

**CONTRIBUTION TOWARDS THE DEVELOPMENT OF A
MANAGEMENT PLAN FOR THE BAITBOAT AND SPORT
FISHERY FOR TUNA IN SOUTH AFRICA**

A thesis submitted in fulfilment of the requirements for the degree of

MASTERS OF SCIENCE

of

RHODES UNIVERSITY

by

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April 2011

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LIST OF ABBREVIATIONS AND ACRONYMS

AIC	Akaike Information Criterion
APCS	Access Point Creel Survey
APE	Age Precision Estimate
BEE	Black Economic Empowerment
BLSMS	Boat Launch Site Monitoring System
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CPUE	Catch-per-unit-effort
CPUE_{pos}	Positive Catch-per-unit-effort
CV	coefficient of variation
DAFF	Department of Agriculture, Forestry and Fisheries
DEAT	Department of Environmental Affairs and Tourism
EEZ	Exclusive Economic Zone
FAO	Food and Agricultural Organization
FL	Fork Length
FTEA	Fresh Tuna Exporters Association
GDP	Gross Domestic Product
GGP	Gross Global Product
GLM	General Linear Model
GPS	Global Positioning System
GRT	Gross Registered Tonnage
HDI	Historically Disadvantaged Individual
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IGFA	International Game Fish Association
IOTC	Indian Ocean Tuna Commission
LCI	Lower Confidence Interval
lnCPUE	Log normally distributed CPUE
LTRH	Long-Term Rights Holder

MCM	Marine and Coastal Management
MLRA	Marine Living Resources Act
MSC	Marine Stewardship Council
MSY	Maximum Sustainable Yield
nm	Nautical mile
NMLS	National Marine Linefish System
NSW	New South Wales
OMP	Operational Management Plan
ORI	Oceanographic Research Institute
PC	Probability of Capture
RFMO	Regional Fisheries Management Organization
SADSAA	South African Deep Sea Angling Association
SARS	South African Revenue Service
SL	Swordfish Longline
SST	Sea Surface Temperature
TAC	Total Allowable Catch
TAE	Total Allowable Effort
TL	Total Length
TL'	Tuna Longline
UCI	Upper Confidence Interval
VBGF	von Bertalanffy Growth Function
WCPO	Western Central Pacific Ocean
WPDSAA	Western Province Deep Sea Angling Association
WWF	World Wildlife Foundation

ACKNOWLEDGEMENTS

First and foremost, I would like to thank the Fresh Tuna Exporters Association for proposing the initial project to me. This has since grown and materialised into gathering information that formed the basis of a managerial framework study on the commercial tuna baitboat and sport fishery in South Africa.

I would like to thank my supervisors, Professor Warwick Sauer and Doctor Olaf Weyl, for their guidance and for helping me to develop a new structural approach to this study. Warwick's personal relationship within the fisheries arena proved to be invaluable as it facilitated data collection. I also thank him for the assistance he gave me during the write-up phase. Olaf's meticulous attention to detail has also proved to be invaluable during the write-up of this thesis.

To my Dad and Mom, who have lived my university career with me, I extend my deepest gratitude for your belief in me and for supporting me through this tidal decade of my life. My ups and downs were carried upon your shoulders; I am truly grateful.

I would like to thank Henning Winker for his expert advice on statistical analysis. Henning, I am most grateful for the hours you spent helping me analyse my data. I also thank Doctor Paul Shaw and Ms Romina Novo-Henriques for their help in analysing *T. albacares* genetic samples. A special thank you is also due to Mr Nick and Mrs Carol De Kock from the FTEA, and to Mr Trevor Hansen (Chairman of Port St Francis Skiboat and Yacht Club) and Mr Bruce Mann (ORI) for all their help. In addition I would also like to thank Mr Craig Smith and Charlene de Silva from the Department of Marine and Coastal Management (MCM) (now the Department of Agriculture, Forestry and Fisheries (DAFF)). I am also grateful to the *Vangie Tunnie*, *Standard Bank Tuna Classic* and the *Port St Francis Tuna and Marlin Challenge* for accommodating me during their annual tuna competitions.

Irene de Moor is thanked for assisting with grammar and language editing of this thesis.

Finally, thanks are due to the FTEA, WWF-SA, and the Claude Leon Foundation for funding this project.

ABSTRACT

Tuna are of significant global economic importance and a prime food source. Increased levels of fishing have resulted in many stocks being under threat and a number of species are considered to be overfished.

The South African tuna industry has had limited management attention from the South African fisheries management agency. A recent development has been an increase in the number of tuna caught by small vessels that target the fresh tuna market in South Africa and overseas. This has highlighted the importance of developing a holistic management plan for the sector and creating an awareness, among vessel owners, of the importance of compliance with initiatives such as the Marine Stewardship Council (MSC).

The South African tuna fishery comprises three sectors: baitboat, sport and longline, all of which are currently in need of acquiring more biological and fisheries data. This project was initiated to collate existing information and to collect additional information where possible. This encompassed a qualitative and quantitative assessment of the size and shape of the tuna fishing industry, which included estimates of total catch, effort, catch-per-unit-of-effort (CPUE) and stock structure (obtained through comparative estimates of age and growth), as well as socio-economic and economic information.

A technique involving an examination of specific vertebrae was used to obtain age-growth information for *T. albacares*. These data were used to estimate von Bertalanffy (VBGF) growth parameters: $F = 2.1$, $k = 0.1$, and $t_0 = -0.1$ year. No significant differences in growth parameters were found in yellowfin tuna (*Thunnus albacares*) from different localities around the South African coast, i.e. from the south eastern Atlantic and the south western Indian Ocean. In addition, growth did not differ between South Africa and other regions (Draganic and Pelzcarski

1984, Fonteneau 1980, Gascuel *et al.* 1992, LeGuen and Sakagawa 1973, Lehodey and Leroy 1999, Lessa and Duarte-Neto 2004, Shuford *et al.* 2007, Stequert *et al.* 1996, Wild 1986, Yang *et al.* 1969).

Further substantiation of the above-mentioned observations was found by recording differences in the sizes of fish caught in the inshore (baitboat and sport fishery vessels) and offshore (large pelagic longline vessels) sectors of South African tuna fisheries. A significant difference between the regions — in terms of the size of fish caught inshore — was noted, with mostly-juvenile fish being caught in KwaZulu-Natal ($5.4 \pm 3.5\text{kg}$), sub-adult fish in the Eastern Cape ($26.2 \pm 13.4\text{kg}$), and adult fish in the Western Cape ($42.3 \pm 14.4\text{kg}$). Since mostly-adult fish were caught offshore by longliners, with no significant differences between regions, it is however possible that adult fish predominantly inhabit the offshore region. Yellowfin tuna caught by the large pelagic longline fishery in the three managerial zones (A, B and C) were predominantly adult fish of similar size, namely Zone A: $38.9 \pm 6.9\text{kg}$; Zone B: $28.7 \pm 4.6\text{kg}$, and Zone C: $36.0 \pm 5.1\text{kg}$.

The recreational ski boat sport fishery has remained stable, in terms of participation, consisting mostly of white middle aged males in the top 25% of household income distribution, having either permanent occupational status or being retired. Fishers within this sector are willing to incur great expense to partake in the fishery and they provide an important economic contribution to coastal towns, particularly in the Eastern Cape. The total catch (of 83t) of yellowfin tuna by the competitive sport fishery within the Western and Eastern Cape regions was considerably lower than that of commercial tuna baitboat catches, which amounted to 186t, and the large pelagic longline sector that caught t in 200 . It is however likely that the competitive sport fishery's total yellowfin tuna catch (of 83t in 2009) of the Eastern and Western Cape competitive sport fishery was considerably less than the total yellowfin tuna catches of the whole South African deep-sea sport fishery.

Longfin tuna are the primary target species of South Africa's baitboat fisheries, comprising an average of 86% of the total catch and generating ZAR49 million in employment income in 2002. South Africa was responsible for 20% of the total longfin tuna annual yield in 2004 in the southern Atlantic Ocean, behind Taiwan with 59%. However, yellowfin tuna only contributes a small percentage towards total catches ($8.4 \pm 8.2\%$ between 1995 and 2009), generating ZAR1.3 million in employment income in 2002. Of the four vessel categories comprising the tuna baitboat fishery, ski boats had the highest yellowfin tuna CPUE in 2009 ($117 \pm 62 \text{ kg.vessel}^{-1}.\text{day}^{-1}$) and the lowest effort. The ski boats sector is the most opportunistic fishery as they are only active when either longfin or yellowfin tuna are in high abundance. At such times catches are guaranteed, so can be expected to offset expenses. In 2009 the CPUE for yellowfin tuna for 15–19m vessels and freezer deckboats was $12 \pm 20 \text{ kg.vessel}^{-1}.\text{day}^{-1}$ and $3 \pm 6 \text{ kg.vessel}^{-1}.\text{day}^{-1}$, respectively. These vessels specifically target longfin tuna when they are in abundance

Since the start of the tuna baitboat fishery in 1995, there has been a substantial increase in the number of new entrants. In 2002 this sector had a fleet size of 82 vessels with a capital value of ZAR163 million and a total employment income of ZAR58 million, employing 2 173 fishers, of which 87% were black African. The commercial tuna baitboat fleet has subsequently grown to 200 vessels and 3600 crew, with 110 active vessels fishing for a combined fleet average of 46 days per year. There are a high number of owner-operated vessels. Since 2007 the fishery's profit to cost ratio has been low due to the low abundance of tuna stocks off the coast of South Africa, which has resulted in poor catch returns, placing economic pressure on the fishery.

The baitboat industry is a low-profit-margin fishery with a total net catch value worth ZAR90 million in 2009 (Feike 2010). The abundance of yellowfin tuna influences profit margins, with very high profits being made when abundance and catches are high.

The large pelagic longline fishery has a total allowable effort of 43 vessels of which only 30 vessels fished during 2009, when a reported 766t of yellowfin tuna were caught, representing a total tonnage far in excess of that obtained by the combined effort of the baitboat and sport fishery. It is, however, assumed that considerable underreporting of catches takes place within this fishery, which means that the estimated total net catch value of ZAR100 million could, in fact, be much higher. Such underreporting of catches is of great concern for this fishery, as is the high bycatch of *Chondrichthians* spp. that significantly outweighs imposed regulatory limits (DEAT 2007).

The present study demonstrates the current lack of comprehensive catch and effort data for the sport, baitboat and longline fisheries as well as the serious limitations and flaws associated with current databases. Results from the present study have drawn attention to a number of high-priority research needs, as outlined below.

(1) A major lack of comprehensive catch and effort data for the sport fishery, which can be rectified by focussing on obtaining more competition data, as well as high-quality catch and effort and socio-economic information, as opposed to relying on information from non-club anglers (Gartside *et al.* 1999, Williams 2003, Cass-Calay 2008). Acquisition of such data is relatively inexpensive: the location of organized clubs and their frequent competition meetings provide widespread coverage along the Southern African coastline. Such data acquisition efforts have the potential to provide reliable information on spatial catch trends.

(2) Validation of vessel catch return data is required for commercial fisheries and on some recent data that has emerged from studies of catch rates and trends for target species, particularly in the longline fishery. In this context it should be noted that the most recent peer-reviewed publications on this exploratory fishery were published more than a decade ago (Kroese 1999,

Penny and Griffiths 1999). Additional studies need to be undertaken and journal articles published on the current stock status of South African catches of yellowfin and bigeye tuna and swordfish.

1. INTRODUCTION – SOUTH AFRICAN TUNA FISHERIES

1.1 General

Tunas are migratory pelagic fish whose habitat ranges are directly related to their physiological tolerances (Block *et al.* 1997, Graham and Dickson 2001, Graham and Dickson 2004). Until the second half of the twentieth century, tuna and tuna-like species were insignificant and discarded as waste (Pauly 1995). This was particularly prevalent in Atlantic Bluefin tuna catches in and around the waters off Denmark (Pauly 1995). At that stage these fish could not even be marketed as pet food, unlike the situation in the 21st century when tuna species are highly valued in the luxury market, particularly as a primary *sashimi* candidate.

The demand for seafood and the ever-expanding global market has encouraged the growth of tuna fisheries worldwide (Pauly *et al.* 2005a). Present-day tuna fleets stretch across all oceans and are highly gear selective, with fishing effort taking place in tropical, sub-tropical and temperate habitats (Figure 1.1) (FAO 2009, ICCAT 2007). Increases in vessel and fleet sizes and technological advances have increased catch rates, resulting in high pressure on fish stocks. Management is largely the responsibility of regional fisheries management organizations (FAO 2007, ICCAT 2007) including the following: the International Commission for the Conservation of Atlantic Tunas (ICCAT) covering the north and south Atlantic; the Inter-American Tropical Tuna Commission (IATTC) covering the eastern Pacific; the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), and the Indian Ocean Tuna Commission (IOTC) (Block and Stevens 2001, ICCAT 2007). These commissions developed from international treaties, the aim being to govern directed fishing effort and to share allowable catch between, and amongst, countries (Block and Stevens 2001, FAO 2007).

In 2005 the global fishery production for tuna and tuna-like species for all commercial catches — including all vessel and gear types — was 6.24 million tonnes, with an estimated value of US\$9 365 million (FAO 2007). Of 23 principal stocks in the four oceans mentioned above (north and south Atlantic, eastern Pacific and Indian) (Table 1.1), five remain moderately exploited, ten are over-exploited or possibly exhausted, and the remaining stocks are diminished or of unknown status (FAO 2007, ICCAT 2007).

Table 1.1 The principal market tunas from the genus *Thunnus*, comprising of seven main targeted commercial species from the total 23 principal stocks (FAO 2007)

Principal Market Tunas	
Common name	Scientific name
Longfin tuna (also called 'Albacore')	<i>Thunnus alalunga</i>
Bigeye tuna	<i>Thunnus obesus</i>
Atlantic bluefin tuna	<i>Thunnus thynnus</i>
Pacific bluefin tuna	<i>Thunnus orientalis</i>
Southern bluefin tuna	<i>Thunnus maccoyii</i>
Yellowfin tuna	<i>Thunnus albacares</i>
Skipjack tuna	<i>Katsuwonus pelamis</i>

Within South Africa the longfin tuna, which is currently well researched, has been shown to be moderately-exploited in the southern Atlantic Ocean and fully-exploited in the Indian Ocean (DEAT 2009b, FAO 2007, Leslie 2001, Leslie *et al.* 2004, Penney *et al.* 1992, Penney *et al.* 1998, Penney and Griffiths 1999, Smith and Glazer 2007). According to ICCAT's latest stock assessment, carried out in 2008 (DEAT 2009b), yellowfin tuna were categorized as under- to optimally exploited in the southern Atlantic Ocean but current catches remain well below the estimated maximum sustainable yield (MSY) and a trend of declining catches has been observed over several years (DEAT 2009b).

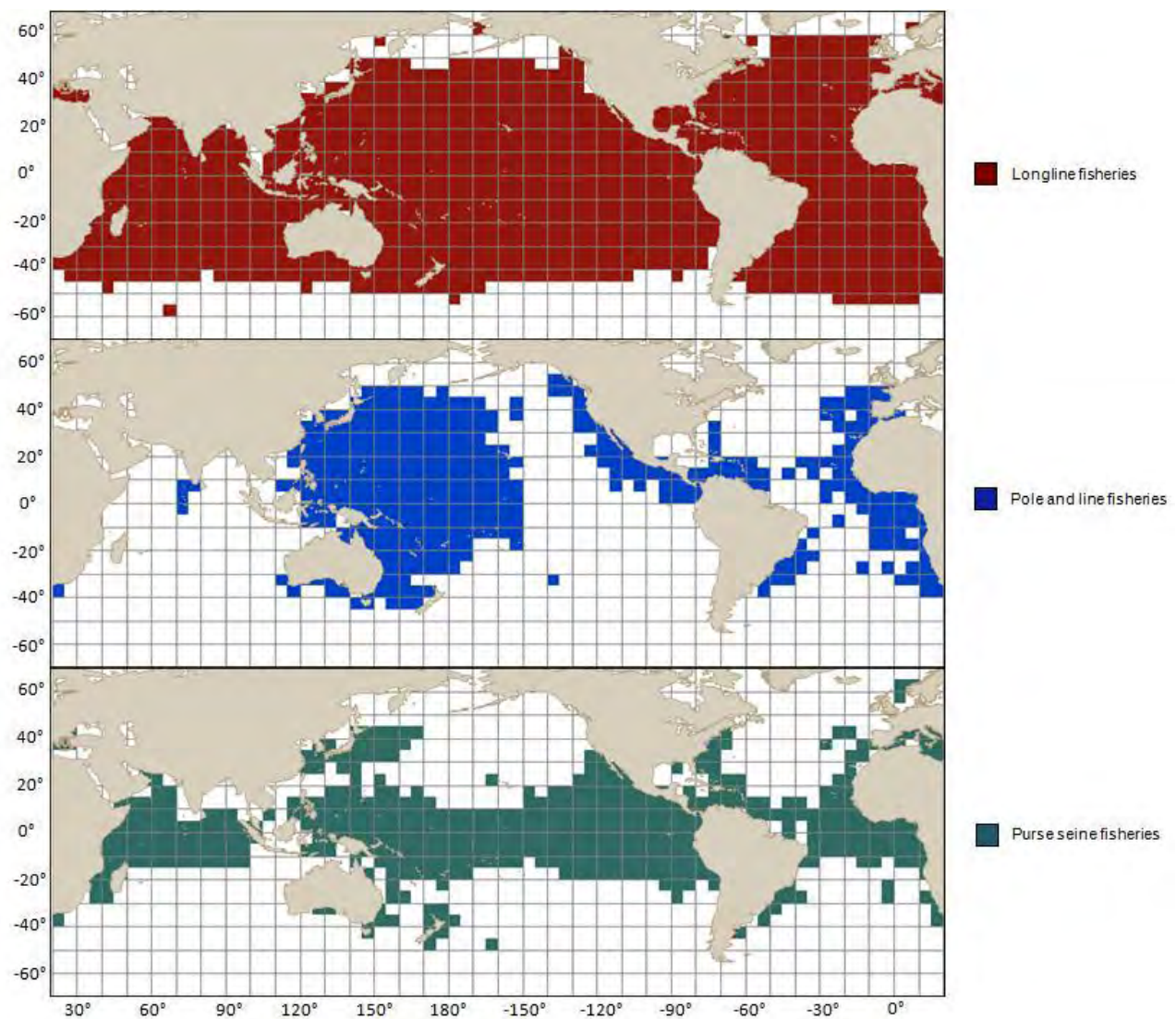


Figure 1.1 Areas of reported global catches of all tunas and billfishes accounted for by gear selectivity for the period 1950–1998 (FAO 2009).

1.2 Tuna biology

1.2.1 *Habitat*

Yellowfin tuna

The distribution ranges of tropical tuna such as yellowfin tuna (*Thunnus albacares*) are generally restricted by temperature. Yellowfin tuna are found in waters above 18° C Sea Surface Temperature (SST), restricting their geographic range to above the thermocline and between the latitudes 35°N in the north east Atlantic to 35°S off Southern Africa (Brill 1994, Block *et al.* 1997, Dagorn *et al.* 2006, Fromentin and Fonteneau 2001, Graham and Dickson 2004, Sauer *et al.* 2003, Schaefer *et al.* 2007).

Longfin tuna

Temperate tunas such as longfin tuna *Thunnus alalunga* inhabit cooler sub-tropical waters, being prominent at higher latitudes and below the thermocline in tropical waters. They are globally distributed, between the latitudes 35°N in the north east Atlantic to 35°S off Southern Africa, with their geographic ranges moderated within a nine degrees Celsius lower bound SST (Brill 1994, Block *et al.* 1997, Dagorn *et al.* 2006, Fromentin and Fonteneau 2001, Graham and Dickson 2004, Sauer *et al.* 2003, Schaefer *et al.* 2007).

Yellowfin and longfin tuna movement off the South African coastline

There is a belief among practitioners in commercial fisheries that longfin tuna within the Benguela region migrate southwards from the fishing grounds of Tripp Seamount, Vema Seamount and South Bank (Figure 1.2), or move northwards from the southern Atlantic along the sub-tropical convergence (Penney *et al.* 1992, Sauer *et al.* 2003). In contrast to longfin tuna movement and location, yellowfin tuna congregate in the warmer waters along the southern Agulhas bank and east coast (Penney *et al.* 1992). It is thought that South Africa's longfin tuna stocks originate from southeast Atlantic stocks, with partial mixing of Indian Ocean stocks (Penney *et al.* 1992) during winter when the Agulhas current does not act as a barrier, preventing migration (Morita 1978), whereas yellowfin tuna are thought to originate from the Indian Ocean and are linked to the movement of the Agulhas current, with significant numbers being caught on the southern Agulhas Bank (Penney *et al.* 1992).

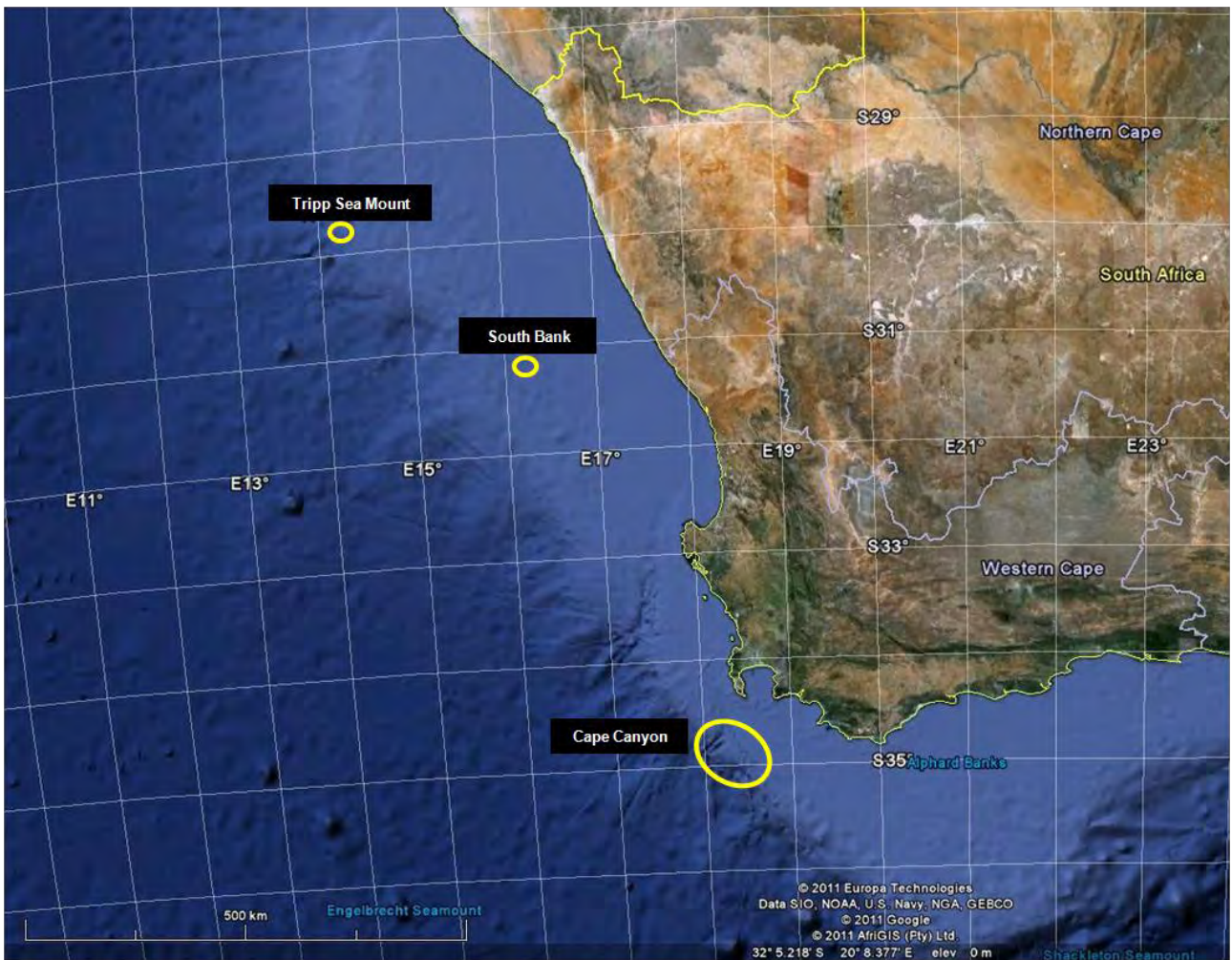


Figure 1.2 The southwest African coast showing the typical fishing areas off Namibia, namely the Tripp Seamount and the South Bank, as well as the Cape Canyon off South Africa (Google Earth Pro 2011).

1.3 The South African tuna fisheries

The history of South African tuna fisheries dates back to the early 1900s with tuna being caught during the summer months in the south Western Cape (De Kock *pers. comm.* 2008: FTEA associate, Penney and Griffiths 1999). Early records (1945) document rock and surf fisherman spinning for small yellowfin tuna (*Thunnus albacares*) off the ledges of Rooikrantz (Cape Point, Western Cape) (Figure 1.3) (De Kock *pers. comm.* 2008: FTEA associate, Talbot and Penrith 1968).



Figure 1.3 The cliffs of Rooikrantz (Cape Point, Western Cape) where early records (1945) document rock and surf anglers spinning for small yellowfin tuna, while fishing from ledges (Google Earth Pro 2011).

Increasing catches of tuna resulted in a growing interest in recreational fishing by the mid 1950s. The sport fishery trolled for southern bluefin tuna, yellowfin tuna and longfin tuna during the summer and autumn months in the near coastal waters off Cape Point and Hout Bay in the Western Cape, with intermittent catches from False Bay (Molteno and Riley 1986, Penney *et al.* 1999, Sauer *et al.* 2003).

Tuna were targeted commercially by Japanese and Taiwanese fishing fleets off South Africa from the 1950s onwards (Kroese 1999). Development of the first South African commercial tuna fishery began between 1960 and 1963, with exploratory research being undertaken for a potential longline fishery off the western and southern Cape between Saldanha Bay and Port Elizabeth (Penney *et al.* 1992). Talbot and Penrith (1968) reported on these surveys, which yielded large catches of temperate tunas (*T. maccoyii* and *T. alalunga*) and tropical tuna (*T. albacares*) between Southern Africa's east coast (Port Elizabeth) and west coast (Lambert's Bay) (Penney and Griffiths 1999).

Commercial interest in tuna remained limited until the sudden appearance of high numbers of yellowfin tuna (*Thunnus albacares*) off Cape Point in 1979 (Penney *et al.* 1992, Penney *et al.* 1998, Shannon 1987, Sauer *et al.* 2003). The high availability of this species raised the interest of the commercial sector (FAO 2009) and an experimental purse-seine fishery was introduced, which proved to be short lived due to the migratory nature of these fish and their unknown life history patterns (Penney *et al.* 1992, Sauer *et al.* 2003). The use of baited poles was also introduced during this period, resulting in record catches (ICCAT 1990). A few of the larger vessels undertook exploratory fishing for longfin tuna, northwest of Cape Town, and were rewarded with catches that increased annually and, from 1980 onwards, saw the establishment of a lucrative fishery (Penney *et al.* 1992). By 1985 monthly catch–effort logbooks were mandatory for the line fishery and tuna fleet (Penney *et al.* 1992). Tuna-specific logbooks were created in 1987, to replace commonly-used multispecies logbooks and to police the reporting of catches. Purchase returns from tuna dealers were used to validate tuna logbook catch records. A substantial amount of under-reporting of catches was documented but this was subsequently corrected by means of allowing submittal of late catch returns (Penney *et al.* 1992). By 2009 information from both SARS and the logbooks was being used to represent average catch and the logbooks are currently being revised to show individual per-species columns, replacing the previously-used multispecies column. To date, 191 applicants have been allocated long term tuna baitboat rights with the tuna baitboat fishery currently having a fleet size of over 200 vessels and some 3600 crew (DEAT 2006).

South African interest in longlining for tuna began in 1980, largely due to developments in the demersal longline fishery. As the hake fishery became better managed and more controlled, permits became mandatory. Permit applications escalated, supposedly towards tuna catches, but these were actually driven by the expanding demersal fishery for hake (Penney *et al.* 1992, Sauer *et al.* 2003). South Africa also entered bilateral agreements with both Japan and Taiwan in 1980, to control fishing within South Africa's exclusive economic zone (EEZ) (Penney *et al.* 1992, Sauer *et al.*

2003). After 1994 increased access to international markets encouraged tuna longline fisheries in South Africa for yellowfin and big-eye tuna (Molteno and Riley 1986, Penney and Griffiths 1999) and 30 new longline rights were made available to South African vessels (Penney and Griffiths 1999, Sauer *et al.* 2003). By 2010, a total of 17 swordfish and 26 tuna long-term rights had been allocated to longline vessels (Feike 2010).

Management

Being the prime target species and accounting for the majority of directed effort, longfin tuna constituted over 80% of South Africa's total annual tuna catch and was considered to be past the replacement yield level (Penney *et al.* 1992, Penney *et al.* 1998). It is estimated that, since the start of the fishery, biomass has been reduced to 20% of the pre-exploitation level (Penney *et al.* 1992, Penney *et al.* 1998). Due to reductions in biomass, the ICCAT issued a TAC upper limit of 22 000 tonnes in 1996 on all catches of longfin tuna fished in Atlantic waters below the 5° N latitude. This came into force in 1998 (Penney *et al.* 1992).

The tuna fishery in South Africa was initially confined to rod-and-reel fishing, from the cliffs at Rooikrantz, together with a limited level of small scale commercial line fishery. The scale of the sport fishery then developed further when 'sport fishers' began to fish from boats offshore using sophisticated/specialized gear (reels with higher gear ratios), until a stage was reached when their vessels and gear were similar to those used in the commercial line fishery. This resulted in a significant increase in fishing effort, particularly in terms of accessibility, since the sport fishers were no longer confined to limited land-based sites. Their vessels could now be launched away from harbours into once un-fished waters (Molteno and Riley 1986, Penney *et al.* 1999, Pulfrich and Griffiths 1988, Sauer *et al.* 1997, Sauer *et al.* 2003).

The South African Deep Sea Angling Association (SADSAA) was created in 1988 and is now affiliated to the International Game Fish Association (IGFA), an international organization created to endorse moral and sporting fishing practices, standardize regulations for application of world game fish records, and provide baseline information for angling guidelines to be used in angling tournaments and any other group activities (IGFA 2010). SADSAA is responsible for the organization of all national sport fish angling competitions held within set venues in South Africa. A total of 15 provincial associations are registered with SADSAA, including Western Province, Zululand (northern Natal) and inland to the province of Limpopo.

The sport fishery has grown substantially, from having comprised more than 200 tuna-going vessels since 1995, to being in excess of 31 800 anglers and an estimated 8 000 vessels by 2008 (Leibold and van Zyl 2008). Such growth can be attributed to the increased marketing of yellowfin tuna since the start of the commercial boom in 1996, and to angler prestige associated with catching such large and powerful pelagic fish.

Historically (up to 1990) South African tuna fleets have exported frozen catches to overseas canneries (De Kock *pers comm.* 2008: FTEA associate). The shipment of low priced frozen catches came as a result of vessels lacking the facilities to preserve catches at sea. Longfin tuna was shipped to the white meat market of the United States of America, whilst yellowfin tuna and small quantities of big-eye tuna were shipped to European and Asian canneries (De Kock *pers comm.* 2008: FTEA associate, Molteno and Riley 1986). An experimental longline swordfish fishery was established within South Africa during the mid 1990s. The onset of fresh swordfish exports to overseas markets provided a stimulus for similar exports of fresh tuna at that time (De Kock *pers comm.* 2008: FTEA associate, Kroese 1999). Tuna baitboat vessels were subsequently modified for the adoption of catching and preservation methods, in order to increase market price by exporting high quality tuna to the fresh fish markets of the USA and Spain. From mid 2006, the export of fresh longfin tuna has

been in demand, diverting fishing methods away from those used for the canneries. This has also led to the further development of fresh tuna preservation methods (De Kock *pers comm.* 2008: FTEA associate).

The tuna industry is one of the few fishery sectors in South Africa that is still in a development phase. The baitboat component has changed from landing fish of fairly poor quality to one which is able to compete internationally in the lucrative demand for a sashimi quality. This fits with government objectives to develop the small to medium commercial sector. The recent development of this sector requires a sound management strategy to promote the sustainability of its activities, in a situation where the participants are able to work closely with the Department of Marine and Coastal Management. There is little knowledge of the baitboat and recreational components of the fishery, which contribute substantially to the total catch, with a portion of the recreationally-landed catch being sold.

Since tuna migrate over long distances, knowledge of the South African component is crucial in terms of obtaining quotas and ensuring the sustainability and resilience of off-shore tuna stocks. The input of such information into discussions with international working groups such as ICCAT is extremely important, from both management and conservation/scientific perspectives. A sound scientific management approach is also required to acquire Marine Stewardship Council affiliation.

1.4 Thesis outline

This research was aimed at understanding the contribution to the total catch of tuna by the recreational sectors from the Western and Eastern Cape to commercial fisheries in South Africa. The study encompasses large commercial pelagic longline, baitboat, and line-fish sectors in South Africa and provides insights into the movement and stock structure of *Thunnus albacares*. Biological, socio-economic and fisheries information collected from both tuna baitboat and Western

and Eastern Cape recreational analyses will contribute towards the development of a management plan for the fishery and towards South Africa's contribution at the International Convention for the Conservation of Atlantic Tunas (ICCAT) and the Indian Ocean Tuna Convention (IOTC).

Information on both the tuna fishery and tuna stocks in South Africa is limited, with exception to that of longfin tuna which is currently well researched. The Department of Marine and Coastal Management (MCM) (now the Department of Agriculture, Forestry and Fisheries (DAFF)) has requested assistance in the collection of baseline information and in the development of an Operational Management Plan for the tuna fishery. To this end, baseline information on the biology of the species, total catch, CPUE, and economic and socio-economic structures of the different sectors is required, together with information on population structure. It is thought that the yellowfin tuna stocks off the Eastern Cape are separate from the larger Western Cape yellowfin stocks. This needs to be established by analyzing the life history of this species as well as its migratory patterns, age-growth relationships and genetic makeup. This information will satisfy the minimum requirements for a fishery management plan.

The framework for a standard fishery management plan requires the following information: a description of the resource (tuna), set goals, specific management objectives, a description of the proposed fishery (baitboat and sport fishery), a management strategy with set measures and alternatives, key performance indicators against which the fishery should be measured, and a sound administration process encompassing strict monitoring and compliance measures (Oosthuizen 2003). To obtain important data and identify significant information gaps, attention must be focussed on the following types of information: the biology of the species, socio-economic aspects for the fisheries concerned (baitboat and sport fisheries) and current management objectives (Oosthuizen 2003). Initially a desktop study will be conducted, accumulating information on the biology of the species (i.e. yellowfin tuna), existing fisheries (large pelagic longline, line fish

commercial, baitboat and sport fishery sectors) together with management approaches currently adopted for existing South African tuna fisheries and tuna fisheries worldwide. This information will include input controls (size limits and effort regulation), output controls (total allowable effort), fishery description (small, medium, large), fishing techniques (vessel and gear type, gear selectivity and catch rates) and management measures adopted (Caddy 1989, Gillespie *et al.* 1998, Halmarick 1999, Perry *et al.* 1999). Obtaining this information will highlight significant information gaps, from which fishery-independent information will be collected.

1.4.1 Thesis Objectives

The overall objective of this research is to contribute to the development of a management plan for the geographic areas of the South Eastern Atlantic and Western Indian Oceans with emphasis on the Western Cape and Eastern Cape tuna recreational sector and the commercial baitboat sector of South Africa by investigating the following aspects.

1. Providing a qualitative and quantitative assessment of the size and shape of the tuna fishing industry; including total catch, effort, CPUE and acquiring relevant socio-economic and economic information.
2. Investigating stock structure of *Thunnus albacares* through comparative estimates of age-growth analysis.

1.4.2 Key Questions

The overall objectives will be met by answering certain key questions as outlined below.

Fishery Information

- What is the directed effort and species composition of the total fish landings in each sector?
- What are the total catch, effort, and CPUE in each sector?

- What is the size selectivity between inshore and offshore sectors?

Socio-economic information

- What is the profitability/economics for the baitboat and sport fishery sectors?
- What is the average expenditure per kilogram of yellowfin tuna in the baitboat and sport fishery sectors per region?
- What are the social demographics for the baitboat and sport fishery sectors?

Biological Information

- Does the age-growth structure of *T. albacares* differ between Atlantic and Indian Ocean stocks?

To achieve the above-mentioned aims, the study was divided into seven chapters. After the introductory chapter (Chapter 1), Chapter two describes the study area and the general methods used. Chapter three addresses the age-growth characteristics of *T. albacares* stocks in the Western and Eastern Cape and KwaZulu-Natal. Chapters four and five discuss the size and shape of the Western and Eastern Cape recreational tuna fisheries and the commercial baitboat industry, including total catch, effort, CPUE, and socio-economic and economic information. Chapter six discusses the size and shape — including total catch, effort, and CPUE — of the South African commercial large pelagic longline fishery. Chapter seven discusses South Africa's yellowfin tuna resource and resource users, suggesting management initiatives and future research priorities. Details of questionnaires used throughout the study are provided in the Appendix.

2. STUDY AREA AND SECTOR DESCRIPTIONS

2.1 Study area

Sampling was undertaken along the entire Southern African coastline with varying intensity in different areas. Data obtained from tuna angling competitions, as well as recreational and commercial catch and effort data, were collected and categorized on the basis of three management areas as set out in the Traditional Line Fishery regulations (Figure 2.1). The three zones are as follows:

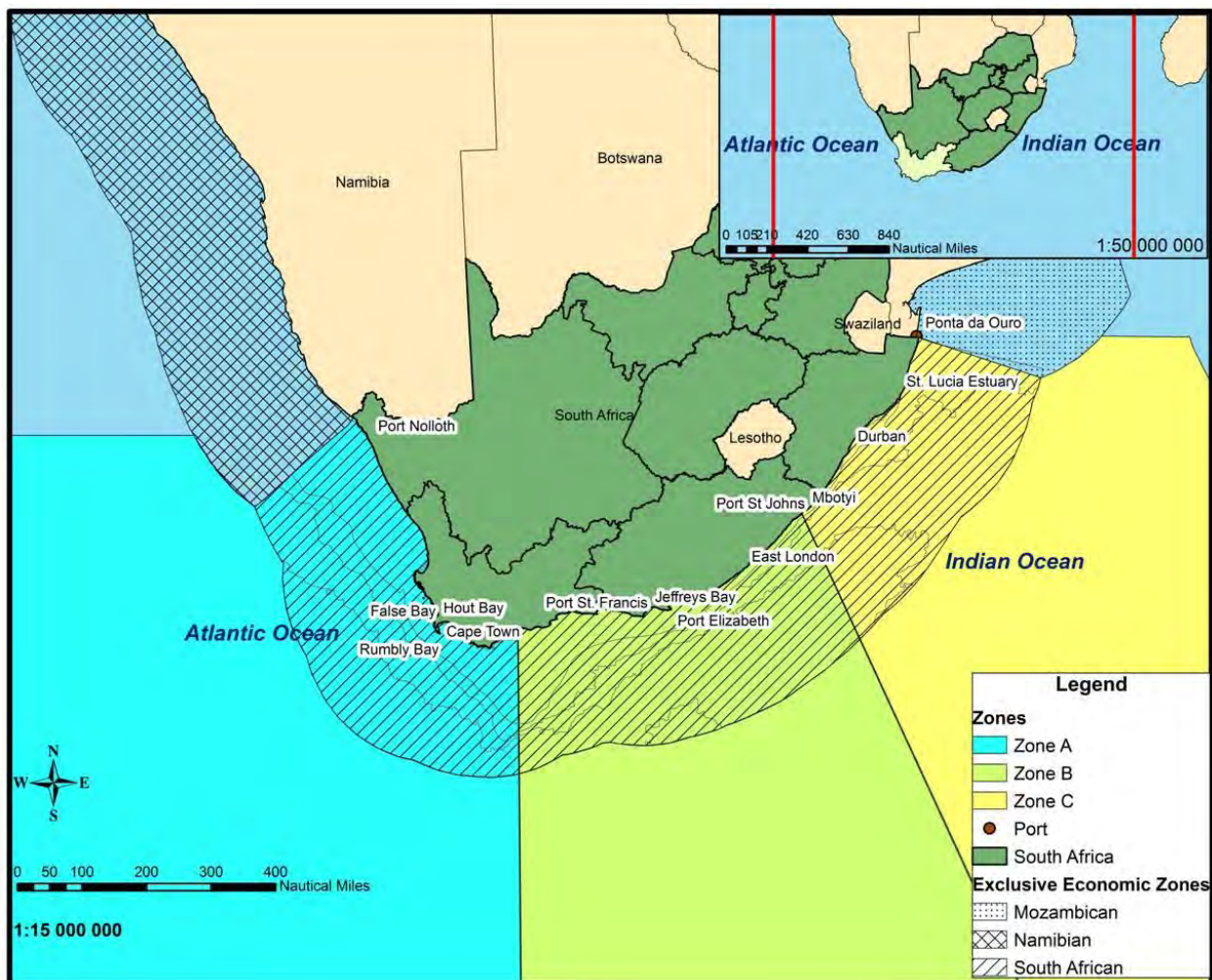


Figure 2.1 The three fishery management zones (A, B and C) based on commercial traditional line fishery regulations.

- Zone A: Port Nolloth to Cape Infanta. The area, which includes the international border, seaward at the Orange River, Namibia, and west of an imaginary line running due south (180° True) from the lighthouse at Cape Infanta (DEAT 2008).

- Zone B: Cape Infanta to Port St Johns: the area within the imaginary line running due south (180° True) from the lighthouse at Cape Infanta and an imaginary line running (128° True) from the northern headland of the Mbotyi River (DEAT 2008).
- Zone C: Port St Johns to KwaZulu-Natal: the area within the imaginary line running (128° True) from the southern headland of the Sikombe River to the international border, seaward at Ponta da Ouro, Mozambique excluding the St Lucia and Maputaland Marine Protected Area (DEAT 2008).

2.2 Sector descriptions

The competitive sport fishery

Angling competitions are generally held over five 'competing days' where each competing day is recorded as a single day event. The competitions are between crews, of four to ten fishers sharing a ski boat that ranges between 6 and 14 m in length. Competitions are species-directed, targeting tunas and bill fishes. Anglers generally troll artificial lures approximately 50 metres from the stern of the boat, at distances of up to 55 nautical miles (nm) offshore, while attempting to entice these species to feed, using up to six rod-and-reel outfits at once. All catches are weighed at the gantry at the end of each competing day.

The Western and Eastern Cape sport fisheries fish in waters up to 55nm offshore, making use of ski boats that vary between 6.4 and 13.6 metres and are either single-hulled or have catamaran-type hulls (Plates 2.1a and 2.1b).



Plate 2.1a A typical catamaran-type hull ski boat powered by two large outboard engines (Photograph from www.africanangler.com).



Plate 2.1b A typical sport fisher (Photograph from www.africanangler.com).

The ski boats are either powered by two outboard motors or by inboard motors, the power of each motor normally being between 60 and 250hp. Each carries a crew of less than ten. The Western

Cape fishery operates from five main harbours and slipways: Cape Town, Hout Bay, Gordons Bay, Simons Town and Rumbly Bay, in the area bounded by 34°–35° S, 18°–19° E (Figure 2.1). The Eastern Cape fishery predominantly operates from the Port Elizabeth harbour and Port St Francis in the area around 35° S, 25° E (Figure 2.1) (Penney *et al.* 1992, Sauer *et al.* 2003). KwaZulu-Natal (KZN) has numerous launch sites along its entire coastline, with traditional "north coast" (a local term signifying the KZN coastal area north of Durban) launch sites at Sodwana Bay, Cape Vidal, St Lucia, Mapelene and Richards Bay harbour. Durban harbour remains the most popular launch site amongst deep sea vessels as well as Shelley Beach on KwaZulu-Natal's "South Coast" (local term signifying the KZN coastal area south of Durban) (Penney *et al.* 1999).

The tuna baitboat fishery

The vessels used in the tuna baitboat fishery are either 8.5m ski boats powered by two large outboard engines with an average crew size of six (Plate 2.2a), or 13.6m deckboats powered by a single inboard engine with an average crew size of ten (Plate 2.2b). The ski boats make a single trip per day whilst the deckboats stay out at sea for three to five days at a time. The South African tuna baitboat fishery operates at average distances of 55nm offshore within the Agulhas bank, with the majority of vessel effort being directed from the Western Cape. The tuna baitboat fishery primarily targets *T. alalunga* (>80% of catch composition), whereas the more marketable *T. albacares* is targeted when available. The tuna baitboat fishery is an active gear surface fishery targeting tuna, primarily using pole and rod-reel methods.



Plate 2.2a A typical tuna baitboat ski boat powered by two large outboard engines (Photograph by Cameron-Dow 2009)



Plate 2.2b A typical tuna baitboat deckboat (Photograph by Piennaar 2009)

Description of the tuna and swordfish longline fisheries

The South African tuna and swordfish longline fisheries operate offshore along the Agulhas bank. The tuna longline fishery primarily targets *T. albacares* within Zone B, whereas the swordfish longline fishery directs most of its effort in Zone C and Zone A. The main feature that distinguishes the swordfish vessels from the tuna longline vessels is the amount of gear deployed, with the former

having ≤ 100 baited hooks rigged per line, whereas tuna longline vessels have more than 1500 hooks per line.

2.3 Age and Growth

In an assessment of accuracy and precision relating to the use of various 'hardparts' (i.e. 'hard organs') for age estimates, Filmalter *et al.* (2009) found that vertebrae were the most suitable hardpart for ageing of *T. albacares*. Vertebrae were therefore collected from Western Cape tuna baitboat commercial fishing vessels during 2007–2009, from sport fishery vessels at fixed competitions held within the Eastern and Western Cape regions during 2008–2009, and from KwaZulu-Natal (Durban) by observers conducting surveys for the Observer Linefish Program during 2009 (Figure 2.1).

The anterior surface of the 36th vertebra was used for measurement and interpretation, following the method of Berry *et al.* (1977) for bluefin tuna *Thunnus thynnus* and that of Filmalter *et al.* (2009). These processing methods were adapted for age estimates of *T. albacares* caught aboard baitboats. The fish tails were sawn off at a point anterior to the caudal peduncle. This vertebra is readily identifiable by the characteristic acute posterior reduction of the lateral transverse process (Berry *et al.* 1977). Growth increments were counted on the anterior cone of whole vertebrae without magnification, using a Fiberoptic–Heim LQ 1600 light source, to further enhance opaque and translucent growth bands.

2.4 Catch and Effort Data

2.4.1 South African sport fishery

Selection of data used

A total of 2 495 records for the Western Cape competitive sport fishery, including zero catches, were obtained from Western Province Deep Sea Angling Associations (WPDSAA) offshore league results between October 2004 and May 2009. A total of 2 964 catch and effort records were obtained from the organisers of the three main Eastern Cape sport fishery competitions between April 2006 and July 2008, namely the Jeffreys Bay *Vangie Tunnie*, Port Elizabeth's *Standard Bank Tuna Classic* and the Port St Francis *Tuna and Marlin Challenge*. A total of 1 551 positive KwaZulu-Natal sport fishery catch and effort records were obtained from unpublished ski boat inspection records and Boat Launch Site Monitoring System records from the Oceanographic Research Institute between January 2004 and December 2009.

2.4.2 South African tuna baitboat fishery

Selection of data

The data was sourced from the National Marine Linefish System (NMLS) database from DEAT, sub-section MCM for the period 1995-2009. These data were comprised of 57 812 days fished, where each individual record reflects the total weight (kilograms) for a single species caught per day. Data for zones B and C were excluded from analysis due to data deficiency. The information provided for each vessel (recorded as daily information) recorded in the NMLS database includes pseudo vessel identification codes, year, month, catch day, locality code, offshore distance (nautical miles), individual species caught per set, and catch expressed as kilograms per species.

Data limitations associated with this fishery

Because this fishery is highly selective, targeting either longfin or yellowfin tuna only, the vessels either have very high catches or many zero catches due to high or “patchy” abundance of target species.

2.4.3 South African tuna and swordfish longline fisheries

Selection of data used

The data used was sourced from the Observer database from DEAT, sub-section MCM for the period 2002-2009. All records before 2002 were rejected and excluded from the study, either because logbooks had previously only recorded combined tuna catches, with no species differentiation, or because catch records were missing. The recorded data comprised 46 438 longline sets, where each individual record reflects a single species caught per day. The information provided for each line shot (recorded as daily information in the Observer database) included pseudo vessel identification codes, set start dates, year, month, positional locality start co-ordinates for each set shot, number of hooks per set, individual species caught per set, and catch expressed as number per species.

Data limitations associated with these fisheries

Observers had only 20% coverage of the domestic swordfish fleet and 100% coverage of the tuna longline fleet. Catches still needed to be verified against vessel logbook recordings because vessel selection was based upon voluntary co-operation of vessel owners (since the observer programme was not mandatory). Unfortunately, observer catch and effort data were recorded in numbers only and not by weight; the total catch thus had to be estimated by multiplying CPUE (expressed as number of fish) by the mean weight (kg) for each species caught. In addition, the obtained Observer catch and effort data set had pseudo vessel identification numbers and the total numbers of hooks

per set were not consistent for the same vessel throughout the database, differing by up to 2000 hooks at a time. This made the differentiation between tuna and swordfish vessels impossible; therefore in both vessel groups the catch and effort data sets were pooled. Unfortunately, poor coverage of active vessels has resulted in few data.

2.4.4 CPUE standardisation procedure

The main limitation of the data (for all fisheries covered in this study) was a high ratio of zero-recorded catches. This required the use of an assessment method that could account for zero catch data with skewed effects (Figure 2.2A). This was achieved by using the hurdle model formulated around delta-X distribution (Fletcher *et al.* 2005, Maunder and Punt 2004, Pereira *et al.* 2008, Punt *et al.* 2000, Stefánsson 1996). Delta represents non-zero probability captures, whereas X represents the distribution of these non-zero captures. Firstly, the probability of a non-zero catch was modelled, normally assuming a binomial error distribution, after which only positive catch data were analysed, using a second-model, log-normal distribution (Stefánsson 1996).

The application of this method was applied to offshore league data and results are summarized in Figure 2.2. Note that non-zero CPUE observations ($CPUE_{pos}$) were log-normally distributed (Figure 2.2B) with the expected CPUE being calculated by scaling $CPUE_{pos}$ in terms of the probability (PC) of a vessel in the sample having caught a yellowfin tuna (or other species) (Figure 2.2C).

Exclusion of commercial line fishery

South Africa's traditional commercial line fishery was excluded from this study because it was found that their contribution of tuna — particularly longfin and yellowfin tuna — in proportion to their overall catch composition was minimal (with longfin tuna in catches from the Western Cape representing <0.5% of the catch).

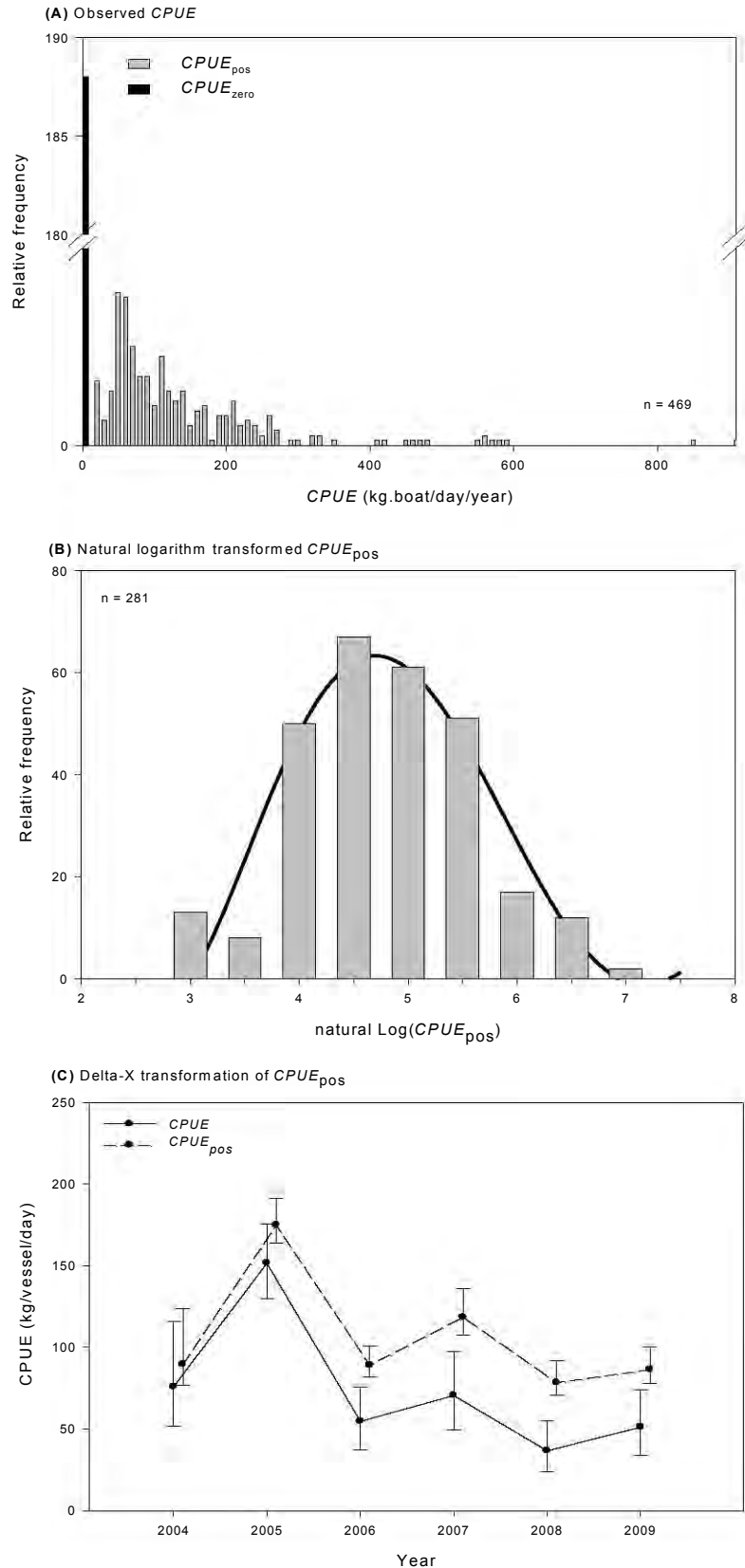


Figure 2.2 Frequency distribution of CPUE (A), log-normal distribution of CPUE_{pos} (CPUE excluding catches) (B) and CPUE scaling (C) for sportfishery yellowfin tuna catches in Western Cape Offshore League competitions between 2004 and 2009. Error bars denote 95% confidence intervals (adapted from Ellender *et al.* 2010).

The hurdle model

(1) A binomial data set for each sector was created, indicating whether *T. albacares* was present or absent in catches (1 or 0). Probability of capture (PC) could then be deduced.

(2) A data set of the log-transformed CPUE (lnCPUE (kg)) for *T. albacares* catches across all five sectors was created and a log-transformed CPUE (lnCPUE (N)) was created for those data sets that contained numbers (N) of *T. albacares* caught.

The effects of year and month per sector within region on the PC was analysed by applying GLMs. In order to acquire best fit parameters between subsets, Akaike Information Criterion (AIC) was used (Akaike 1973), in the following form:

$$AIC = -2 \ln[L(\theta|y)] + 2p \quad \text{(Equation 2.1)}$$

Where p denotes the number of free parameters and $L(\theta|y)$ denotes the likelihood of model parameters provided by the data y (Johnson and Omland 2004). The model building function was used to establish best-described variables for variation in PC.

Binomial data sets were modelled against explanatory variables, applying logit link functionality due to their binomial distribution (McCullagh and Nelder 1995), in the form:

$$f(p) = \ln\left(\frac{p}{1-p}\right) \quad \text{(Equation 2.2)}$$

Where p denotes the underlying continuous probability of the binary dependent variable, 1 to 0.

Binomial data was modelled using logistic regression.

To model annual and monthly interactions within region per fishery sector, the following approach as adopted from Fletcher *et al.* 2005, Maunder and Punt 2004, Pereira *et al.* 2008, Punt *et al.* 2000 and Stefánsson 1996, using GLMs, was undertaken:

$$\ln\left(\frac{p(PC)}{1-p(PC)}\right) = \beta_0 + \beta_1(\text{ear}) + \beta_2(\text{month}) \quad (\text{Equation 2.3})$$

Normality of non-zero, log-transformed catch data was tested using Quantile–Quantile Plots (Statistica 9.0): the normally distributed data sets were tested for annual and monthly interactions within region per fishery sector using a Kruskal-Wallis by ranks test. Statistical analyses were conducted using STATISTICA 9.0, StatSoft®. The observed CPUE for yearly and monthly sampling periods y,m ($\ln\text{CPUE}_{\text{pos},y,m}$) were then calculated for all fishery sectors (adapted from Maunder and Punt 2004), as illustrated in Equation 2.4:

$$\overline{\text{CPUE}_{\text{POS},y,m}} = \exp\left(\ln(\text{CPUE}_{\text{pos},y,m}) + \frac{\sigma^2}{2}\right) \quad (\text{Equation 2.4})$$

The expected CPUE was then calculated where annual and monthly log-transformed $\text{CPUE}_{\text{pos},\text{kg},N}$ was calculated across the probability of capture (PC). CPUE for yearly and monthly sampling periods y,m , $\text{CPUE}_{y,m}$ was expressed in the form of a delta-lognormal model (adapted from Maunder and Punt 2004):

$$\overline{\text{CPUE}_{y,m}} = PC_{y,m} \cdot \exp\left(\ln(\text{CPUE}_{\text{pos},y,m}) + \frac{\sigma^2}{2}\right) \quad (\text{Equation 2.5})$$

where $PC_{y,m}$ = probability of capture in yearly and monthly sampling periods, $\ln\text{CPUE}_{\text{pos},y,m}$ = log-transformed observations during periods y,m and σ^2 = variance of $\ln\text{CPUE}_{\text{pos},y,m}$.

Confidence intervals

Standard error and lower and upper 95% confidence estimates for annual and monthly log-transformed $\text{CPUE}_{\text{kg},N}$ data were calculated using STATISTICA 9.0, StatSoft®. In analysing the observed and expected CPUE, no confidence estimates were calculated within the delta-X model.

For this purpose, the methodology in calculating associated confidence estimates for observed and expected CPUE was adopted from Limpet *et al.* (2001) (Equations 2.6 – 2.9) in the form:

$$\exp(\ln(\text{CPUE}_{y,m})) \quad (\text{Equation 2.6})$$

$$\text{Stderr} \exp(\ln(\text{CPUE}_{\text{stderr}, y,m})) \quad (\text{Equation 2.7})$$

Where μ is μ and Stderr is the standard error of the log-transformed $\text{CPUE}_{\text{kg}, N}$.

Associated lower (LCI) and upper (UCI) 95% confidence estimates for annual and monthly log-transformed $\text{CPUE}_{\text{kg}, N}$ was then calculated using the Equations 2.8 and 2.9:

$$\text{CI} (\mu - 1.96 \text{Stderr}, \mu + 1.96 \text{Stderr}) \quad (\text{Equation 2.8})$$

$$\text{UCI} (\mu - 1.96 \text{Stderr}, \mu + 1.96 \text{Stderr}) \quad (\text{Equation 2.9})$$

Where: N = total number of active vessels during periods y,m

2.5 Access Point Creel Survey

A 12 month Access Point Creel Survey (APCS) was conducted for Gordons Bay, Kalk Bay, Simons Town, Rumbly Bay and Hout Bay harbours within the Western Cape from October 2007 through to October 2008 (Figure 2.2). Survey schedules were randomized using the bus-route method (Robson and Jones 1989) whereby catches were monitored on three randomly selected week days and both weekend days. On every sampling day, catches from as many vessels as possible were sampled. On every sampling day an access point creel survey (see Appendix 9.2 for questionnaire) was performed by the surveyor at a randomly selected harbour for a period of 12 hours, or until light failed, or when no more vessels were scheduled to have radioed into port control.

Yellowtail, dorado, yellowfin tuna longfin tuna and other tuna were measured by fork length (FL). Sub-samples were measured if vessels had large catch numbers. The total numbers of specimens

were recorded down to species level and fish weights were assigned using Type 1 linear regression for length-weight relationships, calculated using specific length-weight equations (van der Elst and Adkins 1991, Torres‘ 1991).

To determine vessel effort and type of fishing activity per harbour, counts of vessels were made during each access point survey and the type of activity, type of vessel, and vessel ID were recorded so as to prevent repetitive counts.

Tuna competitions at specific locations within the Western and Eastern Cape (Figures 2.3 and 2.4) were sampled using creel surveys and skipper directed surveys (for questionnaires see Appendices). Data included total number of specimens, total weight for each fish species caught, crew demographics (# of fishers per vessel/race/age), attitude towards management, socio-economic aspects (occupation/operating costs of vessel), and annual species-directed effort. Since the study was based within the Western Cape, regional constraints required that tuna competitions held within the Eastern Cape during the sampling years 2007–2009 were sampled irrespective of whether they overlapped with Western Cape APCS sampling.

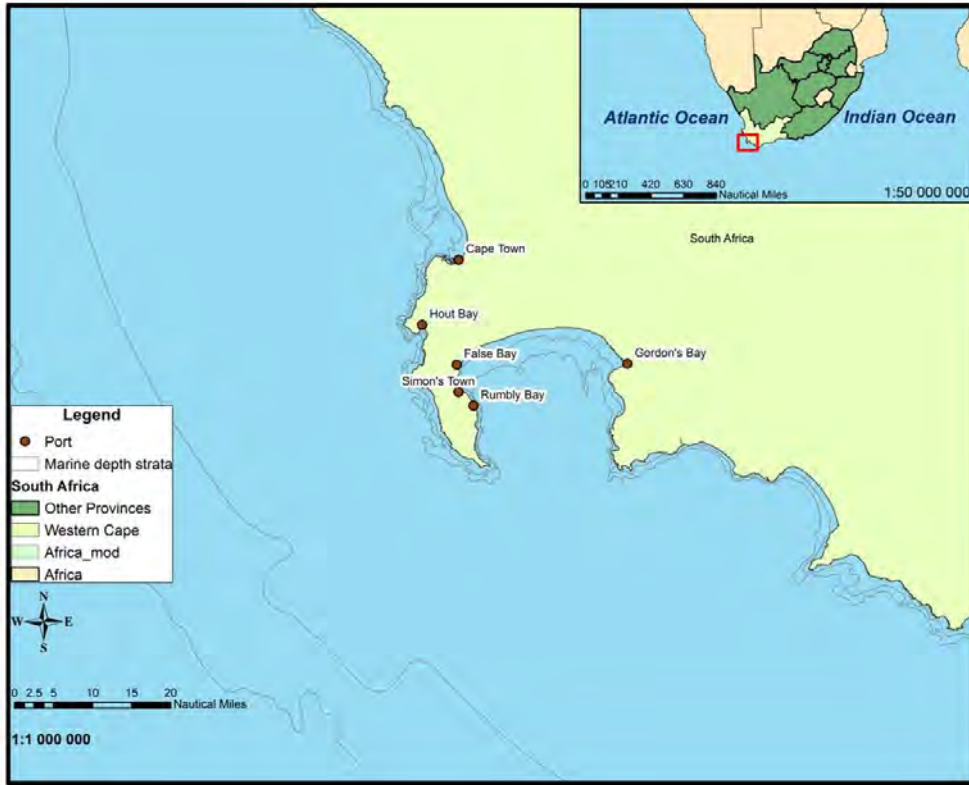


Figure 2.3. The five main harbours and slipways accessed by Western Cape deep sea sport fishery vessels.



Figure 2.4. The three main harbours and slipways and competition venues accessed by Eastern Cape deep sea sport fishery vessels.

2.6 Questionnaire surveys

2.6.1 Questionnaire - informal interviews during Access Point Creel Survey

A questionnaire was administered during Access Point Creel Surveys (APCS) to determine crew demographics, attitude towards management, and socio-economic aspects. These were also administered to vessel skippers after the APCS had been completed. As many skippers as possible were interviewed on any sampling day. Crew demographics included the number of fishers per vessel, as well as the race, gender and age category (<20, 20-40, >40 years) of each fisher. Socio-economic information included the skippers' occupation and residential details, the operating expenses of the vessel, and the capital expenditure associated with owning a vessel.

2.6.2 Questionnaire – informal interview of Fresh Tuna Exporters Association tuna baitboat members

Detailed questionnaires obtained from Sauer *et. al.* (2003) were reworked and directed at LTRH members of the tuna baitboat fishery from the *Fresh Tuna Exporters Association* (for questionnaire see Appendix 9.3). Recorded data included vessel information (specific information), vessel operating (running) costs, ownership of vessel/ rights holder, ownership rights, vessel value, trip information, product distribution, and crew demographics (# of fishers per vessel/ race/ gender/ age/ designation). The targeted species and its percentage of the total catch composition, as well as bycatch species and its/their percentage of the total bycatch were also recorded.

Economic data

Economic data were obtained from questionnaire surveys. All operating costs and capital expenditure were calculated as a daily cost. Operating costs were defined as the running expenses incurred by the vessel per day, while the capital expenditure and date of purchase for fixed assets

was unknown; these were calculated in accordance to the type of fixed asset. Depreciation rates (according to insurance policies) and other information regarding tuna sport and commercial tuna baitboat fisheries fixed assets were obtained from Mr Paul Sherman (active tuna sport fisher and owner of tuna vessel) and Mr Steven Cameron-Dow (active tuna baitboat LTRH and owner of two deckboats). Vessels were insured at current replacement value and maintained at that rate. Motor vehicles were insured at current market value and depreciated at a rate of 0.92 per year until five years, after which they were written off as replaceable. Fishing tackle, which included rods-and-reels and hooks, were insured under an *all risks* policy scheme for up to ZAR 20 000. Trailers were deemed not to depreciate and maintained their resale value. Fixed asset replacement values and associated running expenses for both the sport and tuna baitboat fisheries were expressed as means, with accompanying minimum and maximum values.

3. AGE AND GROWTH OF *THUNNUS ALBACARES*

3.1 Introduction

In the past stock assessments of tuna, particularly of yellowfin tuna (*Thunnus albacares*), have been based on the analyses of standardized longline catch-per-unit-effort (CPUE) data (Hampton *et al.* 1999). As technological advancements improve catch rates, management regimes for tuna fisheries have to be reassessed. More sophisticated assessments have to be made that incorporate, and account for, biological traits that characterize the dynamics of the species (Schnute and Richards 1998), ultimately seeking a more ecologically-based approach.

South Africa's commercial and recreational sectors, fishing from both the Atlantic and Indian oceans, target and harvest yellowfin tuna at different ages by using directed gear types. In such circumstances the analysis of age structure becomes imperative as this enables accurate calculations of stock response in relation to shifting catch rates by different fisheries (Hampton and Fournier, 2001). Obtaining age-growth information for *T. albacares* and estimating von Bertalanffy (VBGF) growth parameters are vital for the development of successful management methods, based on thorough stock assessment using population dynamic models. This is an important aspect of law enforcement for the preservation of the species (Labelle *et al.* 1993).

Different species of tunas exhibit variable longevities, from the short-lived smaller skipjack tuna *Katsuwonus pelamis* (4.5 years) to the larger Atlantic bluefin tuna, *Thunnus thynnus*, which reaches 12 to 15 years, with some specimens of up to 20 years of age having been recorded (Bard 1984, Caton 1991, Cayré *et al.* 1988, Fromentin and Fonteneau 2001). Biological traits affect individual growth characteristics and dynamics, with most scombrids displaying fast growth rates, reaching length-at-maturity at approximately 38% of their maximum ages. Average growth rates vary according to the species, age and geographic location (FAO 2009, Fromentin and Fonteneau 2001).

Life history traits between tropical and temperate tuna species differ quite considerably. Tropical tunas display *r*-selected characteristics, having fast growth rates, early age-at-maturity development, prolonged spawning periods, and reduced longevity (Fromentin and Fonteneau 2001). Compared to tropical tunas, temperate species have *k*-selected characteristics, with reduced growth rates, later age-at-maturity development, shortened spawning periods, and increased longevity (Fromentin and Fonteneau 2001).

As an example of across-group variability, it is interesting to compare two similar-sized tunas: yellowfin tuna *T. albacares*, a tropical species, and southern bluefin tuna, *Thunnus maccoyii*, a temperate species. Yellowfins attain a maximum length, weight and age of 170cm, 176kg and 7.5 years, respectively (Bard 1984, Cayré *et al.* 1988), whilst southern bluefin tunas attain 200cm, 320kg and 19 years (Caton 1991). The faster growth rate displayed by *T. albacares* is depicted in their length and age at first maturity, attained at 105cm and three years, whereas southern bluefin reach length and age at first maturity at 130cm and eight years (Bard 1984, Caton 1991, Cayré *et al.* 1988). In addition to the distinct longevity and growth rate variability between tuna species, there is also evidence for within-species variability in tropical and temperate tunas.

Growth rates in *T. albacares*, and in the genus *Thunnus* in general, are affected by different ecological and physiological factors within their habitual ranges (Lehodey and Leroy 1999). The following growth rates differ slightly as the yellowfin caught are from different waters; however, a comparison between these fish from different localities indicates that the growth rates are in close agreement. Stéquert *et al.* (1996) found the mean growth rate of *T. albacares* in the Indian Ocean to fluctuate, coinciding with different growth phases in the life span. He found that *T. albacares* grew at a rate of $2\text{mm}\cdot\text{day}^{-1}$ for fish measuring 30cm (FL), $1.3\text{mm}\cdot\text{day}^{-1}$ for fish ranging between 60 and 80cm, and that the growth rate decreased to $1\text{mm}\cdot\text{day}^{-1}$ as fish approached maximum length. Similar growth rate patterns are described by Lehodey and Leroy (1999) who validated growth increments

through tagging data. They found that in *T. albacares* the growth rate for fish measuring 40cm (FL) was 3cm month⁻¹; this decreased until the fish reached 55cm (FL), and subsequently increased to a rate of 3cm month⁻¹ until the fish reached 80cm; it then decreased as the fish approached maximum length. Cayré and Ramcharrun (1990) conducted a tagging experiment off the south west Seychelles Islands and within the Mozambique Channel, marking individual specimens of *T. albacares*. Three of these fish were recaptured with liberty-at-sea values ranging from 252 to 613 days. The average growth rate of these fish was 27.3cm. year⁻¹. Marcille and Stéquert (1976) described a similar mean growth for juvenile *T. albacares* (of 40–0 cm) caught off Madagascar; the fish's mean growth rate was 34cm. year⁻¹.

Filmalter *et al.* (2009) evaluated the suitability of various hardparts (otoliths, vertebrae and opercular bones) for ageing *T. albacares* in the south eastern Atlantic Ocean, off the coast of Southern Africa. He evaluated the structures against a set of criteria: ease in obtaining structures, legibility of growth increments, hardpart preparation time, and the precision of age estimates. An assessment of the best method for aging *T. albacares* stocks in the south eastern Atlantic and south western Indian Oceans — based on the nature of the commercial baitboat fishery, the harvesting methods used, and the most suitable calcified structure for ageing — indicated that vertebrae were the most suitable structures to use for this purpose.

This chapter tests the hypothesis that the growth rate of South African *T. albacares* does not differ from other global stocks. A first estimate of the growth rate for *T. albacares* will be undertaken and possible differences in the growth rates of Western and Eastern Cape and KwaZulu-Natal *T. albacares* stocks will also be investigated.

3.2 Material and Methods

Samples of vertebrae were collected throughout the geographic range of *T. albacares* in Southern Africa. Samples were collected from Western Cape tuna baitboat commercial fishing vessels during 2007–2009, from sport fishery vessels at fixed competitions held within the Eastern and Western Cape regions during 2008–2009, and from KwaZulu-Natal by observers conducting surveys for the Observer Linefish Program during 2009.

Preparation was done according to Filmalter *et al.* (2009). The caudal peduncle from each fish was boiled to facilitate the removal of flesh, after which the surrounding flesh was physically removed. The vertebrae were subsequently separated and scrubbed until there was little or no connective tissue remaining. Vertebrae were then soaked in a solution of enzyme-active commercial detergent and water for three to five days (dependant on vertebral size), to withdraw further oils from within the calcified hard part, after which the vertebrae were rinsed in water and dried at room temperature for three to five days.

The anterior surface of the 36th vertebra was used preferentially for measurement and interpretation, following Berry *et al.* (1977) for bluefin tuna, *Thunnus thynnus*, together with the method devised by Filmalter *et al.* (2009) for *T. albacares* caught aboard baitboats. The fish's tails were sawn off before the start of the caudal peduncle, and growth increments were counted on the anterior cone of whole vertebrae without magnification, using a Fiberoptic–Heim LQ 1600 light source to further enhance the band visual. Where bands were difficult to interpret, both anterior and posterior cone surfaces were used.

3.2.1 Age reading

All vertebrae were read three times by the principal reader (VR1), with replicate readings conducted at intervals of two weeks. A second reader (VR2) read three replicate readings conducted over a

similar period. All vertebral readings were conducted randomly, with both readers having no prior knowledge of fish length or band count. Positive bias was unavoidable as hard part structures are directly proportional to fish size (Stéquent *et al.* 1996).

The readings from the third reading of VR1 that were the same as either Reading 1 or Reading 2 were accepted. If the readings differed by up to two counts, the mean age was accepted across the three readings; if the readings differed by more than two counts, the age estimation was rejected (Ellender 2008, Weyl and Hecht 1999). The precision of both the intra- and the inter-reader age estimation for each structure was formulated. Intra-reader precision was formulated across triplicate readings from primary reader VR1, whereas inter-reader precision was formulated between final age estimation from VR1 and the third reading from VR2. Being the second reader, readings one and two from VR2 were discarded, using the third reading for inter-reader precision.

Precision of age estimation was calculated using the average percentage error method (Beamish and Fournier 1981), defined as:

$$APE_j = 100 \% * \frac{1}{R} \sum_{i=1}^R \frac{(X_{ij} - X_j)}{X_j} \quad \text{(Equation 3.1)}$$

Where: X_{ij} = i^{th} age determination of the j^{th} fish

X_j = mean age estimate of the j^{th} fish

R = number of times each fish is aged

In Equation 3.1, the standard deviation is used, instead of the absolute deviation from the mean age, to calculate the coefficient of variation (*CV*), being the ratio of the standard deviation to the mean (Campana *et al.* 1995); formulated as follows:

$$CV_j = 100 \% \sqrt{\frac{\sum_{i=1}^R (x_{ij} - x_j)^2}{R-1}}{x_j} \quad \text{(Equation 3.2)}$$

Where: CV_j = age precision estimate for the j^{th} fish

The CV can be averaged across multiple fish to produce a mean CV. The index of precision (D) as expressed by Chang (1982) is then calculated to further precision estimates, formulated as follows:

$$D_j = \frac{CV_j}{\sqrt{R}} \quad \text{(Equation 3.3)}$$

The VBGF is the most commonly-used growth model (Stéqueret *et al.* 1996), demonstrating good fits to *T. albacares* data. The age data was analyzed using the traditional three-parameter von Bertalanffy growth function (Beverton and Holt 1957), defined as:

$$L_t = L * \left(1 - \exp(-k*(t - t_0))\right) \quad \text{(Equation 3.4)}$$

Where: L_t = length at age t

L = asymptotic fork length (theoretical maximum FL)

k = coefficient of growth

t_0 = theoretical age where FL = 0

In order to include ageing error into the VBGF, the random effects (RE) methods as formulated by Cope and Punt (2007) was used, whereby all three readings from VR1 were included.

Having calculated a set of age–growth parameters from the VBGF, the reliability of their estimates needs to be validated against those from similar studies. The phi–prime test (Φ') (Pauly 1979, Pauly and Munro 1984) uses the parameters L and k , reflecting the overall growth performance (Equation 3.5), whereby Φ' values are very similar within related taxa.

$$\Phi' = \log k + 2 \log L_{\infty} \quad \text{(Equation 3.5)}$$

3.3 Results

A total of 190 fish ranging from 59–175 cm (FL) were sampled from the Western and Eastern Cape and KwaZulu-Natal regions (Figure 3.1). Sample sizes for all age-classes were greater than ten, except for ages zero and six where sample sizes for lower and upper bound length classes were limited by locality.

Growth on the anterior/ posterior cones of the vertebrae was reflected by light and dark rings (Plate 3.1), assumed to be annuli. Up to six full growth rings were visible in the vertebrae sampled.

There was a distinct progression of mean fork length from one size class to the next, with the minimum length of the proceeding age-class overlapping with the maximum length from the preceding age-class (Table 3.1).

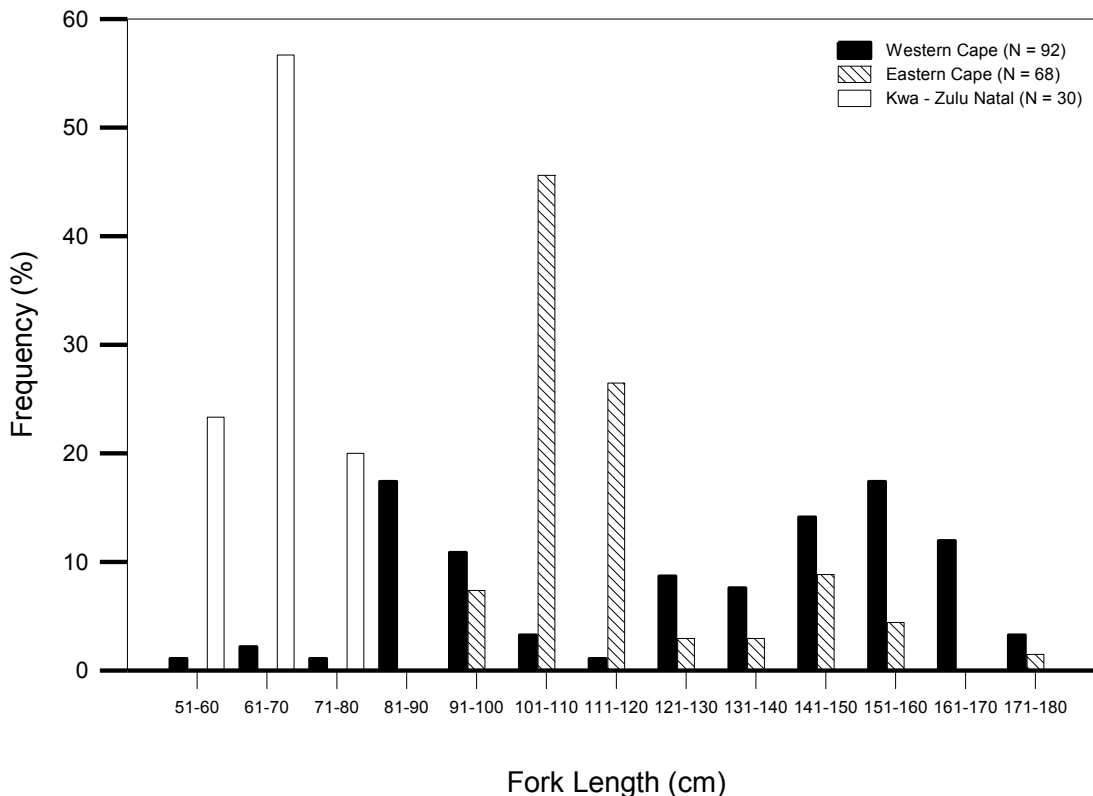


Figure 3.1 Length structure of *T. albacares* sampled from each of the fishing areas: Western Cape (n = 92), Eastern Cape (n = 68) and KwaZulu-Natal (n = 30).

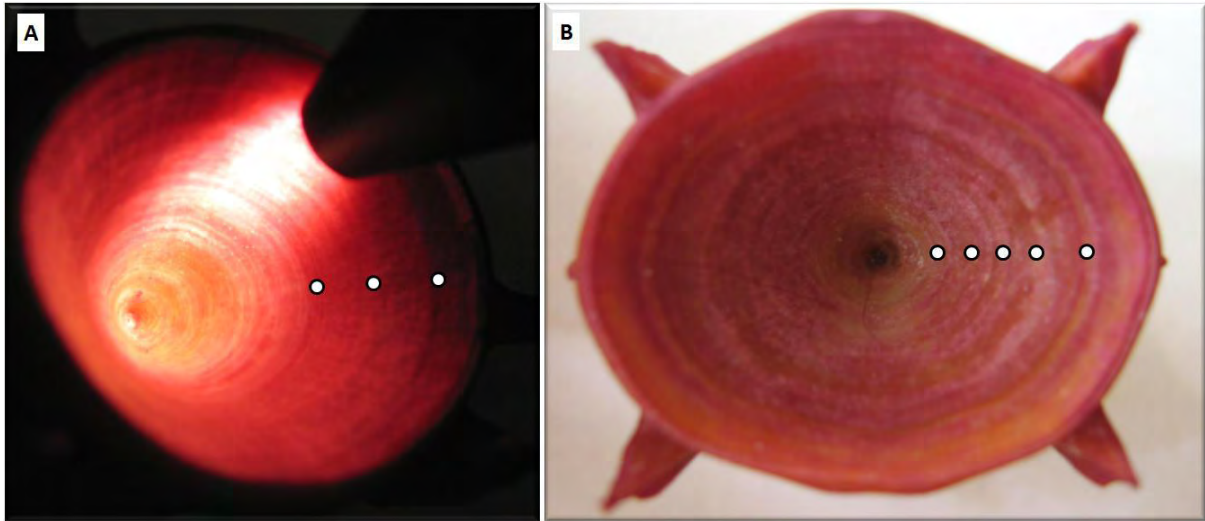


Plate 3.1 Anterior cones of the 36th vertebrae from *T. albacares*, demonstrating clear annual growth increments from the centrum to the outer margin from (A) a three year old, 113 cm (FL) fish from the south western Indian Ocean and (B) a five year old, 170 cm (FL) fish from the south eastern Atlantic Ocean.

Table 3.1 Size distributions (fork length, cm) of *T. albacares* by classes of ring count.

Ring count	1	2	3	4	5	6
Sample size (n)	30	59	40	34	19	8
Minimum (cm)	59.0	61.0	101.5	129.0	150.0	153.5
Maximum (cm)	88.0	114.0	145.0	162.0	169.5	175.0
Mean (cm)	64.8	95.3	115.1	145.3	158.3	169.0
Standard deviation (cm)	7.1	11.1	8.3	7.5	5.6	6.7

Reader bias

Parametric and nonparametric statistical tests were used to test for bias between reader estimates. The parametric test, a linear regression, accounted for significant differences from a slope of 1 and an intercept of 0 (Campana *et al.* 1995). A slope other than 1 suggests inconsistency in the estimates of growth bands from one of VR1 or VR2, whereas obtaining an intercept value other than 0 indicates a systematic difference between readers VR1 and VR2 (Campana *et al.* 1995), as summarized in Table 3.2. Slight bias in age estimates between readers VR1 and VR2 is shown in Figure 3.2 but the estimates were not significantly different between readers (Table 3.2).

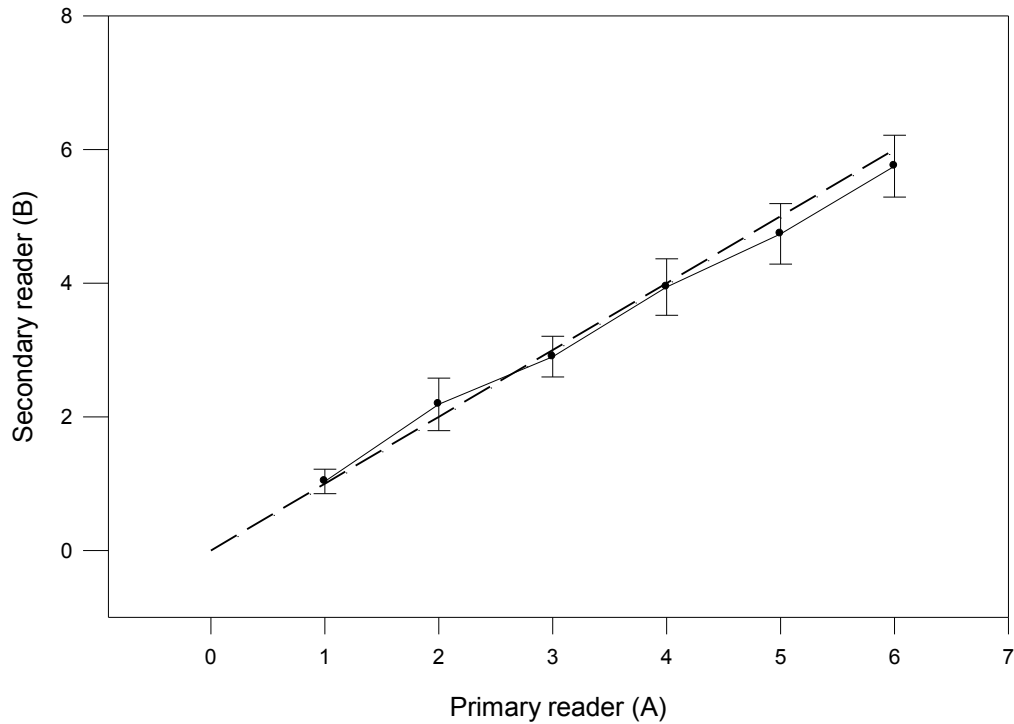


Figure 3.2 Paired comparison of ages of the primary age reader, VR1, with the secondary age reader, VR2. Another two commonly-used tests for systematic differences between readers VR1 and VR2 are a parametric paired t -test, and a nonparametric Wilcoxon matched-pairs rank test (Campana *et al.* 1995). Both tests were applied and results are summarized in Table 3.2, showing no significant bias between readers VR1 and VR2.

Table 3.2 Parametric and nonparametric tests for comparing pairs of age determinations

VR1 versus VR2				
Parametric/ nonparametric test				
	Slope	Intercept	R^2	df
Regression	0.91	0.25	0.92	189
		p (one - tail)	p (two - tail)	df
Paired t - test		0.43	0.85	189
	n_s/r	p (one - tail)	p (two - tail)	W
Wilcoxon	29	0.44	0.87	15

Precision estimates

Estimates of precision were used to assess the degree to which age was determined from the vertebral structures, the reproducibility of a reader's age determination, and the accuracy of band counts between readers (Beamish and Fournier 1981, Chang 1982). These are summarised in Table 3.3.

Table 3.3 Precision estimates for comparing intra- and inter-reader age estimates ()

	Statistic or index		
	(APE _j) ^a	(CV _j) ^b	(D _j) ^c
Intra-reader (VR1)	1.87	2.43	1.40
Inter-reader (VR1 vs VR2)	4.46	5.82	2.60

- ^a Index of average percent error
- ^b Coefficient of variation (%)
- ^c Index of precision

The six-year predicted parameter values for FL, k, and t₀ calculated by the von Bertalanffy growth function were used to estimate accompanying lengths for ages t₀- t₆, which were formulated into an age-length key (Table 3.4).

Table 3.4 Age-length key (estimated fork length (cm) for each year class) for *T. albacares* in the south eastern Atlantic and south western Indian Oceans

Fork length (cm)	Age (years)					
	1	2	3	4	5	6
50	3	0	0	0	0	0
60	22	2	0	0	0	0
70	4	2	0	0	0	0
80	1	14	0	0	0	0
90	0	15	0	0	0	0
100	0	21	9	0	0	0
110	0	5	20	0	0	0
120	0	0	9	1	0	0
130	0	0	1	6	0	0
140	0	0	1	16	0	0

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150	0	0	0	10	10	1
160	0	0	0	1	8	1
170	0	0	0	0	1	6
Total number	30	59	40	34	19	8
L(t) (cm) ^a	64.6	94.5	119.5	140.6	158.3	173.2
Standard deviation ^b	7.1	11.1	8.3	7.5	5.6	6.7

^a Mean fork length (predicted values)

^b Values used from observed data range

The equation for the von Bertalanffy growth function for this study (Equation 3.6) is expressed in Figure 3.3.

$$FL \text{ (cm)} = 251.76 * (1 - \exp^{-0.17 * (t - (-0.71))}) \quad \text{(Equation 3.6)}$$

Figure 3.4 shows different growth curves for *T. albacares* collected from the Western Cape (south eastern Atlantic Ocean) and for *T. albacares* collected from the Eastern Cape and KwaZulu-Natal (south western Indian Ocean).

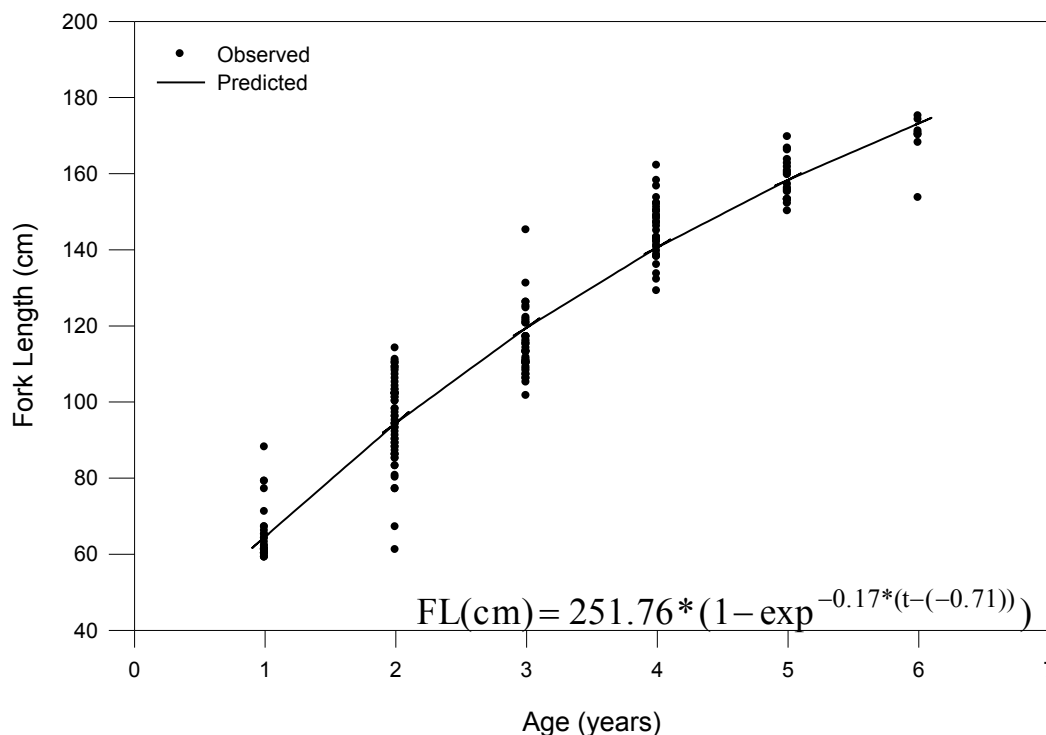


Figure 3.3 Observed fork lengths-at-age (years) of *T. albacares* sampled in the south eastern Atlantic and south western Indian Oceans, South Africa. The curve was fitted using the von Bertalanffy growth model. Ages estimated were obtained from increment counts on whole vertebrae.

A von Bertalanffy growth function, used to describe length-at-age and growth parameters for combined and separate regions, is summarized in Table 3.5.

Table 3.5 Parameter results of fitting the von Bertalanffy growth function to age and length data for individual and combined geographic regions.

Parameters	Region		
	Combined ^a	Western Cape	E. Cape and KZN ^b
	251.8	210.1	213.4
k	0.17	0.28	0.22
t ₀	-0.71	-0.07	-0.70
SE	26.8	16.9	45.6
LCI	215.1	188.8	171.6
UCI	321.3	252.1	326.4
n	190	91	99

^a Length and age data merged from regions Western and Eastern Cape and KwaZulu-Natal

^b Length and age data from regions Eastern Cape and KwaZulu-Natal (south western Indian Ocean)

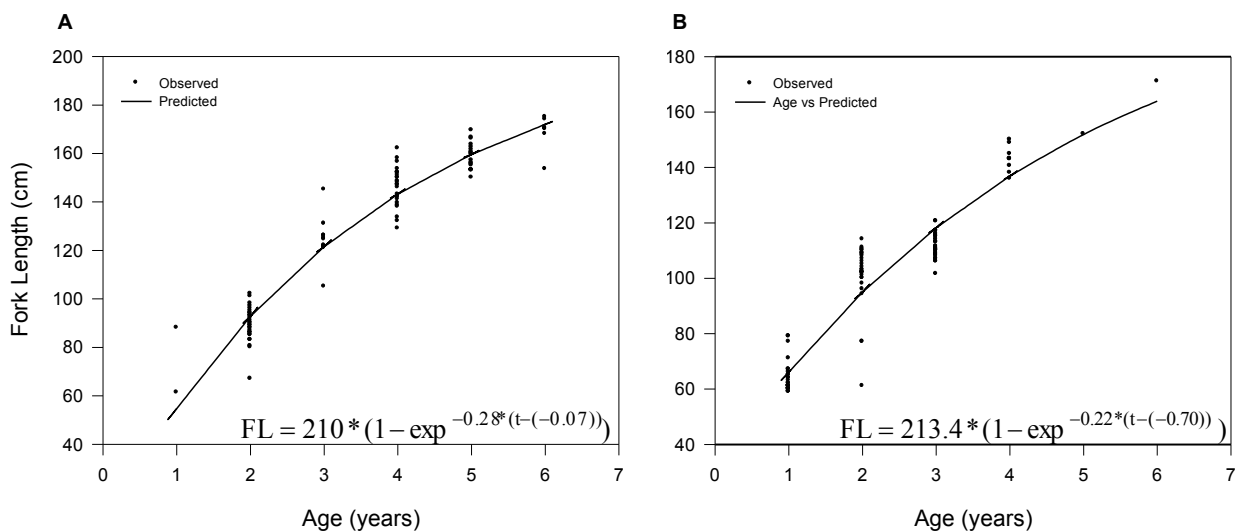


Figure 3.4 Comparative von Bertalanffy growth curve functions for *T. albacares* caught from (A) the Western Cape (south eastern Atlantic Ocean), (B) Eastern Cape and KwaZulu-Natal (south western Indian Ocean). Ages estimated were obtained from increment counts on whole vertebrae.

There was no statistical difference in either asymptotic length (L_{∞}) or overall growth (k) between *T. albacares* from the Western Cape and Eastern Cape and KwaZulu-Natal regions ($P > 0.05$) (Table 3.5). When compared to other global stocks, computed for covariates, at mean age three, the growth

of South Africa’s yellowfin tuna was not significantly different from the growth of the global stocks (ANOVA, $df = 4$, $p > 0.05$) (Table 3.6).

Table 3.6 Comparison of studies of *T. albacares* from different geographical locations for covariate means, age three: $F(4, 29) = 0.9274$, $P = 0.4617$.

Study	Mean Fork Length (cm)	-95% Confidence	+95% Confidence
Newcombe 2011	111.4	99.2	123.6
Shuford <i>et al.</i> 2007	120.9	108.7	133.1
Stéquert <i>et al.</i> 1996	109.5	97.3	121.8
Lehodey and Leroy 1999	122.6	110.3	134.8
Lessa and Duarte-Neto 2004	114.3	102.1	126.5

The calculated phi–prime (Φ') values for these two regions (Table 3.7) are similar to each other and to values estimated for *T. albacares* found in Atlantic, Indian and Pacific Oceans (Table 3.8).

Table 3.7 Likelihood ratio test comparing differences for asymptotic length (FL_{∞}) and overall growth (k) between *T. albacares* from the Western Cape and Eastern Cape and KwaZulu-Natal regions; testing phi–prime (Φ') values for regional comparison.

Study area	Parameters			Chi - Distribution	
	FL	k		FL	k
				p	p
Western Cape	210.1	0.28	4.09	0.9255	0.7304
E. Cape and KZN ^a	213.4	0.22	4.00		

^a Length and age data from regions Eastern Cape and KwaZulu-Natal (south western Indian Ocean)

The values calculated using phi–prime (Φ') for this study ($\Phi' = 4.04$) are similar to those estimated for *T. albacares* found in Atlantic, Indian and Pacific Oceans ($\Phi' = 4.14 \pm 0.28$, $df = 9$) (Table 3.8).

Table 3.8 Phi–prime (Φ') values for other *T. albacares* stocks.

Study	Parameters			Ocean
	<i>L</i>	<i>k</i>		
Current (Newcombe, 2011)	251.8	0.17	4.04	south–eastern Atlantic, south western Indian
Shuford <i>et al.</i> 2007	245.5	0.28	4.23	Atlantic
Steuert <i>et al.</i> 1996	272.7	0.18	4.12	Indian
Wild 1986	188.2	0.72	4.41	eastern Pacific
Lehodey and Leroy 1999	199.6	0.39	4.19	western central Pacific
Lessa and Duarte-Neto 2004	230.7	0.27	4.15	western equatorial Atlantic
LeGuen and Sakagawa 1973	194.8	0.42	4.20	eastern Atlantic
Yang <i>et al.</i> 1969	222.8	0.14	3.84	Atlantic
Draganic and Pelzcarski 1984	192.4	0.37	4.14	central Atlantic
Gascuel <i>et al.</i> 1992	158.5	0.10	3.40	eastern Atlantic
Fonteneau 1980	166.4	0.86	4.38	eastern Atlantic

3.4 Discussion

This study shows that identifying annual growth increments from vertebrae was uncomplicated, as precision in ageing estimates was high, with an APE below 5% and a CV just below 6%. No other studies have reported the use of yellowfin tuna vertebrae for age and growth determination. Vertebrae have been used to estimate age in other *Thunnus* species: Gunn *et al.* (2008) obtained an APE between 2 and 6% for *Thunnus maccoyii* of age classes 1–11 years, and Alves *et al.* (2002) obtained an APE of 4.4% and a CV of 5.8%. Due to the easily distinguishable growth bands found on large pelagic fish's hardpart structures, the upper bound limit for age estimation precision error is low, at 10% (Powers 1983).

It should be noted that the deposition rates of growth zones could not be validated, hence the estimated length-at-age and growth parameters must be used as a reference point only. Other age-growth studies on *T. albacares* used tagging recapture (liberty at sea), microincrement analysis of otoliths, and length-frequency analysis to validate age-at-length and growth rates from the Atlantic (Shuford *et al.* 2007), Indian (Steuert *et al.* 1996) and Pacific oceans (Wild 1986). All the above-

mentioned studies reported that a single growth increment was formed daily. Lessa and Duarte-Neto (2004), who used annuli on first dorsal fin spines for ageing procedure estimates, found similar results, all of which correspond with the growth rate from this study — in which it was found that up to six growth rings, thought to be annuli, were visible on the vertebrae sampled.

Difficulties in obtaining full length ranges from Western and Eastern Cape and KwaZulu-Natal prevented fully comparative VBGF estimates for these regions. Samples were combined to form a uniform VBGF for the south eastern Atlantic and south western Indian oceans. This was done because predominant length classes in catches reflect availability of visiting cohorts and not selectivity of the gear.

Numerous studies have been conducted on the age and growth of *T. albacares* in the Indian, Pacific and Atlantic oceans. These studies used three different techniques: length–frequency analysis, tagging recapture (liberty at sea), and hardpart analyses. LeGuen and Sakagawa (1973) and Gascuel *et al.* (1992) used length–frequency analyses; Fonteneau (1980) and Bard (1984) used tagging recapture; whilst Yang *et al.* (1969), Stéquent *et al.* (1996), Lessa and Duarte-Neto (2004), Shuford (2007) and Filmlalter *et al.* (2009) used hardpart structures — namely vertebrae, otoliths, dorsal spines and scales — for their analyses. The growth parameters obtained for *T. albacares*, from all three Ocean bodies and using different ageing techniques, differ considerably and are summarised in Table 3.9.

Table 3.9 Age and growth parameters formulated from various studies conducted in the Atlantic, Pacific and Indian Oceans for the species *Thunnus albacares*. LFA = Length frequency analysis.

Study	(L) ^a	(k) ^b	(t ₀) ^c	Ocean	Age-growth method
Current (Newcombe, 2011)	251.8	0.17	-0.710	south-eastern Atlantic, south western Indian	Whole vertebrae
Draganic and Pelzcarski. 1984	192.4	0.37	-0.003	central Atlantic	Dorsal spines
Fonteneau. 1980	166.4	0.86	1.292	eastern Atlantic	LFA and tagging
Gascuel <i>et al.</i> 1992	158.5	0.10	37.80	eastern Atlantic	LFA
LeGuen and Sakagawa. 1973	194.8	0.42		eastern Atlantic	LFA
Lehodey and Leroy. 1999	199.6	0.39	-0.177	western central Pacific	Direct analysis of thin-section otolith microincrements and tagging
Lessa and Duarte-Neto. 2004	230.7	0.27	-0.081	western equatorial Atlantic	Dorsal spines
Shuford <i>et al.</i> 2007	245.5	0.28	0.042	Atlantic	Direct analysis of thin-section otolith microincrements
Steuert <i>et al.</i> 1996	272.7	0.18	0.266	Indian	Direct analysis of thin-section otolith microincrements
Wild. 1986	188.2	0.72	1.590	eastern Pacific	Direct analysis of acetate peel otolith microincrements
Yang <i>et al.</i> 1969	222.8	0.14	0	Atlantic	Scales

^a Asymptotic length

^b Coefficient of growth

^c Theoretical age where L = 0

The formulated equation from this study of *T. albacares* across the Atlantic and Indian Ocean boundary (20° E) has growth parameters and parameter estimates (Φ') that are comparable to those of *T. albacares*, from studies conducted using other ageing hardpart structures, namely otoliths (Lehodey and Leroy 1999, Stéuert *et al.* 1996, Shuford *et al.* 2007) and dorsal spines (Lessa and

Duarte-Neto 2004) from surrounding ocean bodies (Figure 3.5 and Table 3.9). Irrespective of graphical dissimilarities (Figure 3.5), when length-at-age estimates using the VBGF were compared statistically using a general linear model for covariate means (for age three), no significant difference was found among them.

It is generally thought that there is only one global stock of *T. albacares* among oceans, as no genetic evidence to date suggests otherwise (Scoles and Graves 1993). It is thus expected and assumed that *T. albacares* from different areas will have similar growth rates (Stéquet *et al.* 1996). This was supported by results from the current study, which supports the global stock hypotheses whereby there are no significant differences in growth rates of *T. albacares*. Growth rates do however differ enough to assume affects by different ecological and physiological factors, encompassed within their habitual ranges, with the response to water temperature being the most likely factor (Lehodey and Leroy 1999).

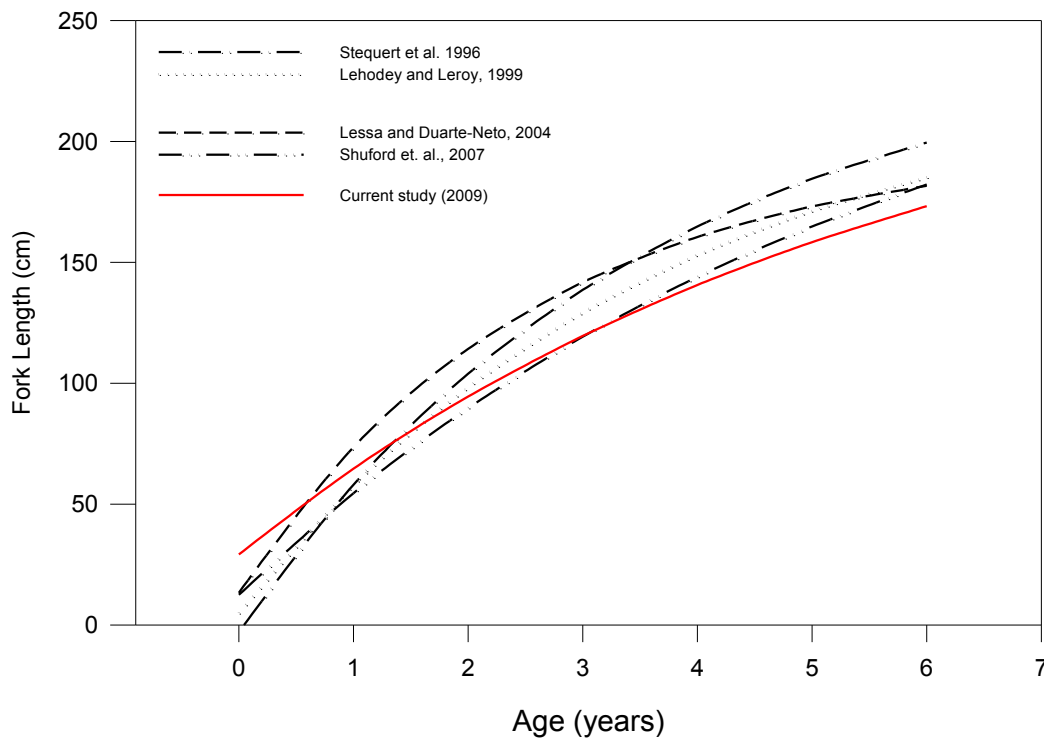


Figure 3.5 Comparison of growth curves from studies conducted using other ageing hardpart structures from *T. albacares* (Shuford *et. el.*, 2007, Lessa and Duarte – Neto 2004, Lehodey and Leroy 1999, Stéquet *et al.* 1996).

Thunnus albacares is a tropical species, classified according to its biology and life history patterns. The above age-growth studies (Figure 3.5) have been conducted primarily on *T. albacares* in tropical areas, where comparable growth curves indicate rapid growth rates for juvenile fish, continuing throughout adulthood, and slow growth on reaching maximum size (Shuford *et al.* 2007). The results of this study show a slower, more uniform, growth rate. The differences in growth rates, pertaining to varying life history patterns among *T. albacares* from all three Ocean systems, can be accounted for by varying environmental factors (Driggers *et al.* 1999). Varying growth rates, coupled with the observation that *T. albacares* is relatively spatially static (Driggers *et al.* 1999, Schaefer *et al.* 2007), supports a slower growth rate occurring in *T. albacares* in the temperate waters off the South African coastline.

Samples used in this study were collected from different areas, due to sample availability constraints, whereas future age-growth studies need representative sample sizes from the entire population per region. This is because each region experiences slightly different oceanographic conditions. In the Indian Ocean *T. albacares* frequents the southern area bordering the warmer waters of the Agulhas bank and east coast (Penney *et al.* 1992). In the Western Cape this species encounters slightly cooler waters, influenced by the cold Benguela jet, whilst the Eastern Cape is influenced more by the Agulhas current during winter months (March to July) and the warm Mozambique current moves continuously past KwaZulu-Natal (Sauer *et al.* 2003). Differing oceanographic conditions that occur off the Southern African coastline substantiate the need for directed sampling within populations and validating ageing procedures.

4. CHARACTERISATION OF THE RECREATIONAL FISHERY FOR TUNA WITH AN EMPHASIS ON THE COMPETITIVE TUNA SPORT FISHERY IN THE WESTERN AND EASTERN CAPE AND KWAZULU NATAL

4.1 Introduction

Worldwide recreational fishing contributes to fishery declines, environmental degradation and ecosystem alterations, but also has significant overriding national and global economic impacts (Cooke and Cowx 2004). Negative and positive impacts derived from recreational fisheries need to be managed in an integrated manner, from a holistic viewpoint. In the United States of America, for instance, the annual contribution (in 2003) of recreational angling to the economy was in excess of US\$21 billion, while in Canada the figure exceeded US\$5.2 billion and the contribution in Australia (in 2003) was approximately US\$1.3 billion (Pauly *et al.* 2005b).

In 2003, the South African Fishing Industry was estimated to have generated approximately ZAR2.6 billion (roughly US\$404 million) of wholesale revenue per annum to South Africa's Gross Domestic Product (GDP), or roughly about one percent of national GDP (FAO 2010). While these South African data are limited, the economic impact of recreational fishing is recognized to be significant. Two studies — an Economic Valuation of the South African Line fishery (McGrath *et al.* 1997) and, more recently, the SADSAA commissioned consulting report by Leibold and van Zyl (2008) — valued the economic impact of recreational angling in South Africa as greater than 80% of the commercial fishery, in terms of economic impact and use of resources. In 2007 the recreational fishery was valued at ZAR18.8 billion (US\$2.7) amongst 2.5 million participants (Leibold and van Zyl, 2008).

In 1996 an estimated 13 800 offshore boat fishermen participated in South African recreational line fisheries and made use of an estimated 3 444 deep-sea recreational vessels (Sauer *et al.* 1997). These ranged from outboard-engine dinghies and ski boats of less than four metres in length to large sport-fishing vessels in excess of 16 metres. The deep sea recreational sector targets an array of species, from sedentary reef species to trans-boundary pelagic species (Sauer *et al.* 1997) and it is estimated that the recreational offshore boating sector is growing at a rate of 2% per annum (McGrath *et al.* 1997). Tuna-directed effort is restricted to the deep sea angling facet, comprising 31 860, or 1.3%, of the total 2.5 million sport and recreational participants. Of these, 9 488 are competitive anglers that belong to affiliated clubs or organizations (Leibold and van Zyl, 2008).

Recorded catch and effort data from South Africa recreational fisheries, whether collected from competition records or monitoring programmes, are limited. The National Marine Linefish System (NMLS) focuses on reporting marine fish catches along the South African Coast, with emphasis on the KwaZulu-Natal area. The NMLS, operational since 1984, provides long-term data of all relevant information related to line fish monitoring. Data are collected by various methods. For instance, catch cards are filled in by volunteer anglers, whilst under supervision, or by qualified officials; organizations submit tournament records; boat inspections are undertaken at frequented launch sites where catch and effort data are collected by KwaZulu-Natal Wildlife officials, and creel surveys are initiated while shore patrols are undertaken (Pradervand *et al.* 2007). Nevertheless, adequate effort to incorporate gamefish records is beyond the capacity of the NMLS, as it is a shore-based program; hence the limited availability of such catch data (Griffiths and Lamberth 2002).

A national survey of the recreational sector was conducted in the mid 1990s to evaluate socio-economic aspects and attitudes as well as catch and effort data (Brouwer *et al.* 1997, Brouwer and Buxton 2002, McGrath *et al.* 1997, Sauer *et al.* 1997). These data were comprised of the estimated

total catch and number of participants and boats in the four main sectors of the line fishery for the period 1994–1996, the demographics of South African shore-anglers and recreational ski boat operators, and the economic value of the South African line fishery (excluding estuaries and the entire Transkei region) (McGrath *et al.* 1997).

The three-year Observer Linefish Program (OLP) was developed at the end of 2007, its aim being to follow on, and update, the Linefish Management Protocol (Griffiths *et al.* 1999). In this programme, shore-based observers were stationed at 10 landing sites around the Western and Eastern Cape to collect catch and effort data on fish landings for a minimum of 30% coverage from the following sectors: the commercial-boat-based traditional line fishery, hake hand-line, tuna baitboat, inshore net fisheries, and the recreational fishery. The observer program commenced in the fourth quarter of 2007 and the data have yet to be analysed (Anchor Environmental 2010). This program is expected to provide recent catch trends along the South African coastline but, unfortunately, the socio-economic data are still outstanding.

Formal competitions provide an additional opportunity for selected catch and effort data. The South African Deep Sea Angling Association (SADSAA) only keeps IGFA catch records and has 7200 formal and 2300 semi-affiliated participants (Leibold and van Zyl, 2008). Each affiliated club hosts an annual sport fish angling competition, open to all SADSAA-affiliated members. Recreational deep sea angling and arranged competition meets occur along the South African coastline, with tuna vessels mostly concentrated in harbour areas (see Figure 2.1).

Angling competition rules and regulations previously allowed all caught gamefish to be weighed in at the gantry. In recent years, however, competitions have moved away from the capture of all species, to focus on the capture of tuna and tuna-like species. The tuna landed at competitions are

all weighed to the nearest kilogram and recorded and, up until recently (2006), a maximum of two fish of the same species per angler were caught and the competition-imposed minimum weight qualified the angler and boat for a positional ranking and prize contention. Top ten angler ranking positions (judged on the weight of fish caught by the respective angler) and the heaviest fish per species could then qualify for prizes. In provincial league events (for example, the *Western Cape Offshore League*) however, competition anglers are permitted to weigh-in any gamefish caught within the angler's ten-fish bag limit. Provincial organizations — for example the WPDSAA — keep current and archived electronic copies of all fish caught during offshore league events. Unfortunately, good reliable catch data are very limited because of the nature of how catch records are captured at angling competitions, due to competition-imposed limitations placed upon angler catches. As a result, only very few angling competitions keep complete records for all species caught.

Catch and effort records are usually recorded in hard copy format, with no, or very few, electronic versions available. Archived club competition catch and effort records are almost non-existent due to the recording methods used and inadequate filing systems for the storage of data. There is also an almost-complete lack of data on the characteristics of the fishery. Provincial organizations — for example, the WPDSAA — keep current and archived electronic copies for all fish caught during Offshore League events, dating back to 2004. A single entry form is completed per competing boat and information includes the name and length of the boat and the names and contact details of the competing anglers.

This chapter concentrates on the previous competitive tuna sport fishery (formal) that has not yet been researched. Due to manpower and funding constraints, primary data collection was restricted to the Eastern and Western Cape and data for KwaZulu-Natal was obtained via line-fishing and competition catch records sourced from the NMLS.

4.2 Material and methods

Characterisation of the sport fishery sector requires a multi-faceted research approach that includes metadata analysis of catch and effort data, creel surveys (size selectivity), and informal socio-economic questionnaire surveys.

4.2.1 Metadata analysis

To describe the Western Cape sport fishery, historical catch data were obtained from the WPDSAA Offshore League results for the period October 2004 and May 2009. Incomplete historical catch records for the Eastern Cape sport fishery were also obtained for the period 2004–2009. However, these catch records only included the weights for the top-ten-placed yellowfin tuna caught per competition; they were therefore excluded from the study. A summary of incomplete positive line-fishing and competition catch records for KwaZulu-Natal were sourced from the NMLS for the period 2004–2009 (Maggs 2010).

Catch composition and species directed effort

Catch data for ski boats competing at Western and Eastern Cape competitions were categorised according to the eight species caught: yellowfin tuna (*Thunnus albacares*), longfin tuna (*Thunnus alalunga*), skipjack (*Katsuwonus pelamis*), Atlantic bonito (*Sarda sarda*), dorado (*Coryphaena hippurus*), yellowtail (*Seriola lalandi*), black marlin (*Makaira indica*) and shortfin mako (*Isurus oxyrinchus*). Data obtained from KwaZulu-Natal coast was more comprehensive: 13 202 ski boat inspections were conducted along the coastline in 2009, with records being obtained from a total of 142 species. Effort data were categorized according to the main species targeted monthly, as indicated in questionnaire surveys (refer to Appendices). The category “other tuna” comprised the pooled catch and effort data for insignificant catches of smaller tuna species, namely skipjack tuna *Katsuwonus pelamis* and bonito *Sarda sarda*. The category “reef species/ line fish” comprised the

pooled catch and effort data for species, including all members of other families, such as the Sparidae and Sciaenidae. The catch composition and effort per region were expressed as a percent of total weight (kilograms) and fish-catch days between 2007–2008 for the Eastern Cape, and between 2004–2009 for the Western Cape and KwaZulu-Natal.

Effort

Mean annual and monthly effort per region was calculated using the following equation:

$$\bar{E} = \text{Mean} \left[\sum_j^n \frac{\sum A_i}{n_i} \right] \quad (\text{Equation 4.1})$$

Where \bar{E} denotes the expected number of vessels during any time of the fishing year/ month; A_i is the number of reported vessels on the i^{th} year/ month, and n_i is the number of vessel counts on the i^{th} year/ month.

Due to the lack of historical data for the Eastern Cape, all competitions for 2007 and 2008 were surveyed through an access point survey, and catch and effort data were recorded for each vessel returning to harbour.

Catch-per-unit-effort

The catch and effort information provided for each ski boat (recorded as daily information) recorded in the WPDSAA database, and from creel surveys at Eastern Cape competitions, were left-skewed due to a high occurrence of zero catches. To calculate CPUE, accounting for zero catch data with skewed effects, a hurdle model formulated around a delta-X distribution was used for analysis (for further detail, with example and equations, refer to Chapter 2: Study Area and Sector Descriptions) (Fletcher *et al.* 2005, Maunder and Punt 2004, Pereira *et al.* 2008, Punt *et al.* 2000, Stefánsson 1996). Positive CPUE was calculated for all catch records obtained from the KwaZulu-Natal NMLS. Catch records were separated according to regional locality. The data were pooled

according to years and months to describe annual and seasonal catchability trends (for further detail on equations, refer to Chapter 2: Study Area and Sector Descriptions).

4.2.2 Access Point Creel Surveys

To determine catch data from informal trips associated with the Western Cape recreational deep-sea fishery, an access point creel survey (APCS) was conducted for five main harbours within the Western Cape between October 2007 and 2008, using the bus-route method (Robson and Jones 1989). All species caught were either measured by fork length (FL) or total length (TL) and, in cases where numbers of catches by vessel were large, total numbers per species were recorded and a sub-sample measured. Individual fish weights were calculated using length-weight relationships, as calculated using van der Elst and Adkins (1991) and Torres (1991) studies on species length-weight growth parameters. Catch, effort and socio-economic data were collected from selected competitions, particularly in the Eastern Cape, through an access point survey. All catch and effort data were recorded for each vessel returning to harbour. Recorded creel data from the Western Cape were not used for modelling CPUE as these data were limited and were thus used only for calculating size selectivity of *T. albacares* between inshore and offshore fisheries (sport and baitboat versus longline fisheries), assuming plausible migratory patterns.

To determine vessel effort and type of fishing activity per harbour, counts of vessels were made during each access point survey. The type of activity and the type of vessel were recorded together with the vessel ID, so as to prevent repetitive counts.

4.2.3 Questionnaire surveys

Questionnaire–informal interviews during Access Point Creel Survey (APCS)

A questionnaire was administered during APCS to determine crew demographics in terms of:-

- number of fishers per vessel/ race/ gender/ age),
- attitude towards management,
- socio-economic (occupation/ residency of vessel owner/ operating expenses of vessel)

Questionnaires were administered to vessel skippers after the APCS was completed. As many skippers were interviewed as possible on any sampling day (Appendix 9.2).

Questionnaire–informal interview of ski boat competition skippers

A competition questionnaire, compiled for skipper interviews, was designed to capture data on catch and effort, attitude to management, and other relevant topics such as economics and non-consumptive–use (see Appendix 9.1).

Economics data

Economics data were obtained from questionnaire surveys. Capital expenditure for fixed assets (boat, rod and reel) were expressed as daily costs and the cost of these assets per competing year were calculated as the mean annual tuna-directed effort in each region (average fishing days per vessel: Western Cape: 27 ± 34 ; Eastern Cape: 21 ± 35) (Table 4.4). The annual costs for licensing and moorage were annual once-off payments that remained as fixed amounts (Table 4.4). The daily costs for the remaining running expenses (i.e. for bait, food, etc.) were calculated according to the average number of competing days spent at sea as recorded in the WPDSAA database and competition creel surveys. All annual expenses were calculated as mean annual tuna-directed effort in each region (Table 4.4). Depreciative insurance rates and other information relating to the tuna sport fishery fixed assets were obtained from Mr Paul Sherman (an active tuna sport fisher and

owner of a tuna vessel). Fixed assets were depreciated using a reduced balance method. This was based on the assumptions that fixed asset purchase dates were unknown, and whether the asset was being depreciated into the future (next five years) or the previous five years. Hence the final value represented slightly inflated accounting in terms of both of the assumptions mentioned above. Vessels were insured at current replacement value and maintained at that rate. Motor vehicles were insured at current market value and depreciated at a rate of 0.92 per year up until five years, after which they were written off. Fishing tackle was insured, under an all risks policy scheme, for up to ZAR20 000.00. Trailers were deemed not to depreciate and maintained their resale value. The fixed asset replacement values and associated running expenses were obtained from direct skipper interviews. Mean values were used for all calculations.

(1) The total fishery expenditure for the Western and Eastern Cape sport fisheries (2008/2009)

(Table 4.5) was calculated as follows: (Equation 4.2):

$$\text{Total fishery expenditure} = \text{total days fished} \cdot \text{year}^{-1} \left(\text{capital expenditure} \cdot \text{year}^{-1} + \text{operating costs} \cdot \text{year}^{-1} \right)$$

4.3 Results

4.3.1 Vessel category analysis: Access point creel survey (APCS)

The Western Cape APCS indicated that recreational vessels made up 32.1% of the total number of sampled vessels, of which 30% of the total sampled recreational vessels (9.4% of the 32.1%) actively targeted tuna. The majority (84%) of the charter vessels were actively involved in fishery operations and actively targeted tuna during 25% of their trips. Figure 4.2 shows vessel category activities per harbour within the Western Cape.

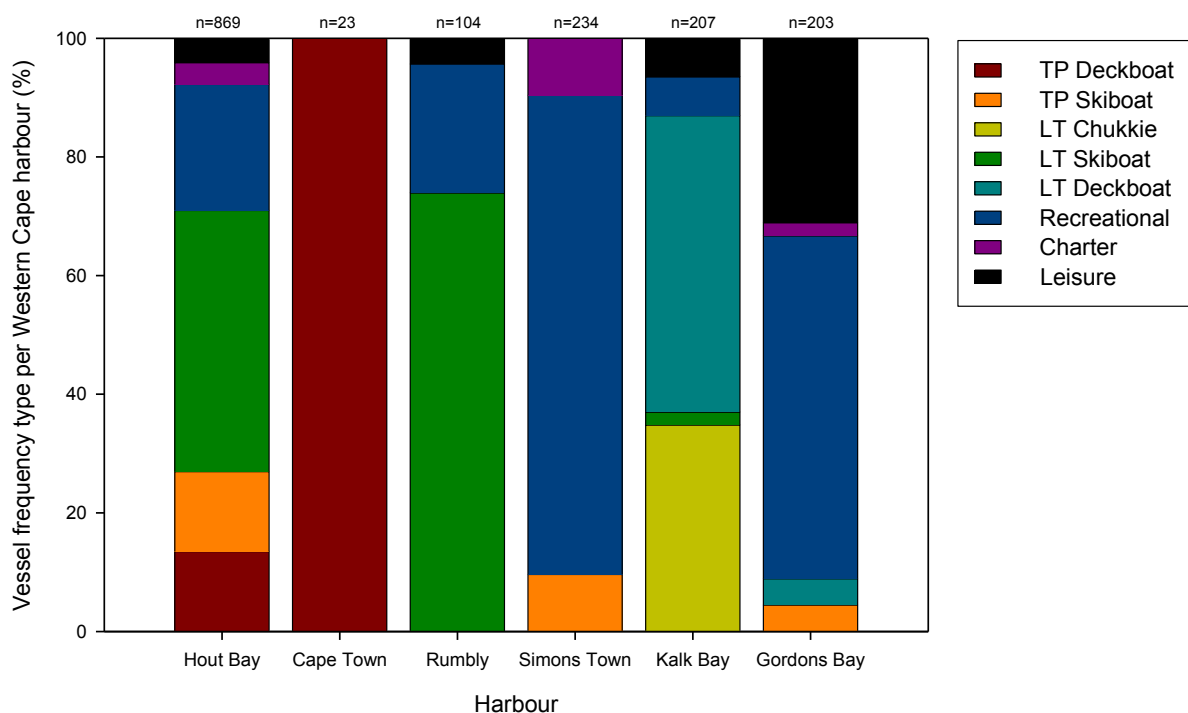


Figure 4.2 Frequency histogram from APCS, describing vessel activity per harbour within the Western Cape for the year 2007–2008 (data source: Western Cape APCS). (TP: Tuna Pole; LT: Linefish Traditional).

The total recorded ski boat launches along the KwaZulu-Natal coastline between 2008 and 2009 showed that private recreational boat fishing made up 58.0% of the 52 170 recorded vessels, of which 68% were ski-boat-type vessels (Table 4.1) (ORI unpublished BLSMS data 2010).

Table 4.1 Total recorded KwaZulu-Natal boat launches between 2008 and 2009 with associated vessel activity. Total number of recorded boat launches = 52 170 (ORI unpublished BLSMS data 2010).

Type of Vessel	% Frequency	Purpose of Launch	% Frequency
Ski boat	63	Private fishing	58
Inflatable	29	Charter scuba	20
Jetski	7	Charter fishing	11
Paddle craft	1	Commercial fishing	3
		Charter pleasure	2
		Practice & testing	1
		Private pleasure	2
		Private spearfishing	1
		Private scuba	1

4.3.2 *Fisher demographics and characteristics*

Eighty seven sport fishery competition skipper interviews were conducted between April 2007 and July 2009 in the Western and Eastern Cape region. These comprised 60 skipper interviews from the Eastern Cape and 27 from the Western Cape. Results are summarised in Table 4.2.

Anglers active within the tuna sport fishery were classified in terms of age, race and gender. This indicated the following dominant groupings: between 20–40 years, and over 40 years (38% and 50%, respectively); predominantly white (92%), and male (91%). A high percentage (86.7%) of the active anglers had a permanent occupation, with a small fraction being retired (13.3%).

The most frequent mode of transport of skippers was a 4X4 sports utility vehicle (SUV) (75%) with the capability of towing large offshore angling boats. A third of the competing skippers resided outside the vicinity of the competition of interest (36%) and these were prepared to either travel by car or by aeroplane to take part in competitions.

Most anglers were found to partake in this fishery for the nature of the sport (90%) and the competitive camaraderie (60%) rather than for a livelihood or for consumptive reasons. Only a minority (15%) admitted to breaking fishing regulations (selling their catch, or catching more than the stipulated bag limit) and the majority strongly believed that fishing had deteriorated over the years (91%) with the main assumed causes for deterioration being trawling (67.8%) and over fishing by both recreational (67.8%) and commercial (67.7%) sectors (Table 4.2b). A large portion of the participating anglers contributed towards the running costs of their competing vessel (79%).

Table 4.2a Competition sport fishery angler characteristics (2007/2009): n = number of respondents to questionnaire interviews; data source: competition creel surveys.

Characteristic	Category	%
Race (n = 87)	White	91.6
	Coloured	5.8
	Black African	2.6
Gender (n = 87)	Male	91.3
	Female	8.7
Age n = 87	> 40 yrs	49.6
	20-40 yrs	37.5
	< 20 yrs	5.6
Crew # (n = 87)		3.9
Employment (n = 83)	Permanent	86.7
	Retired	13.3
Transport method (n = 52)	4X4*	75.0
	Boat	1.9
	Plane	9.6
	Sedan	13.5
Competitors whom reside outside of competition area (n = 87)		35.6
Vessel running cost sharing mechanisms		
(n = 67)	Equal division of costs amongst participants	79.1
(n = 86)	Skipper covers costs	15.1

* Category includes 4x4, bakkies and sports utility vehicles (SUV)

Table 4.2b Frequency of competition sport fishery angler responses towards main causes for fishing deterioration (2007/2009): n = 87, number of respondents to questionnaire interviews; data source: competition creel surveys.

Main causes for deterioration of fishing	Answer		
	No	Yes	No Answer
	%		
Has fishing deteriorated?	8.0	90.8	1.1
<i>Cause for deteriorated fishing</i>			
Trawling	28.7	67.8	3.4
Over fishing: recreational	28.7	67.8	3.4
Over fishing: commercial	29.9	66.7	3.4
Seine-netting	56.3	40.2	3.4
Gill netting	60.9	35.6	3.4
Other	47.1	32.2	20.7
Pollution	83.9	12.6	3.4

4.3.3 *Catch composition and target-species-directed trips of competitive sport fishers*

Surveys of both the Western and Eastern Cape regions indicate seasonally higher fishing effort over the winter months of April–May and summer months of November–January (Figure 4.3). Directed target-species trips in both regions indicate a summer-driven tuna fishery in the Western Cape and a winter-driven tuna fishery in the Eastern Cape. The increased targeting of reef species in the Eastern Cape is attributable to the increased species diversity (Figure 4.3). Comparatively, the KwaZulu-Natal ski boat catches are comprised mainly of line fish species (Table 4.3); of these, tuna comprised 26.4% of total catches by weight, of which yellowfin tuna contributed 17.5% (Table 4.3) (Maggs 2010).

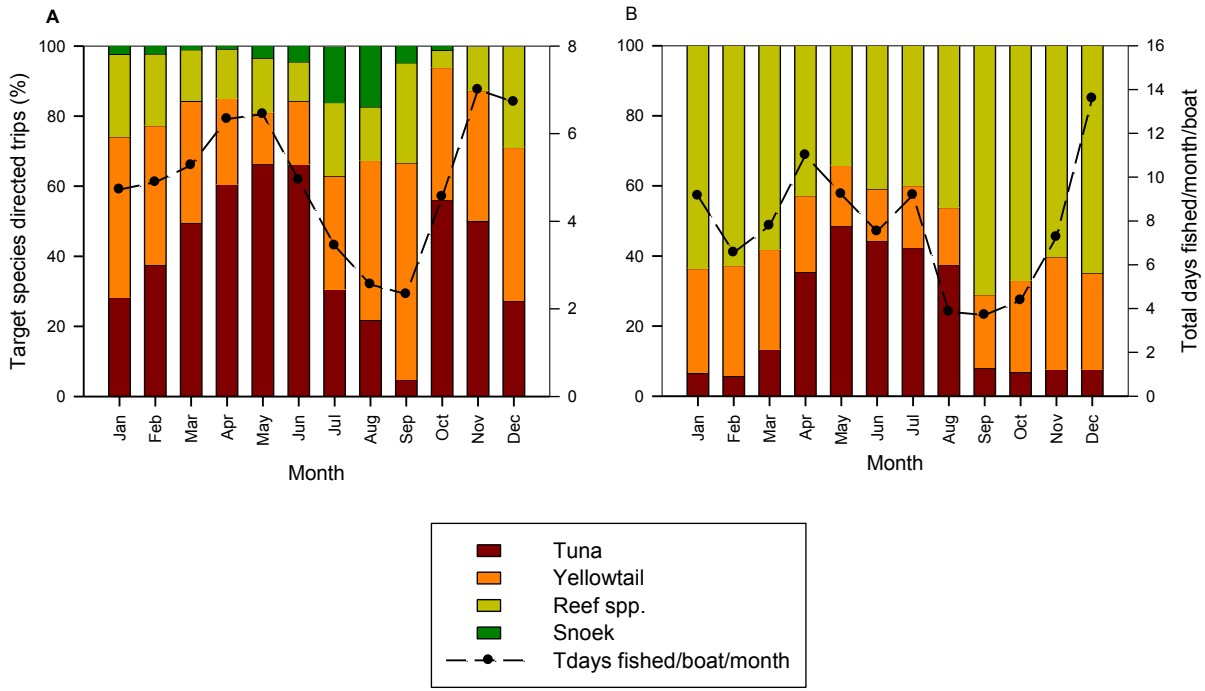


Figure 4.3 Seasonal frequency histogram describing directed effort by the tuna sport fishery for the period 2007–2008, based on 87 skipper interviews: (A) Western Cape; (B) Eastern Cape; (data source: WPDSAA, offshore league database (2004-2009), Eastern Cape competition creel surveys 2007–2009).

Total catches (tonnes) caught over the duration of each competition year for the *Offshore League* increased constantly between 2006 (7.5t) and 2009 (96.7t), of which yellowfin tuna contributed an average of $80.4 \pm 7.3\%$ to the catch by weight (Figure 4.4). Although recognized to be based on limited data, total catches (tonnes) caught over the duration of the three competitions fished in the Eastern Cape have decreased from 3.5t in 2007 to 2.1t in 2008, with yellowfin catches dominating catch composition, contributing on average $74.9 \pm 7.3\%$ to the total catch by weight (Figure 4.4).

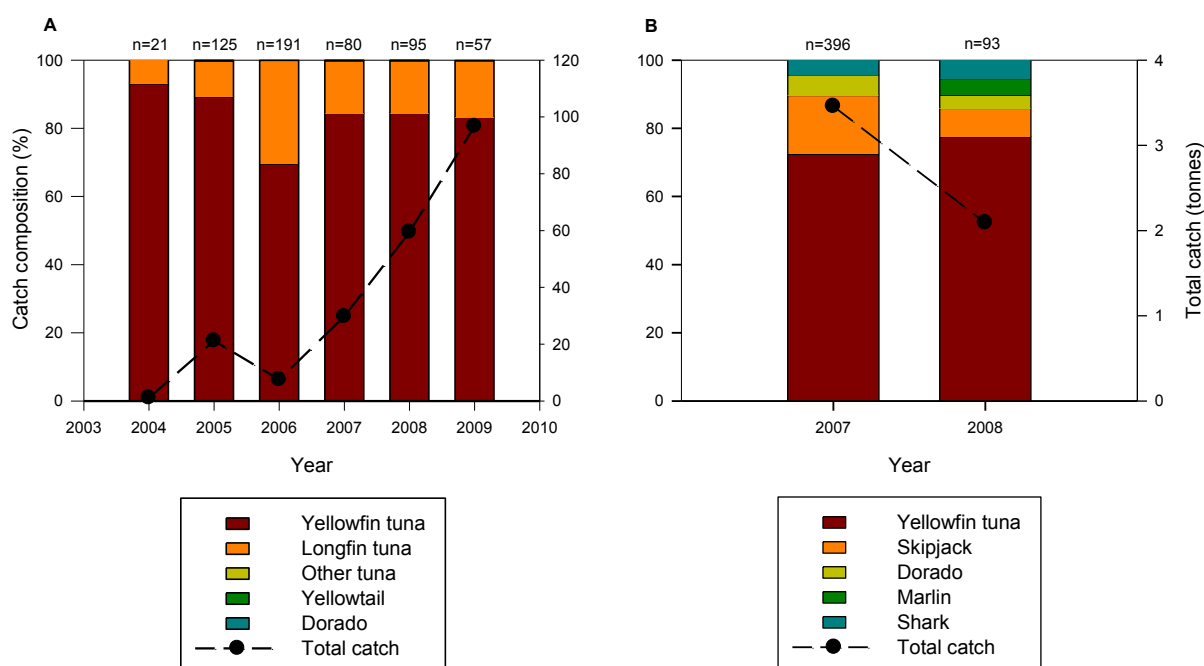


Figure 4.4 Histogram of annual frequency, describing catch composition in weight (t) by region for the tuna sport fishery for the period 2004–2009: (A) Western Cape *Offshore League* competitions (2004–2009); (B) Eastern Cape deep sea angling competitions (2007–2008) (comprising of the *Vangie Tunnie*, *Standard Bank Tuna Classic* and *Port St Francis Tuna and Marlin Challenge* for both sampled years): n = Total number of days fished for the sum of all the competitions per year for (A) and (B); (data source: WPDSAA Offshore league database (2004–2009); Eastern Cape competition creel surveys 2007–2009).

Table 4.3 Recorded catches from ski boat inspections conducted along the KwaZulu-Natal coast in 2009 (Maggs 2010)

Species	Number caught %	Total weight %	Number caught	Total weight (kg)
Yellowfin tuna	8	17	5 486	19 488
Longfin Tuna	0	0	2	8
Big-eye tuna	0	0	1	2
Eastern little tuna	4	6	2 975	6 876
Skipjack tuna	1	2	853	2 567
Striped bonito	0	0	195	475
Other tunas	0	0	4	13
King mackerel	4	12	2 511	13 832
Queen mackerel	3	4	1 686	4 534
Marlins	0	12	123	12 904
Sailfish	0	4	156	4343
Sharks	0	0	50	58
Linefish	79	42	53 052	46 433
TOTAL	100	100	67 094	1 11 532

4.3.4 *Size at capture of fish caught by the sport fishery sector among regions*

A weight frequency histogram comparing mean size class of *T. albacares* caught by the sport fishery sector among regions is summarized in Figure 4.5. The mean size class of yellowfin tuna caught off the Western Cape (Zone A) was $42.3 \pm 14.4\text{kg}$; the mean for the Eastern Cape (Zone B) was $26.2 \pm 13.4\text{kg}$, and the mean for KwaZulu-Natal (Zone C) was $5.3 \pm 3.5\text{kg}$. The relative mean size class of *T. albacares* differed by region (χ^2 test of independence: $\chi^2 = 1$, $df = 2$, $p \leq 0.0$).

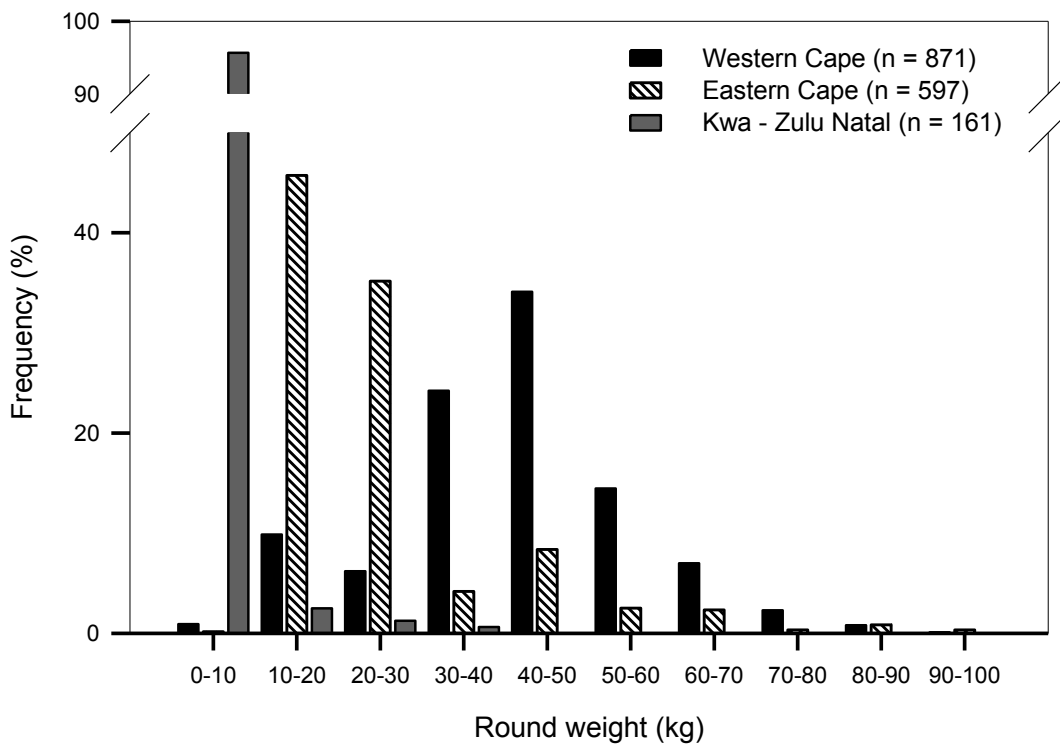


Figure 4.5 Weight frequency distribution for *T. albacares* in sport fishery catches from the Western and Eastern Cape and KwaZulu-Natal between October 2004 and June 2009: (n = Total number of *T. albacares* catch records; data source: WPDSAA Offshore league database (2004–2009); Eastern Cape competition creel surveys 2007–2009; historical Eastern Cape competition catch data; ORI NMLS data 2007–2009).

4.3.5 *Competition angling fixture dates and structure*

Both Western and Eastern Cape competitions apply IGFA governing rules and designate fishing areas specifically bound to each competition. Nevertheless, the structure around the organization for the duration of the number of days fished differs in different regions. The Western Cape’s *Offshore League* has a set number of competitive fishing days spread over the course of the year. From a

total of 2 495 historical catch records, obtained between 2004 and 2009, an average of four separately spaced fixture dates were allocated and spread across the year and fished, weather permitting (Figure 4.6).

The Eastern Cape has three main tuna fishing competitions, all of which are held within the winter months: the Jeffreys Bay *Vangie Tunnie* held in April; the *Standard Bank Tuna Classic* is held in May and the *Port St Francis Tuna and Marlin Challenge* is held in July. Anglers fish for six consecutive days during each competition, weather permitting (Figure 4.6).

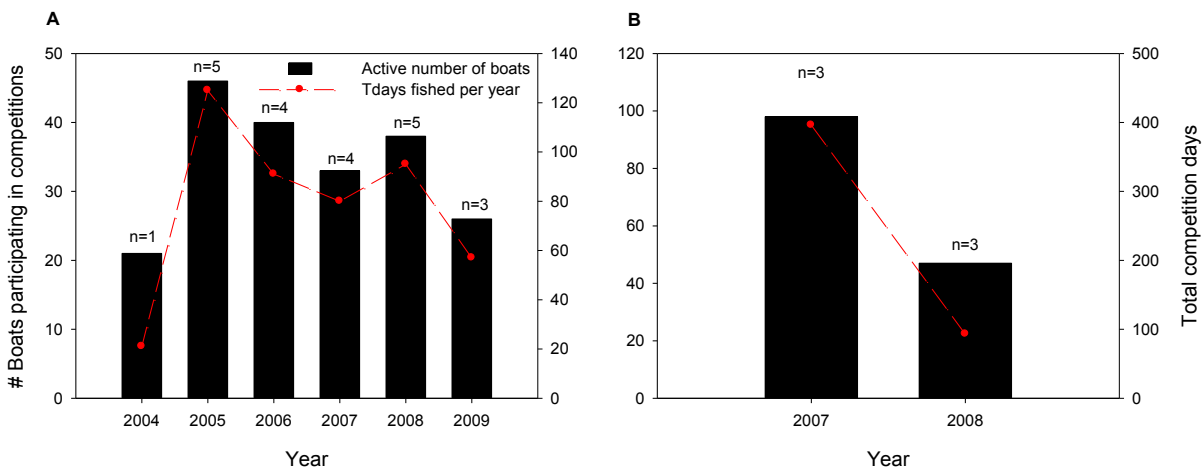


Figure 4.6 Histogram describing the annual directed effort of competitively active tuna sport fishery boats by region for the period 2004–2009: (A) Western Cape *Offshore League* competitions; (B) Eastern Cape competitions (comprising the *Vangie Tunnie*, *Standard Bank Tuna Classic*, and *Port St Francis Tuna and Marlin Challenge*: (n = Total number of competitions fished per year for (A) and (B); (data source: WPDSAA Offshore league database (2004–2009), Eastern Cape competition creel surveys 2007–2009).

4.3.6 Catch-per-unit-of-effort

Fishing area: Western Cape

Annual

The mean annual CPUE for both yellowfin and longfin tuna peaked in 2007, with a high annual mean CPUE for yellowfin in 2005, and was significantly different between years (Kruskall-Wallis rank test: $df = 5, p < 0.05$) (Figure 4.7).

Monthly

This CPUE represents the probability of whether *T. albacares* was present or absent in competitive sport fishery vessel catches, with the percentage odds of capture being lowest in late spring (October Probability of capture (PC) = 0.3) and highest in midsummer (December PC = 0.8) (Figure 4.9). The mean monthly CPUE followed a significant (Kruskall-Wallis by ranks test: df = 6, $p < 0.05$) seasonal trend, gradually increasing from 29.2kg.boat⁻¹.day⁻¹ in October and peaking at 107.2kg.boat⁻¹.day⁻¹ in June (Figure 4.8).

The probability of a competitive sport fishery vessel catching a longfin tuna (PC) was lowest in late autumn (May PC = 0.2) and highest in summer (November PC = 0.6) (Figure 4.9). CPUE differed significantly between months (Kruskall-Wallis by ranks test: df = 6, $p < 0.05$) (Figure 4.8), gradually decreasing from 54.2kg.boat⁻¹.day⁻¹ in November, to 5.7kg.boat⁻¹.day⁻¹ in May.

Fishing area: Eastern Cape

This fishery operates for three months of the year and data were not as comprehensive as those of the Western Cape fishery, which operates for seven months of the year.

Annual

The mean annual CPUE for yellowfin tuna did not differ significantly between years (Kruskall-Wallis by ranks test: df = 1, $p > 0.05$) (Figure 4.7).

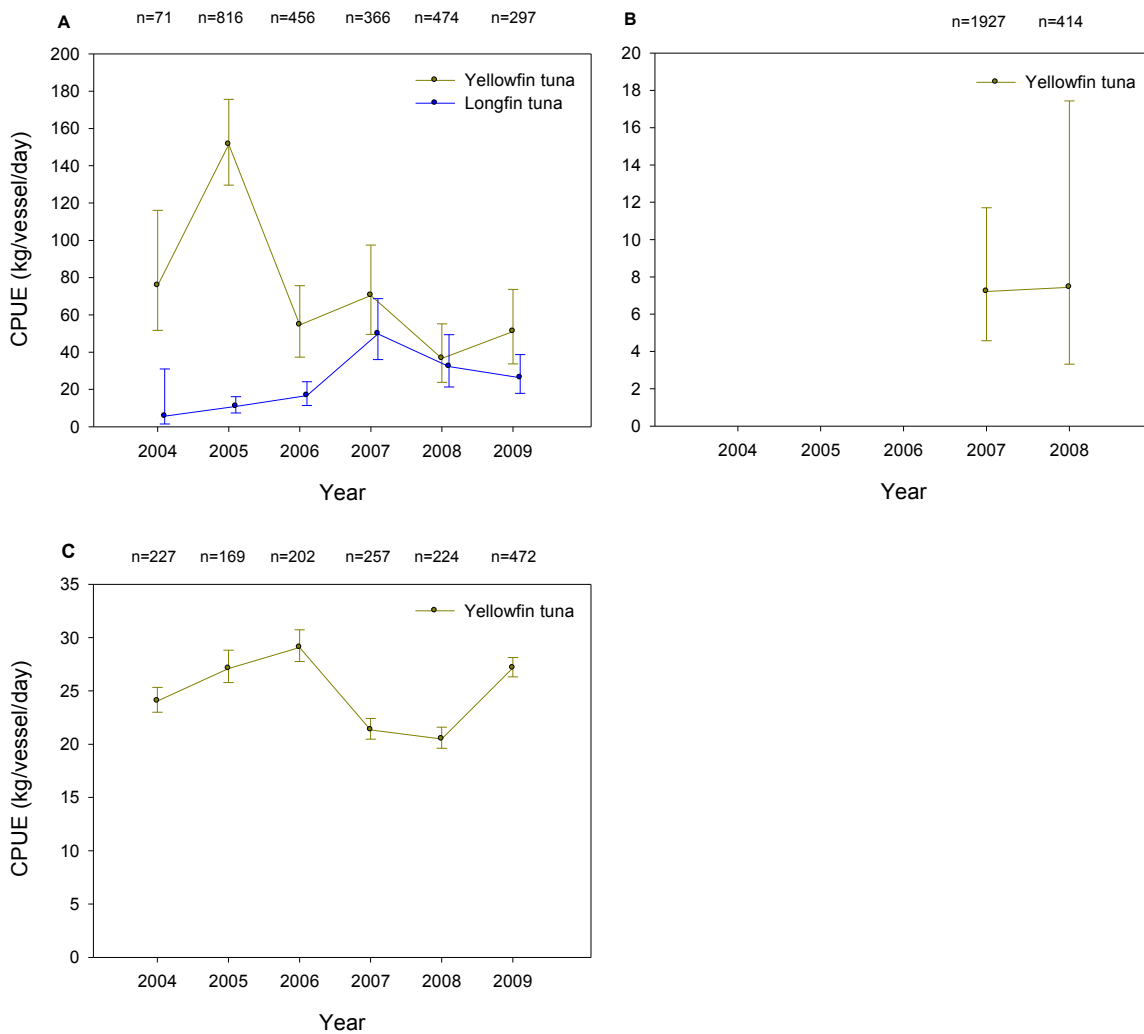


Figure 4.7 Mean CPUE (kg.boat⁻¹.day⁻¹) for all recreational line-fishing and competing sport fishery boats describing annual catch trends for the period 2004–2009 (error bars denote 95 % confidence limits). (A) Western Cape *Offshore League* competitions; (B) Eastern Cape competitions (comprising the *Vangie Tunnie*, *Standard Bank Tuna Classic*, *Port St Francis Tuna* and the *Marlin Challenge*); (C) KwaZulu-Natal yellowfin tuna recreational ski boat catches (CPUE_{pos}): n = Total number of catch records; (data source: WPDSAA Offshore league database (2004–2009); Eastern Cape competition creel surveys 2007–2009, Maggs 2010).

Monthly

The probability of a competitive sport fishery vessel catching yellowfin tuna (PC) was lowest in mid winter (July PC = 0.1) and highest in autumn (April PC = 0.3), differing significantly between months (Kruskall-Wallis by ranks test: df = 2, p<0.05) (Figures 4.8 and 4.9).

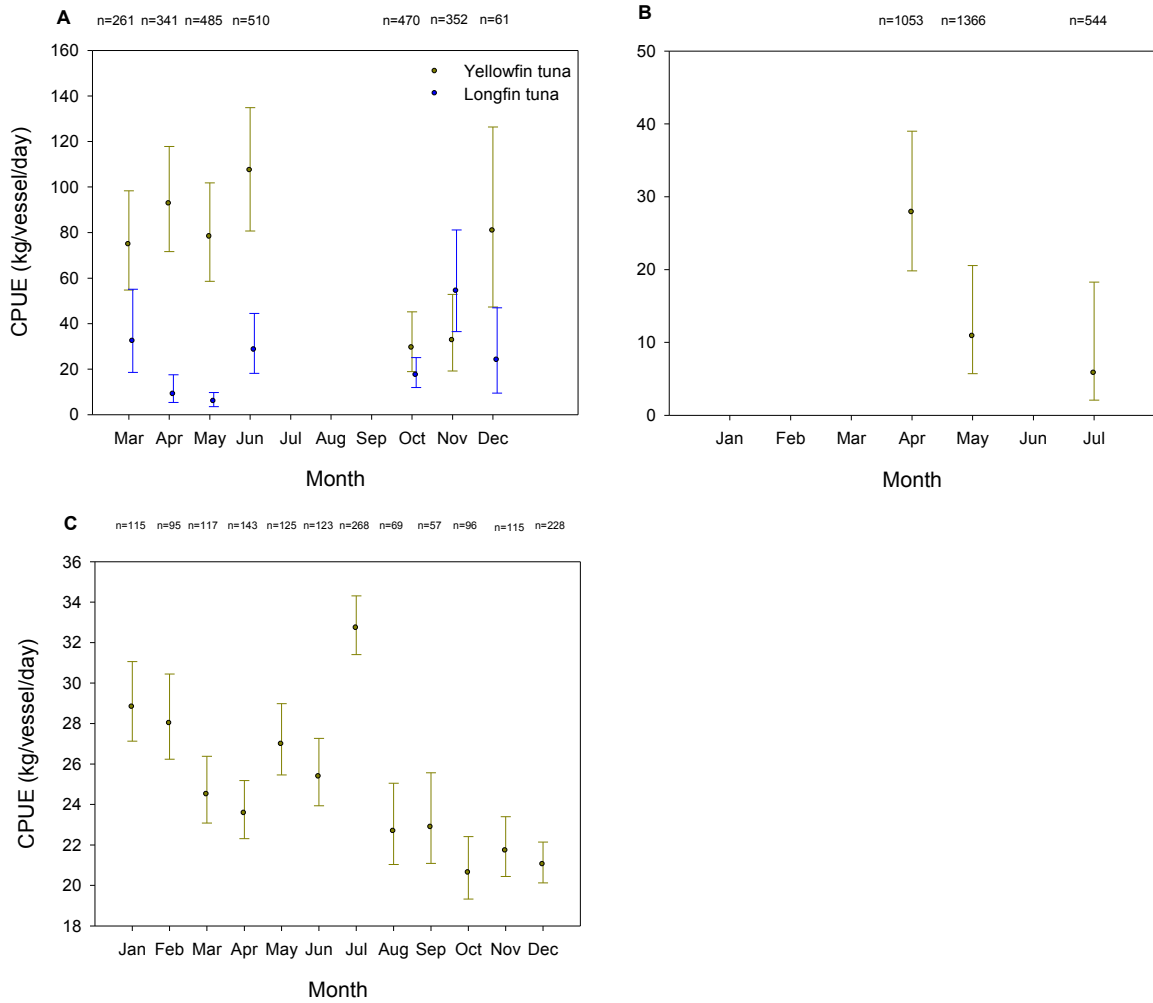


Figure 4.8 Mean CPUE (kg.boat⁻¹.day⁻¹) for all competing sport fishery boats, describing monthly catch trends for the period 2004–2009 (error bars denote 95 % confidence limits): (A) Western Cape *Offshore League* competitions; (B) Eastern Cape competitions (comprising the *Vangie Tunnie*, *Standard Bank Tuna Classic*, *Port St Francis Tuna* and *Marlin Challenge*); (C) KwaZulu-Natal yellowfin tuna recreational skiboat catches (Positive CPUE); n = Total number of catch records; (data source: WPDSAA Offshore league database (2004–2009), Eastern Cape competition creel surveys 2007–2009, Maggs 2010).

Fishing area - KwaZulu-Natal

Annual

The mean annual CPUE_{pos} for yellowfin tuna was highest in 2006 and catch rates differed significantly between years (Kruskall-Wallis by ranks test: df = 5, p<0.05) (Figure 4.7).

Monthly

Yellowfin tuna mean monthly CPUE_{pos} followed a definite bi-seasonal trend, peaking both in January (28.8kg.boat⁻¹.day⁻¹) and July (32.7kg.boat⁻¹.day⁻¹) and differing significantly between months (Kruskall-Wallis by ranks test: df = 11, p<0.05) (Figure 4.8).

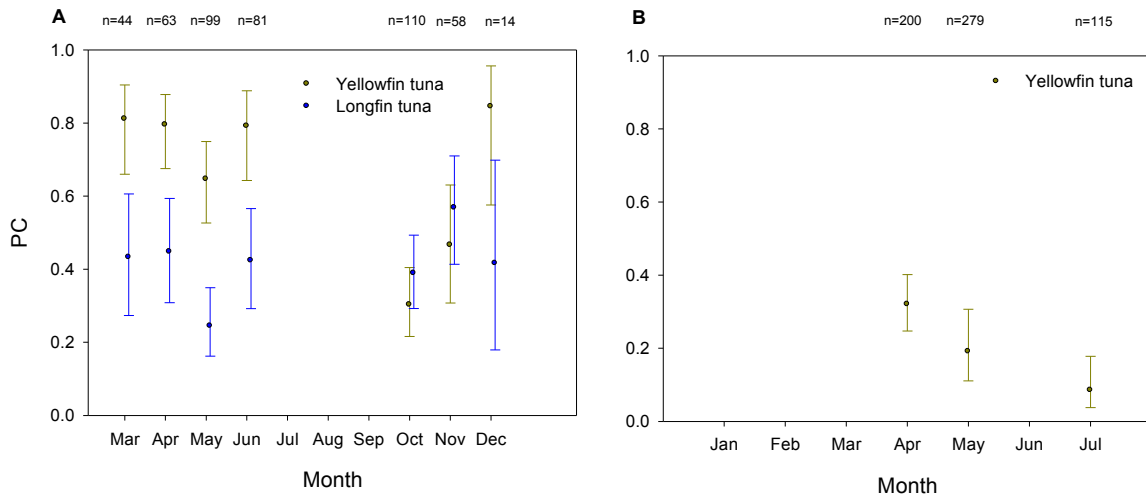


Figure 4.9 The probability of capture for all competing sport fishery boats describing monthly catch trends for the period 2004–2009. (A) Western Cape *Offshore League* competitions; (B) Eastern Cape competitions (comprising the *Vangie Tunnie*, *Standard Bank Tuna Classic*, *Port St Francis Tuna* and *Marlin Challenge*). Error bars denote 95% confidence limits; n = number of recorded data points; (data source: WPDSAA Offshore league database (2004–2009), Eastern Cape competition creel surveys 2007–2009).

4.3.7 Economics of the sport fishery

The main costs incurred were from daily running operating expenses, with fuel being the main expense (ZAR2 881), equating to 71% of total operating costs and 37% of total overheads (Table 4.4). The Eastern Cape tuna sport fishers incur similar overheads per trip and per year, compared to the Western Cape anglers, as they fish in the same manner and travel for similar offshore trip distances (Table 4.4). The value of one kilogram of yellowfin tuna caught by competitive Eastern Cape tuna sport fishers would be worth five times more than that of one kilogram of yellowfin tuna caught by Western Cape tuna sport fishers, when comparing annual and monthly CPUE (Figures 4.7 and 4.8).

Table 4.4 Mean capital expenditure and daily operating costs for the tuna sport fishery (2007–2009) of the Western and Eastern Cape, reflecting all tuna-directed fishing trips. Total number of questionnaire samples = 87; (data source: APCS and Competition questionnaires 2007–2009)

Fixed assets	Capital expenditure (ZAR)			Capital expenditure per day (ZAR)	Capital expenditure per year (ZAR)	
	Mean	Minimum	Maximum		Western Cape (n=27)	Eastern Cape (n=21)
Boat	R 949 024	R 60 000	R 6 000 000	R 2 600	R 69 680	R 55 120
Rods and reels	R 71 713	R 5 500	R 350 000	R 196	R 5 253	R 4 155
Tow vehicle	R 300 708	R 10 000	R 1 000 000	R 824	R 22 083	R 17 469
Trailer	R 45 350	R 2 000	R 200 000	R 124	R 3 323	R 2 629
Tackle	R 21 946	R 500	R 120 000	R 60	R 1 608	R 1 272
subtotal				R 3 804	R 101 947	R 80 645
Running expenses	Operating costs (ZAR)			Operating costs per fishing day (ZAR)	Operating costs per year (ZAR)	
	Mean	Minimum	Maximum		Western Cape (n=27)	Eastern Cape (n=21)
Licensing	R 1 644	R 150	R 50 000	R 5	R 1 644	R 1 644
Storage	R 9 150	R 100	R 35 000	R 25	R 7 398	R 7 398
Maintenance	R 12 979	R 500	R 200 000	R 36	R 12 979	R 12 979
Bait/trip	R 520	R 50	R 6 400	R 520	R 13 936	R 11 024
Fuel/trip	R 2 881	R 500	R 15 000	R 2 881	R 77 223	R 61 087
Refreshments	R 587	R 45	R 6 000	R 587	R 15 724	R 12 438
subtotal				R 4 053	R 128 904	R 106 570
TOTAL				R 7 857	R 230 851	R 187 215

n = average number of tuna directed trips boat⁻¹.year⁻¹

The Western Cape’s *Offshore League* total fishery expenditure for 2009 was ZAR447 862 (Table 4.4), with a total of 57 competitively fished trips undertaken by 26 active boats (Figure 4.6). The joint total fishery expenditure for the Eastern Cape sport fishery competitions in 2008 was ZAR730 723 (Table 4.5), comprising a total of 93 competitively-fished trips by 47 active boats.

Table 4.5 Estimated total expenditure (value) for the sport fishery for those vessels competing in the Western Cape *Offshore League* (2009) and the Eastern Cape competitions (comprising the *Vangie Tunnie*, *Standard Bank Tuna Classic*, *Port St Francis Tuna* and the *Marlin Challenge* (2008)).

Year	Category	Species	Region	
			Western Cape	Eastern Cape
2008			R 746 437	R 730 723
	^a Total fishery expenditure (ZAR)			
2009			R 447 862	
	^a Equation 4.2			

4.4 Discussion

The collection of South African recreational data is somewhat fragmented but descriptions of the size and shape of the South African recreational fishery do exist (Griffths and Lamberth 2002, Leibold and van Zyl 2008, McGrath *et al.* 1997, Sauer *et al.* 1997), which allows for some comparison with other global studies. In South Africa, 37% of recreational anglers participate in saltwater angling, similar to that of USA saltwater anglers (26.7%) as recorded by the 2006 national survey (Leibold and van Zyl 2008, U.S. Fish & Wildlife Service 2006).

Studies conducted by McGrath *et al.* (1997) and Sauer *et al.* (1997) estimated the ski boat recreational fishery within South Africa to be in the range of 3 444 vessels with 12 054 active participants, of which 48% were affiliated to clubs or organizations. Recent studies (2008) show the size of the recreational deep-sea facet to be in excess of 31 800 anglers which, in part, is likely to be due to increased popularity in ski boat angling and a growing interest — since the start of the commercial boom in 1996 — in catching yellowfin tuna (Leibold and van Zyl 2008). Similarly,

pelagic fishing tournaments and clubs in Hawaii have grown from attracting 22 competing teams in 1959 to more than 160 teams in 1990 (Schultz *et al.* 2003).

Not surprisingly, the demographic make-up between South African recreational fisheries and American sport fisheries are similar: the majority of anglers are in the middle-to-late age group and are represented by the more affluent members of society (U.S. Fish & Wildlife Service 2006). Interestingly, the USA's recreational saltwater angler participation decreased by 18% between 1996 and 2000, whereas South Africa's sport fishery has increased (Leibold and van Zyl 2008, McGrath *et al.* 1997, Sauer *et al.* 1997, U.S. Fish & Wildlife Service 2006). This is likely to be a result of an increasing number of more affluent members of South African society, following the democratic elections in 1994. However, in South Africa, participants continue to comprise mostly white males above the age of forty. The low number of historically disadvantaged South Africans taking part in deep-sea angling is not a reflection of lack of access or entry into this sport: two separate studies — by Andrew *et al.* (2000) and Ellender *et al.* (2009) — on the participation by different groups in the recreational fishing have indicated that fishing is not traditionally practiced across all demographic groups.

It is interesting to compare South African and Australian recreational fisheries: in both countries, sports fishers are prepared to travel large distances offshore to target game fish (Galeano 2004). In Australia the sport fishery comprises participants of predominantly 20–40 years and greater than 40 years, from the more affluent members of society (Galeano 2004, McGrath *et al.* 1997). In both groups the proportion of fuel costs to overall operating costs is high. Both fisheries target tuna and tuna-like species, with additional catches of billfish and shark. The offshore species diversity in New South Wales (NSW) is however higher than that in South Africa (Galeano *et al.* 2004, Park 2007): in NSW's monitored gamefish tournaments, yellowfin tuna are reported to comprise 22% of total catch composition per boat per day, whereas this species comprises 84% of total catch

composition per boat per day in tournaments held in the Western Cape, and 75% in Eastern Cape gamefish tournaments (Park 2007).

The Western Cape has the largest catches of yellowfin tuna within southern Africa, which is possibly a result of increased targeting for game fish in the Western Cape and the availability of tuna for longer periods of the year. In comparison, the recorded catches from ski boat inspections, conducted along KwaZulu-Natal in 2009, showed a minimal contribution (of only 17.5% by weight) of yellowfin tuna towards total catches (Maggs 2010).

Monitored CPUE of dedicated gamefish tournaments along the entire New South Wales (NSW) coastline indicated mean catch rates of yellowfin tuna of between 0.41 and 1.28 fish caught per boat per day, where the mean size class of yellowfin tuna caught was 23kg (Park 2007). This is similar to the CPUE of the Eastern (0.2 fish.boat⁻¹.day⁻¹) and Western Cape (1.4 fish.boat⁻¹.day⁻¹) recorded by recreational ski boat fishers in South Africa. The mean size class from these two regions was larger (42.3 ± 14.4kg) for the Western Cape than for the Eastern Cape (26.2 ± 13.4kg). South Africa, in particular the Western Cape, is at the southernmost point of *Thunnus albacares* distribution range; therefore the fluctuating catch rates for regional tournaments may be more related to oceanographic conditions than to regional stock abundance. This relates to the response of this species to water temperature, probably influenced by the warm Agulhas current (Lehodey and Leroy 1999).

The value of the catch is significant and largely dependent on the region fished. For example, the Eastern Cape has a lower CPUE than the Western Cape although the operating expenses in the two regions are similar. The net returns from recreational fishing vary significantly from year to year but can be significant; in 1997 recreational fishing contributed 23.7% of the total gross global product (GGP) of the South African line fishery (McGrath *et al.* 1997). In Australia the total estimated net returns for the commercial, charter and recreational eastern tuna and billfish fisheries in 2001–2002

were AUS\$3.5 million, AUS\$2.5 million and AUS\$4.9 million, respectively (Galeano *et al.* 2004). These findings suggest that the sectors should be managed collectively, as each contributes significantly to the GDP and GGP (Galeano *et al.* 2004).

The present analysis clearly demonstrates the lack of comprehensive catch and effort data for the sport fishery. An inshore observer program to collect catch and effort data on fish landings, in order to evaluate catch trends, is presently being conducted. The aim is to achieve a minimum of 30% coverage for recreational fisheries. The programme does not, however, take socio-economic aspects per fishery sector into account. Although not comprehensive, data from competitions is also extremely useful. When considered in conjunction with biological and socio-economic information such data can be used to evaluate the state of recreational fisheries (Gartside *et al.* 1999). In the future there needs to be a greater focus on obtaining competition data, for the purpose of gaining catch and effort data as well as relevant socio-economic information. Various authors have noted that catch data obtained from participants at competition meetings is of a higher quality than information from non-club anglers who have varied levels of skill (Gartside *et al.* 1999, Williams 2003, Cass-Calay 2008). Collection of data from sports fishers is inexpensive and the location of organized clubs and competition meetings along the Southern African coastline is widespread. Information acquired from such sources can therefore provide useful data for assessing spatial catch trends. At present there is, however, a general lack of resource-user involvement in such activities (Hutton *et al.* 2001).

5. CHARACTERISING AND DESCRIBING THE COMMERCIAL TUNA BAITBOAT FISHERY IN SOUTH AFRICA

5.1 Introduction

The South African commercial tuna fishery consists of a number of full-time (longline and tuna baitboat) and part-time (line fishery and charter) operators (Sauer *et al.* 1997). These sectors actively target the migratory *Thunnus albacares* when it is seasonally available. Baitboats operate from regionally specific home ports along the coastline, whereas the tuna longline fleet, a formal fishery, targets this species in separate offshore waters, actively fishing for up to a month at a time in the Agulhas current along the entire Southern African continental shelf (Sauer *et al.* 1997, Sauer *et al.* 2003). *Thunnus alalunga* catches are exported to canning markets and other tuna species, *T. albacares* and *T. obesus*, are exported to fresh sashimi markets in Europe, the United Kingdom, the United States of America, and Japan (DEAT 2004, DEAT 2006).

Tuna longline and baitboat fisheries are regulated by the allocation of long term commercial fishing rights (DEAT 2004, DEAT 2006) whereby commercial quotas are awarded to operators for a period of ten years by the Department of Environmental Affairs and Tourism: Marine and Coastal Management (DEAT 2006). The main objective for allocating long-term rights is to maintain a sustainable catch yield of tuna (DEAT 2006) and the allocation (for a period of ten years before reapplication: DEAT 2004, DEAT 2006) of long term exploitation rights in 2005 meant that stakeholders had more security than was previously the case. Conditional of the long term rights is that LTRHs must uphold national provisions and regulations as set out in the Marine Living Resources Act (Act No. 18 of 1998), the National Environmental Management Act (Act No. 107 of 1998), the National Biodiversity Act (Act No. 10 of 2004), the Sea Birds and Seals Protection Act (Act No. 46 of 1973) and the Marine Pollution Act (Act No. 2 of 1986).

On a national level, quotas are allocated and awarded by RFMOs, such as the ICCAT and IOTC, and quotas are determined by the catch performance of vessels. As a result, LTRHs still have no guarantee that their quotas will be renewed from year to year. The national quota allocation is also dependent on the development of a management plan that, in the case of tuna fisheries in South Africa, must be promulgated in terms of regulations based on sound scientific information, equitable distribution of the resource amongst user groups, the prohibition on the sale of tuna by recreational fishers, and the development of just management regulations for the species (van der Elst 1993).

To date, there is no management plan for the South African baitboat fishery and this sector is therefore managed on an *ad hoc* basis according to the tuna longline management plan. The paucity of information on both the tuna fishery and the tuna stocks in South Africa constrains further development of the sector as well as the development of a baitboat-specific management plan. This also constrains the development of the sector, particularly the Marine Stewardship Council Affiliation certification for fresh tuna.

As a result of the paucity of information, upon which a comprehensive management plan could be based, the Department of Marine and Coastal Management has begun to compile baseline information and are in the process of developing an Operational Management Plan for the baitboat fishery. Socio-economic information should form the basis for all management plans (McGrath *et al.* 1997) and the development and management of this recently-established tuna fishery urgently requires baseline information. Catch and effort data for this fishery have been recorded since 1995 by the National Marine Linefish System, allowing for the calculation of spatial and temporal catchability trends so as to increase understanding of the fishery dynamics. The objective of this

chapter is therefore to provide baseline information by characterising and describing South Africa's commercial baitboat fishery by qualitatively and quantitatively assessing the size and shape of the baitboat fishery; including total catch, effort, CPUE, and socio-economic information.

5.2 Material and methods

As with the recreational fishery, discussed in Chapter 4, the characterisation of the commercial baitboat sector requires a multi-faceted research approach that includes metadata analysis of catch and effort data, creel surveys (size selectivity), and informal socio-economic questionnaire surveys.

5.2.1 Metadata analysis

To describe the fishery, a review of information characterising the South African baitboat fishery was obtained from the DEAT (subsection MCM) and used to describe the current fishery (DEAT 2004, DEAT 2006, DEAT 2009b).

Historical catch data were obtained from the National Marine Linefish System (NMLS) data base from the Department of Environmental Affairs (DEAT) subsection Marine and Coastal Management (MCM) between February 1995 and December 2009.

Catch composition and species directed effort

Catch and effort data for tuna baitboat vessels were sorted and categorised according to ten main commercial categories: albacore (longfin tuna), big-eye tuna, bluefin tuna, tuna (general), yellowfin tuna, snoek, swordfish, line fish, shark and yellowtail. The category "tuna" comprised the pooled catch and effort data for insignificant catches of smaller tuna species, namely skipjack tuna *Katsuwonus pelamis* and bonito *Sarda sarda*. The category "line fish" comprised the pooled catch and effort data for species such as the atlantic pomfret *Brama brama* and others. The catch

composition and effort per commercial category were expressed as a percentage of total weight (kilograms) of fish caught in Zone A and as a percentage of the total days fished, targeting specific species for the period February 1995 to December 2009.

Effort

Mean annual and monthly effort for the baitboat sector within each region was calculated using the following equation:

$$\bar{E} = \frac{A}{n} \quad \text{(Equation 5.1)}$$

Where \bar{E} denotes the mean number of active vessels fishing, A is the number of recorded vessels fishing, and n is the number of vessels.

Catch-per-unit-effort

Catch and effort information provided for each vessel (recorded as daily information) in the NMLS database was left-skewed due to a high occurrence of zero catches. To calculate CPUE while accounting for zero catch data with skewed effects, a hurdle model, formulated around a delta-X distribution, was used for analysis (for further detail with examples and equations, refer to Chapter 2: Study Area and Sector Descriptions) (Fletcher *et al.* 2005, Maunder and Punt 2004, Pereira *et al.* 2008, Punt *et al.* 2000, Stefánsson 1996). Catch records were categorised according to geographic locality within the three managerial zones. The data were pooled according to years and months, to describe annual and seasonal catchability trends (for further detail on equations, refer to Chapter 2: Study Area and Sector Descriptions).

5.2.2 Access Point Creel Survey

To determine catch an APCS was conducted for five main harbours within the Western Cape between October 2007 and 2008, using the bus-route method (Robson and Jones 1989). All species

caught were either measured by fork length (FL) or total length (TL) and, in cases where numbers of catches by vessel were large, total numbers per species were recorded and a sub-sample measured. Individual fish weights were calculated using length-weight relationships, as calculated using van der Elst and Adkins (1991) and Torres (1991) studies on species length-weight growth parameters (for further details refer to Chapter 2). Recorded creel data were not used for modelling CPUE as data were scarce; hence these data were used only for calculating size selectivity of *T. albacares*.

To determine vessel effort and type of fishing activity per harbour, counts of vessels were made during each access point survey and the type of activity and type of vessel (with vessel ID) were recorded so as to prevent repetitive counts.

5.2.3 Questionnaire surveys

Questionnaire – informal interviews during Access Point Creel Surveys

A questionnaire was administered during APCS to determine crew demographics:

- number of fishers per vessel and the racial group, gender and age of fishers
- socio-economic information (occupation/ residency of vessel owner/ operating expenses of vessel).

Questionnaires were administered to vessel skippers after the APCS was completed. As many skippers as possible were interviewed on any sampling day (Appendix 9.2).

Questionnaire – informal interview of FTEA baitboat members

Detailed questionnaires obtained from Mather *et al.* (2003) were reworked, incorporating tuna baitboat aspects. These were completed by skippers affiliated to the *Fresh Tuna Exporters*

Association (for further detail refer to Chapter 2: Study Area and Sector Descriptions; for the questionnaire refer to Appendix 9.3).

Economic data

Economic data were obtained from questionnaire surveys. The annual costs, licensing, moorage and levies were paid as fixed annual once-off payments (Table 5.2). Daily costs for remaining running expenses (bait, fuel, food and ice) were calculated according to the average number of days spent at sea per vessel category. All annual expense calculations were based on mean annual effort per vessel category, according to the days spent at sea: ski boat (24.5 ± 13 days), 11–15m deckboat (72 ± 52 days), 15–19m deckboat (55 ± 36 days) and freezer deckboats (37 ± 24 days) (Table 5.2). Depreciative insurance rates and other information relating to fixed assets were obtained from Mr Steven Cameron-Dow (active tuna baitboat long-term rights holder and owner of two 11–15m deckboats). Fixed assets were depreciated using a reduced balance method, based on the assumption that fixed asset purchase dates were unknown and on whether the asset was being depreciated into the future (next five years) or the previous five years; hence the final value was slightly inflated in terms of both assumptions. Vessels were insured at current replacement value and maintained at that rate. Fishing tackle, which included rods-and-reels and hooks, were insured under an *all risks* policy scheme, to values of up to ZAR20 000. Trailers were deemed to not depreciate, i.e. to maintain their resale value. Mean values were used for all calculations.

The total value for a kilogram of tuna, the market value, and the total fishery expenditure (fishery value) for the tuna baitboat fishery (2009) of Southern Africa (Table 5.3) were originated for this study and calculated as follows:

- (1) Total value of a kilogram of tuna to the baitboat fishery in 2009 was calculated as follows (Equation 5.2):

$$\text{Total value} = \frac{((\text{total catch of F T FT m arket value}) (\text{total catch of FT FT m arket value}))}{\text{Total fishery catch}}$$

(2) The total market value for a given species per year was the total net worth of the total catch (tonnes) for that species, calculated as follows (Equation 5.3):

$$\text{Total market value} = \text{total catch} \times \text{market price} \quad \text{Equation 5.3}$$

(3) Total vessel category expenditure (value) per vessel category for the baitboat fleet (n =81) in 2009 was calculated as follows (Equation 5.4):

$$\begin{aligned} \text{Total vessel category expenditure (value per year)} = & (\text{total days fished. year}^{-1} \cdot \text{category}^{-1} \\ & \times \text{operating costs. day fished}^{-1} \cdot \text{category}^{-1}) \\ & + (\text{number of vessels. category}^{-1} \times \text{depreciated capital expenditure. category}^{-1}) \quad \text{Equation 5.4} \end{aligned}$$

Data limitations associated with the baitboat National Marine Linefish System database

The tuna baitboat vessel catch and effort NMLS data base obtained from MCM is incomplete: there are some currently-active vessels fishing for which management have no details, and some inactive vessels are recorded as being active, having catch data even though there is a complete absence of effort data corresponding to the IDs of such vessels. For this reason, the complete NMLS data base (1995–2009) has been used to compile and describe catch composition, species directed effort, mean annual and seasonal CPUE only. However, when micro-scaling down and assessing the catch and effort data among the four described vessel categories for 2009, certain deficiencies in the data coverage were noted: of the recorded 115 active vessels, only 81 had complete legitimate catch and effort data that could be used to calculate estimated tuna value, market value, total fishery expenditure and the relationship between effort (total days fished per vessel for 2009) and species-specific CPUE (kg. boat⁻¹.day⁻¹) (Figures 5.5a to 5.5d and Table 5.5a).

5.3 Results

5.3.1 *The Baitboat Fishery: Metadata Analysis*

The tuna baitboat fishery is a surface-gear-orientated fishery that targets juvenile albacore in the southeast Atlantic. Yellowfin tuna constituted less than five percent of the annual catch up until 2007, after which a greater effort was directed towards this species, resulting in a dramatic increase in its contribution towards the total catch (DEAT 2006, DEAT 2009b). This fishery can now be separated into two components: the West Coast tuna baitboat fishery that operates in waters above 17°E longitude, fishing as far west as Sea Tripp and Vema and as far south as the 35°S latitude and 18°E longitude; and the South Coast fishery that operates between longitudes of 17°E and 21°E.

Long-term rights were allocated in 2005 in an effort to achieve a sustainable and manageable catch performance based fishery (DEAT 2006). This policy was implemented by allowing and capping a Total Allowable Effort of 200 vessels, or 3 600 crew, in 2006 (DEAT 2006, DEAT 2009b). In 2005, effort in the fishery consisted of 163 vessels and 2 734 crew, and since 2007 the effort has consisted of 198 vessels and 2 961 crew.

Vessel categories

Four types of vessels are present in this fishery (DEAT 2004, DEAT 2009a), which can be loosely grouped into the following categories:-

(1) Large onboard freezer vessels in excess of 19m with a crew above 20 members. These vessels can operate for long periods out at sea and normally venture to Tripp Seamount and South Bank for extended periods in search of longfin tuna.

(2) Larger deck boats of 15–19m that can stay out to sea for up to five days. They supply the fresh fish market from fish kept fresh within ice slurries. These boats are powered by a single inboard motor of between 180 and 255 hp and carry fewer than 20 crew members.

(3) Smaller deck boats, known as "tullys". These carry fewer than 12 crew, are 11–15m in length, are powered by a single inboard motor of between 180 and 255 hp, and can stay out to sea for up to five days. They supply the fresh fish market from the fish kept fresh within ice slurries.

(4) Ski boats of 7–11m long, powered by two outboard motors in excess of 200 horse-powers, carrying an average of six crew members. They make days trips to the tuna grounds (<55nm), keeping fish chilled within ice slurries (DEAT 2009b, DEAT 2006).

5.3.2 Vessel category analysis: Access Point Creel Survey

Results of Western Cape ACP surveys have indicated that tuna baitboat vessels make up 17.6% of the total number of sampled vessels, of which 8.5% are comprised of tuna baitboat deckboats and 9.1% are tuna baitboat ski boats. Hout Bay and Cape Town harbours support the bulk of the tuna baitboat fishery, with smaller harbours (Simons Town and Gordons Bay) supporting the smaller baitboat ski boats only. Figure 5.1 shows vessel category activities per harbour within the Western Cape.

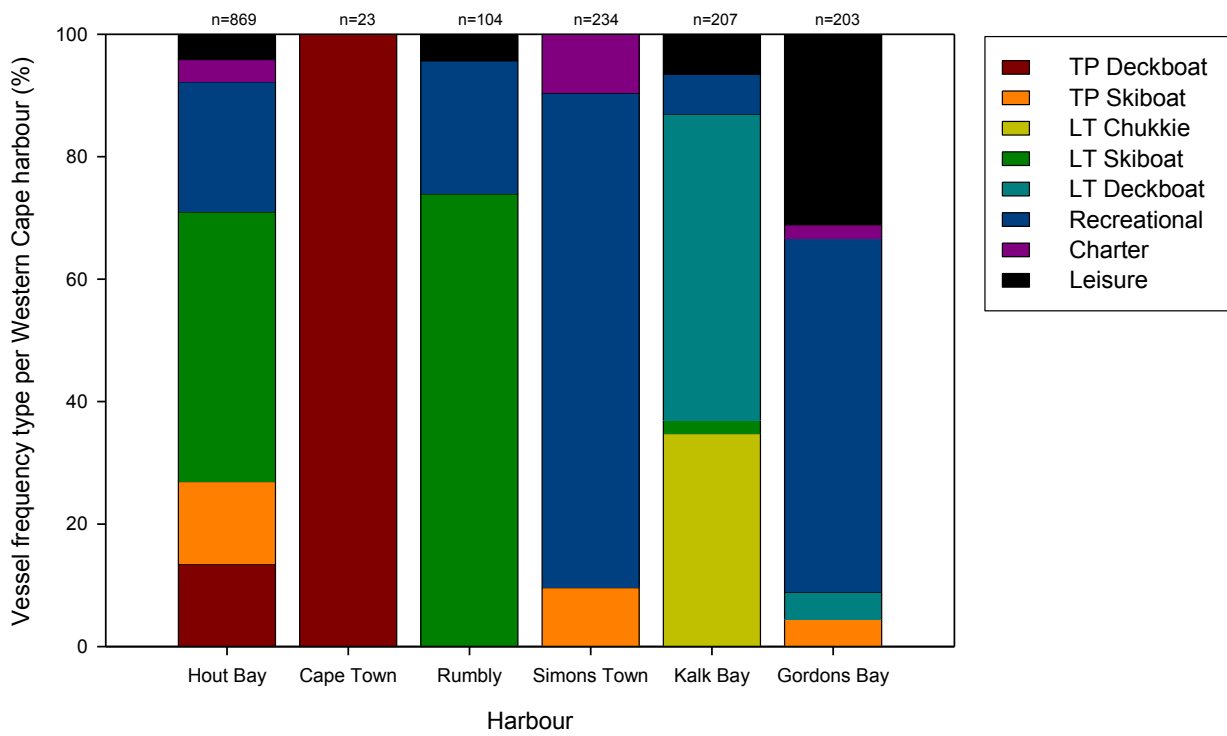


Figure 5.1 Frequency histogram describing vessel activity per harbour within the Western Cape for the year 2007–2008. (Data source: APCS 2007/2008)

5.3.3 Baitboat Fishery Demographics and Characteristics

Access Point Creel Survey and Questionnaire analysis

Due to the confidential nature of this type of structured survey, only eighteen returns from a possible sixty were obtained.

Each deck boat was predominantly manned by 9.8 ± 2.0 crew members of 20–40 years in age (87.6%) (Table 5.1a). Crew were predominantly Black African (74%) with 22% white and 4% coloured (Table 5.1a). The tuna baitboat ski boats were manned by 5.8 ± 1.4 crew in an even age category split of 20-40 and >40 years (Table 5.1a). The racial composition among crew members of baitboats was 45% white, 48% Black African, and 7% coloured (Table 5.1a). Ninety percent of tuna baitboat skippers were white, and accompanying first mates were either white or coloured. Racial designation amongst crew was highly variable (refer to Table 5.1a) and all members actively

participated and shared responsibilities aboard the vessel, whether their work involved being a “rod-reel man”, a “poler” or a “gaffer” (Plate .1).

Table 5.1a Tuna baitboat angler characteristics by user group (2007/2009) (data source: APCS and ESS).

Characteristics	Category	Skiboat	Deck boat	
^a Race	White	44.6%	21.8%	
	Coloured	7.2%	4.0%	
	Black	48.2%	74.2%	
^{a+b} Racial designation		Skipper	Mate	Crew
	White	90%	50%	26%
	Coloured	10%	50%	29%
	Black	0%	0%	45%
^b Nationality (combined for all vessels)	Angolan	8%		
	Mozambican	3%		
	Namibian	13%		
	South African	75%		
	Other	1%		
^a Gender	Male	100%	100%	
^a Age	< 20 yrs	0.5%	0%	
	20-40 yrs	54.1%	87.6%	
	> 40 yrs	45.4%	12.4%	
^a Number of crew		5.9 ± 1.4	9.8 ± 2.0	
^b Employment type (combined for all vessels)	Commission	100%		
	Full-time	21%		
	Part-time	72%		
	Day	7%		

^a Values based on APCS

^b Values based on ESS questionnaire returns (n = 14); total of 100 crew demographic entries.

The tuna baitboat fishery is entirely skippered and crewed by men, with 75% of the crew being South African. The fishery is commission based, whereby wages are calculated as a percentage of total catches landed per trip. The skippers and first mates are employed full-time, while general crew have part-time employment engagements, lasting up to seven months at a time (Table 5.1).

The majority of vessel skippers were white (90%), coloured fishers were mates and crew, and black fishers were all crew (Table 5.1).

Crew designation type and description

Rod-reel man:

Fisher who targets yellowfin tuna using heavy duty stand-up rod and reel gear with a single baited hook.



Photograph by: Steven Cameron-Dow (2007)

Poler:

Fisher who targets tuna using a 4. m bamboo pole “rod” with a short length of thick 4 k g monofilament attached to the end with a single barbless hooked artificial lure (plastic squid “cavalas”) tied to the end of the monofilament. The poler holds the pole over the side of the gunwhale and “wims” cavalas on the surface of Ocean, enticing tuna to strike. Once the tuna is hooked, the poler pulls the tuna toward the gunwhale and gaffer by shortening his grip toward the end of the pole.

Gaffer:

Fisher solely responsible for the gaffing and bringing tuna aboard the vessel.



Plate 5.1 Characterising baitboat crew designation.

5.3.4 *Economics of the tuna baitboat fishery*

Costs can be divided into capital costs and running expenses.

Running costs

Daily mean expenditure, in different types of boats, for fuel usage and for bait was as follows: in ski boats fuel cost ZAR2 302.boat⁻¹.day⁻¹ fished and bait cost ZAR419. boat⁻¹.day⁻¹ fished (Table 5.2); 11–15m deckboats used ZAR1 650.boat⁻¹.day⁻¹ of fuel and ZAR1 035 for bait; 15–19m deckboats used ZAR4222.boat⁻¹.day⁻¹ of fuel and ZAR889 worth of bait; freezer deckboats used ZAR4217.boat⁻¹.day⁻¹ for fuel and ZAR600 for bait (Table 5.2). For ski boats, 11–15m and 15–19m deckboats, fuel and bait costs amounted to an average of $67.9 \pm 9.1\%$ of the total running costs per

day, whereas fuel and bait accounted for 82.8% of the total running costs per day in freezer deckboats (Table 5.2).

Cost per kilogram of tuna

In 2009, the running costs incurred per day fished for ski boats was ZAR4 214, ZAR4 409 for 11–15m deckboats, ZAR6 540 for 15–19m deckboats, and ZAR5 820 for freezer boats (Table 5.2), whereas the average CPUE of yellowfin tuna across all four vessel categories was 58.8kg.boat⁻¹.day⁻¹ and longfin tuna was 373.2kg.boat⁻¹.day⁻¹. The total catch composition was comprised of 4% yellowfin tuna with an average selling price of ZAR30.kg⁻¹ and 92% longfin tuna at an average price of ZAR13.kg⁻¹. The remaining 4% of the catch composition, of which 2.4% was predominantly skipjack tuna, were mostly consumed by crew members. The combined mean value of tuna per kilogram for all vessel categories in the baitboat fishery in 2009 was ZAR13.1.kg⁻¹, whereas the value of tuna was highest in 2006 (ZAR17.kg⁻¹) when the contribution of yellowfin tuna to total catches was high (26.5%). Tuna values were low when the yellowfin tuna contribution to total catches was minimal (Figure 5.2).

The total market value for 3 684 tonnes of yellowfin and longfin tuna caught in 2009 by the 81 recorded vessels was ZAR50.1 million (Table 5.3), whereas the total fishery running expense for 2009 was ZAR23.6 million. The total fishery expenditure (fishery value), undertaken by 81 active boats in 2009 was estimated at ZAR160.2 million for a total of 4 204 days fished (Table 5.3).

Table 5.2 Mean capital expenditure and daily running costs per vessel category for the commercial tuna baitboat fishery (2008/2009) of Southern Africa. Total number of questionnaire samples = 18; (data source: ESS questionnaire directed at FTEA members).

Fixed assets	Capital expenditure (ZAR) (Reduced balance depreciation (9.2% over 5yrs))			
	Ski boat (7-11m)	Deckboat (11-15m)	Deckboat (15-19m)	Freezer deckboat
Boat	R 608 405	R 1 747 547	R 1 941 719	R 2 158 544
Rods, reels and poles	R 4 050	R 10 053	R 6 849	R 296
Total	R 612 456	R 1 757 600	R 1 948 568	R 2 158 840

Running expenses	^a Operating costs per day fished (ZAR)				^b Operating costs per annum (ZAR)			
	Ski boat (7-11m)	Deckboat (11-15m)	Deckboat (15-19m)	Freezer deckboat	Ski boat (7-11m)	Deckboat (11-15m)	Deckboat (15-19m)	Freezer deckboat
	(n = 39 days fished)	(n = 91 days fished)	(n = 90 days fished)	(n = 120 days fished)	(n = 25 days fished)	(n = 72 days fished)	(n = 55 days fished)	(n = 37 days fished)
Licensing/maintenance	R 450	R 222	R 133	R 108	R 17 352	R 20 208	R 12 000	R 13 000
Moorage	R 394	R 86	R 11	R 21	R 15 200	R 7 798	R 1 000	R 2 500
Levies	R 48	R 89	R 118	R 124	R 1 838	R 8 141	R 10 620	R 14 880
Tackle	R 95	R 218	R 167	R 83	R 2 381	R 15 680	R 9 167	R 3 083
Bait	R 419	R 1 035	R 889	R 600	R 10 476	R 74 496	R 48 889	R 22 200
Fuel	R 2 302	R 1 650	R 4 222	R 4 217	R 57 552	R 118 782	R 232 222	R 156 017
Food	R 383	R 453	R 500	R 667	R 9 566	R 32 619	R 27 500	R 24 667
Ice	R 124	R 656	R 500	-	R 3 095	R 47 257	R 27 500	-
Total	R 4 214	R 4 409	R 6 540	R 5 820	R 117 460	R 324 981	R 368 898	R 236 347

n = average number of days at sea. boat⁻¹.vessel category⁻¹ in 2009

^aOperating costs per day fished (ZAR) = values based on mean effort values per vessel category from returned FTEA questionnaires

^bOperating costs per annum (ZAR) = values based on mean effort values per vessel category from NMLS data set (2009).

Table 5.3 Estimated total tuna value, total market value and total per vessel category for the commercial tuna baitboat fishery (2009) of South Africa (n = 81 active vessels; data source: NMLS 2009 figures).

Vessel category	^a Total tuna value.kg ⁻¹	^b Total market value	Total running expenses	Total fishery expenditure (value)
Ski boat (7-11m)	R 12.2	R 2 564 063.0	R 1 135 321.8	R 7 872 337.8
Deckboat (11-15m)	R 13.3	R 13 340 108.0	R 6 014 978.3	R 39 409 378.3
Deckboat (15-19m)	R 11.9	R 25 624 450.0	R 13 399 370.0	R 79 650 682.0
Freezer deckboat	R 12.5	R 8 769 679.0	R 3 036 100.0	R 33 259 860.0
Total		R 50 298 300.0	R 23 585 770.1	R 160 192 258.1

^a Equation 5.2 (market value.kg⁻¹.species⁻¹: yellowfin tuna = ZAR30.kg⁻¹; longfin tuna = ZAR13.kg⁻¹)

^bTotal catch (kg).vessel category⁻¹.species⁻¹

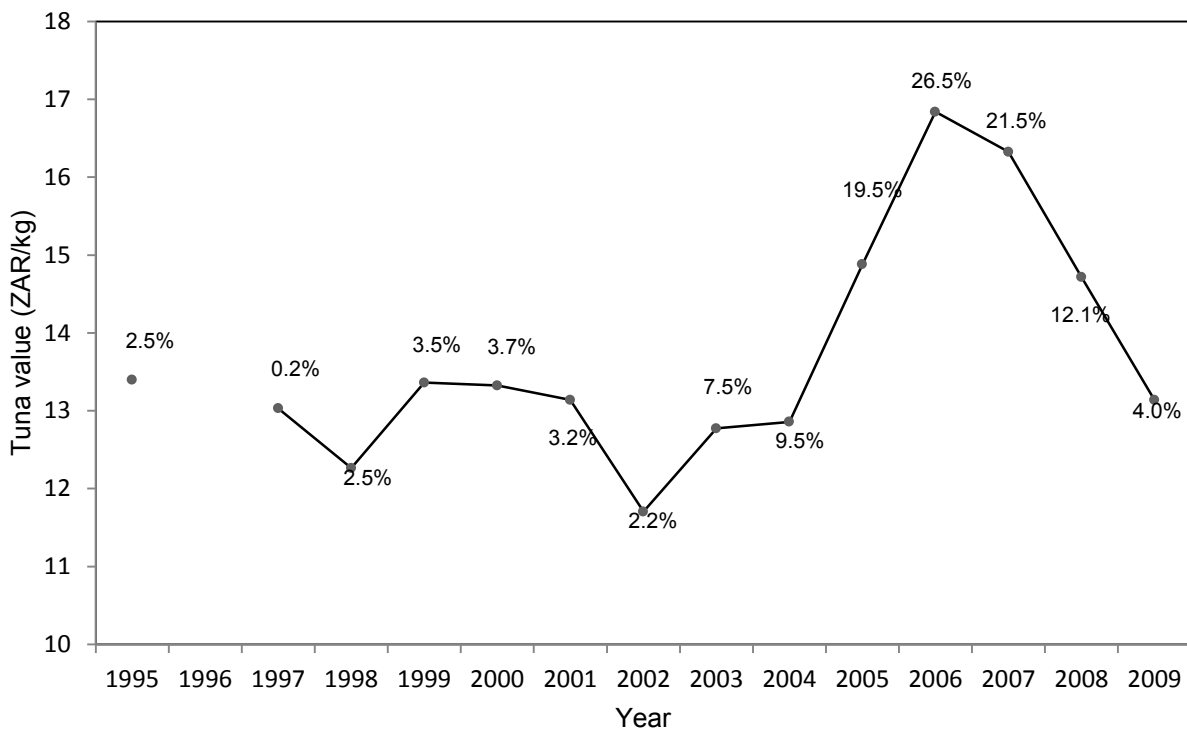


Figure 5.2 Relationship between tuna value (ZAR.kg⁻¹) for total catches of *T. albacares* and *T. alalunga* and the percentage contribution of *T. albacares* toward tuna baitboat catches for the period 1995–2009 (Port Nolloth to Cape Infanta; data source: NMLS 1995–2009).

5.3.5 Catch composition, Effort, Size selectivity and CPUE

Catch Composition and Target Species Directed Trips

The data was sourced from the National Marine Linefish System database of DEAT, sub-section MCM for the period 1995–2009. The data comprised 57 812 catches, with each individual record reflecting a single species caught per day. Data for zones B and C were excluded from analysis due to data deficiency. The information provided for each vessel (as daily information) recorded in the

NMLS database includes pseudo vessel identification codes, year, month, catch day, locality code, offshore distance (nautical miles), individual species caught per set, and catch in kilograms per species.

Catch composition

Of the individual tuna species, longfin tuna (*Thunnus alalunga*) constituted, on average, more than $86 \pm 10\%$ of tuna baitboat fishery catches between 1995–2009 and 92% in 2009 (Figure 5.3; Table 5.4).

Table 5.4 Species composition expressed as a percent of total weight (n = 4682.2t) of fish caught by tuna baitboat vessels for zone A in 2009: n = total catch for 2009; data source: NMLS 1995–2009.

Category/ common name	Species	Catch composition	
		Mass (tonnes)	Mass (%)
Albacore	<i>Thunnus alalunga</i>	4303.6	91.9
Big-eye tuna	<i>Thunnus obesus</i>	33.4	0.7
Bluefin tuna	<i>Thunnus thynnus</i>	0.6	0.0
Tuna		112.0	2.4
Yellowfin tuna	<i>Thunnus albacares</i>	186.0	4.0
Snoek	<i>Thyrsites atun</i>	13.9	0.3
Swordfish	<i>Gladias xyphius</i>	5.8	0.1
Line fish		6.5	0.1
Shark		1.8	0.0
Yellowtail	<i>Seriola lalandi</i>	18.7	0.4

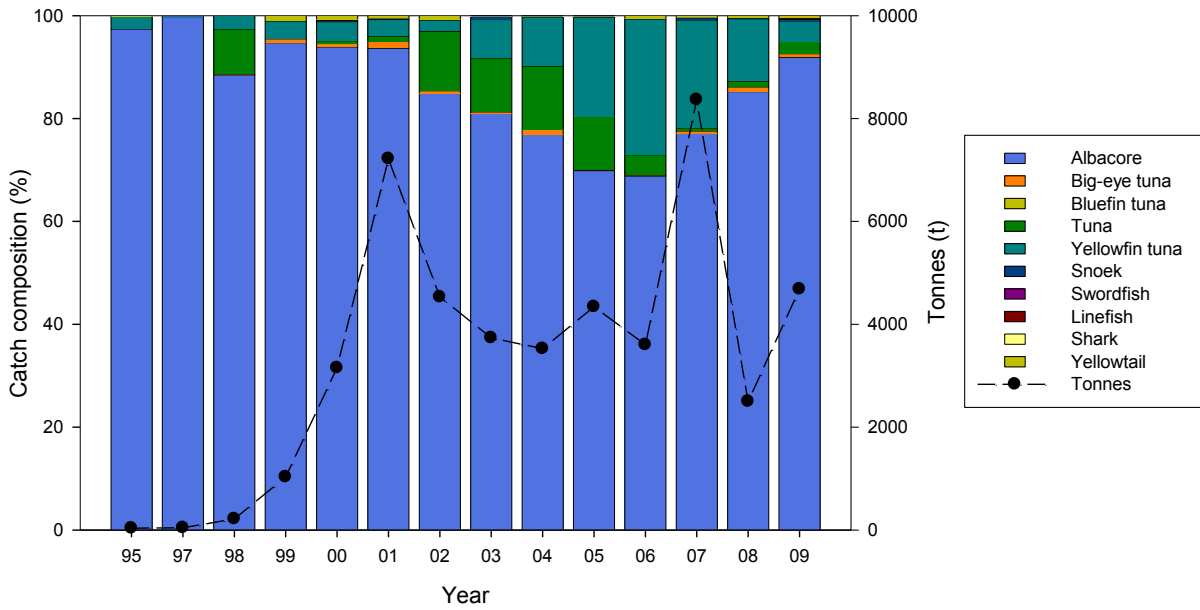


Figure 5.3 Frequency histogram describing annual catch composition in weight (t) for the tuna baitboat fishery for the period 1995–2009 (data source: NMLS 1995–2009).

Effort

Effort increased rapidly between the inception of the fishery in 1995 and 2001 when 110 active vessels fished for a total of 7588 total boat days (Figure 5.4). Thereafter, the fishery continued to increase, but at a slower rate, to a maximum of 139 active vessels, reaching an effort of 9 805 total boat days in 2007 (Figure 5.4 and Table 5.5).

Table 5.5 Growth of the tuna baitboat fishery in numbers of actively recorded LTRH per year (data source: NMLS 1995–2009).

Year	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
# Vessels	2	4	7	26	83	110	104	109	116	104	126	139	116	115

Since 2004, fishing vessels have increased targeting for yellowfin tuna and have decreased longfin-tuna-directed trips (Figure 5.4). Total catches in South Africa were driven by effort and peaked in 2007 at 8 365t with longfin tuna contributing 77% and yellowfin tuna 21% toward total catches, combined both longfin and yellowfin tuna contributed 8 209t to the total catch by weight (Figure 5.3). Since 2007, longfin-tuna-directed trips have increased, as shown by the catch

composition in 2009 (Figure 5.3 and Table 5.5), in which this species contributed 92% to the total catch by weight, whereas the yellowfin-tuna-directed catches and trips have decreased (Figures 5.3 and 5.4 and Table 5.4).

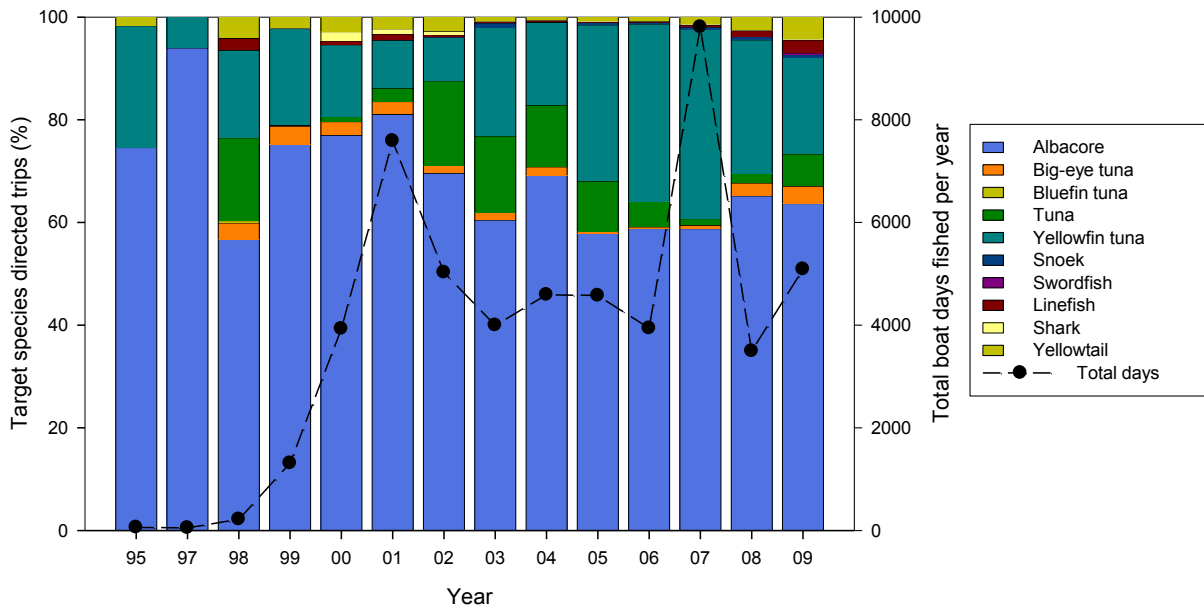


Figure 5.4 Frequency histogram describing target-species-directed trips (%) (i.e. effort) as total boat days fished for the tuna baitboat fishery for the period 1995–2009 (Port Nolloth to Cape Infanta): data source: NMLS 1995–2009.

Separating the tuna baitboat fishery into four vessel categories indicates that the ski-boat fishery has the lowest annual effort; fishing for 23 ± 14 days in 2009 (Figure 5.5a and Table 5.6). The ski boat vessels predominantly target longfin tuna, having a mean CPUE of $492.2 \pm 652.1 \text{ kg.boat}^{-1} \cdot \text{day}^{-1}$ in 2009, and they have the highest yellowfin tuna CPUE of $116.7 \pm 61.8 \text{ kg.boat}^{-1} \cdot \text{day}^{-1}$ (Figures 5.5a to 5.5d and Table 5.6). Their mean annual effort describes a fishery that only targets tuna when in high abundance. As vessel size increases CPUE increases, since larger vessels carry more crew, thereby increasing fishing effort (Figures 5.5a to 5.5d and Table 5.6). The larger 15–19m boats and the freezer deckboats predominantly target longfin tuna with low catches of yellowfin tuna, as indicated by the mean CPUE values (Figures 5.5c and 5.5d), whereas smaller 11–15m deckboats target longfin tuna, but also direct targeting towards yellowfin tuna if stocks are abundant (Figure 5.5b).

Table 5.6 Mean annual effort, total catch, and CPUE for longfin and yellowfin tuna for the tuna baitboat fishery per vessel category for the period 2009 (7–11m: n = 11; 11–15m: n = 19; 15–19m: n = 34; Freezer: n = 14) (data source: NMLS 2009).

Vessel Category		Effort (days fished)	Total catch (kg)	LFT CPUE(kg)	YFT CPUE(kg)
Length	Type				
7-11m: Ski boat	Ice	24 ± 13	19 038 ± 19 756	492 ± 652	117 ± 62
11-15m: Deckboat	Ice	72 ± 52	52 878 ± 32 006	858 ± 860	57 ± 67
15-19m: Deckboat	Ice	55 ± 36	57 999 ± 42 704	1 048 ± 937	12 ± 20
Freezer Deckboat	Freezer	37 ± 24	49 930 ± 35 004	1 339 ± 599	3 ± 6

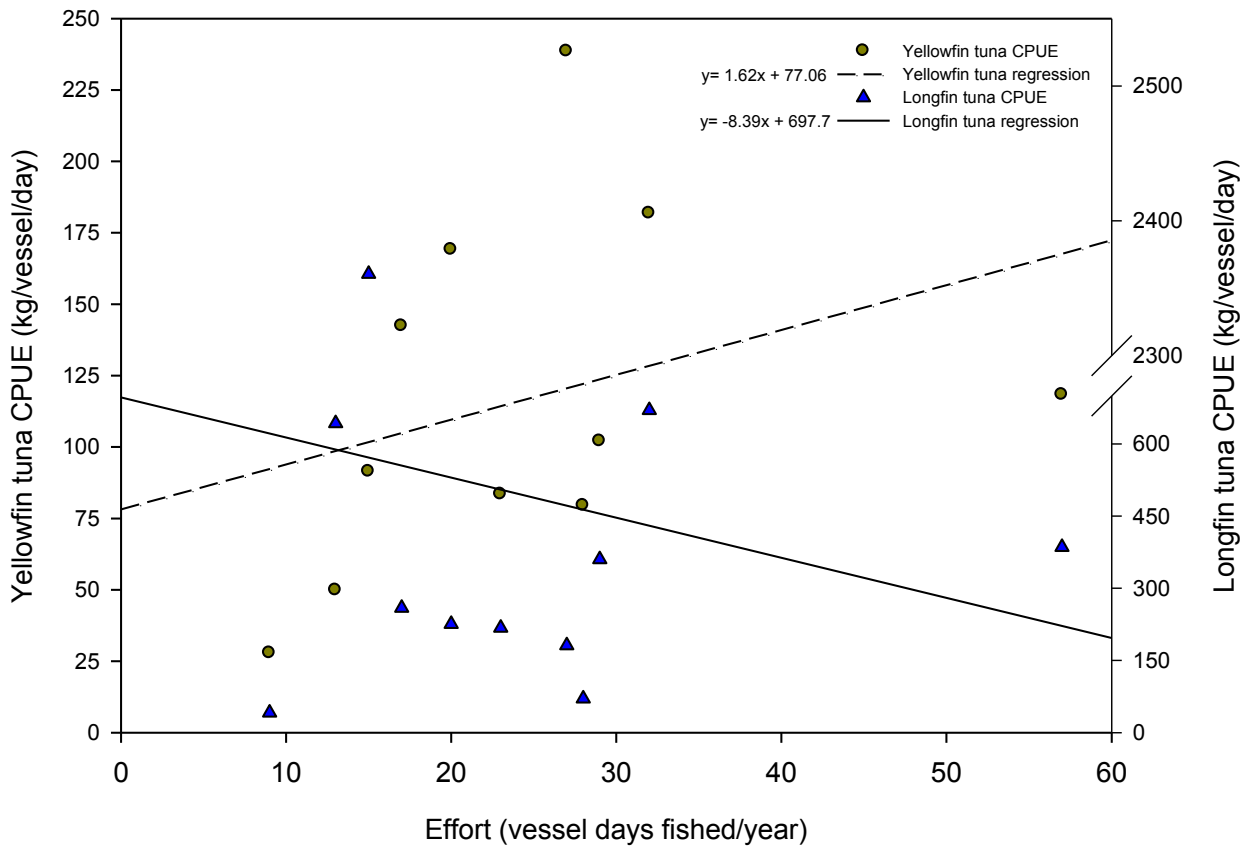


Figure 5.5a Relationship between effort (total days fished per vessel for 2009) and species-specific CPUE ($\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$) for the ski boat vessel category in the tuna baitboat fishery (Port Nolloth to Cape Infanta): n = 11 = number of recorded active vessels in 2009 (data source: NMLS 2009).

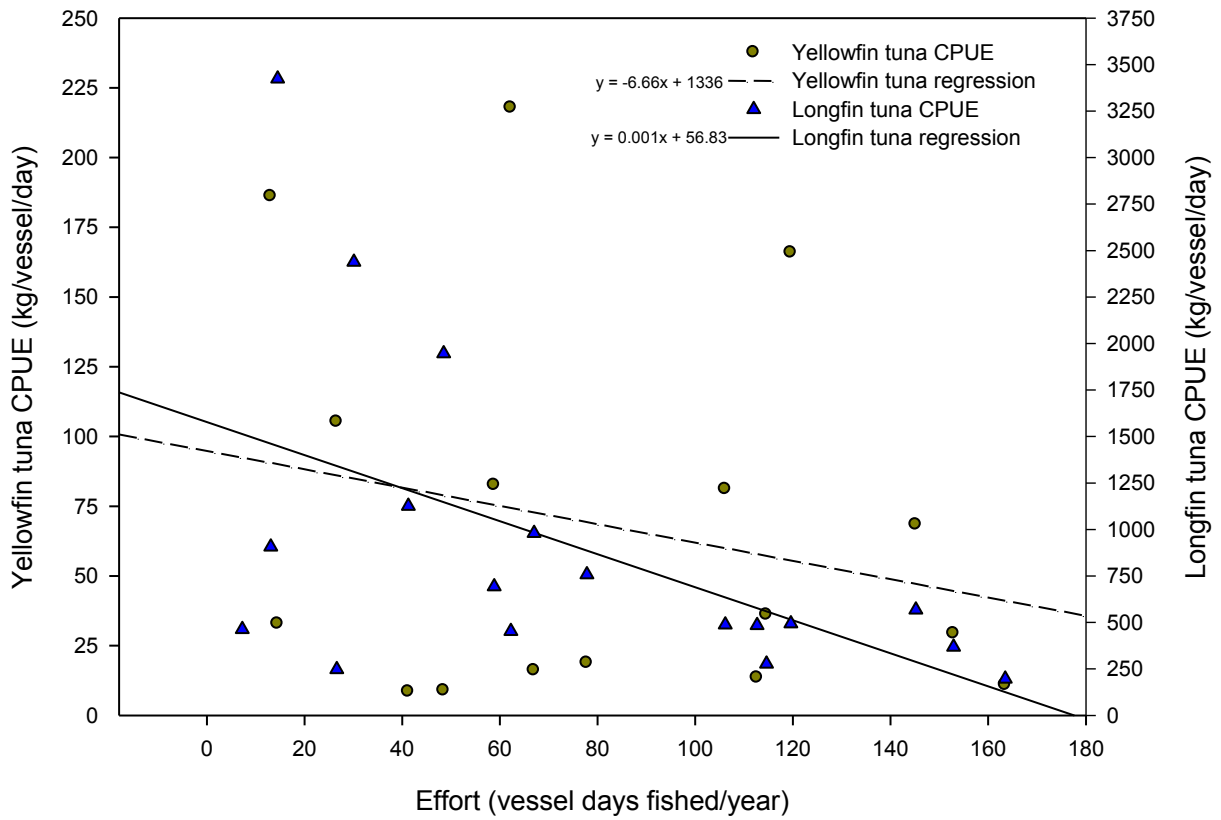


Figure 5.5b Relationship between effort (total days fished per vessel for 2009) and species specific CPUE ($\text{kg. boat}^{-1}.\text{day}^{-1}$) for the 11–15m deckboats (tullys) in the tuna baitboat fishery (Port Nolloth to Cape Infanta); $n = 19$ = number of recorded active vessels in 2009; (data source: NMLS 2009).

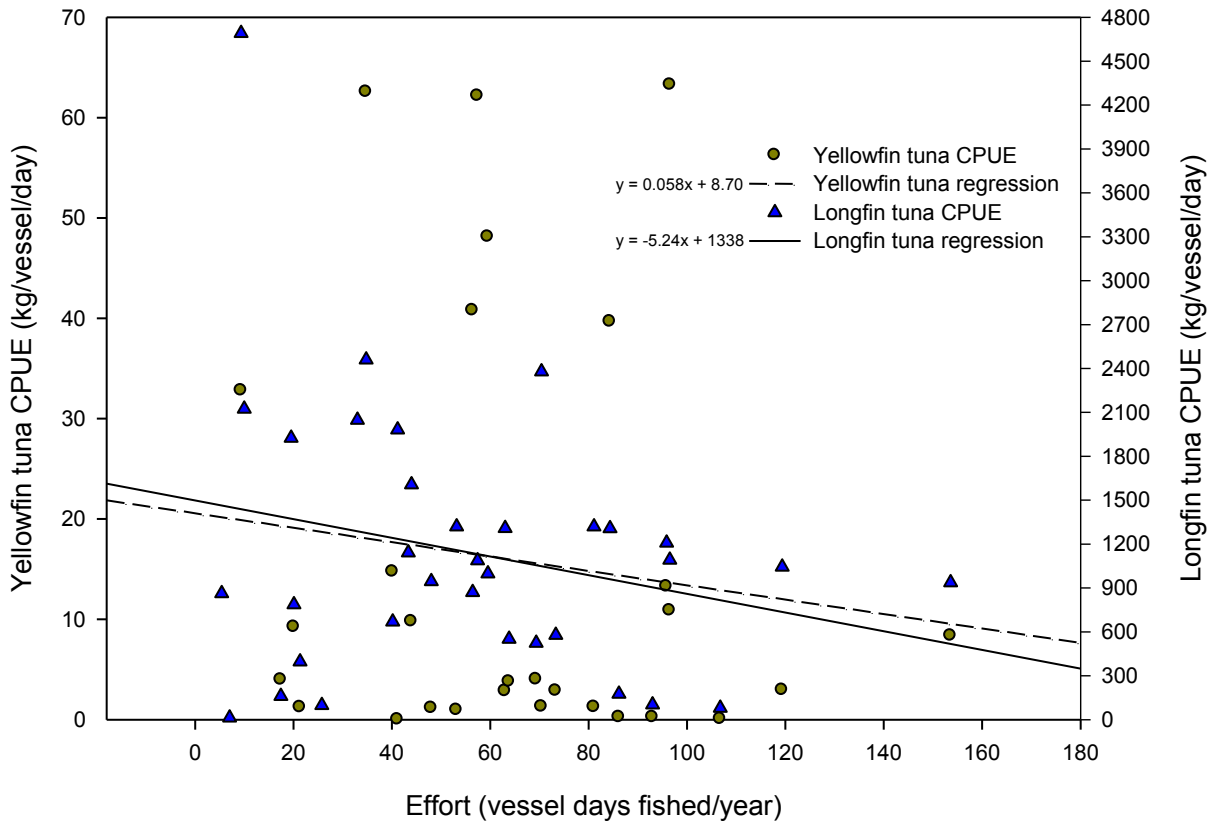


Figure 5.5c Relationship between effort (total days fished per vessel for 2009), and species specific CPUE ($\text{kg.boat}^{-1}.\text{day}^{-1}$) for the 15–19m long deckboats in the tuna baitboat fishery (Port Nolloth to Cape Infanta). $n = 34$ = number of recorded active vessels in 2009 (data source: NMLS 2009).

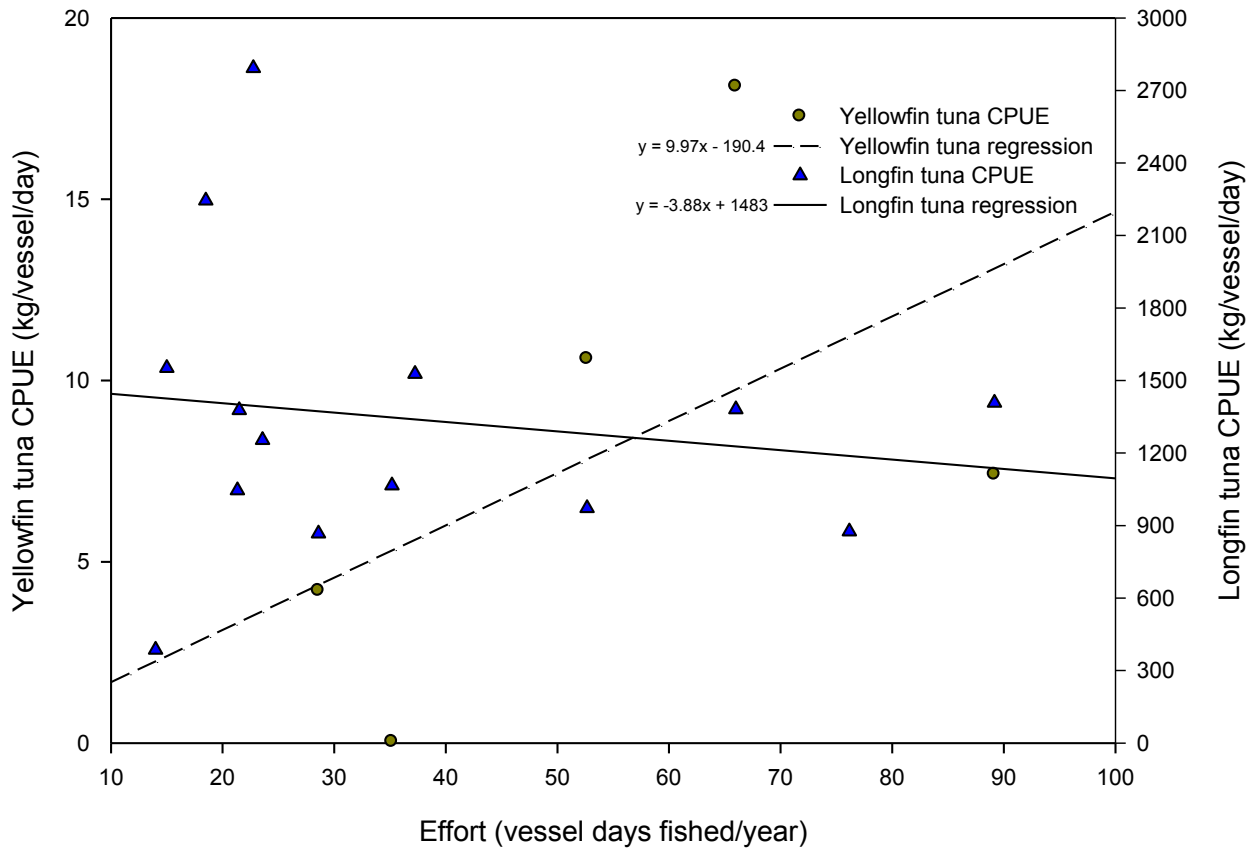


Figure 5.5d Relationship between effort (total days fished per vessel for 2009), and species specific CPUE ($\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$) for the onboard freezer deckboats in the tuna baitboat fishery (Port Nolloth to Cape Infanta). $n = 14$ = number of recorded active vessels in 2009 (data source: NMLS 2009).

Size at capture of fish caught by the tuna baitboat fishery

Weight frequency histogram comparing mean size class of *T. albacares* caught by the tuna baitboat sector, summarised in Figure 5.6. The mean size class of yellowfin tuna caught in zone A was $53.5 \pm 11.2\text{kg}$.

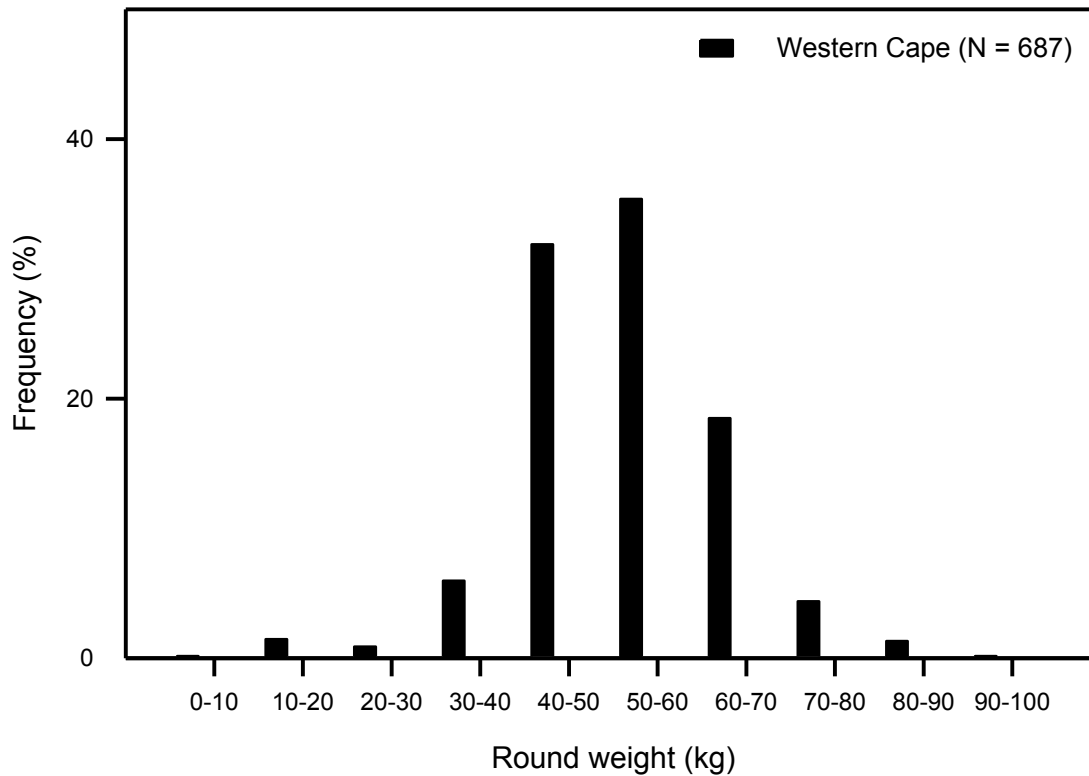


Figure 5.6 Weight frequency distribution for *T. albacares* in tuna baitboat catches for the period 2007/2008 for the Western Cape); n = Total number of *T. albacares* catch records (data source: APCS 2007/2008).

Catch-Per-Unit-of-Effort

Annual trends

Mean annual CPUE for yellowfin and longfin tuna was highly variable from year to year, with mean CPUE differing significantly between years for both species (Kruskall-Wallis by ranks test: yellowfin tuna: $df = 13$, $p < 0.05$; longfin tuna: $df = 13$, $p < 0.05$) (Figure 5.7). The mean daily CPUE for yellowfin tuna peaked at $599.5 \text{ kg} \cdot \text{boat}^{-1} \cdot \text{day}^{-1}$ in 2007, after which it decreased dramatically to $58.9 \text{ kg} \cdot \text{boat}^{-1} \cdot \text{day}^{-1}$ in 2009 (Figure 5.7). From 1995 until the present (2009), the mean daily CPUE for longfin tuna has remained fairly constant at $330.0 \pm 78.7 \text{ kg} \cdot \text{boat}^{-1} \cdot \text{day}^{-1}$, with a mean range of between 211.6 – $458.3 \text{ kg} \cdot \text{boat}^{-1} \cdot \text{day}^{-1}$ (Figure 5.7).

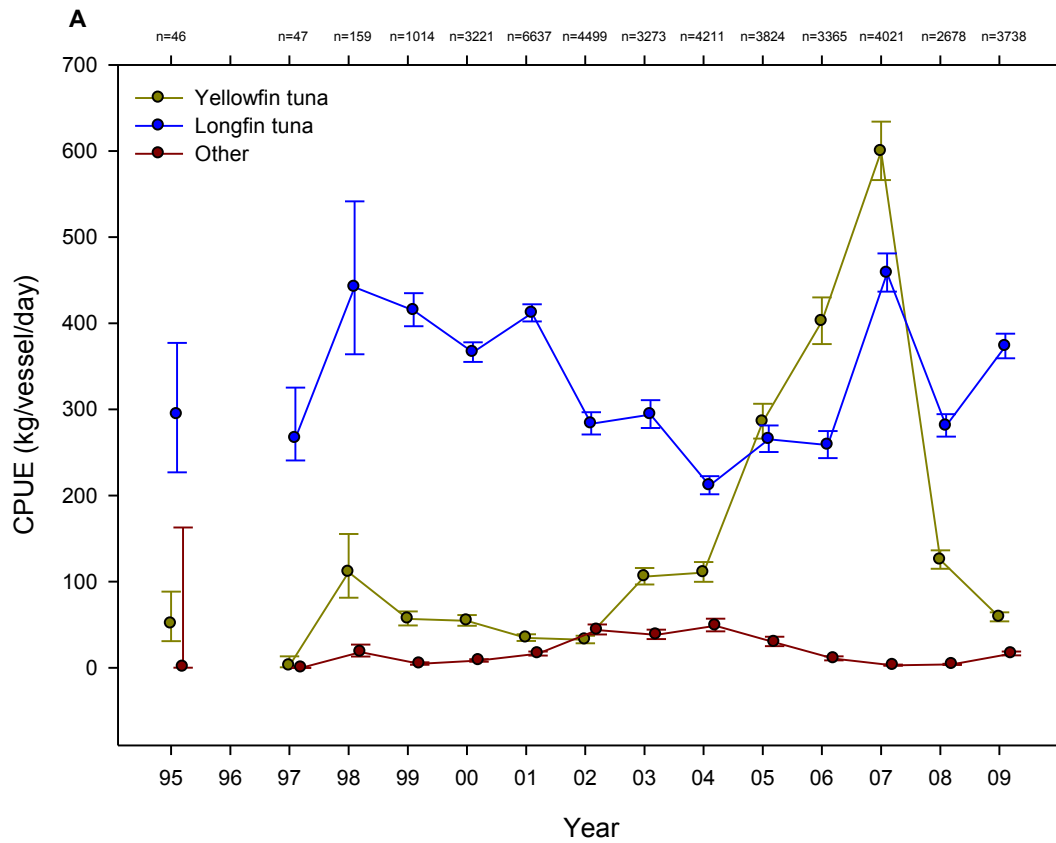


Figure 5.7 Mean CPUE ($\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$) for the tuna baitboat fishery, describing annual catch trends for data pooled over the period 1995–2009 (Port Nolloth to Cape Infanta): (error bars denote 95% confidence limits; n = number of catches assessed; data source: NMLS 1995–2009).

Monthly trends

The probability of a tuna baitboat vessel catching a yellowfin tuna (PC) was lowest in mid-summer (January PC = 0.16) and highest in spring, with 57% of trips being successful in September (Figure 5.9). Yellowfin tuna mean daily CPUE catches differed significantly between months (Kruskall-Wallis by ranks test: $df = 11, p < 0.05$) and followed a seasonal trend, gradually increasing from $33.0\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$ in December to $251.8\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$ in September (Figure 5.8).

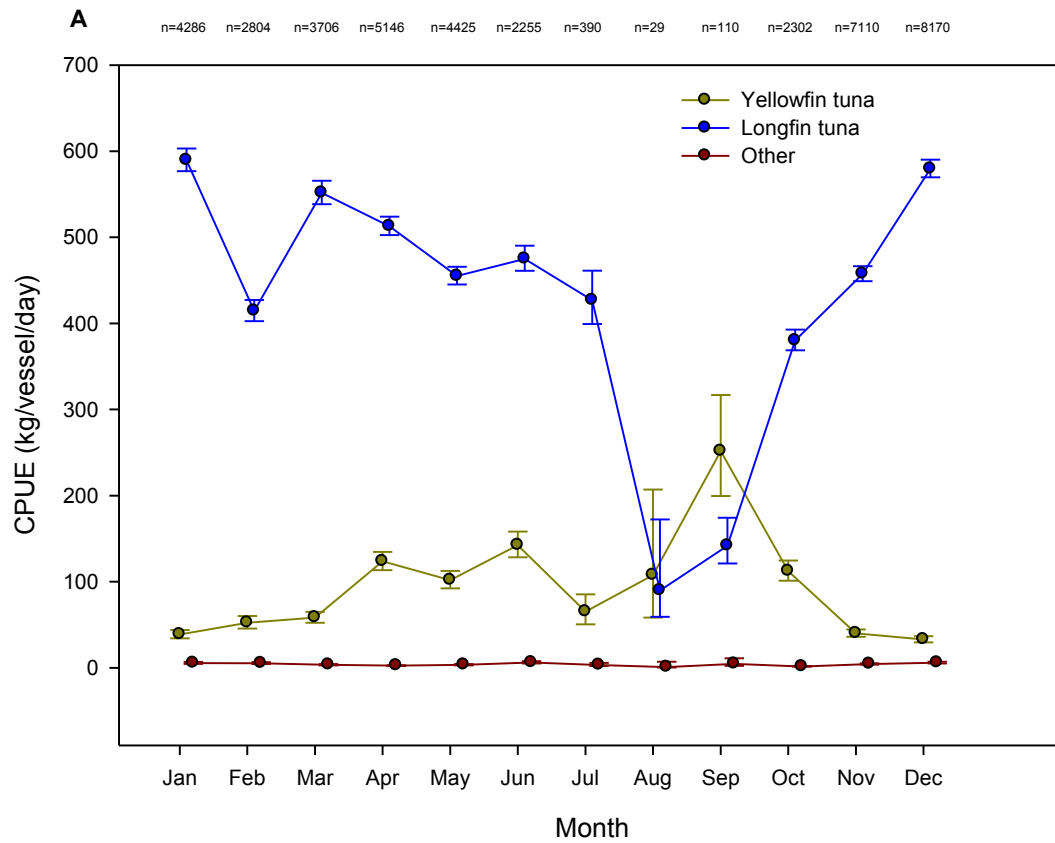


Figure 5.8 Mean CPUE (kg.boat⁻¹.day⁻¹) for the tuna baitboat fishery, describing monthly catch trends for data pooled over the period 1995–2009 (Port Nolloth to Cape Infanta); error bars denote 95 % confidence limits; n = number of recorded data points; data source: NMLS 1995–2009).

The probability of a tuna baitboat vessel catching a longfin tuna (PC) was lowest in late winter (August PC = 0.74) and highest in mid-summer (January PC = 0.96) (Figure 5.9). The mean daily CPUE catches of longfin tuna differed significantly between months (Kruskall-Wallis by ranks test: df = 11, p<0.05) (Figure 5.8), gradually decreasing from 589.5kg.boat⁻¹.day⁻¹ in January, to 89.7kg.boat⁻¹.day⁻¹ in August.

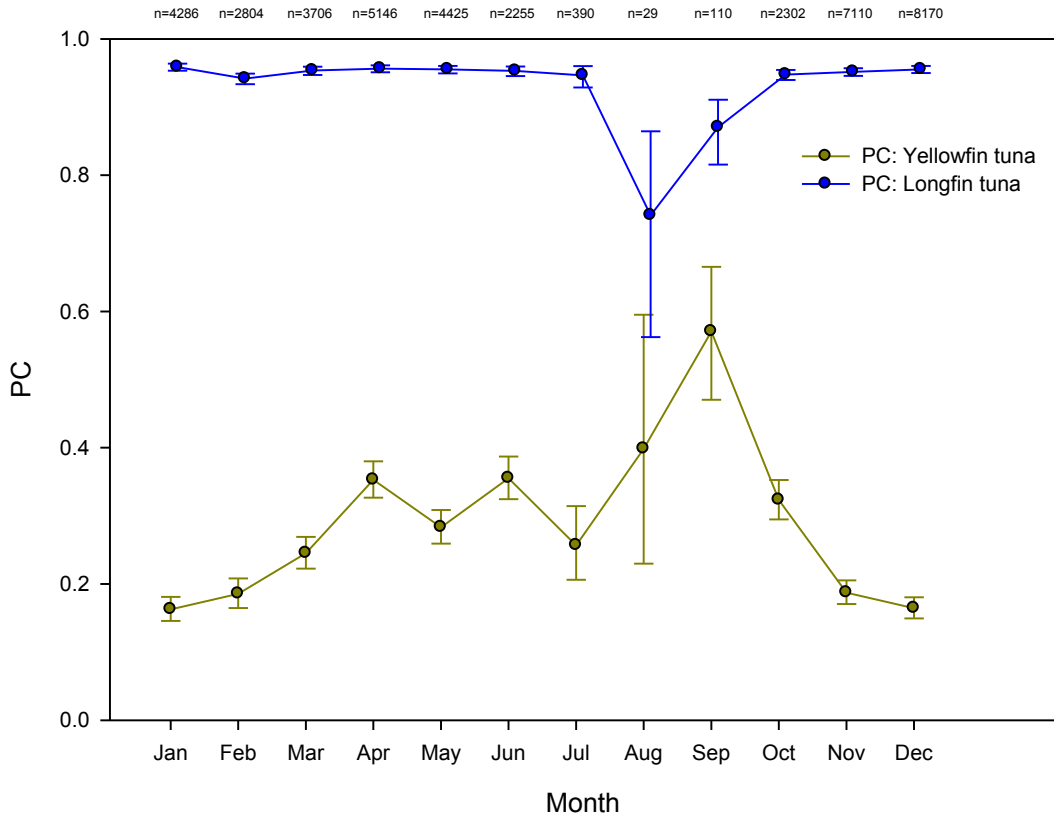


Figure 5.9 The probability of a tuna baitboat vessel catching yellowfin or longfin tuna, showing monthly trends for data pooled over the period 1995–2009 (Port Nolloth to Cape Infanta) (error bars denote 95%.confidence limits; n = number of recorded data points; data source: NMLS 1995–2009).

5.4 Discussion

In 2002 the commercial baitboat fishery had a capital value of ZAR163 million and a total estimated employment income of ZAR58 million, whereas the commercial tuna longline fishery had a capital value of ZAR92 million and an estimated employment income of ZAR16 million. The line fishery had a capital value of ZAR124 million and estimated employment income of ZAR98 million (Mather *et al.* 2003). Overall, the South African commercial fishing industry had a total capital value of ZAR1.4 billion with an estimated total combined capital value of commercial tuna-targeting operators in excess of ZAR378 million (US\$42 million) (Mather *et al.* 2003).

The South African commercial fishing industry landed approximately 650 000t of fish in 2005 (Feike 2010). The gross landed value of the fish was approximately ZAR4.5 billion (US\$750 million) of which total tuna landings contributed roughly one percent, 6 474t (Fishing Industry

Handbook, 2006). This is only 0.1% of global fishery production for tunas, which — in 2005, for all commercial catches including all vessel and gear types — reached 6.24 million tonnes with a value of US\$9.4 billion (FAO 2006). Although small by global standards, the South African tuna fishery contributes significantly to employment provision from fisheries, particularly the baitboat fishery that is currently the third largest primary sector with regard to employment (crew numbers) (Mather *et al.* 2003).

Globally the majority of tuna and tuna-like species are being caught by purse seine fleets, which account for 70% of Pacific Ocean catches by weight, and baitboat and longline vessels account for 10% and 8% of the global catch, respectively (FAO 2007). In the Indian and Atlantic oceans, purse seine fleets account for an estimated 50% of total tuna and tuna-like species catches by weight, of which baitboat and longline fleets account for 40% of catches and artisanal fisheries the remaining 10% (FAO 2007). In South Africa the baitboat fishery is the main longfin tuna fishery that accounted for 92% of total commercial catches in 2004 (FAO 2007). Despite the highly selective sustainable practices, endorsed by the baitboat fishery, other commercial tuna sectors use more efficient methods.

5.4.1 Tuna baitboat fishing industry participation and employment

In the context of South African marine fisheries, the tuna baitboat fishery is a medium scale industry that is the third largest primary sector with regard to vessel employment (Mather *et al.* 2003). The majority of vessels are owned by small individual South African companies or closed corporations and operate independently in the capture and marketing of tuna. A number of different fish buyers/agents/traders take ownership of the tuna when it is landed and they process and market the fish locally and for export (De Kock *pers. comm.* 2008: FTEA associate). One such example of an organisation is Global Fish (Pty) Limited who supply fresh and frozen tuna to South African, North American (the USA), Asian, and European markets. Tuna prices in the export market are

determined by world market prices, since the South African economy follows an open market system with no influence on prices (Mather *et al.* 2003). Tuna prices are determined by supply and demand. Currently, with the increase in production and storage facilities, supply is exceeding demand for fishery products, causing a lowering of market prices (Zhang *et al.* 2005).

Due to their size, shape and fishing practices, the majority of South Africa's small to medium scale fisheries are commission based (Mather *et al.* 2003, Sauer *et al.* 2003), particularly in the case of the traditional line fishery, chokka squid fishery, and tuna baitboat fishery, where wages are completely commission based.

Labourers in this tuna sector are employed on a share basis, which is similar to practices in tuna fisheries in the Philippines (Cesar and Hipolito 2006), whereby a labourer's wages are dependent upon the importance of the job and/or the individual's contribution towards overall catch, calculated as a percentage of the total income generated by the catch per day or per trip. Prior to South Africa's transformation in 1994, only 0.1% of South Africa's TAC was allocated and a mere 7% of 2 700 registered boats were owned by historically disadvantaged individuals (HDI's) (Hauck and Sowman 2001).

The fishery has grown rapidly since its start in 1995, to 3600 crew and 200 vessels, with growth further accelerating due to the increase in the redistribution of equitable rights to black economic empowerment counterparts (80% shareholding by 2005) (DEAT 2006b). Growth of the fishery has recently been capped at a TAE of 200 vessels (DEAT 2009b). Compared to a total average of 87% black African participation of tuna baitboats in 2002 (Mather *et al.* 2003), 74% of tuna deckboat participants and 48.2% of ski boats are black African (Table 5.1). Before the allocation of long-term rights in 2005, black shareholding of medium term rights was 54%, of which female shareholding was 29%, whereas current transformation has increased shareholding ratios in favour of 80% black

African with 40% female rights (DEAT 2006). It must be noted that up until 2002, 96% of the numbers of baitboat vessels were white-owned (Sauer *et al.* 2003). Of the surveyed participants, 21% are employed full-time, 72% part-time and 7% on a daily basis, with the majority of full-time employees being skippers/vessel owners, with the length of employment for part-time fishers being six months, on average.

The demographics for the majority of the baitboat fishery largely reflects black African and coloured males between the ages 20 and 40 years, while boat owners and skippers were predominantly white, the more affluent members. Not surprising are racial similarities among crew from the commercial sectors, traditional linefish, the large pelagic longline fishery, and tuna baitboats. On average, 80% of the crew members of these four commercial sectors are black. However, the size of commercial fleets are substantially different, with a common trend being that the larger the vessel, the smaller the relative fleet size. Despite this trend, both the baitboat and large pelagic longline fleets have grown, nearly doubling in size. The commercial large pelagic longline fishery had a fleet size of 19 vessels employing 335 fishers in 2002, this having expanded to 43 vessels and 43 LTRH in 2010, employing an estimated 758 fishers (Mather *et al.* 2003, Feike 2010). Opposing the general growth trend, the commercial line fishery has decreased in size from 458 vessels employing 4 535 fishers to 450 active vessels and an estimated 3450 crew (DEAT 2009a).

The baitboat sector holds a higher employment capacity to fleet size, generating greater capital value as opposed to other commercial tuna fisheries, in particular the high-capital-value large pelagic longline fishery. Both commercial fleets have nearly doubled in size, but the baitboat fleet has an estimated capital value of ZAR162 million that accounts for 8% of total capital of all fishers, whereas the tuna longline fleet has a value of ZAR92 million and 4% of total capital of all fishers only (Mather *et al.* 2003). The baitboat fleet is the third largest primary sector (vessels only)

employer that has an estimated 12% of total employment, earning 9% of the total employment income (Mather *et al.* 2003).

Even though there has been a substantial increase in the number of new entrants since the start of the fishery in 1995, the amount of fished days per year has remained the same since 2002. In 1995, boat owners relied heavily on commercial fishing for their livelihood, whereas today LTRHs have other means of generating revenue, not relying heavily on fishing for their livelihood. Hence they only fish when the weather is good or when there is a high abundance of fish. This was indicated by the total numbers of baitboat LTRHs in South Africa in 2009, with 152 LTRHs in total and 190 registered vessels, whereas the numbers of active vessels representing these active rights were far fewer, with 115 vessels being represented by the number of registered LTRH submitting catch return information. Hence 75 LTRHs were not generating an income from fishing and were receiving an income from an outside source.

5.4.2 *Effort*

All baitboat effort occurs out of the Western Cape, predominantly from Hout Bay and Cape Town harbours (Figure 5.1). Although the lack of handling facilities is likely to have contributed to the lack of baitboat fisheries in the Eastern Cape and KwaZulu-Natal, the short winter fishing season in the Eastern Cape and faster flowing Agulhas current are more likely to have constrained the industry, because such conditions make fishing activities more difficult and annual catches less profitable than is the case in the Western Cape.

Ski boat activity for 2009 was the lowest among the four vessel categories but the CPUE for yellowfin tuna caught in these boats was the highest. This could indicate that this fishery is opportunistic, only fishing when either longfin or yellowfin tuna are in high abundance, when catches are guaranteed, and expenses can be offset. The 11–1 m “tully” deckboats are the second

most active vessel category, each vessel having fished for an average of 72 days in 2009. These boats have a higher effort than is the case for the 15–19m deckboats and freezer vessels, as they predominantly target longfin tuna, but increase effort by targeting yellowfin tuna if stocks are abundant. The 15–19m deckboats and freezer deckboats have lower effort than the tullys as they only target longfin when the species is in abundance.

5.4.3 *Tuna landings*

Being an active gear fishery, baitboat catch composition is dominated by tuna with negligible by-catch of non-tuna species (snoek, swordfish, linefish, shark and yellowtail). The percentage contribution by any given tuna species to South Africa's baitboat catch composition is similar to global fisheries compositions, whereby larger higher-valued tuna species represent the secondary target species, with the primary target being a smaller more abundant tuna species (Adam 2006, Andrade 2009, Greenpeace 2009, McElroy and Uktolseja 1992, Mohamed 2007, MSC 2010a, MSC 2010b, MSC 2010c). In northern, southern and western American Pacific longfin tuna pole-and-line fisheries, for example, the main target species is longfin tuna, while yellowfin tuna contributes negligibly to the catch (Andrade 2009, MSC 2010a, MSC 2010b, MSC 2010c). In the Western Central Pacific Ocean (WCPO) tuna pole-and-line fisheries, the ratio of target species (skipjack tuna) to yellowfin tuna is similar to the ratio of South Africa's longfin to yellowfin tuna catches (Andrade 2009). In the Solomon Islands, yellowfin tuna comprises 30% of the skipjack tuna (*Katsuwonus pelamis*) dominated fishery (MSC 2010a, MSC 2010b, MSC 2010c), whereas in the Maldives yellowfin tuna only accounted for 14% of the catch (Adam 2006, Mohamed 2007, Greenpeace 2009). Within the Indonesian pole-and-line fishery, skipjack tuna comprised 80.5% of the total catch, with negligible amounts of juvenile yellowfin tuna (McElroy and Uktolseja 1992).

5.4.4 Catch rates

South Africa's baitboat CPUE varies both spatially and temporally. An increased probability of capture of yellowfin tuna in summer can be attributed to the Western Capes summer-driven fishery, whereby the months of August to October can yield high catches of tuna, largely influenced by the warm Agulhas current being pushed further inshore due to summer trade south easterly winds. (Note also that the squid (*Loligo vulgaris reynaudi*) season on the Agulhas bank extends from June to December (Penney *et al.* 1992, Punt *et al.* 1996, Sauer *et al.* 2003)). By early January, longfin catches dissipate as fish migrate northwards up the west coast along the sub-tropical convergence towards cooler waters. There was a direct correlation between fishing effort and catch, as the total number of days spent at sea per year increased when the mean annual CPUE was high and vice versa. During 2006–2007, directed targeting increased due to the high abundance of yellowfin tuna off the Western Cape coastline in 2006 and 2007, its large size ($54 \pm 11\text{kg}$), and high associated market price. The contribution of this species towards catches rose from 9.5%, with a mean annual CPUE of $111\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$ in 2004, to 21% with a mean annual CPUE of $600\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$ in 2007, and the total tuna yield for 2007 was 8 365t. Subsequently, the yellowfin tuna contribution to catches decreased dramatically to 4% with a mean annual CPUE of $59\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$ in 2009. Such a decrease in catch would normally suggest a fishery collapse, which was not the case. Yellowfin tuna's mean contribution to total catches between 1995 and 2009 was $8.4 \pm 8.2\%$ with a CPUE of $145 \pm 170\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$. Thus the abnormally high CPUE shown for 2006 and 2007 can be attributable to a particularly high abundance of this species during this period.

In comparison to other baitboat fisheries, the Maldivian tuna pole-and-line fishery has similar catches of tuna to that of the South African baitboat fishery: the mean skipjack contribution in the Maldives was 94.3%, with a mean annual CPUE of $500\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$, whereas the mean contribution of yellowfin tuna was 5.7% and the mean annual CPUE was $100\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$ (Adam 2006, Andrade 2009). The Indonesian pole-and-line fishery predominantly targets skipjack tuna,

which is comparable to the South African baitboat vessels targeting longfin tuna. The Indonesian vessels had a CPUE of $59\text{t.boat}^{-1}\cdot\text{day}^{-1}$ in 1989, similar to South Africa's baitboat CPUE of $45\text{t.boat}^{-1}\cdot\text{day}^{-1}$ in 2009 (McElroy and Uktolseja 1992).

5.4.5 *Value of the fisheries*

The high per capita value and employment income of the South African baitboat fishery substantiates the importance of this fishery to the local economy and the livelihoods of previously disadvantaged individuals. Even though the baitboat sector has the highest capital value and employment income, participants make low average profits, with low average yearly income (white: ZAR40 200; black African: ZAR24 548 in 2002) as opposed to the tuna longline participants who generate a higher average yearly income (white: ZAR89 727; black African: ZAR40 020 in 2002) (Mather *et al.* 2003). The fishery is commission-based, with profits being determined by yield less generated running expenses. The value of the catch is highly significant, which directly affects the profits generated.

The values of South African baitboat catches are lower than that for tuna pole-and-line fisheries in Japan where pole-and-line vessels supply skipjack and yellowfin tuna to higher-value markets, i.e. similar markets to those sourced by South African fisheries. The prices obtained per kilogram for skipjack and yellowfin tuna by the Japanese fleet in 2000 are similar to the prices that the South African baitboat fleet are only now obtaining, in 2009 (Bertignac *et al.* 2000). Notably, the costs of running a domestic Japanese pole-and-line vessel per day are far greater than is the case for South African baitboats. The higher daily operating costs can be attributed to the larger vessels used (>30 GRT) (Bertignac *et al.* 2000).

6. LARGE PELAGIC LONGLINE FISHERIES IN CONTEXT TO THE COMMERCIAL TUNA BAITBOAT AND SPORT FISHERIES

6.1 Introduction

The South African large pelagic longline fleet consists of 43 long term rights holders (26 tuna and 17 swordfish longline vessels) (Feike 2010). This formal sector actively targets migratory yellowfin tuna and localised swordfish populations in offshore waters along the entire Southern African continental shelf, fishing for up to a month at a time in the Agulhas current (Sauer *et al.* 1997, Sauer *et al.* 2003). This fishery exports to similar markets as those of the baitboat fishery (DEAT 2004, DEAT 2006).

An experimental tuna longline fishery was initiated in 1997 with a fleet size of 20 existing tuna baitboat rights holders and ten non-rights holders. The fishery was formed to develop a performance history, to assist in the technological advancement in gear discipline, and to collect scientific data (DEAT 2004). The allocation of long-term rights had four main objectives:

- To consolidate all commercial large pelagic longline fisheries,
- To maintain a sustainable yield of large pelagic species (DEAT 2004),
- To redistribute equitable BEE rights, and
- To develop a catch performance history of target species including yellowfin, longfin and bigeye tuna and swordfish, which would secure grants for further national allocations by RFMO (DEAT 2004).

Before 2002, the majority of longline fishing effort was conducted on the Atlantic Ocean with vessels offloading catches at the ports of Saldanha, Cape Town and Hout Bay (DEAT 2004). Fishing effort only began increasing in the Indian Ocean after 2001, with the development of ice,

and processing, facilities at Richards Bay, situated on the east coast of South Africa (Clarke and Smith 2007). In recent years, a sizeable amount of the fishing effort was concentrated in the Indian Ocean. The Richards Bay fishery is now the most important South African tuna longline fishery, contributing 31% to South Africa's combined commercial sector tuna catch (Clarke and Smith 2007).

6.1.1 Description of the large pelagic longline fishery

The large pelagic longline fishery is a deepwater-gear oriented fishery that can be separated into two components: (1) the tuna longline fishery that targets yellowfin tuna predominantly off the east coast of South Africa, and (2) the swordfish longline fishery that targets swordfish, mostly in the southeast Atlantic and off KwaZulu-Natal, but also has a considerable bycatch of tuna (Penney and Griffiths 1999, DEAT 2004).

As per large pelagic longline permit conditions, each vessel must set and retrieve their gear within South Africa's EEZ (DEAT 200 a). No setting or retrieval of gear may occur within the nearshore zone, which extends from the shore, seaward to 12nm offshore and stretches along the entire South African coastline. In the case of KwaZulu-Natal, however, the exclusion zone extends seaward to 20nm (Figure 6.1).

The fishery is diverse with a number of different vessel types. These range from modified beam trawlers to small purchased or chartered longliners (Sauer *et al.* 2003). The vessels vary in size with the majority being between 30 and 54m in length, having onboard freezer capabilities, customised for pelagic longlining using the American mono-filament fishing gear of the North and South Atlantic longline fisheries (Penney and Griffiths 1999, Sauer *et.al.* 2003).

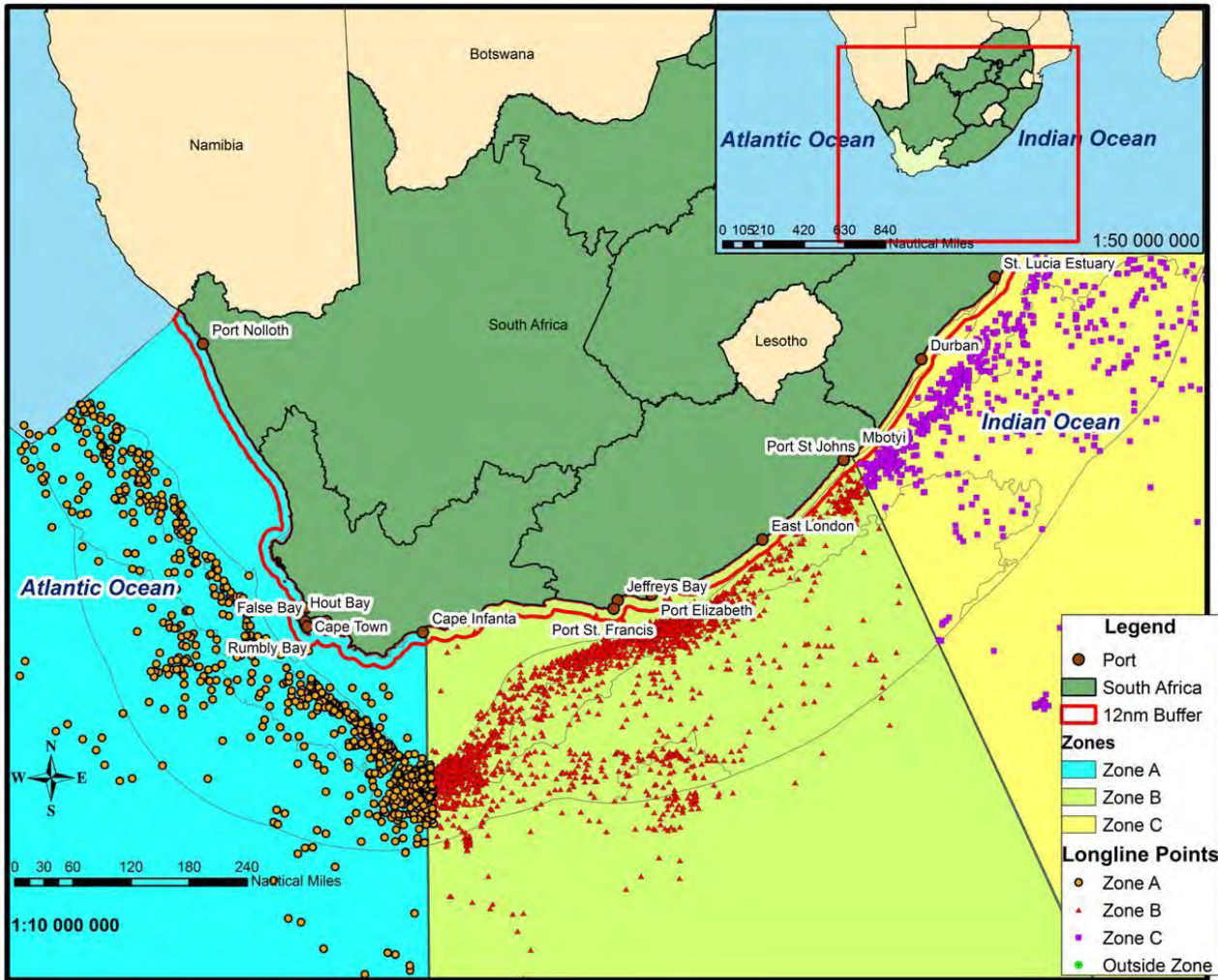


Figure 6.1 Map of Southern Africa indicating set GPS vessel co-ordinates for the large pelagic longline deep sea fishing sectors (tuna and swordfish), captured from MCM observer catch data records (2002–2009). Most longline effort is concentrated along the contour of the Agulhas Bank.

The tuna vessels used in this sector are all foreign vessels fishing on joint venture agreements, whereas the swordfish longline fleet are all domestic vessels (DEAT 2004, DEAT 2009a, DEAT 2009c). The latter fishery is surface oriented, drifting a longline with 20m long buoylines and 20m long trace lines and having the capability of fishing effectively at a depth of 40m (FAO 2002). The tuna longline fishery sets their lines mid-water at depths of between 100 and 300 metres (175m for conventional longlines and 300m for deep longlines) (FAO 2003). Both fisheries use trace lines normally rigged with a 16m leader and a 4m hook trace of 2mm thick mono-filament nylon, connected by a lead swivel (Penney and Griffiths 1999). Traces are usually baited with squid and lightsticks and clipped to the main line during the set (Kroese 1999). Lines are generally deployed in a single night, set in each 24 hour period, and retrieved the following day (Penney and Griffiths

1999). The length of line deployed averages between 35 and 40nm per night (Penney and Griffiths 1999, Sauer *et al.* 2003). Typically, swordfish longliners deploy, on average, 1 500 hooks per set, whereas tuna longliners deploy between 2 000 and 3 500 hooks per set (Sauer *et al.* 2003).

In both tuna and swordfish longline fisheries, total catches of Chondrichthyes (comprising sharks and rays) and billfishes (comprising marlin species and sailfish, but excluding swordfish) per vessel may not exceed 10% (dressed weight) of the total dressed weight of the target species per annum (DEAT 2009a, DEAT 2009c). Imposed government regulations permit the tuna longline fishery to unlimited tuna in both the Atlantic and Indian Oceans, except for a 2 100t annual TAC for bigeye tuna in the Atlantic Ocean. Swordfish catch restrictions imposed upon the South African flagged tuna vessels permit all vessels to catch a total combined 500t per year in the South Atlantic Ocean; thereafter by-catch per vessel may not exceed 15% (dressed weight) of the total dressed weight of the target species per trip, whether fishing within the Atlantic Ocean (EEZ and High Seas) or the Indian Ocean (EEZ) (DEAT 2009a). South Africa may only land 40 tonnes of southern bluefin tuna per annum, divided among the tuna longline LTRHs, providing each vessel with 1.30t (round weight only) in 2009.

The swordfish longline fishery has no catch limits on tunas in both the Atlantic and Indian Oceans. Currently no catch limit exists for swordfish in the Indian Ocean, but catch restrictions restrict South African flagged vessels to 400t in the South Atlantic Ocean (DEAT 2009c). In contrast to the annual 40t quota for southern bluefin tuna imposed on the tuna longline fleet, the weight of southern bluefin tuna caught per swordfish longline vessel trip may not exceed 10% of swordfish catches, provided the vessel is fishing north of 36°S and within the RSA EEZ; this also applies to other tuna species landed (DEAT 2009c).

The large pelagic sector is a fairly new experimental fishery that needs to develop a performance history to secure further country allocations by RFMOs. Unfortunately, little analysis has been completed using the existing longline National Tuna Database and the validation of catches with recently-collected data from onboard observer coverage has also been neglected. Despite annually-published statistical bulletins by ICCAT and IOTC and annual reports from the Department of Environmental Affairs (DEAT) sub-section Marine and Coastal Management that highlight total species catches by fishery and sector, there has been a paucity of scientific publications on catches of South African tuna species by the large pelagic sector. The most recent scientific publications about the South African large pelagic longline fishery are over a decade old and include studies by Kroese (1999) and Penny and Griffiths (1999). Kroese (1999) provided an overview of the South African tuna fishery, describing the exploratory large pelagic longline fishery, whereas Penny and Griffiths (1999) described the catches of the developing South African pelagic longline fishery. Unfortunately Penny and Griffiths (1999) only used data from two active longline vessels for the year 1998. Currently, no peer-reviewed publications exist for yellowfin or bigeye tuna or swordfish caught by the South African large pelagic fishery.

This chapter concentrates on an assessment of observer coverage data for the large pelagic longline sector, for both the swordfish and tuna longline fleets. It serves as a contextual chapter only, describing current catch trends for tuna and swordfish within the large pelagic sector and estimating total species catches per fleet per zone for yellowfin and longfin tuna and swordfish. Due to manpower and funding constraints, data collection was restricted to the metadata analysis of catch records, sourced from the Observer programme's National Marine Linefish System database from DEAT. No socio-economic analysis was undertaken.

6.2 Analytical Approach

To estimate catch and effort, historical catch data for commercial tuna and swordfish longline fisheries obtained from the Observer programme's database from DEAT, sub-section MCM, for the period April 2002 to December 2009, were reviewed (DEAT 2004, DEAT 2009a, DEAT 2009c). Observer vessel coverage is randomly distributed for the swordfish sector but, in the tuna longline sector, 100% observer coverage is required because all the vessels within this sector are foreign, fishing on joint venture agreements. The information obtained by onboard observers for each vessel (recorded as a single longline set shot per day) are recorded in the Observer database and includes pseudo vessel identification codes, year, month, catch day, location, offshore distance (nautical miles), individual species caught per set and catch, as number per species. Data were represented by numbers of fish only.

Catch data for the large pelagic longline vessels were sorted and categorised according to the species list shown within the Fishing Industry Handbook (2009) that describes the South African tuna and swordfish longline fishery catches for 2009. The list consists of three main groups, comprising five different tuna species, three marlin species and three shark species. The group "other" comprised pooled catch data for fish species considered as being of low importance to the large pelagic longline fishery, such as the Atlantic pomfret *Brama brama*, rainbow runner *Elagatis bipinnulatus* and louvar *Luvaris imperialis*, amongst others.

Effort

The mean annual effort and the monthly effort for the observer tuna and swordfish longline vessels were calculated using the following equation:

$$\bar{E} = \frac{A}{n} \tag{Equation 6.1}$$

Where \bar{E} Denotes the mean number of active vessels fishing, A is the number of recorded longline sets per year, and n is the number of recorded observer vessels per year.

Total catch

The onboard observer programme randomly covers 20% of the domestic swordfish longline fishery and all of the tuna longline fleet annually. The estimated total catch (in numbers) by species for the South African longline fishery for 2009 was estimated using a three step process:

1. Calculate mean CPUE (in numbers per vessel.day⁻¹) by species per observer longline vessel fishing in 2009.
2. These species catch values were then multiplied by 30, the actual number of registered longline vessels fishing in 2009.
3. The figures were then multiplied by the mean annual vessel effort per Japanese tuna longline vessel fishing in the South Atlantic Ocean (114 days.vessel⁻¹.year⁻¹) (Matsumoto *et al.* 2005, Matsumoto 2006).

The total catch weight (kg) by target species for the longline fishery for the period 2002–2009 was estimated using extrapolations obtained by multiplying the total estimated number of the target species caught by its respective mean weight (kg) (Equation 6.2 below was originated for this study):

$$CW_{i,t} = CN_{i,t} \cdot \bar{w}_{i,t} \tag{Equation 6.2}$$

Where $CW_{i,t}$ is the total estimated catch weight (kg) for species i for the year t , $CN_{i,t}$ is the total estimated fish caught for species i for the year t and $\bar{w}_{i,t}$ is the mean weight in kilograms for species i for the year t .

6.3 Results

6.3.1 Size at capture of fish caught by the large pelagic longline sector among regions

Mean monthly size class distribution, comparing *T. albacares* caught by the large pelagic longline sector among the regions — west, south and east coasts and KwaZulu-Natal — are summarised in Figure 6.2. Mean size class of *T. albacares* was independent of the offshore region where it was caught (χ^2 test of independence: $\chi^2 = 131$, $df = 3$, $p > 0.05$).

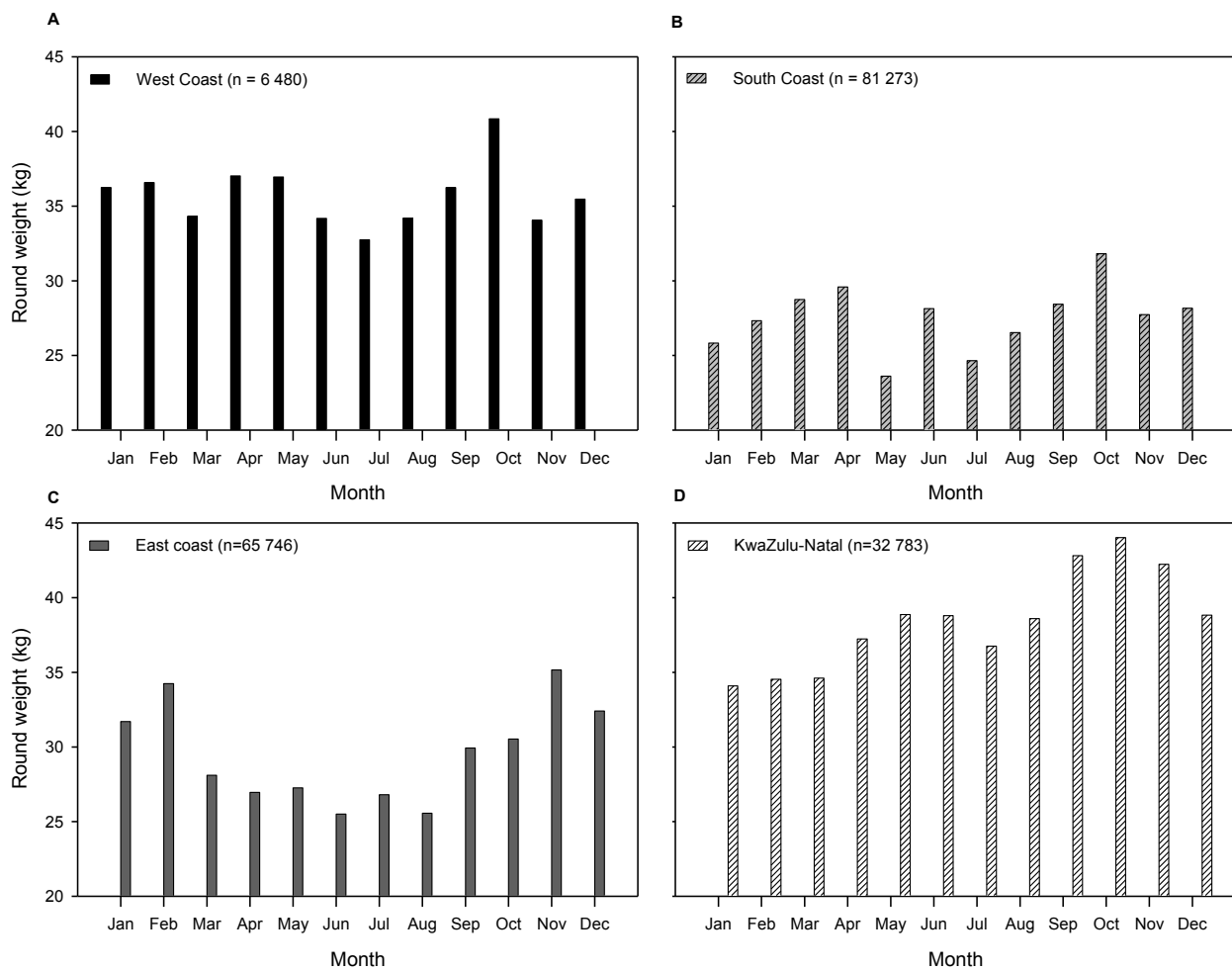


Figure 6.2 Mean monthly size class distribution for *T. albacares* in large pelagic longline catches from the (A) west, (B) south and (C) east coasts and (D) KwaZulu-Natal of South Africa between November 1997 and December 2008; (data sourced from The National Tuna Database; n = number of yellowfin tuna).

6.3.2 Effort, Total catch and Catch-per-unit-effort

The data recorded for the South African tuna and swordfish longline fisheries was comprised of 46 438 catch records, where each individual record is the catch of a species category per vessel per day.

The number of vessels and total days monitored by observers varied each year. Only nine vessels (a total of 80 days fished) were monitored in 2002 whereas 22 vessels (a total of 1288 days fished) were monitored in 2005 (Table 6.1). Between 2002 and 2009, the large pelagic longline fishery caught a total of 74 different species (Table 6.1). Total catches (by weight) were predominantly comprised of tunas, swordfish and sharks (Table 6.1). In 2009 yellowfin tuna catches made up 44% of the total catch, bigeye tuna 24%, blue shark 14%, swordfish 5%, longfin tuna 5%, and mako sharks 3%, with the remaining 7% constituting low-importance bycatches (Table 6.1). The large pelagic longline CPUE remained constant between 2002 and 2009, with each observed vessel catching, on average, $1\ 645 \pm 317\text{kg}\cdot\text{day}^{-1}$. In 2005, however, the catches increased to $2252\text{kg}\cdot\text{vessel}^{-1}\cdot\text{day}^{-1}$. The high CPUE attained by observed vessels in 2005 can mostly be attributed to the increased effort from Asian flagged vessels fishing within South African waters where high catches of yellowfin tuna ($1\ 110\text{kg}\cdot\text{vessel}^{-1}\cdot\text{day}^{-1}$) and bigeye tuna ($636\ \text{kg}\cdot\text{vessel}^{-1}\cdot\text{day}^{-1}$) were made (Table 6.1).

To validate total 2009 Observer catches with the total catch figures described in the Fishing Industry Handbook (2009), while not knowing the total vessel fishing effort for 2009, the South African large pelagic longline fishing effort was assumed to be similar to the Japanese tuna longline fishery in the Atlantic Ocean (Matsumoto *et. al.* 2005, Matsumoto 2006). The reason for this decision relates to South Africa's joint venture agreements with Japanese tuna longline vessels. It was calculated that the average longline vessel fishes for 114 days per year so it can therefore be assumed that the total South African tuna and swordfish longline vessel effort for 2009 was 3 418

days fished, based upon a total active vessel count of 30 (Table 6.2). Assuming that the South African longline fleet fished 3 418 days in 2009, and their total catches were 6 427t, it can be concluded that each of the 30 vessels caught approximately 214t (Table 6.2). From this, one could assume that the observer data base had 16.5% coverage of the 3 418 days actively fished in 2009 (Table 6.2).

Table 6.1 CPUE per species per day fished, total CPUE, total catch, and total effort, for the large pelagic longline fishery for the period 2002–2009, recorded by onboard observers (Observer Programme dataset).

Species	CPUE kg per day (per observed vessel per day for all species)							
	2002	2003	2004	2005	2006	2007	2008	2009
Tuna, Longfin	53.8	90.6	87.9	133.0	62.9	135.8	187.0	93.7
Tuna, Yellowfin	145.9	263.5	310.8	1110.1	308.3	666.6	388.6	834.9
Tuna, Bigeye	383.6	266.3	242.6	635.6	185.8	385.6	267.1	457.1
Tuna, Southern Bluefin	1.0	9.3	7.4	11.0	0.0	26.1	38.7	8.3
Tuna, Skipjack	0.1	0.0	0.0	1.1	0.0	0.5	1.2	2.5
Tuna, Unspecified	0.0	0.0	0.0	7.0	0.0	0.0	0.0	2.0
Swordfish	514.1	718.2	230.1	126.1	357.9	71.4	93.4	91.3
Marlin, Blue	8.3	13.7	0.0	2.2	13.2	1.1	9.0	1.9
Marlin, Striped	0.5	0.0	2.2	0.5	0.4	0.1	1.9	0.1
Marlin, Black	5.2	6.4	0.0	1.9	2.7	4.9	8.9	3.3
Marlin, Unspecified	0.0	0.0	0.0	0.4	0.0	1.2	0.8	1.8
Shark, Mako	21.9	33.1	35.1	46.7	237.9	35.1	48.3	51.1
Shark, Blue	177.7	170.3	169.7	81.1	255.0	146.2	243.6	265.8
Shark, Thresher	12.2	6.5	20.0	16.7	19.0	26.3	12.5	7.7
Shark, Unspecified	20.9	10.3	48.1	3.5	55.4	6.6	20.6	10.6
Sailfish	0.0	7.4	0.0	0.6	1.2	0.2	1.7	0.3
Dorado	4.0	28.0	4.7	4.3	4.9	2.8	13.5	2.9
Oilfish	28.4	10.9	5.8	27.0	8.1	53.2	48.3	10.6
Escolar	28.6	40.0	16.6	21.6	4.8	37.7	57.1	23.3
Other	39.0	22.1	12.0	21.4	7.7	68.8	56.0	11.1
Total CPUE (kg) per vessel	1445.1	1696.7	1193.0	2251.6	1525.4	1670.3	1498.3	1880.2
Total catch sampled by observers (n=tonnes)	115.6	239.2	88.3	2898.3	209.0	2031.1	1735.4	1062.4
Total days on which observers were present and recorded catches (n=days sampled)	80	141	74	1288	137	1216	1158	565
Total vessel count (n= active vessels monitored by observers)	9	13	5	22	10	16	20	20

Table 6.2 Recorded observer catch, assumed true catch, and actual gazetted figures of target species caught by the large pelagic (tuna and swordfish) longline fishery for the period 2009 (data sourced from Onboard Observer Programme and the *Fishing Industry Handbook, 2009*).

Species	^a Recorded Observer catch (tonnes.year ⁻¹)	^b Assumed true catch (tonnes.year ⁻¹)	^c South African Handbook catch figures
Tuna, Longfin	52.9	320.2	247.1
Tuna, Yellowfin	471.7	2853.6	766.2
Tuna, Bigeye	258.3	1562.4	581.8
Tuna, Southern Bluefin	4.7	28.4	22.6
Tuna, Skipjack	1.4	8.7	0.0
Tuna, Unspecified	1.2	6.8	0.9
Swordfish	51.6	312.0	303.6
Marlin, Blue	1.1	6.4	3.5
Marlin, Striped	0.0	0.2	0.1
Marlin, Black	1.9	11.4	5.6
Marlin, Unspecified	1.0	6.1	3.5
Shark, Mako	28.9	174.7	51.2
Shark, Blue	150.2	908.6	68.1
Shark, Thresher	4.3	26.2	3.0
Shark, Unspecified	6.0	36.1	2.8
Sailfish	0.2	1.1	13.1
Dorado	1.6	9.8	5.5
Oilfish	6.0	36.2	44.9
Escolar	13.2	79.7	11.5
Other	6.3	38.1	1.3
Total catch (tonnes)	1062.4	6426.8	2136.3
Total effort (n=vessel days monitored and or estimated)	564	3418	-

^aRecorded Observer catch: total active vessel count = 20 tuna and swordfish longline vessels monitored

^bAssumed true catch based upon mean effort figures obtained from Matsumoto *et al.* (2005) and Matusmoto (2006).

^cSouth African Handbook catch figures: total vessel count = 30 tuna and swordfish longline vessels

6.4 Discussion

Fishing by the swordfish and tuna longline fisheries takes place in different zonal areas because of the higher abundances of their respective target species. There is, however, a considerable overlap in effort within the zones by both fisheries (Smith *pers. comm.* 2011: MCM, Deputy Director General of Large Pelagics Division). Yellowfin tuna are targeted and caught in Zone B by the tuna longline fishery, whereas swordfish are targeted in Zones A and C by the swordfish longline fishery (Smith *pers. comm.* 2011: MCM, Deputy Director General of Large Pelagics Division). Because tuna and swordfish longline fisheries use a passive type of fishing technique, i.e. lines with baited hooks as fishing gear, they are responsible for catches of considerably large volumes of the same

target species, together with incidental catches of non-target species or juveniles and endangered species, such as sharks, turtles and seabirds (particularly the black browed *Thalassarche melanophrys* and shy *Thalassarche cauta* albatrosses and the white-chinned petrels *Procellaria aequinoctalis*) (FAO 2002, FAO 2003). Since both of these fisheries target similar species in different areas, it was assumed that possible size differentiation of yellowfin tuna caught amongst regions would be evident between fishery catches. However, the mean weight of fish caught offshore by the large pelagic longline sector was not significantly different amongst regions (Bigelow *et al.* 2006, Løkkeborg and Bjordal 1992). The majority of yellowfin tuna targeted and caught by these fisheries along the Agulhas Bank in offshore waters were adult fish.

Unfortunately, observer catch and effort data are recorded in numbers only and not by weight. Thus, total catch needs to be estimated by multiplying by CPUE, expressed as number of fish, by the mean weight (kg) for each species caught. The obtained Observer catch and effort data set also had pseudo vessel identification numbers and the total numbers of hooks per set were not consistent for the same vessel throughout the database, differing by up to 2000 hooks at a time. This made the differentiation between tuna and swordfish vessels impossible. For this reason the catch and effort data from both vessel groups' sets were pooled.

After comparing the total net catch of the *assumed true catch* to that of the supposedly correct figures published in the Fishing Industry Handbook (2009), it becomes apparent that considerable under-reporting is occurring within the South African large pelagic longline fishery. The total estimated catch was three times greater than the reported 2 136t. If the figures within the Fishing Industry Handbook (2009) were correct, this would mean that each of the 30 vessels caught an average of 71t of fish in 2009, which is not economically feasible when based upon an estimated average sale price of ZAR46.kg⁻¹, as calculated from a total net catch value of ZAR100 million (Fishing Industry Handbook 2009, Feike 2010), which would generate a gross annual income of

ZAR3 million per vessel, especially when considering that 13 of the 30 South African longline vessels are foreign. Such foreign vessels would need catches of a much greater magnitude to make a foreign venture worthwhile.

In comparison to catches made by tuna longline vessels in the Australian Eastern Tuna and Bill Fishery, the east Australian tuna longline fishery had a total catch of 6 686t in 2008 (Wilson *et al.* 2009) whereas the South African large pelagic longline fishery had an *assumed true catch* of 6 427t in 2009. The target species of the former fishery included longfin, bigeye, and yellowfin tuna, broadbill swordfish and striped marlin and comprised 5 857t of the total catch (Wilson *et al.* 2009). The east Australian tuna longline fishery had a total active vessel count of 54 where each vessel caught an average of 108t total catch and fished for 107 days per year (on average), whereas South African longline vessels caught an average weight of 214t per vessel and fished for an average of 114 days per year (Wilson *et al.* 2009). It should be noted that the South African longline vessels are twice as large, measuring 30–54m in length, whereas the east Australian tuna longline vessels are only 15–25m in length (Penney and Griffiths 1999, Sauer *et al.* 2003, Wilson *et al.* 2009). In addition, the South African longline target species catches, which are similar to Australia's, comprised 79% of the total catch, whereas the Australian Eastern Tuna and Bill Fishery's target species catches comprised 88% of the total catch by weight (Wilson *et al.* 2009) (Table 6.2). The Australian fishery reported no sharks in their catches, whereas sharks comprised 18% of South Africa's total longline catch. A comparison of South African longline catches with global catches by longline fleets within the Atlantic and Indian Oceans, indicates that South Africa contributed less than 3% toward total longline catches of yellowfin, bigeye and longfin tuna from the Atlantic Ocean and less than 1% toward total catches of yellowfin, bigeye and longfin tuna from the Indian Ocean (FAO 2007).

7. GENERAL DISCUSSIONS AND RECOMMENDATIONS

7.1 South African tuna resource assessment

Current information on both the tuna fishery and tuna stocks in South Africa is limited, particularly relating to yellowfin tuna. MCM requested assistance in the collection of baseline information to aid the development of an Operational Management Plan for the tuna fishery. The collection of this information — on the biology of the species, total catch, CPUE and economic and socio-economic structure of the different sectors — was required together with information on population structure. These data were needed to improve understanding of the contribution by various sectors to the total catch of tuna: the recreational sectors from the Western and Eastern Cape, and commercial large pelagic longline, baitboat and line fish traditional sectors of Southern Africa. Further study on the movement and structure of *Thunnus albacares* stocks was also required to determine whether yellowfin tuna (*T. albacares*) stocks off the Eastern Cape were separate from the larger Western Cape yellowfin stocks. This required an analysis of their age-growth relationships and their genetic makeup.

7.1.1 *The biological analysis of the yellowfin tuna resource in South Africa*

Age-growth and genetic analyses

No previous research on age-growth relationships or genetic analyses of *T. albacares* off the South African coastline had been undertaken. In the present study, an examination of annual growth increments on vertebrae was used to obtain age-growth information for *T. albacares* and for the estimation of von Bertalanffy (VBGF) growth parameters. It was found that there were no differences in the growth characteristics of yellowfin tuna (*Thunnus albacares*) sampled from the south eastern Atlantic and from the south western Indian Ocean. In addition, no differences in growth patterns were found in populations from southern African waters and from other regions (Draganic and Pelzcarski 1984, Fonteneau 1980, Gascuel *et al.* 1992, LeGuen and Sakagawa 1973, Lehodey and Leroy 1999, Lessa and Duarte-Neto 2004, Shuford *et al.* 2007, Stequert *et al.* 1996,

Wild 1986, Yang *et al.* 1969). Recent concurrent genetic analyses by Dr. Paul Shaw and Ms Romina Novo-Henriques supported the hypothesis that the South African yellowfin tuna are a single stock. Nevertheless, on a micro-scale, there were differences between localized sub-populations of yellowfin tuna between western Indian Ocean and Atlantic regions around southern Africa. More extensive sampling is needed for genetic studies so as to provide definitive results for identifying any of these localized differences. Current results from both age-growth and genetic analyses indicate, however, that yellowfin tuna caught off the South African coastline are from a single stock.

Size at capture of *T. albacares*

To further substantiate the above-mentioned observations, differences in the size of fish caught in the inshore (baitboat and sport fishery vessels) and offshore (large pelagic longline vessels) sectors of South African tuna fisheries were investigated. A significant difference was noted in the size and age of fish caught from different inshore regions, with mostly juvenile fish in KwaZulu-Natal, sub-adult fish in the Eastern Cape and adult fish in the Western Cape (Table 7.1). The mean weight of fish caught offshore by the large pelagic longline sector was however not significantly different between regions (Bigelow *et al.* 2006, Løkkeborg and Bjordal 1992). The size differences in fish caught inshore therefore suggest a possible westward migratory pattern from juvenile fish caught in KwaZulu-Natal to sub-adult fish in the Eastern Cape and adult fish the Western Cape. As mostly adult fish were caught offshore by longliners (Bigelow *et al.* 2006, Løkkeborg and Bjordal 1992), with no significant differences between regions, it is possible that adult fish predominantly inhabit the offshore region.

7.2 Yellowfin tuna resource users

Total effort data indicate that the competitive tuna sport fishery is South Africa's largest tuna sector, comprising 7200 formal and 2300 semi-affiliated participants (Leibold and van Zyl, 2008). Club-held regional competitions attract numerous SADSAA members to compete in five-day species-directed competitions that target tunas and bill fishes whilst fishing up to 55nm offshore. There is currently little knowledge of the recreational component of the tuna fishery, as well as a growing concern about the portion of the recreationally-landed catch being sold to local markets, particularly the high-valued yellowfin tuna. The South African tuna baitboat fishery comprises four vessel categories: ski boats, 11–1 m "alley" deckboats, 1–19m deckboats, and freezer deckboats. The tuna baitboat fishery operates in waters within the Agulhas bank that are, on average, 55 nautical miles offshore, with the majority of vessel effort being directed from the Western Cape. The tuna baitboat fishery primarily targets *T. alalunga*, whereas the more marketable *T. albacares* is targeted when available. The tuna baitboat fishery is an active-gear surface fishery targeting tuna, primarily using pole and rod-reel methods. The baitboat component exports fresh tuna, competing internationally in the lucrative *sashimi* quality-product market. The large pelagic longline fishery is South Africa's largest fishery by value, constituting over ZAR100 million in total net catches (Feike 2010). This sector is a passive-gear fishery, operating offshore along the Agulhas Bank targeting a plethora of species. Their main target species by weight include yellowfin and bigeye tuna, various Chondrichthyes, and longfin tuna.

7.2.1 Baitboat fishery

Longfin tuna are the primary target for South Africa's baitboat fisheries, comprising, on average, 8% of South Africa's total baitboat catches (Table 7.1) and generating ZAR49 million in employment income in 2002 (Mather *et al.* 2003). Yellowfin tuna only contribute a small percentage towards total catches ($8.4 \pm 8.2\%$; from 1995–2009), generating ZAR1.3 million in employment income in 2002 (Mather *et al.* 2003). The baitboat industry is a low-profit-margin

fishery that obtained a total net catch value worth ZAR90 million in 2009 (Table 7.1) (Feike 2010). The abundance of yellowfin tuna catches affects baitboat profit margins, as this fish obtains a higher market price than longfin tuna. The value effect of this species was demonstrated in the 2006/2007 fishing season when a high abundance of yellowfin tuna started a renewed interest in the fishery. Effort increased with re-directed targeting, away from the primary target species (longfin tuna) resulting in increased catches and steeper profit margins.

arine and Coastal Management's concern with regard to the growth of the fishery and increased resource use is due to the lack of resource information available and the poor catch trends shown over the past few years, where catches based upon MSY levels set by ICCAT in 2007 for both southern Atlantic longfin (33 300t) and Atlantic yellowfin tuna (130 600t) have not been achieved (DEAT 2009b), even though ICCAT labelled the status of yellowfin tuna as under- to optimally-exploited (DEAT 2009b).

7.2.2 *Sport Fishery*

The majority of the participants in the sport fishery are from within the top 25% of household income distribution, having either permanent occupational status or being retired. Even though they incur great expense to partake in this fishery, they continuously target yellowfin tuna, contributing considerable capital toward South Africa's economy but, unfortunately, high market prices and market demand for yellowfin tuna encourage the illegal sale of these fish (Cowx 2002). The total yellowfin tuna catch, of 83t, by the competitive sport fishery is low in comparison to the catches of the two commercial sectors (Table 7.1). Yet this figure may indicate significant under-reporting by the sport fishery as it represents catches made by the Eastern and Western Cape competitive sport fishery only. When comparing the total tonnes of yellowfin tuna caught by sector, the impact by recreational fisheries is often invisible to higher management, but has the potential to play a role in

local stock depletion and even global collapse when coupled with the impacts of commercial fisheries (Cooke and Cowx 2006).

Table 7.1 Yellowfin tuna resource distribution among the commercial large pelagic longline and tuna baitboat sectors and the competitive sport fishery for the period 2009; data sources: Fishing Industry Handbook (2009), Observer longline database (2002–2009), NMLS database (1995–2009), Competition creel surveys (2007–2009), WPDSAA Offshore League database (2004–2009).

Category	Large pelagic longline		Tuna baitboat	Sport Fishery
	Tuna LL	Swordfish LL		
Number of active vessels	13	17	115	148 ^c
Total yellowfin tuna catch (tonnes)	766 ^b – 2 854 ^c		186	83 ^c
Total longfin tuna catch (tonnes)	247 ^b – 320 ^c		4304	16 ^f
Total swordfish catch (tonnes)	304 ^b – 312 ^c		-	-
Total fishery catch (tonnes)	2 136 ^b – 6427 ^c		4 682	99
Total net catch value (ZAR)	R100 000 000 ^d		R90 000 000 ^d	Not determined
Tuna directed effort by zone (boat days fished)				
Zone A			5 088	2 160
Zone B			224	1 428
Zone C			0	
CPUE per species by zone				
Zone A	YFT (CPUE: kg.boat ⁻¹ .day ⁻¹)		58.8	51.0
	YFT (CPUE: fish.boat ⁻¹ .day ⁻¹)		-	0.9
Zone B	YFT (CPUE: kg.boat ⁻¹ .day ⁻¹)		-	7.4
	YFT (CPUE: fish.boat ⁻¹ .day ⁻¹)		-	0.2
Zone C	YFT (CPUE: kg.boat ⁻¹ .day ⁻¹)		-	27.2 ^a
	YFT (CPUE: fish.boat ⁻¹ .day ⁻¹)		-	-
Mean yellowfin tuna size class (round weight: kg)				
Zone A		36.0 ± 5.1	53.5 ± 11.2	42.3 ± 14.4
Zone B		28.7 ± 4.6	-	26.2 ± 13.4
Zone C		38.9 ± 6.9	-	5.4 ± 3.5

a = CPUE_{pos}

b = Figure sourced from *Fishing Industry Handbook (2009)*

c = Assumed true catch (table 6.2)

d = Figure sourced from *Feike (2010)*

e = Western Cape offshore league and Eastern Cape competitive sport fishery

f = Western Cape offshore league

7.2.3 Large pelagic longline fishery

The large pelagic longline fishery had 30 active vessels fishing in 2009 from which a supposed 766t of yellowfin tuna were caught, a total tonnage far greater than the baitboat and sport fishery

combined (Table 7.1). There is assumed to be a considerable amount of under-reporting of catches within this fishery, which would greatly increase the fisheries total net catch value (Table 7.1). Not only is this of great concern for the fishery, but so too is the size and composition of the catches of bycatch species (Chondrichthyes), which far outweigh the imposed regulatory limits (DEAT 2007).

7.3 Management initiatives

The main goal of fishing policy in South Africa is to develop a comprehensive fisheries framework with a local operational management plan (OMP) in place to manage the fishery on an ecosystem-based approach. At present the most prioritised criterion for allocating country quotas is catch performance records, hence coupling the framework and OMP as a main objective, to either maintain or improve tuna catch performance so that South Africa can motivate for equitable country allocations (DEAT 2009b). However, stock uncertainty between RF O 's (ICCAT and IOTC) and RFB (MCM) regarding yellowfin tuna status as well as the consideration that the species is currently fully-exploited in all four Oceans (FAO 2007), is of primary concern and warrants the adoption of a precautionary approach until more reliable catch data can be obtained. On the other hand, longfin tuna are well researched and shown to be moderately-exploited in the southern Atlantic Ocean and fully-exploited in the Indian Ocean (FAO 2007, Leslie 2001, Leslie *et al.* 2004, Penney *et al.* 1992, Penney *et al.* 1998, Penney and Griffiths 1999, Smith and Glazer 2007). This should be a motivating factor for the development of more complex fisheries models to manage this fishery (Beddington *et al.* 2007, DEAT 2009b, ICCAT 2009, IOTC 2009).

Due to the current deficiency of information, either socio-economic and/or catch and effort data, an ecosystem-based approach may not yet be appropriate.

7.4 Limitations of the current study

Both the baitboat NMLS (1995-2009) and the Observer longline (2002-2009) catch and effort databases obtained from MCM had data deficiency implications.

Baitboat NMLS (1995-2009) database

The tuna baitboat vessel catch and effort database obtained from MCM was incomplete as there were current active fishing vessels for which MCM had no details. Some vessels were recorded as actively fishing, having catch data next to corresponding vessel ID's, but these vessels were inactive and had no corresponding effort data. Due to these deficiencies, the complete NMLS database (1995-2009) was only used to compile and describe catch composition, species-directed effort, and mean annual and seasonal CPUE. However, when micro-scaling down and assessing the catch and effort data among the four described vessel categories for 2009, it was noted that, of the recorded 115 active vessels, only 81 vessels had complete legitimate catch and effort data that could be used to calculate estimated tuna value, market value, total fishery expenditure, and the relationship between effort (total days fished per vessel for 2009) and species-specific CPUE ($\text{kg}\cdot\text{boat}^{-1}\cdot\text{day}^{-1}$). It would take MCM six months to a year to rectify the problems associated with this NMLS database that had the capacity to provide accurate catch and effort records (da Silva *pers. comm.* 2011: MCM, Marine Scientist, Inshore Resource Research).

Observer longline (2002–2009) database

Observer catch and effort data were recorded in numbers only and not by weight. Thus the total catch had to be estimated by multiplying CPUE, expressed as number of fish, by the mean weight (kg) for each species caught. In addition, the Observer catch and effort data set had pseudo vessel identification numbers and the total numbers of hooks per set were not consistent for the same vessel throughout the database, differing by up to 2000 hooks at a time. This made the differentiation between tuna and swordfish vessels impossible, and for this reason the catch and

effort data sets from these two sectors were pooled. Unfortunately, poor vessel coverage has resulted in few data. Due to time- manpower- and funding- constraints, the chapter on the large pelagic longline sector was used as a contextual chapter, to reference catch and effort data only. Since no socio-economic information was obtained, no mention of this aspect was considered in the discussion.

Sport fishery

Due to manpower and funding constraints, primary data collection was restricted to the Eastern and Western Cape and data for KwaZulu-Natal were obtained via line-fishing and competition catch records sourced from the NMLS (Maggs 2010). To holistically assess the impact of the sport fishery with regard to yellowfin tuna catches in South Africa, in comparison to other yellowfin tuna resource users, additional sampling would be required from the KwaZulu-Natal region. This would provide a more accurate estimate of the current yellowfin tuna catch and effort figures (since current catch figures by this sector are grossly under-reported: Table 7.1). Such additional sampling would also enable an estimation of the total net catch value.

7.5 Recommendations and Future research priorities

Age-growth and genetic analyses

Results from both age-growth and genetic analyses indicate that yellowfin tuna caught off the South African coastline are from a single stock. Small genetic differences are, however, evident between localized sub-populations of yellowfin tuna from South Africa caught between western Indian Ocean and Atlantic regions. It is therefore recommended that a larger genetic sample be collected from the Western and Eastern Cape and KwaZulu-Natal regions and from Africa's west coast. Results would provide some insights into any stock similarities/ dissimilarities between localized yellowfin tuna sub-populations.

Recreational fishery

Data in South Africa are limited, whether collected from monitoring programmes or from competition records. It is recommended that additional research studies, similar to those of the N S, be conducted along South Africa's entire coastline, covering popular ski boat access points. However, as current recreational socio-economic data are very limited, the NMLS needs to obtain and incorporate socio-economic data whilst collecting routine catch and effort data. Since gamefish records do not form part of the brief of the NMLS and there is a lack of comprehensive catch and effort data for the sport fishery, an increased focus on obtaining competition data is needed. Catch and effort data, as well as socio-economic information, obtained from club-based angling competitions are of higher quality than data obtained from non-club anglers who have varied skill levels (Cass-Calay 2008, Gartside *et al.* 1999, Williams 2003). The availability of this data is inexpensive and the location of organized clubs and their competition meetings along the Southern African coastline is widespread, so these clubs represent a opportunity for obtaining reliable information on spatial catch trends.

Large Pelagic Longline Fisheries

In future, the onboard observer programme needs to include weights of species caught, by using length-weight conversion equations. This will enable the groundtruthing of logbook catch data submitted by individual longline vessels. The validations of catches have not yet been initiated and it is apparent from the estimated and reported net catches of target species that there has been both under-reporting and over-reporting of catches. Illegal, unregulated and under-reporting of catches is therefore occurring within the South African large pelagic longline fishery.

The large pelagic longline fishery is managed by restrictions on fishing areas and total catches of non-target species, which need to be less than a specified percentage of the total dressed weight of the target species per annum (DEAT 2009a, DEAT 2009c). Current restrictions on non-target

catches are failing and need to be reassessed, as current catches of Chondrichthyes are far greater than the imposed 10% limit, irrespective of the suggested upper catch limit of 1 068t (dressed weight) (DEAT 2007). Likewise, a swordfish TAC country allocation of 1 200t granted by ICCAT was never reached, in fact the *assumed true catch* of swordfish was a mere quarter of the granted MSY. The allocated swordfish MSY was also based on inaccurate data and on the premise that swordfish stocks are healthy in the Atlantic, yet South African vessels cannot even catch a third of this quota. Hence, it is recommended that the precautionary approach, already in place, concerning upper catch limits needs to be revised and recalculated, based upon true numbers of active vessels fishing and not on the capped TAE of 50 vessels.

Fisheries stock status

Groundtruthing of catches, required for commercial fisheries, and up-to-date results from recent studies are needed to verify data on catch rates and to analyse trends for target species, particularly in the longline fishery — noting that the most recent peer-reviewed publications on stock status were published more than a decade ago (Kroese 1999, Penny and Griffiths 1999). Since the near-collapse of swordfish stock in 1997, no literature has been published on the current status — describing spatial and temporal catch trends — of this species. The last stock assessment, conducted by ICCAT in 2006, stated that swordfish stocks were healthy, with current catches being 33% below the MSY of 17 000t (DEAT 2007). There is, however, much concern over the state of the swordfish stock in the southwest Indian Ocean where high fishing effort and catches continue to occur (DEAT 2007). South African longline vessels have been allocated a catch quota from ICCAT for 1 200t of swordfish in 2009, yet total net catches for 2009 reflect only 304t of swordfish being caught (DEAT 2007, Fishing Industry Handbook 2009). In addition, studies need to be conducted and journal articles need to be published on the current stock status of South African caught yellowfin and bigeye tuna. The MCM has struggled to implement and enforce management regulations, due to an insufficiently-sized task team, which has lead to poor human resource

allocation. This has had a direct effect on the collection of monitoring data, poor analysis of that data, underproduction of workable recommendations, and lack of enforcement of these recommendations.

Commercial TAC and TAE management measures

Currently the large pelagic longline and baitboat commercial sectors are managed by TAE regulations and not by TAC. In previous years neither of these fisheries has been able to reach country-allocated quotas and set MSY levels for tuna and tuna-like species (DEAT 2007, DEAT 2009b). The MCM currently has a lack of resource information available coupled with untrustworthy catch records, present and archived, that describe incomplete fisheries. It is recommended that in order to rectify these problems and those of under-reporting of catches, more emphasis needs to be placed upon TAC limits with regard to fisheries' poor past catch performance records. The collection of complete catch records from all TRH's and active vessels is a necessity. The current stock status is of growing concern regarding yellowfin tuna status as the species is currently fully-exploited in all four Oceans (FAO 2007). It is recommended that the existing precautionary-approach upper catch limits be revised and recalculated, based upon true numbers of active vessels fishing and not on the capped TAE (DEAT 2007, DEAT 2009b). With regard to the large pelagic longline fishery, current restrictions on non-target catches need to be reassessed, as these exceed the imposed upper limits (DEAT 2007).

Socio-economic impact

Studies resulting in the compilation of two reports on South Africa's fishing industry were published in 2003 (Mather *et al.* 2003, Sauer *et al.* 2003). Volume 1 assessed economic and regulatory principles, survey results, transformation, and socio-economic impacts of South Africa's fishing industries, whereas Volume 2 described the profiles for 15 fisheries. The comprehensive socio-economic information comprising these reports has not been used by government, MCM, and

neither has the recommended future management measures. These reports are outdated and it is imperative that similar studies be conducted, as little is known of South Africa's current fishing industry profiles and economic impact.

Observer longline programme

It was assumed that the Observer data base had 16.5% coverage of the 3 418 days actively fished in 2009 and this figure still under-represents the total prescribed observer vessel coverage as per government legislation (DEAT 2009c). Hence a more structured onboard observer sampling method needs to be adopted and implemented to improve coverage of fleet activity.

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APPENDICES

9. QUESTIONNAIRES AND SURVEYS

9.1 Recreational Competition Questionnaire – Skipper interview

Department of Ichthyology and Fisheries Science, Rhodes University
 Department of Marine and Coastal Management²
 Recreational Questionnaire



Date: _____
 Questionnaire # _____

Disclaimer:

Thank you for the time and effort taken to fill out this questionnaire. This questionnaire is devised to qualitatively and quantitatively assess the size and shape of the sport fishery. This will provide us with answers on catch, effort, catch per unit effort and socio-economic information so we (scientists) can further understand it and its importance to the local and international economy and the way our fish stocks are responding. Please note, the more truthful you are with your answers the better, as we are NOT here to police you and won't point fingers, but critically need accurate answers.

Hylton Newcombe
 Large Pelagics researcher
 Department of Ichthyology and Fisheries Science,
 Rhodes University, Grahamstown

SECTION A: (Catch and effort – Skipper interview)

Skipper's age: _____
 How many days have you spent fishing in the last 7 days _____, month _____ and in the last 12 months? _____
 Is your vessel night rate: Yes No If Yes, how often have you been night fishing in the last 12 months? _____
 Which fishing club are you affiliated to? _____
 How many years have you been skiboat fishing? _____

SECTION B: (Attitude to management and other)

Which of the following regulations, in your opinion, are effective in managing our fish stocks? (Ranked 1-5)

1 = Great, 2 = Good, 3 = okay, 4 = not effective, 5 = Bad.

Minimum size limits _____ Bag limits _____ Closed seasons _____ Marine reserves _____

Have you on occasion not complied with: Minimum size limits: Yes No Bag limits: Yes No Closed seasons: Yes No

Marine reserve boundaries: Yes No Has your catch ever been inspected: Yes No

If Yes, how often in the last month? _____; 12 months? _____

Whilst fishing has your bag limit ever been reached: Yes No For which species (specify) _____

Do you participate in any other forms of fishing? _____

Have you ever caught a tagged fish: Yes No

Reason for fishing (# order of importance): Food: Recreation: Competition: Livelihood: Other: _____ (specify)

Has fishing deteriorated over the years: Yes No If Yes, what is the cause for this decline:

Pollution: _____	Siltation: _____
Seine netting: _____	Gill-netting: _____
Trawling: _____	Over-fishing (commercial): _____
Over-fishing (recreational): _____	Other (specify): _____

SECTION C: (Economics)

State occupation (in detail): _____

If unemployed/retired, state previous occupation: _____

Place of current residency (province and suburb): _____

Are you a mid-week fisher , weekend fisher or both

Skipper: Do you sell fish to cover costs: Yes No Gamefish Other Price/kg: Gamefish: _R _____, Other: _R _____

Do crew contribute to the costs of the trip: Yes No

Do crew share vessel costs: Yes No or do they get free trip but don't keep fish: Yes No or Fish cover costs: Yes No

Method of transport used (vehicle type, model etc.): _____

Expenditure on: general tackle last month? _R _____; rods and/or reels in last 12 months? _R _____

Total estimated value of your sidboating equipment (sales value)?

1. Tow vehicle: R _____
2. Boat (including accessories) R _____
3. Motors: R _____
4. Tackle R _____
5. Rods and reels: R _____
6. Tackle R _____

Is vehicle use exclusively for towing the boat? Yes No

Expenditure on sidboat for:

1. Leasing: R _____
2. Storage: R _____
3. Maintenance: R _____

SECTION D: (Charters and non-consumptive use)

Do you ever take charters: Yes No If Yes, how many times in the last 12 months _____

How many crew do you have: _____; what do you pay crew on average per trip: R _____

On average, how many fish are sold per trip in your boat? Fish sold: _____ Other: _____ Other: _____

What do you charge per day: R _____

How many days have you used the vessel for fishing in the last 12 months _____ and in the last 12 months _____

Type of leisure activity: _____; Duration of activities _____

SECTION E: (Disposed effort P4) List the number of days spent per month for the year targeting the below listed species

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Tuna												
SeaH												
YellowT												
Bottom												

9.2 Access Point Creel Survey - Questionnaire

Department of Anthropology and Fisheries Science, Rhodes University
 Department of Marine and Coastal Management
 ACPS Questionnaire



Date: _____
 Questionnaire #: _____

SECTION A: (to be completed by interviewer)

Harbour: _____

Own boat? Yes/No

Deckload:	Commercial:	Crew size:
Skiboat: 2	Charter: 3	Crew composition: (M/F)
Infatable: 3	Recreational: 4	Estimated age: 100, 20-40, 40+
PWEst: 4	Letsubo: 5	

SECTION B: (Catch and effort - Skipper interview)

Skipper's age: _____

How many days have you spent fishing in the last 7 days _____ month _____ and in the last 12 months? _____

Is your vessel night rated? Yes No If Yes, how often have you been night fishing in the last 12 months? _____

Which fishing club are you affiliated to? _____

How many years have you been skiboat fishing? _____

SECTION C: (A. Grade of management activities)

Which of the following regulations, in your opinion, are effective in managing non-fish stocks? (Rank 1-5)

1 = Great, 2 = Good, 3 = okay, 4 = not effective, 5 = Bad.

Minimum size limits _____ Bag limits _____ Closed seasons _____ Marine reserves _____

Have you in possession and complied with: Minimum size limits Yes No Bag limits Yes No Closed seasons Yes No

Marine reserves (annular) Yes No Has your catch been inspected? Yes No

If Yes, how often in the last month? _____ 12 months? _____

While fishing has your bag limit ever been reached? Yes No For which species (specify) _____

Do you participate in any other forms of fishing? _____

Have you ever caught a tagged fish? Yes No _____

Reason for fishing (in order of importance): Food Recreation Competition Live food Other: _____ (specify)

Has fishing deteriorated over the years? Yes No If Yes, what is the cause for this decline:

Hollard:	Stobart:
Some nothing:	all nothing
Trawling:	Overfishing (commercial):
Overfishing (recreational):	Fine (specify):

SECTION D: (Economic)

State occupation (in detail): _____

If unemployed/retired, state previous occupation: _____

Place of current residency (province and suburb): _____

Are you a mid week fisher weekend fisher or both

Skipper: Do you sell fish to cover costs? Yes No Sportfish Other Price/kg: Commercial: R _____; Other: R _____

Do crew contribute to the costs of the trip? Yes No

Do crew share vessel costs? Yes No or do they get free trip but don't keep fish? Yes No or fish cover costs? Yes No

Method of transport used (vehicle type, model, etc.): _____

Expenditure on: general tackle last month? R _____; rods and/or reels in last 12 months? R _____

Total estimated value of your skiboating equipment (sales value)?

1. Tow vehicle: R _____
2. Boat (including accessories): R _____
3. Motor: R _____
4. Trailer: R _____
5. Rods and reels: R _____
6. Tackle: R _____

Is vehicle use exclusively for towing the boat? Yes No

Expenditure on skiboat for:

1. Licensing: R _____
2. Storage: R _____
3. Maintenance: R _____

COMMERCIAL

How many crew do you employ? _____ How much do you pay your crew per month? ZAR _____

SECTION E: (Charter and non-consumptive use)

Do you ever take charters. Yes No If Yes, how many times in the last 12 months: _____

How many crew do you have _____: What do you pay crew on average per trip: R _____

On average, how many fishermen/divers/other do you take: Fisherman: _____; Diver: _____; Other: _____

What do you charge per day: R _____.

How many days have you used the vessel for leisure in the last month _____ and in the last 12 months: _____

Type of leisure activity: _____ Duration of activities: _____

SECTION F: (Directed effort FIA) List the number of days spent per month for the year targeting the below listed species

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Line												
Snork												
Yellow												
Bottom												

9.3 Economic Sectoral Study Questionnaire – Tuna Baitboat

TP ESS DATA SHEET - QUESTIONNAIRE - TUNA RESEARCH

PLEASE USE 2008 TAX YEAR (MAR 2007 – FEB 2008) FOR ANY FIGURES OR FINANCIAL INFO REQUIRED

EMAIL TO: g01n0954@campus.ru.ac.za

ALL INFO WILL BE TREATED CONFIDENTIALLY

1. Vessel information

1.1	Vessel no.(Reg./Area No -HTB/CT)		
1.2	Vessel name		
1.3	Construction year		
1.4	Vessel length		
1.5	Call sign - (ZR No)		
1.6	GRT:		

If any other General Vessel Information is necessary or appropriate to the specific fishery add it under sub section 1.6

2. Specific information

2.1	Vessel type (model/make)		
2.2	Deck material		
2.3	Hull material		
2.4	Hull type (displacement/planning)		
2.5	Engine type (inboard/ outboard)		
2.6	Horse power of motors		
2.7	Propellor type		
2.8	Power type- eg. Generator		
2.9	Onboard storage		
2.10	Processing and cooling(eg.ice,slurry,freezer)		
2.11	Fuel capacity (litres)		

3. Vessel running costs

3.1	Licences (Rand)		FILL OUT SCHEDULE 'A' ATTACHED
3.2	Mooring/ Boatyard costs (Rand)		
3.4	Levies (Rand PER ANNUM)		
	3.5 Fuel expenditure (Rand)		
3.5.1	Ave. no days(NOT TRIPS) at sea per annum		
3.5.2	Annual fuel cost		
	3.6 Food costs (Rand)		
3.6.1	annual food costs		

3.7	Tackle costs (Rand)		
3.7.1	Annual tackle costs		
	(hooks, line, lures etc. - NOT poles, rods & reels or shortsticks)		
3.8	Outfits		
3.8.1	Outfit values (poles; rod and reel; shortsticks)		
3.8.1.1	Total pole value on boat (Rand)		
3.8.1.2	Total rod and reel value on boat (Rand)		
3.8.1.3	Total shortsticks and reels value on boat		
3.8.2	Replacement cost of outfit:		
3.8.2.1	pole replacement		
3.8.2.2	rod and reel replacement		
3.8.2.3	shortstick and reel replacement		
3.8.3	Ave no purchased per annum:		
3.8.3.1	pole outfits		
3.8.3.2	rod and reel		
3.8.3.3	shortstick and reel		
3.9	Bait costs (Rand)		
3.9.1	Annual bait costs		
3.10	Ice costs (Rand)		
3.10.1	Annual ice costs		

4. Harbour

4.1	Official port of call (HB,KB,CT ETC)		
4.2	Port of call where 75% of off loadings occur		

5. Crew

	PLEASE FILL OUT SCHEDULE B ATTACHED USING ONE LINE PER CREW MEMBER.		
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6. Ownership of vessel/ Rights Holder

6.1	Name of company (CC or Pty Ltd.)		
6.2	MCM Authorised contact person		
6.3	Current shareholding percentage see SCHEDULE C ATTACHED		

7. Ownership of Rights where a charter or catching agreement has been entered into:

7.1	Name of Rights Holder		
7.2	MCM Authorised contact person		
7.3	Current shareholding percentage see SCHEDULE C ATTACHED		

8. Other allowable species info as per permit excluding Tuna species

8.1 Type and % of total catch (total catch means all fish caught including Tuna species)

TYPE		%
Snoek		
Angel fish		
Oil fish		
Escolar		
Dorado		
Wahoo		
Squid (excluding Loligo vulgaris)		
Yellowtail		

8.2 Discards (dead or released fish) and % of total catch

TYPE (eg. Blue sharks, Mako's)		%

9. Vessel value

9.1	Market value of vessel (includes all accessories, and engines)	
9.2	Replacement value of vessel	

10. Vessel specific trailer and launching costs

10.1	Trailer cost (Rand)	
10.2	Tractor launching facility costs per month (Rand)	

11. TRIP INFORMATION

11.1	Trips per year	
11.1.1	Maximum no of days at sea per annum	
11.1.2	Average no. of days at sea per annum	
11.2	Hold capacity (kg's)	

TP ESS DATA SHEETS - PAGE 4

12. Product distribution

PLEASE FILL IN SCHEDULE D ATTACHED	
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11. Nature of fishing gear and type

NB: For questions 13.1 to 13.4, please give a score between 1 and 10 (10 is a little impact)

QUESTION	SCORE or YES/NO ANSWER
13.1 Environmental impact of your fisheries fishing gear.	
13.2 Threat of your fisheries fishing practice to bird and mammal life	
13.3 Threat of your fisheries fishing practice to other allowable fish species (discards as well)	
13.4 Do you believe that your fisheries fishing practice is beneficial to the sustainability of your target species (Y=yes, N - no)	
13.5 Is the current size of your fishery sectors fleet too large? (Y=yes, N-no)	
13.6 Are there too few compliance officers monitoring fisheries? (Y- yes, N-no)	

THANK-YOU FOR YOUR TIME SPENT IN FILLING THIS OUT.

PLEASE EMAIL YOUR COMPLETED FORM TO HYLTON NEWCOMBE

EMAIL: g01n0954@campus.ru.ac.za

SCHEDULE A - LICENSING COSTS (PER ANNUM)

	NAME	TYPE	COST
			RANDS P/A
3.1.1	ICASA	VHF	R
		29mhz	R
3.1.2	SAMSA	GROSS COST	R
		(FOR TOP & BOTTOM INCLUDING SLIPPING FEES, SHAFT BLEUING, ANTIFOWL, PRE-SEA CERT. ETC	
3.1.3	SABS	CREW MEDICAL CERTIFICATES	R
		PEST CONTROL	R
		INSPECTION FEE	R
		TEMP GAUGE CALIBRATION	R
3.1.4	MCM	FISHING VESSEL LICENCE	R
		PERMIT TO UNDERTAKE COMMERCIAL FISHING	R
		FOR TUNA BY MEANS OF THE POLE METHOD	
3.1.5	OTHER	E.G. (LIFE SAVING EQUIP. (RAFT))	R

