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Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania

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The fisheries data supplied to the Food and Agriculture Organization of the United Nations (FAO) by national agencies have served as the primary tool for many global and regional studies. However, it is recognised that these data are incomplete and often underestimate actual catches, particularly for small-scale fisheries. This study reconstructed total marine fisheries catches from 1950 to 2005 for Mozambique and the United Republic of Tanzania, by applying an established catch reconstruction approach utilising all available quantitative and qualitative data, combined with assumption-based estimations and interpolations. Since the 1950s, Mozambique has reported primarily industrial catches and has substantially under-reported the country's small-scale fishing sector due to lack of resources and civil war. In Tanzania, Zanzibar's recorded fisheries statistics prior to 2000 are absent from Tanzania's marine fisheries catches reported to FAO, and total mainland catches are at least one-third larger than officially reported. Based on our reconstruction, since 2000, Mozambique caught between 150 000 and 172 000 t y^{-1}, while the United Republic of Tanzania caught at least 95 000 t y^{-1}. For the period 1950–2005, reconstructed total marine catches were 6.2 and 1.7 times greater than data supplied to FAO by Mozambique and Tanzania respectively. The reliance on incomplete and substantially under-reported national data puts authorities under serious risk of over-licensing fishing access and mismanaging marine ecosystems and national food security.

Keywords: catch rates, catch reconstructions, food security, Malthusian overfishing, small-scale fisheries, sub-Saharan Africa, subsistence fisheries

Introduction

To assess hunger and malnutrition by country, the United Nations Food and Agriculture Organization (FAO) requires the collection, analysis, interpretation and dissemination of information relating to nutrition, food, and agriculture, including fisheries (Ward 2004). The FAO FishStat database, which offers time-series data on marine fisheries landings from 1950 to the present, is fed by national statistical data compiled by its member countries. Therefore, the quality of global FAO data depends on the capacity and political willingness within these countries for statistical collection and estimation. Data supplied to FAO have served as the primary tool in many global fisheries studies (e.g. Grainger and Garcia 1996, Garcia and Newton 1997, Pauly et al. 1998, Garcia and de Leiva Moreno 2003), but they are recognised as deficient and incomplete in many regions (e.g. Zeller et al. 2007, Zeller and Pauly 2007), including Africa (van der Elst et al. 2005, Tesfamichael and Pitcher 2007).

Data supplied to FAO are unfortunately not readily distinguishable by sector (e.g. commercial vs subsistence). Domestic small-scale fishing (both small-scale commercial as well as non-commercial subsistence) often contributes significantly to coastal or even national food security, as well as GDP (Zeller et al. 2006a), particularly in developing countries. However, small-scale fisheries have often been marginalised politically due to their socio-economic, political, as well as physical remoteness from urban centres (Pauly 1997), resulting in under-representation in official statistics (e.g. Zeller et al. 2006b, 2007). Instead, government focus and support is often directed toward industrial fishing, which provides foreign exchange earnings. This dichotomy is also often reflected in data collection emphasis and the resultant reported data, and hence impacts interpretation of regional and global analyses.

In Mozambique and Tanzania, small-scale fishing takes place both from shore and from canoes and dhow-type planked boats, mostly propelled by sails (Mngulwi 2006), and almost exclusively in the nearshore waters of 40 m depth or less (UNEP 2001). In Mozambique, small-scale fisheries catch data are estimated as subsets of national landings sites, and the estimated and recorded sample data are not extrapolated

countrywide by the national fisheries divisions (e.g. IIP 2003, 2004; N Faucher, Instituto Nacional de Desenvolvimento da Pesca de Pequena Escala, pers. comm.). In the 1960s, industrial fishing began in the waters off Mozambique and Tanzania. Fishing vessels were often financed or entirely operated by European countries and allowed to operate in Mozambique and Tanzanian waters in exchange for foreign revenues. For example, in the 1980s shrimp became Mozambique's largest earner of foreign exchange after cashews (Nelson 1984). Similar to the situation in West Africa (e.g. Marquette et al. 2002), Mozambican and Tanzanian industrial shrimp trawlers disobey legal requirements to stay offshore, and encroach on inshore areas, damaging bottom habitats and destroying passive fishing gear set by small-scale fishers (Lopes and Gervásio 1999). Tropical shrimp trawl fisheries also discard large fractions of their catch as unwanted bycatch (e.g. Kaczynski and Fluharty 2002), which often overlaps directly with those resources that small-scale fisheries rely on (and rarely discard). Industrial landings data (see below for definitions of 'catches' and 'landings') are generally accounted for in national reported data, while discards are missing.

In Mozambique, there are around 120 000 fishers and 658 small-scale landing sites, while in Tanzania (mainland and Zanzibar combined) there are an estimated 55 000 fishers and more than 400 landing sites (Jiddawi and Muhando 1990, Shao et al. 2003, IDPPE 2004). Difficulties in data collection and substantial under-reporting of small-scale marine catches have been recognised repeatedly in both countries (e.g. Herrick et al. 1969, Anon. 1988, Mongi 1991, Charlier 1995, Gillett 1995, Guard et al. 2000). The present study uses an established catch reconstruction approach (Zeller et al. 2007) to estimate total marine fisheries catches for both countries for the period 1950–2005 to derive a historic baseline and evaluate the overall magnitude of under-reporting. In line with the move towards ecosystem-based fisheries management, we define 'catch' as any sea life killed by fishing gear, irrespective of this catch being landed for direct or indirect human use ('landings') or discarded.

Material and methods

Fisheries catches have been successfully reconstructed in other regions of the world (Zeller et al. 2006b, 2007). Here, we follow the conceptual framework and approach outlined by these studies to reconstruct historic marine fisheries catches for Mozambique and Tanzania. This required data and information from published and grey literature collected during field visits by the senior author in August 2006 and subsequently (see Jacquet and Zeller 2007a, 2007b)[1], combined with interpolations and clearly defined assumptions. The catch reconstruction approach utilised here consists of six general steps (based on Zeller et al. 2007):

(a) identify and source existing, reported catch times-series, e.g. national data and data supplied to FAO by each country;
(b) identify sectors, time periods, species, gears, etc. not covered by (a), i.e. missing catch sectors, via literature searches and consultations;
(c) source available alternative information sources dealing with missing sectors identified in (b), via extensive literature searches and consultations with local experts;
(d) develop data anchor points in time for missing data items, and expand to countrywide catch estimates;
(e) interpolate for time periods between data anchor points, often via per capita catch rates; and
(f) estimate final total catch times-series estimates, combining reported catches (a) and interpolated, country-expanded missing data-series (e).

Countries differ in terms of fisheries sectors, their coverage of reported data, and available alternative information, requiring this general procedure to be customised for each country.

Mozambique

At the national level, Mozambique's fisheries are considered in three subsectors: industrial, semi-industrial, and artisanal or small-scale (see contributions in Pauly 1992). For this study, we combined the latter two sectors to consider Mozambique's fisheries in two categories: small-scale and industrial, where the small-scale sector includes boat-based fisheries as well as 'collectors' (consisting of shore-based collectors and boat-based divers, most often for home consumption).

Small-scale sector

Time-series data on small-scale catches were not available, although unpublished reports provided estimates for the small-scale fleet for certain years (e.g. Krantz et al. 1986, Charlier 1995). However, these studies did not present details of their methods for estimation, nor did they appear to include the collector component in catch estimates. Therefore, they were considered as minimal estimates.

The data that were most comprehensive were the 2003 and 2004 national catch data as collected and reported by the Instituto Nacional de Investigação Pesqueira (IIP), which explicitly included estimated small-scale fisheries catches with a clearly described estimation method (IIP 2003, 2004). Whereas the 2004 data were derived from sampling 115 of the larger fishing centres, expansions were never made to the other 543 (smaller) centres (N Faucher pers. comm.). As discussed in Jacquet and Zeller (2007a), the 2003 data included full coverage of three coastal provinces (Maputo, Sofala and Zambezia), 70% coverage of two other coastal provinces (Nampula and Inhambane), and excluded the southern province of Gaza and the northern province of Cabo Delgado (Figure 1), which has the largest number of active boats and the second largest number of fishers (KPMG 2006). This information was combined with the 2002 fisher census (IDPPE 2004) to determine that, overall, small-scale catches for approximately 62% of the total number of fishers were included in the national statistics (Table 1). This suggests that the reported catch for 2003 and 2004, being 67 074 and 57 747 t respectively, was caught by 62% of all coastal small-scale fishers. Assuming proportionality, we increased the reported catches for 2003 and 2004 by 38% to derive '100% estimates' for these years. This resulted in a reconstructed small-scale catch of 108 184 and 93 140 t for 2003 and 2004 respectively.

[1] Available at www2.fisheries.com/archive/publications/reports/report15_2.php

Based on these adjusted total small-scale catches and the associated fisher population, we derived estimated daily per fisher catch rates of 2.47 and 2.09 kg fisher^{-1} day^{-1} for 2003 and 2004 respectively.

Anecdotal evidence suggests that, because of additional fishing pressure from refugees, catch rates declined during the civil war, which lasted from 1975 to 1992 (Dutton and Zolho 1990, Lopes and Gervásio 1999). A case study on the small-scale fishery of Inhaca Island (part of the province of Maputo; Figure 1) presented data from fisher interviews, and suggested that catch rates declined by 62% over the past 30 years from 29 kg fisher^{-1} day^{-1} to 11 kg fisher^{-1} day^{-1} (de Boer et al. 2001). Fishers on Inhaca Island are thought to have generally better catch rates than national averages (de Boer et al. 2001). However, we applied the 62% decline inversely to the 2003 national catch rate of 2.47 kg fisher^{-1} day^{-1} (derived above) to derive an estimated catch rate of 6.5 kg fisher^{-1} day^{-1} at the start of the civil war in 1975. Hence, the national small-scale catch rate was assumed to have declined from an estimated 6.5 kg fisher^{-1} day^{-1} in 1975 to 2.47 kg fisher^{-1} day^{-1} in 2003. To remain conservative, the catch rate was assumed constant (6.5 kg fisher^{-1} day^{-1}) for the 1950–1974 pre-war period (Figure 2). Assuming that the civil-war driven migration impacted Inhaca Island less than mainland coastal regions, the catch rate decline may even have been larger along the mainland coast. Therefore, our inverse application of the change in catch rates from Inhaca Island remains conservative with regards to the potential magnitude of pre-war mainland catch rates.

Estimates of fisher populations were available for seven different years spanning 1965–2002 (Table 2); however,

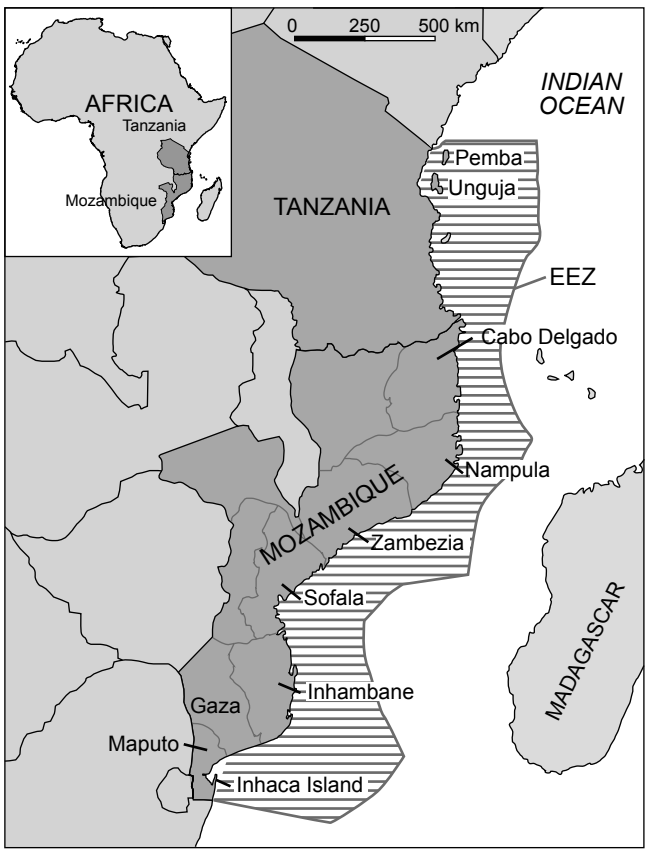

Figure 1: Map of Mozambique and Tanzania (mainland and the two main islands Pemba and Unguja, which comprise Zanzibar) including the Exclusive Economic Zones (EEZ), and the coastal provinces of Mozambique. Inhaca Island in the province of Maputo is also shown

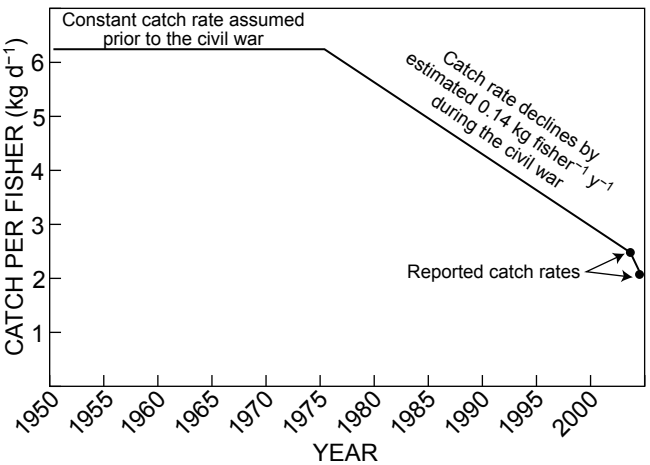

Figure 2: Small-scale catch rates (catch per fisher) estimated and reported for Mozambique, 1950–2004; catch rate was assumed to decline with the start of the civil war in 1976

Table 1: Number of fishers by province, and the proportion of fishers represented in Mozambique's national fisheries statistics

Coastal province	2002 census of fishers[a]	National fisheries statistics		
		Percentage represented[b]	Number of fishers represented	Number of fishers not represented
Cabo Delgado	26 609	0	0	26 609
Nampula	39 585	70	27 710	11 876
Zambezia	14 151	100	14 151	0
Sofala	11 838	100	11 838	0
Inhambane	17 784	70	12 449	5 335
Gaza	1 497	0	0	1 497
Maputo	6 783	100	6 783	0
Total	118 247	62	72 930	45 317

[a] IDPPE (2004)
[b] KPMG (2006)

estimates prior to 1995 excluded data on collectors. Therefore, we took the average proportion of collectors to total fishers for 1995 and 2002 (45%), and applied this average proportion to estimate collector populations for the earlier years (Table 2). The ratio of fishers plus collectors to the entire Mozambique population (based on interpolated census data from www.populstat.info) was determined for these years, while ratios for the remaining years were estimated proportional to the whole population trends. This derived time-series of ratios was used to estimate numbers of fishers and collectors for 1950–2004 (Figure 3). Combining these derived fisher plus collector estimates with the derived catch rates provided total small-scale catch estimates from 1950 to 2004.

Industrial sector

Landings

Historically, more resources have been allocated to monitoring and reporting the fisheries catch by the industrial sector, suggesting that reports presenting industrial catch can conservatively be accepted as best-data for total industrial landings (Table 3). For years when data were unavailable, catch estimates were interpolated linearly between adjacent periods, thus assuming that no direct correlation existed between industrial catch development and human population trends or civil war (see also Zeller et al. 2006b).

Discards

The increase in industrial shrimp fisheries in the 1970s (Nelson 1984) meant a corresponding increase in bycatch (landed) and discards (not landed). Bycatch is likely under-reported, whereas discards are entirely absent from the reported data. Schultz (1997) reported an annual bycatch of 21 000–29 000 t between 1993 and 1996, while in 1982 discards were estimated at 15 000–20 000 t (Anon. 1982). However, it is thought this latter amount is conservative and was at least 25 000 t (Tenreiro de Almeida, former Secretary of State for Fisheries, Mozambique, pers. comm.). Assuming 25 000 t of discards in 1982, and comparing this to the total reported shrimp catch of 8 900 t for the same year (based on data supplied to FAO), resulted in a 2.8:1 ratio of discards to shrimp catch. This ratio was applied to the time-series of reported shrimp catches to produce a time-series of estimated discards (Table 4). Total reconstructed catch was derived from estimates of small-scale catch plus industrial catch plus discards.

Tanzania

Examination of data Tanzania supplied to FAO as of December 2008 revealed that data for Zanzibar, a region of Tanzania comprised of two large offshore islands, are missing from official statistics, because annual totals of the national data for mainland Tanzania (i.e. Tanganyika) matched the total landings supplied by the United Republic of Tanzania to

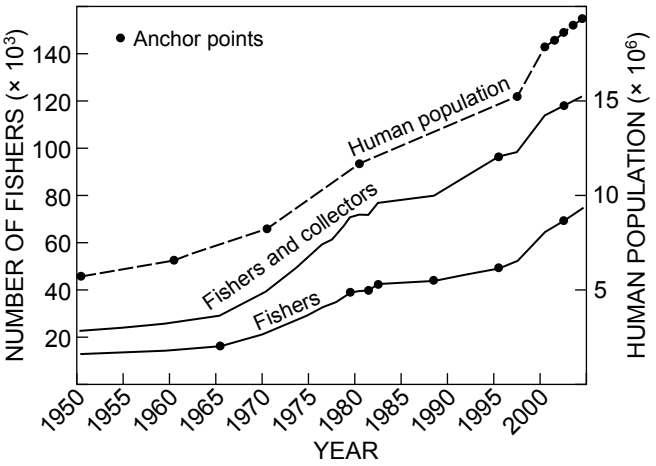

Figure 3: Number of fishers, number of fishers and collectors, and human population for Mozambique, 1950–2004. Reported data indicated by anchor points

Table 3: Industrial sector reported catches and sources for Mozambique, 1955–2003

Year	Reported catch (t)	Source
1955–1960	3 300–3 900[a]	Krantz et al. (1986)
1961–1975	3 285–15 655[b]	DNP (1976)
1981	24 650	Konigson et al. (1985)
1982	20 000	SIDA (1982)
1985	49 100	Gréboval et al. (1994)
1986	51 610	Gréboval et al. (1994)
1987	48 050	Gréboval et al. (1994)
1990	33 436	Gréboval et al. (1994)
1994	23 229	Charlier (1995)
2003	22 037	Tembe (2004)

[a] 1955 catch was 3 300 t; 1960 catch was 3 900 t

[b] 1961 catch was 3 285 t; 1974 catch was 15 655 t

Table 2: Fisher, collector and human population data for Mozambique, and ratio of fishers and collectors to total population with sources and estimates

Year	Reported fishers	Reported collectors	Source	Collector estimates[a]	Fishers and collectors	Population (×10⁶)	Ratio (fishers and collectors 1 000 people⁻¹)
1965	16 131	–	Herrick et al. (1969)	13 198	29 329	7 414	3.96
1979	38 883	–	Konigson et al. (1985)	32 086	70 969	11 329	6.26
1981	39 609	–	Debeauvais et al. (1990)	32 407	72 016	11 885	6.06
1982	42 300	–	Konigson et al. (1985)	34 609	76 909	12 097	6.35
1988	43 876	–	Debeauvais et al. (1990)	35 899	79 775	13 369	5.97
1995	49 045	47 378	IDPPE (1998)	–	96 423	14 854	6.49
2002	69 359	48 888	IDPPE (2004)	–	118 247	18 676	6.33

[a] Based on a 45% proportion of collectors to total fishers, as derived from reported data for 1995 and 2002

– Denotes no data

FAO.[2] This may be an artefact of the complexity and history of Tanzanian bureaucracy: mainland Tanzania and Zanzibar each have autonomous institutional and legal structures for managing of and reporting on fisheries. It is clear that Zanzibar's reported data are not supplied to FAO as part of the annual national reporting by the United Republic of Tanzania. We estimated total catches for the mainland and Zanzibar separately, and combined these estimates to derive country totals.

Mainland Tanzania

For the mainland, we retained the data as reported to FAO for the years 1950–1969. However, it is possible that catches from this period were underestimated. A new data collection system implemented in Tanga (the northernmost province) in the early 2000s suggested that catches since the 1970s were at least 35% greater than previously reported (Verheij et al. 2004). Hence, we increased the 1970–2005 time-series of reported marine fisheries catches for the mainland by 35%. This adjustment is conservative (M Guard, Eco2 Dive Centre, pers. comm.).

This adjusted time-series of fisheries catches did not include any catches by collectors (shore-based collectors and boat-based divers). Mainland frame surveys estimated 576 and 796 collectors in 2001 and 2005 respectively (Fisheries Division 2002, 2005). For the period 1970–2000, for which we had reliable number of fishers, the ratio of collectors to fishers from 2001 (3:100) was applied to the 1970–2000 time-series of number of fishers to derive estimated number of collectors (Table 5). The numbers of collectors for 2002–2004 were estimated using linear interpolation between the 2001 and 2005 reported numbers of collectors. To obtain estimates of collector catch, we used the reported collector catch rate and effort data for Matemwe, Zanzibar (4.0 kg collector^{-1} day^{-1} for 240 days per year; Jiddawi and Stanley 1999). Because there were no data on the number of fishers and number of collectors from 1950 to 1969, the estimated 1970 collector catch as a ratio to the 1970 fishers catch (0.8:100) was used to conservatively estimate collector catches from this period. Total marine catch estimates for the mainland were obtained by combining the adjusted catch time-series for fishers and the estimated catch time-series for collectors.

Zanzibar

As discussed in Jacquet and Zeller (2007b), for Zanzibar (consisting mainly of the two islands Unguja and Pemba), fisheries catches by boat-based fishers were available from 1980 to 2005 from Zanzibar's fisheries department (supplied by the Department of Fisheries and Marine Resources, Zanzibar), whereas the missing data for 1989 were interpolated.[2] For 1980 and 1981, these catch data were thought to represent Unguja Island only, because catch levels were substantially lower than for 1982 onwards and similar to 1982–1983 Unguja catches. To estimate the 1980 and 1981 catch for Pemba, we utilised frame survey information on the number of fishers for 1980 (Ngoile 1982) and 1985 (Carrara 1987). We used the 1980 reported catch

[2] From August 2009, Zanzibar's reported landings from 2000 onwards are available via FAO FishStat

Table 4: Decadal industrial shrimp catch and estimated discards for Mozambique, 1950–2000

Year	Reported shrimp catch (t)[a]	Estimated discards (t)[b]
1950	0	0
1960	400	1 120
1970	800	2 240
1980	11 700	32 760
1990	10 539	29 509
2000	11 195	31 346

[a] FAO FishStat Plus, Version 2.3, 2000

[b] Based on 25 000 t of discards for the early 1980s, a discard:shrimp ratio of 2.8:1 was estimated

Table 5: Number of fishers and collectors on the Tanzanian mainland, 1970–2005

Year	Number of fishers	Number of collectors
1970	6 719[a]	202
1971	8 200[b]	246
1972	8 531[b]	256
1973	8 188[b]	246
1974	8 331[c]	250
1975	8 500[b]	255
1976	11 157[d]	335
1977	10 033[d]	301
1978	9 800[b]	294
1979	8 100[b]	243
1980	7 600[b]	228
1981	13 200[b]	396
1982	13 500[b]	405
1983	9 500[b]	285
1984	13 783[b]	413
1985	11 392[e]	342
1986	12 619	379
1987	12 739	382
1988	13 855	416
1989	13 887	417
1990	16 178	485
1991	16 361	491
1992	15 027	451
1993	15 027	451
1994	15 027	451
1995	13 822	415
1996	13 822	415
1997	13 822	415
1998	20 625	619
1999	20 625	619
2000	20 625	619
2001	19 071	576[f]
2002	19 071	631
2003	19 071	686
2004	19 071	741
2005	29 754	796[g]

[a] Fisheries Division (1970)

[b] Bagachwa et al. (1994)

[c] Fisheries Division (1975)

[d] Mkisi (1984)

[e] 1985–2005: F Sobo, Fisheries Division, Tanzania, pers. comm.

[f] Fisheries Division (2002)

[g] Fisheries Division (2005)

Table 6: Number of fishers and collectors for the islands of Unguja and Pemba (comprising Zanzibar, Tanzania) for 1980–1989. Italicised numbers indicate interpolated values, whereas '–' indicates data not estimated

Year	Number of fishers (Ungaja)	Number of fishers (Pemba)	Collectors (Zanzibar total)
1980	5 884[a]	7 058[a]	4 555[a]
1981	*5 954*	*7 194*	*3 937*
1982	*6 024*	*7 330*	*3 319*
1983	*6 094*	*7 467*	*2 700*
1984	*6 164*	*7 603*	*2 082*
1985	6 234[b]	7 739[b]	1 464[b]
1986	–	–	*1 679*
1987	–	–	*1 894*
1988	–	–	*2 108*
1989	–	–	2 323[c]

[a] Ngoile (1982)
[b] Carrara (1987)
[c] Mongi (1991)

for Unguja and the 1980 number of fishers on Unguja (i.e. 5 884; Table 6) to calculated the 1980 Unguja catch rate of 0.67 t fisher^{-1} y^{-1}. We assumed this catch rate also applied to Pemba, and used the number of Pemba fishers for 1980 (i.e. 7 058; Table 6) to establish Pemba catch in that island for 1980. For 1981, we interpolated the number of fishers between the 1980 (Ngoile 1982) and 1985 (Carrara 1987) frame surveys (Table 6), and repeated the steps used for 1980 to determine the 1981 catch estimates for Pemba. For all other years between 1980 and 2005, boat-based fisheries catch data were accepted from the Zanzibar fisheries department dataset. However, these data did not include the catch by collectors, except for the years 1980 (Ngoile 1982), 1985 (Carrara 1987) and 1989 (Mongi 1991). We interpolated the number of collectors between these years to determine the number of collectors from 1980 to 1989 (Table 6). Jiddawi and Stanley (1999) estimated catch rates for collectors in Matemwe, Zanzibar, to be 4.0 kg collector^{-1} day^{-1}. At Matemwe, fishers go to sea 16–20 days per month, whereas in other parts of Zanzibar fishers go to sea as often as 25 days per month (N Jiddawi, Institute of Marine Sciences, pers. comm.). Here, we assumed this collector catch rate (4.0 kg collector^{-1} day^{-1}) to represent the average rate for all Zanzibar collectors, and also assumed an effort of 20 days per month, resulting in an annual rate of 0.96 t collector^{-1} y^{-1}. This assumption is conservative for earlier years because catch rates appear to have declined (N Jiddawi pers. comm.). This rate was multiplied by the derived time-series of collectors (Table 6) to estimate collector catches from 1980 to 1989. Because 1989 was the last reliable data point for the number of collectors in Zanzibar, we used the ratio of collector catch to boat-based catch in 1989 (23:100) to estimate a time-series of collected fish from 1990 to 2005 based on assumed proportionality to reported fisheries catches.

For 1950–1980, we had only two data points for estimated catches, 1959 and 1975, which were assumed not to include collectors. We linearly interpolated these boat-based catch data between 1959 and 1975 and between 1975 and 1979. For 1950–1958, we assumed that catches increased at the same rate as between 1959 and 1975, hence the catches were extrapolated backwards from 1959 based on the linearly increasing catches interpolated annually from 1959 to 1975 (an increase of 250 t y^{-1}). To estimate catches taken by collectors, we used the ratio of collector catch to boat-based catch in 1980 (33:100) and carried this ratio back unaltered to 1950. We then aggregated the boat-based and collector catch for a time-series of Zanzibar marine fisheries catches from 1950 to 2005. Finally, we aggregated the estimated total catches for Zanzibar and the mainland to obtain an estimate of total catches for the United Republic of Tanzania from 1950 to 2005.

Results

Mozambique

Data supplied to FAO by Mozambique suggested a steady increase in landings from 7 800 t in 1950 to a peak of 37 130 t in 1981, before declining to around 25 000 t y^{-1} in the late 1990s–early 2000s (Figure 4a). In contrast, the estimated total marine fisheries catches as reconstructed here suggested catches of around 55 000 t in 1950, followed by a rapid increase in total catches starting in the late 1960s and continuing through the civil war, reaching a peak of around 220 000 t in 1986, before beginning a decline (Figure 4a). Using the reconstruction approach as outlined here, Mozambique's annual catches were potentially between 47 000 and 177 000 t y^{-1} higher than the reported data suggested. Since 2000, the data supplied to FAO reported annual catches between 24 000 t and 32 000 t, whereas our study suggested annual catches between 150 000 t and 170 000 t for the same time period (Figure 4a).

The reconstructed time-series data also illustrate the magnitude of small-scale catches. In terms of tonnage, the small-scale sector caught nearly six times the amount of the industrial sector (Figure 4b). Important to note also is the magnitude of estimated discarding due to industrial shrimp fisheries in Mozambique, accounting for nearly 900 000 t over the time period considered here (Figure 4b). Excluding freshwater catches and ignoring imports and exports of industrial catches, and assuming that the entire small-scale catch was consumed within Mozambique, the average per capita seafood consumption over the 55-year period was 9.6 kg person^{-1} y^{-1} for Mozambique. From 2000 to 2004, marine seafood consumption was estimated between 4.8 kg person^{-1} y^{-1} and 6.7 kg person^{-1} y^{-1}.

Tanzania

Data supplied to FAO by Tanzania suggested an increase in fisheries landings from around 14 000 t y^{-1} in the 1950s to a peak of nearly 62 000 t y^{-1} in 1996, followed by a slow decline. In contrast, the reconstruction showed that total fisheries catches increased from 25 000 t y^{-1} in the 1950s to around 97 000 t y^{-1} in the 2000s (Figure 5a). The present study illustrated that, for the Tanzanian mainland and Zanzibar, total marine catches over the past two decades averaged 66 000 t y^{-1} and 17 000 t y^{-1} respectively. Thus, mainland catches were nearly four times those of Zanzibar (Figure 5b).

For Mozambique and Tanzania combined, the overall reported catches potentially underestimated total reconstructed

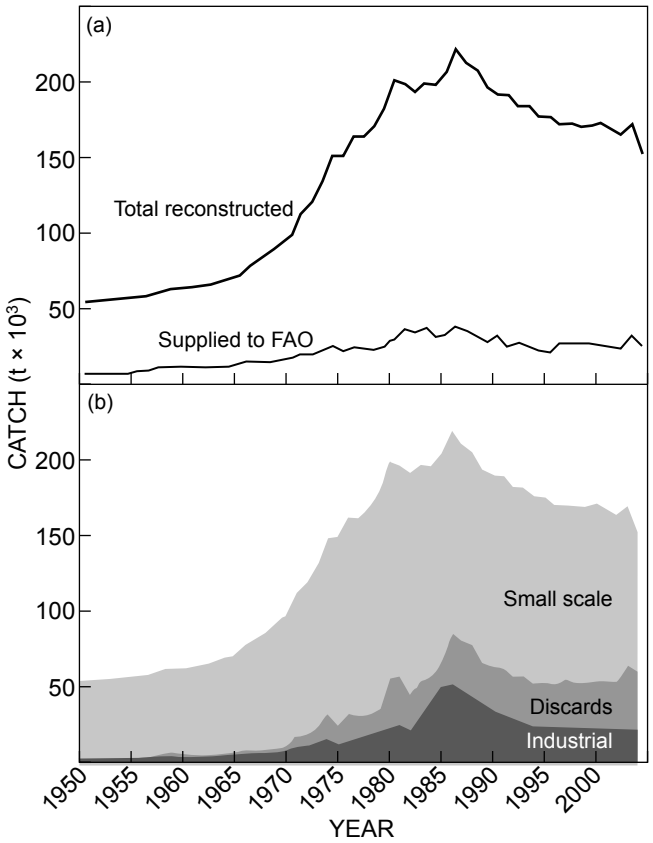

Figure 4: Mozambique's marine fisheries catches, 1950–2005, showing (a) total reconstructed catches compared to data supplied to FAO and (b) catch reconstructions by sector

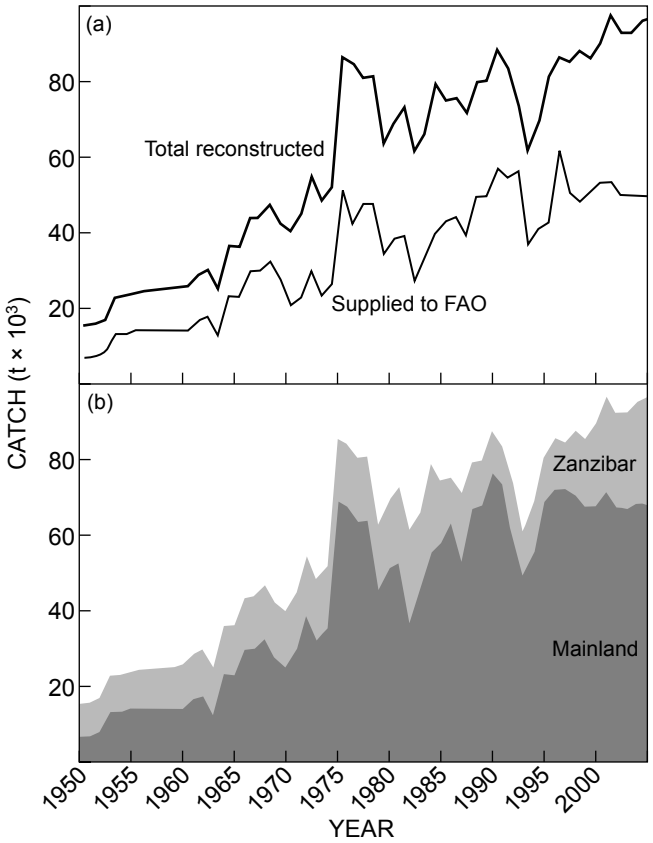

Figure 5: Tanzania's marine fisheries catches, 1950–2005, showing (a) total reconstructed catches compared to data supplied to FAO and (b) reconstructed catches separated by Zanzibar and mainland

catches in this part of Africa by a factor of 3.5 over the period 1950–2005. For each country separately, reported data were 6.2 and 1.7 times lower than reconstructed total catches for Mozambique and Tanzania respectively.

Discussion

The Western Indian Ocean represents 8% of the world's oceans but, according to data supplied to FAO by member countries, generates only 4% of reported global landings (van der Elst et al. 2005). As we have shown by examples of Mozambique and Tanzania, such an assessment is more an indicator of incomplete reported data than underutilised fisheries productivity. According to our reconstructions, Mozambique and Tanzania's marine fisheries catches from 1950 to 2005 were 6.2 times and 1.7 times greater respectively than those reported to FAO based on country reports. These findings support broader research in the region that suggested that data supplied to FAO do not reflect the real catch (van der Elst et al. 2005). Our findings also reinforce what Pauly and Zeller (2003) emphasised: 'there is a need to complement the data supplied to FAO and incorporate estimates of previously ignored catches, even if these are based on estimations and assumptions'.

In both countries, marine fisheries data estimated and recorded by the national fisheries divisions were not extrapolated countrywide (e.g. IIP 2003, 2004). Furthermore, the catch by collectors (fishers on foot and divers) was often omitted from official fisheries data (Herrick et al. 1969, Konigson et al. 1985, Debeauvais et al. 1990, F Sobo pers. comm.). The reconstruction for Mozambique, as undertaken here, now accounts for catches by all fishers and collectors, as well as discards by the shrimp fishery. For Tanzania, reconstructed catches now incorporate Zanzibar, as well as catches by collectors on both the mainland and Zanzibar. They also conservatively compensate for general underreporting on the Tanzania mainland. These reconstructed data better reflect total catches taken from marine ecosystems compared to data reported by these countries to FAO. Although there is a level of uncertainty associated with our estimates, they were based on conservative assumptions throughout. The reconstructed data better illustrate historical trends and patterns of total sea life extractions for Mozambique and Tanzania over the past 50 years. Importantly, the catch estimates presented here are closer to the truth than the alternative of continuing to rely on reported landings only, and therefore to assume that 'no data' means 'no catch'.

The present study is specific to Mozambique and Tanzania; however, the situation presented is relevant for other African countries, for which Mozambique and Tanzania may be representative. Declining trends in fisheries catches over time, such as those documented here for Mozambique, suggest overfishing of local resources, especially in light

of the observed declining catch rates. Given the common ontogenetic linkages between inshore (shallow) and offshore (deeper) shelf waters for many fish and invertebrate resources (e.g. Zeller and Pauly 2001), the heavy fishing pressure by the small-scale fisheries in shallow, nearshore waters can be exacerbated by catches granted through revenue-generating foreign access agreements to the same resources (especially demersal), as has been shown for West Africa (Kaczynski and Fluharty 2002). This may substantially impact local food security, and needs to be considered carefully.

In recent years, the Mozambique's Fisheries Research Institute has made great improvements in data collection, which is reflected in recent government reports (e.g. Afonso 2006). The new system has resulted in higher estimates of catch, 800% greater than estimates derived using previous approaches (Afonso 2006). These recent improvements to data monitoring may be adopted for the data supplied to FAO after several years of reporting have taken place (D Gove, IIP, pers. comm.). But unless Mozambique, and thereby FAO, retroactively use these data and knowledge to hindcast back to 1950 and adjust the substantial historic under-reporting, the future data will continue to misrepresent the historic baseline, with potentially dire consequences for ecosystem-based interpretation of the effects of fishing.

According to the present study, small-scale fisheries catches were substantial and, on average, accounted for 75% of total marine catches. Inshore, small-scale resources are important to coastal people, many of whom live a marginal existence. The reconstructed small-scale fisheries catch estimates suggest that fish is a more important part of food security than previous estimates indicated. Our reconstruction showed that previous per capita fish estimates based on reported data (e.g. 3 kg person^{-1} y^{-1} for Mozambique but 8 kg person^{-1} y^{-1} for sub-Saharan Africa as a whole)[3] substantially underestimated true consumption. Using the reconstruction, average per capita marine fish consumption over the 55-year period was 9.6 kg person^{-1} y^{-1}. In Mozambique and Zanzibar, collectors play an important role in food security, because the invertebrates they collect are often eaten at home while the fish caught by fishers at sea are sold (Semesi and Ngoile 1993, de Boer and Longamane 1996, de Boer et al. 2000, Guard et al. 2000, Silva 2006). On the Tanzanian mainland, collecting appears to occur at a reduced rate, compared to Mozambique and Zanzibar, possibly on account of the availability of alternative sources of animal protein.

There are several reasons for the concern over the status of fisheries in Mozambique and Tanzania. Historically, fishers in Tanzania were considered better off than farmers (Wenban-Smith 1965), but this has changed since more people have entered the fishery (Shao et al. 2003). The decline in catch rates is coupled with other indications of overexploitation, e.g. reduced mean size and decreased abundances (Kristiansen and Poiosse 1996, de Boer et al. 2001) and the widespread use of unsustainable fishing practices (Lopes and Gervásio 1999, Verheij et al. 2004). Reconstructed data show that the number of small-scale fishers in both countries has quadrupled over the past four decades. Combined, fishing practices and fisher-population pressure suggest that 'Malthusian overfishing' (Pauly 1997) could likely be occurring in Mozambique and Tanzania. Although there are attempts at fisheries management in both countries, and the level of enforcement has increased significantly in Mozambique (Afonso 2006), enforcement of existing legislation should be a high priority along with parallel efforts to develop, implement and support additional community-based management actions, such as community-based, no-take fishing zones and bans on unsustainable gears (McClanahan et al. 1999, 2006, 2009). However, focus on fisheries and related measures alone will not be sufficient as overall poverty needs to be addressed through vigorous and innovative moves to enhance and support alternative livelihood options.

The present study illustrates that the marine fishing sector is a far more important asset to national food security for Mozambique and Tanzania — and the magnitude of resource extraction much greater — than has been previously recognised. In both countries, little data do not mean small catches. These reconstructions provide impetus for the reconsideration of the role of fish in domestic food security, and for caution in allowing international markets to stimulate additional fishing effort, especially through ill-conceived foreign access agreements.

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