An Update of the Reconstructed Marine Fisheries Catches of Tanzania with Taxonomic Breakdown*

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Abstract

Reconstructed catch estimates of the marine fisheries sectors in Tanzania were updated to 2010 from a previous study by Jacquet and Zeller (2007), which covered 1950 to 2005. In addition, a taxonomic breakdown was developed and applied to the annual catches for the 1950–2010 time-period. The reconstructed catch for 1950–2010 totalled 4.2 million t, 77% higher than the 2.4 million t reported by the Food and Agriculture Organization of the United Nations (FAO) on behalf of Tanzania. On average, discards represented 2% of the total catch and sectors were represented as follow: artisanal (83%), subsistence (14%), and industrial (3%). Overall, Tanzanian catches were dominated by Clupeidae (14%), Lethrinidae (13%), Scombridae (9%) and Elasmobranchii (7%). Noteworthy is that the unreported portion (i.e., the difference between the reconstructed and FAO totals) has decreased from over 50% in the 1950s to 30% in the 2000s. Also, the number of taxonomic groups included in the catch reported to FAO has increased since 2005, thus decreasing the proportion of undetermined taxa previously reported as 'marine fishes nei'.

Introduction

The United Republic of Tanzania (referred throughout as 'Tanzania') is located along the Mozambique Channel, and its Exclusive Economic Zone (EEZ) covers over 240,000 km² (Figure 1). The overwhelming bulk of its land area, which corresponds to the former 'Tanganyika', is situated between Mozambique in the South and Kenya in the North (Figure 1). Tanzania also includes three large islands: Mafia, Pemba and Zanzibar, the latter two forming the region of Zanzibar (hence the name 'Tan-Za-nia'). Zanzibar has an autonomous institutional and legal structure for managing fisheries, so both mainland and Zanzibar regions have separate reporting systems (Jacquet and Zeller 2007). Tanzanian fisheries are mainly composed of small-scale fisheries, which represent about 95% of the total marine catch (Jiddawi and Öhman 2002; Abdallah 2004). Large industrial fishing vessels are few and those that exist are mainly involved in the shrimp fishery (Kimaro 1995). Since 1998, artisanal longliners have also targeted pelagic species such as tuna and billfishes (Kimaro 1995; Shao *et al.* 2003; Mngulwi 2006). Marine resources are used for subsistence and as a source of income for people living along the coast (Jiddawi and Öhman 2002), and exported products include holothurians, shells, lobsters, octopuses and shrimps (Marshall *et al.* 2001; Jiddawi and Öhman 2002; Abdallah 2004).

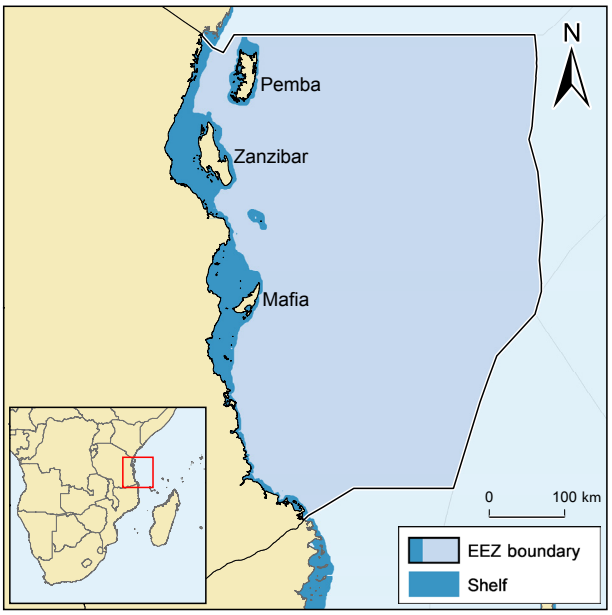

Figure 1. Map of the Tanzanian Exclusive Economic Zone (EEZ), showing the extent of the shelf and the islands of Mafia, Pemba, and Zanzibar.

Accurate historical baselines are useful for fisheries management and monitoring long-term changes in marine ecosystems. Data reported to the Food and Agriculture Organization of the United Nations (FAO) are the only source of global catch statistics and are often used to evaluate the status of both global and regional fisheries (Garibaldi 2012). These data often underreport small-scale fisheries, though, and do not include other important sectors such as recreational fisheries and industrial discards, nor do they include illegal catches (Garibaldi 2012; World Bank 2012). Furthermore, a large portion of FAO catch statistics are often reported as 'marine fishes, nei' or assigned to high taxonomic levels (i.e., higher than family), and although the number of reported species in the database has

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increased in recent years (Garibaldi 2012), there is still a need to further disaggregate FAO catch statistics into more specific taxa, particularly for earlier years. The present study aims to improve the initial catch reconstruction published by Jacquet and Zeller (2007) updating it to 2010, refining some of the previous estimates, and providing taxonomic and sectoral breakdowns.

Methods

Small-scale boat-based catches

Mainland

Baseline reported catch data for marine fisheries from 1950 to 2010 were extracted from FishStatJ (FAO 2012), the fisheries catch database of the FAO. These data reported to FAO were treated as the baseline of reported catches and were considered representative of boat-based catches, assuming that they did not include any catch by shore fishers (Jacquet and Zeller 2007). Changes occurred in the FAO database between this new extraction and the one made by Jacquet and Zeller (2007), as member countries can retroactively modify the data they submitted to FAO, and FAO staffers also modify submitted data if they judge it necessary (Anon. 2013). Indeed, several new taxa were added, but *Thunnus maccoyii* (southern bluefin tuna; accounting for 3 t in the 2000s) was removed. Total annual tonnages also differed from 2000 to 2008, but there has been little change in quantities reported as 'marine fishes nei', implying that this category has not been further disaggregated.

The primary phase of our work was to update to 2010 the reconstructed data of Jacquet and Zeller (2007), using their methodology by applying a 35% unreported catch increase to FAO data from 1970–2010 (distributed proportionally to the reported taxa). We then improved the FAO taxa disaggregation for the early years. There were only two taxa reported to FAO for mainland Tanzania in the 1950s, but this figure has since increased to 48 in 2010.

First, the poor taxonomic resolution in FAO data from 1950 to 1974 (less than nine taxa before 1969) was improved using the catch composition of the 26 reported taxa from the FAO data for the 1975–1979 period. For each year from 1950–1974, the 'marine fishes nei' group was further divided into these 26 taxonomic groups based on the average catch composition from the 1975–1979 period, which also contained a 'marine fishes nei' portion. There were two exceptions: the catch of large pelagics and holothurians were assumed to be zero prior to the first year they were reported to FAO (1974 and 1963, respectively), as they were not being targeted then: large pelagic fisheries (tuna and billfishes) started in the late 1970s in the Western Indian Ocean (Majkowski 2007) and the exploitation of holothurians started in the 1960s with the arrival of Chinese settlers (Marshall *et al.* 2001). The FAO data were therefore consistent with trends observed in the literature and the zero catch of large pelagics and holothurians in earlier years was considered accurate.

Once the taxonomic resolution of the early time-period was improved, we addressed the remaining 'marine fishes nei' and the 'percoids' catch (Table 1). 'Percoids' were considered to be mostly comprised of reef species and were disaggregated using the same method. The taxonomic breakdown used for these two categories was developed from i) a study by Jiddawi and Stanley (1999), who sampled landings from two auction sites on Zanzibar Island from 1995 to 1997; and ii) a study by Silva (2006), who surveyed households from

Table 1. Taxonomic breakdown (%) used to disaggregate 'marine fishes nei' and 'percoids nei' reported in FAO landings for mainland Tanzania and Zanzibar.

Family	Original (%)		Applied (%)	
	Silva (2006)	Jiddawi and Stanley (1999)	Mainland[a]	Zanzibar[b]
Acanthuridae	9.1	14.5	7.2	14.5
Arridae	-	3.3		3.3
Balistidae	-	0.8	0.4	0.8
Belonidae	-	7.8	4.1	7.8
Caesionidae	-	3.9	2	3.9
Chaetodontidae	-	0.2	0.1	0.2
Clupeiformes	-	1.3		1.3
Coryphaneidae	-	2.1	1.1	2.1
Diodontidae	-	5.5	2.9	5.5
Drepaneidae	-	1.5	0.8	1.5
Echeneidae	-	0.1	0.1	0.1
Ephippidae	-	0.1	0.1	0.1
Fistulariidae	-	1.8	0.9	1.8
Gerreidae	14.4	10.2	11.5	10.2
Haemulidae	3.6	13.5	2.8	13.5
Hemiramphidae	-	4.1		4.1
Labridae	-	8.2		8.2
Leiognathidae	-	0.1	0.1	0.1
Lutjanidae	22.4	-	17.9	-
Mullidae	18.7	-	14.9	-
Muraenidae	-	11.3	5.9	11.3
Nemipteridae	-	4.9		4.9
Ostraciidae	-	0.3	0.1	0.3
Platycephalidae	-	0.4	0.2	0.4
Pleuronectiformes	-	0.3	0.1	0.3
Pomacentridae	-	1.5	0.8	1.5
Rachycentridae	5.5	1	4.4	1
Scaridae	26.5	-	21.2	-
Sciaenidae	-	0.2	0.1	0.2
Teraponidae	-	0.5		0.5
Tetraodontidae	-	0.1	<0.1	0.1
Trichiuridae	-	0.5	0.2	0.5

[a] Fish families documented in these two studies and unreported in the FAO landings were similar. Those reported in Silva (2006) made up approximately 80% of those documented by Jiddawi and Stanley (1999). We thus assumed that the remaining families observed should also make up 20% of the 'marine fishes nei' breakdown for mainland Tanzania and we rescaled the taxonomic breakdown to reflect this.

[b] Zanzibar breakdown was calculated based on the frequency of observation of fish families sampled by Jiddawi and Stanley (1999), but not included in the FAO landings.

six coastal sites on both the mainland and Zanzibar, asking them to rank the top five species in order of their importance in the catch. Table 1 summarizes the taxonomic breakdown derived from these two studies and applied to both the 'marine fishes nei' and 'percoid' pooled categories.

Lobster catches were also not reported in FAO landings until 2010 and were not considered to have previously been included in the 'marine fishes, nei' category. It is known that they have been fished in Zanzibar since at least 1958 (Mutagyera 1975), and thus we assumed that the lobster catch was zero prior to 1958. Catch and export statistics for crustaceans were available in Bwathondi and Mwaya (1984) for 1966, 1968–1972, 1974–75 and 1980. These data were used as anchor points and linear interpolations were used to reconstruct lobster catches for missing years.

Zanzibar

Landing data for Zanzibar have only been reported to FAO since 2000, but separately from mainland Tanzania. They were also considered to account for boat-based catches only. Landing data for Zanzibar for 1950–1999 were completely missing from the FAO database and were previously reconstructed by Jacquet and Zeller (2007). However, fisheries catches reconstructed prior to 1982 remained lower than annual catches from 1982–2010 and there was no explanation for the increase in catches from 1980 to 1982 (an increase of 64%). Furthermore, catch data from 1980 and 1981 were incomplete and did not include landings from Pemba Island (Jacquet and Zeller 2007). These had been previously adjusted by Jacquet and Zeller (2007), but, based on catches from 1982–1999, they still appeared underreported. The first year where accurate catch data were available for both of Zanzibar's islands was 1982, so we used this year as an anchor point to generate estimates for earlier years. Since population data for Zanzibar were sparse, we used the Tanzanian population growth as a proxy. This seemed reasonable, as census data for Zanzibar (www.nbs.go.tz) during the period of interest (1967, 1978, and 1988) showed that Zanzibar's population followed a trend similar to that of the rest of the country and has consistently accounted for 3% of the overall population. We divided the 1982 boat-based catch by Tanzania's population in 1982 to estimate the boat catch per person, and then multiplied this ratio by the Tanzanian population from 1950 to 1981.

To disaggregate Zanzibar's catch from 1950 to 1999, we used the taxonomic proportions reported in the 2000–2010 FAO data along with additional information from the literature. The FAO taxonomic composition reported from 2000–2010 consisted of 19 groups, all of which could be attributed to larger taxonomic groups (demersal species, small and large pelagics, sharks and rays, octopuses and squids, lobsters and other marine species; see Table 2) that were reported by Jiddawi and Shehe (1999) and Mhitu and Jiddawi (1999) for both the 1989–1995 and 1996–1999 periods. Reconstructed catches for these periods were allocated to these larger groups and then further disaggregated to taxa reported by FAO based on their average proportions from 2000–2010. Based on the landings reported by Jiddawi and Shehe (1999) and Mhitu and Jiddawi (1999), it seems likely that more specific taxonomic catch data do exist, but they were not available to us.

Table 2. Taxonomic breakdown (%) of reconstructed catch from 1989–1995 and 1996–1999, based on relative abundances of major taxonomic groups from Jiddawi and Shehe (1999), Mhitu and Jiddawi (1999) and 19 taxa reported in the FAO landings from 2000–2010

Major taxa	FAO Taxa in group	1989–1995 (%)	1996–1999 (%)
Demersals	Barracudas nei	4	5
	Carangids nei	4	5
	Emperors(=Scavengers) nei	8	11
	Goatfishes, red mullets nei	3	4
	Groupers, seabasses nei	2	2
	Mullets nei	1	1
	Parrotfishes nei	4	5
	Snappers, jobfishes nei	2	3
	Spinefeet(=Rabbitfishes) nei	4	5
Large pelagics	Marlins,sailfishes,etc. nei	6	5
	Seerfishes nei	5	4
	Tuna-like fishes nei	9	7
Lobsters	Tropical spiny lobsters nei	3	1
Octopus and squids	Marine molluscs nei	6	7
Sharks and rays	Sharks, rays, skates, etc. nei	7	5
Small pelagics	Anchovies	7	6
	Clupeoids	17	16
	Sardinellas	5	5
Others	Marine fishes nei	3	3

We found no catch composition data prior to 1989 and applied the 2000–2010 FAO taxonomic breakdown for 1950–1988, excluding taxa that were not targeted during this period (similarly to mainland; see above). As previously stated, the fishery for large pelagics (recorded as 'marlins', 'sailfishes' and 'tuna-like' in the FAO data) did not begin in the Western Indian Ocean until the late 1970s (Majkowski 2007), and the lobster fishery did not start until 1958 (Mutagyera 1975). From 1950 to these respective years, these two taxa were therefore not included in the improved taxonomic composition. The 'marine fishes nei' portion of Zanzibar catches was redistributed to the taxa present in Jiddawi and Stanley (1999), but missing from the FAO data (Table 1).

Overall, a few taxa were missing from Zanzibar's FAO data (marine shells, shrimps and holothurians), although they were known to be targeted in this area, mainly for export (Bwathondi and Mwaya 1984; Jiddawi and Muhando 1990; Newton *et al.* 1993; Marshall *et al.* 2001; Sabel 2005; Hampus Eriksson *et al.* 2010). Nevertheless, we did not add any 'shell' catches to the boat-based catch data, as it was unknown whether they were already included in the 'marine mollusks' FAO category. It was assumed that shrimp and holothurians catches were not included in the 'marine fishes nei' category and were thus unreported. Due to lack of any additional data, we also assumed a similar proportion of these taxa in the overall boat-based catches in Zanzibar as what was observed on the mainland, and estimated their catch using the annual percentages obtained from the reconstructed mainland catch.

Small-scale shore-based catches

Shore fishing activities are an important source of subsistence for coastal communities, and are most often performed by women and children (Jiddawi and Muhando 1990; Marshall *et al.* 2001; Guard and Mgaya 2002; Jiddawi and Öhman 2002; Silva 2006). As a result, they usually are not included in official catch statistics, and thus, not reported to the FAO. In this study, shore fishing activities refer to all fishing activities that do not use boats. These most commonly involve shore collection on foot, beach seines, fixed fences, cast nets, spears, reef gleaning, and diving. Catches from divers using boats were assumed to be included in the boat-based catches and were not part of the shore-based catch estimate. Shore-based fishers target a variety of taxa such as small pelagics, small and juvenile reef fish, shrimps, crabs, octopuses, rays, holothurians and shells (Table 3).

Table 3. Estimated percentages of shore fishing catch by different activities and taxonomic breakdown for Tanzania

Activity		Targeted taxa	Source	Catch (%)
Diving, shore collection (20.0%)		Holothuroidea[a]	improved FAO; Silva (2006)	0–83[b]
		Panuliridae	improved FAO; Bwathondi and Mwaya (1984); Silva (2006)	0–62[b]
		Shells	improved FAO; Silva (2006)	3–100[b]
Nets	Beach seines (22.2%)	'Marine fishes nei'	Assumed 5% of beach seines	5
		Acetes spp.	Jiddawi and Öhman (2002)	8
		Atherion africanum	Jiddawi and Öhman (2002)	23
		Carangidae	Hoekstra *et al.* (1990)	8
		Clupeidae	Hoekstra *et al.* (1990)	8
		Gerres oyena	Jiddawi and Öhman (2002)	23
		Plotosus lineatus	Jiddawi and Öhman (2002)	23
		Portunus pelagicus	Bwathondi and Mwaya (1984)	1
	Cast nets (7.8%)	'Marine fishes nei'	Assumed 5% of cast nets	5
		Acetes spp	Jiddawi and Öhman (2002)	19
		Anguilliformes	Jiddawi and Öhman (2002)	19
		Ariidae	Jiddawi and Öhman (2002), Silva (2006)	19
		Gerres spp	Jiddawi and Öhman (2002), Silva (2006)	19
		Mugilidae	Jiddawi and Öhman (2002), Silva (2006)	19
	Fixed fences (3.3%)	'Marine fishes nei'	Assumed 5% of fixed fences	5
		Labridae	Jiddawi (ND)	14
		Lethrinidae	Jiddawi (ND), Silva (2006)	14
		Mugilidae	Jiddawi (ND), Silva (2006)	14
		Penaeidae	Shunula (2000)	14
		Rastrelinger carnaguta	Shunula (2000), Silva (2006)	14
		Scylla serrata	Shunula (2000), Silva (2006)	14
		Siganidae	Jiddawi (ND), Silva (2006)	14
Spears (47.0%)		'Marine fishes nei'	Assumed 5% of spear fishing	5
		Diodon holocanthus	Jiddawi and Öhman (2002)	4
		Echidna nebulosa	Jiddawi and Öhman (2002)	4
		Lethrinus harak	Jiddawi and Öhman (2002)	4
		Myliobatiformes	Jiddawi and Stanley (1999), Jiddawi and Öhman (2002), Silva (2006)	15
		Octopus cyanea	Jiddawi and Stanley (1999), Jiddawi and Öhman (2002), Silva (2006)	60
		Sepia latimanus	Jiddawi and Öhman (2002)	4
		Teuthida	Jiddawi and Muhando (1990), Silva (2006)	4

[a] At least 20 species of holothurians are traded in Tanzania (Marshall *et al.* 2001; Jiddawi and Öhman 2002). High value species are *Holothuria scabra*, *H. nobilis*, *H. spinifera*, *H. lessoni*, and *Theleonota ananas*, but they also exhibit the most marked declines (Marshall *et al.* 2001; Hampus Eriksson *et al.* 2010).
[b] Collected taxa percentages varied significantly between years depending on FAO catches. Ranges are shown in the table and their average percentages are 62% (shells), 16% (Panuliridae) and 22% (Holothuroidea).

Estimates of shore-based catches for the mainland by Jacquet and Zeller (2007) were based on a census of shore fishers by the National Fisheries Division for 2001 and 2005, with 576 and 796 shore fishers, respectively. Given that the number of shore fishers in Zanzibar for the same period ranged from 4,724 to 5,338 (Jacquet and Zeller 2007), and that Silva (2006) found that 20% of households were involved in shore fishing activities, we believed that earlier estimates by Jacquet and Zeller (2007) underestimated the shore fishing catches in mainland Tanzania. Therefore, we re-estimated shore fishers' numbers and their catches from 1950 to 2010 based on the methods outlined below.

Silva (2006) reported that one out of five fishing households fished on foot in 2005. Therefore, we used this ratio to estimate the number of shore fishers based on the number of boat fishers in 2005. In Zanzibar, the number of shore fishers and boat fishers is known for 1980, 1985 and 1989 (Ngoile 1982; Carrara 1987; Mongi 1991). The ratios of shore fishers to boat fishers for these years were 0.35, 0.1 and 0.16, respectively, showing a potential decline in the number of shore fishers from 1980 to 1989. A linear regression fitted to these three points suggested that the ratio was 0.5 in 1970 in Zanzibar. We assumed a similar trend for the mainland, but adopted a slightly more conservative ratio of 0.4 for 1970. We then applied a linear interpolation between the 1970 and 2005 ratios to estimate the number of shore fishers.

Before 1970 and after 2005, boat fisher data were not readily available. Thus, for the 1950–1969 period, we used the ratio of reconstructed shore fisher catch to boat catch from 1970 (i.e., 0.07) to estimate shore fishing catch. The ratio of shore fishers to the mainland population in 2005 (0.15×10^{-3} shore fisher per inhabitant) was used to estimate

the number of shore fishers from 2006 to 2010. From 1970 to 2010, the corresponding shore fishing catch was calculated by multiplying the number of shore fishers with a catch rate of 0.96 t·year^{-1} (Jacquet and Zeller 2007).[1]

Information on the catch rates and composition of shore fishing activities was limited. To estimate the taxonomic breakdown of shore-based catches, we first estimated the proportion of catch derived from three main fishing activities (see Table 3) using effort data documented in Silva (2006):

- The use of nets was estimated to account for 33% of shore-based catch. This catch was further subdivided into catch by beach seine, fixed fence and cast nets (66%, 10% and 24%, respectively), based on effort information from Mgawe (2005);
- Diving and shore collection were estimated to account for 20% of shore-based catch; and
- Spearfishing was estimated to account for 47% of shore–based catch.

We then estimated a catch composition for each of these activities based on taxa and proportions reported in the literature (Table 3).

Jiddawi and Öhman (2002) reported that *Plotonus lineatus* (striped eel catfish), *Atherion africanum* (pricklenose silverside) and *Gerres oyena* (common silver-biddy) accounted for approximately 70% of the catches from beach seine activity. Due to a lack of any other information, we divided this percentage equally among these three species (i.e., 23.3% each). Miscellaneous marine fishes (i.e., 'marine fishes nei') were assumed to make up 5% of the beach seine catch, and 1% was allocated to *Portunus pelagicus* (flower crab), which is occasionally caught (Bwathondi and Mwaya 1984). *Acetes* spp. (paste shrimp) were also reported to be spatially and temporally very common (Jiddawi and Öhman 2002), and Clupeidae (sardines) and Carangidae (jacks) were documented as target species in Hoekstra *et al.* (1990). Therefore, the remaining percentage was allocated to these three groups proportionately (i.e., 8% each).

Taxonomic breakdowns for fixed fences and cast nets were based on Jiddawi (ND), Shunula (2000), Jiddawi and Öhman (2002), and Silva (2006), who reported taxa commonly caught in these fisheries in both Zanzibar and Tanzania. Since there was no information regarding the proportion of these species in the catch, we divided the fixed fence and cast net catches equally among the taxa that were reportedly targeted by these gears (see Table 3). We attributed 5% of the catch to 'marine fishes nei', unaccounted for in the literature that was reviewed.

Taxa collected by diving and shore collection were primarily composed of marine shells, holothurians and lobsters (Mutagyera 1975; Jiddawi and Muhando 1990; Jiddawi and Öhman 2002; Silva 2006). These taxa were also caught by boat fishers to a lesser extent, and were included in the reconstructed boat catches for the mainland and Zanzibar. These fisheries are often highly variable due to changes in market demands and boom and bust characteristics (Anon. 1990; Anderson *et al.* 2011). Therefore, it was difficult to assume one breakdown to divide diving and shore collection catch among these taxa for the 1950–2010 period. As there was no information on the relative proportion of these taxa for any given year, we assumed that these taxa were being collected in the same proportions as those occurring by boat for mainland Tanzania.

Octopuses dominated spear fishing (Jiddawi and Stanley 1999), but other species are also targeted. For example, Jiddawi and Stanley (1999) reported large volumes of Myliobatidae (rays). Based on this information, we allocated 60% of the spear fishing catch to *Octopus cynaea* (octopuses; Guard and Mgaya 2002) and 15% to Myliobatidae. Miscellaneous marine fishes ('marine fishes nei') were assumed to make up 5% of the spearfishing catch and the remaining catch was equally divided among the other taxa reported in Jiddawi and Muhando (1990), Jiddawi and Öhman (2002) and Silva (2006; see Table 3).

Sectoral breakdown

Industrial shrimp trawlers accounted for approximately half of the total shrimp catch[2] and started in 1966 (Bwathondi and Mwaya 1984). Thus, we assumed 50% of shrimp caught by boats were industrial from 1966 onward. We estimated a *discard:shrimp* ratio of 2:1 in order to remain consistent with the values documented in Jacquet *et al.* (2010) for Mozambique (2.8:1; see also Doherty *et al.* this volume). This was likely conservative, given reported shrimp to bycatch ratios of 1:5 and 1:8 in Tanzania (Silas 2011). However, it is unknown how much of this bycatch may be landed. Bycatch species from shrimp trawling were documented in Silas (2011), but their relative proportions were not available. Thus, we allocated 10% of discards as 'marine fishes nei' and divided the remaining discards equally among the eight species listed (*Pellona ditchela*, *Pomadasys stridens*, *Pelates quadrilineatus*, *Leiognathus equulus*, *Equulites leuciscus*, *Aurigequula fasciatus*, *Secutor insidiator* and *Gazza minuta*).

Most of the boat-based catch came from the artisanal sector, except for a small portion, which was often retained for home consumption (i.e., subsistence) and reported to be less than 5% by Jiddawi and Stanley (1999). We assumed that the proportion of catch retained by boat fishers for subsistence purposes has likely been in this range since the early 1980s. Thus, we considered that 5% of boat catch was used for subsistence purposes from 1980–2010. However, Haji (1999) reported that, due to tourism development, the fishery sector in Zanzibar had been redirected from subsistence to commercial fishing, and it is likely that the proportion of catches used for subsistence was higher in earlier years for all Tanzania. As there was no additional information for the earlier period, we assumed that 15%

[1] This catch rate was based on an estimate of shore fisher catch by Jiddawi and Stanley (1999) of 4 kg·day^{-1}·person^{-1} and an assumed effort of 20 days per month (240 days per year).

[2] The five main components of artisanal shrimp fishery used to be *Penaeus indicus*, *P. semilsulcatus*, *P. latisulcatus*, *P. monodon* and *Metapenaeus monoceros* (Bwathondi and Mwaya 1984). In recent years, *P. indicus* made up the majority of the catch and *P. latisulcatus* was replaced by *Marsupenaeus japonicus* in the five most dominant species (Silas 2011).

of total boat-based catch was being taken home for subsistence in 1950. We used linear interpolations to estimate the proportion of take-home catch from 1950–1980. The annual subsistence catch was allocated proportionally to all taxa except for lobster, shrimp, holothurians, and large pelagics, which were considered to be exclusively artisanal (i.e., commercial).

All shore-fishing catches were assumed to be exclusively used for subsistence (except for lobsters, penaeid shrimps and holothurians).

Results

The reconstructed total catch for Tanzania during the 1950–2010 period reached over 4.2 million t, which is 77% higher than the landings of 2.4 million t reported to the FAO by Tanzania (Figure 2). Reconstructed catches for mainland and Zanzibar represented 3.1 and 1.2 million t, respectively, as opposed to 2.1 and 0.25 million t reported to FAO. Total catches gradually increased from 18,100 t·year^{-1} in 1950 to around 114,600 t·year^{-1} in 2010, but peaked at 115,000 t·year^{-1} in 2005. Tonnages were greater than 100,000 t·year^{-1} for the 2000–2010 period, averaging over 105,500 t·year^{-1}. There were noticeable declines in the catch in the early 1980s and mid-1990s (Figure 2). Overall, Tanzanian marine fisheries catches for the whole period were dominated by Clupeidae (14%), Lethrinidae (13%), Scombridae (9%) and Elasmobranchii (7%; Figure 3).

Small-scale boat- and shore-based catches accounted for 4.1 million t for the 1950–2010 period, 85% of which was artisanal and 15% of which was subsistence. Shore fishing activities were an important part of small-scale catches, accounting for 10% of total small-scale catch and 64% of the total subsistence catch. Artisanal catches ranged from over 13,000 t·year^{-1} in 1950 to over 95,000 t·year^{-1} in 2010, while subsistence catches ranged from nearly 5,000 t·year^{-1} in 1950 to almost 15,500 t·year^{-1} in 2010. Artisanal catches peaked at around 96,000 t·year^{-1} in 2005, while subsistence catches peaked at almost 15,500 t·year^{-1} in 2010 (Figure 4).

Industrial shrimp catches ranged from 360 t in 1966 to 1,300 t in 2010, peaking at nearly 2,300 t in 1998 (Figure 4). Total industrial shrimp catches and discards accounted for 2.4% and 4.8% of Tanzania's reconstructed catch at their peak in 1998 and overall accounted for 1% and 2%, respectively over the 1950–2010 period.

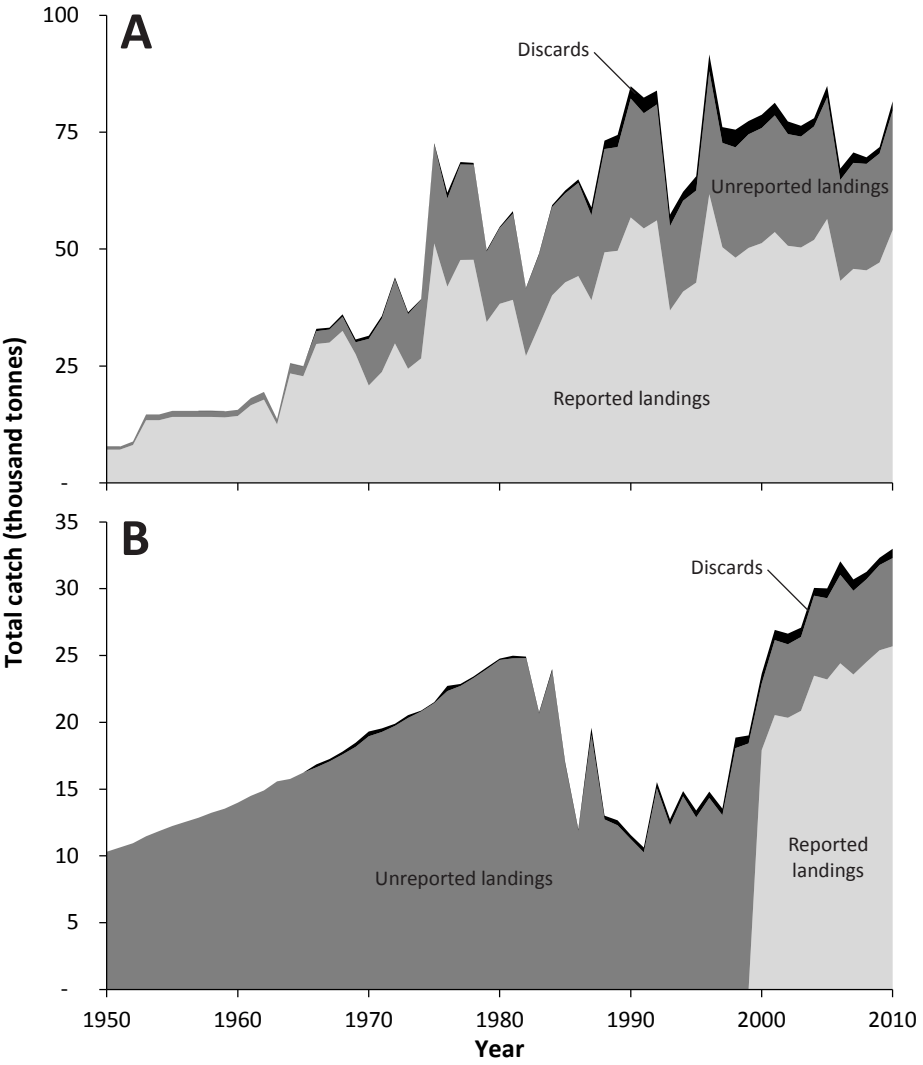

Figure 2. Total reconstructed catches by type ('reported landings' corresponds to the data published by FAO) for A) mainland Tanzania, and B) Zanzibar.

Discussion

The catch reconstruction completed for Tanzania (for both mainland and the Zanzibar islands) allowed for a more comprehensive baseline of the development of Tanzanian fisheries since 1950. The peak observed in the mid-1970s is synchronous with the increasing number of boat and shore fishers at that time (Jacquet and Zeller 2007). The declines observed in the 1980s and 1990s are interpreted as a sign of overexploitation by Jiddawi and Öhman (2002), but they reported that there were insufficient data for full resource assessments during these periods, and thus it is also possible that these declines were artifacts of poor catch accounting. The last ten years have produced the highest catches in Tanzania's history, a trend which was observed for both mainland and Zanzibar. It could be due to i) increased fishing effort due to larger coastal populations and improved technologies; ii) improved fisheries management; and/or iii) the fact that the reconstructed catches for the earlier period are still underestimated.

It is likely that the increase in coastal populations and fishers (Bagachwa *et al.* 1994), together with the use of motorized and commercial boats (Jiddawi and Öhman 2002; Muhando and Rumisha 2008), has led to higher catches. Indeed, with modernization of the fishing fleet, fishers could exploit fishing grounds further offshore and target new taxa, as was the case, e.g., in Mayotte and the Seychelles (see Doherty *et al.* this volume and Le Manach *et al.* this volume). This is the case for tunas and other large pelagics, which were absent from catch prior to 1970, but make up as much as 7% of the total catch in recent years, and may be a case of spatial expansion driving local fisheries (Swartz *et al.* 2010).

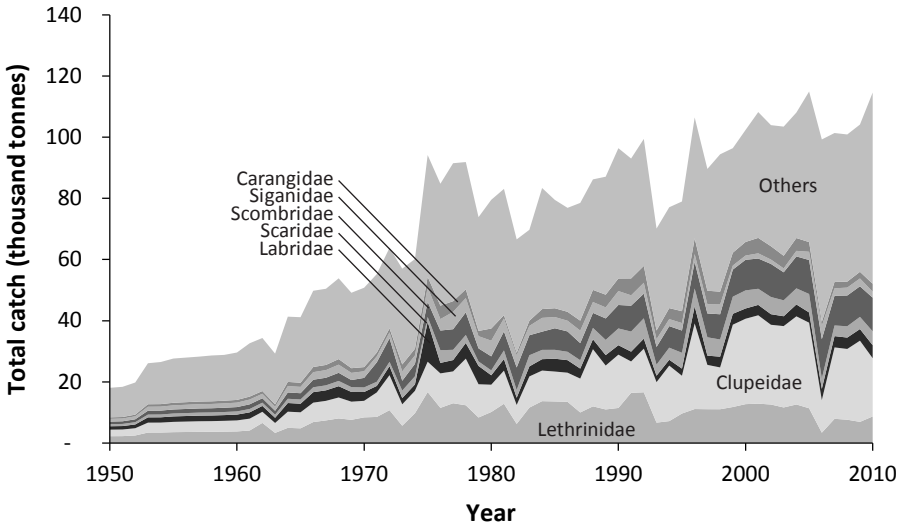

Figure 3. Breakdown of total marine fisheries catches for Tanzania (mainland and Zanzibar combined) by major taxa. 'Others' includes 85 additional taxa. Details are provided in Appendix Table A1.

New legislation (e.g. enforcing bans on dynamite fishing in 1995 and beach seines in 1997) and participatory management plans (Verheij *et al.* 2004) may have also contributed to increased catches since 2000 (similarly to Kenya; see Le Manach *et al.* this volume). The establishment of marine parks and development of ecotourism in the 1990s (Riedmiller and Carter 2000; Mngulwi 2006) may have also played a role.

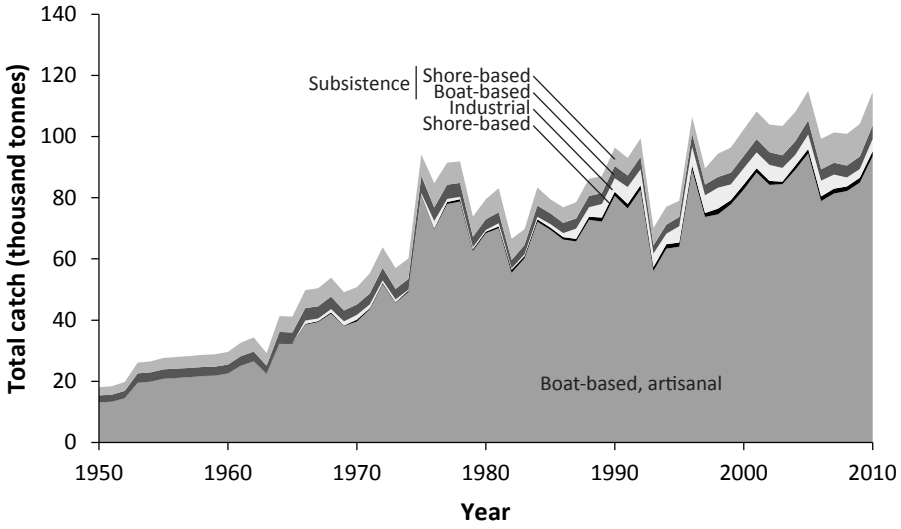

Figure 4. Breakdown of total marine fisheries catches for Tanzania (mainland and Zanzibar combined) by fishing sectors, which includes small-scale (artisanal and subsistence) and industrial fisheries. Details are provided in Appendix Table A2.

It is possible that some holothurians included in the boat catches may contain some shore-based catch, resulting in an overestimate. Indeed they are mainly collected while gleaning (Jiddawi and Öhman 2002; Hampus Eriksson *et al.* 2010), and since they are mostly exported they may have been included in the FAO database (which was assumed to contain only boat catches). However, catches of holothurians are also often underreported and/or illegally exported, as is the case in Mayotte or Madagascar (Pouget 2004; Le Manach *et al.* 2011, 2012, this volume; Doherty *et al.* this volume), in which case they would not appear in the FAO database. Thus, there is some uncertainty in our estimates of holothurians catches; however, it is apparent that they have been overfished in Tanzania, as catches have dramatically declined since the 1990s and there has been a severe decline in observed size and abundance (Marshall *et al.* 2001; Hampus Eriksson *et al.* 2010).

There is also inherent uncertainty associated with the assumed taxonomic breakdown for the shore-based catch, given that there was essentially no catch reporting for this sector. This study is a first attempt to estimate the contribution and species composition of shore-based catches to Tanzania's national fisheries and we hope our estimates may serve as a starting point, which may be improved through future efforts. Our results do demonstrate that shore-based catches are not negligible, accounting for 10% of Tanzania's total catch and the majority of subsistence catches. This is a sector that warrants further investigation and monitoring, particularly for species heavily exploited by shore fishing activities such as gastropods, lobsters, octopuses, holothurians and other reef fish species outlined in Table 3, which may not be typically targeted by boat-based fisheries.

It should be acknowledged that some improvements in the catch data reported to FAO have occurred. The taxonomic resolution of catch reported to FAO has improved since the previous work by Jacquet and Zeller (2007), as several new taxa were included between 2005 and 2010, and a lower proportion of catch was reported as 'marine fishes nei'. Also, perhaps as a result of the contribution by Jacquet and Zeller (2007), Zanzibar's catches are now included in the FAO data for the years 2000 to 2010 (but are still missing from 1950–1999). This latter improvement was documented in Jacquet *et al.* (2010), contrary to comments in Garibaldi (2012).

It is our hope that this study may be used to further improve the historic time-series of catch data that is reported to FAO, and serves as a useful tool for improved catch data monitoring and estimation for all areas and sectors in Tanzania's fisheries.

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Appendix Table A1. Total reconstructed catch by major taxa ('Others' includes 85 additional taxa).

Year	Lethrinidae	*Sardinella* spp.	Elasmobranchii	Carangidae	Siganidae	Scombridae	*Rastrelliger kanagurta*	Scaridae	Labridae	Clupeidae	Others
1950	2,243	988	1,156	1,111	681	633	219	893	489	1,345	8,310
1951	2,269	1,000	1,170	1,124	694	643	220	906	493	1,383	8,481
1952	2,485	1,093	1,277	1,233	739	691	249	982	549	1,421	9,076
1953	3,436	1,502	1,743	1,721	905	885	388	1,300	811	1,460	11,950
1954	3,443	1,506	1,748	1,724	915	892	386	1,307	810	1,498	12,263
1955	3,564	1,558	1,809	1,785	944	921	401	1,351	840	1,536	12,922
1956	3,616	1,581	1,836	1,810	964	938	405	1,373	850	1,583	12,990
1957	3,667	1,604	1,863	1,835	983	954	408	1,396	859	1,630	13,054
1958	3,687	1,613	1,874	1,845	993	962	409	1,405	862	1,659	13,322
1959	3,737	1,635	1,900	1,869	1,012	979	413	1,427	872	1,705	13,275
1960	3,807	1,666	1,936	1,904	1,035	999	419	1,455	886	1,751	13,742
1961	4,108	1,796	2,085	2,058	1,097	1,066	461	1,560	966	1,803	15,629
1962	6,594	1,678	1,953	1,919	1,067	1,018	418	1,475	886	1,857	15,478
1963	3,328	1,496	1,747	1,694	1,007	942	346	1,341	759	1,913	14,664
1964	4,978	2,451	2,835	2,831	1,385	1,390	672	2,082	1,372	1,971	19,357
1965	4,818	2,430	2,812	2,803	1,390	1,389	659	2,072	1,351	2,031	19,388
1966	6,867	2,947	3,402	3,419	1,603	1,636	833	2,476	1,681	2,093	22,834
1967	7,411	2,967	3,427	3,440	1,625	1,653	835	2,498	1,687	2,157	22,741
1968	8,059	3,177	3,667	3,687	1,720	1,759	901	2,666	1,816	2,223	24,174
1969	7,602	2,751	3,184	3,174	1,573	1,571	747	2,344	1,531	2,292	22,371
1970	8,402	2,504	2,904	2,881	1,498	2,461	658	2,161	1,366	2,365	23,578
1971	8,546	2,164	5,858	2,111	1,370	3,984	2,369	1,948	1,237	2,167	23,490
1972	10,755	4,212	7,235	2,945	1,395	3,721	3,991	1,972	1,245	2,238	24,117
1973	5,674	1,670	5,334	2,021	2,455	2,735	481	3,065	2,270	2,311	29,003
1974	9,746	2,458	4,877	2,095	2,655	3,263	807	2,744	2,187	2,387	26,938
1975	16,680	3,977	5,935	13,059	1,574	3,552	1,398	4,764	3,422	2,465	37,326
1976	11,510	5,484	5,790	3,424	4,151	4,598	1,834	3,735	4,401	2,544	37,305
1977	13,017	5,562	4,852	3,698	3,358	5,554	1,183	5,660	3,492	2,625	42,483
1978	12,355	8,006	7,248	5,121	2,616	4,492	2,905	4,670	2,859	2,708	38,885
1979	8,360	3,830	7,041	5,988	1,461	3,564	712	3,991	1,715	2,794	34,399
1980	10,149	3,990	4,942	3,087	1,598	3,513	1,068	5,129	3,969	2,883	39,197
1981	12,853	4,549	6,284	3,775	2,826	4,090	2,121	4,257	1,055	2,975	38,302
1982	6,267	2,477	3,724	2,349	2,515	5,139	2,247	3,983	802	3,070	34,009
1983	11,598	4,437	5,756	3,280	3,638	4,403	2,140	3,066	1,676	2,560	27,165
1984	13,701	4,571	5,430	3,724	3,037	3,578	2,383	4,505	2,876	3,094	36,478
1985	13,607	4,165	5,611	4,192	2,907	3,745	3,305	3,668	2,874	2,174	33,255
1986	13,491	4,044	5,476	4,093	2,738	3,245	3,411	3,506	2,910	1,444	32,535
1987	10,010	7,268	3,805	3,267	2,727	3,292	2,307	4,083	3,255	2,381	36,112
1988	12,003	14,201	4,491	3,231	3,721	3,231	1,679	3,553	3,962	1,488	34,639
1989	10,993	9,200	5,153	3,411	4,965	3,436	3,590	3,607	4,157	1,626	36,933
1990	11,479	11,584	5,840	3,090	5,478	4,441	3,229	4,557	4,100	1,501	41,096
1991	16,426	3,778	6,474	3,209	6,566	3,225	5,237	3,384	5,519	1,351	37,847
1992	16,599	7,374	6,900	3,270	6,643	3,929	4,131	3,562	5,505	1,990	39,516
1993	6,684	7,886	5,347	2,113	3,595	2,298	3,507	2,524	2,848	1,589	31,731
1994	7,178	12,148	5,992	1,912	3,949	2,586	4,464	2,297	3,589	1,875	31,104
1995	9,657	5,581	6,774	2,342	5,160	2,501	4,783	2,436	3,885	1,653	34,198
1996	11,125	19,880	8,112	5,598	5,809	2,438	6,308	2,509	5,130	1,735	37,802
1997	11,069	7,241	7,248	3,019	5,998	2,320	5,471	3,018	4,415	1,567	38,253
1998	11,058	6,680	6,993	3,515	5,616	2,679	5,569	3,203	4,185	2,145	42,749
1999	11,787	19,612	7,303	3,555	5,593	2,683	6,178	1,329	4,189	2,271	31,902
2000	12,726	20,547	7,371	3,349	5,917	3,814	6,186	1,384	4,450	1,424	35,181
2001	12,888	21,497	7,391	3,393	5,271	3,030	6,862	1,694	5,050	3,202	37,921
2002	12,599	19,799	6,270	3,460	5,617	3,616	7,199	1,427	4,365	3,772	35,808
2003	11,648	19,881	6,713	3,218	5,209	2,297	6,862	1,285	4,119	4,882	37,334
2004	12,616	21,383	7,431	3,877	5,269	3,576	6,868	1,816	4,188	4,055	36,974
2005	11,383	21,881	6,092	3,343	6,039	3,564	7,544	2,692	3,161	5,267	43,950
2006	3,385	5,689	4,979	3,663	3,389	5,182	7,684	4,363	1,256	3,110	56,551
2007	7,928	17,471	5,874	3,695	3,475	4,338	5,382	2,432	2,079	2,374	46,310
2008	7,639	17,139	5,990	3,718	3,698	4,890	5,170	2,582	1,950	2,405	45,700
2009	6,930	20,477	6,064	3,803	3,979	4,668	5,329	2,569	2,166	2,446	45,700
2010	8,703	12,019	7,021	4,248	4,524	5,024	5,987	1,950	2,598	2,473	60,039

Appendix Table A2. Total reconstructed catch by sector compared to the total catch reported to FAO.

Year	Artisanal	Industrial	Subsistence	Total reconstructed	Reported to FAO
1950	13,079	-	4,988	18,067	7,100
1951	13,332	-	5,053	18,385	7,100
1952	14,444	-	5,351	19,795	8,100
1953	19,509	-	6,590	26,099	13,400
1954	19,874	-	6,617	26,492	13,400
1955	20,834	-	6,799	27,633	14,100
1956	21,090	-	6,855	27,945	14,100
1957	21,345	-	6,907	28,252	14,100
1958	21,703	-	6,927	28,630	14,100
1959	21,880	-	6,945	28,825	14,000
1960	22,579	-	7,022	29,602	14,300
1961	25,110	-	7,518	32,628	16,600
1962	26,558	-	7,786	34,344	17,800
1963	22,573	-	6,665	29,238	12,500
1964	32,541	-	8,783	41,324	23,400
1965	32,474	-	8,668	41,142	22,800
1966	38,788	1,079	9,926	49,793	29,700
1967	39,662	868	9,910	50,440	30,000
1968	42,537	1,069	10,246	53,851	32,500
1969	38,230	1,365	9,545	49,140	27,500
1970	40,159	1,547	9,071	50,777	20,820
1971	43,907	1,210	10,127	55,244	23,701
1972	52,160	844	10,821	63,826	29,826
1973	45,860	918	10,240	57,019	24,392
1974	49,661	296	10,200	60,158	26,616
1975	80,959	549	12,645	94,153	51,210
1976	69,974	2,426	12,377	84,776	41,960
1977	78,601	1,007	11,876	91,484	47,669
1978	79,528	768	11,569	91,865	47,709
1979	63,167	685	10,003	73,855	34,389
1980	68,929	543	10,053	79,526	38,292
1981	70,641	1,047	11,399	83,087	39,137
1982	56,484	466	9,632	66,582	27,132
1983	60,937	576	8,206	69,720	33,559
1984	72,944	833	9,599	83,376	40,091
1985	70,267	1,140	8,096	79,503	42,883
1986	67,141	1,314	8,438	76,893	44,230
1987	66,555	3,362	8,591	78,508	39,065
1988	73,795	3,109	9,296	86,201	49,306
1989	73,523	4,440	9,108	87,072	49,626
1990	81,971	4,413	10,012	96,395	56,762
1991	77,967	5,551	9,500	93,018	54,410
1992	84,128	5,147	10,144	99,420	56,133
1993	57,357	4,403	8,360	70,120	36,868
1994	64,811	3,445	8,837	77,093	40,907
1995	65,356	5,347	8,267	78,970	42,826
1996	90,553	6,106	9,789	106,447	61,740
1997	75,005	5,800	8,815	89,619	50,393
1998	76,443	6,852	11,098	94,392	48,155
1999	79,223	5,152	12,028	96,403	50,250
2000	84,316	5,347	12,686	102,349	69,186
2001	89,646	5,191	13,361	108,198	74,175
2002	85,497	5,245	13,188	103,930	71,042
2003	85,267	4,491	13,688	103,447	71,194
2004	90,520	3,507	14,025	108,052	75,453
2005	95,934	4,747	14,233	114,914	79,645
2006	80,442	5,156	13,653	99,252	67,613
2007	82,959	4,621	13,777	101,356	69,340
2008	83,697	2,942	14,244	100,883	69,966
2009	86,532	2,870	14,728	104,130	72,526
2010	95,225	4,006	15,355	114,586	79,770