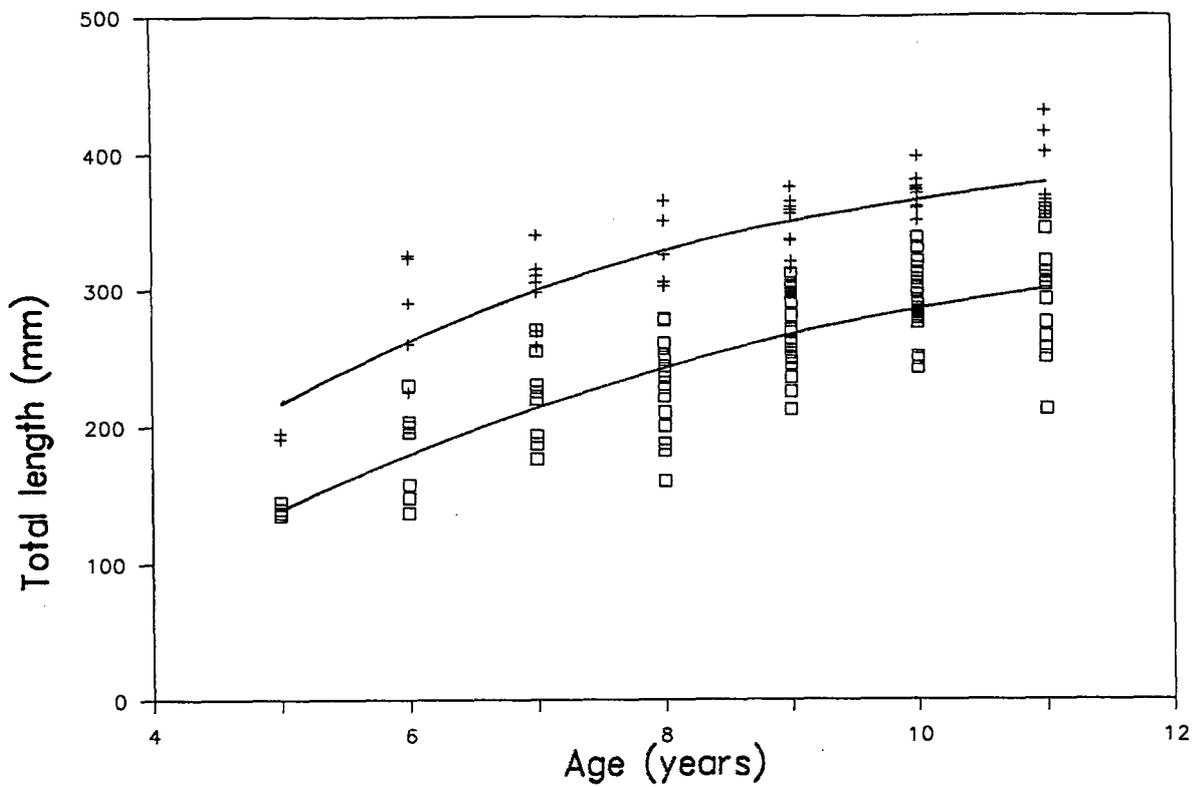


Figure 6.4. Observed length-at-age for *S. capensis* (ages 5 - 11) at Tristan da Cunha (squares) and Gough Island (plusses), and the fitted Von Bertalanffy growth curves for this species at the two localities. (n = 89 and 49 respectively)

Table 6.4. Von Bertalanffy growth parameters for the entire sample from the Tristan da Cunha group and for ages 5 - 11 at Tristan da Cunha and Gough Island.

PARAMETER	Tristan (ages 3 - 18)	Tristan (ages 5 - 11)	Gough (ages 5 - 11)
L_{∞}	467.2 mm	383.4 mm	421.9 mm
k	0.105	0.182	0.267
t_0	1.15	2.51	2.29
n	129	89	49
Predicted length-at-age 5	155 mm	140 mm	217 mm
Predicted length-at-age 10	283 mm	285 mm	368 mm

6.4 - DISCUSSION

Although sample sizes in this study were relatively small the results clearly show that *S. capensis* grow more rapidly at Gough Island than at the Tristan da Cunha group. The largest fish from the Tristan da Cunha group were aged at 18 years while similar sized fish from Gough Island were found to be only 11 years old.

If the two populations are reproductively isolated from each other differences in growth rate could be genetically based (Boehlert & Kappenman, 1980). However, Moser & Ahlstrom (1978) and Thresher (1984) have suggested that *Sebastes* species may have extended pelagic phases of up to one year. In Chapter 3 it was suggested that the wide distribution of *S. capensis*, including southern Africa and possibly South America (Eschmeyer, 1986), was a consequence of the extended pelagic phase. In addition, no benthic stage specimens of less than 70 mm TL were observed during SCUBA dives in the present study indicating that juveniles must have remained in the pelagic for a sufficient period to allow growth to this size to occur. The large scale nature of ocean circulation in the South Atlantic (Chap. 2) and the relative close proximity of Tristan da Cunha and Gough Island would suggest that mixing of pelagic phases from the two populations would occur. Based on these factors and the implied evidence in the literature (Moser & Ahlstrom, 1978; Thresher, 1984) it is assumed that *S. capensis* at the two localities are not reproductively isolated.

Empirical data have shown that rapid intraspecific changes in growth, reproduction and life-span can occur in response to changes in environmental conditions such as temperature and food availability (Mann & Mills, 1979; Craig, 1985). Although each species has a characteristic genetically determined life-span, the mean life-span is influenced by environmental parameters, and will vary widely (Craig, 1985).

In certain species temperature *per se* is important in regulating growth rate and longevity. For example, Craig & Fletcher (1984) found that populations of zebra fish, *Brachydanio rerio* fed on high or low energy diets, had higher mortality rates and lower growth rates at higher temperatures, than populations fed on the same diets but maintained at lower temperatures. On the other hand numerous workers have shown that growth rate increases with temperature within the tolerated thermal range of a species (Beverton & Holt, 1959; Loeng, 1989; Tandler

et al., 1989), as a result of increased metabolic activity. Opposing results of this nature suggest that metabolic functions may not be enhanced by increased temperature within the tolerated thermal range of all fish species. In other words, tolerance limits and optimum conditions for certain body functions vary from species to species.

The most obvious difference in the ocean environment between Tristan da Cunha and Gough Island is sea surface temperature (Fig. 2.5, Chap. 2). It is apparent that the Gough Island *S. capensis* which live in cooler waters, grow faster than the fish in the warmer waters at the Tristan da Cunha group. The observed difference in growth rate and longevity in the two populations could result from the influence that different sea temperatures at the two islands have on metabolic activity, as discussed above. It is possible that thermal conditions at Gough Island are optimal for this species while those at Tristan da Cunha are sub-optimal, although tolerable to the species.

Diet has also been identified as important in influencing growth and longevity. Comfort (1960) found that longevity could be increased in the guppy, *Lebistes sp.*, by restricting its diet. Gerbase-DeLimar *et al.* (1975) also found this in mice. Because of the results of these studies it was considered possible that differences in food availability at Tristan da Cunha and Gough Island may influence growth and longevity in *S. capensis*.

It has been suggested (Chap. 2 & 4) that different temperature regimes at Tristan da Cunha and Gough Island result in differences in food quality and availability at the two localities. In the feeding study of *A. monodactylus* (Chap. 4) it was found that this species fed on a far greater variety of prey items at Gough in comparison to Tristan. It was also suggested that this difference in diet led to morphological variation in this species at the two localities. Although direct evidence is not available at this stage, it is possible that food availability and quality is superior at Gough Island than at Tristan da Cunha. Measurements of salinity at Tristan da Cunha indicated that this island group may be situated just north of the STC throughout the year. Temperatures at Gough Island, on the other hand, indicated that this island was located within the STC throughout the year, albeit on the southern fringe of the front (Chap. 2). In Chapter 2 it was hypothesised that primary productivity at Tristan da Cunha may be enhanced during the summer through sea surface heating and a resultant increase in stratification of the surface layers of the ocean. This would theoretically make nutrients available to phytoplankton

that are unable to benefit from the nutrient rich waters at the STC during the winter because of an intolerance to cooler water temperatures. At Gough Island it is therefore possible that annual primary production is higher than at Tristan da Cunha because the enhanced nutrients within the STC are available to organisms throughout the year. In addition to enhanced nutrient availability at Gough Island, the concentrating effect of convergence within the frontal zone on phytoplankton may also be greater through the year than at Tristan da Cunha. This physical concentration of phytoplankton at fronts has been noted previously (eg. Okubo, 1978; Olson & Backus, 1985). A preliminary examination of the stomach contents of *S. capensis* showed that the species is a benthic carnivore feeding on organisms that would benefit directly or indirectly through the food chain from increased primary production.

Love (1977) and Boehlert & Kappenman (1980) found that growth rate increased with latitude and a decrease in water temperature in certain species of *Sebastes* on the Pacific coast of North America. Boehlert & Kappenman (*op cit.*) suggested that changes in growth rates with latitude in *S. diploproa* may be explained by density-independent, evolutionary responses to environmental predictability. As reproductive strategies within a species may change under different environmental conditions in order to ensure maximum reproductive success, these authors have suggested that in unpredictable environments where reproductive success may change from year to year, species may exhibit iteroparity (repeated spawnings) or increased fecundity at the expense of somatic growth. MacArthur & Wilson (1967) also recognised that reproductive effort should be greatest when density-independent mortality is erratic. At Tristan da Cunha the seasonal oceanographic changes brought about by an increase in stratification (Fig. 2.8, Chap. 2), and a possible associated change in nutrient availability in the summer months, could be considered less predictable than the relatively stable frontal conditions thought to be present at Gough Island throughout the year. Mann & Mills (1979) found that reproductive uncertainty, as affected by annual changes in the severity of spring spates in streams, led to increased longevity in the bullhead, *Cottus gobio*. *S. capensis* at Tristan da Cunha displayed both greater longevity and slower growth rate than at Gough Island.

Increased longevity would enable each individual to produce more offspring during its lifespan than a short lived individual and therefore enhance the survival capabilities of a species occurring in an environment where reproductive success was variable from year to year. In the soldier, the benthic stages are probably not as severely affected by environmental conditions

in unfavourable years as are pelagic larvae which would experience extremely high mortalities if the timing of events such as summer phytoplankton blooms was not synchronised with spawning (Cushing, 1975). It is proposed that in a more unpredictable environment it would be adaptive for a species to protect the spawner biomass by exhibiting increased longevity to ensure that spawning could take place in years when favourable environmental conditions prevailed. Taking these factors into consideration it is plausible to suggest that a change in reproductive strategy in the two populations, related to the degree of environmental predictability at Tristan da Cunha and Gough Island may result in the phenomena observed in the present study. However, not enough detailed information on the reproductive biology of the two populations is available at present to allow for a meaningful comparison.

Although a definite explanation for the different growth rates in *S. capensis* at Tristan da Cunha and Gough Island has not been presented, it is evident that differences in environmental conditions at the two localities may be important in influencing the growth rate of the species. Based on results reported in the literature it seems plausible to suggest that varying levels of food abundance and availability could affect growth rate at the two localities. Also, the temperature regime at Gough Island may be optimal for metabolic activity in this species as opposed to possible sub-optimal thermal conditions present at Tristan da Cunha. It has also been suggested that the reproductive strategy of this species may be influenced by different levels of environmental predictability resulting in different growth rates and longevity in the two conspecific populations. Additional information on the feeding and reproductive biology of *S. capensis* at Tristan da Cunha and Gough Island is needed in order to more accurately identify the factors affecting growth in this species. It would also be important to quantitatively determine the relative levels of food abundance at the two localities throughout the year.

Although this study has shown conclusively that the growth rate of *S. capensis* at Tristan da Cunha and Gough Island is significantly different, it would be desirable to compare growth in the two populations using a larger sample in which the smaller size classes were more comprehensively represented. A comparison with growth rates of soldier on the west coast of South Africa where environmental conditions are considerably different from those at the mid-ocean islands would further elucidate possible environmental effects on the growth of this species.

The observed differences in the growth rate of soldier at Tristan da Cunha and Gough Island suggests that seasonal changes in temperature, or factors such as food availability which are influenced by temperature, probably has significant effects on the growth rate of other species at the islands. These findings, together with the seasonal growth pattern found in *A. monodactylus* (Chap. 4) provide a further understanding of the influence of environmental parameters on the biology of fishes at the islands.

CHAPTER 7 - THE TRISTAN DA CUNHA FISHERY AND THE IMPLICATIONS OF SPECIES-SPECIFIC LIFE-HISTORY STRATEGIES FOR EXPLOITATION

7.1 - INTRODUCTION

General biological information collected on the fishes of Tristan da Cunha presented in previous chapters is drawn upon in this chapter to evaluate the component species in the local linefishery. A study of the fishery provided useful information on the spatial and temporal distribution of fish, and the relative abundance of common species occurring at the islands. This information allows for a better understanding of the ecological processes affecting the fishes of the islands. In addition, this investigation provides the basis upon which to evaluate the current status of the various species in the fishery and to propose recommendations on their exploitation in the future.

Subsistence activities, including fishing, still form an important part of community life at Tristan da Cunha, although a cash economy exists which is based on the revenue gained from the local rock lobster industry. Linefish have formed an important component of the Tristan islanders' diet since the island was first inhabited some 180 years ago (Crawford, 1982). Up until the 1940s the resource was exploited purely for subsistence purposes. With the advent of the commercial rock lobster industry in 1949 (Roscoe, 1979) linefish were caught for rock lobster bait as well as for the table. At present the Tristan rock lobster fleet consists of between 18 and 20 two-man powerboats which fish only around Tristan Island. In addition two larger Cape Town based rock lobster vessels operate around the other islands. These vessels do not fish around Tristan Island due to an agreement reached between the fishing company and the Island authorities. It was agreed that only the fleet of power-boats would fish around Tristan as it was believed that the combined fishing effort of the Island fleet and the lobster vessels would have a detrimental impact on lobster stocks at this island (Mr J. Glass, Tristan Fisheries Officer, pers. comm.).

Virtually no quantitative data has been published on the linefishery at Tristan, although Sivertsen (1945) recorded some catch data. Roscoe (1979), as part of a study on the rock lobster

fishery at the islands, mentions that certain species were used as bait for rock lobster traps and nets.

A significant decrease in the catch per unit of effort (CPUE) for the rock lobster *Jasus tristani* (Roscoe, 1979; data from present study) has led to speculation about the possible inclusion of the linefish resource into the commercial catch (see Chap. 1). Because of the desirability of this resource to any fishing concession holder and because so little was known about the diversity, abundance and aspects of the ecology of the fishes of the region it was considered important to document as much as possible about the fishery and to assess current stocks in order to offer some guidelines concerning the possible future commercial exploitation of the resource.

7.2 - METHODS

The extent and nature of the fishing grounds frequented by the Tristan fleet as well as the two lobster ships was determined by accompanying vessels regularly during the study period. Roscoe (1979) also presented an estimate of the area of the lobster fishing grounds which are essentially similar to those grounds fished for linefish (see Fig. 2.2, Chap. 2). Historical data were obtained from various published sources (eg. Sivertsen, 1945; Roscoe, 1979; Crawford, 1982) and from discussions with local fishermen.

On each fishing day ($n = 87$) throughout the 18 month study period a size range of individuals of each species in the catch were measured for Total Length (TL), mass, sex and the state of gonad development. In addition stomachs, gonads and otoliths were removed from the fish samples to facilitate studies on feeding, reproduction and growth. Information on catch composition, total catch weight, and effort was collected from individual boats on 32 occasions throughout the study period. As it was impossible to sample the catch of all boats in the fleet on each fishing day, it was decided that the catches of different boats would be examined on each sampling occasion to ensure some measure of randomness. The number of boats fishing and the localities fished on each fishing day were recorded. These data were extrapolated for the entire fleet in order to obtain estimates for total annual catch and seasonal fluctuations in mass and species composition for the fishery. Catch rate (kg/man-day) for individual species and the entire catch were calculated for each month to determine catch seasonality. The length

at 50 percent recruitment for each species was estimated by plotting cumulative length frequency data against TL.

Information on the catches of linefish on the two larger lobster vessels was obtained by accompanying these vessels on four occasions. Information was also gathered from the captains and crews of these vessels by the Tristan Fisheries Officer (Mr J. Glass) who accompanied these vessels regularly in order to obtain data on the lobster catch.

Sufficient biological data on the fivefinger, *A. monodactylus* was available from this study to allow for a more sophisticated assessment of the stock. A computer programme (PC-YIELD 2.11) which performs Beverton & Holt (1957)-like yield-per-recruit analyses (Punt & Hughes, 1989) was used for this purpose. The yield-per-recruit model is a simplified version of the full dynamic pool model (Beverton & Holt, 1957) and allows analysis of the relationship between the increase in mass of individual fish and the decrease in the size of a cohort with time. The model also allows the relationship between fishing mortality, recruitment age, and equilibrium yield-per-recruit to be analyzed. The software programme calculated estimates of the following management variables:

- a) $F_{0.1}$ i.e. the level of fishing effort at which the marginal yield-per-recruit drops to 10 % of its value for the unexploited stock. Increasing F beyond $F_{0.1}$ provides very small returns in terms of yield-per-recruit in relation to the increased costs associated with a higher F .
- b) F_{MSY} i.e. the level of fishing effort at which "maximum sustainable yield" is attained.

The yield-per-recruit model assumes the following:

- 1) Recruitment is constant from one year to the next.
- 2) The stock is in an equilibrium state (i.e. the biomass and its age-structure are the same this year as last year).
- 3) The population is closed (i.e. no immigration or emigration).

The special Von Bertalanffy growth equation was used to fit a growth curve to the age-length data (see Chap. 4). Parameters from this equation were used in the yield-per-recruit analysis (see later). Instantaneous total mortality (Z) was determined by the method of Ricker (1975).

The adjusted age-length data used in this procedure are shown in Table 7.1, where;

N = the number of fish in the size frequency distribution sample

t1 = the age of fish at the lower limit of the size class

t2 = the age of fish at the upper limit of the size class

dt = the time needed to grow from the lower to the upper limit of a given size class

t = the relative age corresponding to the mid-range of a particular size class

A catch curve (Fig. 7.1) was constructed by plotting the natural logarithm (ln) of the number of fish in the sample (N) divided by dt, against relative age as follows:

$$\ln(N/dt) = a + bt$$

The numbers of fish in each age class were adjusted to compensate for the phenomenon of larger size classes containing more age groups than smaller size classes. Fish with sizes close to the asymptotic size were excluded from the catch curve as their ages were grossly over-estimated using this method (Pauly, 1983). Z was taken as the slope of the descending arm of the plot with the sign changed (ie. from age 3 - 24).

It was attempted to estimate instantaneous natural mortality (M) using the equations of Pauly (1980) and Rikhter & Efanof (1977). The Pauly equation incorporates asymptotic length in conjunction with the growth coefficient, K, and mean environmental temperature as follows:

$$\ln(M) = -0.0066 - 0.279\ln(L_{\infty}) + 0.6543\ln(K) + 0.4634\ln(T)$$

where L_{∞} = theoretical maximum length

K = Brody growth coefficient

T = mean annual bottom temperature

The Rikhter & Efanof equation incorporates the age at 50 % sexual maturity as follows.

$$M = 1.521/(0.7t_m) - 0.155$$

where t_m = age at 50 % maturity

These two equations produced widely differing values for M (Pauly = 0.29; Rikhter & Efanof = 0.68). This was to be expected as the precision of estimates provided by these formulae are known to be low; for example, 95 % confidence intervals for the Pauly estimates span a range of about a third to three times the value obtained (Butterworth *et al.*, 1989). The estimate for M obtained from the Rikhter & Efanof equation was greater than the estimate for Z (see later) and was therefore spurious. On the advice of Dr A. Punt, one of the authors of the software programme used, it was decided for the purpose of the yield-per-recruit analysis to estimate an

Table 7.1. Adjusted age-length data for *A. monodactylus* used to construct a catch curve for the estimation of instantaneous total mortality (after Ricker, 1975).

Size Class	Mid-Range	N	t1	t2	dt	t	LnN/dt	Data range used
138-162	150	4	1.948	2.429	0.480	2.185	2.883	*
163-187	175	61	2.449	2.956	0.506	2.699	8.111	*
188-212	200	146	2.978	3.514	0.535	3.242	9.301	*
213-237	225	194	3.537	4.105	0.568	3.817	9.264	*
238-262	250	215	4.130	4.735	0.605	4.428	8.864	*
263-287	275	143	4.762	5.410	0.648	5.080	7.653	*
288-312	300	96	5.438	6.136	0.697	5.780	6.542	*
313-337	325	49	6.166	6.921	0.755	6.536	5.152	*
338-362	350	54	6.954	7.777	0.823	7.357	4.843	*
363-387	375	45	7.813	8.719	0.915	8.255	4.202	*
388-412	400	49	8.759	9.765	1.006	9.249	3.866	*
413-437	425	48	9.810	10.943	1.133	10.359	3.414	*
438-462	450	48	10.993	12.291	1.297	11.620	2.983	*
463-487	475	39	12.349	13.867	1.518	13.077	2.413	*
488-512	500	30	13.936	15.767	1.831	14.807	1.857	*
513-537	525	14	15.852	18.162	2.309	16.935	1.142	*
538-562	550	7	18.272	21.408	3.135	19.707	0.620	*
563-587	575	10	21.565	26.477	4.912	23.695	0.468	*
588-612	600	2	26.752	38.851	12.099	30.926	0.057	

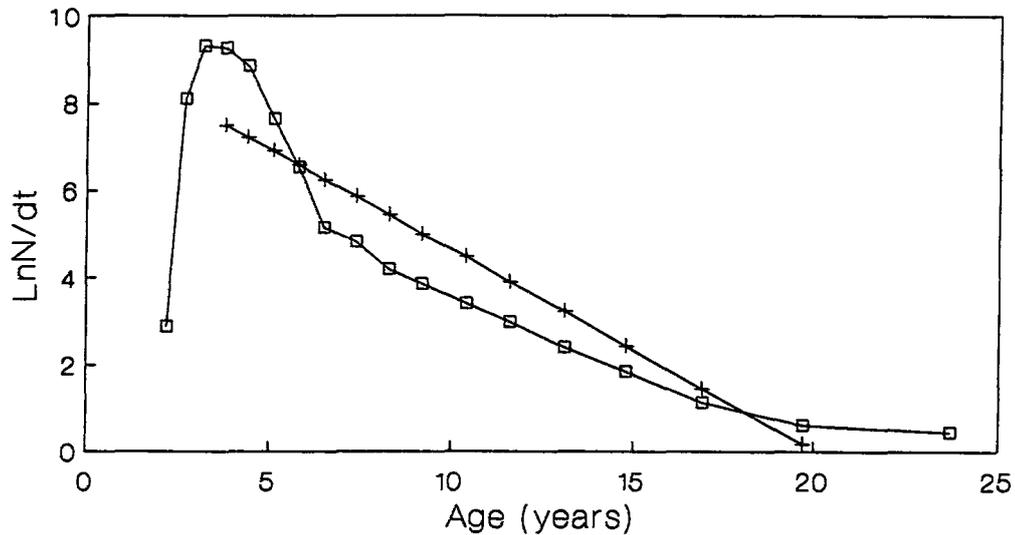


Figure 7.1. Catch curve for *A. monodactylus* constructed from adjusted age-length data.

M based on other reef living species with similar growth, longevity and fecundity characters to the fivefinger, but for which more extensive data bases were available. Estimates of M for the South African sparid species, *Chrysolephus laticeps* and *C. cristiceps* were deemed suitable as both these species are suprabenthic omnivores, reaching ages in the order of 20 years at a maximum length similar to that of the fivefinger. These two species are also relatively fecund and have small pelagic eggs. M values for these sparids ranged from between approximately 0.1 and 0.2 (Buxton, 1987). It was decided to use the mean of these two M estimates (ie. 0.15). It should be stressed that various values of M are used in the yield-per-recruit analyses that follow which allows the sensitivity of the results of the M estimate to be checked (Butterworth *et al.*, 1989). Instantaneous fishing mortality (F) was determined by subtracting M from Z.

Recruitment was assumed to be knife-edged as data indicating conclusively that either logistic or normal recruitment was taking place in the fishery was not available. The parameters used in the yield-per-recruit analysis of fivefinger are summarised below:

L_{∞} , theoretical maximum length = 620.64 mm

K, Brody growth coefficient = 0.11

t_0 , theoretical age when length is 0 = -0.419 years

t_c , age at first capture (50 % recruitment) = 4.4 years

t_m , age at 50 % sexual maturity = 2.5 years

Z = 0.46

M = 0.15

F = 0.31

The poor mortality estimates from the present data, and in particular the cumulative variance inherent in the basic age-length data and the construction of catch curves, necessitates that the results of the yield-per-recruit analysis be used only as an additional aid in understanding the dynamics of the fivefinger at these islands. By varying the value of parameters used in the yield-per-recruit equations such as F, M and T_c , an idea of the response of the fished population to various types of exploitation may be obtained. Even though an M value of 0.15 exceeded the F estimate of 0.31, which is probably unlikely in reality, this was not considered to detract from the overall value of the yield-per-recruit analysis as the response of the fished population to F values ranging from 0 to 0.65 was tested. Therefore the effects of fishing on the population could also be estimated when F was lower than M.

7.3 - RESULTS

7.3.1 - DESCRIPTION OF THE FISHING GROUNDS

Linefishing at all the islands was carried out to a maximum depth of approximately 150 - 200 m. The planar areas around the islands down to the 183 m isobath was previously estimated by Roscoe (1979). Tristan has a planar shelf area of 71 km², Nightingale 38 km², Inaccessible 124 km² and Gough 96 km². Because of the volcanic origin of the islands the shelf areas drop off rapidly into abyssal depths. Depths of up to 3000 m were recorded between Tristan da Cunha, Nightingale and Inaccessible during the present study. The bottom topography around

all the islands was typically a combination of sand and high relief reef with many pinnacles extending to near the surface. Kelp beds (*Macrocystis pyrifera*) commonly extended to a depth of about 20 m, although these beds were found substantially deeper at some localities. Linefishing seldom occurred on the landward side of the kelp beds. As mentioned previously, only the shelf at Tristan Island was exposed to a significant level of fishing effort while the other islands experienced only limited exploitation from the two larger lobster vessels. The maximum distance travelled in one day by the Tristan powerboats was a complete circum-navigation of the island, a distance of approximately 40 km.

7.3.2 - HISTORY OF THE LINEFISHERY

During the 1930s the fishery at Tristan was of great importance to the islanders, as besides potatoes, fish formed the main food of the population (Sivertsen, 1945). In 1937/38 during his visit to the Island he noted that one or more boats were out fishing nearly every day in fine weather. His limited records of fishing during the summer of 1937/38 indicated that a maximum of three boats fished at one time. Simple handlines baited with pieces of fish or cuttlefish were used. Comparison with data from the present study showed that the catch composition in the 1930s was different to present times with bluefish, *Hyperoglyphe perciforma* and stumpnose, *Schedophilus velaini* only caught on a seasonal basis (see Fig. 7.2 & 7.3 later).

Developments in the linefishery have closely paralleled those in the commercial rock lobster fishery, since the inception of the latter in 1949. The Tristan Exploration Company was granted sole rites to export lobster from the islands. This company operated a ship from Cape Town and set up a small canning plant on the Island in 1949. The Tristan Development Company was formed in 1950 and commissioned a second ship in 1951. The canning plant functioned inefficiently up until 1960 when a larger freezing facility was installed to freeze lobster tails. This factory was destroyed by the volcanic eruption in 1961. When the islanders returned in 1963 the fishing company, now called the South Atlantic Islands Development Corporation (S.A.I.D.C) re-negotiated its exclusive concession to fish the waters of the islands for lobster. The operating company in Cape Town, Tristan Investments Ltd., a subsidiary of S.A.I.D.C., re-established its factory on Tristan in 1966 (Day, 1966).

Roscoe (1979) mentioned that rock lobster fishing from rowing dinghies occurred mostly near the Settlement on the north west shore of Tristan from 1949 - 1961. Although two powerboats were available to tow dinghies it is likely that the grounds to the south of the Island were only exploited by the islanders during the calmer summer months. From 1955 - 1958 islanders fished for an average of only 32 days in the year. Linefishing became secondary to lobster fishing after commercial exploitation of the latter commenced. Fishing for bait and the table was carried out only between deploying and recovering rock lobster traps and nets.

With the completion of the small harbour at the settlement in 1967 dinghies were gradually replaced by larger motor boats which substantially increased the distance that could be travelled to fishing grounds and thereby the fishing power of the fleet. A patrol boat carrying engine spares joined the fleet in 1970 and further increased the independence of the fleet from grounds close to the harbour. In 1973, 15 powerboats were fishing from the Tristan harbour (Roscoe, 1979). This number increased to about 20 by 1990. Prior to the 1980s fishing was generally carried out in waters to a maximum depth of 110 m (Roscoe, 1979). Lobster gear was subsequently set at depths of up to 200 m in particular seasons. This is likely to have affected the effort put into fishing for deeper water linefish such as bluefish, stumpnose and steambras (*Polyprion oxygeneios*). Although no records have been kept on linefish catches since 1949, catches probably increased proportionately to effort in the rock lobster fishery.

7.3.3 - THE PRESENT LINEFISHERY

During the present study period the fishing fleet operating from Tristan generally fluctuated between 18 and 20 two-man diesel powerboats, although at times when important subsistence activities were undertaken as few as five boats went fishing. Boats ranged in size from 4 to 6 m and carried from 6 to 12 lobster traps and 15 to 20 lobster nets. An experienced fisherman determined each morning if the weather was suitable for fishing. The other fishermen were then informed of his decision by the ringing of the "dong", a gong situated centrally in the village. Individuals then decided if they wished to fish that day. The boats put to sea on 87 occasions during the study period. Records kept by the Tristan factory showed that the fleet had fished an average of about 60 days a year since at least 1973. The occurrence of fishing days was determined by good weather or when the swell allowed boats to leave the exposed harbour on the north west shore of the island.

Daily line fishing effort averaged out at four hours/man/fishing day. The area fished on a particular day depended on prevailing weather conditions with most boats fishing in or near the lee of the island. Actual fishing positions were located using traditional land marks as no echo - sounding equipment was carried by any of the boats. The control launch usually fished in deeper waters than the lobster boats which, for practical purposes, remained near their lobster fishing gear. Bait consisted almost exclusively of octopus (probably *O. vulgaris*) captured in lobster traps. Handlines with either 2/0 or 7/0 hooks were generally used to fish for fivefinger, soldier, bluefish, stumpnose and steambras (see Table 7.2 for scientific names) on or near the bottom while Cape snoek lures were used near the surface when conditions indicated that snoek were present. Primitive longlines anchored at one end and buoyed at the other and set with up to 30 7/0 hooks were sometimes deployed in deeper water and checked sporadically throughout the day. The returns from this method were low and consisted mainly of bluefish.

Boats remained at sea for an average of about 10.5 hours in summer and about nine hours in winter. After the lobster catch had been unloaded on returning to the harbour in the evenings baits for lobster traps and nets were made up and kept in cold storage in preparation for the next fishing day. These baits consisted of whole small fish or pieces of larger fish strung together with twine. Whole fish were sliced open on the assumption that this would render the bait more attractive. If bait was scarce on a particular day larger specimens were used as bait rather than being saved for the table. Table fish were normally gutted and filleted at the harbour and the carcasses used for lobster bait.

The two larger lobster vessels that fished around Nightingale, Inaccessible and Gough Island had eight small powerboats between them which were used to set traps and nets in shallow water.

SPECIES COMPOSITION

Approximately 61.5 tonnes of linefish were harvested around Tristan Island by the local fleet from January to December 1989. The catch was made up of eight commonly caught species. The scientific and common names of these species are presented in Table 7.2. Their percentage contribution by mass over the 18 month period is shown in Figure 7.2. Fivefinger were the

most abundant species caught, although bluefish was the dominant species in terms weight. These two species made up 77 percent of the catch over the study period. Stumpnose, soldier (*S. capensis*), snoek, mackerel, steambras and *H. mouchezi* made up the remaining 23 percent of the catch in that order of priority.

Table 7.2. Common species caught in the Tristan da Cunha linefishery.

Family	Species	Tristan name
Cheilodactylidae	<i>Acantholatris monodactylus</i>	Fivefinger
Scorpaenidae	<i>Sebastes capensis</i> <i>Helicolenus mouchezi</i>	Soldier Soldier
Stromateidae	<i>Hyperoglyphe perciforma</i> <i>Schedophilus velaini</i>	Bluefish Stumpnose
Polyprionidae	<i>Polyprion oxygeneios</i>	Steambras
Gempylidae	<i>Thyrsites atun</i>	Snoek
Carangidae	<i>Trachurus longimanus</i>	Mackerel

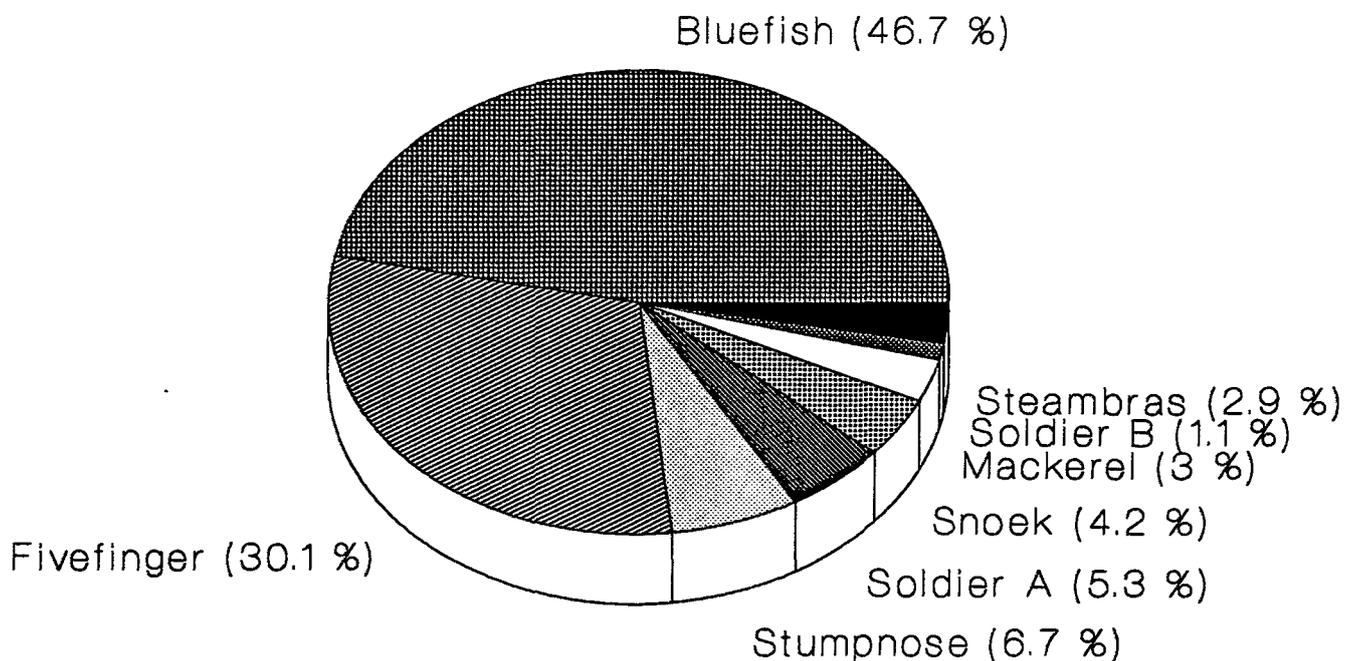


Figure 7.2. Contribution by mass of the component species in the Tristan da Cunha fishery from October 1988 to March 1990.

According to data collected by Sivertsen (1945) species composition and contribution to the catch were significantly different during the summer months of 1937-38 (Fig. 7.3). He mentioned that bluefish were only caught in winter at that time. Data from the present study showed that this species was caught in all seasons with peaks in summer and winter. This does not indicate a change in abundance of bluefish but is a consequence of increased fishing power and effort, especially in depths greater than those fished in the 1930s.

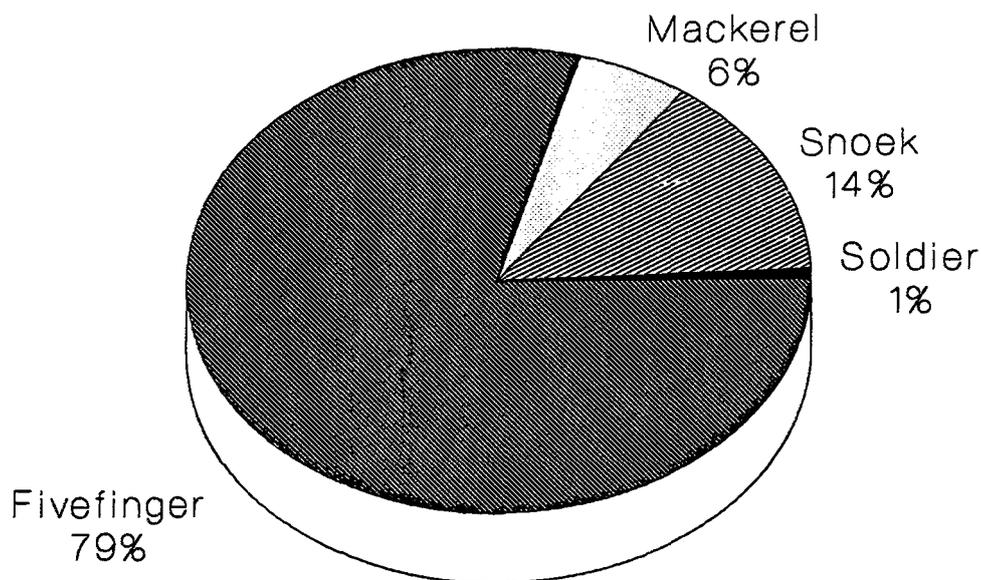


Figure 7.3. Contribution by mass of the various species caught during the summer of 1937/38 (data from Sivertsen, 1945).

In addition to the catch of the local fishermen around Tristan Island, the two fishing vessels landed an estimated 15 tonnes of fish per annum during the study period from the other islands. Fillets were packed and frozen on board and taken back to South Africa. The powerboats of the lobster vessels harvested the same species of linefish for lobster bait as the Tristan fleet.

CATCH RATE AND SEASONALITY

Figure 7.4 shows mean monthly catch rate for all species combined. Catch rates remained above 10 kg/man-day throughout the year. The peaks during December and January reflect a

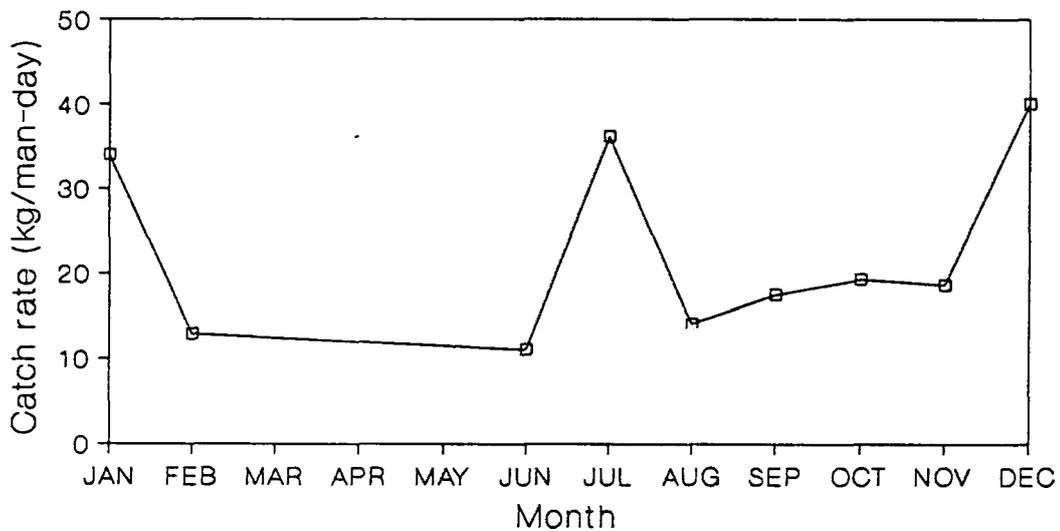


Figure 7.4. Mean monthly catch rate for all species caught in the Tristan da Cunha fishery from October 1988 to March 1990.

general increase in catch rate for all species at this time. The winter peak in July was mainly due to the good catches of bluefish during this month. The average catch rate for the summer months (October to March) was 25 kg/man-day while in the winter months (April to September) this dropped to 19.8 kg/man-day. During the present study, fishing occurred on an approximately equal number of days in summer and winter although the islanders said that in bad years less fishing occurred in winter.

Figure 7.5a and b show the seasonal fluctuations in the catch rates for the six most important species. Catch rate for fivefinger remained above 5 kg/man-day throughout the year except for June and July. Bluefish catch rate peaked in summer and again in winter. This is a result of intensified targeting for this species at certain times. More bluefish were taken in those months when the fishermen fished deeper waters while following lobster to different depths on a seasonal basis. The catch rates of the two species not included in Figure 7.5, steambras and the soldier, *H. mouchezi*, remained at a low level throughout the year.

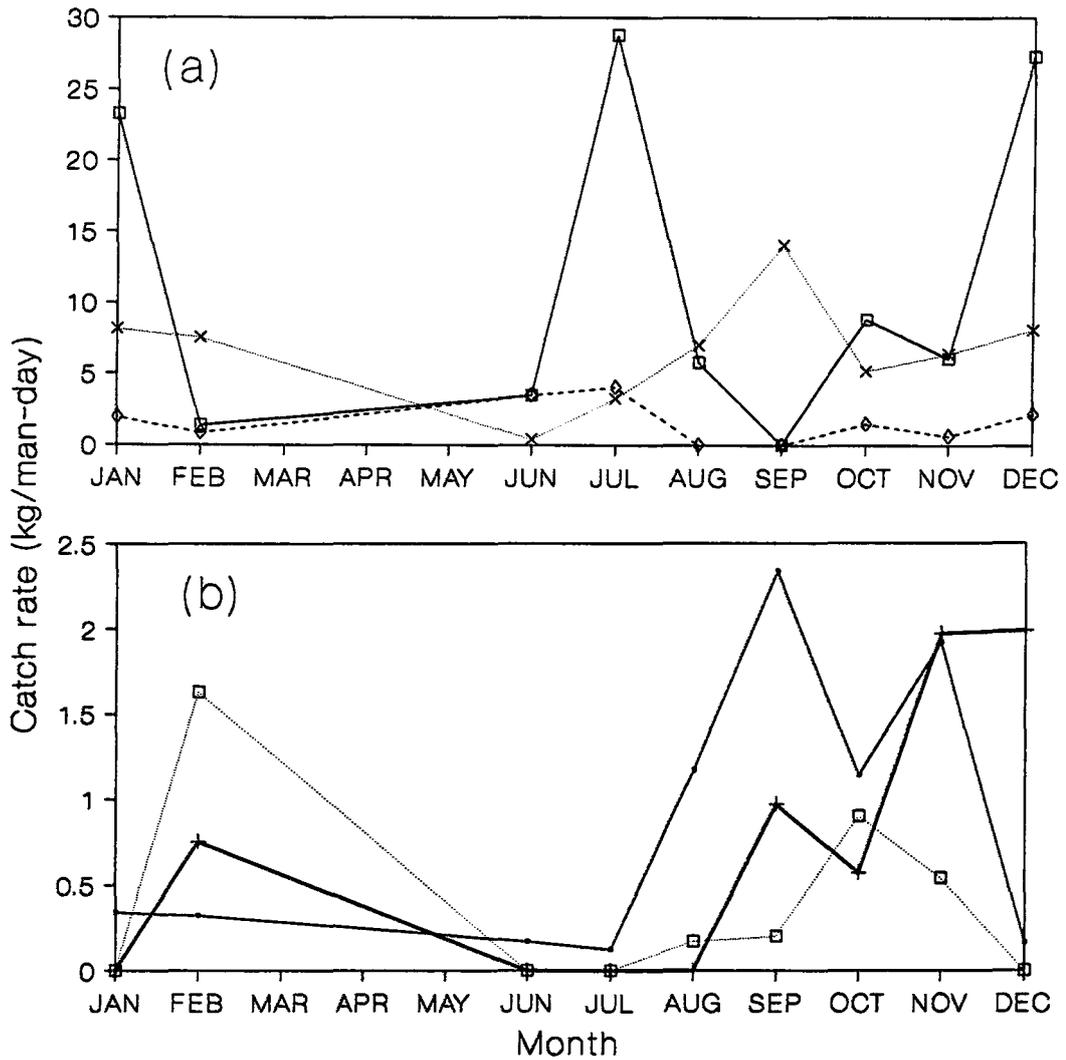


Figure 7.5. (a) Mean monthly catch rates for fivefinger (crosses), bluefish (squares) and stumpnose (diamonds), and (b) soldier, *S. capensis* (solid squares), snoek (plusses) and mackerel (squares) in the Tristan da Cunha fishery from October 1988 to March 1990.

LENGTH FREQUENCY AND THE STATUS OF THE COMPONENT SPECIES

Figure 7.6a to h shows the length frequencies and the size at 50 % recruitment of species caught in the linefishery.

Fivefinger, *Acantholatris monodactylus*

Fifty percent sexual maturity was reached at approximately 170 mm TL in this species (Chap. 4). The length at 50 percent recruitment into the fishery was approximately 250 mm TL indicating that only a small part of the fivefinger catch was smaller than the mean size at sexual maturity. Fish were first recruited into the fishery at the relatively small size of 150 mm TL. The 237.5 mm - 262.5 mm size class was the most abundant in the catches (Fig. 7.6a).

Figure 7.7 to 7.10 show the results of the yield-per-recruit analysis. Yield-per-recruit plotted against F (Fig. 7.7) shows that the present level of F exceeds $F_{0.1}$ at M values ranging from 0.1 to 0.2. The present level of F is exceeded by F_{MSY} only with M set at 0.2.

Changes in the yield-per-recruit curves at various ages of 50 % recruitment (T_c) and constant M (0.15) are shown in Figure 7.8. As could be expected a lower T_c reduced yield-per-recruit resulting in the present level of F being pushed further in excess of the recommended $F_{0.1}$ level. When T_c was increased to a level above 4.4 years the present F was still much greater than the $F_{0.1}$ level although lower than F_{MSY} .

Figure 7.9 is a plot of spawning biomass against varying levels of fishing mortality (F). It is apparent that the present level of fishing (0.31) is far beyond the optimum level of 0.5K (Shaeffer, 1954; Butterworth *et al.*, 1989) at which 50 % of the spawning biomass remains. This was the case at various levels of M .

If percent surviving recruits are plotted against age (Fig. 7.10) it is apparent that approximately 50 % of recruits to a particular size class will die through natural causes before they are recruited into the fishery. The curve for the exploited population deviates from that of the unfished stock only after 50 % recruitment is reached at an age well beyond sexual maturity. Exploitation reduced surviving recruits to an extremely low level in the older age classes.

Survivorship was low in these older fish even in the theoretical unexploited population.

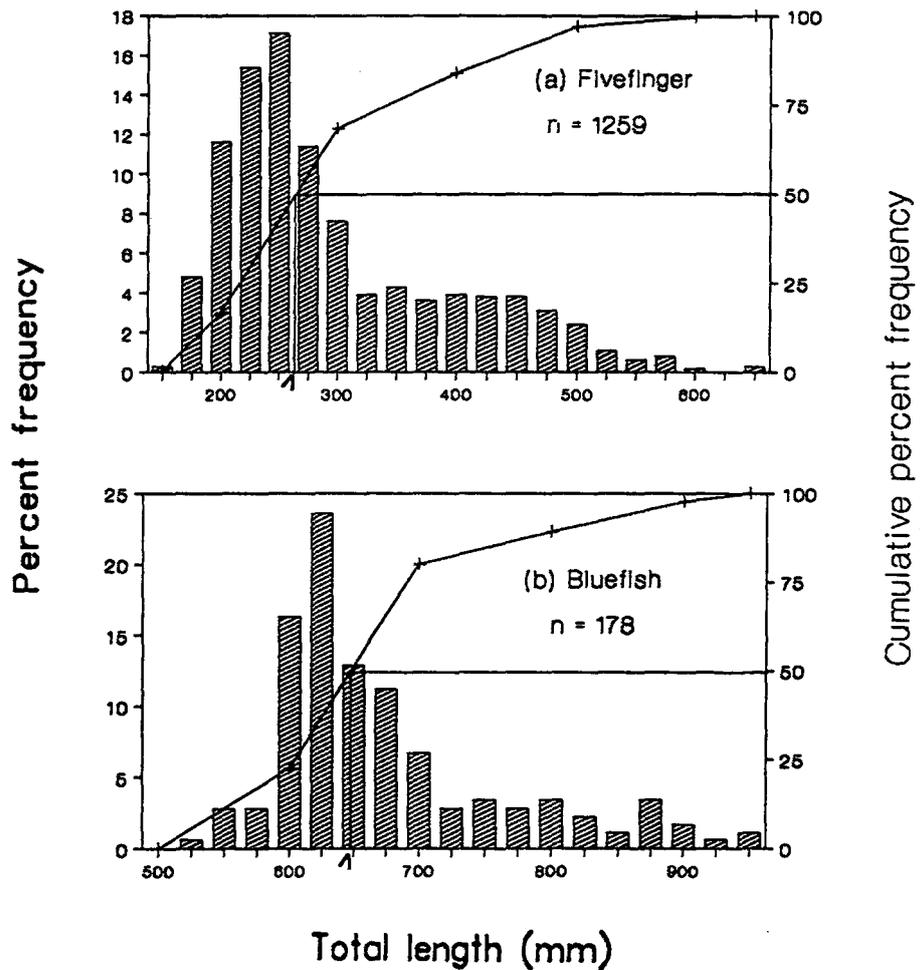


Figure 7.6a and b. Length frequency distributions and size at 50 % recruitment to the fishery (indicated by arrows) of species caught in the Tristan da Cunha linefishery.

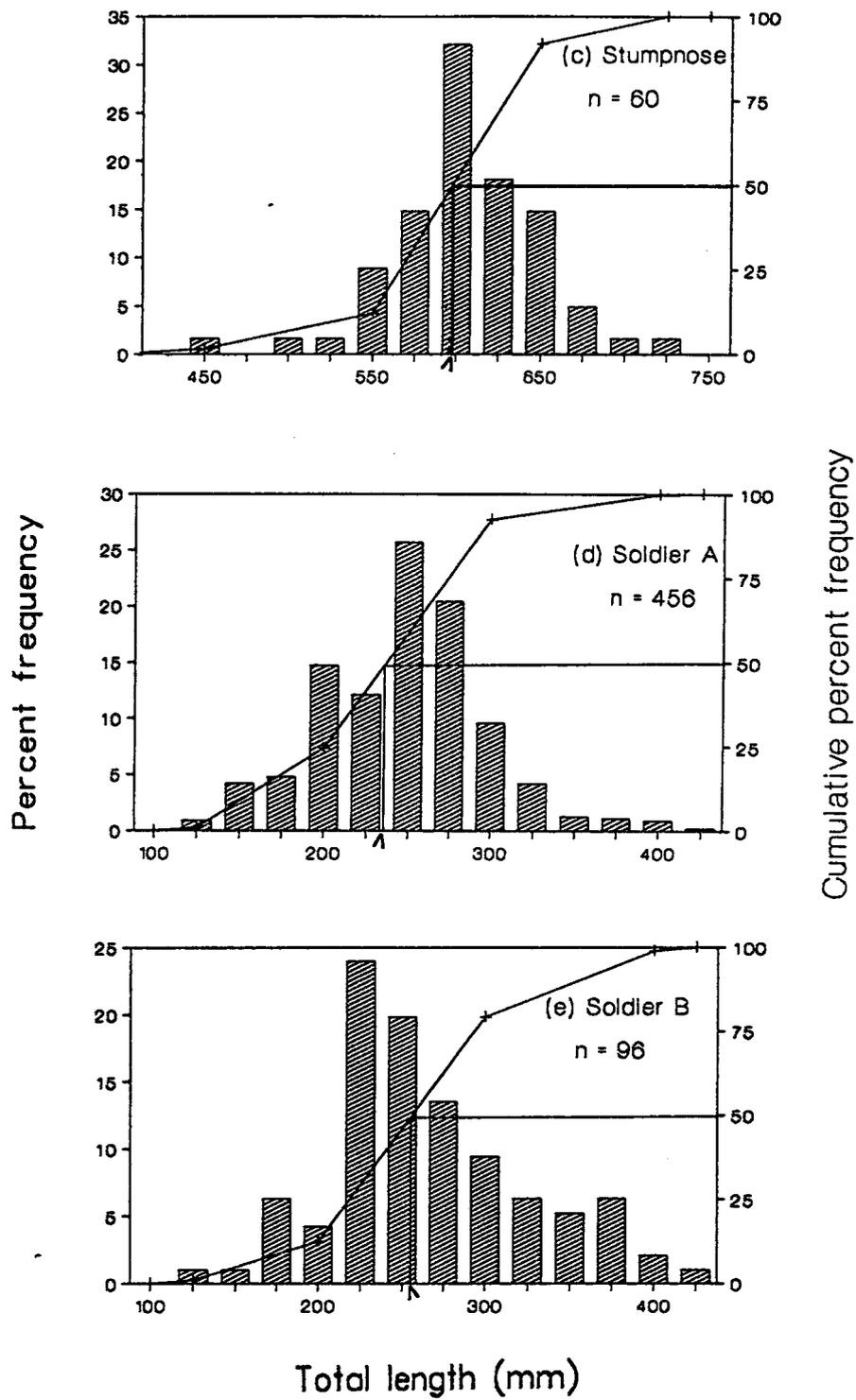


Figure 7.6c to e. Length frequency distributions and size at 50 % recruitment to the fishery (indicated by arrows) of species caught in the Tristan da Cunha linefishery.

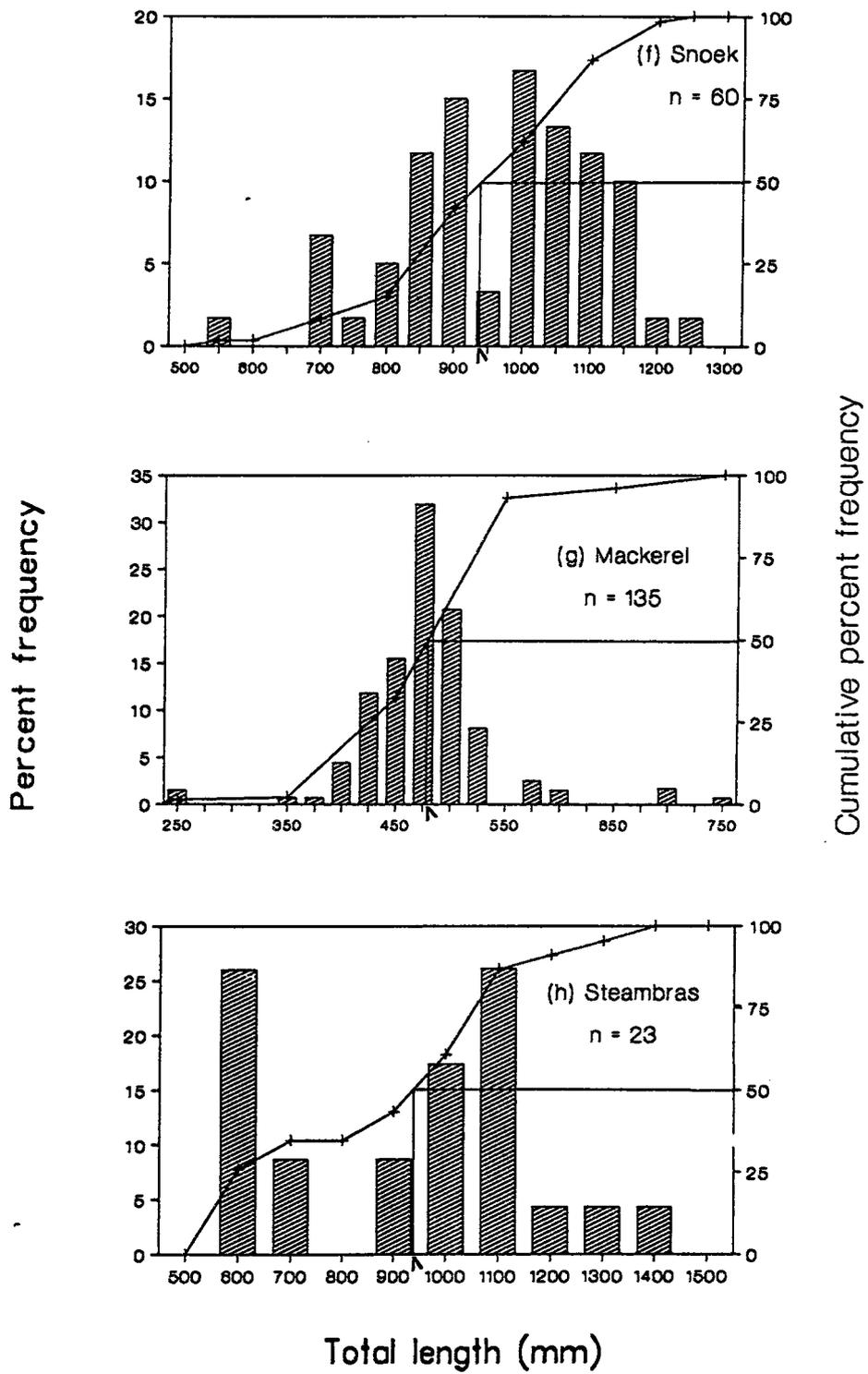


Figure 7.6f to h. Length frequency distributions and size at 50 % recruitment to the fishery (indicated by arrows) of species caught in the Tristan da Cunha linefishery.

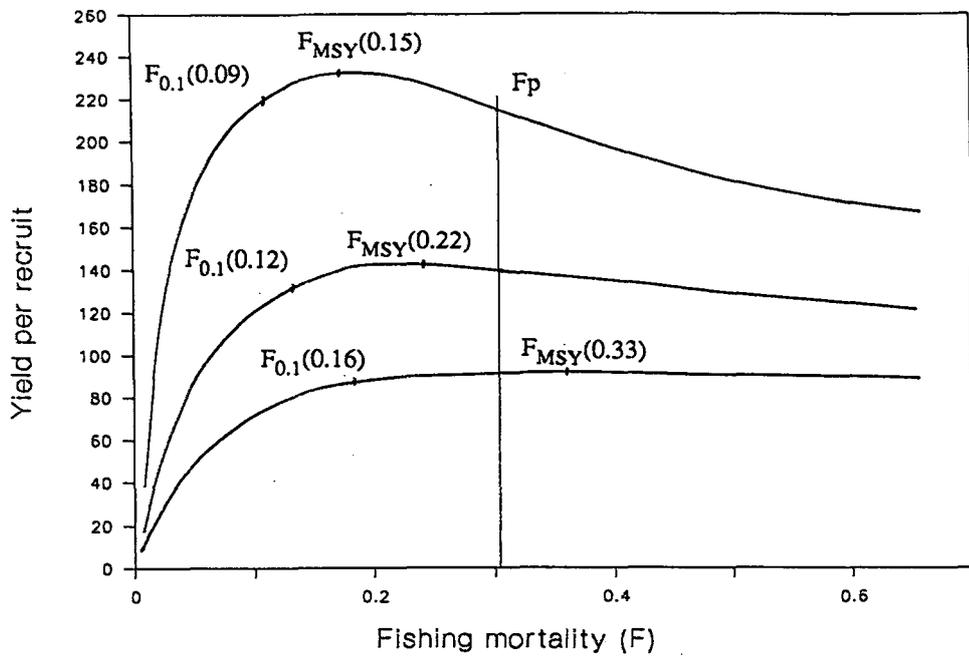


Figure 7.7. Yield-per-recruit as a function of increasing fishing pressure at different levels of instantaneous natural mortality (M) for *A. monodactylus* in the Tristan da Cunha fishery. M = 0.1 in top plot; 0.15 in middle plot; and 0.2 in bottom plot.

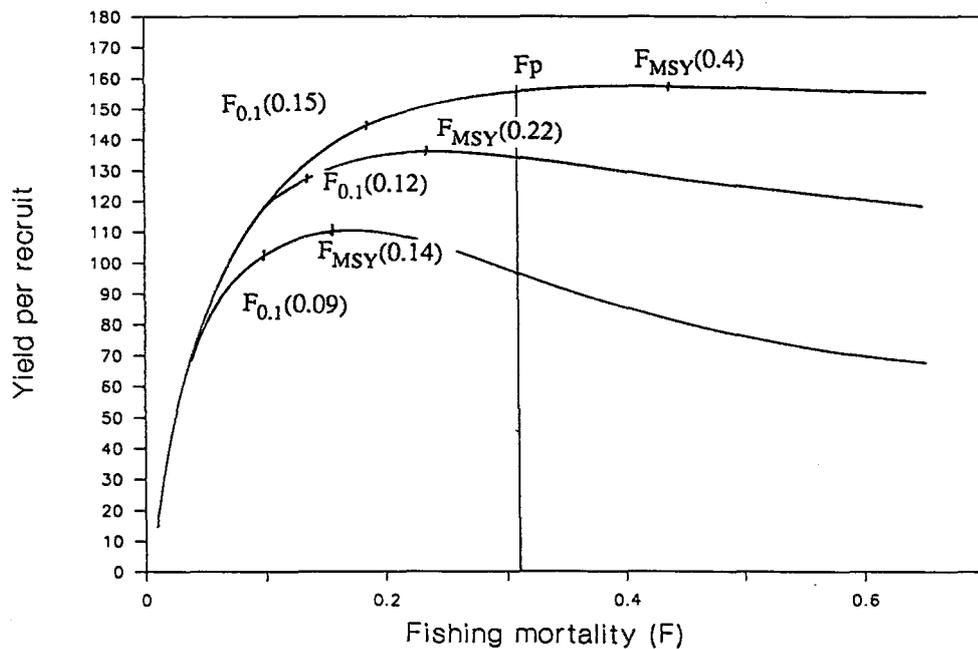


Figure 7.8. Yield-per-recruit as a function of increasing fishing pressure at different ages of first capture (t_c) for *A. monodactylus* caught in the Tristan da Cunha fishery. $t_c = 6.6$ years in top plot; 4.4 years in middle plot; and 2.2 years in bottom plot.

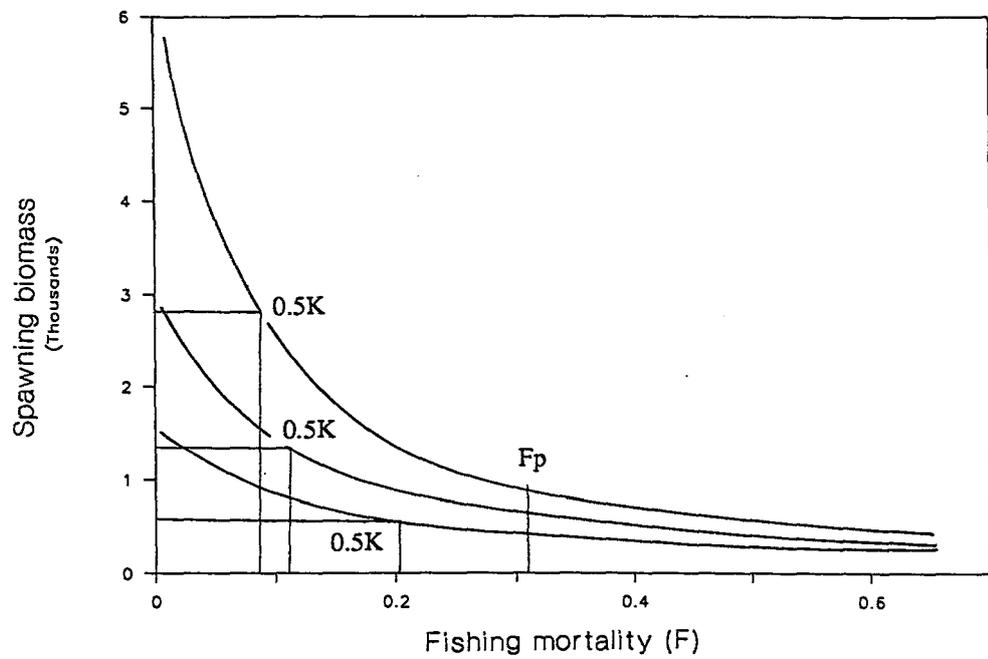


Figure 7.9. Spawning biomass as a function of increasing fishing pressure at different levels of instantaneous natural mortality (M) for *A. monodactylus* caught in the Tristan da Cunha fishery. $M = 0.1$ in top plot; 0.15 in middle plot; and 0.2 in bottom plot.

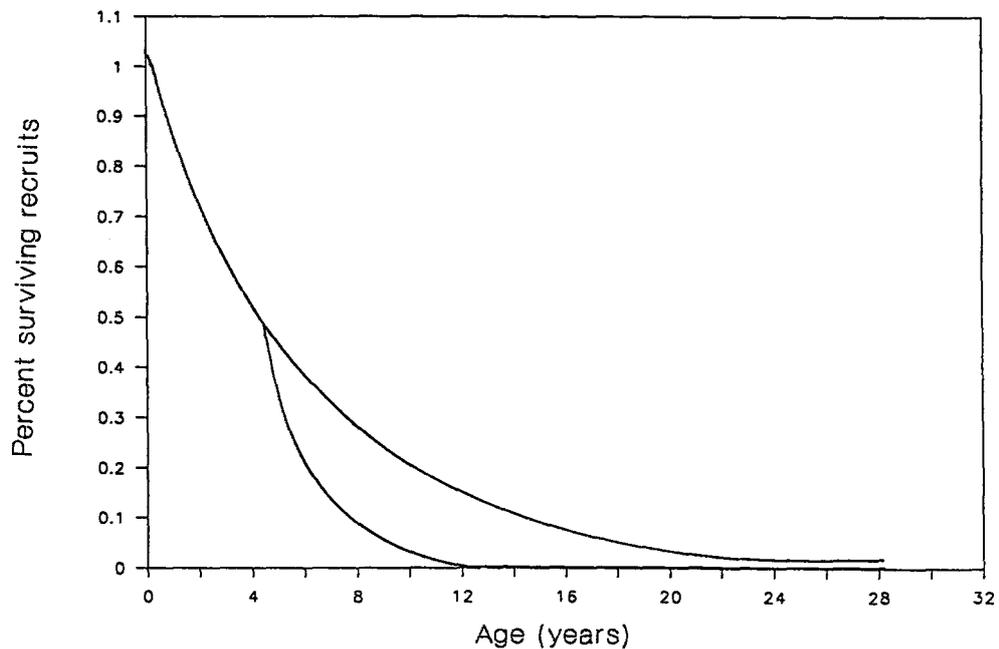


Figure 7.10. Percent surviving recruits as a function of age under different levels of fishing pressure (F) for *A. monodactylus* caught in the Tristan da Cunha fishery. $F = 0$ in top plot; $F =$ current fishing mortality (0.31) in bottom plot.

The results of the yield-per-recruit analyses presented above indicate that the fivefinger stock is presently being over-exploited. This would suggest that a serious decline in abundance and the size of fish caught should be noticeable. However, evidence from the local fishermen and from comparison with catch data recorded by Sivertsen (1945) indicate that the abundance and size of fivefingers caught has not changed significantly over time. This suggests that the stock has not suffered even at apparently detrimental fishing levels. There could be a number of reasons for this. Firstly, distant recruitment from the unfished neighbouring islands is thought to occur. Therefore a reduction in local spawning biomass would have little effect on the number of recruits entering the fishery. Also, because of the small size at sexual maturity in this species, a relatively high proportion of fish are able to spawn before entering the fishery. This small size at sexual maturity and the high longevity of the species ensures that each individual has a high reproductive output during its life span (Chap. 4.)

The present study has shown that the fivefinger is a slow growing, long-lived species taking up to 25 years to reach a maximum length of about 670 mm TL (Chap. 4). The territorial nature of adults and the limited space on the island shelf indicates that space is an important parameter determining the abundance of benthic phases at the islands. The protracted pelagic phase, although facilitating dispersal, must result in a high level of mortality in fish younger than one year. It is thought that the high fecundity of the species compensates for the theoretical high mortality of the pelagic phases (see Chap. 4).

The yield-per-recruit model assumes that recruitment is constant from one year to the next. In the present case recruitment is thought to be dependent on the density of the benthic phases resident on the island shelves. The results obtained are probably affected by the fact that the population is not strictly closed, in that immigration and emigration of pelagic juveniles occurs between the islands. The parameters used in the yield-per-recruit analysis are based only on the population at Tristan Island and are therefore obviously somewhat misleading. Because of possible distant recruitment from the other islands, it is suggested that the population at Tristan Island is capable of sustaining itself at the present level of fishing. It was, however, noticed that fivefingers caught on the more heavily fished northern shores of Tristan were generally smaller than those caught on the less commonly fished southern shores. In order to test if this observation was valid, the total fivefinger catches of powerboats fishing north and south of the island respectively, on eight fishing days, were compared for mean length (Fig. 11). It was

found that fish in this sample were on average 16 % smaller on the northern shores and it was concluded that the abundance of larger size classes may have been diminished by greater exploitation on the northern shores of the island. Sivertsen (1945) also noticed that fivefingers collected further away from the settlement were larger than those collected directly off the settlement. In order to maintain the present level of exploitation it is proposed that fivefingers at the other islands be protected as spawner stock refuges.

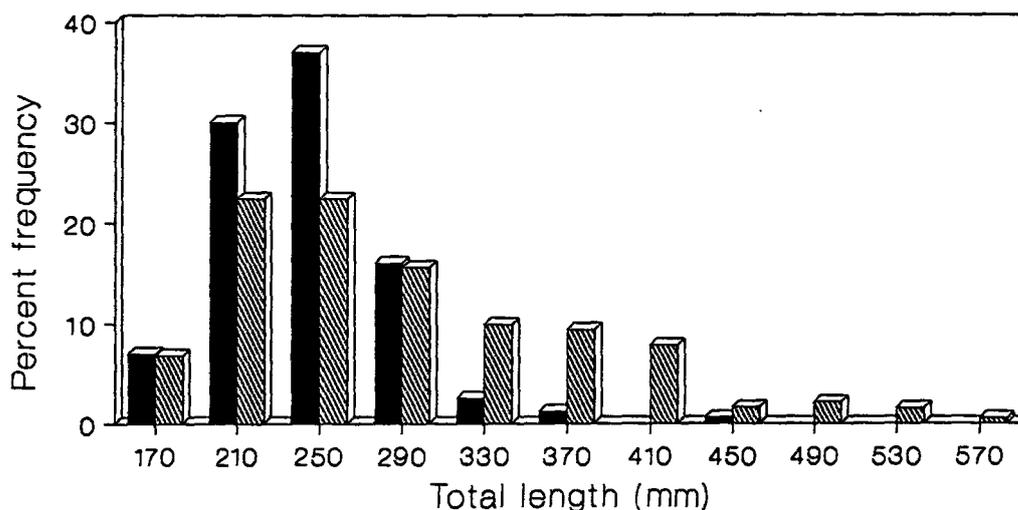


Figure 7.11. Length frequency distributions of *A. monodactylus* caught off the northern shore (solid bars) and the southern shore (hatched bars) of Tristan Island.(n = 174 and 193 respectively).

Bluefish, *Hyperoglyphe perciforma* (Fig. 7.6b)

The bluefish is a fast growing species. Specimens of up to 1000 mm TL and 14 kg have been estimated to be in the order of nine years old (Horn, 1988; and present study). Fifty percent recruitment occurs at a size of 650 mm TL. Mature fish were only recorded in size classes above 800 mm TL. Fishes smaller than 500 mm TL are thought to be pelagic (Haedrich, 1986; Horn, 1988) and therefore unavailable to the fishery. This factor provides some protection to the population, however the low numbers of mature fish captured is cause for concern. The size classes caught in the fishery are bound to particular depths on the island shelf which reduces the area suitable for colonisation by the species. In other areas of the species'

distribution, such as New Zealand, it is known to occur to depths of 600 m (Horn, 1988). It is therefore possible that the majority of the spawner biomass occurs in waters not fished by the local fishermen at present.

This species appears to be suitable for increased exploitation. It would be advisable to direct more effort to deeper waters to ensure that effort is spread over all size classes in the population. This would also significantly reduce effort on other species in shallower water that are not as suited to exploitation as the bluefish.

Stumpnose, *Schedophilus velaini* (Fig. 7.6c)

Stumpnose were first recruited into the fishery at a size of 450 mm TL. Fifty percent recruitment occurred at a size of 590 mm TL. All animals above this size were sexually mature. As with the bluefish the smaller size classes of this species are pelagic (Haedrich, 1986) and thus unavailable to the fishery. The biological characteristics of this species, including rapid growth and high fecundity, would also suggest that it is suited to exploitation but, compared to bluefish were relatively scarce in the catches. Again any increase in fishing effort should be directed to deeper water where the species is known to occur (Haedrich, 1986) thereby reducing fishing pressure on other inshore species. It was noted that directed fishing for both bluefish and stumpnose in deeper water was more productive during the present study.

The two soldier species, *Sebastes capensis* and *Helicolenus mouchezi* (Fig. 7.6d and e)

Large numbers of relatively small specimens of both soldier species were caught. The length at 50 % recruitment for both species was approximately 250 mm TL. Fifty percent maturity in both species was above this size. *S. capensis* were generally caught in shallower water (10 - 50 m) than *H. mouchezi* (40 - 100 m) with larger specimens generally occurring at the deeper limits of their ranges. These species were found to be highly territorial from a very small size, of at least 100 mm TL. This behavioral trait would result in space on the shelf areas being a limited resource. It is suggested that immature fish caught for lobster bait should be protected by imposing restrictions on the collection of bait in Tristan waters.

Snoek, *Thyrsites atun* (Fig. 7.6f)

Although snoek were first recruited into the fishery at a relatively small size of 550 mm TL the length at 50 % recruitment occurred at about 940 mm TL. Most fish caught were mature with a high proportion of the catch consisting of large fish of over 1000 mm TL. Catches of this species were highest from August to December, a period coinciding with the spawning season. It is suggested that more effort would have no negative effects on the snoek population at the islands as most snoek are caught incidentally and schools are not searched for. In addition evidence from the South African snoek fishery indicates that this species is highly resilient to fishing pressure (Crawford, 1989a).

Mackerel, *Trachurus longimanus* (Fig. 7.6g)

Fifty percent recruitment occurred at 480 mm TL. All mackerel larger than 400 mm TL were sexually mature. The major component of the catch of this species at Tristan consisted of fish between 400 and 500 mm TL, although smaller and larger specimens were occasionally caught. Mackerel are known to be present all year round although no catches were recorded in June, July or December. This was probably as a result of unfavourable water conditions on fishing days during these months. Generally, best catches of mackerel were made in calm water. As with snoek this species was mostly caught if schools occurred around a boat's anchored position. Catches were made in mid-water or near the surface. The mackerel has biological characteristics such as high fecundity and rapid growth which indicates that the species is suitable for exploitation (Adams, 1980).

Fisheries for congeneric species of horse mackerel exist in many areas of the world, and are usually associated with cold water current systems (Crawford, 1989b). Populations of species such as the Cape horse mackerel, *Trachurus trachurus capensis* have shown evidence of resilience by recovering rapidly after years of particularly intense fishing pressure (Crawford, 1989b). Catches of this species off the west coast of southern Africa were also found to increase in years when catches of other species with similar habitat and food requirements, such as the Cape Hake, *Merluccius capensis*, were poor (Crawford, *et al.*, 1987). This indicates that horse mackerel are able to optimise production when favourable conditions abound, such as decreased competition for resources. Because of these factors it is suggested that the catch of

mackerel at Tristan Island could be increased through targeting without detriment to the stock.

Steambras, *Polyprion oxygeneios* (Fig. 7.6h)

Approximately 100 specimens of this species are caught each year. During this study fish caught ranged in size from about 600 to 1400 mm TL. It is probable that the small numbers landed is a result of fishing occurring only in the upper range of the species depth distribution. Steambras are known to occur to depths of at least 550 m in New Zealand (Roberts, 1989) and 300 m in South Africa (Heemstra, 1986g).

7.4 - DISCUSSION

As mentioned previously the linefish stocks in the inshore waters of the Tristan da Cunha islands are an extremely important component of the islanders' diet.

A CPUE of about 6 kg/man/hour for the fishery as a whole suggests that the stocks around Tristan Island are in a relatively healthy state when compared to other linefisheries such as that off Port Alfred, South Africa, where a CPUE of about 3 kg/man/hour is evident (Hecht & Tilney, 1989). Also, differences in the catch rate of the control launch which targeted for certain species, and the powerboats which generally fished closer inshore near their lobster gear, indicated that catch rate could be increased up to two times by directed effort.

Changes in species composition in exploited multi-species communities is a common occurrence (Koslow *et al.*, 1988; Hecht & Tilney, 1989). The composition of catches at Tristan, at least during the summer months, were similar to those recorded in the 1930s (Sivertsen, 1945), a further indication of the healthy status of the fishery. The present level of fishing which is limited by suitable weather and by the type of fishing gear used is thought to be responsible for the maintenance of good returns for effort. The presence of virtually unexploited grounds at the neighbouring islands probably ensures that recruitment to Tristan Island is maintained from a healthy spawner biomass.

Yield-per-recruit analysis of the fivefinger showed that the level of fishing is at present beyond

recommended levels. The maintenance of good catches of this species at Tristan Island since at least 1945 indicated that some factor not taken into account in the model was responsible for the disparity between the modeled and observed status of the fishery for this species. Distant recruitment from relatively unfished areas is thought to be the mechanism through which fisheries are maintained in a variety of species. Buxton (1987) put forward the idea of distant recruitment as playing a major role in maintaining populations of some sparid species on the east coast of South Africa and suggested that if this was the case it would lend strong support for the establishment of marine reserves on that coast.

Commercial exploitation would have a pronounced effect on the structure of fish stocks at all the islands. Given the financially expensive nature of operating vessels far from their home ports, it is probable that the stocks of all the islands would have to be exploited in order to show profits. Also, ships would be able to exert far greater effort than the Tristan fleet does at present. This type of fishing would effectively reduce the present reservoirs of unexploited stocks thought to sustain the Tristan fishery. As recruitment of most of the commercially desirable species does not occur from outside of the immediate island ecosystem, the limited shelf areas (fishing grounds) would theoretically allow local fish stocks to become easy targets for over-exploitation.

It is generally accepted that species tending towards r- selection or which display an altricial life-history strategy are suitable candidates for exploitation (Adams, 1980; Bruton, 1989) because of their capacity for high production (see Chap. 4). Bluefish, stumpnose, snoek and mackerel have been identified as species which tend towards being r- selected. These species have life-histories focused on production and display features such as high fecundity, rapid growth and relatively low longevity. On the other hand fivefinger, the two soldier species, and steambras are not strongly r- selected and are longer lived and slower growing than the other species in the fishery. It would be logical to suggest that the more r- selected species should be targeted in the fishery at Tristan da Cunha.

At present the species that are not strongly r- selected, especially the fivefinger and soldier, *S. capensis*, make up a significant proportion of the total catch at Tristan Island; with few negative effects on the stocks being apparent. However, if all the islands were fished intensively, the scenario which becomes apparent from the yield-per-recruit analysis of the fivefinger, where

the population was assumed to be closed and recruitment constant from year to year, could become a reality, especially for the less strongly r- selected species. In short, the fish stocks may yield good returns for a limited period but would probably become overfished within a very short timespan. The short term economic gain realised from commercial exploitation of the linefish resource is believed to be outweighed by the long-term gain in terms of a reliable food source for the Tristan community.

Although the present level of fishing apparently has no negative effect on local fish stocks, planned extensions to the harbour could lead to increased fishing pressure by allowing boats to put to sea more regularly. This possible increase in fishing effort calls for some changes (outlined below) that would help to ensure the healthy status of the Tristan linefish resource.

Fish caught for the table are normally relatively large. The need for bait for the rock lobster industry makes it essential that the fishermen keep small immature fish. If this incentive was removed then the smaller size classes would be automatically protected ensuring a greater spawning output.

Any fishing company applying for a rock lobster concession around the islands should therefore be required to supply their own bait from elsewhere. Hake (*Merluccius capensis*) heads should be used more extensively on powerboats than at present. In addition, ships belonging to the concessionaires should be restricted from taking out linefish. These measures would not impose a great financial burden on the concession holder but would help to ensure continued availability of inshore linefish to the islanders of Tristan da Cunha.

CHAPTER 8 - CONCLUSIONS

This study on the fish fauna of Tristan da Cunha and Gough Island has contributed towards our understanding of biological processes occurring at oceanic islands. The taxonomic review and biogeographic analysis undertaken in this thesis have far reaching implications for the understanding of current distributional patterns of fishes in the Southern Ocean. The revised taxonomic status of species from the islands has allowed for meaningful comparisons with the fish fauna from other areas of shallow water in this region. The first conclusion that was reached is that latitudinal distribution is determined primarily by temperature, and the rapid change of temperature at the STC was considered particularly important in this regard. It is proposed that future studies in the STC region should accept at the outset, that this ecosystem may be an entity that differs from the oceans to the north and south of it. Ecological studies should be designed to determine the relationship that organisms living in the STC region have with the surrounding environmental conditions. Further, frontal zones should be seriously considered as biological barriers affecting the distribution of organisms.

It also became apparent that widely separated localities near the STC in the Southern Ocean shared many resident species. It was found that an STC ichthyofauna could be characterised. Although this had been noted before (Sivertsen, 1945; Penrith, 1967; Duhamel, 1989; Collette & Parin, 1991, amongst others), the mechanisms resulting in this pattern of distribution had not been clearly analyzed or understood. One of the common biological characteristics among most of the coastal species at Tristan and Gough is the presence of an extended pelagic phase which would allow these species to reach distant localities by passive or active interaction with ocean currents. The presence of this adaptation was recognised in 11 species from eight families. The early life-histories of the other species at the islands is unknown, but the common occurrence of an extended pelagic phase suggested that this adaptation may be present in these species as well. Because of the strong dispersive capabilities of the resident species and the observation that few endemics occur at any of the islands close to the STC, it was concluded that the populations at these localities are not completely isolated from each other. It is believed that sufficient genetic interaction occurs between these populations to inhibit speciation through isolation (Ribbink, 1988; Greenwood, 1991).

If the origin of the resident species at Tristan and Gough is considered, the conclusion that must

be reached is that the occurrence of these species at the islands was facilitated by their dispersive pelagic phase. The islands are relatively young compared to the continents, which must have been the source areas from which these species, or their ancestors, originated, and colonisation would therefore be dependent on the ability of certain species to initially reach these isolated localities, and to survive in the environmental conditions present there. Many other species of the families occurring at the islands, but which are only found on the continental coasts, also exhibit an extended pelagic phase which would theoretically have enabled them to reach the mid-ocean islands in the past. Why then were these species unable to colonise the islands?

Firstly, as suggested by Sinclair (1988), the geographic distribution of populations is probably determined by the relationship of species-specific life-cycles to environmental phenomena such as current systems. Species with extended pelagic phases must overcome the problem of becoming separated from local or regional retention areas in order for life-cycle closure to occur. Clearly, the life-history of a species would have to be closely synchronised with local environmental conditions to allow successful colonisation to take place. This may explain why certain species that were capable of reaching Tristan da Cunha and Gough Island were able to establish breeding populations while others were not.

In previous chapters it was suggested that resources such as space and possibly food are limited on the relatively small shelf areas of the islands. If this were the case then it is plausible that certain species were able to out-compete others during the colonisation stage, and especially when a more stable, climax community had established itself, during which it has been suggested (MacArthur & Wilson, 1967) that competition for resources would be intense. The relatively low extant species diversity and the absence of congeneric species would suggest that a limited number of ecological niches are present at the islands. Also, it was noticed during this study that very little interspecific resource overlap occurred. These factors are considered to be indications of the ability of certain species to "use up" particular resources, thereby excluding other species with closely aligned life-histories (such as congenics), from obtaining a "foot hold" at the islands. Once a species had established a viable breeding population and filled a particular niche, it would be difficult for vagrant individuals of other species with similar ecological requirements to successfully compete with the resident population.

It has been shown that character displacement or habitat shift invariably results when two normally allopatric, morphologically and behaviorally similar species become sympatric (MacArthur, 1972; Price, 1975; Schoener, 1974). In addition, Hixon (1980) found that competitive exclusion occurred from the preferred foraging environment between two congeneric species of surfperch, *Embiotoca lateralis* and *E. jacksoni*. This supports the suggestion that congeneric species were competitively excluded from Tristan da Cunha and Gough Island by species already resident there.

Munro (1990) stated that most, if not all, habitats are seasonal and that this seasonality is reflected in adaptive cyclic changes in the biology of their associated fauna and flora. As could be expected therefore, biological processes were found to display seasonality in the fishes of Tristan da Cunha and Gough Island. Although seasonal changes in growth, reproduction and feeding were relatively easy to detect, the causes of these changes are largely speculative at present because of the lack of quantitative data on the environment at the islands.

Growth in two families was found to vary with water temperature. In the case of the cheilodactylid, *Acantholatris monodactylus*, it was suggested that growth was enhanced seasonally during periods of higher water temperature. Growth has been found to be positively influenced by increased temperature within the thermal limits of some species through the effect that temperature has on metabolic activity (Smith, 1989). It is probable that seasonal changes in diet related to the temperature fluctuations also contribute to enhanced growth rate during the summer months.

In the scorpaenid, *Sebastes capensis*, growth rate was found to be more rapid in a population occurring in cooler waters. As with *A. monodactylus* it was hypothesised that important factors affecting growth were temporal or spatial changes in diet, as diet had been shown to affect growth and longevity in animals (Comfort, 1960; Gerbase-DeLimar *et al.*, 1975). Food abundance and quality was thought to be influenced not only by temperature, but by oceanographic conditions in general. Latitudinal environmental variation has been acknowledged to have an influence on life-history strategies within a species through affecting factors such as food availability (Munro, 1990). To determine if this hypothesis is valid it would be necessary to obtain data on primary production and food abundance throughout the year at both Tristan da Cunha and Gough Island. It was also suggested that reproductive strategy may vary

in the two *S. capensis* populations because of differences in environmental predictability at the two localities and that this could result in different growth and longevity characteristics (Mann & Mills, 1979; Boehlert & Kappenman, 1980).

The timing of reproduction was found to coincide with the period of highest water temperatures in the majority of species at the islands. Reproduction in two species in which a pelagic phase was included in the life-cycle, but which differed widely in other aspects of their reproductive strategy, were studied in detail. In both species the placing of young into the pelagia obviously enhanced reproductive success in some way. It was hypothesised that this was a mechanism through which larvae could gain access to a more suitable food supply (Cushing, 1975), and/or allow enhanced predator avoidance in the early stages. If this mechanism had evolved to enhance access to food it would be plausible that the timing of reproduction would be synchronised with the period of highest food availability; which for larval prey organisms would be related to increased primary production (Bye, 1990). This explanation would account for the summer spawning periodicity exhibited by the majority of Tristan and Gough fishes. Again, the paucity of data on biological production at the islands does not allow these questions to be answered with confidence.

Most species at the islands had an extended breeding season and displayed iteroparous spawning. This characteristic is indicative of unpredictable environments (Mann & Mills, 1979). Although seasonal changes in surface water temperature appeared to be fairly predictable when compared to previous years, it was apparent from thermal infrared tracking that the STC in the Tristan da Cunha region is variable (Chap. 2). The STC is not represented by a well defined thermal front in this region but consists as a series of smaller fronts concentrated in the general latitude of the islands. The irregularity of these smaller fronts may result in biological processes such as enhanced primary productivity being highly variable on a seasonal basis at the islands. In such an unpredictable environment it would be adaptive for a species to have a longer breeding season and spawn at intervals throughout this season so as to ensure that some larvae are produced to coincide with favourable conditions (Bye, 1990).

In order to further understand the environment at the islands, traits of the fish community are compared to typical traits associated with predictable and unpredictable environments as viewed by altricial/precocial life-history theory. This is shown in Table 8.1 (after Bruton, 1989).

Table 8.1 Community traits associated with predictable and unpredictable environments (after Bruton, 1989) and community traits present in the fish community at Tristan da Cunha and Gough Island.

Community traits	Unpredictable environment	Predictable environment	Tristan/Gough community
species diversity	low	high	low
life form diversity	?high	?low	?high
breeding guilds	many	few	many
species interdependence	low	high	low
mutualisms	uncommon	common	uncommon
rare species	uncommon	common	uncommon
migratory species	common	uncommon	common
sedentary species	uncommon	common	uncommon
speciation rates	low	high	?low
extinction rates	low	high	?low
resource defence	uncommon	common	uncommon
niche overlap	?wide	?narrow	?narrow
species saturation	low	high	?low

Based on the information compiled in the present study it is apparent that the community at the islands is more typical of a community associated with an unpredictable environment than one associated with a predictable environment. This is regarded as evidence to back up the assertion that a protracted breeding season and multiple spawnings are important characteristics allowing species to be successful at Tristan da Cunha and Gough Island.

The feeding biology of *A. monodactylus* was found to vary significantly under different temperature regimes. It was suggested that this was a result of a combination of temperature directly affecting the distribution of prey items, and a change in the abundance of prey items related to ambient oceanographic conditions. This study indicated that the fivefinger was able to optimise on particular prey items that were abundant at different localities or during different seasons. If food availability was as seasonal as was suggested from the results of this study it

is highly probable that other species at the islands would also display an opportunistic feeding strategy and have diets comprising a large variety of prey items. The seasonality of catches in the Tristan fishery also indicated that environmental factors influenced seasonal distribution and abundance of fishes at the islands. This could be a result of some species moving into shallower water near the islands to optimise on increased food availability during the summer months.

Most species at the islands were not found to be strongly adapted towards either an altricial or precocial (Balon, 1985), or an r- or K- selected (MacArthur & Wilson, 1967) life-history strategy, as defined in Chapter 4. This indicates that a variety of combinations of life-history characteristics can result in a common end; biological success at the islands. The two common biological factors identified in the ichthyofauna of the islands during this study; the presence of an extended pelagic phase in many species, and a relatively long breeding season and iteroparous spawning, were apparent in species from a wide variety of families. This indicates that these two features are probably essential for the survival of most species in the seasonal environment of the STC zone.

All the biological processes discussed above were linked to sea temperature changes. Temperature data was the only physical parameter that these processes could be related to with confidence during this study. However, although temperature is thought to directly influence the distribution of species, it is not believed to be the direct cause of variation in seasonal biological processes. The major shortcoming of this thesis, therefore, is the inability to explain the causes of seasonal biological variation with confidence. It is quite clear that the missing link is the lack of quantitative data on the effects that the noted seasonal variation in oceanographic processes, such as temperature, have on primary production and hence food availability at the islands.

Even though these shortcomings detract from the overall value of this work, the practical implications of this research are far reaching. Information gathered during this study has been included in a document currently in preparation (Cooper, *et al.*, in prep.) on the conservation status of the Tristan da Cunha Islands. These islands lend themselves to successful conservation measures because of the few players that are involved in the exploitation of their natural resources. The islanders are generally conservation minded, with some exceptions, and realise that the cash economy of Tristan da Cunha is reliant on natural resources. A strong tradition

of independence exists in the community, a factor which further encourages the islanders to maintain traditional rational exploitation of resources. With only one concessionaire having access to the marine resources of the islands, implementation of conservation measures should be relatively easy. The Tristan Administration is in a position at present to ensure that any conservation measures are carried out as the concession is due to be re-negotiated in the near future. Size limits, quotas or closed areas can be included into any future contract between the island administration and the concessionaire. A suitable method of monitoring the catches of the concessionaire needs to be implemented. Effective monitoring could be attained by ensuring that Tristan Conservation Officers are appointed and accompany fishing vessels for at least part of the year.

Recommendations on the exploitation of the fish stocks have already been submitted to the Tristan Administration. So far, a minimum size limit of 250 mm has been implemented for the fivefinger, *A. monodactylus*, based on recommendations arising from this study (Anon., 1992). In addition, bait for the lobster fishery will be imported from January 1993 thereby reducing the harvest of immature fish at the islands. These measures constitute a fundamental break-through in the conservation of marine resources at the islands as no legislation concerning the fish stocks has previously been implemented.

Data from this study will also add to a Management Plan for Gough Island currently in press (Cooper & Ryan, in press). Through this Plan the present study will support an intended motivation to the World Heritage Convention (Cooper & Ryan, in press) that Gough Island be included as a Natural Heritage Site. At present this island is a proclaimed Wildlife Reserve equivalent to an International Union for Conservation of Nature and Natural Resources (IUCN) Scientific/Strict Nature Reserve (Cooper & Ryan, in press). Under this proclamation emphasis is placed on the conservation of terrestrial organisms. It is hoped that the new information on the fishes of the islands will encourage wider inclusion of marine resources in order to maintain the true ecological balance of the system. It should be emphasised that most of the animal life on the island are reliant on the surrounding marine resources for survival. It is envisaged that a Management Plan for Inaccessible Island will be prepared once the Gough Island Plan is completed (Cooper *et al.*, in prep.). As pointed out in Chapter 7 the conservation of the spawner biomass at this island should help to maintain viable stocks at the neighbouring exploited islands through distant recruitment.

This thesis should be considered as a baseline investigation of the fishes of Tristan da Cunha and Gough Island. The fact that very little information existed on the fishes prior to this study limited the detail in which various aspects could be examined. It was first necessary to determine the nature of the fish community at the islands before more detailed objectives could be identified. Obviously, all the facets needing further investigation could not be addressed in this study due to time and logistic constraints. However, it is believed that the knowledge gained has pointed out the weaknesses in the data collected and has identified areas requiring further attention. Three major areas of research can be prioritized from this thesis.

Firstly, it is important to quantify the relationship between food availability and seasonal variation in oceanographic processes at the islands. Once a better understanding of the environment is achieved it will be possible to determine if many of the hypotheses proposed in this thesis are valid or not.

Secondly, studies on the early life-histories of species at the islands are needed to assess the importance of this stage of the life-cycle, in determining the distributional pattern displayed by the STC ichthyofauna.

Thirdly, it is also considered important to quantify density-dependent resources such as space availability on the shelves of the islands. A better knowledge of these resources would enable inter- and intra-specific competitive relations to be better understood.

In conclusion it is hoped that the insights that have been gained through this study will serve to stimulate further research into the fauna and flora of the mid-ocean islands. These isolated localities are often amongst the most pristine ecosystems remaining and an understanding of them will better enable scientists and managers of the environment to cope with the massive environmental problems that are ever increasing. Although evolution does not allow any entity to ever return to its previous state, a knowledge of that previous state is essential in order to come to terms with our changing natural world.

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