

## SOUTH AFRICA'S MARINE FISHERIES CATCHES (1950–2010)\*

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## ABSTRACT

The official fisheries catch data reported by South Africa to the Food and Agriculture Organization of the United Nations (FAO) is thought to focus on commercial catches, and exclude subsistence (i.e., small-scale non-commercial fishing for self- and family-consumption) and recreational (i.e., small-scale non-commercial fishing for pleasure) catches. The reconstruction of fisheries catches from 1950 to 2010 was undertaken, and combined official data reported to the FAO with estimates of unreported catches for the recreational and subsistence sectors, illegal artisanal catch, and discards from industrial fishing. Total recreational and subsistence catches were estimated to be approximately 3,400 t·year<sup>-1</sup> and 1,600 t·year<sup>-1</sup> in the 1950s, respectively, and increased steadily to almost 6,400 t·year<sup>-1</sup> and 4,300 t·year<sup>-1</sup> in the 2000s (of which about 65% of the respective catches came from the South African Exclusive Economic Zone [EEZ] in the Western Indian Ocean; FAO area 51). In comparison, domestic industrial catches averaged 370,000 t·year<sup>-1</sup> in the early 1950s, peaked at 2.1 million t in 1968, and have been around 720,000 t·year<sup>-1</sup> in the 2000s. Reconstructed artisanal catches increased from about 45,000 t·year<sup>-1</sup> in the early 1950s to 42,000 t·year<sup>-1</sup> in the 2000s. Discards by the industrial sector totalled 3.6 million t from 1950 to 2010, making up about 6% of total reconstructed catch. Almost all industrial catches were from South Africa's EEZ in the Southeast Atlantic Ocean (FAO area 47). South African catches taken in Namibian waters during the South African occupation of Namibia (1915–1990) were identified and assigned as South African flagged catches taken in Namibian waters. These catches from Namibian waters totalled 18 million t from 1950 to 1990, and were on average 200,000 t·year<sup>-1</sup> in the 1950s before peaking at 1.6 million t in 1968, then dropping to 162,000 t·year<sup>-1</sup> in the late 1980s. Once reported landings were adjusted for the spatially reassigned catches taken in Namibian waters, reconstructed total catches for South Africa proper were 1.1 times the adjusted landings reported by FAO on behalf of South Africa. Although reconstructed subsistence and recreational catches made up less than 1% of annual domestic commercial catches, these sectors are of considerable socio-economic importance for a large fraction of South Africans. The reconstruction of fisheries catches in these marginalized sectors emphasizes the necessity for political action in support of new management measures, and for ensuring a sustainable and equitable use of ecologically, socially and economically important marine resources in South Africa.

## INTRODUCTION

In times of dwindling natural marine resources and ever increasing pressure on the marine environment induced by human activities such as overfishing, pollution and global warming, there is the need for more comprehensive and sustainable approaches in fisheries management and a shift in the exploitation of marine resources in general. Global fisheries overall are in a crisis of overexploitation and ongoing stock depletion (Pauly *et al.* 2002; Myers and Worm 2003). It has been suggested that a combination of traditional management methods (e.g., catch quotas) and closed areas (marine protected areas in which fishing is prohibited), gear and effort restrictions, as well as new management approaches in general hold promise for rebuilding of stocks (Worm *et al.* 2009).

In order to facilitate adequate fisheries management and to account for fisheries in an ecosystem-based setting, comprehensive knowledge on stock status and the amount of withdrawal from these stocks is required. Despite the socioeconomic importance of recreational and subsistence/small-scale fisheries, catch data for these sectors are seldom available and catches are therefore unreported. The marginalization of these sectors and the neglect in quantifying respective catches, systematically tend to underestimate both the actual extent of catches and subsequently the potential adverse effects on marine ecosystems (Pauly and Zeller 2003; Cooke and Cowx 2004; Pauly 2006).

In recent years, increased scientific effort has been undertaken in order to quantify and map formerly unreported catches, by reconstructing or reestimating historic catches for various countries and regions, in order to complement existing time series of catches of the Food and Agricultural Organization of the United Nations (FAO) and to examine relationships between fishing and ecological changes (Watson *et al.* 2004; Pauly 2007).

This report is the first attempt to reconstruct previously unreported catches in South African fisheries, following the catch reconstruction methodology of Zeller *et al.* (2007a). Reconstructed catches were taxonomically assigned and spatially split to various Exclusive Economic Zones (EEZ) within FAO areas.

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South Africa has a long coastline that spans two oceans, the Atlantic Ocean in the west and the Indian Ocean in the east (Figure 1). The Benguela ecosystem of the west coast is one of the most productive ocean ecosystems in the world in terms of biomass production and fishery resources due to the upwelling of cold, nutrient rich water (Cochrane *et al.* 2009). South African waters are characterized by high endemism due to the distinct oceanographic conditions and the variety of habitats (Van der Elst *et al.* 2005). Today, the fishing industry in South Africa provides employment and income for at least 27,000 people, but contributes less than 1% of the country's Gross Domestic Product (GDP; FAO 2010). South Africa is the largest fishing country in Africa, and ranked 30<sup>th</sup> in the world in the 1990s (Hersoug and Holm 2000). The fisheries of South Africa can be separated into three components: the commercial/industrial, recreational, and subsistence/artisanal fisheries, jointly all targeting over 250 marine species (FAO 2010). Here, we distinguished between four fishing sectors: industrial (i.e., large-scale commercial), artisanal (small-scale commercial), subsistence (small-scale non-commercial) and recreational (small-scale non-commercial).

### Commercial fisheries

The commercial fishing industry is being separated into large-scale (i.e., industrial) and small-scale (i.e., artisanal) in the present context, and each consists of several fisheries. The most important fishery is the deep-sea trawling subsector and the smaller inshore trawl fishery (both deemed industrial) mainly targeting hake stocks (*Merluccius paradoxus* and *M. capensis*; Burgener 2011). There are also small fisheries for hake using demersal longlines and handlines (FAO 2010), which are deemed artisanal.

There is also a pelagic purse-seine fishery targeting sardine (*Sardinops ocellatus*), anchovy (*Engraulis capensis*) and round herring (*Etrumeus whiteheadi*) for the production of fishmeal, oil and canned fish (this fishery represents 25% of the value of commercial fisheries in South Africa; Hersoug and Holm 2000; Okes and Burgener 2011a). A midwater trawl fishery is targeting horse mackerel (*Trachurus capensis*) on the Agulhas Bank. Both these fisheries were treated as industrial.

There are two important rock lobster fisheries in South Africa. On the West Coast, an inshore fishery is targeting West Coast rock lobster (*Jasus lalandii*), and on the South Coast a deep water fishery is targeting *Palinurus gilchristi*; Okes and Burgener 2011b). Rock lobster contributes less than 1% by mass to the total fishery, but its contribution by value is approximately 9–10%. Lobster fisheries were treated as artisanal.

There is also a very valuable, but politically highly disputed abalone fishery (*Haliotis midae*), which has been operating since the late 1940s (DAFF 2012). High levels of poaching and resulting overexploitation led to the temporary closure of the industry in the late 2000s (Hauck and Sweijd 1999; Raemaekers and Britz 2009). This fishery was treated as artisanal.

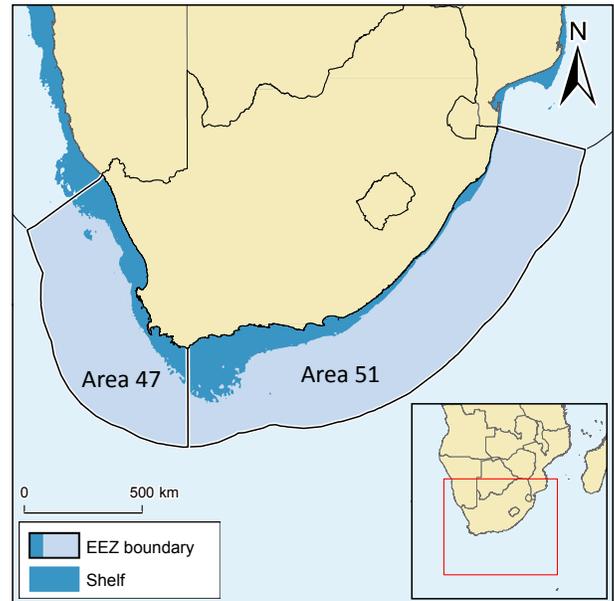
Other smaller fishing sectors include trawl fleets targeting shrimp off the coast of Kwa-Zulu Natal (industrial; Okes and Burgener 2011c), a pelagic longline fishery targeting various tuna species, sharks and billfishes (industrial; Okes and Burgener 2011d,e), a tuna bait and pole fishery (industrial), a small squid jig fishery (artisanal fishery targeting chokka squid [*Loligo vulgaris reynaudi*] for export; Okes and Burgener 2011f), and a linefish sector (artisanal) that is large in terms of area fished and people employed, targeting a great diversity of fish species including sharks, tunas, and groupers (FAO 2010).

In general, catch data for the South African commercial fisheries appeared to be well documented and catch statistics were readily available. South African national statistics made provision for illegal fishing by adding on an illegal catch component to the commercial landings of some fisheries, but the true level of illegal fishing that actually takes place remains unknown (DAFF 2012).

### Foreign fishing in South Africa

There appear to be a few South African commercial fisheries that have foreign involvement (David Japp, CapFish, pers. com.), notably:

- A large pelagic fishery, which at present has about 15 joint venture arrangements between South African fishing rights holders and mainly Japanese and Chinese fishing entities (Okes and Burgener 2011d);
- A deep-water hake trawl fishery, which has catch arrangements with Spanish vessels that are not officially sanctioned, and hence could be deemed illegal; and



**Figure 1.** Map of the South African's Exclusive Economic Zone (EEZ) in both Atlantic and Indian Oceans, as well as the extent of the continental shelf (dark blue).

- A patagonian toothfish (*Dissostichus eleginoides*) fishery, which seems to include at least two vessels with foreign beneficial ownership holding South African joint venture fishing rights.

Here we did not estimate catches of these foreign operations, as we had to assume that legal joint venture operations engaged in proper reporting procedures, and hence such catches would need to be reported to South African authorities (except possibly the potentially illegal operations of non-sanctioned Spanish hake fishing; see item 2 above).

### *Recreational fisheries*

In recent years, the exploitation of marine resources by various types of recreational fisheries has become a topic of increasing concern for some countries. It is now acknowledged that the recreational fishing sector has the potential to negatively affect fish stocks and may lead to overexploitation of marine resources (Coleman *et al.* 2004; Cooke and Cowx 2004). In countries such as Australia and the USA, the scientific community acknowledges that public perception and the *modus operandi* of managing recreational fisheries needs to change, bearing in mind that recreational fisheries have various long-term effects on fish stocks and marine ecosystems (McPhee *et al.* 2002). Thus, information about total catches, total number of fishers, fishing effort and species composition is crucial. Unfortunately, due to the diversity and spatial and temporal dispersion of the recreational fisheries sector, it is often difficult to obtain such data. As there are no comprehensive estimates for the recreational sector and no official catch statistics for the marginalized subsistence sector in South Africa, this report is the first attempt to reconstruct the total marine recreational catch in South Africa for the period 1950–2010.

The South African marine recreational fishing sector is a large and economically important component of South African fisheries. An extensive coastline and a rich and diverse marine fauna offer thousands of recreational fishers the right conditions for their hobby. Major recreational fisheries target abalone, West Coast rock lobster and around 200 pelagic and demersal species targeted using line fishing (of which 31 contribute significantly to the overall total catch; Griffiths and Lamberth 2002). The recreational linefish component can be separated into various sectors: boat- and shore-based estuarine fishers, including recreational fishers using cast nets; marine inshore rock and surf anglers; a boat-based offshore sector; and the spearfishing sector operating both from the shore and from boats. Additionally, there is a charter boat sector offering sport and big game fishing, which has become increasingly popular in recent years, especially in the province of Kwa-Zulu Natal (Pradervand and Van der Elst 2008).

Historically, recreational fishing permits for most species were not required in most parts of South Africa until 1999, when new fishing legislation (Marine Living Resource Act of 1998) was put in place. In Kwa-Zulu Natal, a licensing system was implemented in 1971 under a Provincial Ordinance. Nationwide size limits, bag limits, marine protected areas and closed seasons for some species were the only measures implemented in order to manage the recreational fisheries (Cockcroft *et al.* 1999; Griffiths and Lamberth 2002). In contrast to subsistence fishing, which has existed in South Africa for thousands of years, and commercial fisheries that were initiated by Dutch colonists in the 17<sup>th</sup> century, recreational shore-based fisheries were introduced by British settlers in the early 19<sup>th</sup> century (Van der Elst 1989). According to Horne (1974), boat-based recreational angling was only introduced after World War II. Around the same time, various technological developments with respect to gear and fishing methods led to recreational fishing becoming an increasingly popular pastime. Already in the early 1960s, there were an estimated 250,000 recreational fishers in South Africa engaging in shore- and boat-based angling (Schoeman 1962). World record catches of giant bluefin and yellowfin tuna, various types of sharks, marlins, sailfish and giant barracuda were recorded from South African waters before 1950 (Schoeman 1962). Due to its popularity and the economic importance of generating 81% of employment and 82% of revenue of the total South African line fishery sector (Griffiths and Lamberth 2002), the recreational fishing sector can be regarded as an integral part of the South African economy, as well as the fishing industry as a whole.

It is accepted that recreational fishing is responsible for the decline of various fish stocks, crustaceans and other marine organisms in South Africa. Both boat- and shore-based anglers have substantially contributed to the collapse of several stocks (Griffiths and Lamberth 2002) and catch declines are reported in various scientific papers (e.g., Brouwer *et al.* 1997; Sauer *et al.* 1997). In the early 2000s, the South African Government officially declared the marine linefish fishery as being in a state of emergency due to the collapsed or overexploited state of many linefish stocks (Griffiths and Lamberth 2002).

Estimating recreational catches, especially for periods in the past, is a difficult task. The management of the recreational fisheries sector in South Africa appeared complicated due to its numerous species, multi-user nature and temporal and spatial diversity and variability. This report made a first attempt to reconstruct the total recreational catch from 1950 to 2010 as accurately as possible in order to acquire a better understanding of the extent of catches.

### *Subsistence fisheries*

Subsistence fisheries provide food (and occasional income from selling surplus catch or high value catch) for millions of people throughout the world. In South Africa, despite its importance in terms of food security and poverty alleviation, this sector has not been sufficiently integrated into management and policy systems (Sowman 2006). The reforms of the post-apartheid transformation process and the implementation of the new Marine Living Resource Act in 1998 have not yet reached its aims of sustainability, equity and stability (Isaacs 2006). Many traditional fishers have been excluded from the new fisheries management framework and consequently were left without fishing rights and adequate support (Sowman and Cardoso 2010). Nevertheless, the Marine Living Resource Act contains the initial

legal recognition of subsistence fishers in South Africa, and some progress has been made since then. In Kwa-Zulu Natal, a system of co-management has been implemented in some communities and a limited commercial sector for historically disadvantaged individuals (HDI) in South Africa was created in 2001 (Sowman 2006), thus turning some former subsistence fishers into artisanal fishers.

Scientific studies have concentrated on political, socio-economic and management-related issues concerning the subsistence sector in South Africa (Hauck and Sowman 2001; Branch *et al.* 2002a,b; Harris *et al.* 2002a,b; Hauck *et al.* 2002; Sowman 2006; van Sittert *et al.* 2006; Sowman and Cardoso 2010). Some studies identified the present number of subsistence fishers and the type of resources they exploit in South Africa (Clark *et al.* 2002; Cockcroft *et al.* 2002; Napier *et al.* 2009). This report attempted to reconstruct the marine fisheries catches for the subsistence sector in South Africa for the 1950–2010 period. Several studies have identified the extent and economic importance of underreporting of subsistence fisheries catches in various countries in which official statistics mainly focus on commercial fisheries only (Zeller *et al.* 2006, 2007a,b; Jaquet and Zeller 2007).

There is a general consensus that subsistence fishers are poor fishers who catch marine resources as food source although they may sell or exchange surplus catches to meet basic needs of food security (Branch *et al.* 2002a; Sowman 2006). Furthermore, they catch resources near or on the shore, as well as in estuaries, apply low-technology gear and mostly live in close proximity to the fishing area (Branch *et al.* 2002a). Thus, here we defined subsistence fishing as small-scale non-commercial fishing with the primary purpose of feeding one's family, while recognizing that subsistence fishers may sell part of their catch, especially if catches exceed their immediate food security needs or can provide needed cash (e.g., from high-value specimen).

Artisanal fishers are also often poor fishers but have a principle commercial involvement with fishing marine resources. Artisanal fishers go fishing to primarily sell their catches rather than using it primarily for their own consumption (Branch *et al.* 2002a). Thus, here we defined artisanal fishing as small-scale commercial fishing with the primary intent of generating cash income. We recognize the overlap between these two sectors, and hence the potential arbitrariness of differentiation at times.

Many fishers in South Africa, defined as subsistence or artisanal fishers, actually intend to gain small-scale commercial rights in order to legally sell high-value resources such as abalone and rock lobsters (Branch *et al.* 2002a). The idea of creating a small-scale commercial fisheries sector was to enable subsistence/artisanal fishers to generate revenues by allocating specific fishing rights. The potential socioeconomic benefits of the commercialization of some subsistence fisheries in South Africa have been documented (Arnason and Kashorte 2006). The process of implementing a management strategy for the small-scale sector by means of creating sufficient numbers of fishing rights and providing adequate support is continuing. The government's lack of experience with a subsistence sector lead to the appointment of a Subsistence Fisheries Task Group (SFTG) in 1999 to advise the government in various issues regarding the management of the new subsistence sector (Sowman 2006).

## MATERIAL AND METHODS

### *Human population data<sup>1</sup>*

### *Recreational fisheries*

The various components of recreational fisheries have been subject to numerous individual studies and offer information for estimating the total recreational marine catch if one accepts some assumptions. Available information included data on catches, catch rates and targeted species composition, geographic and socio-economic information, as well as historical and general background information

### Marine inshore surf and rock recreational fisheries

In general, shore angling data are sparse for South Africa. An exception to this is the province Kwa-Zulu Natal, where several investigations have been undertaken to estimate catches and effort, species compositions, the economic importance of recreational shore fishing, and anglers' attitudes towards and compliance with fishery regulation (Brouwer *et al.* 1997). Information obtained from government shore patrols, voluntary catch and effort data, and inspections, are collected in the National Marine Linefish System (NMLS; Brouwer *et al.* 1997). Due to the fact that almost no recreational data are collected for provinces other than Kwa-Zulu Natal, the flexibility of data sources and the unreliability of voluntary and compulsory catch data from individual fishers; the NMLS is unfortunately perceived as being a poor and unrepresentative data source (Sauer *et al.* 1997). Therefore, the focus has been on obtaining additional data from individual studies, reports and scientific papers.

<sup>1</sup> Population data for South Africa were obtained from the United Nations World Population Division (United Nations 2009) and the World Bank (World Bank 2010).

### Boat-based marine inshore recreational fisheries

Gears used are the same as in the shore angling sector, i.e., rod and reel or handlines. Even though there are varying levels of competition between all recreational fishing sectors and the commercial linefishery sector, the commercial and recreational boat sectors compete most directly. Similar vessels and gear are used and the same fish species are targeted in the same geographic regions and marine environments. The resulting user conflicts were reported in the literature, which highlighted the difficulty in distinguishing between recreational and commercial fishers due to the fact that many operate in both sectors, depending on seasonal availability of fish and the availability of supplementary incomes (Sauer *et al.* 1997). Collection of information about catch rates, effort, total catches and targeted species started in the 1970s, similarly to the shore angling sector. Data on commercial and recreational boat-based fisheries were separate until 1982, when the NMLS database was initiated. As with the other recreational sectors, numerous scientific studies have been done, which reveal important information on the nature of recreational boat-based fisheries in South Africa.

### Spearfishing

Spearfishing is regarded as one of the most dangerous forms of fishing in South Africa, as it often occurs in challenging underwater conditions, requiring excellent mental and physical fitness of its participants. Nevertheless, this form of fishing has enjoyed great popularity since the 1950s along the South African coast, where fishers operate both from shore or from boats (Mann *et al.* 1997).

### Estuarine recreational angling

Along the South African coastline, there are approximately 250 well-defined estuaries and many are used as recreational fishing sites. Due to the lack of inlets and bays in South Africa, estuaries offer popular fishing grounds, as they are sheltered from rough seas and are productive fishing grounds attracting mainly recreational boat-based and shore-based fishers who also use cast nets to catch baitfish such as mullet. Linefishing and netfishing (mostly gillnets and seine netting) for commercial and subsistence purposes also occurs in estuaries (Lamberth and Turpie 2003). The most important ecological role of estuaries is that they provide nursery areas for many fish, contributing to healthy fish stocks and a healthy marine environment (Whitfield 1994). It is estimated that the estuarine catch in the early 2000s totalled 2,480 tonnes per year (including commercial, subsistence and recreational catches), and that recreational fisheries generate by far the biggest share of the GDP value in comparison to the commercial fisheries within estuaries (Lamberth and Turpie 2003).

### Abalone

Recreational diving for abalone has a long tradition in South Africa and has become a highly sought-after marine resource for illegal poachers in organized crime networks in recent years. The increasing pressure on the abalone stocks both in western and eastern provinces of South Africa led to the closure of recreational fisheries for abalone in 2003 (Raemaekers and Britz 2009). Before the increase of illegal abalone poaching activities in South Africa in the early 1990s, recreational and commercial abalone fisheries in the Western Cape provinces were stable (Raemaekers and Britz 2009). Nevertheless, early concern over declining commercial catch rates resulted in stricter management regulations, introduced in 1970. The regulations included annual catch quotas (total allowable catch), which have been gradually lowered (Cockcroft *et al.* 1999).

### Rock lobster

There are several different species of rock lobster that are targeted by recreational divers or trappers. The main species, however, are the West Coast rock lobster, which inhabit near shore areas from about 23° S (Walvis Bay, Namibia) to about 28° S near East London, and the East Coast rock lobster, which inhabit shallow reef habitats from Port Elisabeth to north to Mozambique (Cockcroft and Payne 1999). This report focused on the recreational fisheries for West Coast rock lobster, since it is the largest recreational rock lobster fishery in South Africa, both in terms of catches and number of fishers (Okes and Burgener 2011b)

According to Cockcroft (1997), commercial exploitation of West Coast rock lobster began in the late 19<sup>th</sup> century. By 1933, the same regulations applied to both the recreational and commercial sectors, and it was not until 1961 that the authorities differentiated these sectors by introducing a bag limit for recreational fishers. The selling of recreational catches was prohibited and non-conformity continues to be heavily penalized. Over the years, regulations regarding the recreational fishery were steadily updated as fishing pressure increased, e.g., legal minimum sizes and catch bans for specific times of the day were implemented. Legal obligations for the possession of catch permits was introduced in the 1983–84 season (Cockcroft and Mackenzie 1997). In comparison to the recreational abalone fishery, which has been banned since 2003, the recreational rock lobster fishery continues to be a popular pastime for South Africans (Okes and Burgener 2011b).

## Charter boat fishing

Charter boat fishing was practiced in South Africa before 1950, and gained popularity during the apartheid period (1948–1994). During this time, mainly wealthy white South Africans went fishing for marlin, swordfish and tuna along the South African coast (Schoeman 1962). Today, hundreds of different operators offer fishing trips to customers in South Africa, particularly in the Kwa-Zulu Natal Province.<sup>2</sup> According to Pradervand and van der Elst (2008), the introduction of stricter legal obligations and resulting economic disincentives for commercial fishing has led some commercial fishers to switch to operating charter boat trips. In comparison to the commercial linefish industry, income from the charter boat business is not directly linked to total catch but rather to the experience. Since estimates of annual participation in South Africa are sparse, this report quantified total retained catch only, based on the assumption that at least 50% of nationwide total annual catches were made in Kwa-Zulu Natal, the province where charter boat fishing has been the most popular.

### *Number of recreational fishers*

The number of fishers was derived from the literature (Mann *et al.* 1997; Sauer *et al.* 1997; Griffiths and Lamberth 2002; Lamberth and Turpie 2003). For the years when the number of fishers were missing, linear interpolations were used between time spans of known data, or missing data were derived by applying compound annual growth rates.

Information on the number of participants in the charter boat sector was not available. Thus, the focus was on deriving estimates for total annual retained catches. Abalone and rock lobster fisheries participation was derived from the number of licenses sold and directly translated into the number of fishers or divers, thus assuming one license equalled one fisher or diver. Missing data were derived by applying a ratio of total population to number of licenses sold, based on respective years, and linear interpolation between years of known data.

The purpose of deriving the number of recreational fishers by sector was to determine an estimate of the total number of recreational fishers, in order to calculate the proportion of recreational fishers in the total population, and to derive total catches for each sector using catch rates per fisher.

### *Recreational catch rates*

The annual average fishing effort per fisher was assumed to have remained stable in the recreational fishing sector over the study period. Catch rates varied significantly over-time for the recreational boat-based, estuarine, shore and rock fisheries. Catch rates for abalone and West Coast rock lobster did not experience significant changes and therefore were kept at a constant rate, based on estimates obtained from the literature. Information and data from scientific papers and grey literature suggested trends of decreasing catch rates over-time (Coetzee *et al.* 1989; Guastella 1994; Pradervand and Baird 2002) and states that many important linefish stocks have been heavily overfished and in a state of overexploitation (Griffiths 1997a,b, 2000; Griffiths and Lamberth 2002). According to Griffiths (2000) and Griffiths and Lamberth (2002), most of the overexploitation of linefish already occurred in the 1970s. Therefore, a catch trend scenario was developed reflecting these changes.

The nationwide catch rates for the shore and rock, boat-based and estuarine recreational fisheries were adjusted conservatively, in relation to documented catch rates for 1995 (Lamberth and Turpie 2003). Catch rates for 1950 were set 25% higher than the 1995 rate, based on the assumption that stocks were much less exploited and not overfished in the 1950s. The technological advances in fishing gear, boats, knowledge and fishing methods, as well as the increasing popularity of fishing as a pastime (Schoeman 1962), was reflected in the assumption that from the 1950s onwards, catch rates increased steadily, peaking in 1970 at a rate 50% higher than in 1995. Catch rates for missing years between 1950 and 1970, as well as for the period 1970–95, were derived through linear interpolation. The decreasing trend was carried forward unaltered to 2010.

### Shore and rock anglers

Shore and rock angling is considered the most popular form of recreational angling in South Africa and is practiced all along the South African coast and, therefore, is the biggest recreational sector in terms of number of participants. It was estimated that in 1991, there were roughly 365,000 recreational shore fishers (Van der Elst 1993), increasing to 412,000 by 1995 (McGrath *et al.* 1997). Contrary to the suggested annual compound growth rate of 6% by van der Elst (1993), a slightly smaller rate of 2% annual compound growth was suggested by McGrath *et al.* (1997). Estimates of shore anglers were based on those data anchor points. Missing numbers of participants were estimated for 1950–91 and from 1995–2010 by applying an annual compound growth rate of 2%, backward (declining) and forward (increasing), respectively. A linear interpolation between 1991 and 1995 provided estimates for the number of anglers in this time-period. Using the 2% growth rate (McGrath *et al.* 1997) supported a conservative approach in estimating the number of recreational fishers, especially for the post-1995 period.

An annual average catch rate of 7.37 kg-fisher<sup>-1</sup>-year<sup>-1</sup> was calculated for the year 1995 based on the total catch estimates (3,037 tonnes) for the recreational shore angling sector (Brouwer *et al.* 1997; Lamberth and Turpie 2003). The same logic as mentioned above was applied in order to construct a time-series of catch rates. Catch rates for 1950 and 1970 were set 25% and 50% higher than the 1995 rate, respectively. The trend was carried forward unaltered to estimate likely catch rates for recent times.

<sup>2</sup> However, these operators do not restrict their activities to South African waters. See, e.g., Le Manach and Pauly (this volume) and their discussion on recreational fishing by South Africans in the EEZ and Bassas da India (France).

### Boat-based inshore anglers

Numbers of recreational boat-based inshore marine fishers for similar periods varied in the literature. Sauer *et al.* (1997) suggested that there were 13,800 fishers in 1996. For this report, the more conservative estimate of 12,000 participants in 1995 was chosen as an anchor point (Lamberth and Turpie 2003). It was assumed that the development and popularity of boat-based recreational fishing in South Africa followed the same consistent growth trend as the shore and rock sector. Therefore, the same annual compound growth rate of 2% (McGrath *et al.* 1997) was applied to calculate missing numbers of fishers over the period 1950 to 2010.

An annual average catch rate of 106.92 kg·fisher<sup>-1</sup>·year<sup>-1</sup> for the year 1995 was calculated, based on 12,000 fishers catching 1,283 tonnes (Lamberth and Turpie 2003). The same logic as mentioned above was applied in order to construct a time-series of catch rates. Catch rates for 1950 and 1970 were set 25% and 50% higher than the 1995 rate, respectively. The trend was carried forward unaltered to estimate likely catch rates for recent times.

### Spearfishers

It was estimated that in 1987, there were 4,000 recreational spearfishers in South Africa (Van der Elst 1989). The number of participants rose to 7,000 in 1995 and an annual growth rate of approximately 6% was suggested (Mann *et al.* 1997). For the time-period of 1987–95, linear interpolation provided the missing data, whereas a growth rate of 6% was applied to calculate the remaining years.

Mann *et al.* (1997) report that there was neither evidence for declining catch rates, nor a change in species composition between 1984 and 1995 for the recreational spearfishing sector in Kwa-Zulu Natal (i.e., where most spearfishing activity is occurring). Thus, it was assumed that no significant changes in catch rates between 1950 and 2010 occurred. The respective annual catch rate per fisher for 1995 was estimated at 30 kg·speafisher<sup>-1</sup>·year<sup>-1</sup>, based on 7,000 spearfishers catching 210 tonnes in 1995 (Mann *et al.* 1997; Lamberth and Turpie 2003). Consequently, this constant catch rate was applied to the estimated number of recreational spearfishers in order to derive total annual catches.

### Estuarine boat-based & shore anglers

It was estimated that there were 72,000 recreational estuarine fishers in 1995 (Griffiths and Lamberth 2002; Lamberth and Turpie 2003). The reconstructed number of fishers for the period 1950–2010 was derived by applying an annual compound growth rate of 2% (McGrath *et al.* 1997) to the fixed data point of 1995 (Lamberth and Turpie 2003), based on the assumption that the development of recreational estuarine fisheries followed a similar trend as inshore marine shore and rock angling.

In 1995 an estimated 72,000 recreational estuarine fishers were catching roughly 1,068 tonnes of fish and other marine organisms from boats or the shore, using handlines, rods and reels, or nets (Griffiths and Lamberth 2002; Lamberth and Turpie 2003). This translated into an average catch rate of 14.83 kg·fisher<sup>-1</sup>·year<sup>-1</sup>, which was used here. The 1995 catch rate was adjusted for 1950 (25% higher) and 1970 (50% higher), and the declining trend was carried forward from 1995 to 2010 by linear interpolation.

### Abalone

Participation in the abalone fisheries was represented in the literature by the annual number of licenses sold, and for the purpose of this report, was directly translated into actual number of fishers using a ratio of 1 to 1 (one license equalled to one fisher). The period 1989–2003 was fairly well documented in scientific reports in regards to annual number of licenses and the associated total catch. From 2003 onwards, recreational permits were no longer sold due to the closure of the fisheries. In order to estimate participation before 1989, a ratio of total population to abalone fishers was derived for the year 1989 (total population of 34,490,549) in which 20,000 recreational licenses were sold (Cockcroft *et al.* 1999). This ratio of 0.0006 was applied to the total South African population in the years prior to pre-1989, to estimate likely numbers of participants.

For abalone, a catch rate of 14.80 kg·fisher<sup>-1</sup>·year<sup>-1</sup> for the year 1989 was calculated from reports stating that 20,000 individual recreational divers and fishers caught 296 tonnes of abalone in that respective season (Cockcroft *et al.* 1999). This rate was held constant from 1950 to 1989 and applied to the reconstructed number of participants in order to derive total annual catches for the period 1950–1989.

### West Coast rock lobster

Due to the fact that permit requirements were nonexistent before 1983, it was difficult to estimate the actual amount of fishers before this period. The most reliable data found in the literature involve voluntary cooperation of fishers and indirect estimation methods such as questionnaires (Cockcroft and Mackenzie 1997; Cockcroft *et al.* 1999).

A total population to licenses ratio was established based on the fixed data point of 38,000 sold licenses in 1989 (total population of 34,490,549). This ratio of 0.0011 was applied to population data over the period 1950–89 in order to reconstruct participation. From 1989 to 1998, the actual number of licenses purchased, and thus the number of fishers/divers, was known (using the same approach as abalone where the ratio of one license equalled to one fisher). From 1999 onwards, the number of permits sold was unknown and thus not represented, but annual catch estimates were available from government reports (Anon. 2010a,b).

For the rock lobster sector, an annual catch rate of 6.2 kg-fisher<sup>-1</sup>-year<sup>-1</sup> in 1995 was derived based on 54,000 participants catching 336 tonnes and applied to the reconstructed number of participants for times, in which data were unavailable (Cockcroft and Mackenzie 1997; Cockcroft *et al.* 1999; Cockcroft and Payne 1999). For the period 1999–2010, government estimates for recreational catches were available (Anon. 2010a).

### Charter boat fishing

Estimates of retained catch for the charter boat sector in Kwa-Zulu Natal in 2003 amounted to approximately 200 t (Pradervand and Van der Elst 2008). Based on the estimated number of operators throughout South Africa, it was assumed that this represented only 50% of the total annual retained charter boat catch (Africa 2010; Directory 2010). Consequently, it was assumed that the nationwide retained catch totalled 400 t in 2003. Assuming that this industry was still underdeveloped in the early 1940s (Schoeman 1962), the total catch for the year 1945 was set at zero and a linear interpolation for the period 1945–2003 provided annual, nationwide catch estimates for 1950–2002. The increasing trend was carried forward to 2010.

### *Targeted species*

The development of sound fisheries management policies and the process of assessing the fisheries impact on marine ecosystems were not solely based on improvements of spatial and quantitative information. Another vital part was the improvement of taxonomic information about the overall catches. Griffiths and Lamberth (2002) collected catch contribution information from various sources and assigned the most important species by weight, targeted by recreational anglers (grouped into shore angling, boat angling, estuarine angling and spearfishing) to the five main coastal geographical regions, namely Western Cape, Southern Cape, Eastern Cape, Transkei and Kwa-Zulu Natal.

### *Subsistence fisheries*

Both academic and grey literature was reviewed for data and information about subsistence fisheries in South Africa. The findings of the SFTG comprised information about the social and economic background (Branch 2002; Branch *et al.* 2002a,b) and the number and geographical distribution of subsistence fishers and fishing communities in South Africa (Clark *et al.* 2002). This information was combined with individual studies about the localized subsistence catch of marine resources in order to derive nationwide estimates of subsistence catches (Lamberth and Turpie 2003; Steyn *et al.* 2008; Napier *et al.* 2009).

### *The number of subsistence fishers and their geographical distribution*

It was difficult to derive accurate estimates for the number of subsistence fishers in South Africa for several reasons. Due to the interchangeable usage of different definitions for 'subsistence fishers', the numbers varied in the literature. Furthermore, many subsistence fishers operate with recreational permits. Subsistence linefishers are known to be dispersed within the recreational shore and estuary fisheries (Griffiths and Lamberth 2002). No more than 10% of the 27,000 commercial fishers in South Africa could be defined as purely subsistence or artisanal (Elst *et al.* 2005). They represent the poorer participants of the industrial fisheries sector in South Africa. McGrath *et al.* (1997) estimated that at least 25,000 households in South Africa (excluding Transkei) depend on shore angling only in order to meet their needs for protein supply. In the early 2000s, 147 fishing communities comprising 28,338 fisher households and 29,233 individual subsistence fishers were identified in South Africa (Clark *et al.* 2002). Most of these subsistence fishers are found on the East Coast of South Africa and more than 75% (more than 22,500) live in Kwa-Zulu Natal and the Transkei (Clark *et al.* 2002). It is reported that the lion's share of subsistence linefishers is located in the Transkei and Kwa-Zulu Natal (Griffiths and Lamberth 2002). The breakdown of the number of subsistence fishers into respective geographical areas along the South African coastline demonstrates that most subsistence fishers catch marine resources in the eastern provinces. Approximately 82% of subsistence fishers operate in marine environments and only 18% catch marine resources in estuaries (Table 1). For this report, it was assumed that these distribution patterns were similar throughout the period 1950–2010 and that the number of participants and the catch rates or effort varied over-time.

It is believed that subsistence fisheries activities on the East Coast of South Africa have been carried out rather unchanged throughout the years (Siegfried *et al.* 1994; Griffiths and Branch 1997). Being confined to so-called 'homelands' during apartheid and the lack of alternative ways of generating income, many traditional fishers in the eastern provinces were restricted to a subsistence lifestyle (Clark *et al.* 2002). On the contrary, subsistence fisheries on the west and south coast disappeared with the arrival of settlers from Europe for various reasons. Many traditional fishers were enslaved, killed or died because of diseases (Siegfried *et al.* 1994). However, the current perception that subsistence fisheries are exclusively confined to Kwa-Zulu Natal and the Transkei region is erroneous. Clark *et al.* (2002) suggested that subsistence fishers did not disappear altogether, but rather changed their catch and consumption behaviour and adapted to new social and cultural circumstances. Advances in fishing gear after World War II enabled fishers to target a greater variety of marine resources, requiring less effort (Schoeman 1962). The introduction of a cash economy and the growth of tourism incentivized many subsistence fishers in western and southern coastal regions to catch more and sell the surplus, as well as live closer to urban areas in order to improve access to markets (Clark *et al.* 2002). These facts have contributed to the public erroneous perception that subsistence fishers solely live in rural areas in eastern South Africa.

Population density was highest in the eastern provinces. This trend still remains unchanged and is also reflected in the overall geographical distribution of subsistence fishers, of which approximately 70% live and fish in eastern South Africa (see Table 1).

**Table 1.** Breakdown of the number of households and subsistence fishers in eight coastal regions in South Africa and the number of ocean fishers vs. estuarine fishers in percentage for the early 2000s. Sourced/modified from Clark *et al.* 2002.

Region	Households	Subsistence fishers	Fishers in ocean	Fishers in estuaries
Namibia border to Olifants River	411	458	320 (70%)	138 (30%)
Olifants River up to and including Hout Bay	675	643	630 (98%)	13 (2%)
Hout Bay to the Breede River	1,352	1,272	1,247 (98%)	25 (2%)
Breede River to the western boundary of Tsitsikamma National Park	1,269	1,424	712 (50%)	712 (50%)
The western boundary of Tsitsikamma National Park to Kei River	1,031	1,452	842 (58%)	610 (42%)
Kei River to Mtamvuna River	4,830	4,239	3,391 (80%)	848 (20%)
Mtamvuna River to Umvoti River	16,811	18,399	16,191 (88%)	2,208 (12%)
Umvoti River to Mocambique border	1,959	1,346	538 (40%)	808 (60%)
Total	28,338	29,233	23,871 (81.7%)	5,362 (18.3%)

It was assumed that subsistence fishers were and still are mainly non-white South Africans. In order to estimate historic participation in the subsistence sector, a ratio between total non-white population and subsistence fishers was calculated based on the 'anchor' point of 2002, for which 29,233 subsistence fishers were reported in South Africa (Clark *et al.* 2002). A time-series for the total non-white population was derived by linear interpolation between six data points of known statistical population data. The resulting ratio of 0.000713 subsistence fishers per non-white South African was applied to the estimates for total non-white population over the period 1950–2010. Additionally, the estimated total numbers of subsistence fishers were classified into two groups (estuarine and ocean fishers), as well as subdivided in accordance to their geographical distribution (Clark *et al.* 2002).

### Taxa targeted by subsistence fishers

There is a great variety of marine resources caught by subsistence fishers in South Africa. In general, there is an increasing trend in diversity of exploited organisms from the west to the east coast. This gradual increase is closely linked to biogeographic conditions and based on the fact that most subsistence fishers live in the eastern coastal regions (Cockcroft *et al.* 2002). The uneven regional distribution of marine resources is also reflected in the fact that approximately 95% of all commercial fishing activities in South Africa operate from the Western Cape (Hersoug 1998). This is related to the high biomass productivity of the Benguela ecosystem due to upwelling, making it one of the most productive ocean areas in the world (Cochrane *et al.* 2009). Subsequently, most jobs in the commercial fishing and processing industry are concentrated in the Western Cape. There is also still an extremely uneven distribution of resources between whites and blacks<sup>3</sup> in South Africa, especially in regards to the main commercial and industrial fishing resources (Branch *et al.* 2002b). The legacy of apartheid, the political neglect and the resulting marginalization of subsistence fishers in South Africa, as well as specific socioeconomic and biogeographical factors, affected the state of resource use by subsistence fishers. It was assumed that the subsistence resource use was fairly similar throughout the study period, but that individual catch rates varied over time due to several reasons. Technological advances in fishing gear may have enabled fishers to fish more efficiently, as it has been shown in the case of the recreational fishing sector. Additionally, reported overfishing and collapsed stocks of several linefish species, rock lobsters and abalone would have had adverse effects on the resource availability of subsistence fishers (Cockcroft *et al.* 1999; Griffiths and Lamberth 2002).

Fish and various intertidal rocky-shore invertebrates are the most commonly targeted resources by subsistence fishers in South Africa. Various fish species are targeted both in estuaries and the open ocean (Branch *et al.* 2002b). The species composition varies along the coastline, but a general trend of increasing diversity of fish species from the west to the east coast is apparent (Branch *et al.* 2002b; Clark *et al.* 2002; Cockcroft *et al.* 2002). Mulletts (Mugilidae) were identified as the most commonly caught family along the entire South African coast. Additionally, grunts (*Pomadasys* spp.), rock cod (*Epinephelus* spp.), kob (*Argyrosomus* spp.) and elf (*Pomatomus saltatrix*) were identified as very important and commonly targeted fish species (Branch *et al.* 2002b). Table 2 summarizes the most important species and groups caught by subsistence fishers in South Africa in decreasing order of importance.

The group of rocky-shore invertebrates comprises mainly the mussel *Mytilus galloprovincialis* on the west coast and *Perna perna* on the east coast, as well as different species of oysters (*Striostrea margaritacea*, *Saccostrea cucullata*), octopus, winkles and limpets.

Other groups of marine organisms caught throughout South Africa — often used as bait — are sandy-beach invertebrates (e.g., worms and redbait) and estuarine invertebrates (e.g., sand and mud prawns *Callinassa*

**Table 2.** Most important fish species targeted by subsistence fishers in South Africa, listed in decreasing order of importance. Sourced/modified from Branch *et al.* 2002b.

Name	Taxonomic Name
Harders, mullet	<i>Liza</i> and <i>Mugil</i> spp.
Kob	<i>Argyrosomus</i> spp.
Elf	<i>Pomatomus saltatrix</i>
Grunters	<i>Pomadasys</i> spp.
Rock cod	<i>Epinephelus</i> spp.
Galjoen	<i>Dichistius capensis</i>
Stumpnose	<i>Rhaphidosargus</i> spp.
Bronze bream	<i>Pachymetopon</i> spp.
Steenbras	<i>Lithognathus lithognathus</i>
Hottentot	<i>Pachymetopon blochii</i>
River bream	<i>Acanthopagrus berda</i>
Roman	<i>Chrysolephus laticeps</i>
Yellowtail	<i>Seriola lalandii</i>
Leervis	<i>Lichia amia</i>
Blacktail	<i>Diplodus sargus capensis</i>
Musselcracker	<i>Sparodon durbanensis</i>
Snoek	<i>Thyrskites atun</i>
Geelbek	<i>Atractoscion aequidens</i>
Strepies	<i>Sarpa salpa</i>

<sup>3</sup> 'Black' includes groups and people that were identified as 'African', 'Indian' or 'Coloured' during the apartheid regime in South Africa. Contrary to usage in other parts of the world, in South Africa the term 'Coloured' does not refer to [black] people only.

*kraussi*, *Upogebia africana*; Branch *et al.* 2002b; Clark *et al.* 2002). Furthermore, some high value species are also targeted by subsistence fishers. West and East Coast rock lobsters are caught by subsistence fishers, mainly to generate much needed income, rather than for personal consumption. Abalone is a less frequently caught marine resource (Branch *et al.* 2002b; Clark *et al.* 2002). Table 3 summarizes the most important marine resources in decreasing importance, based on interviews and scientific studies (Branch *et al.* 2002b).

### Catch rates for the subsistence sector

Most scientific studies about subsistence fisheries in South Africa focused on socioeconomic issues, but neither adequately quantified relevant catches, nor explicitly mentioned individual catch rates for various marine organisms (Branch 2002; Branch *et al.* 2002a,b; Clark *et al.* 2002; Cockcroft *et al.* 2002; Harris *et al.* 2002a,b; Hauck *et al.* 2002). Due to the lack of sufficient catch information, it was difficult to derive estimates for catch rates and subsequently for total catches for the purpose of this report. Despite the insufficient data on a nationwide scale, there were some individual studies on local catch rates and annual catch estimates for some regions (Steyn *et al.* 200; Napier *et al.* 2009). These studies provided information about catch rates for some main subsistence marine resources, such as fish, sand and mud prawns, and rock lobster. Individual catch rates were applied on a nationwide scale in order to extrapolate total annual catches for the subsistence sector for the period 1950–2010.

Napier *et al.* (2009) identified annual subsistence catch rates for mud prawns and fish in the Knysna estuary in South Africa in 2004. Approximately 230 part- and full-time subsistence fishers caught an annual amount of 600,000 mud prawns, 5,000–7,500 spotted grunters, 5,000–7,500 white steenbras (*Lithognathus lithognathus*) and approximately 36,000 cape stumpnose (*Rhabdosargus holubi*), as well as more than 13,000 other bait organisms such as worms, shrimp and sand prawns. An average annual catch rate per fisher was derived by applying specific average weights for fish and mud prawns. Based on an average wet weight for *U. africana* of 4.83 grams, the total annual catch was estimated at 2.898 t·fisher<sup>-1</sup> for fish and 0.0126 t·fisher<sup>-1</sup> for mud prawns in 2004 (Richardson *et al.* 2000). Based on a weight/length regression for cape stumpnose (Van der Elst and Adkin 1991) and an average size of 15–20 cm (Napier *et al.* 2009), an average weight of 0.135 grams per fish resulted in a total annual catch of 4.86 tonnes of cape stumpnose. A total annual catch estimate for white steenbras and spotted grunters was derived by applying an average weight of 2 kg per fish, based on a conservative assumption and taking into account that many undersized and juvenile fish are caught and retained by subsistence fishers in general, especially in estuaries (Griffiths and Lamberth 2002; Whibley 2003). It was assumed that 6,000 individuals of each of these species were removed by subsistence fishers, resulting in a total annual catch of approximately 24 tonnes. In total, approximately 28.86 tonnes of fish were thought to have been caught by 230 subsistence fishers in 2004 in the Knysna estuary. Hence, an annual average catch rate of 0.125 t·fisher<sup>-1</sup>·year<sup>-1</sup> of fish and 0.0126 t·fisher<sup>-1</sup>·year<sup>-1</sup> of mud prawns was estimated in 2004.

Based on the current overexploited or collapsed state of many fish species in South Africa, historical catch rates for fish were assumed 25% higher for the period 1950–1960, reflecting a more pristine stock biomass (Griffiths and Branch 1997; Griffiths 1997a,b, 2000; Griffiths and Lamberth 2002). Technological advances in regards to fishing gear did not have a significant influence on catch rates, as it has been reported for the recreational sector, since subsistence fishers mainly used low technology gear and continue to do so (Schoeman 196; Branch *et al.* 2002b; Napier *et al.* 2009). From the 1960s onwards, catch rates were assumed to have been declining to current levels. The assumption of declining catch rates matched reported decreasing internal per capita fish consumption in South Africa, which has been declining since the 1970s (9.7 kg in 1970; 9.4 kg in 1980s; 8.2 kg in the 1990s; 7.6 kg in 2002; and 7.23 kg in 2003; Crosoer *et al.* 2006). Catch rates for mud prawns have been kept constant over this period. Catch rates for subsistence fishers operating in the ocean were indirectly derived from estuary subsistence catch rates. Based on the assumption that estuaries function as nursery areas and fishers would generally catch bigger fish in the ocean, catch rates were assumed 15% higher than estuarine catch rates in any given year (Whitfield 1994). Individual catch rates for the period 1950–2010 were then applied to the number of subsistence fishers in order to derive total annual catch estimates.

Due to insufficient subsistence catch information for rock lobster, abalone and oysters, as well as for other subsistence marine resources, no total catch estimates could be derived at this point. Further research should be undertaken in order to quantify respective catches.

### South African industrial catch taken from Namibian waters

Namibia was occupied by South Africa from 1915–1990, and South African fleets, amongst a large number of other distant-water fishing fleets fished in Namibian waters until the Declaration of Independence and subsequently the declaration of the Namibian 200-mile EEZ in 1990 (Lees 1969; van Zyl n.d.). South African flagged vessel catches taken from Namibian waters are therefore represented in FAO catch information for South Africa for the period 1950–1990.

**Table 3.** Most commonly caught marine resources by subsistence fishers in South Africa, listed in decreasing order of importance. Source modified from Branch *et al.* 2002b; Clark *et al.* 2002; Cockcroft *et al.* 2002.

Resources	Taxon
Fish	Different species (see Table 3)
Mussels	<i>Mytilus galloprovincialis</i> (West Coast) <i>Perna perna</i> (South/East Coast)
Octopus	<i>Octopus vulgaris</i>
Rock lobster	<i>Jasus lalandii</i> (West Coast) <i>Panulirus homarus</i> (South/East Coast)
Redbait	<i>Pyura stolonifera</i>
Worms	Nereids, eunicids, sabellarids, etc.
Abalone	<i>Haliotis midae</i>
Oysters	<i>Striostrea margaritacea</i> (South Coast) <i>Saccostrea cucullata</i> (East Coast)
Squid	<i>Loligo vulgaris reynaudii</i>
Crabs	<i>Sesarma meinerti</i> , <i>Scylla serrata</i> <i>Ocypode</i> spp.
Other misc. marine organisms	various

We identified South African catches taken in what we deemed Namibian waters through a comparison with 'national' data from Namibia for the 1950–1990 period (Belhabib *et al.* 2015), and relabelled these quantities as landings by South African vessels from Namibian waters. We focused on species that contributed most to South African landings — these were South African anchovy, South African pilchard, Cape Hake, Cape horse mackerel, and Cape rock lobster, which together made up almost 87% of total landings. Quantities of these species were analyzed in two time-periods, from 1950–1990, and 1991–2010. We assumed those species that showed a large decline in landed quantity after 1990 were likely those that were being caught in Namibian waters. Of the identified species, South African anchovy, South African pilchard, Cape rock lobster, and Cape horse mackerel declined by 40%, 80%, 83%, and 50%, respectively, between the two periods, while Cape hake catches remained relatively stable. We then cross-referenced these species with Namibian catch statistics that were attributed to South Africa (see Belhabib *et al.* 2015). Of the foreign fleets that exploited Namibia's fisheries prior to 1990, the former Soviet Union and Spain caught the majority of fish off the Namibian coast, while South Africa's share was 10–12% (Belhabib *et al.* 2015). Of the five identified species, data for Cape rock lobster, South African pilchard, and South African anchovy caught in Namibia by South African vessels were directly available. Catch data for Cape horse mackerel and Cape hake taken by foreign fleets in Namibia were not broken down by country, therefore, we allocated 10% as being from South Africa. To adjust South African landings from South African waters, we subtracted Namibia-sourced catches from South African landings; this yielded the amount of domestically caught fish (i.e., from within South African waters).

### *Discards*

As for most countries in the world, South African reported data do not account for fish that are caught but discarded at sea (Attwood *et al.* 2011). Estimated discard rates of South African trawlers range from an overall rate of 4.1% (Kelleher 2005) to 31% for south coast trawlers (Japp 1997), and 19% and 5% for sole and hake trawlers, respectively (Walmsley *et al.* 2007), while another observer-based study estimated a discard rate of about 16% for the inshore fleet (Attwood *et al.* 2011). We omitted the high discard rate of 31% and rather used a conservative average discard rate of 7% to estimate the quantity of discarded fish. South Africa's trawl fishery dates back to the 1880s when it was concentrated in inshore areas before substantial offshore expansion beginning in the 1950s (Sink *et al.* 2012). Thus, we accounted for discards from 1950 to 2010.

### *Illegal fishing*

Illegal fishing (poaching) has been implicated for declines in some of South Africa's fisheries, most notably the abalone, lobster and linefish fisheries (DAFF 2012). The Department of Agriculture, Forestry and Fisheries (DAFF) accounts for illegal fishing by adding on an amount to national landing statistics of some fisheries. For example, since 1990, 500 t·year<sup>-1</sup> has been added to total landed West Coast lobster in South Africa's national fisheries statistics (DAFF 2012). This amount is not reflected in FAO statistics, but is added in this reconstruction. The extensive black market trade in abalone has been well documented, and illegal abalone catch estimates exist starting from 1980 (Raemaekers *et al.* 2011). We visually approximated the proportion of illegal catch to national legal landings from a bar graph (Raemaekers *et al.* 2011) for the period 1980 to 2000. From 1980 to 1991 illegal catch was relatively stable at 10% of national legal landings, then increased to an average of 50% until 2000. We applied these percentages to FAO landing statistics to estimate illegal abalone catch from 1980 to 2000. From 2001 to 2008 annual illegal catch of abalone averaged 2000 t (Raemaekers *et al.* 2011). Illegal activity in the linefish fishery is high but the level is unknown (DAFF 2012). To approximate the level of illegal linefish activity, we considered that: i) illegal abalone catch in the past decade has been up to 10 times the commercial catch in some years; ii) the amount of poached lobster estimated by (DAFF 2012) ranged between 16% and 33% of commercial catch; and iii) the linefish fishery encompasses subsistence, recreational, and small-scale commercial fishers (DAFF 2012), which are difficult to monitor. We remained on the conservative side and took the average lobster illegal catch percentage, i.e. 24%, and applied this to total linefish landings to estimate illegal catch in the linefish fishery starting from 1985, the year that the first management framework for South Africa's linefish fishery was introduced (DAFF 2012).

### *Fishing sector allocation*

Marine fisheries statistics reported to the FAO were allocated to the industrial sector from 1950 to 2010, with the exception of small-scale commercial species. So-called 'subsistence' catches in South Africa are either consumed, sold, or used as bait (Branch *et al.* 2002b), thus, these fisheries have an artisanal (i.e., small-scale commercial) component. A comprehensive socioeconomic survey found that 84% of fishing households identified themselves as being 'subsistence', i.e. fishing primarily for household consumption, while the remainder fished to make a profit (Branch *et al.* 2002b). Thus, we allocated 84% of the reconstructed subsistence catch to the true 'subsistence' sector as defined here, and 16% to the 'artisanal' sector in 2000, and maintained these values to 2010. We assumed that subsistence fishing in 1950 was close to 100% and linearly increased this percentage to the anchor point in 2000.

Small-scale commercial species were allocated to the artisanal sector. West Coast/Cape rock lobster was caught primarily with hoop nets prior to the 1960s, before motorized boats and traps came into use (DAFF 2012). Therefore, we allocated lobster catches to the artisanal sector from 1950 to 1960, and thereafter to the industrial sector. The domestic jigging fishery for squid began in 1984 (DAFF 2012). We allocated Cape Hope squid catches from 1984 to 2010 to the artisanal sector and all other squid catches to the industrial (trawl) fishery. A small amount of Cape hakes are taken by the small-scale commercial longline and handline sectors. Based on annual catch statistics of

Cape hakes kept by the DAFF (2012), we estimated that from 1986 onwards approximately 3–5% of total hake catches were taken by handlines and/or longlines, and allocated this portion to the artisanal sector. Abalone catches were also allocated to the artisanal sector, as were fish species identified as belonging to the linefish fishery (Mann 2013; Table 4).

### Species composition

The composition of industrial catches was based on that of reported fish landings. Recreational fish catch was broken down according to the percentage contribution of species listed in Appendix Table A1. The composition of discards was based on the top 10 species from observer records from South Africa's trawl fishery (Attwood *et al.* 2011). Reconstructed total subsistence catch had two components, fish and mud prawn. The subsistence fish component was made up of seven major taxa (Table 5), of which Mugilidae was the most commonly caught fish group, while Sciaenidae, Pomatomidae, Haemulidae, and *Epinephelus* spp. were also very important and commonly targeted fish species by so-called 'subsistence' fishers (Branch *et al.* 2002b). Based on this qualitative assessment, we assigned highest weighting to Mugilidae, followed by equal medium weightings for Sciaenidae, Pomatomidae, Haemulidae, and rock cod, and finally equal and lowest weighting to the remaining two taxa, Dichistidae and Sparidae. Besides fish, bivalves, cephalopods, and prawns are also commonly targeted species (Branch *et al.* 2002b). Eighty-one percent of sampled fishing households from a socio-economic survey reported catching fish, and those catching rocky shore invertebrates ranged from 6% for urchins to 58% for mussels (Branch *et al.* 2002b). Surveyed households caught fish for commercial intent, whereas invertebrates were used mainly for consumption (Branch *et al.* 2002b). Given the importance of fish as a source of income and the high proportion of households that caught fish, we assumed that fish comprised the bulk (85%) of the so-called 'subsistence' catches, and the remaining 15% was equally distributed between bivalves and cephalopods.

## RESULTS AND DISCUSSION

After accounting for South African catches taken in Namibian waters, reconstructed total catches taken by South Africa in South African waters increased from 340,000 t in 1950 to 2.3 million t in 1968, and have been around 770,000 t·year<sup>-1</sup> in the 2000s (Figure 2). Unreported catches made up 77.3% of total reconstructed catches in the Western Indian Ocean (FAO area 51; Figure 2A), but only 6.9% in the Southeast Atlantic (FAO area 47; Figure 2B). Of the 153,000 t of unreported subsistence catch primarily intended for household consumption, almost two thirds were taken from the Western Indian Ocean. The taxonomic composition in the two oceans was also very different, with a high diversity in the Indian Ocean (e.g., Sparidae, Sciaenidae, Haemulidae, Mugilidae; Figure 3A), and an overwhelming small pelagic component in the Atlantic (Figure 3).

Due to lack of data, we only started accounting for illegal catches in 1980, the earliest year for which we could find any hard evidence. Illegal catches estimated in this reconstruction thus likely represent an underestimate of the true level of poaching in South African waters.

Discards by the industrial sector totalled 3.6 million t from 1950 to 2010, with only 100 t attributed to the Western Indian Ocean.

Industrial catch statistics reported to the FAO included catches taken by South Africa in what we considered Namibian waters, which accounted for around 24% of all reported South African catches in FAO area 47 from 1950–1990, with highest discrepancy occurring between 1968 and 1970, when approximately 41% of South African reported landings were likely sourced from Namibian waters. South African pilchard made up the bulk of catches from Namibian waters (72%), followed by South African anchovy (21%).

Small pelagic taxa targeted by industrial fleets in western South Africa's EEZ comprised well over half of the country's marine catches in this area, with South African pilchard and anchovy accounting for 36% and 26% of reconstructed total catches, respectively. The artisanal, subsistence and recreational fisheries were more diverse, with many taxa of small pelagics (e.g., *Scomber japonicus*; 34%) and demersal species making up the catch.

### Recreational catches

The total number of recreational fishers in South Africa increased substantially over the 1950–2010 time-period. In 1950, the total estimated number of recreational fishers was more than 225,000 actively targeting marine organisms on a regular basis in various subsectors. This represented roughly 1.65% of the total population. The biggest sector in terms of participants in the past was shore- and rock-based angling with more than 160,000 participants. This is not

**Table 4.** Species allocated to the linefish fishery.

FAO name	FAO name
Albacore	Red steenbras
Bigeye tuna	Sargo breams nei
Black marlin	Sea catfishes nei
Blue shark	Shortfin mako
Bluefish	Skipjack tuna
Broadnose sevengill shark	Smooth-hound
Canary drum (=Baardman)	Snoek
Cape elephantfish	Southern meagre (=Mulloway)
Chub mackerel	Swordfish
Common dolphinfish	Tope shark
Copper shark	Tuna-like fishes nei
Daggerhead breams nei	White steenbras
Dusky shark	White stumpnose
Geelbek croaker	Yellowfin tuna
Hector's lanternfish	Yellowtail amberjack
Panga seabream	-

**Table 5.** Composition of subsistence fish catch.<sup>a</sup>

Species	Percentage
Mugilidae	21.3
Sciaenidae	12.8
Pomatomidae	12.8
Haemulidae	12.8
<i>Epinephelus</i> spp.	12.8
Dichistidae	6.4
Sparidae	6.4

<sup>a</sup> Derived from Branch *et al.* (2000)

surprising, given that this type of fishing would have required less technological expertise and equipment than for the relatively small boat-based sector, with an estimated 4,000 participants in 1950. Spearfishing was only practiced by very few recreational divers at that time, but the number steadily increased at a rate of 6% per year, and in 2010 it was estimated that there were 16,000 recreational spearfishers operating throughout South Africa. The second biggest sector was, and still is, estuarine fisheries with nearly 30,000 fishers in 1950 and almost 100,000 estimated recreational estuary anglers today.

Participation in abalone and West Coast rock lobster fisheries was relatively low in 1950 with 9,000 and 19,000 fishers, respectively. Both sectors experienced peak participation in the 1990s. The abalone sector was shut down in 2003 which slowed down the overall rate of increase in total number of fishers.

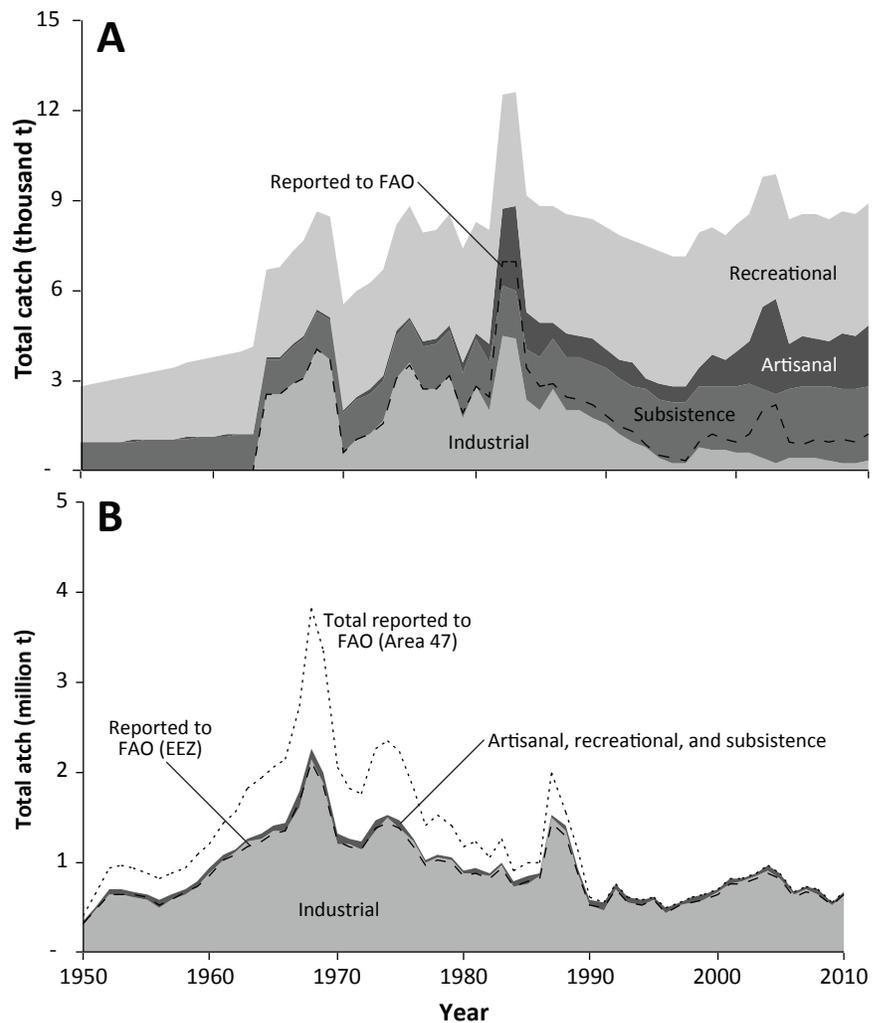
It is estimated that there were approximately 250,000 recreational fishers in South Africa in the early 1960s (Schoeman 1962). This estimate, which is mostly based on fishing club membership data, supports our estimates suggesting a total of 280,000 recreational fishers among all sectors for the same period.

We found that in the mid-1990s there were nearly 600,000 recreational fishers, which seems to be an underestimate compared to government appraisals at more than 750,000 marine recreational fishers for the same period (Anon. 1997). Furthermore, government information reported on one million individual participants in 2010 (Anon. 2010b), whereas our estimates suggest a more conservative number of 700,000. Our estimates suggest that approximately 1.5% of the total population of South Africa participate in recreational fishery activities of various kinds. Griffith and Lamberth (2002) suggest that approximately 0.5% of South Africans engage in recreational linefishing only. In other countries, recreational fishing seems to be more popular. The average participation in Europe is estimated at 4.7% of the total population. In Germany, roughly 2.1% of the total population are fishing recreationally in freshwater only, whereas in some northern European countries such as Norway, participation reaches up to 50% (Toivonen 2002). In Australia, estimates vary from 4% to 26% (Kearney 2002; Lyle *et al.* 2002). Hence, our estimates for South Africa appear to be realistic and may even be an underestimate due to conservative assumptions.

The actual number of recreational fishers is difficult to obtain and official government estimations vary greatly and lack comprehensible statements and references. For the purpose of deriving long-term estimates and growth trends for the period 1950–2010, more conservative choices were made. Furthermore, there is a certain degree of overlap between the individual sectors. For instance, it is impossible to distinguish between recreational fishers who fish from the shore on a regular basis, but sometimes also participate in boat-based recreational fishery activity. The exclusive categorization of fishers is impossible to attain and therefore conservative choices are more sensible and consequently more meaningful if it comes to reconstructing catches landed in the past.

Estimated recreational catches for the shore- and rock-based sector totalled approximately 157,000 t over the 1950–2010 period. Estimated at roughly 1,500 t in 1950, the annual total catches increased due to growing participation and catch rates, and peaked in 1995 at 3,040 t. Since 1996, a decreasing trend in annual catches is noticeable, mainly due to diminishing individual catch rates.

Estimated recreational catches for the boat-based sector totalled approximately 68,000 t for the 1950–2010 period. While the catches totalled 658 t in 1950, they peaked in the early 1990s at 1,283 t. It is estimated that even with continuously increasing number of participants over the entire period, landings were relatively stable at approximately 1,200 t·year<sup>-1</sup>, due to decreasing individual catch rates. As stated earlier, many linefish species targeted by recreational boat fishers are heavily overexploited and some stocks have even collapsed. Many of those species are also targeted by the commercial linefish sector and direct user conflict and competition is reported in the literature



**Figure 2.** Reconstructed catch by sector in A) the Indian Ocean and B) the Atlantic Ocean, 1950–2010. See Appendix Table A2 for details.

(Griffiths and Lamberth 2002). This recreational sector has the highest per fisher catch rate, estimated at 75 kg·fisher<sup>-1</sup>·year<sup>-1</sup> in 2010. The precarious stock conditions of some main targeted species raises concerns for the future of this specific sector.

The total spearfishing catches for the 1950–2010 period was estimated at 8,440 t. In 1950, annual catches were very small due to the fact that spearfishing was not commonly practiced in South Africa. Increasing availability of equipment (e.g., masks and spear guns) resulted in a sharp increase in the number of participants and an estimated 38-fold increase in annual catches between 1950 and 2010, estimated at around 14 t and 503 t, respectively. The time series shows a nearly exponential growth trend of annual spearfishing catches.

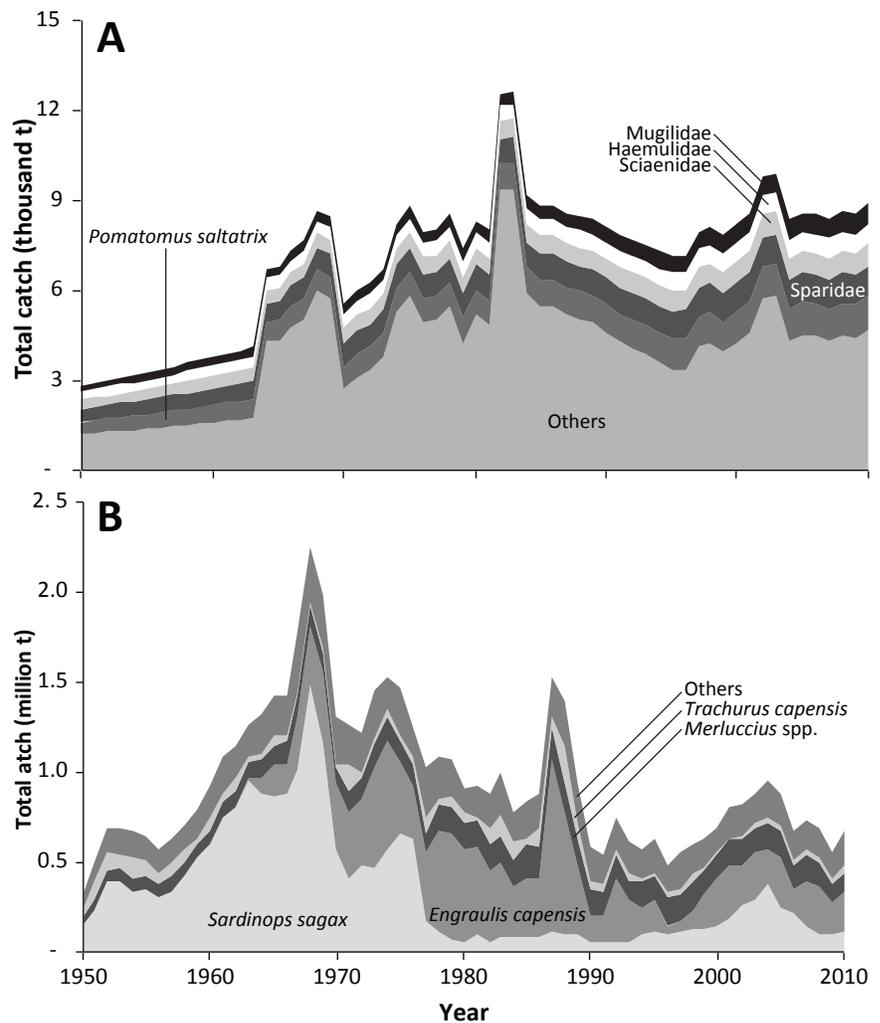
Estimated recreational catches for the estuary sector totalled approximately 57,000 t over the 1950–2010 period, making this the third most important recreational sector in terms of landed tonnage. In 1950, an estimated 29,000 fishers landed around 550 t of fish. Total catches peaked in 1995 at 1,070 t and decreased slightly to an estimated 1,000 t in 2010.

The total estimated recreational catch for abalone was approximately 12,100 t of whole weight for the period 1950 to 2003. Recreational catches were estimated at around 120 t in 1950. Total annual catches increased steadily with rising rates of participation, peaking in 1994 at 540 t. The sharp decrease of catches in 1997–1998 was a result of declining effort because a moratorium was placed on the sale of recreational permits in order to allocate catch quotas to subsistence fishers in line with the implementation of the new Marine Living Resources Act 18 (MLRA) in 1998; the new post-apartheid regulation scheme regarding marine management (Cockcroft *et al.* 1999). Downward adjustments with respect to permits sold to compensate for over exploitation since 2000, exacerbated by illegal harvesting, ended in the closure of the recreational abalone sector in 2003. Illegal activity continues to thrive and puts additional pressure on the already heavily exploited resource.

Estimated recreational catches of lobster totalled approximately 13,300 t over the 1950–2010 period. Starting off at around 100 t·year<sup>-1</sup> in the 1950s, catches increased steadily until the 1990s. Catches fluctuated in the 1990s, peaking at nearly 600 t in the 2002–2003 season. The increase in catches in the mid-1990s is related to the decrease of the legal minimum size for recreationally-caught lobster, as well as an increased season length in that period (Cockcroft *et al.* 1999).

The total retained catch for the charter boat sector was estimated at 14,700 t over the 1950–2010 period. In 1950, catches were estimated to be very low (35 t), accounting for its recent introduction and assumed slow evolution. Technological advances in tackle and gear and greater availability of boats since the end of World War II are reflected in the expansion of the industry and continuous increase of annual catches. Due to the lack of sufficient data and information, reconstructed catches for this sector may underlie the highest degree of uncertainty. Furthermore, estimating retained catches exclusively may under represent actual mortality in this sector. Post-release mortality and severe impairments of released fish due to barotrauma-induced stress is believed to be very high (Bartholomew and Bohnsack 2005; Gravel and Cooke 2008). It is estimated that approximately 37% of the total catch in this sector in Natal is released, with the remaining 63% retained (Pradervand and Van der Elst 2008). The reasons for releasing catch are varied, including unwanted species, undersized or protected fish or the general underlying catch-and-release policy, which is common in this industry with respect to sharks, sailfish and swordfish. Therefore, the reconstructed catch estimates are conservative and if also accounting for mortality of released catch, estimates would likely be much higher.

Estimated recreational catches for all sectors totalled approximately 332,000 t over the 1950–2010 period. In 1950, catches totalled just under 3,000 t, increasing rapidly to 5,400 t in 1970. The overall reduction in catch rates due



**Figure 3.** Reconstructed catch by taxon in A) the Indian Ocean and B) the Atlantic Ocean, 1950–2010. See Appendix Table A3 for details.

to overfishing is reflected in the decreased growth rate of total catches from 1970 onwards. Total catches peaked in 1997 at nearly 7,000 t and decreased to an estimated 6,300 t in 2010. This decrease is mainly due to the closure of the abalone sector in 2003 and the decreased effort for West Coast rock lobster. Based on increasing participation and overall population growth, catches are likely to continue to increase.

In comparison to the landings of several hundred thousand tonnes each year by the commercial fishing fleet in South Africa, the reconstructed catch estimates for the recreational sector seem to be negligible in terms of weight. For most years, this amount represented less than 1% of the overall industrial landings. So far, these catches are not reported to the FAO and therefore not represented in official reports. Nevertheless, with regards to the overall sustainability of the marine ecosystems and its productivity, these catches play an important role. Bearing in mind that many endemic fish species are fully or nearly fully exploited, severely overexploited or have even collapsed, the influence and effects of recreational fishing becomes apparent. According to Griffiths and Lamberth (2002), recreational fishers are directly responsible for the depletion of many species. Additionally, for some user groups such as subsistence and artisanal fishers, who rely on fish for monetary income and as their primary source of protein, decreased availability of marine resources threatens their livelihood and food security.

The estimated catches in this report may be under reported due to various facts. As a result of the multi-sector nature of this industry, smaller categories such as the east coast rock lobster fisheries were excluded. Additionally, individual effort and catch rates were solely based on diurnal fishing activity in all sectors. Night fishing, which is commonly practiced in South Africa, was excluded in all scientific studies used and therefore not represented in this report. Furthermore, rather conservative choices for catch rate trends and number of recreational fishers were made.

### *Subsistence catches*

The total number of subsistence fishers in South Africa was estimated at around 7,800 in 1950, and increased to about 32,700 by 2010. Based on the information for the early 2000s, it was assumed that approximately 82% of the total number of fishers operated in the open ocean, whereas the remaining 18% fished in estuaries only (Clark *et al.* 2002).

Due to the lack of further information about historic numbers of subsistence fishers, estimates were solely based on data for the year 2002 (Clark *et al.* 2002). By applying a constant ratio of subsistence fishers per single non-white South African over the period 1950–2010, the resulting trend corresponds to the increasing population development and may underestimate socioeconomic circumstances in regards to food supply during apartheid. During the 1960s, many black South Africans were restricted to regions in the eastern part of South Africa, such as Transkei, Ciskei and Kwa-Zulu Natal. The subsequent high population density and competition for resources in those areas forced many people to go fishing for their daily protein supply (Clark *et al.* 2002). It is very likely that the actual number of subsistence fishers was higher during apartheid due to the lack of alternative food and income sources. Therefore, the estimated number of fishers used here is based on conservative assumptions.

Reconstructed fish catches for the subsistence fisheries sector in South Africa totalled approximately 153,000 t for the period 1950–2010. The majority of the catches were taken in the eastern provinces where most subsistence activity took place. Therefore, approximately 65% of reconstructed subsistence catches were taken in FAO area 51. Total annual catches steadily increased over the period, from approximately 1,400 t in 1950 to an estimated 4,600 t in 2010. Despite assumed declines in individual catch rates and per capita consumption rates for fish, partly linked to overexploitation and unsustainable catches, total annual subsistence fish catches increased over time.

Due to the lack of information and catch data on other marine subsistence resources, no estimates could be derived for the respective subsectors. Reconstructed total subsistence catches are likely to be underestimated (likely substantially) due to various reasons. Firstly, not all targeted organisms were included in the reconstruction process. Secondly, individual catch rates were likely underestimates since they were based on conservative assumptions.

Despite the rather small amount of total subsistence catches in comparison to commercial catches for South Africa, subsistence fishing plays a crucial role for many households and communities alongside the South African coastline, generating much needed income, as well as providing a daily source of protein for thousands of people. Thus, subsistence fishing (including artisanal) is fundamental for domestic food security purposes. The subsistence fishery is worth many millions of USD per year, with some full-time fishers earning at least USD 1,500 per year from estuarine fishing and bait-collecting activity (Napier *et al.* 2009). In general, subsistence fisheries play an integral role in the livelihood and socioeconomic stability for subsistence fishers. Poverty levels are high among subsistence fishing households, education levels are low and unemployment is widespread (Branch *et al.* 2002b). These factors decrease food security and emphasize the importance of subsistence fishing activities and the availability of marine resources in alleviating poverty.

Despite the high degree of dependence on marine resources by fishers and their families (Clark *et al.* 2002), policies and laws were focused primarily on recreational and the export-oriented commercial fisheries sectors, systematically neglecting the needs of subsistence fishers until the promulgation of the MLRA in 1998.

Subsistence fishers directly compete with the recreational and artisanal sectors for various marine resources. Many fish species, some targeted by recreational and artisanal as well as subsistence fishers, are severely overexploited in South Africa (Griffiths 2000; Branch *et al.* 2002a; Griffiths and Lamberth 2002). Subsistence fishers are known to retain undersized fish due to lack of compliance with, and enforcement of existing rules indicating general problems due to unsustainable catch methods (Griffiths and Lamberth 2002). Illegal fishing activity and poaching is common, especially for high value resources (Hauck and Sweijd 1999; Harris *et al.* 2002b).

## CONCLUSIONS

This reconstruction focused on quantifying catches from the recreational and small-scale (i.e., subsistence and artisanal) sectors that are not included in the officially reported catch data of South Africa (primarily industrial catches only). In comparison to industrial catches reported to the FAO, the reconstructed catches for the recreational and the subsistence fisheries sector in South Africa do not appear to be significant in terms of tonnage, amounting to less than 1% of the annual total commercial landings in most given year. The importance of these two fisheries becomes more apparent when catches of the eastern and western coasts are viewed separately. Then, the recreational and subsistence sectors along the eastern coast (i.e., the Western Indian Ocean; FAO area 51) combine to make up 73% of reconstructed total catches (see Figure 2 and Appendix Table A2).

Poor compliance and inadequate management measures for recreational fisheries sectors have led to overfishing of many species. This report shows the actual extent of annual catches and emphasizes the necessity for further research in regards to modeling the ecosystem effects of recreational fishery in South Africa; and the need for a more complex management approach geared towards the sustainable use of marine resources, to meet the requirements of this diverse fishing sector.

The legacy of apartheid and the marginalization of the subsistence fishery sector in South Africa, in terms of political neglect, constitute a threat to the livelihood of subsistence fishers and their families. The catch reconstruction for this sector has given an indication of the likely extent of catches. For this report, catches of some subsectors could not be quantified due to the lack of data and information. Therefore, the catch estimates derived are conservative. More scientific research should be undertaken in order to improve and continuously update catch information in order to optimize management approaches that guarantee a sustainable resource use and allow a harvest of marine organisms, so that the livelihood of thousands of people in South Africa can be preserved and can continue to function as a potential safety net that can be relied upon, especially in times of hardship. Of major importance would be the inclusion of annual subsistence, artisanal and recreational catch estimates in the officially reported catch data provided by South Africa to FAO and thus to the international community.

Given the overexploited state of many important marine resources in South Africa, it becomes apparent that there is no room for expansion (Griffiths and Branch 1997; Griffiths 1997a,b, 2000; Cockcroft *et al.* 1999; Hauck and Sweijd 1999; Griffiths and Lamberth 2002; Raemaekers and Britz 2009). Pressure on marine resources is likely to increase with population growth and may lead to further deterioration of stocks.

Many challenges remain in finding and applying appropriate management measures given the diverse nature of the fishery sectors in South Africa. This report was the first attempt to quantify formerly unreported subsistence, artisanal and recreational catches in South Africa. Further research and continuous updates should be undertaken in order to improve data, fill the gaps of knowledge, and facilitate appropriate natural resource management aimed at sustainable, efficient and equitable use of marine resources in South Africa.

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**Appendix Table A1.** Percentage of catch contribution (by mass) of the most important recreational species according to subsectors. Regions W = Western Cape, S = Southern Cape, E = Eastern Cape, T =Transkei, K = Kwa-Zulu Natal.

Subsector	Family	Taxon. Name	Common name	Region					
				W	S	E	T	K	S+E
Shore and rock angling	Dichistidae	<i>Dichistius capensis</i>	Galjoen	29.8	14	1.1	1		
	Haemulidae	<i>Pomadasys commersonni</i>	Spotted grunter		0.3	0.7	4.1	1.1	
		<i>P. olivaceum</i>	Piggy/Olive grunt		1.7	13	2.5	3.1	
	Mugilidae	<i>Liza richardsonii</i>	Harder/Mullet	9.5	1.6	5.8			
	Pomatomidae	<i>Pomatomus saltatrix</i>	Bluefish/Elf	0.1	52	22	19	25	
	Sciaenidae	<i>Argyrosomus inodorus</i>	Mild meager	1.7	4.6				
		<i>A. japonicus</i>	Dusky kob				2.9	3.5	1
		<i>Umbrina spp.</i>	Baardman		1.4	0.2			
	Scorpidae	<i>Neoscorpis lithophilus</i>	Stonebreem			1.6	15	4.3	
	Sparidae	<i>Diplodus sargus</i>	Blacktail/Dassie	1	1.5	7.8	16	8.9	
		<i>Lithognathus lithognathus</i>	White steenbras	0.5	4.7	1.4	0.3		
		<i>Pachymetopon blochii</i>	Hottentot	12.5	0.6				
		<i>P. grande</i>	Bronze breem				4	13	0.1
		<i>Sarpa salpa</i>	Strepie	0.3	3.3	24	11	44	
		Misc. marine fish	Other	<45	<15	<17	15	<13	
	Boat-based angling	Carangidae	<i>Seriola lalandii</i>	Yellowtail amberjack	1.1	20			
		Gempylidae	<i>Thysites atun</i>	Snoek	58.4	21			
		Merlucciidae	<i>Merluccius capensis</i>	Cape hake	0.2	0.3	23		
		Pomatomidae	<i>Pomatomus saltatrix</i>	Spotted grunter	0.1	1.3	0.4		1.2
		Sciaenidae	<i>Argyrosomus inodorus</i>	Piggy/Olive grunt	0.1	7.3	18		
<i>A. japonicus</i>			Harder/Mullet					0.6	
		<i>Atractoscion aequidens</i>	Geelbeck croaker	0.1	9.1	13		3.3	
Scombridae		<i>Scomberomorus commerson</i>	Spanish mackerel					33	
		<i>S. plurilineatus</i>	Queen mackerel					2	
		<i>Thunnus alalunga</i>	Albacore tuna	28.4	0.3				
		<i>T. albacares</i>	Yellowfin tuna	0.7	0.4	10		19	
Sparidae		<i>Argyrosomus argyrosomus</i>	Carpenter	0.1	14	2.2			
		<i>Cheimerius nufar</i>	Santer seabream		0.2	3.2		2.4	
		<i>Chrysoblephus laticeps</i>	Roman seabream	0.1	1.7	2.5			
		<i>C. puniceus</i>	Slinger seabream	0.1				3.8	
		<i>Pachymetopon blochii</i>	Hottentot	3.8	3.5				
		Misc. marine fish	Other	<7	<22	<27	-	<35	
Estuary angling		Carangidae	<i>Lichia amia</i>	Leervis/Garrick		3.9	1.8		
		Haemulidae	<i>Pomadasys commersonni</i>	Spotted grunter		62	33		18
		Mugilidae	<i>Liza richardsonii</i>	Harder/Mullet	2	0.1			
	Pomatomidae	<i>Pomatomus saltatrix</i>	Bluefish/Elf	92.1	0.1	0.7		0.6	
	Sciaenidae	<i>Argyrosomus japonicus</i>	Dusky kob		7.8	51		64	
	Sparidae	<i>Diplodus sargus</i>	Blacktail/Dassie		0.7	0.1			
		<i>Lithognathus lithognathus</i>	White steenbras	0.7	14	2			
		<i>Sarpa salpa</i>	Strepie		0.6	0.1			
		<i>Sparodon durbanensis</i>	Musselcracker seabream		0.6	0.1			
		Misc. fish	Other	<6	<11	<12	-	<19	
Spearfishing	Carangidae	<i>Lichia amia</i>	Gerrick				4.7	0.6	
		<i>Seriola lalandii</i>	Yellowtail amberjack	4.3			0.3	1.9	
	Dichistidae	<i>Dichistius capensis</i>	Galjoen	6.1			0.3	6.7	
	Oplegnathidae	<i>Oplegnathus conwayi</i>	Cape knifejaw				3	15.4	
	Sciaenidae	<i>Argyrosomus inodorus</i>	Piggy/Olive grunt	0.1					
		<i>Umbrina spp.</i>	Baardman				3.8	4.8	
	Scombridae	<i>Scomberomorus commerson</i>	Spanish mackerel				17		
		<i>S. plurilineatus</i>	Queen mackerel				31		
	Sparidae	<i>Chrysoblephus laticeps</i>	Roman seabream	0.1				19.3	
		<i>Diplodus sargus</i>	Blacktail/Dassie	0.1				1	
		<i>Gymnacrotaphus curvidens</i>	Janbruin			11			
		<i>Pachymetopon blochii</i>	Hottentot	88.1				6.7	
		<i>P. grande</i>	Bronze seabream				9.8	6.7	
		<i>Sparodon durbanensis</i>	Musselcracker seabream				2.8	2.9	
		Misc. marine fish	Other	<2		-	<27	<24	
Charter boat	Coryphaenidae	<i>Choryphaena hippurus</i>	Dolphinfish				20		
	Scombridae	<i>Thunnus albacares</i>	Yellowfin tuna				14		
	Sparidae	<i>Chrysoblephus puniceus</i>	Slinger seabream				11		
	Misc. marine fish	Other	Other (reef fish, sharks, billfishes, tuna)			55			
Charter boat (by number)	Lethrinidae	<i>Lethrinus nebulosus</i>	Blue emperor				16		
	Sparidae	<i>Chrysoblephus puniceus</i>	Slinger seabream				34		
		<i>Cheimerius nufar</i>	Santer seabream				14		
		<i>Chrysoblephus anglicus</i>	Englishman seabream				11		
	Misc. marine fish	Other	Other (reef fish, sharks, billfishes, tuna)			25			

**Appendix Table A2.** Total reconstructed catch by sector and Ocean, 1950–2010.

Year	Indian Ocean					Atlantic Ocean							
	Reconstructed catch				Reported to FAO	Reconstructed catch				Reported to FAO in EEZ	Reported to FAO in Area 47		
	Artisanal	Industrial	Recreational	Subsistence		Total	Artisanal	Industrial	Recreational			Subsistence	Total
1950			1,923	902	2,825		44,200	291,906	1,035	486	337,627	316,600	390,745
1951	3		1,984	922	2,909		46,402	453,869	1,068	497	501,835	470,100	635,536
1952	6		2,047	942	2,995		50,803	638,202	1,102	507	690,615	646,700	930,681
1953	9		2,111	962	3,083		53,605	633,288	1,137	518	688,547	644,500	961,536
1954	13		2,177	981	3,171		52,707	618,240	1,172	528	672,647	629,500	932,728
1955	16		2,244	1,001	3,261		66,609	582,030	1,208	539	650,386	608,700	886,575
1956	20		2,313	1,024	3,358		69,611	499,260	1,246	551	570,668	533,700	805,056
1957	24		2,384	1,048	3,456		45,213	576,990	1,284	564	624,051	583,600	859,702
1958	28		2,458	1,071	3,557		55,915	647,495	1,324	577	705,310	659,601	938,346
1959	32		2,532	1,095	3,659		63,317	724,875	1,363	589	790,145	738,401	1,069,375
1960	37		2,608	1,118	3,764		57,320	859,996	1,405	602	919,322	858,901	1,205,081
1961	42		2,689	1,144	3,875		72,222	1,014,346	1,448	616	1,088,632	1,016,500	1,438,402
1962	47		2,768	1,169	3,984		40,625	1,101,335	1,491	629	1,144,080	1,068,201	1,548,330
1963	52		2,854	1,189	4,094		31,219	1,225,207	1,537	640	1,258,602	1,175,014	1,823,272
1964	57	2,500	2,937	1,209	6,703	2,500	68,461	1,243,461	1,582	651	1,314,154	1,226,607	1,921,861
1965	62	2,500	3,024	1,226	6,812	2,500	59,743	1,356,955	1,629	660	1,418,986	1,324,710	2,047,415
1966	67	2,900	3,111	1,244	7,322	2,900	74,928	1,350,315	1,675	670	1,427,589	1,332,693	2,147,477
1967	73	3,100	3,203	1,263	7,639	3,100	156,740	1,614,486	1,724	680	1,773,631	1,655,702	2,731,690
1968	78	4,000	3,295	1,283	8,656	4,000	106,843	2,145,285	1,774	691	2,254,593	2,104,802	3,835,787
1969	84	3,700	3,390	1,304	8,479	3,700	104,946	1,879,911	1,826	702	1,987,385	1,854,802	3,362,996
1970	91	601	3,493	1,325	5,509	601	105,850	1,195,133	1,881	713	1,303,576	1,217,203	2,042,557
1971	97	1,001	3,524	1,347	5,969	1,001	71,753	1,186,340	1,897	725	1,260,716	1,176,403	1,828,388
1972	104	1,201	3,554	1,370	6,229	1,201	81,311	1,139,034	1,914	738	1,222,997	1,141,657	1,771,351
1973	111	1,608	3,586	1,392	6,697	1,600	112,825	1,341,370	1,931	750	1,456,876	1,362,078	2,264,116
1974	118	3,081	3,614	1,417	8,229	3,073	44,415	1,481,383	1,946	763	1,528,507	1,426,265	2,346,088
1975	125	3,567	3,645	1,439	8,775	3,548	83,348	1,375,489	1,962	775	1,461,574	1,363,620	2,242,844
1976	133	2,690	3,674	1,461	7,957	2,690	16,985	1,227,073	1,978	787	1,246,823	1,163,256	1,829,868
1977	140	2,728	3,702	1,482	8,052	2,728	47,488	979,181	1,994	798	1,029,461	962,172	1,389,817
1978	148	3,149	3,731	1,506	8,534	3,144	24,319	1,054,273	2,009	811	1,081,411	1,009,268	1,524,649
1979	351	1,729	3,759	1,529	7,369	1,913	42,649	1,017,857	2,024	823	1,063,354	993,749	1,405,848
1980	165	2,811	3,787	1,555	8,318	2,778	28,375	880,392	2,039	837	911,643	850,870	1,168,972
1981	563	2,030	3,815	1,583	7,991	2,413	41,907	875,595	2,054	852	920,409	859,936	1,235,974
1982	2,609	4,502	3,843	1,614	12,568	6,927	35,541	835,043	2,070	869	873,522	815,513	1,063,203
1983	2,777	4,363	3,870	1,645	12,655	6,946	31,519	959,926	2,084	886	994,414	928,124	1,250,323
1984	1,256	2,352	3,898	1,677	9,182	3,398	39,992	739,721	2,099	903	782,715	730,946	898,610
1985	1,159	2,028	3,925	1,711	8,823	2,789	77,874	757,714	2,113	921	838,622	772,720	978,597
1986	480	2,680	3,951	1,743	8,853	2,884	42,928	834,578	2,127	939	880,572	816,943	986,203
1987	814	2,006	3,976	1,777	8,573	2,470	47,289	1,479,711	2,141	957	1,530,097	1,423,096	2,006,383
1988	694	1,973	4,004	1,807	8,479	2,331	58,101	1,335,258	2,156	973	1,396,488	1,297,941	1,565,957
1989	759	1,765	4,024	1,835	8,382	2,166	78,613	862,411	2,167	988	944,179	873,385	1,124,854
1990	625	1,569	4,065	1,862	8,121	1,853	65,446	509,490	2,189	1,002	578,127	531,908	601,364
1991	657	1,171	4,112	1,887	7,827	1,471	63,808	469,759	2,214	1,016	536,797	494,001	536,797
1992	745	906	4,091	1,915	7,657	1,267	47,960	694,751	2,203	1,031	745,946	690,241	745,946
1993	404	751	4,393	1,946	7,494	826	50,413	553,839	2,365	1,048	607,665	560,717	607,665
1994	505	371	4,417	1,976	7,269	517	46,308	516,206	2,379	1,064	565,957	522,130	565,957
1995	523	224	4,374	2,009	7,129	373	46,781	571,969	2,355	1,082	622,187	574,966	622,187
1996	525	210	4,397	2,041	7,173	349	44,230	429,395	2,368	1,099	477,091	439,540	477,091
1997	634	722	4,508	2,077	7,941	936	44,630	506,966	2,427	1,118	555,141	511,412	555,141
1998	1,093	666	4,237	2,113	8,110	1,238	56,466	543,702	2,282	1,138	603,587	555,947	603,587
1999	854	635	4,196	2,153	7,838	1,000	38,715	590,646	2,259	1,159	632,780	585,324	632,780
2000	1,100	621	4,250	2,192	8,162	986	34,411	653,513	2,288	1,181	691,393	640,000	691,393
2001	1,430	621	4,263	2,240	8,554	1,175	39,027	766,478	2,296	1,206	809,006	747,719	809,006
2002	2,714	430	4,349	2,276	9,769	2,046	41,460	779,631	2,342	1,226	824,658	763,482	824,658
2003	3,181	211	4,174	2,306	9,871	2,170	37,103	843,359	2,248	1,241	883,951	819,034	883,951
2004	1,486	387	4,124	2,336	8,332	898	47,521	905,059	2,220	1,258	956,058	885,717	956,058
2005	1,704	391	4,124	2,365	8,584	863	47,335	828,954	2,221	1,273	879,783	815,322	879,783
2006	1,643	384	4,111	2,397	8,534	1,073	33,759	629,668	2,213	1,291	666,931	616,174	666,931
2007	1,542	329	4,080	2,426	8,377	986	37,321	690,270	2,197	1,306	731,094	676,396	731,094
2008	1,830	266	4,076	2,456	8,628	1,065	38,879	652,332	2,195	1,322	694,728	642,107	694,728
2009	1,728	262	4,071	2,485	8,545	950	41,257	509,060	2,192	1,338	553,847	510,086	553,847
2010	1,993	282	4,066	2,547	8,888	1,206	41,906	632,256	2,190	1,371	677,723	625,828	677,723

**Appendix Table A3.** Total reconstructed catch by taxon and Ocean, 1950–2010.

Year	Indian Ocean						Atlantic Ocean							
	<i>Sparidae</i>	<i>Pomatomus saltatrix</i>	<i>Sciaenidae</i>	<i>Haemulidae</i>	<i>Mugilidae</i>	Others	<i>Sardinops sagax</i>	<i>Engraulis capensis</i>	<i>Merluccius spp.</i>	<i>Trachurus capensis</i>	<i>Etrumeus whiteheadi</i>	<i>Merluccius capensis</i>	<i>Scomber japonicus</i>	Others
1950	421	431	305	263	221	1,183	155,700	-	47,600	36,700	-	8,972	5,700	82,954
1951	435	444	314	271	227	1,219	226,600	-	59,200	101,900	-	13,878	6,000	94,258
1952	450	456	323	279	233	1,255	395,800	-	58,900	103,800	-	19,459	5,900	106,756
1953	464	469	332	286	239	1,293	399,300	-	61,900	85,900	-	19,498	12,200	109,749
1954	479	482	341	294	244	1,330	338,900	-	69,900	120,500	-	19,062	13,100	111,185
1955	494	496	350	302	250	1,369	349,100	-	74,100	80,700	-	18,368	26,500	101,618
1956	509	510	360	311	257	1,410	307,700	-	76,000	47,200	-	16,173	36,900	86,694
1957	525	525	371	319	264	1,452	335,000	-	80,800	85,600	-	17,751	11,400	93,500
1958	542	540	381	328	271	1,495	418,300	-	83,600	65,100	-	20,145	20,100	98,065
1959	559	555	392	337	278	1,538	531,500	-	69,500	22,100	-	22,896	33,100	111,049
1960	576	571	402	347	285	1,583	600,800	-	76,600	67,800	-	26,862	29,100	118,161
1961	594	587	414	356	293	1,631	744,700	-	95,000	46,100	-	32,221	52,300	118,311
1962	612	603	425	366	300	1,677	805,400	0	93,900	72,700	-	33,918	21,200	116,962
1963	630	620	437	376	307	1,725	947,600	23,300	90,700	26,700	-	37,436	13,400	119,466
1964	649	636	448	385	313	4,272	878,400	95,400	102,200	26,900	2,500	39,231	52,000	117,524
1965	668	653	459	395	319	4,319	868,900	178,300	99,600	57,800	2,100	42,299	39,500	130,487
1966	687	670	470	404	325	4,765	882,300	159,900	124,400	29,400	4,500	42,557	54,900	129,632
1967	707	688	483	414	332	5,016	1,005,100	297,500	118,700	12,000	12,700	53,123	138,900	135,607
1968	727	706	495	424	339	5,966	1,481,000	331,000	118,600	4,700	13,500	67,751	90,100	147,942
1969	748	724	508	435	346	5,718	1,159,700	397,400	104,300	31,700	14,300	59,805	92,800	127,380
1970	771	745	520	446	353	2,674	576,200	358,300	94,100	16,000	23,900	38,516	77,900	118,660
1971	780	752	526	451	360	3,101	412,900	367,000	111,400	150,300	23,700	37,554	54,600	103,262
1972	788	759	531	456	366	3,328	477,600	372,200	118,100	28,100	20,600	36,171	56,600	113,626
1973	796	766	537	462	373	3,763	470,300	558,200	133,000	21,200	30,000	42,347	58,800	143,029
1974	804	773	543	467	380	5,263	572,017	595,778	134,870	43,712	1,779	45,756	30,670	103,925
1975	812	780	549	472	386	5,776	659,395	400,949	113,083	29,901	29,628	43,769	69,344	115,505
1976	820	787	555	477	393	4,926	630,043	299,405	118,205	39,926	18,510	37,136	545	103,052
1977	828	793	560	482	399	4,990	173,957	376,913	101,583	97,886	35,979	29,634	21,336	192,173
1978	836	800	566	488	406	5,439	110,973	564,291	143,115	25,136	67,165	31,852	2,443	136,436
1979	844	807	572	493	413	4,242	65,188	587,693	153,294	62,146	14,095	30,670	11,139	139,129
1980	851	813	577	498	420	5,158	57,629	508,750	150,241	57,014	14,132	26,557	4,213	93,106
1981	860	820	584	504	428	4,795	91,254	492,970	143,905	22,284	24,301	26,404	10,943	108,348
1982	868	828	590	510	437	9,335	57,868	389,571	156,858	83,453	31,491	25,253	13,643	115,385
1983	876	835	597	516	446	9,385	79,189	424,011	137,619	126,906	69,662	29,049	13,271	114,707
1984	884	842	604	523	455	5,874	78,205	285,962	152,499	103,998	29,551	22,352	6,962	103,186
1985	893	850	610	529	464	5,477	85,475	323,239	183,228	36,237	42,461	22,860	6,818	138,304
1986	901	857	617	535	474	5,470	86,527	315,110	182,089	99,749	57,521	25,364	5,990	108,222
1987	909	864	624	542	483	5,152	106,841	969,401	168,918	61,042	34,820	44,887	6,990	137,198
1988	918	871	630	548	492	5,020	101,080	682,079	161,023	199,645	62,006	40,510	9,197	140,947
1989	927	877	636	553	500	4,890	101,461	372,916	153,484	83,828	44,363	26,180	22,278	139,669
1990	935	882	641	558	508	4,596	56,871	150,100	135,168	51,074	44,710	15,482	17,759	106,963
1991	944	887	647	563	516	4,270	52,011	150,560	136,484	35,564	33,484	14,266	16,783	97,644
1992	959	898	653	570	525	4,053	53,436	347,312	135,805	33,640	47,341	21,074	5,286	102,051
1993	973	909	660	576	535	3,840	50,702	235,606	108,336	35,429	56,329	16,801	5,854	98,608
1994	987	919	667	588	545	3,564	93,438	155,554	136,917	20,031	54,147	15,649	5,590	84,630
1995	1,005	934	683	594	555	3,358	115,205	170,308	137,742	10,262	76,858	17,334	5,799	88,679
1996	1,013	939	688	597	565	3,371	105,210	40,712	155,155	31,995	47,117	13,043	5,132	78,727
1997	1,021	944	693	609	576	4,098	116,995	60,095	141,076	31,206	92,209	15,417	9,968	88,175
1998	1,029	950	692	620	586	4,231	128,019	107,548	151,317	46,384	52,476	16,546	3,969	97,328
1999	1,038	956	699	621	598	3,926	131,316	180,542	141,165	17,970	58,856	17,936	2,189	82,806
2000	1,046	961	706	623	610	4,216	136,060	267,840	135,000	15,000	37,750	19,868	1,984	77,891
2001	1,054	966	712	631	621	4,569	192,160	287,190	146,393	9,659	55,330	23,260	2,009	93,006
2002	1,062	969	716	635	630	5,756	260,710	213,440	149,548	21,883	54,800	23,647	1,086	99,544
2003	1,069	971	720	637	637	5,838	289,994	258,876	139,160	28,285	42,529	25,580	1,647	97,880
2004	1,075	973	723	641	644	4,276	373,827	190,093	153,252	34,131	47,236	27,447	2,287	127,785
2005	1,082	974	726	644	651	4,507	246,777	282,728	143,987	35,105	28,896	25,142	3,084	114,064
2006	1,089	975	729	646	659	4,436	217,328	134,360	132,943	27,016	42,660	19,101	1,071	92,452
2007	1,096	975	731	647	666	4,262	139,489	252,782	141,357	31,740	48,108	20,939	1,022	95,658
2008	1,102	985	734	655	673	4,479	90,969	265,823	132,426	30,502	64,701	19,788	2,939	87,580
2009	1,109	974	736	652	679	4,395	94,362	174,465	107,489	35,219	40,632	15,439	1,364	84,877
2010	1,119	978	742	658	694	4,696	112,386	217,042	112,870	33,458	88,574	19,172	1,741	92,480