

Extracting fish abundance indices from recreational fishing competition data

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Man's life is but vain, for 'tis subject to pain,
And sorrow, and short as a bubble;
'Tis a hodge-podge of business, and money, and care,
And care, and money, and trouble.
But we'll take no care when the weather proves fair,
Nor will we vex now though it rain;
We'll banish all sorrow, and sing till to-morrow,
And angle, and angle again.
-“Walton & Cotton – The Compleat Angler”

Abstract

Over-exploited fisheries result in global economic losses and can lead to the degradation of marine ecosystems. Commercial and recreational fisheries have grown substantially over the past decades placing fish stocks under increasing pressure. Fisheries management aims to conserve and restore stocks to economically and environmentally sustainable levels. Stock assessments are mostly based on analyses of fishery-dependent data, however, this practice often neglects uneconomically important species, making ecosystem approaches to fisheries management challenging. Competitive recreational angling has the potential to provide accurate and consistent records of catch and effort data for a variety of unassessed fish species as well as data for currently assessed commercial species, but without the market influence on targeting. The data from five boat based recreational competitions in the Western Cape were studied. Records for the competitions varied in length with the longest dataset from running from 1994 to 2014, and the shortest from 2003 to 2014. The competitions were divided into three inshore and two offshore groups with each targeting different assemblages of fish. In total 38 species of teleost were caught, but at least 90% of the total catch for each competition was comprised of seven species or less. Catch composition was determined for each competition and the standardised catch per unit effort (CPUE) of the ten most abundant species across the competitions were assessed. CPUE trends for red roman, snoek and geelbek were comparable to commercial fishery-dependent CPUE data. The targeting of specific species in the multi-species fishery noticeably influenced CPUE values. Catch limits resulted in lower estimations of the CPUE for snoek, and potentially for red stumpnose. Boat based competition data is accurate and consistent enough for the extraction of abundance indices for certain species. Further work on these data may involve the standardisation of CPUE values to account for targeting in the multi-species fishery. With a large number of boat based competitive anglers in the country, there is a scope for using these data for stock assessments, either as stand-alone data sources, or as an adjunct to well-established commercial catch time-series.

Keywords – catch composition, competition boat fishery, CPUE, Western Cape

Introduction

Overexploitation of marine stocks not only results in substantial economic losses due to poor yield, but can be severely detrimental to ecosystem health and functioning which can lead to a reduction in the resilience of marine ecosystems (Mora *et al.* 2009, World Bank 2009, Worm *et al.* 2009, Curtin and Prellezo 2010). A less resilient system is more vulnerable to additional anthropogenic influences, such as the warming of ocean surface waters, ocean acidification and pollution (Walker 1995, Guinotte and Fabry 2008, Doney *et al.* 2009, Hoegh-Guldberg and Bruno 2010, Curtin and Prellezo 2010).

With a growing recognition of the implications associated with overexploitation, efforts have been focused on the regulation and management of commercial and recreational fisheries (Pauly *et al.* 2005, Worm *et al.* 2009, Sumaila *et al.* 2012). These steps, in conjunction with the development of marine protected areas (MPAs), are adapted into a holistic approach to rebuild heavily and overexploited stocks (Pinnegar *et al.* 2000, Hilborn *et al.* 2004, Worm *et al.* 2009, McLeod *et al.* 2009). In the past, the primary objective of fisheries management was to keep stocks at an economically optimum level, whereby recruitment would replenish the stocks removed by fisheries and account for loss due to natural mortality (Mace 2001, World Bank 2009, Sumaila *et al.* 2012). Keeping stocks at a maximum sustainable yield results in a renewable economic asset and provides stable jobs in a productive industry (Walters and Martell 1994, Jennings *et al.* 2001). With a greater understanding of ecosystem services, and the need to protect ecosystems as a whole for a healthy, resilient environment, the attention of fisheries management has gradually expanded to incorporate the environmental benefits of healthy fish populations (Larkin 1996, Branch and Clark 2006, Mora *et al.* 2009, Worm *et al.* 2009, Curtin and Prellezo 2010). In order to effectively carry out the conservation efforts associated with the rebuilding of exploited fisheries it is vital to have an understanding of the current structure of the stock, and beneficial to have historical and biological data with which to assess changes over time and predict the recovery or decline of stocks under fishing pressure (Begg *et al.* 1999, Worm *et al.* 2009).

Stock assessment

Stock assessment involves the quantifying of a targeted population, observing factors such as abundance, age structure and individual length or weight (Jennings *et al.* 2001, Worm *et al.* 2009). These data can be collected in a variety of ways depending on the species or fishery that is being assessed, but they are typically gained through fisheries independent surveys or,

more commonly, through fisheries dependent methods (Gulland 1983, Worm *et al.* 2009). Fisheries independent surveys, such as scientific research trawls, provide some of the best quality data through repeated standardized methodology that assess targeted and non-targeted species (Worm *et al.* 2009). They allow for the study of community trends as well as provide a snapshot of the population structure of specific species, or groups of species, at the time of the survey (Worm *et al.* 2009). Fisheries independent surveys are, unfortunately, often costly to conduct and so, despite their usefulness, they are often run infrequently and over limited spatial scales. Fisheries dependent data, on the other hand, can provide useful long-term catch records with quantifiable information on their targeted populations over longer time frames and over large areas, however variations in the gear used can lead to inconsistency in the catchability of targeted species (Quinn and Deriso 1999, Maunder and Punt 2004, 2013). Using data generated by fisheries, it is possible to calculate relative abundance indices of fish stocks based on the catch per unit effort (CPUE) (Quinn and Deriso 1999, Maunder and Starr 2003, Campbell 2004).

Raw fisheries dependent data are used to calculate the nominal CPUE, which is the total catch divided by a measure of effort, for example the number of fishing hours, which is often calculated for a defined temporal duration (Maunder *et al.* 2006). An index based on the nominal CPUE fails to take into account an array of factors that may influence the proportional abundance of the stock, and therefore requires standardization in order to remove the effects of these variables (Maunder and Starr 2003, Maunder and Punt 2004, Maunder *et al.* 2006, Campbell 2015). Of the many statistical modelling techniques applied to fisheries stock assessment, Generalized Linear Models (GLMs) are one of the most commonly used for the standardisation of the CPUE (Venables and Dichmont 2004, Maunder and Punt 2004, 2013, Campbell 2015). GLMs take into account the relationship between the statistical distribution of the dependent variable, such as the abundance of fish caught, and the independent explanatory variables that influence them (Guisan *et al.* 2002, Campbell 2015). The standardized CPUE is a more accurate reflection of the proportional abundance of the stock, and it has become widely used in stock assessment (Guisan *et al.* 2002, Maunder and Punt 2004, Maunder *et al.* 2006). When compared over time, standardized CPUE values show trends in a population and can be used in conjunction with biological data to develop management strategies for achieving an appropriate target such as the maximum sustainable yield (Bonfil 1992, Maunder *et al.* 2006, Campbell 2015). CPUE measures do have limitations and are potentially better suited to monitoring a single species, rather than

multispecies communities or ecosystems, however with standardization they are useful tools for stock assessment (Winker *et al.* 2013).

South African linefisheries and stock assessment

South Africa's geographic location, being the meeting point of two of the world's major oceans, as well as being on the fringe of the Southern Ocean, provides it with a rich diversity and abundance of marine flora and fauna (Branch *et al.* 2002). The upwelling Benguela current provides nutrients to one of the most productive ecosystems in the world on the west and south-west coasts of the country (Hutchings *et al.* 2009), while the warm, less productive Agulhas current on the east coast contains inshore and deep sea reefs which host high levels of biodiversity (Branch *et al.* 2002, Branch and Clark 2006). Although fishing takes place throughout South African waters in both the Atlantic and the Indian Ocean, it is the rich Benguela system on the west coast that is the most economically important, supporting a well-established recreational fishery, in addition to a large commercial fishery (DAFF 2012).

Linefishing in the Cape has been an important industry since the 1800s, harvesting a number of economically valuable fish species along the west and south west coasts (Griffiths 2000). The industry typically targets omnivorous or carnivorous species using lines with baited hooks or artificial lures, but excludes the longline industry (Mann 2013).

The linefishery is comprised of a large commercial and recreational sector and a smaller subsistence sector. The industry began expanding in the 1900s and as the fleets grew there was a noted decline in fish stocks from the 1930s onwards (Griffiths 2000). Larger fleets housing modern technological equipment resulted in ever increasing fishing pressure, which was compounded by an influx of foreign trawlers in the 1960s (McGrath *et al.* 1997, DAFF 2012). A number of economically important, and presumably resilient, fish stocks had fallen to dramatically low levels, with catch rates of species such as kob (*Argyrosomus* spp.), carpenter (*Argyrozona argyrozona*), seventyfour (*Polysteganus undulosus*), geelbek (*Atractoscion aequidens*), red roman (*Chrysoblephus laticeps*), and red stumpnose (*Chrysoblephus gibbiceps*) falling to a fraction of historically recorded catches (Griffiths 2000).

The first management protocols were developed in 1985, however these were found to be ineffective and studies showed a continued decline in stocks (Griffiths 2000). With further research, a linefish management protocol was developed and implemented in 1999 in the hopes of rebuilding the stocks to sustainable levels (McGrath *et al.* 1997, Griffiths 2000). The

protocol was designed to take not only the economic, but also the social and environmental impacts of overexploited fisheries into consideration (Petersen *et al.* 2010). It imposed a severe reduction in the total allowable effort of 70% for commercial fisheries, and attempted to reduce the impact of recreational fishing by imposing size and bag limits for certain species, as well as closed seasons and restricted fishing areas (Griffiths 2000). Stock assessments indicate that many important line fish species are severely over exploited and continued fishing pressure threatens a number of endemic linefish populations. With current measures in place, 14.8% of South Africa's fish stocks are shown to be overexploited, 48.1% are optimally exploited, and 7.4% are underexploited, leaving 29.6% unaccounted for with their status unknown (DAFF 2010).

In South Africa, stock assessment relying on fisheries dependent data from commercial catches provide useful indices of abundance for commercially important fish stocks (DAFF 2012). Since these fisheries tend to target the most economically viable species, this leaves many economically less desirable, but no less ecologically important species unaccounted for. With gaps in the assessment of certain species within the ecosystem, the implementation of an ecosystem approach to conservation and rebuilding of fish stocks is made difficult. It is therefore necessary to find unutilised or underutilised sources of fisheries data which may be beneficial for the development of abundance indices.

Recreational fishing

Recreational fishing differs from commercial fishing in that the fish that are caught are not the primary source of food for the individual or their family, are rarely sold or traded, and if they are they do not constitute the primary income of the individual (FAO 2012a). It is not clear when people began fishing recreationally, however it has certainly been an important part of human culture for centuries with recorded appreciation of the pastime dating back to the 1650s (Walton 1653). Despite its popularity over the ages the impact of recreational fishing on fish stocks has rarely been of concern, particularly so in the marine environment where large spatial scales contribute to the resilience of stocks when they are at sustainable, healthy levels (Cooke and Cowx 2004). Compared to the impact from the commercial sector, the minimal pressure exerted on stocks by a relatively small number of anglers was of not much concern (Cooke and Cowx 2004, Coleman *et al.* 2004). Over the past few decades improving economies and an unprecedented increase in the size of the human population have resulted in many more people participating in recreational fishing around the world (Cooke and Cowx 2004, Coleman *et al.* 2004, Leibold and van Zyl 2007, Pawson *et al.* 2008,

Zischke *et al.* 2012). The increase in participation has been highly beneficial for local and national economies due to high levels of economic expenditure by recreational anglers, however the impact that the industry is having on fish stocks is becoming increasingly apparent (Cooke and Cowx 2004).

The economic benefits of recreational fishing are enormous and it forms a multibillion-dollar global industry (FAO 2012b). In 2002 an estimated 3.4 million Australian anglers spent US\$ 1.3 billion on recreational fishing equipment and trips (Australian Department for Agriculture and Forestry 2003). A 2011 national survey in the United States estimated that 33.1 million Americans participated in recreational fishing, of which 8.9 million were saltwater anglers. The survey revealed that the total fishing expenditure of recreational anglers during the year was US\$ 41.8 billion, with marine anglers contributing an estimated US\$ 10.3 billion and participating in an 86.2 million fishing trips (U.S. Fish and Wildlife Service 2011). Surveys and figures of expenditure related to recreational fishing exist mostly for economically developed countries and regions, making it difficult to estimate the total economic impacts of recreational fishing globally, however it is predicted to come close to, or in some cases exceed that of commercial fishing (Cooke and Cowx 2004, FAO 2012a).

Due to the extent of recreational fishing around the world, it is impossible to give exact figures on the total catch. Through extrapolation and statistical modeling, estimates suggest that the annual catch by anglers in 2004 was 12 percent of the total catch globally, with 47 billion fish caught, of which an estimated 60 percent were released (Cooke and Cowx 2004). Despite the popularity of catch and release methods, it has been shown that post-release mortality can be quite high and may account for the substantial loss of many of these fish (Cooke and Cowx 2004, 2006). Technological advances have made recreational fishing easier and more efficient, allowing anglers access to previously inaccessible waters and stocks, and bringing catch rates up to those of commercial fisheries, for certain species (Valdemarsen 2001, Brouwer and Buxton 2002, Cooke and Cowx 2004). Fish finders, GPS mapping and communication networks can result in anglers targeting specific fish populations to the point that they are completely consumed; this is particularly the case for populations of resident reef fish and other non-migratory species (Brouwer and Buxton 2002, Griffiths 2012). Anglers tend to be highly selective, targeting larger individuals, which can lead to alterations in the population structure and composition (Alós *et al.* 2014). The targeting of certain species can also affect ecosystem functions and interrupt trophic cascades (Scheffer *et al.* 2005, Cooke and Cowx 2006). Despite the negative impacts that recreational

fishing can have on fish stocks, the socio-economic importance of the industry is undeniable, and there is a growing awareness of the need for conservation from stakeholders (FAO 2012a).

Due to the importance of the recreational fishing industry further management is required; however this is complicated by the vast extent of the sector. The open-access scenario of millions of anglers targeting a multitude of species makes monitoring and implementation of rules and regulations very difficult (McPhee *et al.* 2002, Pauly *et al.* 2005). With large-scale commercial fisheries, it is possible to monitor and track their catch accurately and efficiently as they return to specific points with their catch. This makes assessment and regulation of commercial fishing effort far easier than that of the recreational sector. Additionally, management plans for recreational fishing are further complicated as data on many recreational fish stocks are often lacking. It is therefore a priority to assess recreationally important species in order to develop management schemes for the preservation of the stocks and the associated industry.

Recreational fishing has the potential to provide useful data for the assessment of species targeted by the industry. Acting in the same way that commercial fisheries dependent stock assessment is carried out, the standardized CPUE from anglers can provide an index of abundance if the fishing methods are consistent and the data are accurately recorded. Much of the recreational fishing data that have been studied come from interviews, surveys and diarised entries from recreational anglers. In many cases, these surveys use unverified data, which, although useful, may not be entirely accurate (Pollock *et al.* 1994, Bray and Schramm 2001, Mallison and Cichra 2004, Griffiths *et al.* 2010).

Fishing competitions can provide fisheries management with good quality data that are usually verified, and for which records have been kept for multiple years. Competitions tend to be standardised, with a set of rules and regulations that all participants must abide by. Specified fishing times within demarcated fishing areas allow for consistency of records and the data must have a level of accuracy as it is used for league standings and competitive rankings.

Recreational fishing in South Africa

Saltwater angling is a highly popular pastime in the country, with the number of participants in 1996 estimated at 400 000 shore based anglers (McGrath *et al.* 1997) and 13 800 boat based anglers (Sauer *et al.* 1997). An estimate by Leibold and van Zyl (2008) placed the

number of recreational anglers at 900 000 (Leibold and van Zyl 2007). These figures have probably increased if global trends have been followed (FAO 2012a). Recreational anglers target approximately 200 species of marine fish, many of which are not caught by boat based commercial fisheries. Although a number of studies have been done on recreational catches in South Africa, including shore, boat and estuarine angling, the majority have focused on shore based and estuarine angling along the east coast of the country (van der Elst 1979, Coetzee and Baird 1981, Smale and Buxton 1985, Clarke and Buxton 1989, Coetzee *et al.* 1989, James *et al.* 2001, Brouwer and Buxton 2002, Mann *et al.* 2002, Pradervand and Govender 2003, Pradervand 2004, Pradervand *et al.* 2007, Everett and Fennessy 2007, Beckley *et al.* 2008, Dicken *et al.* 2012). Fewer studies have been done along the southern and west coasts, and those that have were mainly focused on shore based angling (Bennett 1991, Bennett *et al.* 1994, Attwood and Bennett 1995, Pradervand and Hiseman 2006). The trend in literature is partially reflective of the structure of the recreational fishing industry in the country, with the majority of anglers being shore based, however there is a well-established recreational boat based sector, and not all recreational fishing effort is focused along the east coast. In the Western Cape, deep sea recreational fishing is an important sector in the linefishing industry and numerous competitions are held throughout the year.

The South African Deep Sea Angling Association (SADSAA) is the national governing body of deep sea sport fishing in the country, with the aims of promoting and controlling sports fishing in line with national and international regulations. The association is made up of 14 regional member bodies which represent allocated geographical areas. Each regional member body contains a minimum number of clubs for which it is responsible for. As of the end of 2014, there were 112 clubs affiliated with SADSAA, with over 9000 members and 3684 registered boats (M. Grant, WPDSAA, pers. comms.). Registered members actively participate in competitive leagues and standalone competitions organised by the associated regional bodies. The records and rules of these events are documented and archived by the regional bodies.

Competition data from South African anglers have been used before. A study done by Smale and Buxton (1985) looked at reported lists of species caught by the Port Elizabeth Deep-Sea Angling Club (Smale and Buxton 1985). Studies done by Pradervand *et al.* (2004 & 2007) looked at competitive shore angling data along the coast in the Transkei and KwaZulu Natal (Pradervand 2004, Pradervand *et al.* 2007). Dicken *et al.* (2012) studied catch and effort data from a shore based competition in the Eastern Cape (Dicken *et al.* 2012). As has been

mentioned already, little to no research has been conducted on the recreational sector in the Western Cape, and very little has been done on boat based competitive fishing in the country.

The objectives of this project were to assess the usefulness of recreational fishing data as potential abundance indices through observable trends in the standardised catch and effort data for specific fish species caught during boat based competitions in the Western Cape. Although stock assessments of a number of important linefish species in the region have already been carried out, mostly through fisheries dependent stock assessment from commercial data sources, a number of less economically important species lack sufficient information to assess the abundance of the populations (Mann 2013). With the use of catch data from SADSAA affiliated clubs it may be possible to provide abundance indices for species which are poorly represented in commercial catches. Recreational catches might also provide new and better information, as competitions potentially exploit different stocks to those targeted by commercial fleets. Additionally, recreational fishing is not influenced by the market value of fish and the cost of running a fishing business, which may influence targeted species and fishing effort. This additional source of information can potentially allow for the development of more comprehensive management plans to ensure the continued productivity of these stocks.

Methods

Study area and Competitions

The data for this study were made available by the Western Province Deep Sea Angling Association (WPDSAA). The WPDSAA acts as the regional body for SADSAA on the Cape Peninsula and surrounding areas. As of the start of 2015 the WPDSAA had 11 affiliated clubs, the majority of which were located on and around the Cape Peninsula and False Bay, with the eastern most club being Struisbaai and the northern most club being Yzerfontein. There were 988 registered members and 572 registered boats at the start of 2015. The WPDSAA runs three competitive leagues throughout the year and is responsible for organising and running the SADSAA Tuna Nationals on an annual basis, all of which are well attended. The Simon's Town Military Deep Sea Angling Club, with 45 members as of the end of 2014, falls under the auspices of the WPDSAA but runs independent leagues throughout the year. Five datasets were provided from the competitions run by the WPDSAA. They were: Inshore South league (INS), Inshore West league (INW), Offshore league (OFF), Simon's Town league (SIM) and the Tuna Nationals (TNAT).

The five datasets were broadly divided into two groups based on their location to the shore and their catch composition. These divisions were inshore, comprising of the Simon's Town league, the Inshore West league and the Inshore South league; and offshore, including the Tuna Nationals and the Offshore league.

All leagues were fished throughout the years on multiple leg days which were dependent on weather and sea conditions. The rules for all leagues remained fairly consistent over the period of available data. Variations in the rules are discussed below in summaries of each competition.

WPDSAA Inshore South league

The Inshore South league was fished around the southernmost tip of the continent, with launching sites at Kleinbaai, Gansbaai and Struisbaai. Between 2000 and 2012 the fishing days hosted by the Gansbaai and Kleinbaai clubs were allowed to fish within 10 nautical miles of the launching sites, with a southern boundary of three nautical miles south of the Quoin Point Lighthouse. During this time a six nautical mile boundary was set from the Struisbaai launch site. These boundaries were changed in 2013 to seven nautical miles from all three launching sites. Between four and six weekends were set aside throughout the years,

with launches typically alternating between Gansbaai, Kleinbaai and Struisbaai. Since 2010 split launches allowed anglers to launch at either Gansbaai or Kleinbaai during leg days taking off from these locations, however split launches were only recorded on datasheets from 2012 onwards.

Launch and line up times were dependent on season and varied by an hour or two over the years. The longest recorded fishing days were 11 hours and the shortest were 8.5 hours. Launch times in winter, between March and September, were between 07.00 and 07.30, and in summer, October to February, at 06.00. On Saturdays lines had to be taken up by 16.00 in winter, and 17.00 in summer. If a leg day fell on a Sunday, the line up times varied between 14.00 and 15.00 over the years.

WPDSAA Inshore West league

The Inshore West league included launching sites on either side of the Cape Peninsula and Gordon's Bay. Between 2000 and 2009 leg days launching from sites within False Bay were confined to the bay within a straight line from Cape Point Lighthouse and the Cape Hangklip Lighthouse, including a five nautical mile radius from each of the points. These rules changed in 2010, increasing the fishing area for leagues launched from within False Bay and on the western side of the peninsula to include an area three nautical miles around Robben Island, down the peninsula and across to Cape Hangklip, within five nautical miles from land.

Leg days varied slightly over the years, typically five or six fishing days were set aside throughout the year, with two spare days in case of cancellations due to poor weather or sea conditions.

Start times and line up times changed according to the season, and varied by an hour or two over the years. The longest fishing days were 11 hours and the shortest were six hours. In winter, March to September, launch times were from 06.00 between 2000 and 2006, and 07.00 between 2007 and 2013. In the summer months, October to February, launch times were at 04.00 between 2000 and 2005, and 06.00 from 2006 onwards. Lines up times were at 14.30 between 2000 and 2004, they were extended to 15.00 from 2005 onwards, unless the leg day was fished on a Sunday, in which case the lines up time was 14.00.

WPDSAA Offshore league

Launching sites for the Offshore league included any WPDSAA affiliated club-launching venue. The fishing area was limited to a maximum of 40 nautical miles from Cape Point,

unless anglers launched from Struisbaai, Gansbaai or Klein Bay, in which case the fishing area was a maximum of 40 nautical miles from their respective harbours.

No launching times were imposed, however line-in times were 07.00 for leg days in November and December, and 07.30 from March to October. Line-up times were at 15.00 for all leg days. The longest fishing days for the league were eight hours and the shortest were seven and a half hours.

Simon's Town Military Defence league

The Simon's Town league was run similarly to the aforementioned three leagues as it was associated with the WPDSAA and followed the rules set out by the association. The fishing boundaries were the same as the Inshore West league, around the Cape Peninsula, including False Bay. The launch and retrieval of the boats was at the Simon's Town Slipway.

In the winter months, between March and September, anglers fished for eight hours per leg day and in the summer months, October to February, they fished for nine hours a day.

General rules applicable to all WPDSAA leagues

Anglers in the leagues had to be registered members of the WPDSAA and agreed to follow the rules imposed by the WPDSAA and SADSAA. Additionally, they had to have valid national fishing licences and abide by the national laws pertaining to sport and recreation regarding bag limits, minimum sizes, protected species, and protected areas.

Leg days were cancelled due to inclement weather and ocean conditions, unless they could be fished on a spare leg day during the year, in which case they were postponed. This meant that not all months were equally represented over the years.

Anglers were allowed a maximum of 4 rods and 4 reels on board, but were not allowed more than two lines in the water at any one time.

For all Inshore leagues, a minimum weight of 1 kg was imposed, unless otherwise regulated by national laws regarding the minimum legislated size & weight per species. In cases where minimum length of the fish was required, such as red stumpnose and yellowfin tuna, fish length was checked before weighing. Elasmobranchs did not contribute to the point system per angler and were rarely recorded at the weigh-ins, those that were recorded were not taxonomically identified. The minimum weight for all game fish species caught in the Offshore league was 10 kg or the legal limit, whichever was greater.

Anglers were not allowed to weigh more than 10 fish per leg and boats could be inspected at any stage to check for illegal bag limits, or failure to comply with the rules. At the weigh-ins, individual anglers had to present their fish to a nominated weigh master, who used certified scales to record the weight and length of the fish. All information was recorded on official weigh sheets and later captured into a spread sheet database. Points were awarded to anglers based on the number of fish caught, the weight of fish, and for the Inshore South and West competitions, for the number of legal species weighed.

The rules and points for different line weights and line classes changed over the years, particularly so in the Inshore leagues, where minimum line weights increased from 2kg to 6kg between 2002 and 2014. Line weights were not focused on in this study, however this would be an interesting factor to explore in future research.

SADSAA Tuna Nationals

The Tuna Nationals were held annually towards the end of April and the beginning of May. The rules for the competition were similar to those set out in the Offshore league. All anglers would launch from, and return to one of the WPDSAA affiliated clubs, the venue typically changed over the years. They fished for eight hours a day over four allocated fishing days, with one spare day set aside in case of inclement weather. A maximum limit of 40 nautical miles from Cape Point was set as the fishing area. Anglers were allowed two lines in the water at a time and the main target species were yellowfin and longfin tuna.

Data recording

Official weight sheets from the five competitions were submitted to the WPDSAA where they were verified and entered into standardised spreadsheets. These contained information on the dates, launching site, boat and angler outings, number, weight and species of fish caught, and in more recent years the fish length, measured as total fish length. Successful and unsuccessful boat and angler outings were recorded on the weigh sheets.

Records were well documented and consistent across the years and across the competitions. The only competition with a differing format was from the Simon's Town league, which did not include individual angler outings, but rather had boat outing and number of anglers on board. The data were checked for errors that may have been input as they were transposed from the weigh sheets to the spreadsheets.

Calculation of the CPUE

In the calculation of the CPUE, and the resulting statistical analyses, the number of fish caught per individual angler per hour was used. Of the species caught, not all were sufficiently represented over the years and across the competitions to potentially reflect changes in abundance over time. Of the 38 species that were caught, ten were selected due to their abundance in individual competitions and across multiple competitions. Species with a high research priority were also selected based on current understandings of their conservation and stock status.

The ten species that were selected were: red roman (*Chrysoblephus laticeps*), red stumpnose (*Chrysoblephus gibbiceps*), snoek (*Thyrsites atun*), yellowtail (*Seriola lalandi*), kob (*Argyrosomus* spp.), hottentot (*Pachymetopon blochii*), geelbek (*Atractoscion aequidens*), Atlantic bonito (*Sarda sarda*), longfin tuna (*Thunnus alalunga*), and yellowfin tuna (*Thunnus albacares*).

Species composition for the inshore competitions

Multivariate statistics were used to assess the similarity in catch composition among the three inshore competitions and shifts in composition among the decades. A matrix of catch composition by year was imported into PRIMER (Clarke and Gorley 2006). The competitions (Simon's Town, Inshore South and West) and decades (1990, 2000, 2010) were input as factors and the data were standardised and square-root transformed to reduce the influence of highly abundant species within the data. The Bray-Curtis index was used to calculate similarity among years and competitions. A multidimensional scaling plot (MDS) was used to graphically represent the similarity among competitions and years.

A permutational multivariate analysis of variance (PERMANOVA) was run to compare the variation in the catch composition for two interactions namely *competition* and *decade*, which were set as fixed factors. PERMANOVA were carried out using a pseudo-F statistic with 999 random permutations of the data. The aim of the analysis was to determine if changes in the catch composition were due to decadal effects, competition effects or interactions between the two. PERMANOVA were performed using the extension software PERMANOVA+ in PRIMER-E v6 (Clarke and Gorley 2006).

A two-way ANOSIM was then run with *competition* and *decade* as factors. The species contributing most to the similarity of each grouping were identified by SIMPER (Clarke 1993, Clarke and Gorley 2006).

CPUE Standardisation

Generalized Linear Models (GLMs) were used to assess the effects of interannual temporal variance including seasonal and, by combining multiple competitions for suitable representation, monthly variables on the abundance of fish caught. The influence of the effects of spatial variance on fish abundance was also assessed, though only through combined datasets containing multiple competitions. The response variable, number of fish caught for each of the selected species, was measured against independent variables such as year, season, month and, between competitions. The factors that were selected in the GLMs were dependent on the distribution of the samples across the independent variables. If there was inconsistency in the sampling of certain factors they were combined; months, for example, were combined into season if there was inconsistent sampling throughout a year. A quasi-Poisson statistical distribution with a log-link function was used for the catch per species, with the angling hours included as an offset in the model. A quasi-Poisson error model was selected, rather than a Poisson model, due to evidence of over-dispersion of variance. Model selection was determined by exploring the deviance of the residuals for each model. Residual deviance, proportion of deviance explained, as well as pseudo- R^2 and dispersion values calculated from GLM are shown in Table 12.

The standardisation of the CPUE was calculated independently for each of the selected species in each individual competition. Catch rates for certain species may be subject to seasonal influences; therefore season was included as a covariate. The winter months included March to September, and summer months included October to February. Month was only included as covariates for combined datasets as there was limited representation in individual competitions. Competitions were also considered as covariates in models run on the combined datasets. All models were carried out using R 3.0.2 (R Development Core Team. 2013), running packages MASS (Vernables and Ripley 2002), and Plotrix (Lemon 2006).

Results

Fishing effort

Across the five competitions a total of 4 217 boat outings were recorded with 12 957 angler outings contributing to a total of 94 527 angler hours. There was a strong positive correlation ($n = 21$, $R^2 = 0.96$, $p < 0.001$) between the number of boat outings and the number of angling hours per year due to consistency in the number of anglers per boat. On average there were three anglers per boat over the duration of the five competitions.

Boat and angler outings for the individual competitions are shown in Table 1. Monthly and annual angler hours for the individual competitions are shown in Tables 2 – 7. Over the years there was a decrease in the number of angling hours per year across all the competitions. The trend was noticeable in the Tuna Nationals ($n = 12$, $R^2 = 0.39$, $p < 0.05$), the Offshore league ($n = 15$, $R^2 = 0.33$, $p < 0.01$) and Simon's Town league ($n = 21$, $R^2 = 0.25$, $p < 0.05$). Attendance of the two Inshore leagues showed very slight declines, Inshore South ($n = 15$, $R^2 = 0.01$, $p = 0.81$) and Inshore West ($n = 14$, $R^2 = 0.01$, $p = 0.69$), however there were sporadically high numbers of angling hours towards the end of the data series, a trend most notable in 2009 for both competitions.

The average monthly fishing effort, in terms of angling hours, varied between competitions. The combined angling hours in the inshore competitions showed a greater amount of fishing effort towards the beginning of the years with a decrease over the months from January to December. The greatest number of angling hours were recorded between January and April with March having the highest number of cumulative hours. No fishing days were set aside in December for any of the inshore competitions, additionally the Inshore South league was not fished in October and November. The Offshore league took place between March and June and between October and December with April having the greatest number of fishing hours. The Tuna Nationals were only held in May thus eliminating seasonal and monthly variation from the data.

For all competitions there was a 10 fish limit per angler per trip. This limit was not often reached during the competitions. Over the years the Inshore West league had the highest number of individual angler outings recording 10 fish with 9.1%. The Simon's Town league had 5.7%, the Inshore South league had 2.6%, the Offshore had 2.1%, and the Tuna Nationals had 0.5%.

Catch composition

Of the 28 577 fish recorded from the five competitions, almost all were Teleosts, representing 13 families and 38 different species. Over the competitions 40 sharks that were caught and brought to the weigh-in during the inshore competitions, they were recorded but not identified taxonomically. The total weight of fish caught across all five competitions was 215.9 t.

There were similarities in the catch composition between the Offshore league and the Tuna Nationals (Table 7), as well as similarities between the three inshore competitions, namely the Inshore South and West, and Simon's Town (Table 8).

Despite the variety of species caught in each of the inshore competitions, the majority of the catch was made up of only a few species over the duration of the competitions. The most commonly caught species in the Inshore South league were red roman (21.2%), red stumpnose (19.4%), snoek (16.2%), Atlantic bonito (11.4%), and kob (8.8%).

The Inshore West and Simon's Town leagues were both fished within False Bay and around the Cape Peninsula and shared a number of commonly caught species. Snoek made up the majority of the catch in both leagues, comprising of 71.7% and 58.8% respectively. Yellowtail (7.1% and 9.5% respectively) was the second most commonly caught species for each league. Geelbek (5.8%), red roman (5.3%), and hottentot (3.4%) were the following most commonly caught species from the Inshore West league. The third, fourth most common species caught in the Simon's Town league were longfin tuna (5.9%), red roman (4.1%) and skipjack tuna (*Katsuwonus pelamis*) (4.1%).

The five most commonly caught species in each inshore competition for the entirety of the competitions constituted 77, 82 and 93% of the total catch for Inshore South, Simon's Town and Inshore West leagues respectively.

The catch composition of the Offshore league and the Tuna Nationals were similar to one another as anglers targeted pelagic offshore species, with almost the entire catch comprised of two species. The Offshore league was dominated by *Thunnus alalunga* (64.6%) followed by *Thunnus albacares* (35%). While the Tuna Nationals catch was dominated by *T. albacares* (53.5%) and by *T. alalunga* (46.3%).

Species composition of the Inshore Competitions

The MDS plot and PERMANOVA analysis showed a difference in the catch composition between decades and between competitions (Fig. 2 and Table 9). There were strong influences for the two factors when looked at individually with both showing high significance ($p < 0.01$). The catch composition was less influenced by the interaction between decade and competition; however it was still significant ($p < 0.01$). This showed variation in the influence of decades between competitions.

SIMPER analysis of decadal species abundance and percentage contribution to the total catch for the three competitions are shown in Tables 10 - 12.

In the Inshore South league the catch contribution of the two most abundant species, red stumpnose and red roman, declined by 17.2%. There were also reductions in geelbek, snoek, and hottentot. The percentage contribution increased for kob, Atlantic bonito and santer. Yellowtail and carpenter had the greatest increase in percentage contribution with each increasing by 8% (Table 10).

Only five species contributed at least 90% of the catch in the Inshore West league. The competition saw decreases in the percentage contribution to the total catch between decades for yellowtail, geelbek and red roman, with a cumulative decrease of 21.5%. This decrease was matched by an increase in the contribution by snoek (14.9%) and hottentot (3.9%) (Table 11).

The Simon's Town league had the highest diversity of species making up 90% of the total catch composition. There were large declines in the contribution of snoek and kob between the 1990s and the 2000s of over 11% each. These declines were matched by increases in the contribution of hottentot (9.6%), yellowtail (9%) and yellowfin tuna (5.8%). The percentage contribution of snoek to the total catch increased by 43.3% between the 2000s and the 2010s. This large increase saw declines in the percentage contribution from all other species, most notably yellowtail (12.1%), yellowfin tuna (7.5%), hottentot (7%) and longfin tuna (6.9%). Red roman, kob and white stumpnose continually decreased in abundance between the 1990s and the 2010s, to the point that none of these species were caught in the 2010s (Table 12).

Standardised CPUE

Model selection for the calculation of the standardised CPUE was based on the explanation of the deviance. For species assessed in individual competitions inclusion of covariates *Year* and *Season* provided the greatest explanatory power. In almost all cases the covariate *Year* provided the greatest explanation of deviance, with the exception of models run for red roman and red stumpnose in the Inshore South league, in which case *Season* provided greater explanatory power. For the combined datasets containing multiple competitions, a combination of *Year*, *Month* and *Competition* covariates provided the greatest explanation of deviance.

Red roman showed varying CPUE trends between competitions. The Inshore South trend remained constant at about 0.1 fish per angler hour between 2000 and 2012 before a peak of 0.4 fish per hour in 2013 (Fig. 3a). The Inshore West league showed an increase in CPUE over time (Fig 3c). The average CPUE for this competition was 0.02 fish per angler hour, which ranged from 0.005 fish per angler per hour in 2002 to 0.04 fish per angler per hour in 2013. There was a defined increase in fish per angler per hour between 2003 and 2004, reaching 0.03 fish per angler per hour, decreasing to 0.01 fish per angler per hour in 2005 before a steady annual increase from 2006 onwards. The Simon's Town league did not show an increase in CPUE over the years, and showed a highly variable trend over the years (Fig. 3e). There was no increase at the end of the time series corresponding to the other competitions. The average CPUE for the competition was 0.02 fish per angler per hour, with a maximum CPUE of 0.09 fish per angler per hour in 1999 and a minimum of less than 0.01 fish per angler per hour in 1995. Seasonally, a higher CPUE was recorded in the winter months across all the competitions (Fig 3 b-f). The trend in the combined CPUE showed an increase was stable between 1998 and 2012 followed by an increase towards the end of the time series (Fig 4a). There was a cyclical trend in the catch over the course of the year, with catch rates almost doubling from June to November (Fig. 4b).

Red stumpnose were only caught in high enough numbers to produce a reflective CPUE trend in the Inshore South league (Fig. 5 a & b). The average CPUE was 0.06 fish per angler per hour. Values for the species remained consistent, ranging between 0.05 and 0.1 fish per angler per hour between 2003 and 2013. The range in the CPUE was 0.12 fish per angler per hour. In 2002 the CPUE was at its highest at 0.15 and in 2010 it fell to 0.03 fish per angler per hour. Since the decline in 2010, the CPUE values appear to be increasing. The seasonal trend was similar to that of red Roman, with a greater CPUE value in winter than in summer.

Snoek were well represented in the Inshore West and Simon's Town league, however the Inshore South league had consistently low CPUE values with many years recording no catch. Almost all snoek recorded from the Inshore South league were caught in 2004, 2006 and 2010, resulting in high variation in the confidence intervals (Fig. 6 a). The catches for the Inshore West and Simon's Town league fluctuated over the course of the years, with higher catch rates between 2011 and 2013 (Fig. 6 c & e). Similar trends were noticeable in the combined dataset of the Inshore West and Simon's Town league, with an increased catch rate in 2002 and from 2010 till 2013 (Fig. 5 a). Seasonally there was a consistently higher CPUE value for snoek in the winter months across all leagues (Fig. 6 b, d, f).

The CPUE for yellowtail in the Inshore South league were very low over all the years, below 0.002 fish per hour (Fig. 8a). The Inshore West league showed a decrease in the catch rate (Fig. 8c), while the Simon's Town league had high fluctuations with rates of over 1 fish per angler per hour, to no fish per hour (Fig. 8e). The summer catch rate was higher for the Inshore South and Simon's Town leagues, but lower for the Inshore West league (Fig. 8 b, d, f). The combined dataset gave an unpredictable trend line, with fluctuations in the catch rate between years (Fig. 9).

The CPUE for kob was consistently low across all three leagues and the combined dataset (Fig. 10 & 11). It rarely exceeded 0.01 fish per hour, with the only record exceeding that from the Simon's Town league in 1995 (Fig. 10 e). The seasonal catch rate for kob was higher in the summer months across all three leagues.

Longfin tuna caught in the Simon's Town league showed similar trends to those of yellowtail, with high fluctuations in the CPUE values between years (Fig. 12a). The CPUE was higher during winter than summer (Fig. 12b).

The combined dataset for hottentot showed an increase in the CPUE of regular intervals between 1994, with a catch rate of 0 fish per angler per hour, to 2006 with a large increase 2007, 0.08 fish per angler per hour, after which time it began to decrease to low levels again (Fig. 13a). The catch rate for the species showed little variation across the months (Fig. 13b).

Geelbek (Fig. 14) and Atlantic bonito (Fig. 15) displayed similar trends in the CPUE with consistently low catch rates, interspersed with sporadic increases for a few years before falling back down to low levels again. This was particularly the case for the Atlantic bonito which had an increased catch rate of between 0.2 and 0.3 fish per hour between 2007 and

2009 with catch rates of almost 0 on either side (Fig. 15). The monthly catch rates for Atlantic bonito species were fairly regular throughout the years (Fig. 15b). Geelbek had a higher CPUE value during the winter months (Fig. 14b).

The standardised CPUE values for the two species of tuna caught in the Offshore league and in the Tuna Nationals fluctuated between years and between competitions for both species. The trend for longfin tuna caught in both leagues was not clearly defined as the CPUE values varied greatly over the years (Fig. 16a & 16c). However the Offshore league, despite its fluctuations, showed a decreasing trend (Fig 16a). There was a higher CPUE during the summer months than the winter months during the Offshore leagues (Fig. 16b).

Yellowfin tuna also had varying CPUE values over the years and between the competitions (Fig. 18a and 18c), However the combination of the Offshore league and the Tuna Nationals showed a decreasing CPUE trend for the species, with catch rates dropping from 0.23 fish per angler per hour in 1999 to 0.02 fish per angler per hour in 2014 (Fig. 19a). Seasonally, the CPUE value was higher in the summer months in the Offshore league (Fig. 19b).

Discussion

Previous studies on competition fishing data have warned fisheries managers to use angling club records with caution, citing several limitations in the datasets that could influence management decisions (Gartside *et al.* 1999). Potential problems may arise from undocumented changes to the rules and regulations with regards to angling methods and locations. There may also be variation in record keeping over the years and a lack of records for certain aspects of either catch or angling effort.

The issues mentioned above were mostly accounted for and mitigated in the data from the WPDSAA competitions as the rules were well documented over the years and a relatively standardised format was kept when documenting the results for the duration of the competitions. Competition records are more reliable than club records as there has to be a level of consistency and accuracy for competitive rankings.

In addition to the accuracy and consistency of the data, the competitions were well attended throughout the years, providing useful records of between 13 and 20 years of continuous data. These timeframes were long enough to reveal short term trends due to exploitation or recruit variability. Effects of management action could potentially also be detected. Since the competitions were fished throughout the year, with the exception of the Tuna Nationals, it was also possible to detect seasonal variation in species abundance.

Having catch records from five multi-year competitions fished independently, but with overlapping or adjacent fishing areas also allowed for the comparisons of the records between competitions. The catch composition showed clear distinctions between the 3 inshore and 2 offshore competitions.

Despite the strengths of the WPDSAA data, the nature of competitive fishing did inevitably influence some trends in the results. Targeting of specific species based on point allocation as well as restrictions of the total allowable catch per angler were two main factors influencing the CPUE of some species and were reflected in the results.

Targeting of species

A variety of species were caught in the three inshore competitions, however the majority of the catch was dominated by a small number of species, a feature typical of a multi-species fishery and one that has been extensively documented in prior literature for the South African linefishery (Brouwer *et al.* 1997, Mann *et al.* 1997, Penney *et al.* 1999, Pradervand and

Govender 2003, Pradervand and Hiseman 2006, Pradervand *et al.* 2007, Dicken *et al.* 2012). A small number of species contributing to the majority of the catch gives an indication of their abundance in the system, however it also reflects their catchability and may reflect targeting by anglers (Pradervand and Govender 2003).

Fishing tactics employed by anglers can greatly influence the CPUE of certain species during a fishing trip (Winker *et al.* 2014). The allocation of effort towards specific species can result in an increase in the CPUE of the targeted species and a reduction in the CPUE of other non-target species in the fishery. The tactics employed by anglers can be directly influenced by point scoring systems and bag limits (Pradervand and Govender 2003). The point scoring developed by SADSAA, which is usually consistent within a competition, may encourage anglers to target larger species, specific species or a variety of species.

In this study, anglers participating in the Inshore South and West competitions were awarded more points for a varied catch, with scores based on weight and total catch being multiplied with the addition of each legal species caught on the day. The rules for the Offshore league were also based on catch composition, points awarded to longfin tuna on the basis of weight only contributed 80% of the points awarded to other species of tuna. The Simon's Town league did not use a species factor and points were awarded based on the number of fish caught and their total weight. No attempt was made to correct for targeting using the point systems, but this possibility could be a future consideration.

Targeting can be accounted for in a multispecies fishery by further standardization of the CPUE. It is done by looking at clusters of fishing tactics identified through principal component analysis (Winker *et al.* 2013). This standardization has already been used successfully on linefish species in South Africa and should be considered in further assessment of these data (Winker *et al.* 2013).

Additional factors

Changes and improvements in gear can directly influence the efficiency of anglers, allowing for higher catches over shorter time spans (Pradervand and Govender 2003). It is possible that the CPUE from the data was influenced by gear improvements, however with a lack of records relating to changes in gear nor the efficiency of the gear, over the years it is difficult to identify or account for these effects. There is a possibility that gear improvements have resulted in the overestimation of CPUE values in the data (Attwood and Farquhar 1999, Dicken *et al.* 2012).

A point of concern is the decline in the number of angling hours per year, with significant negative trends in three of the five competitions. Increased fuel prices were mentioned as a factor responsible for a reduction in the number of boat outings by members of the WPDSAA (M. Grant & G. Pengelly, WPDSAA, pers. comm.). A decrease in the number of angling hours will not influence the calculated CPUE, however a reduction in the total catch will influence the strength of the data.

Trends in the abundance indices

The structure and format of the competitions directly influenced the species targeted by anglers. The most notable distinction was between the inshore and offshore competitions, with the Offshore league and the Tuna Nationals exclusively targeting migratory species, particularly tuna, while the Inshore and Simon's Town leagues were more varied with a greater focus on resident and nomadic species, and with less focus on migrants.

Bottom-dwelling and reef species

These species made up a large proportion of the total catch composition for all inshore competitions, with red roman, red stumpnose, hottentot, kob and geelbek being the most important.

*Red roman (*Chrysoblephus laticeps*)*

Red roman are protogynous hermaphrodites and live in small home ranges (Kerwath *et al.* 2007). They are an important species for recreational and commercial boat based fisheries and are considered optimally exploited (Götz and Kerwath 2011). Stock assessment is carried out through per-recruit analysis and historical records of CPUE for the species are fairly well documented (Götz and Kerwath 2011). Historical CPUE trends from the south western Cape have shown a dramatic reduction in the average catch per boat from 560kg in the late 1920s and early 1930s, to 71kg between 1986 and 1998 (Griffiths 2000). Stocks have appeared to stabilize since 1985, although recent declines in the commercial catch of the red roman have been recorded (Götz and Kerwath 2011).

Trends from the competition data reveal stability of the annual CPUE with an increase in the number of fish caught per hour in both the Inshore South and Inshore West leagues in recent years. Higher catch rates in the Inshore South league may be attributed to the proximity of the fishing area to marine protected areas (MPAs) to the east. Stocks of red roman, both within and on the outskirts of MPAs, have been shown to benefit from the protection of the stock

and dispersal of larvae to surrounding areas (Kerwath *et al.* 2007, 2013). A clear trend in the CPUE was not distinguishable in the data from the Simon's Town league with fluctuations in the catch rate between years. The combined dataset for the three competitions showed recent increases in the CPUE.

Data from the competitions can potentially provide an indication of the success of larval dispersal from surrounding MPAs, highlighting the potential recovery of stocks due to the designation of MPAs and no take zones.

Red stumpnose (*Chrysoblephus gibbiceps*)

Red stumpnose has been greatly impacted by fishing efforts and is suggested to be heavily over exploited, however there is limited information on the stock status as the species has not been fully assessed (Wilke and van Zyl 2012). There is a great need for stock assessment and as such competition data might be useful for a preliminary overview of the stock.

The competition data showed relatively high CPUE values for the species of between 0.04 and 0.16 fish per angler per hour caught in the Inshore South league. The trend in the CPUE was fairly constant over the years, however a decline was noted between 2002 -2010.

Increased fishing pressure due to the accessibility of False Bay from anglers in Cape Town and surrounding developed areas has probably resulted in reductions in the catch which is reflected in the catch rates in the Inshore West and Simon's Town leagues. The population has retracted to less accessible areas, such as Struisbaai, where there are suitable habitats and abundant reefs, resulting in increased catch rates in the Inshore South league.

CPUE values for this species may not be reflective of their abundance as the national catch limit is one fish per person (Wilke and van Zyl 2012). Without records of catch and release, it is difficult to determine the influence of the catch limit.

The development of marine protected areas may help in the recovery of the species (Kerwath *et al.* 2013). Continued comparative assessment between the Inshore South league and those in False Bay may give an indication of the effectiveness of MPAs to the east of the Struisbaai.

Hottentot (*Pachymetopon blochii*)

Hottentot are resident gonochorist species that breed throughout the year and can reach ages of up to 21 years (Kerwath and Winker 2013a). They are identified as an important part of the

commercial and subsistence linefishery during times when larger, more economically valuable species are not available (Kerwath and Winker 2013a). This trend was noted in the results, with hottentot contributing far more to the total catch composition during years when other species, particularly snoek and yellowtail, were not as abundant. In the Simon's Town league between 2000 and 2009, snoek and hottentot made up 29.2% and 12.2% of the catch respectively. Over the following four years, 2010 to 2014, snoek contribution increased to 72.5% of the total catch which saw a reduction in the hottentot contribution, dropping to 5.2%.

There was a steady increase in the number of hottentot caught, from none in 1994 to 0.008 fish caught per angler hour in 2007. This trend was probably not due to an increased abundance of the species, but is more likely due to targeting by anglers, and most likely due to the poor catch rates of snoek between 2000 and 2008. These factors potentially lead anglers to targeting hottentot. The subsequent decrease in the catch rates of hottentot can potentially be linked to improved catches of snoek between 2009 to 2013.

The species is well assessed and considered optimally exploited; however additional impacts from subsistence fishing may reduce the stocks (Pulfrich and Griffiths 1988, Kerwath and Winker 2013a). The use of recreational competition data may not be vital for stock assessment, however it may provide useful insights into recreational targeting of the species. Additionally the importance of hottentot as a substitute species during years when more desirable fish species are absent may be of conservational importance.

Geelbek (*Atractoscion aequidens*)

Geelbek is an important commercial and recreational species and is usually targeted along the migration route from Cape Point to the east coast (Sauer et al. 1997). The stock is estimated to be far less than 25% of historical levels and considered collapsed. Despite current regulations, the CPUE for the species has not improved in recent years and further management plans are required for the species (Kerwath and Winker 2013b).

Trends in the data from this study are comparable with the commercial CPUE trends for the stock in the Western Cape. Both commercial and recreational data showed poor catch rates prior to 1998 followed by a brief increase in CPUE around the year 2000 and subsequent decrease in 2005 followed by low catch rates from then onwards (Kerwath and Winker 2013b).

With CPUE trends that are very similar to those of commercial CPUE values, recreational competition data appears to provide useful abundance indices for this species, and may prove useful for stock assessment in the future.

Silver kob (*Argyrosomus inodorus*)

Kob are an important linefish species, but due to heavy exploitation, by line and trawl, the stock is considered to be collapsed (Attwood *et al.* 2011, Donovan and Kerwath 2012). Silver kob is a gonochoristic, long lived species that migrate inshore during the summer months and offshore during the winter months (Donovan and Kerwath 2012). Recorded CPUE data has shown a recovery in the stock since 2002 (Winker *et al.* 2012) , however this trend was not reflected across the competitions in this study. Catch rates for kob were low with the CPUE mostly falling below 0.001 fish per angler hour, with occasional intermittent increases in catch rates.

The trends shown by competition data differ from commercial CPUE records due to targeting preferences by anglers. It is possible that competitive anglers will target kob once the populations have recovered, however at present it appears that CPUE values from competition data are not useful for the assessment of this species, due to very infrequent catches.

Pelagic species

Pelagic species were targeted by all five competitions, with the inshore competitions targeting mainly snoek and yellowtail and the offshore competitions targeting tuna.

Longfin tuna (*Thunnus alalunga*)

Longfin tuna have a wide global distribution and they are an important commercial and recreational linefish species, however their migratory behavior in southern African waters is not well recorded (West and Marsac 2012a). They are considered over-exploited, with their population currently at 25-40% of its carrying capacity (West and Marsac 2012a).

CPUE records from the South African pole and commercial linefisheries have not shown a noticeable trend for the species in recent years (ICCAT 2011). There was no clear trend across the combined dataset of both offshore competitions. CPUE data from the Offshore league, however, shows an apparent decline in the catch rates of longfin between 2001 onwards, with one sporadic peak recorded in 2011. The decline in the catch rate of this

species from the Offshore league may be a point of concern and further research into possible explanations for this decline are required.

Recreational competition data for this species might be showing trends in stock abundance not reflected by the commercial fisheries.

Yellowfin tuna (*Thunnus albacares*)

Yellowfin tuna have a very wide global distribution and migrate along the west coast of South Africa. They are a commercially important and are highly sort after as a gamefish species targeted by recreational anglers along the east and south coast of South Africa (West and Marsac 2012b). Stock assessment of the species shows the populations to be optimally exploited. CPUE trends, however, show a decline in catch rates of about 50% since 1990, with the lowest levels in 40 years recorded in 2007 (West and Marsac 2012b).

Similar declining trends have been noted in the competition data, with declines in the CPUE particularly apparent from the Tuna Nationals. CPUE values from the Offshore league show a very different trend, with variation in the catch over the years. There were noticeable increases in the CPUE between 2002 and 2005, followed by a decline in the catch from 2006 onwards, until another peak in 2014. The reason for this apparent 11 year cyclical trend is not clear.

Snoek (*Thyrsites atun*)

Snoek are a gonochoristic and relatively short lived nomadic species that move widely along the coastline. They are a highly important commercial linefish making up 40% of the total recorded catch (Kerwath and Wilke 2012b). The species has been well assessed through fishery dependent data and is considered to be optimally exploited (Kerwath and Wilke 2012b). Annual CPUE trends fluctuate due to the nomadic nature of the species resulting in erratic availability of stock, however the reported catch has remained stable for the past 25 years (Kerwath and Wilke 2012b).

Snoek are targeted by competitive anglers focused on scoring points by catching the maximum allowed number of fish per day. Snoek were one of the few species affected by a daily limit of 10 fish per person, as they were actively targeted when they were present. In this study, the catch composition of trips recording a maximum of 10 fish per angler consisted almost entirely of snoek for both the Inshore West and Simon's Town league. The

catch limit potentially resulted in lower CPUE values during years with high snoek catch rates.

The results show the importance of snoek for competitive anglers, with the species making up a large contribution of the catch in the inshore competitions fished within in False Bay. When snoek were not present, anglers varied their catch and appear to focus on resident species such as hottentot and roman.

Despite the erratic availability of snoek, the combined datasets of Inshore West and Simon's Town leagues clearly showed two peaks in the number of fish caught per angler hour in 2002 and between 2009 and 2012. This trend was similar to the total reported landings from commercial fisheries, recorded between 2000 and 2010 (DAFF 2012).

Recreational data has the potential to be used in conjunction with commercial data for the assessment of this species. Additionally catches from recreational anglers may reflect trends in the stock that are otherwise masked or influenced in commercial catches due to fluctuations in market price.

Yellowtail (*Seriola lalandi*)

Yellowtail roam between offshore reefs along the Agulhas Bank, with adults following the sardine run up the east coast in the winter. They are gonochoristic with a summer spawning season between November and February (Kerwath and Wilke 2012a). They are an important recreational linefish species but are targeted by a range of sectors in the linefishery. The stock has been well assessed through surplus production models and they are considered optimally exploited, with a 2010 estimate showing the stock was at 44% of the carrying capacity (Winker et. al 2010).

The CPUE values for the species were highly erratic providing very little evidence of a trend in the data. With recruitment success driving fluctuations in the CPUE for commercial fisheries it is difficult to detect annual trends for the species (Winker *et al.* 2012).

Recreational competition fishing data does not provide much use for stock assessment of the species due to high variation in CPUE values between years. However it may be beneficial for providing catch rates which are not influenced by market demand or commercial targeting. Based on the life history and migratory behaviour of the species, the research priority for the species is low (Kerwath and Wilke 2012a).

Conclusion

This study has been the first look at boat based recreational fishing competition data in the Western Cape. The format and structure of the WPDSAA competition fishing data appears to be a useful source of information for the assessment of certain fish stocks, however its limitations must be taken into consideration. The indices have the potential to provide fisheries management with a set of reference points for unassessed species and can also be used in conjunction with current assessment tools for species already assessed through commercial fishery dependent data.

Boat based recreational competition data has the potential to provide abundance indices for certain bottom-dwelling and pelagic species. This study has shown CPUE trends comparable to commercial fishery data for red roman, geelbek, and snoek. The data also has the potential to show recovery trends of bottom-dwelling reef associated species adjacent to MPAs.

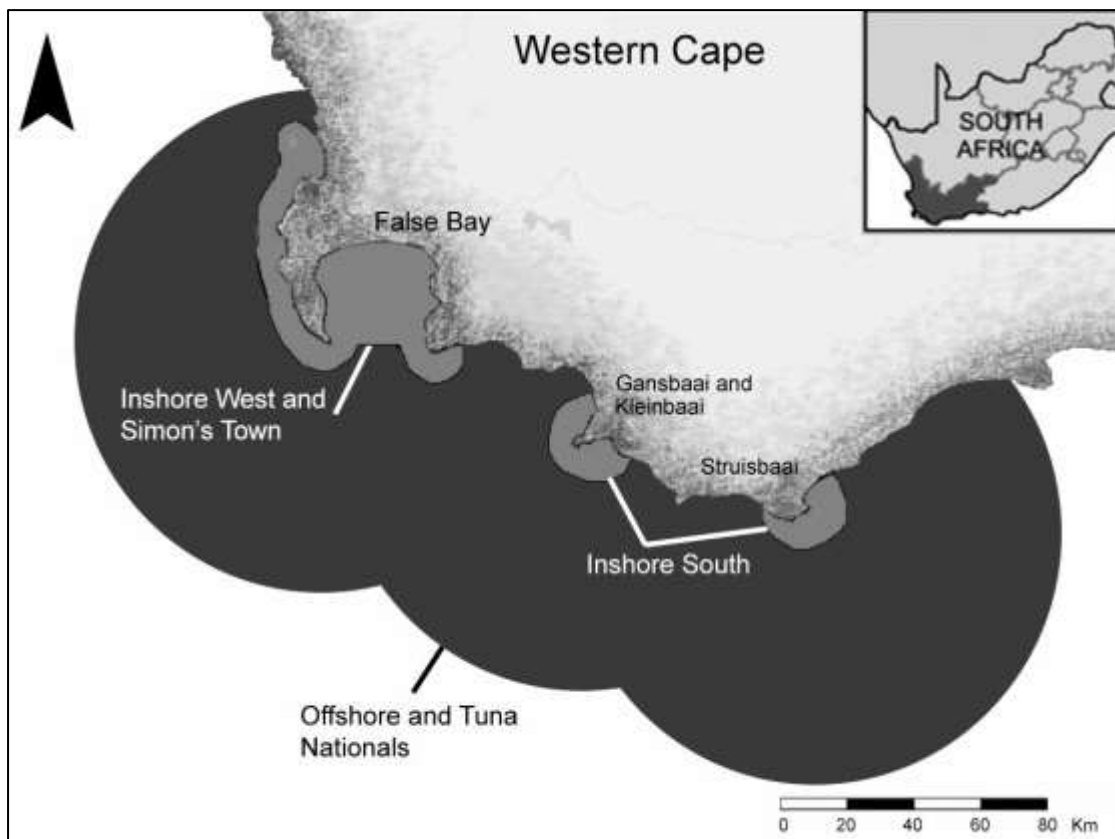
The use of recreational competition data can be recommended to fisheries managers for the assessment of certain species.

Continued accuracy and consistency in the recording of data and rules by WPDSAA and other SADSAA affiliated associations is highly important for the future usefulness of competition data. Changes of rules must be documented in order to account for them when analysing the data.

Very low catch rates of silver kob are a point of concern for fisheries managers, and should be investigated. Managers should also be aware of increased targeting of species such as hottentot during periods when the abundance of snoek is low.

Further analysis should include the standardization of the CPUE taking targeting behavior of the multispecies fishery into account. Additionally, factors present in the data, but unassessed in this study, such as catch weight, may prove useful for future stock assessment purposes.

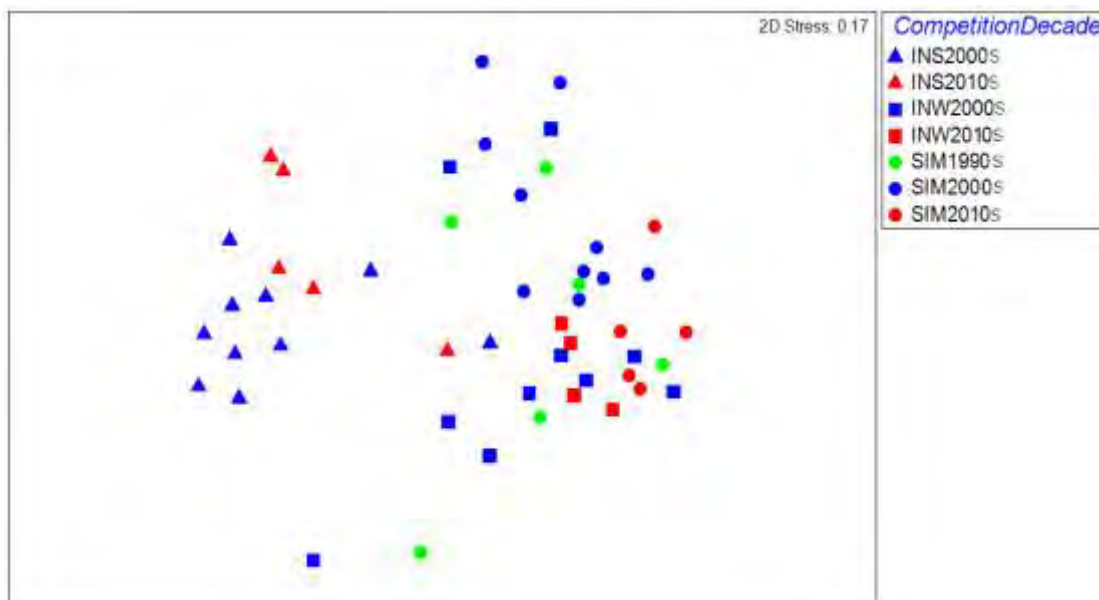
With 112 affiliated clubs and over 9000 registered members around the country, there is a great scope for future research using SADSAA affiliated competition data. Catch records from clubs around the country may provide additional data for further assessment and management of recreationally and commercially important linefish.



Figures and Tables

Figure 1: Map of the Western Cape, South Africa, showing the extent of the fishing boundaries for the Inshore South and West leagues and Simon's Town league (shown in light grey) and the Offshore league and Tuna Nationals (shown in dark grey) according to rules between 2013 and 2014.

Figure 2: Multidimensional scaling (MDS) plot based on standardised square-root transformed catch data from three inshore competitions (Inshore South, Inshore West and Simon's Town). Data points represent catch composition by year. Competitions are represented as symbols (Inshore South = triangle, Inshore West = square, Simon's Town = circle) decades are represented as colours (1990 – 1999 = green, 2000 – 2009 = blue, 2010 onwards = red)



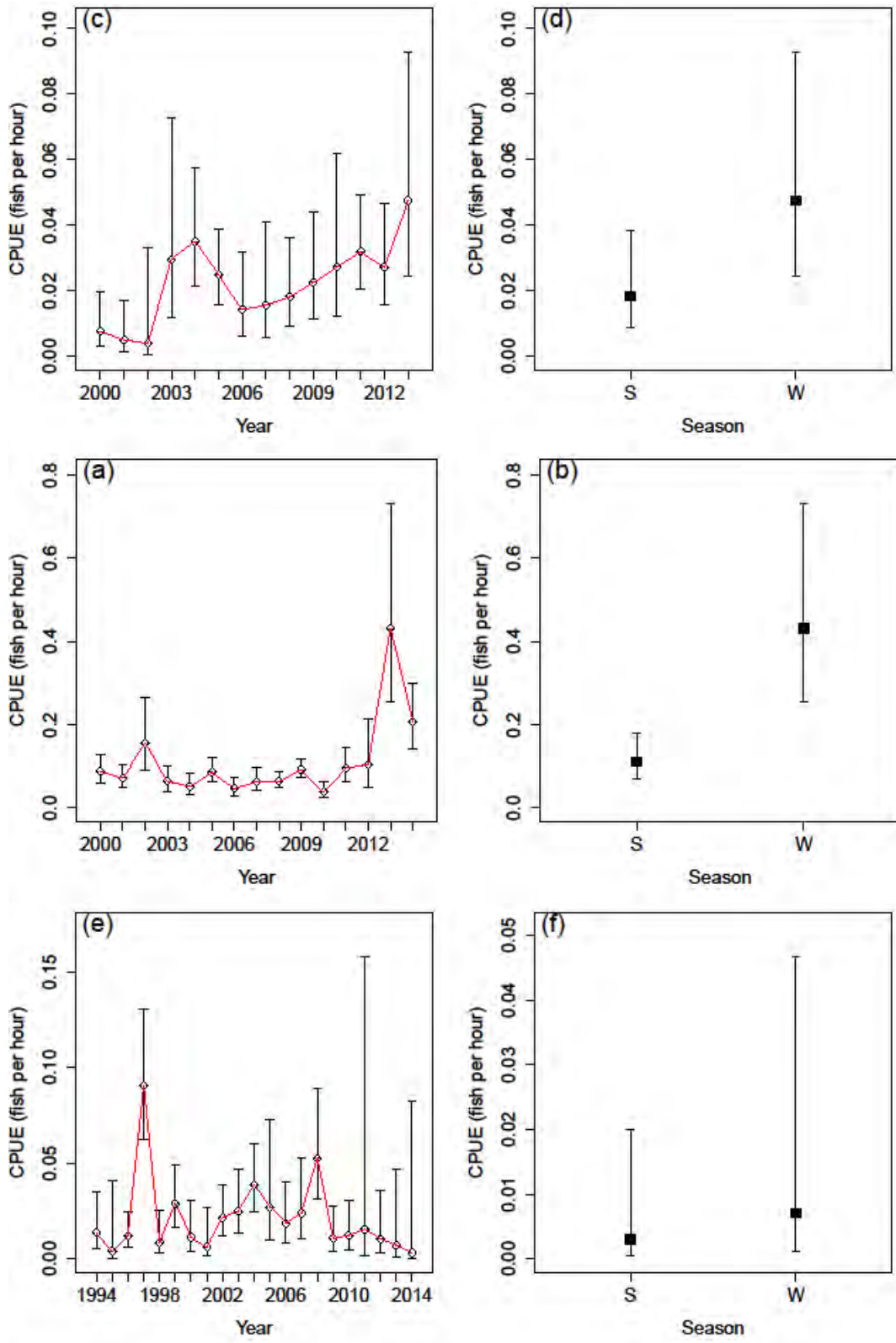


Figure 3 – Predicted standardised CPUE showing year (left) and season effects (right) with 95% confidence intervals for red roman (*Chrysoblephus laticeps*) caught in the Inshore South league between 2000 and 2014 (a & b), Inshore West league between 2000 and 2013 (c & d), and Simon's Town league between 1994 and 2015 (e & f)

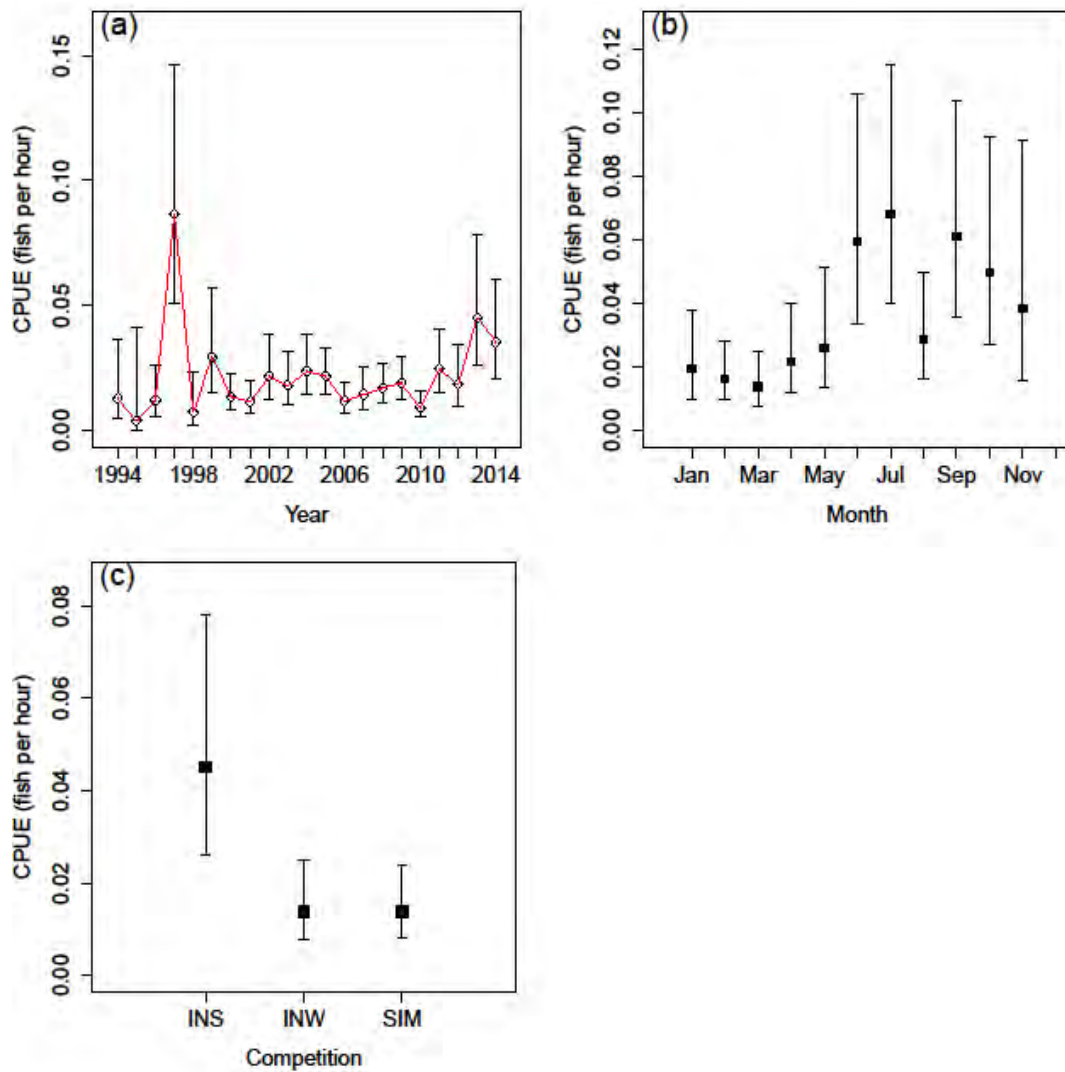


Figure 4 – Predicted standardised CPUE showing year (a), monthly effects (b), and comparative CPUE values between competitions (c) with 95% confidence intervals for red roman (*Chrysoblephus laticeps*) caught between 1994 and 2014 across the three inshore competitions (Inshore South, Inshore West and Simon's Town)

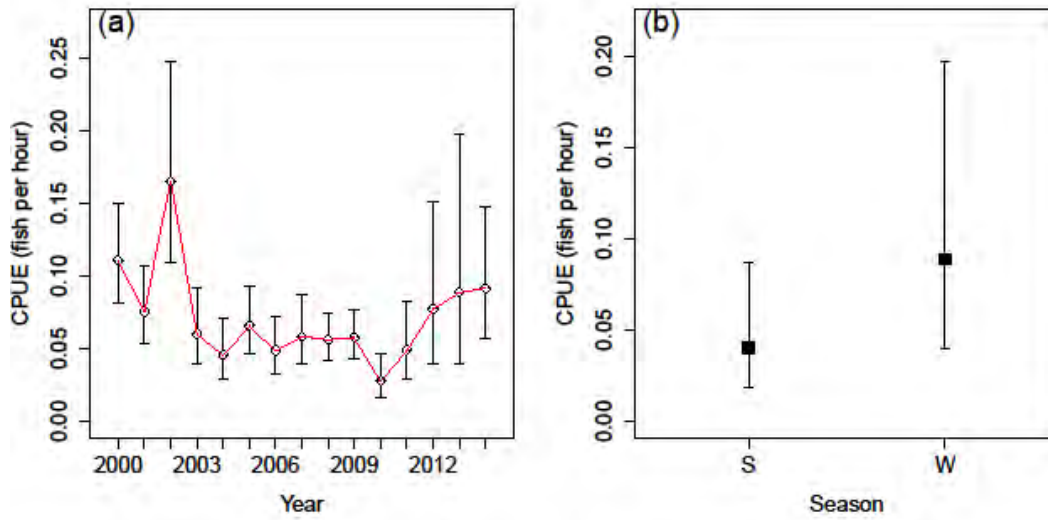


Figure 5 – Predicted standardised CPUE showing year (a) and seasonal effects (b) with 95% confidence intervals for red stumpnose (*Chrysoblephus gibbiceps*) caught during the Inshore South league between 2000 and 2014

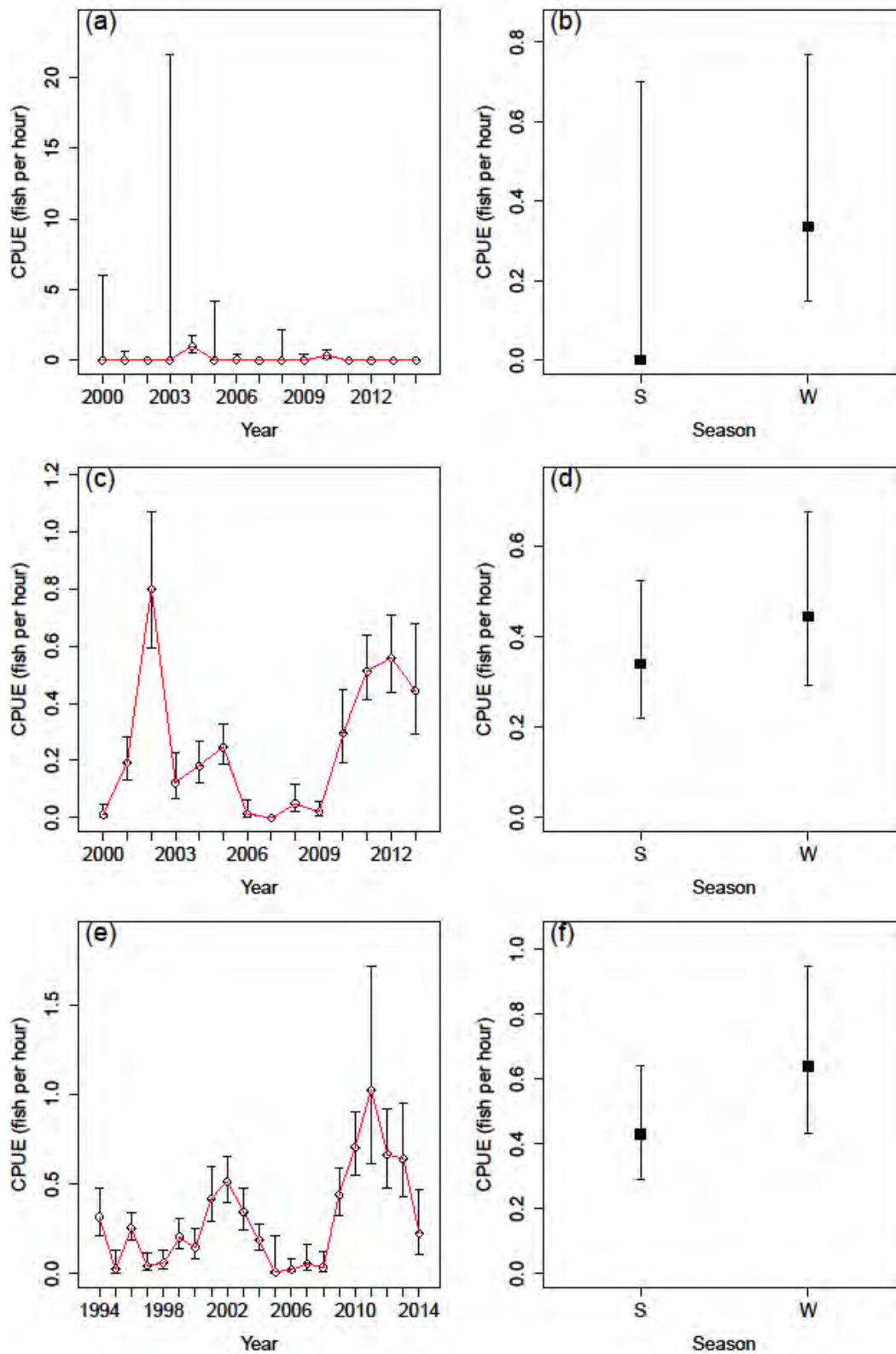


Figure 6 – Predicted standardised CPUE showing year (left) and season effects (right) with 95% confidence intervals for snoek (*Thyrsites atun*) caught in the Inshore South league between 2000 and 2014 (a & b), Inshore West league between 2000 and 2013 (c & d), and Simon’s Town league between 1994 and 2015 (e & f)

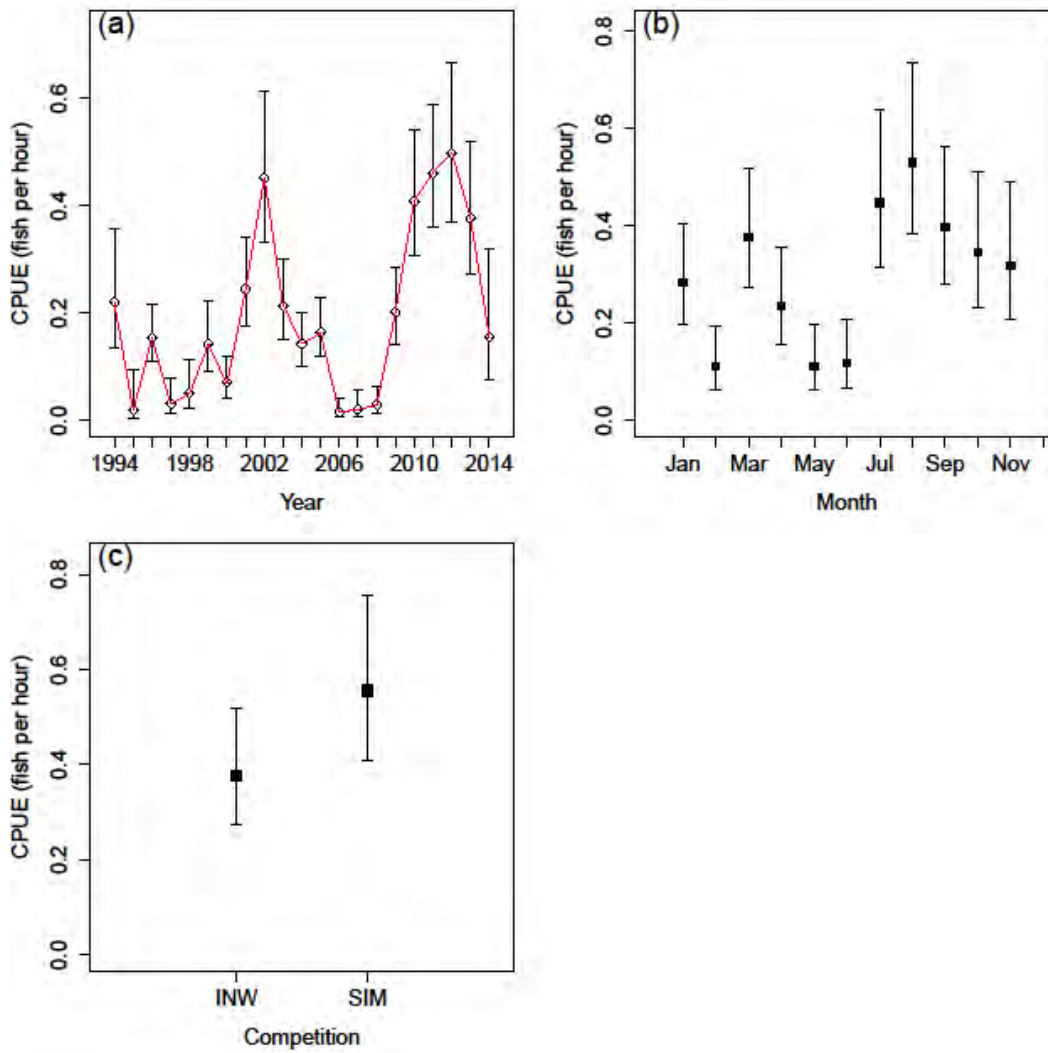


Figure 7 – Predicted standardised CPUE showing year (a), monthly effects (b) and comparative CPUE values between competitions (c) with 95% confidence intervals for snoek (*Thyrstites atun*) caught between 1994 and 2014 in two inshore competitions (Inshore West and Simon’s Town)

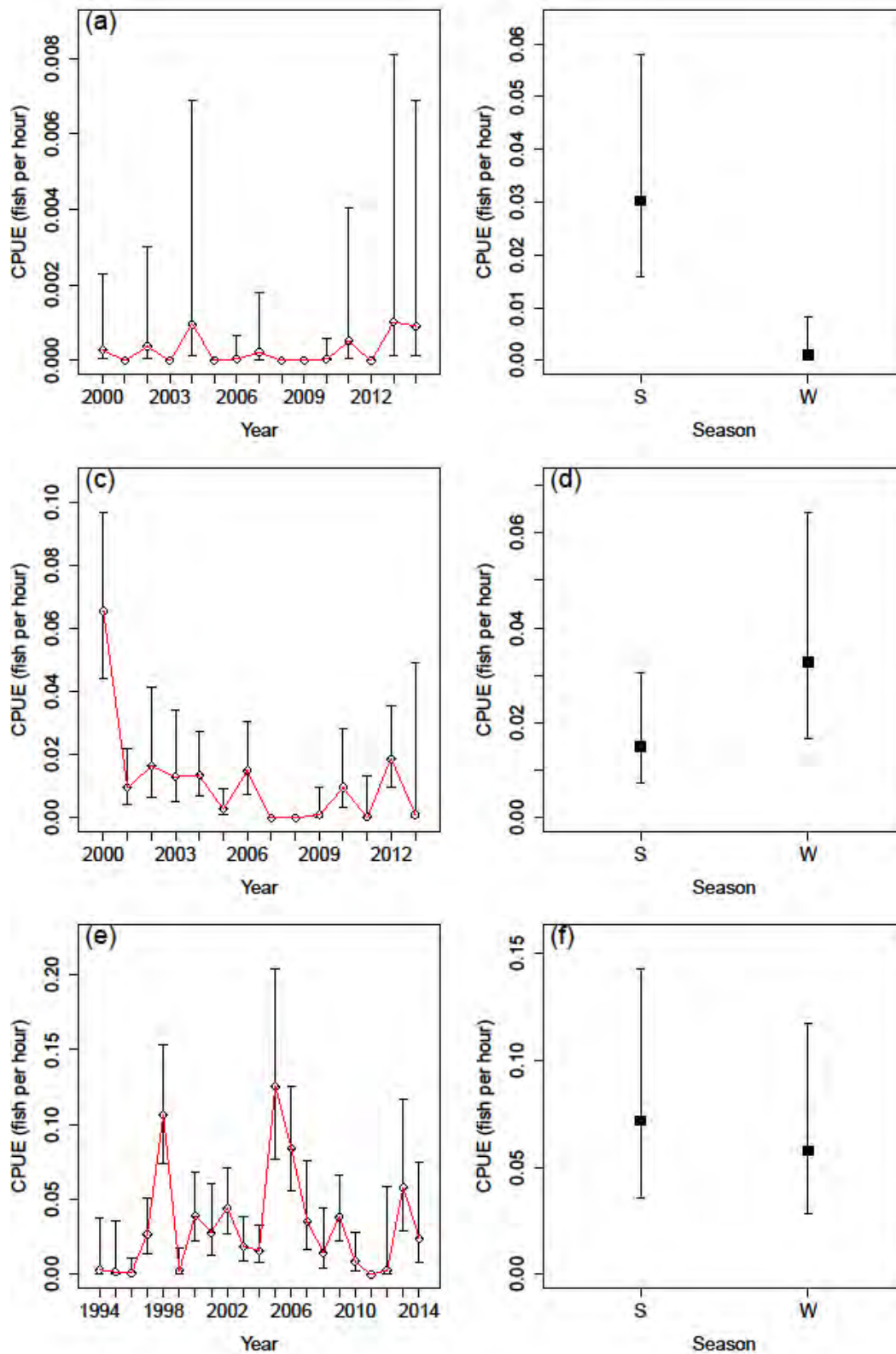


Figure 8 – Predicted standardised CPUE showing year (left) and seasonal effects (right) with 95% confidence intervals, for yellowtail (*Seriola lalandi*) caught during the Inshore South league between 2000 and 2014 (a & b), Inshore West league between 2000 and 2013 (c & d), and Simon's Town league between 1994 and 2014 (e & f)

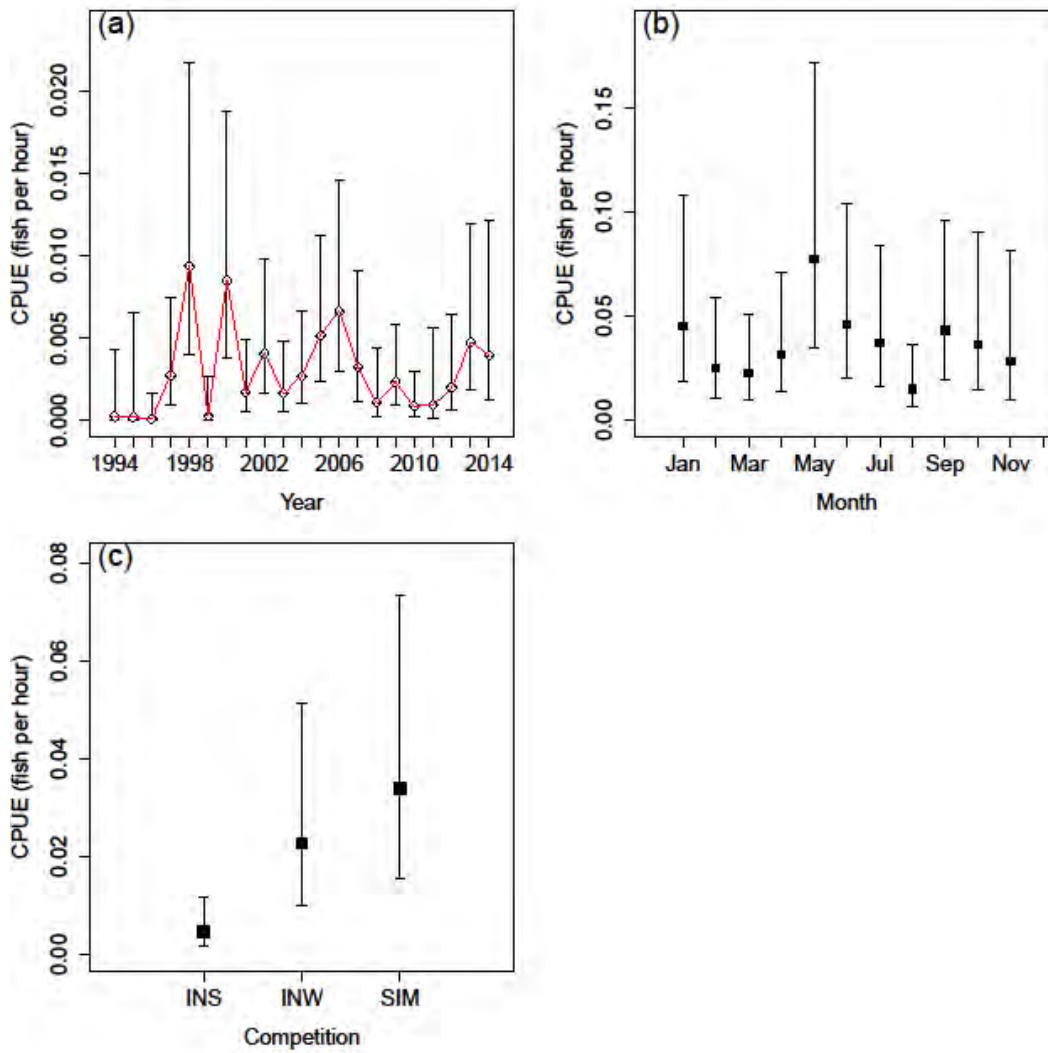


Figure 9 – Predicted standardised CPUE showing year (a), monthly effects (b) and comparative CPUE values between competitions (c) with 95% confidence intervals for yellowtail (*Seriola lalandi*) caught between 1994 and 2014 in three inshore competitions (Inshore South, Inshore West and Simon's Town)

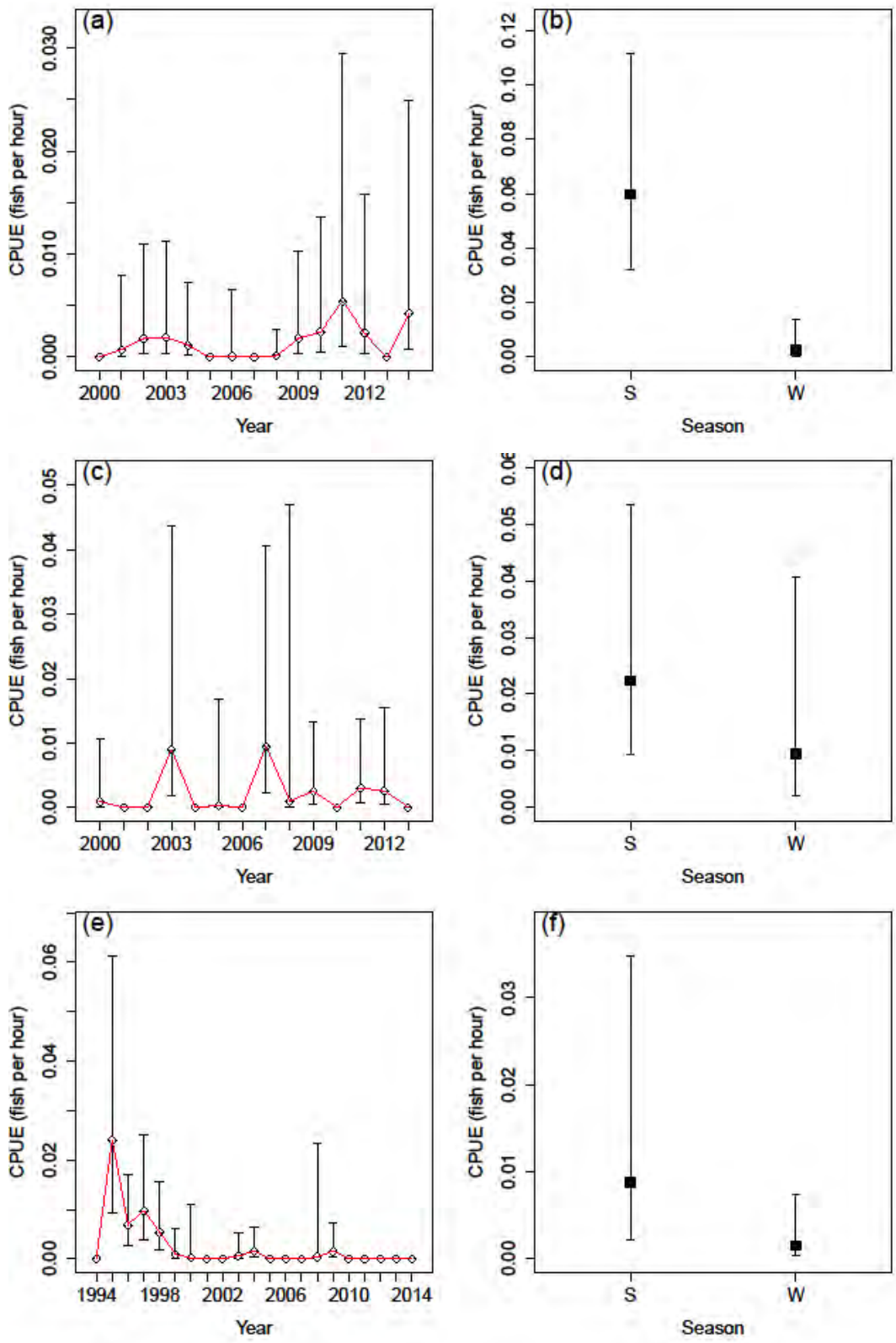


Figure 10 – Predicted standardised CPUE showing year (left) and seasonal effects (right) with 95% confidence intervals, for kob (*Argyrosomus inodorus*) caught in the Inshore South league between 2000 and 2014 (a & b), Inshore West league between 2000 and 2013 (c & d), and Simon's Town league between 1994 and 2014 (e & f)

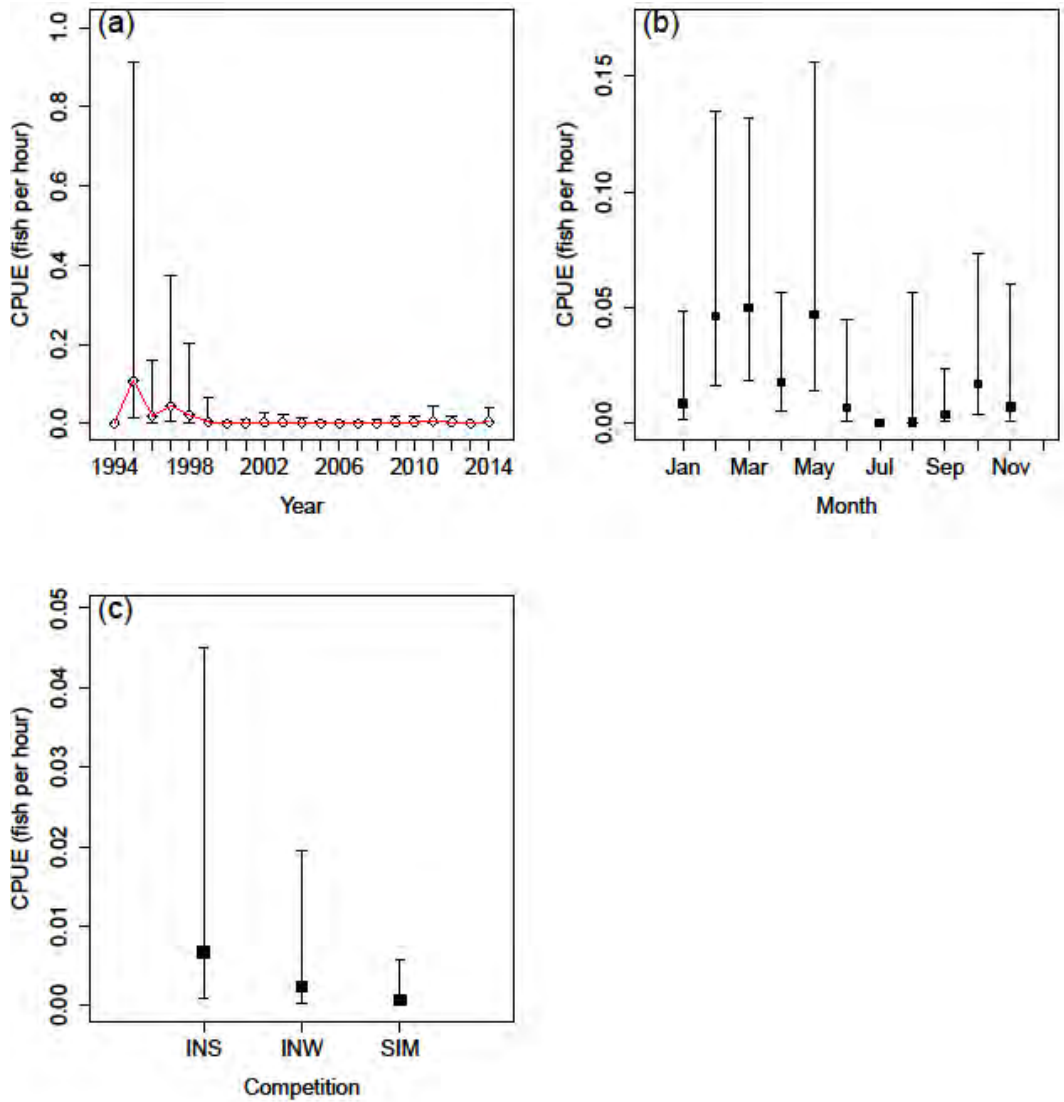


Figure 11 – Predicted standardised CPUE showing year (a), monthly effects (b) and comparative CPUE values between competitions (c) with 95% confidence intervals for kob (*Argyrosomus inodorus*) caught between 1994 and 2014 in three inshore competitions (Inshore South, Inshore West and Simon’s Town)

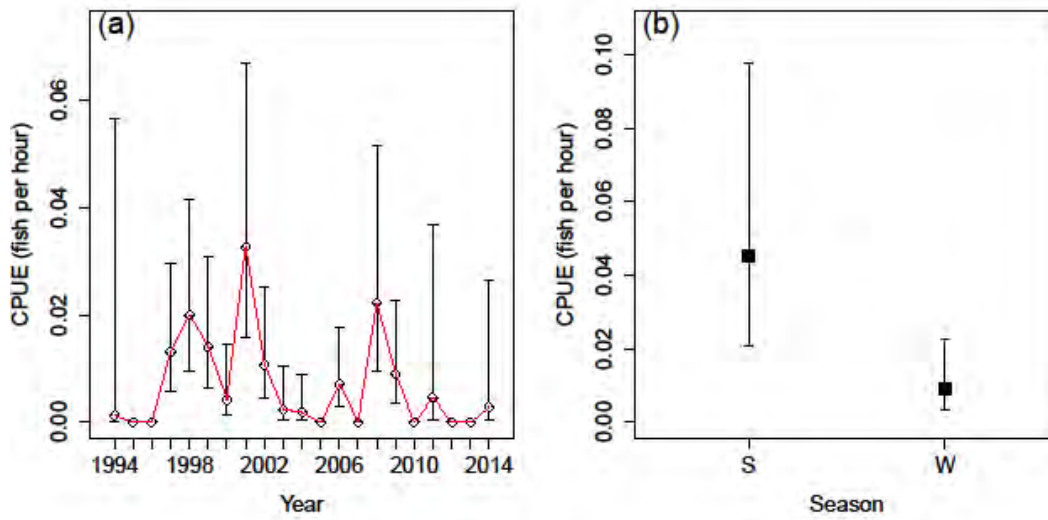


Figure 12 – Predicted standardised CPUE showing year (a) and seasonal effects (b) with 95% confidence intervals for longfin tuna (*Thunnus alalunga*) caught in the Simon’s Town league between 1994 and 2014

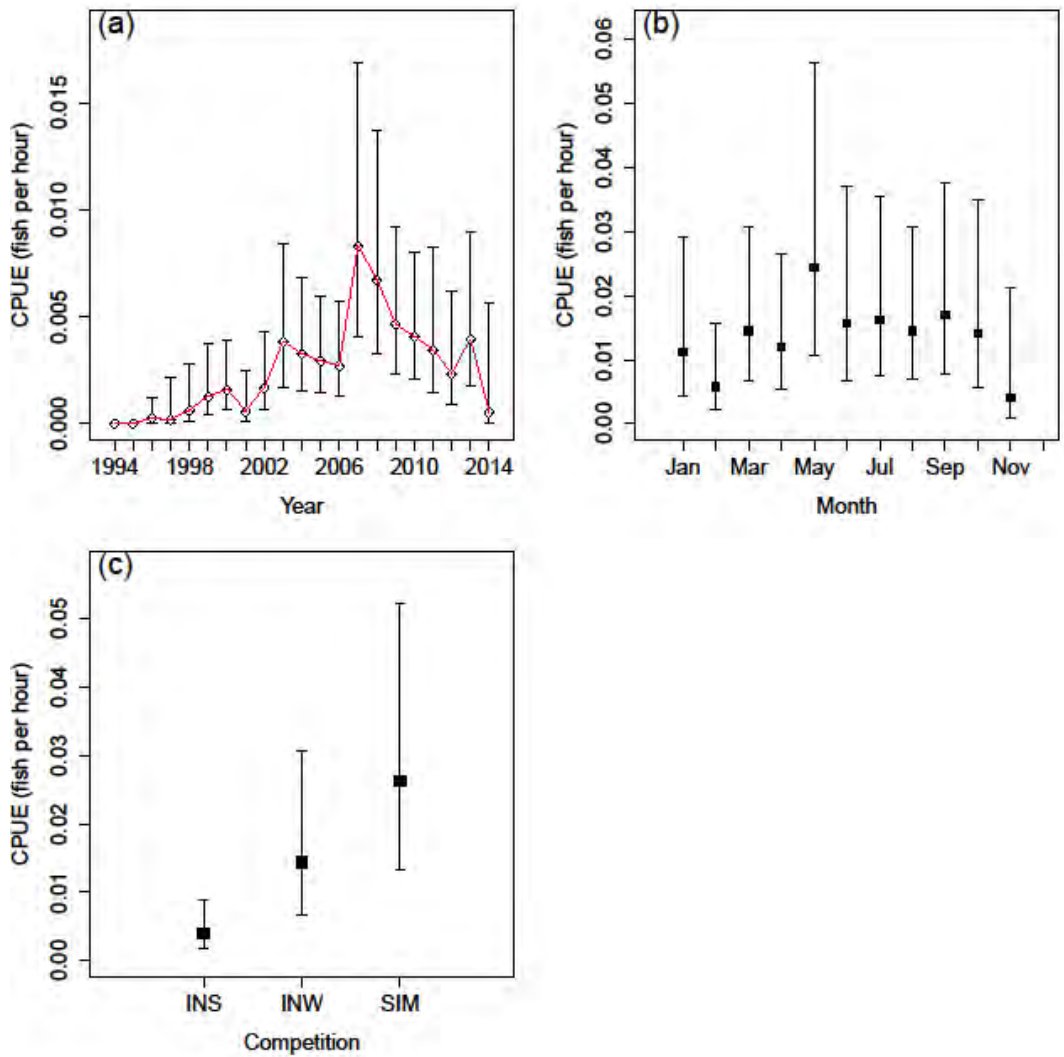


Figure 13 – Predicted standardised CPUE showing year (a), monthly effects (b) and comparative CPUE values between competitions (c) with 95% confidence intervals for hottentot (*Pachymetopon blochii*) caught between 1994 and 2014 in three inshore competitions (Inshore South, Inshore West and Simon's Town)

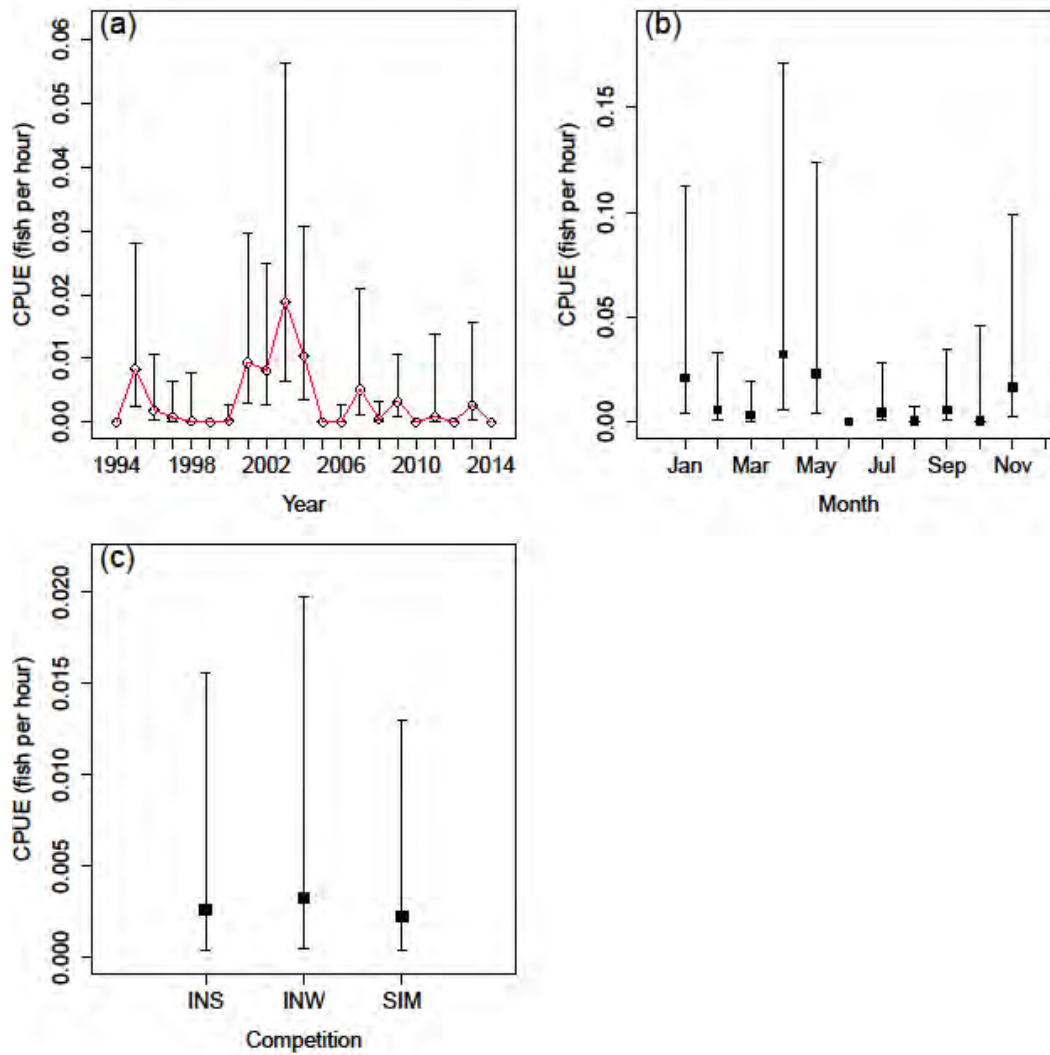


Figure 14 – Predicted standardised CPUE showing year (a), monthly effects (b) and comparative CPUE values between competitions (c) with 95% confidence intervals for geelbek (*Atractoscion aequidens*) caught between 1994 and 2014 in three inshore competitions (Inshore South, Inshore West and Simon's Town)

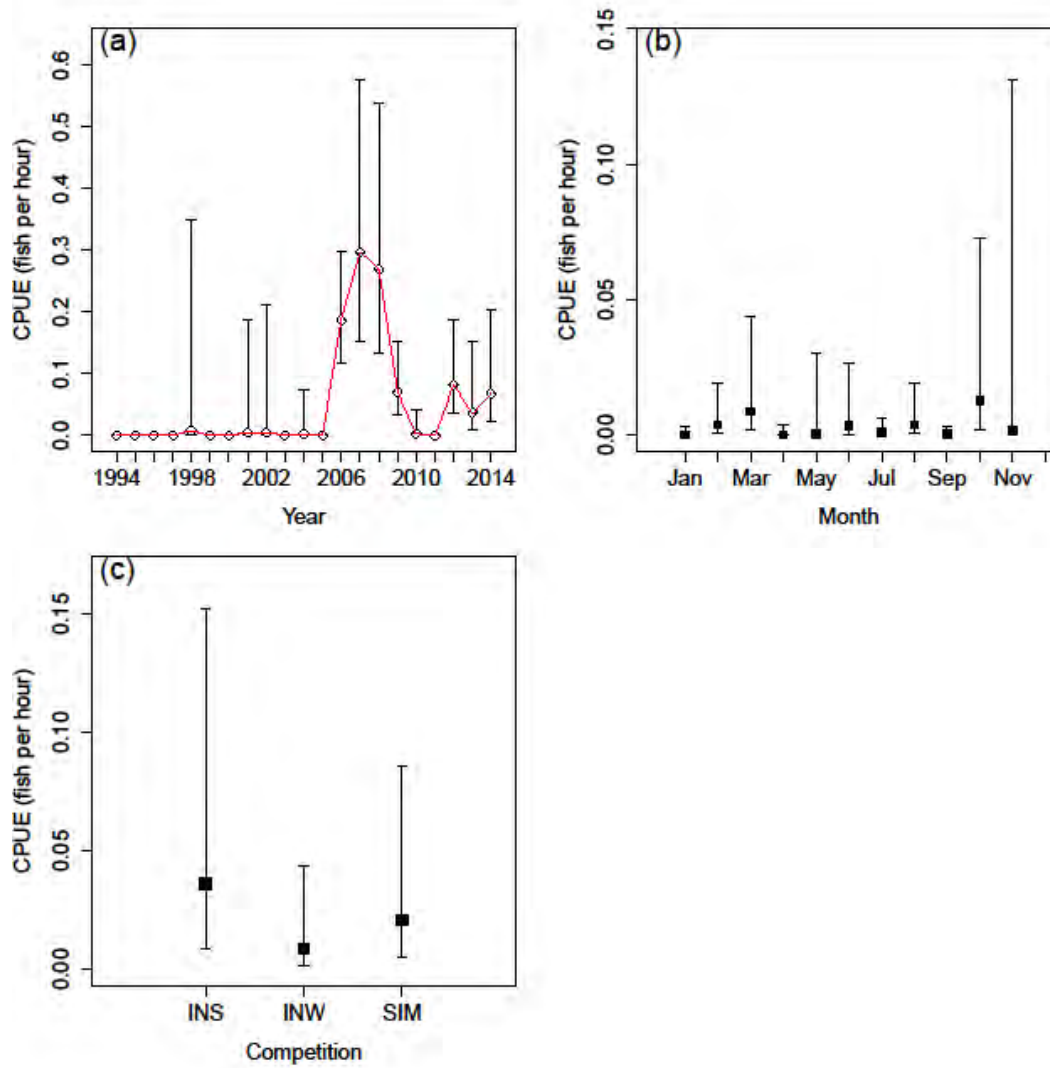


Figure 15 – Predicted standardised CPUE showing year (a), monthly effects (b) and comparative CPUE values between competitions (c) with 95% confidence intervals for Atlantic bonito (*Sarda sarda*) caught between 1994 and 2014 in three inshore competitions (Inshore South, Inshore West and Simon's Town)

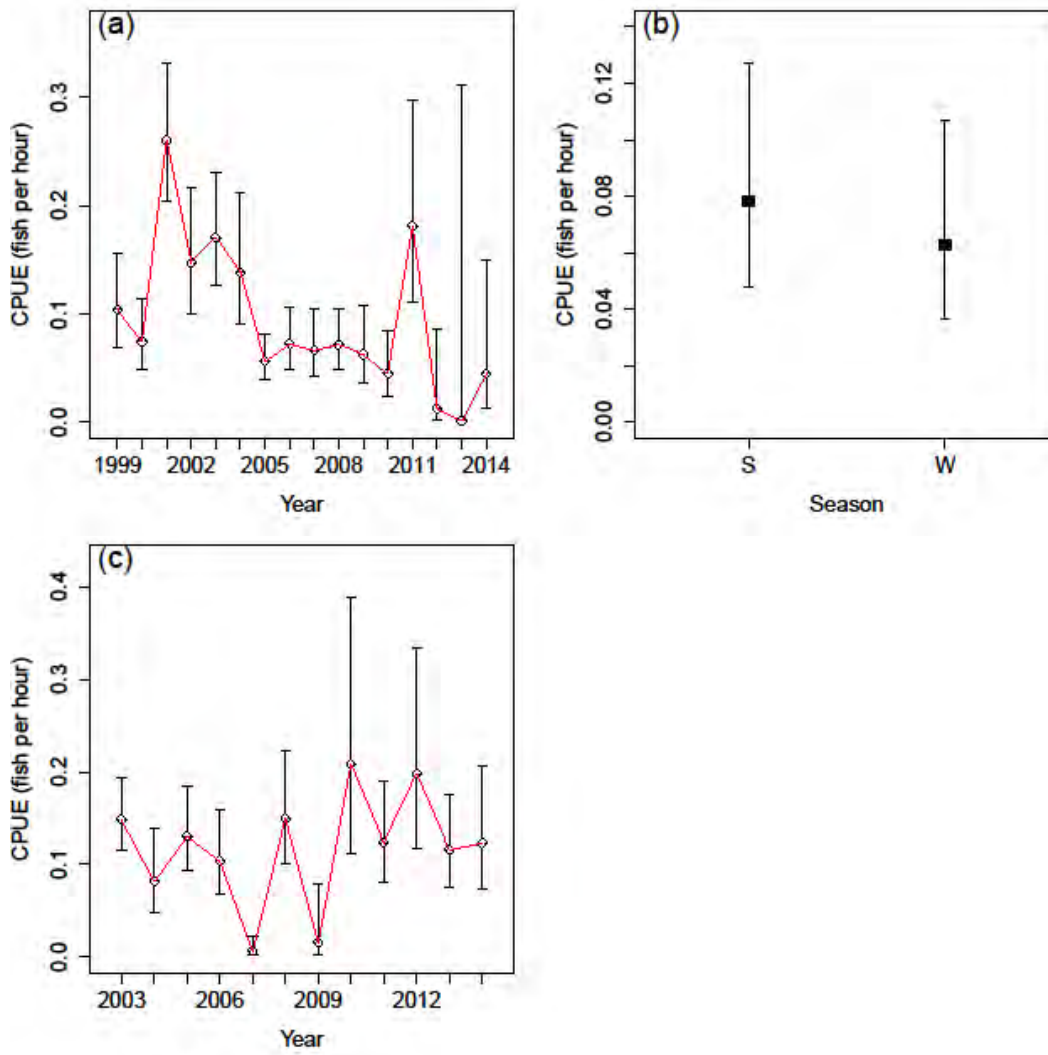


Figure 16 – Predicted standardised CPUE showing year (left) and seasonal effects (right) with 95% confidence intervals, for longfin tuna (*Thunnus alalunga*) caught in the Offshore league between 1999 and 2014 (a & b), and the Tuna Nationals between 2000 and 2013 (c)

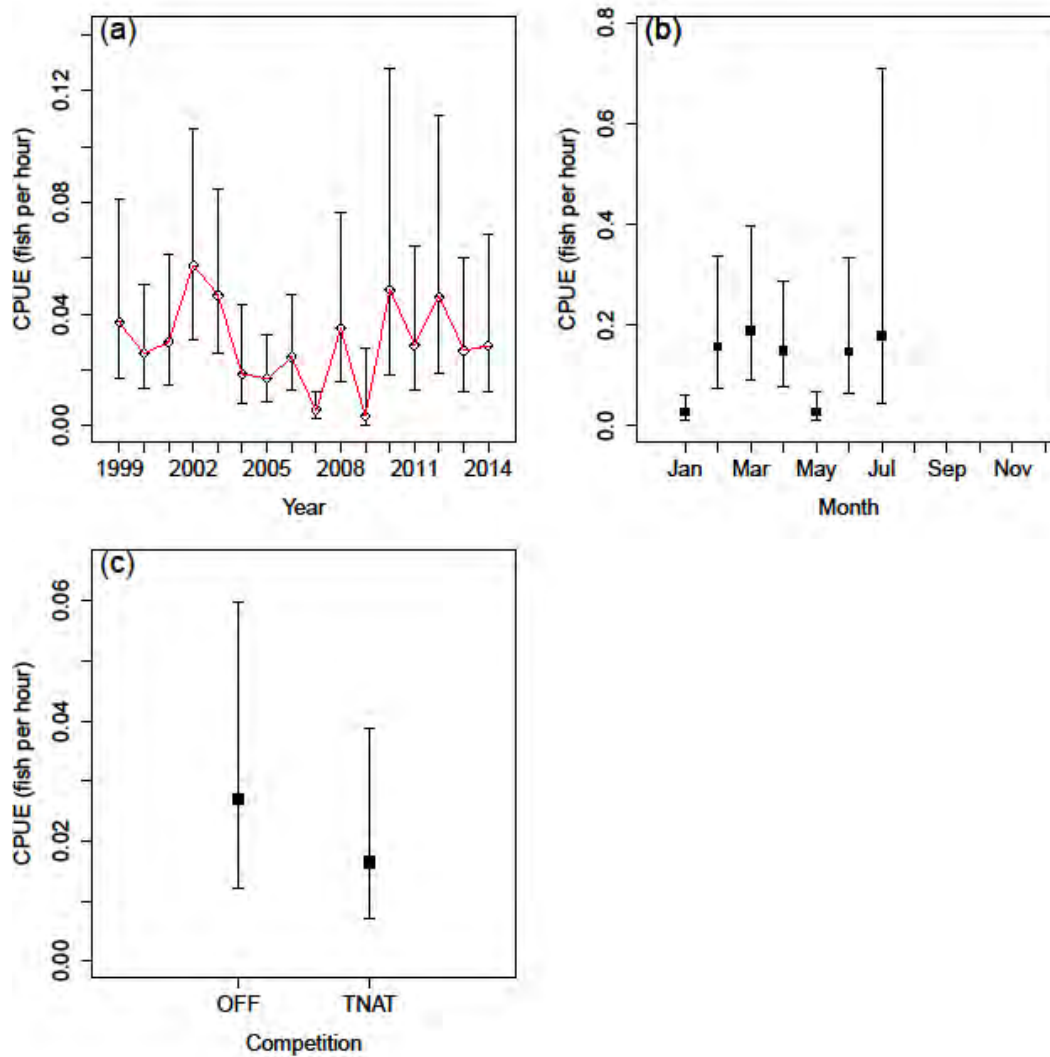


Figure 17 – Predicted standardised CPUE showing year (a), monthly effects (b) and comparative CPUE values between the Offshore league and the Tuna Nationals (c) with 95% confidence intervals for longfin tuna (*Thunnus alalunga*) caught between 1999 and 2014 in the Offshore league and the Tuna Nationals

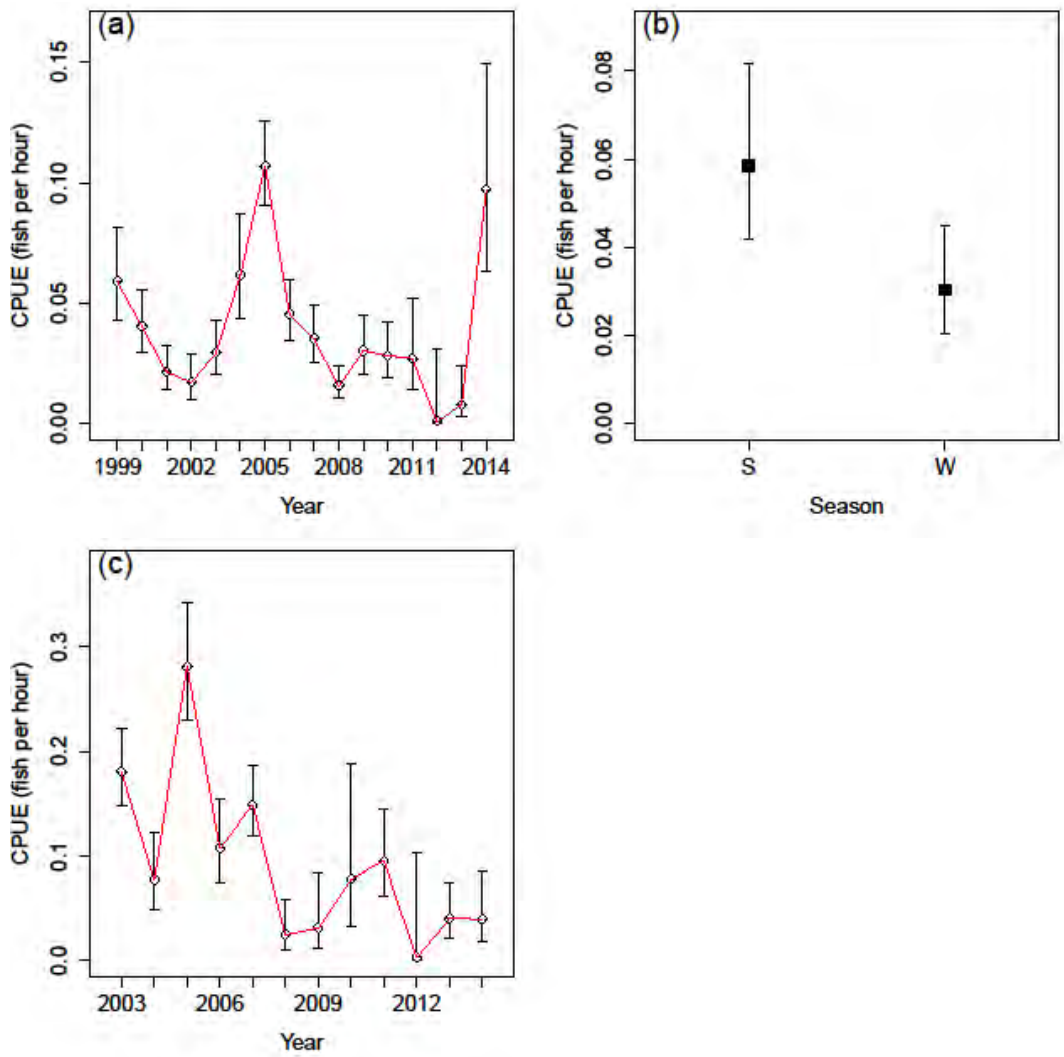


Figure 18 – Predicted standardised CPUE showing year (left) and seasonal effects (right) with 95% confidence intervals, for yellowfin tuna (*Thunnus albacares*) caught in the Offshore league (a & b) between 1999 and 2014, and the Tuna Nationals (c) between 2000 and 2013

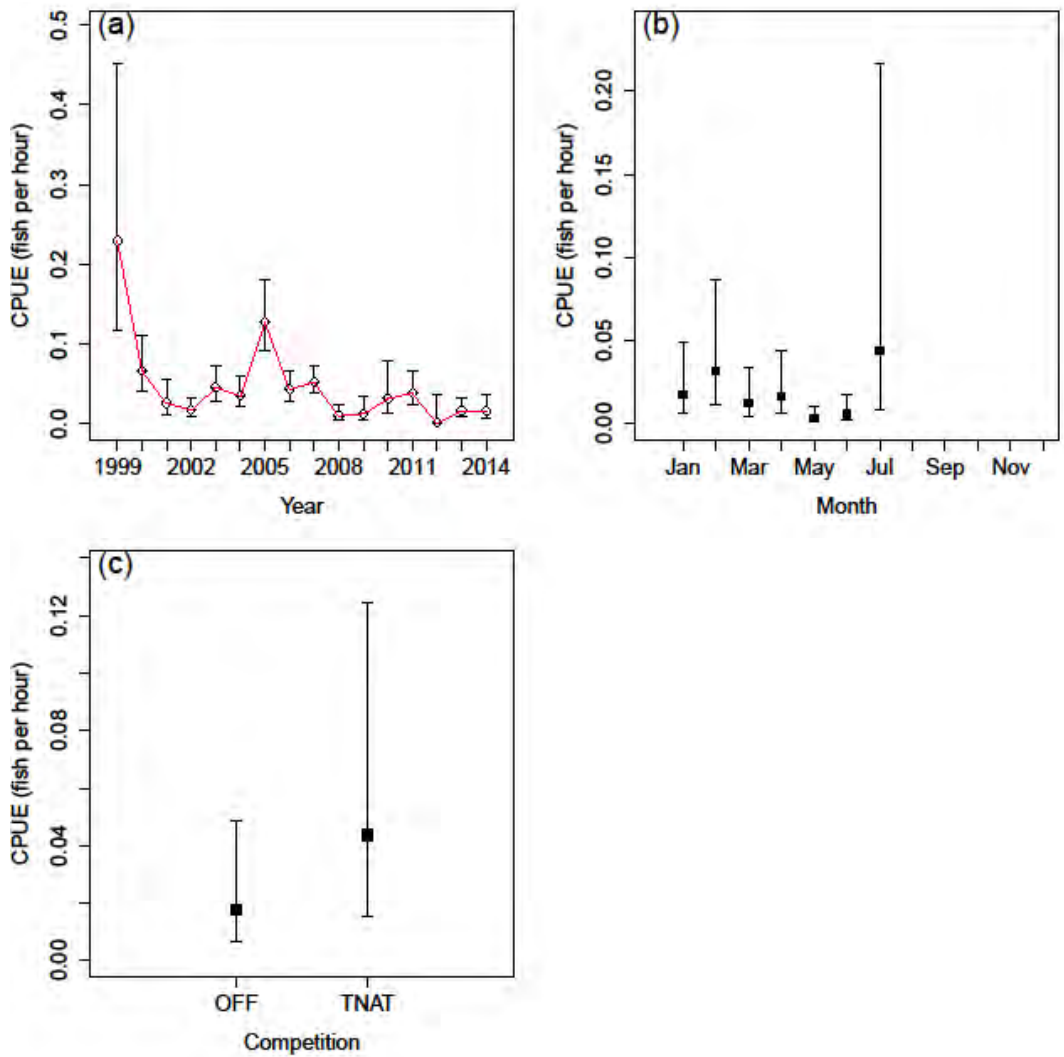


Figure 19 – Predicted standardised CPUE showing year (a), monthly effects (b) and competition effects (c) with 95% confidence intervals for yellowfin tuna (*Thunnus albacares*) caught between 1999 and 2014 for the combined datasets of the Offshore league and the Tuna Nationals

Table 1: Total number of boat and angler outings per competition.

Competition	Number of boat outings	Number of angler outings
Inshore South	955	3273
Inshore West	738	2297
Simon's Town	952	3020
Offshore	1195	3236
Tuna Nationals	377	1131
Total	4217	12957

Table 2: Summary of recreational fishing effort from the WPDSSA Inshore South League recorded as the number of angler hours per month between 2000 and 2014.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
2000	-	272	230	378	-	392	371	-	-	-	-	-	1643
2001	-	323	612	-	294	-	175	-	469	-	-	-	1873
2002	289	621	349	224	287	-	-	-	-	-	-	-	1770
2003	-	519	-	245	-	273	-	91	-	-	-	-	1128
2004	-	374	349	-	252	-	-	427	-	-	-	-	1402
2005	-	-	729	-	-	-	412	210	-	-	-	-	1351
2006	810	-	774	-	-	-	637	-	540	-	-	-	2761
2007	-	830	-	-	-	-	416	-	464	-	-	-	1710
2008	910	740	740	-	-	-	648	-	640	-	-	-	3678
2009	-	1575	902	-	-	-	1250	-	630	-	-	-	4357
2010	-	-	880	-	-	576	612	-	-	-	-	-	2068
2011	-	580	468	-	-	-	-	-	713	-	-	-	1761
2012	-	470	378	-	-	-	-	-	378	-	-	-	1226
2013	-	360	-	-	-	-	198	-	-	-	-	-	558
2014	-	420	312	-	-	-	176	-	-	-	-	-	908
Monthly total	2009	7084	6723	847	833	1241	4895	728	3834	-	-	-	28194
Monthly avg.	670	590	560	282	278	414	490	243	548	-	-	-	1879

Table 3: Summary of recreational fishing effort from the WPDSSAA Inshore West league recorded as the number of angler hours per month between 2000 and 2013.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
2000	515	483	-	-	-	298	-	425	187	-	-	-	1907
2001	651	-	-	-	-	153	111	179	485	-	-	-	1578
2002	483	-	-	-	-	-	306	-	-	-	-	-	789
2003	-	704	525	-	-	-	-	-	-	-	-	-	1229
2004	483	-	515	-	-	-	204	-	-	-	525	-	1727
2005	-	-	630	-	-	306	-	585	-	715	-	-	2236
2006	-	390	-	459	-	-	369	279	-	-	-	-	1497
2007	-	459	342	-	-	-	-	328	-	-	-	-	1129
2008	-	-	-	-	-	-	-	688	352	-	-	-	1040
2009	506	660	671	418	-	-	-	279	-	-	-	-	2534
2010	504	-	-	424	-	-	-	-	189	-	-	-	1117
2011	576	-	336	-	-	-	-	371	424	384	-	-	2091
2012	296	312	-	-	-	-	-	280	344	279	-	-	1511
2013	-	-	261	-	-	-	-	144	176	-	-	-	581
Monthly total	4014	3008	3280	1301	-	757	990	3558	2157	1378	525	-	20964
Monthly avg.	502	501	469	434	-	252	247	356	308	459	525	-	1497

Table 4: Summary of recreational fishing effort from the WPDSSA Offshore League recorded as the number of angler hours per month between 1999 and 2014.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
1999	-	-	-	-	-	-	-	-	-	297	250	-	547
2000	-	-	261	-	216	-	-	-	-	-	220	-	697
2001	-	-	135	207	-	-	-	-	-	-	180	220	742
2002	-	-	171	198	-	-	-	-	-	99	-	-	468
2003	-	-	144	171	-	153	-	-	-	153	-	-	621
2004	-	-	-	171	-	-	-	-	-	198	-	-	369
2005	-	-	-	-	243	369	-	-	-	261	280	-	1153
2006	-	-	234	-	-	360	-	-	-	225	-	-	819
2007	-	-	-	196	213	-	-	-	-	162	-	126	697
2008	-	-	-	196	230	-	-	-	-	136	279	-	841
2009	-	-	145	162	170	-	-	-	-	-	-	-	477
2010	-	-	119	85	221	-	-	-	-	-	-	27	452
2011	-	-	-	111	-	85	-	-	-	-	-	-	196
2012	-	-	-	-	85	43	-	-	-	-	45	-	173
2013	-	-	-	162	-	-	-	-	-	-	-	-	162
2014	-	-	-	60	60	-	-	-	-	-	-	-	120
Monthly total	-	-	1209	1719	1438	1010	-	-	-	1531	1254	373	8534
Monthly avg.	-	-	173	156	180	202	-	-	-	191	209	124	533

Table 5: Summary of recreational fishing effort from the Simon’s Town Military Ski-Boat Angling Club League recorded as the number of angler hours per month between 1994 and 2014

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
1994	-	-	-	-	135	-	-	153	234	240	184	-	946
1995	-	200	144	558	-	-	-	-	-	-	112	-	1014
1996	-	176	1360	-	225	270	270	306	-	288	-	-	2895
1997	200	160	160	351	135	144	126	225	-	104	-	-	1605
1998	88	216	-	378	243	63	-	-	243	168	192	-	1591
1999	-	-	240	594	-	198	-	243	-	296	224	-	1795
2000	-	168	-	369	387	180	-	126	162	-	112	-	1504
2001	176	-	272	-	-	234	-	-	198	-	168	-	1048
2002	168	184	-	225	225	-	252	189	225	192	232	-	1892
2003	200	-	-	585	279	-	171	279	-	-	224	-	1738
2004	104	-	216	837	-	225	324	171	126	184	-	-	2187
2005	-	-	368	-	108	-	207	-	-	-	-	-	683
2006	128	144	200	720	198	99	117	81	135	-	-	-	1822
2007	-	120	128	-	-	117	198	117	117	56	-	-	853
2008	-	-	-	360	18	-	153	207	117	104	-	-	959
2009	-	128	152	612	-	171	135	153	153	104	32	-	1640
2010	-	-	472	-	189	171	225	180	108	-	88	-	1433
2011	-	-	304	-	-	-	-	-	-	-	-	-	304
2012	-	-	-	-	90	-	63	243	216	-	112	-	724
2013	-	-	264	-	90	72	144	54	-	-	-	-	624
2014	120	-	264	-	-	153	-	-	-	-	-	-	537
Monthly total	1184	1496	4544	5589	2322	2097	2385	2727	2034	1736	1680	-	27794
Monthly avg.	148	166	325	508	179	161	183	182	170	174	153	-	1234

Table 6: Summary of recreational fishing effort from the SADSAA Tuna National Angling Competition recorded as the number of angler hours per month between 1994 and 2014

Year	May
2003	1560
2004	696
2005	1032
2006	816
2007	1512
2008	648
2009	384
2010	192
2011	672
2012	288
2013	768
2014	480
Total	9048
Average	754

Table 7: Species composition of recorded catches from the WPDSAA Offshore league, between 1999 and 2014, and from the SADSAA Tuna Nationals Competition, between 2003 and 2014. Species are arranged taxonomically according to Smith and Heemstra (1986)

Scientific name	Offshore		Tuna Nationals	
	Number	Weight (Kg)	Number	Weight (Kg)
OSTEICHTHYES				
Carangidae <i>Seriola lalandi</i>	18	141	-	-
Coryphaenidae <i>Coryphaena hippurus</i>	3	27	-	-
Scombridae	<i>Acanthocybium solandri</i>	1	6	-
	<i>Katsuwonus pelamis</i>	-	-	2
	<i>Thunnus alalunga</i>	2992	35691	950
	<i>Thunnus albacares</i>	1620	60423	1097
<i>Thunnus obesus</i>	-	-	1	73
Total	4634	96288	2050	52303

Table 8: Species composition of recorded catches from the WPDSAA Inshore South league, between 2000 and 2014, Inshore West league, between 2000 and 2013, and from the Simon's Town Military Ski-Boat Angling Club league, between 1994 and 2014. Species are arranged according to Smith and Heemstra (1986)

Family	Scientific name	Inshore South		Inshore West		Simon's Town	
		Number	Weight (Kg)	Number	Weight (Kg)	Number	Weight (Kg)
CHONDRICHTHYES							
	Unknown shark species	2	27	1	12	37	455
OSTEICHTHYES							
Parascompididae	<i>Parascomps typus</i>	1	1	-	-	1	1
Merlucciidae	<i>Merluccius</i> spp.	29	52	-	-	4	10
Scorpaenidae	<i>Helicolenus capensis</i>	87	93	8	10	13	14
Triglidae	<i>Chelidonichthys capensis</i>	42	58	14	18	36	16
Serranidae	<i>Epinephelus marginatus</i>	6	11	-	-	-	-
Potatomidae	<i>Potatomus saltatrix</i>	2	2	6	8	65	56
Sparidae	<i>Argyrozona argyrozona</i>	127	172	10	13	1	0
	<i>Cheimereus nufar</i>	176	301	4	7	9	8
	<i>Chrysolephus cristiceps</i>	4	6	-	-	-	-
	<i>Chrysolephus gibbiceps</i>	1112	2699	32	82	7	17
	<i>Chrysolephus laticeps</i>	1211	1759	301	445	435	562
	<i>Cymatoceps nasutus</i>	2	8	-	-	-	-
	<i>Diplodus cervinus hottentotus</i>	2	1	1	1	-	-
	<i>Diplodus sargus capensis</i>	1	1	1	1	2	2
	<i>Gymnocrotaphus curvidens</i>	5	5	1	2	2	2
	<i>Pachymetopon aeneum</i>	4	4	-	-	6	6
	<i>Pachymetopon blochii</i>	87	93	192	231	417	321

Table 8: (Continued)

Family	Scientific name	Inshore South		Inshore West		Simon's Town	
		Number	Weight (Kg)	Number	Weight (Kg)	Number	Weight (Kg)
Sparidae	<i>Pachymetopon grande</i>	7	10	-	-	-	-
	<i>Petrus rupestris</i>	10	36	1	15	5	24
	<i>Pterogymnus lanarius</i>	-	-	-	-	14	5
	<i>Rhabdosargus globiceps</i>	3	3	3	3	50	38
	<i>Sarpa salpa</i>	-	-	-	-	2	1
Dichistidae	<i>Spondyllosoma emarginatum</i>	-	-	1	1	53	15
	<i>Dichistius capensis</i>	10	12	-	-	-	-
	<i>Argyrosomus inodorus</i>	504	1292	82	341	331	1253
Sciaenidae	<i>Atractoscion aequidens</i>	292	935	327	1412	417	2435
	<i>Umbrina canariensis</i>	2	5	-	-	-	-
Carangidae	<i>Lichia amia</i>	1	8	-	-	-	-
	<i>Seriola lalandi</i>	244	1192	403	1285	993	3350
	<i>Clinus supersciliosus</i>	-	-	-	-	2	1
Clingidae	<i>Thyrsites atun</i>	925	2336	4063	11871	6178	17695
	<i>Euthynnus alletteratus</i>	2	3	-	-	-	-
Gempylidae	<i>Katsuwonus pelamis</i>	120	403	79	222	429	1252
	<i>Sarda sarda</i>	653	1227	51	118	209	380
Scombridae	<i>Scomber japonicus</i>	-	-	38	46	5	6
	<i>Scomberomorus plurilineatus</i>	1	3	1	3	-	-
	<i>Thunnus alalunga</i>	-	-	49	247	618	6265
	<i>Thunnus albacares</i>	45	347	-	-	164	3577
Total		5719	13105	5669	16395	10505	37765

Table 9: Summary of PERMANOVA analysis of the catch composition from three inshore competitions (Inshore South, Inshore West and Simon’s Town) in relation competition, decade and their interactions

Source of variation	Df.	SS	MS	Pseudo-F	P(perm)
Competition	2	26739	13370	13.21	0.001
Decade	2	6772	3386	3.35	0.001
Competition x Decade	2	4574	2287	2.26	0.009

Table 10: Composition of catch from the Inshore South league showing the most abundant species contributing at least 90% towards the total catch between decades

Species	2000-2009		2010-2014	
	Average Abundance	Contribution %	Average Abundance	Contribution %
Red stumpnose	5.1	30.2	3.6	17.5
Red roman	4.7	27.5	4.9	23.0
Kob	2.3	8.6	3.1	10.7
Geelbek	2.1	5.7	0.8	1.5
Snoek	2.1	5.4	2.2	2.0
Hottentot	1.1	5.4	1.1	4.4
Atlantic Bonito	2.2	3.8	1.6	6.2
Santer	0.9	2.6	2.5	6.6
Yellowtail	0.8	2.2	2.4	10.2
Carpenter	0	0	2.3	8.0
Total		91.4		90.1

Table 11: Composition of catch from the Inshore West league showing the most abundant species contributing at least 90% towards the total catch between decades

Species	2000-2009		2010-2013	
	Average Abundance	Contribution %	Average Abundance	Contribution %
Snoek	6.1	46.1	8.9	61.0
Red roman	2.7	20.0	2.1	13.7
Yellowtail	2.6	12.6	1.3	4.5
Hottentot	2.1	8.3	2.0	12.2
Geelbek	2.1	7.1	0	0
Total		94.1		91.4

Table 12: Composition of catch from the Simon's Town league showing the most abundant species contributing at least 90% towards the total catch between decades

Species	1990-1999		2000-2009		2010-2014	
	Average Abundance	Contribution %	Average Abundance	Contribution %	Average Abundance	Contribution %
Snoek	6.3	41.0	5.9	29.2	9.1	72.5
Red roman	2.4	13.2	2.1	10.6	1.0	7.4
Kob	3.2	12.1	0.4	0.9	0	0
Yellowtail	2.3	8.9	3.7	17.9	1.6	5.8
Longfin tuna	2.4	7.7	2.1	8.2	0.7	1.3
White stumpnose	0.7	3.5	0.7	1.8	0	0
Hottentot	0.7	2.6	2.6	12.2	1.1	5.2
Yellowfin tuna	0.6	2.4	1.3	8.2	0.5	0.7
Geelbek	0	0	1.4	2.8	0	0
Total		91.4		91.8		92.9

Table 13: Statistics for model selection for GLMs run for selected fish species with appropriate selections of independent variables. Figures in bold represent combinations of variables that result in the lowest residual deviance and the best selection for the model

Model	Competition*	Species	Residual deviance				GLM quasipoisson		Proportion of total deviance explained (%)					
			Null	Year	Year + Season	Year + Month	Year + Month + Comp.	R ²	Dispersion	Year	Season	Month	Comp.	Total explained deviance
1	INS	<i>C. laticeps</i>	1363	1237	973	-	-	0.29	1.91	9	19	-	-	29
2	INW	<i>C. laticeps</i>	1034	941	893	-	-	0.14	2.29	9	5	-	-	14
3	SIM	<i>C. laticeps</i>	1798	1540	1470	-	-	0.18	2.75	14	4	-	-	18
4	IN+SIM	<i>C. laticeps</i>	4072	3764	-	3263	2974	0.27	2.64	8	-	12	7	27
5	INS	<i>C. gibbiceps</i>	1217	1132	1037	-	-	0.15	1.83	7	8	-	-	15
6	INW	<i>T. atun</i>	10167	5964	5902	-	-	0.42	10.25	41	1	-	-	42
7	SIM	<i>T. atun</i>	15622	11260	11050	-	-	0.29	12.51	28	1	-	-	29
8	INW+SIM	<i>T. atun</i>	35959	28835	-	24805	21633	0.53	12.29	20	-	11	9	40
9	INS	<i>S. lalandi</i>	492	322	282	-	-	0.43	0.99	35	8	-	-	43
10	INW	<i>S. lalandi</i>	2017	1387	1333	-	-	0.34	3.83	31	3	-	-	34
11	SIM	<i>S. lalandi</i>	4128	3107	3097	-	-	0.25	4.95	25	0	-	-	25
12	IN+SIM	<i>S. lalandi</i>	8295	6741	-	6397	6075	0.27	5.35	19	-	4	4	27
13	INS	<i>A. inodorus</i>	1691	1212	981	-	-	0.42	5.49	28	14	-	-	42
14	INW	<i>A. inodorus</i>	585	431	424	-	-	0.28	3.94	26	1	-	-	28
15	SIM	<i>A. inodorus</i>	2238	1401	1296	-	-	0.42	4.40	37	5	-	-	42
16	IN+SIM	<i>A. inodorus</i>	5557	4559	-	3678	3467	0.38	5.42	18	-	16	4	38
17	SIM	<i>T. alalunga</i>	3808	3040	2764	-	-	0.27	7.24	20	7	-	-	27
18	IN+SIM	<i>P. blochii</i>	3186	2953	-	2739	2452	0.24	2.58	7	-	7	9	23
19	IN+SIM	<i>A. aequidens</i>	6372	4035	-	3516	3472	0.46	4.18	37	-	8	1	46
20	IN+SIM	<i>S. sarda</i>	6184	4674	-	3822	3560	0.45	12.35	24	-	14	4	42
21	OFF	<i>T. alalunga</i>	6865	5745	5716	-	-	0.17	7.62	16	0	-	-	17
22	TNATS	<i>T. alalunga</i>	1617	1245	-	-	-	0.23	4.08	23	-	-	-	23
23	OFF+ TNATS	<i>T. alalunga</i>	3882	3350	-	2825	2807	0.28	5.83	14	-	14	0	28

Table 13: (Continued)

Model	Competition*	Species	Residual deviance				GLM quasioisson		Proportion of total deviance explained (%)					
			Null	Year	Year + Season	Year + Month	Year + Month + Comp.	R ²	Dispersion	Year	Season	Month	Comp.	Total explained deviance
24	OFF	<i>T. albacares</i>	2902	2367	2249	-	-	0.22	2.71	18	4	-	-	22
25	TNATS	<i>T. albacares</i>	1493	1002	-	-	-	0.33	3.00	33	-	-	-	33
26	OFF+TNATS	<i>T. albacares</i>	2655	2150	-	1750	1660	0.37	2.74	19	-	15	3	37

*Abbreviations for competitions: INS – Inshore South league, INW – Inshore West league, SIM – Simon’s Town league, IN – combined Inshore South and West leagues, OFF – Offshore league, TNATS – Tuna Nationals

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