Estimating Total Fishing Effort over Tidal to Annual Periods in the Diani-Chale-Gazi Reef Fishery in Kenya

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ABSTRACT

The Diani-Chale area of the southern Kenya coast has been the subject of considerable fisheries research and management for over 2 decades, however a detailed estimate of fishing effort is not yet available. A seasonal census of fishers and activity patterns was held from 2003 to 2006, to capture variability by tide, lunar phase and season in fishing effort by all local gear types. The confluence of religious and lunar/tidal calendars results in a very strong cyclical pattern in fishing, with low tides during the full moon spring phase in the northeast monsoon being the preferred time for fishing and half moon neap phase in the southeast monsoon the least preferred. On average, daily fishing effort was 27.3±8.9 to 42.3±6.6 fishers at each landing site, in the SEM and NEM, respectively. Over a full year this exerts a pressure of 85,551 fisher-days in Diani-Gazi. The total fisher population is estimated at 570 fishers, and the total annual catch, based on gear-specific catch rates is estimated at 403 tonnes. Both spearguns and beach seines are illegal gears in Kenya but between them they support 37% of fishers in the NEM and 57% in the SEM in the study area. Spearguns alone account for 33% of the total fishery. Based on their importance and current knowledge on impacts of these gears it is recommended that beach seine regulation be strengthened and rationalized, but that the social importance and limited evidence for damaging effects of spearguns will require softer regulations to reduce their prevalence but not eliminate them totally. Extrapolated to the national level, recognizing many limitations in doing this, these results from Diani-Gazi suggest the national artisanal fishery employs almost 23,000 fishers catching over 16,000 tonnes of fish annually. Both figures are 2-3 times higher than officially reported levels of 10,000 fishers and 5-7,000 tonnes/year, respectively.

INTRODUCTION

The Diani-Chale of the southern Kenya coast area has suffered intense reef degradation for decades (Khamala 1971), evident through lower abundance of finfish and coral cover, increased numbers of sea urchins and increased turf algae cover (McClanahan and Muthiga 1987, Obura, 2001), nonetheless the area supports one of the oldest artisanal fishing communities in Kenya (McClanahan et al., 1997). Nevertheless, a precise estimate of the number of fishers in the area is not yet available.

Obura, D.O., Tamelander, J., & Linden, O. (Eds) (2008). Ten years after bleaching - facing the consequences of climate change in the Indian Ocean.CORDIO Status Report 2008. Coastal Oceans Research and Development in the Indian Ocean/Sida-SAREC. Mombasa. http//:www.cordioea.org

Table 1. Fishing gear used in the study sites.

Local name	English Name	Description.
Bunduki	Speargun	Locally made using wooden or metal tube shafts, with steel harpoon powered by rubber/inner tube strips. Illegal.
Mkuki	Spear	Metallic rod (steel) sharpened at one end, may have a wooden handle or not, mostly targeting octopus and rays. Traditional.
Shomo	Harpoon	Wooden Harpoon without metallic tips mostly targeting octopus. Traditional.
Malema	Basket traps	Wooden strips woven in hexagonal patterns with an entry point for the fish, with pieces of rocks attached to weigh the trap down. Traditional.
Uzio	Stake traps	Intertidal traps and fences (used without boat). Traditional.
Mshipi	Hand line (hook and line)	Hook and line, made of steel hooks and nylon monofilament, uses bait. Modified traditional.
Nyavu	Gill net	General term for fishing nets, made of nylon, but of various mesh sizes and used differently. Modified traditional.
Jarife	Bottom set net	Net with large mesh size targeting large fish such as sharks, mesh size range of 5 cm to 12 cm Usually set offshore.
Nyavu ya kutega	Bottom set net	Used similar to *jarife*, smaller mesh size ranges from 1.5-2.5 cm..Set in channels along the path of fish.
Cha cha cha	Cast net	Large net with fine mesh sizes of < 3cm, targeting sardines and sprats. The net is set in the middle of two nets of different mesh size, held on either side by two moving vessels.
Juya/kimia kigumi	Beach seine net	Large robust net, with small mesh size and fine-mesh cod end. Illegal as damages habitat, juveniles populations and bycatch. Requires large group of fishers to operate. Introduced gear.
	Ring net	Large seine nets, medium mesh from 5-9 cm, set in a circle, originally in deep water for fish shoaling at the surface. Two sets of ropes on the top and bottom, pulled by the fishers from a boat. Requires large group of fishers to operate. Introduced gear.

Kenya's Fisheries Department estimates that there are about 10,000 fishers directly engaged in fish production along the Kenyan coast (SOC 2008), however local level numbers are not known. The national estimate is derived from the number of licenses issued for fishers and boats registered at the different landing sites. However there are a number of problems with these methods. First, compliance is low, particularly for the registration of fishers. Second, an average of two or three fishers per traditional fishing vessel at the coast is used, however some vessels carry over 12-15 fishers (un-powered) or over 20 (powered). Also, the bulk of fishers neither have nor use vessels, particularly speargun fishers who swim and those who glean on the reefs and in shallow water. In addition, some people fish as a part time activity and likely to excluded in such counts.

Kenya's artisanal fishery includes a wide range of gear types (Table 1), the selection of which involves many historical and preference factors for individual fishermen (Glaesel, 1997), and these change with environment, social and economic pressures over time (Ochiewo, 2004). Further, fishing activity changes according to tidal and seasonal cycles as water depth, daylight and the monsoon seasons affect accessibility of different fishing grounds for different vessels and gears.

Participatory monitoring and research activities have been carried out from 1997 to the present in Diani-Chale, supported by CORDIO (Obura et al.

2002, Alidina, 2005). More broadly, the area has been the focus of community involvement in co-management of marine resources following many years of lack of any formal management since the area residents resisted the establishment of an MPA in 1994 by the Kenya Wildlife Service (Rubens 1996, Obura et al 2001, Alidina, 2004). A problem with fishery management in Diani-Chale has been the lack of a total effort estimate, i.e., knowing how many active fishers use the reef from one day to the next, and over relevant cycles such as the tidal, lunar and seasonal cycles and in a calendar year.

To address this issue, a seasonal census of fishers and activity patterns was held from 2003 to 2006, the results of which are reported here. The specific objectives of the study were to estimate the fisher population at the selected the landing sites, and determine if fishing activity follows temporal patterns related to the tides and seasons.

METHODOLOGY

The census was initiated in 2003 at four primary landing sites, Mwaepe, Mvuleni, Mwanyaza, and Chale, and by 2006 included measurements at the other three main landing sites in Diani-Chale: Mkwakwani, Mvumoni and Gazi (Fig. 1, Table 2). Data was collected during the two main monsoon seasons that determine the degree of fishing activity. The northeast monsoon (NEM), or *kaskazi*, from November to March, is characterized by gentler winds from the northeast and sunny, dry conditions making fishing easy. By contrast the southeast monsoon (SEM), or *kusi*, from April to October, is dominated by strong winds off the ocean from the southeast, with rough seawater conditions and frequent rain, making fishing difficult. Additionally, Kenya has a strong semi-diurnal tide (Tobisson et al., 1998), with two cycles in a 25 hour period and a strong cycling between neap and spring tides twice during a lunar phase (Fig. 2). The timing of the high tides and low tides over the lunar cycle is stable such that the peak of the morning high tide on the first day of the new or full

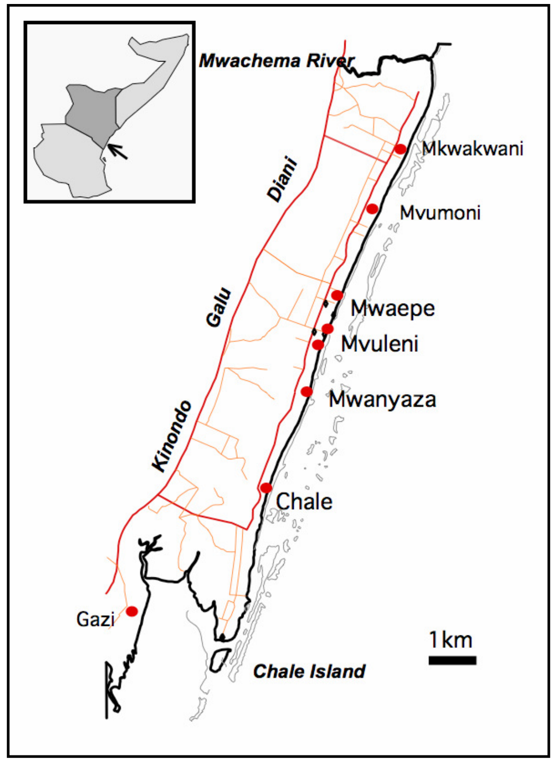

Figure 1. Map of the Diani-Chale area showing the fish landing sites sampled in this census.

Table 2. Number of years and seasons sampled at the main sites, 2003-6 and at the Additional sites less frequently.

Year	Season	Long term sites				Short term sites		
		Chale	Mvuleni	Mwaepe	Mwany.	Gazi	Mkwakw.	Mvumoni
2003	SEM	X	X	X	X			
2003-4	NEM	X	X	X	X			
2004	SEM	X	X	X	X			
2004-5	NEM	X	X	X	X	X	X	X
2005	SEM	X	X	X	X	X	X	X
2005-6	NEM	X	X	X	X	X	X	
2006	SEM	X						

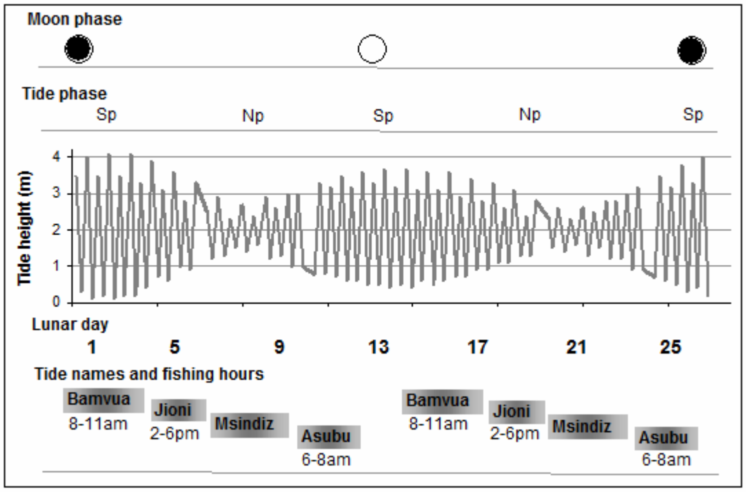

Figure 2. Lunar and tide calender for artisanal fishery in Diani-Chale. Moon phase, tidal phase (spring/neap), tide height (m), lunar day, local names for tides (see text for details) and optimum fishing times.

moon occurs at about 2 am ±30 min throughout the year (Jiddawi et al. 2002).

Sampling was conducted during a full lunar period at the peak of each season. Eight sampling days were chosen to fall on the spring and neap phases of the tidal cycle in each lunar month (e.g. days 2/3, 7/8, 15/16 and 22/23). On each day, data was collected for a full 12 working hours. Data recorded included: the actual time that each fisher or fishing unit set out to go fishing, the type of vessel used, the fishing gears used, and the total of captain and crew for each fishing unit. In addition, the name of the captain was recorded. For accurate recording the data collector was strategically placed at the landing site to record even those fishers who do not directly use the landing site when going in to fish, a common behavior among the spear gun fishers who do not have anchored vessels at the site. Depending on the time spent by fishers in the sea, the data collector also recorded the time each of the fishers returned.

Extrapolations from numbers of fishers to total catch for the Diani-Chale fishery used catch per fisher estimates from Maina et al. (2008).

RESULTS

The Moon, Tides and Fishing Activity

Islam is the main religion among fishers in Diani-Chale hence much emphasis is put on the Islamic calendar, and the lunar month (Fig. 2). This lasts approximately 29 days based on observation of the moon phase. The first time that the thin waxing crescent moon is visible after new moon (low in the evening sky just after sunset) marks the beginning of the month, and is designated day 1. The lunar month ends on days 28-30, depending on sighting of the moon. In practice, the dependence of the Islamic month on observation of the moon is affected by variability in local conditions (weather, presence of mountains, etc.), and this results in some disagreement on the precise day of the month. This can vary across countries, and also among religious leaders. At the study site, the sighting of the moon and days of the Islamic month are coordinated by radio broadcast Zanzibar, Tanzania, daily.

Local terminology is used in describing the tidal phase relative to the moon (Fig. 2): the days of the large spring tides bracketing the new or full moon are referred to as *bamvua*, which generally lasts for 3-4 days around the full moon from days 29- 3 and 15-18 of the Islamic calendar. Following these days, the tidal range decreases until a week later during neap tide when the range is smallest. This is known as *msindizo* and falls between days 8-10 and 21-23. The period associated with receding springs (*bamvua*) towards neaps (*msindizo*) is referred to as *maji ya jioni* as the good tides for fishing occur in the late afternoon (*jioni*) and occurs between days 5-7 and 18-20. The period as neap tides build back up into spring tides is called *maji ya asubuhi* as the good tides for fishing occur in the early morning (*asubuhi*) and occurs from days 11-13 and 24-27. *Msindizo* means to rest and during this period the malema (basket trap) fishers don't fish as the late low tide in the afternoon limits

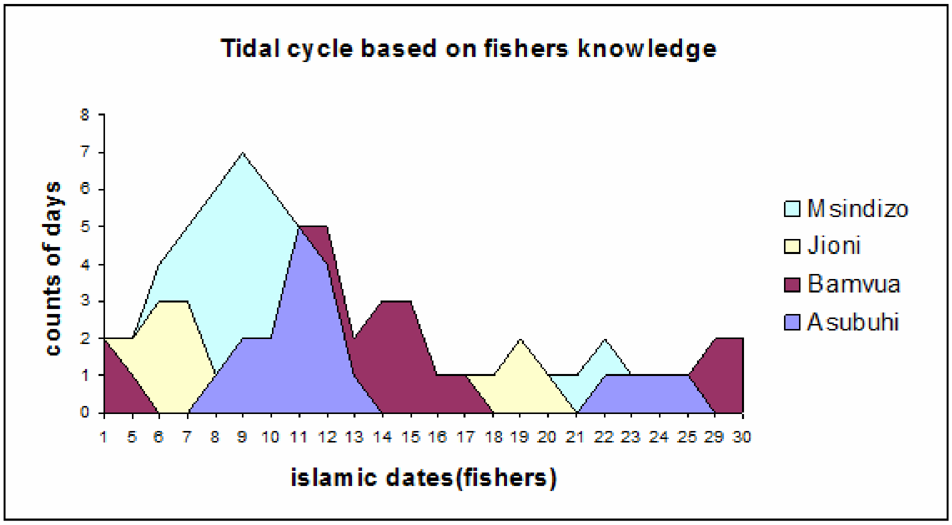

Figure 3. Reporting by fishers of the phases of the tidal cycle based on Islamic/ lunar day over the study period from 2003 to 2006.

them from setting their traps as a result of darkness. Additionally, there is a lore that traps should be set with the opening facing east and the baited side on the west, so that as the sun sets it illuminates the bait attracts the fish into the trap. But with the late low tide in *msindizo* it is dark shortly after setting the traps, and the fish are unable to see the bait, reducing the catch.

Of relevance here, data recorded over multiple lunar cycles and years results in overlap of some of the named phases (Fig. 3). Additionally, variation and overlaps in the actual day that have been reported by the fishers, are attributed by fishers to the morphology of the landing sites. For example, one fisher stated that the tides vary slightly from one end of the 10 km study site to the other (i.e. from Diani to Chale/Gazi); Diani has a shallow lagoon compared to Gazi and Chale, hence the tide recedes faster at the former. As a result the tide may be perceived as *asubuhi* in Chale but as *bamvua* in Mwaepe.

Fishing Effort

The main landing sites, Chale, Mvuleni, Mwaepe and Mwanyaza were sampled each season from the SEM 2003 (July) to NEM of 2005-6 (December-February), while the additional sites were sampled once in the NEM of 2003-4 and in NEM and SEM in 2005-6. On average, the number of fishers censused each day during the NEM (36-42) was higher than the SEM (26-27, Fig. 4), and with slightly lower variation during the NEM. The number of fishers varied greatly across the landing sites. Gazi had by far the highest number (Fig. 5) with over 100 per day during the NEM decreasing to less than 80 during the SEM, with

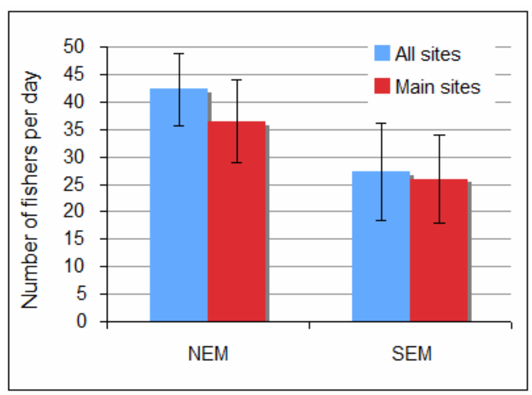

Figure 4. Number of fishers per lunar day by season at all landing sites, 2003 – 2006.

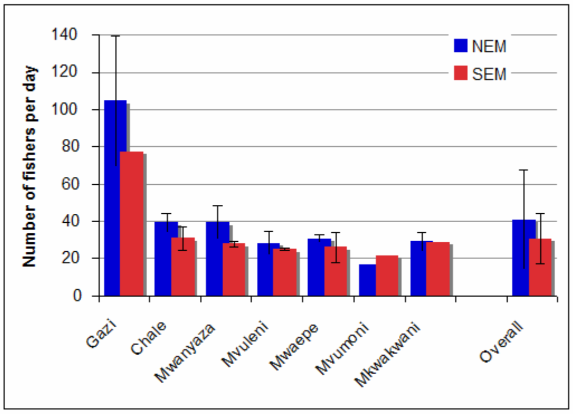

Figure 5. Number of fishers per day by season for each landing site in Diani-Chale.

wide error bars (the SEM was only sampled in one year, so no error bar shown). All other sites had more or less similar numbers, though the number decreased from Chale in the south (35-40 per day) to Mvumoni and Mkwakwani in the north (15-30 per day).

The number of fishers varied with the lunar and tidal cycles (Fig. 6). During the NEM however, variation was less, with almost no cyclical trend observable for fishers at all sites over the lunar phase (Fig. 6a), and only a small degree of variation over the tidal phase (Fig. 6b) showing slightly more during days 4-6 and slightly less during days 10-12, corresponding to *bamvua* and *msindizo* periods respectively. At the main sites the variation is more pronounced, with a distinct increase in fishers during the spring tides after the full moon (lunar days 15-18) and less during both neap tides (*msindizo*) on lunar days 8-11 and 22-26, and tidal days 8-10. Variation in fishers per day is more pronounced during the SEM particularly for the neap tide/msindizo days preceding the new moon around lunar days 20-24. At the main sites during the NEM, the slight increase in fisher activity during the spring tides (*bamvua*, tidal days 2-4, lunar days 2-4 and 15-18) is clearly shown.

From 2003 to 2006 there was no consistent trend in number of fishers per day at the landing sites. Overall, numbers stayed approximately the same (Fig. 7). Notably, there was neither an increase nor a decrease in fishing effort over the 3 years of the census (DSIC – stable fishery). Chale and Mwaepe

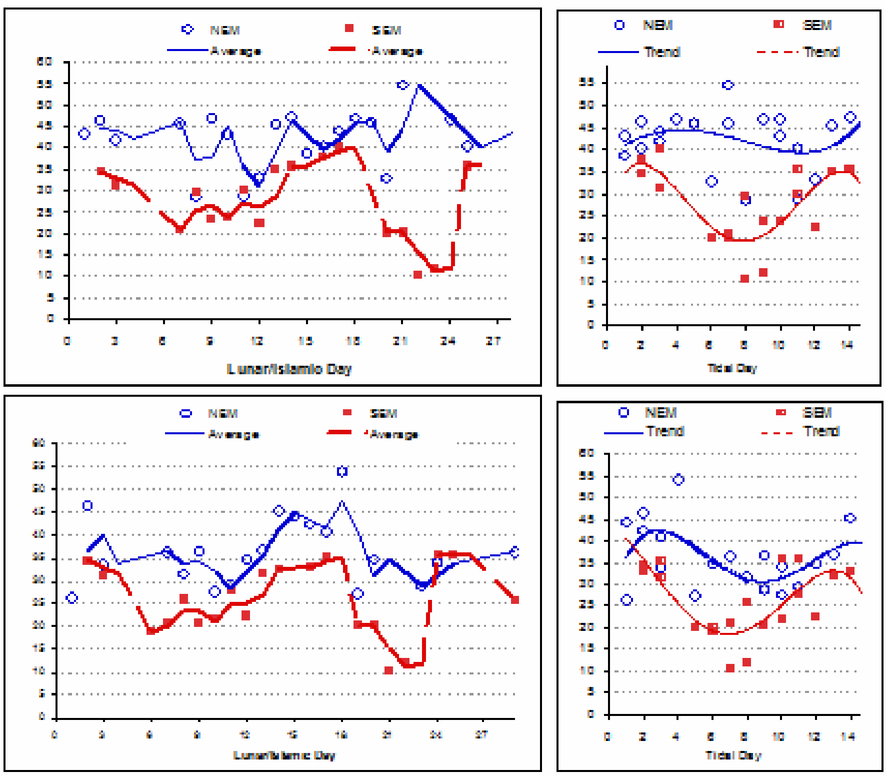

Figure 6. Numbers of fishers per day in each season, by lunar and tidal day. Top row – all sites, bottom row, main sites with continuous record, 2003-6. Left – plot of number of fishers by lunar/Islamic day. The trend lines are 3-point moving averages for each season. Right – plot of number of fishers by tidal day. The trend lines are 4th-order polynomials.

showed declines in numbers of fishers during the SEM while Mwanyaza and Mvuleni showed declines during the NEM.

Based on the number of fishers per lunar day, the total number of man-fishing-days per season and year can be calculated (Table 3). With an average of 42.25 and 27.30 fishers per day during the NEM and SEM respectively, we estimate that 1,225 and 792 fishers are active per lunar month, and 6,379 and 5,842 in each season. Using a global mean of 3.8 kg/fisher/day catch from the same dataset (Obura et al. 2002), these correspond to 24,240 kg and 22,201 kg of fish caught in the NEM and SEM respectively, and an annual catch for the Diani-Chale reef system of 46,442 kg.

The above numbers give the average daily fishing effort. However fishers don't fish every day, and we calculated a possible maximum number of fishers as follows: for each captain's name, the maximum crew size was taken and added together to estimate a total number of fishers. Table 4 shows the numbers estimated by landing site and year. Overall, the numbers suggest a population of approximately 570 fishers in the Diani-Chale area. With 36.4-42.2 active fishers on average at each of the seven landing sites in the two seasons (Fig. 4), and therefore 252 – 294 fishers overall across the study sites, 45-52% of all potential fishers are active on any given day.

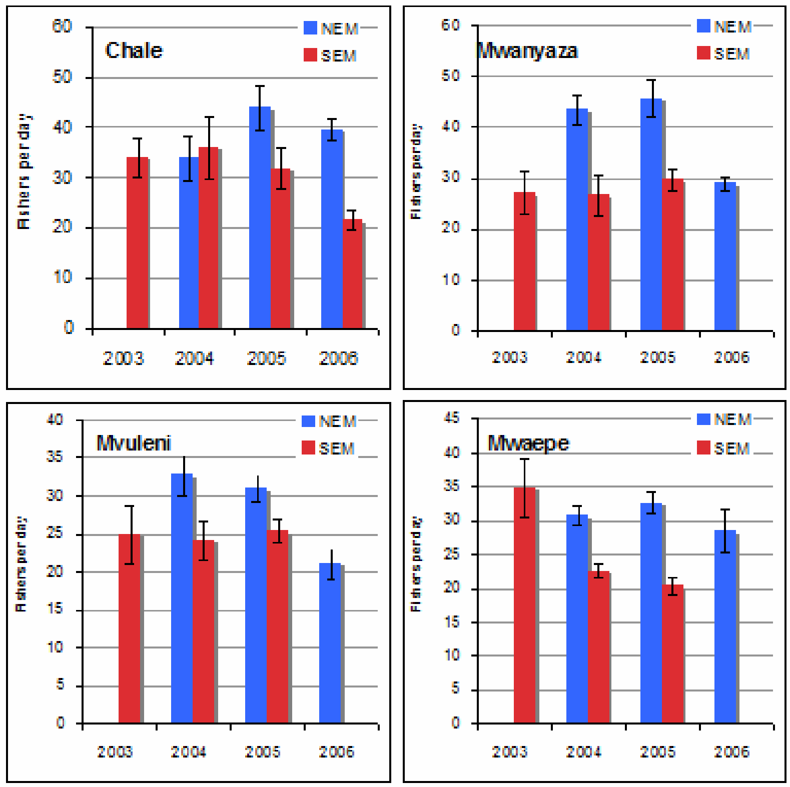

Figure 7. Change in average number of fishers per day during the NEM and SEM from 2003 to 2006 at the four main landing sites in Diani-Chale.

Gear Use

Spearguns were the most common gear used in both seasons, by 84 and 74 fishers in the NEM and SEM, respectively (Table 5) corresponding to > 30% of fishers among all sites combined, and slightly more in the main sites (Fig. 8). Beach seines, or juya, were the next most common gear (10-25%) due to their heavy use in Gazi particularly during the SEM (61 fishers per day). Next most common in use were the traditional gears hook and line (*mshipi*), gill nets (*nyavu*) and basket traps (*malema*), at 10-15% of fishers overall. Beach seines and ring nets at Gazi, and bottom set nets (*jarife*) at all sites showed strong seasonal differences in use. Ring nets and set nets are used outside the reef, so use is restricted to the calm NEM. Use of beach seines at Gazi is strongly seasonal, and predominant in the SEM when their use in shallows close to shore may favour them over other gears that need to be used in deeper waters, and due to a local regulation at the landing site restricting their use in the NEM in order to minimize conflict with others gears. Gill nets in Gazi were much more common during the NEM, and fishers may trade off between the two depending on the season.

Based on catch rates for each of the gear types

	Per landing site		Diani-Chale area	
	NEM	SEM	NEM	SEM
Number of fishers per day				
Mean	42.2	27.3	296	191
Standard deviation	6.6	8.9	46	62
Standard error of mean	2.3	3.0	16	21
Number of fisher-days per lunar phase				
# days	29	29		
Total fishing days	1,225	792	8,576	5,542
1 se range	68	86	473	604
Upper 95%	1,090	619	7,630	4,335
Lower 95%	1,360	964	9,522	6,749
Number of fisher-days per season				
Total (season)	6,379	5,842	44,654	40,897
1 se range	352	636	2,463	4,454
Total (annual)	12,222		85,551	
Estimated total catch				
Average catch per fisher	4.4			
Total (season)	28,068	25,707	196,476	179,948
Total (annual)		53,775		376,423

Table 3. Total fishing effort by lunar month and season for the average landing site and for the Diani-Chale areas as a whole (7 landing sites). NEM/SEM season transitions have been assigned as 1 April and 1 November, with 151 and 214 days in each season, respectively. Average catch per fisher for 2003-6 obtained from Maina et al., 2007.

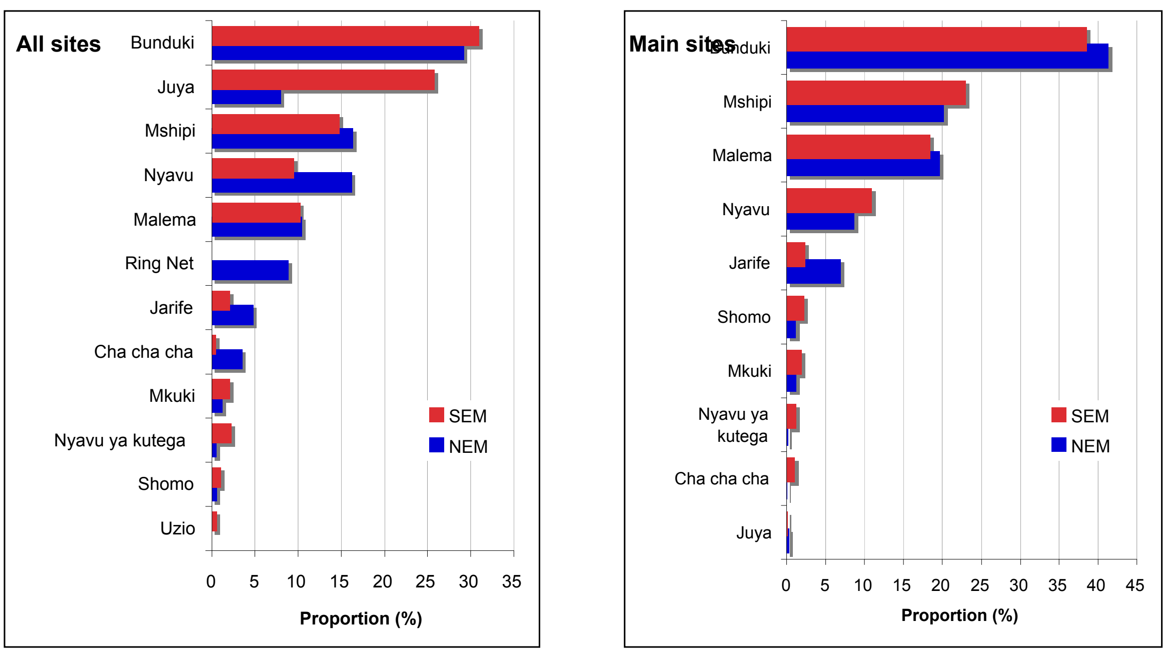

Figure 8. Proportions of different gear types used in the NEM and SEM, at all sites (left) and for the main study sites (right).

Table 4. Estimate of total number of fishers by landing site.

	2003	2004	2005	2006	Average
Chale	135	179	88	113	129
Gazi		220	155	67	147
Mkwakwani		94	67	46	69
Mvuleni	84	156	69	84	98
Mvumoni		38	35		37
Mwaepe	109	123	52	81	91
Mwanyaza	78	127	54	62	80
All		**810**	**466**		**571**

Table 5. Average daily number of fishermen using each gear at all the landing sites, by season.

	Chale		Mvuleni		Mwaepe		Mwanyaza	
Gear	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM
Bunduki	18.3	14.3	9.1	7.4	8.8	8.5	20.6	12.5
Juya	0.0	0.2	0.5	0.0				
Mshipi	2.7	1.5	7.6	7.3	9.8	9.1	7.7	7.6
Nyavu	2.9	4.8	3.8	3.9	2.6	1.2	2.6	2.3
Malema	6.3	5.9	6.2	3.3	6.8	6.9	7.7	4.3
Ring Nt								
Jarife	6.9	1.2	0.5	0.4	2.0	0.4	0.1	0.6
Cha	0.0	0.1	0.0	1.1			0.2	0.0
Mkuki	0.4	0.7	0.4	0.5	0.5	0.6	0.3	0.4
Ny kut.			0.2	1.1	0.0	0.2	0.1	0.0
Shomo	1.7	2.5						
Uzio								
Total	39.1	31.2	28.3	24.9	30.6	27.0	39.3	27.7

Table 5 continued.

	Gazi		Mkwakwani		Mvumoni		Total	
Gear cont.	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM
Bunduki	5.0	5.1	11.3	10.8	11.3	15.5	84.3	74.1
Juya	22.5	61.5					23.0	61.7
Mshipi	10.1	2.0	6.7	4.6	2.6	3.1	47.2	35.2
Nyavu	25.3	0.0	8.2	7.4	1.5	3.1	46.8	22.7
Malema	0.1	0.0	3.2	4.1			30.2	24.5
Ring Nt	25.6	0.0					25.6	0.0
Jarife	4.4	2.5					13.9	5.1
Cha	10.0	0.0					10.2	1.2
Mkuki	0.0	1.0	0.3	2.0	1.6	0.0	3.6	5.1
Ny kut.	1.3	4.1					1.6	5.5
Shomo							1.7	2.5
Uzio	0.1	1.4					0.1	1.4
Total cont.	104.4	77.6	29.5	28.9	17.0	21.8	288.2	239.1

Table 6. Estimated total catch by gear for the Diani-Chale artisanal fishery for northeast and southeast monsoons, annual total and proportion of total catch by gear. Estimates based on numbers from Table 3 and CPUE from Waweru et al., this volume). * uzio CPUE not estimated in Waweru et al., 2008, so is assigned the mean rate.

Gear	CPUE (kg/man/ trip)	Number of fishers daily		Total catch (kg)			% total
		NEM	SEM	NEM	SEM	Annual	
Bunduki	4.7	84.3	74.1	59,809	74,548	134,358	33%
Mshipi	4.2	47.2	35.2	29,903	31,679	61,582	15%
Juya	3	23.0	61.7	10,419	39,590	50,009	12%
Nyavu	3.3	46.8	22.7	23,331	16,024	39,355	10%
Ring Net	9.4	25.6	0.0	36,372	-	36,372	9%
Malema	3.7	30.2	24.5	16,879	19,435	36,314	9%
Jarife	6.2	13.9	5.1	13,043	6,776	19,819	5%
Cha cha cha	6.9	10.2	1.2	10,593	1,746	12,339	3%
Mkuki	3.3	3.6	5.1	1,801	3,633	5,434	1%
Nyavu ya kutega	2.8	1.6	5.5	678	3,280	3,958	1%
Shomo	2.6	1.7	2.5	649	1,406	2,055	1%
Uzio*	4.1	0.1	1.4	77	1,206	1,284	0%
Overall				203,554	199,325	402,879	

(Maina et al., 2008) the total contribution of each gear to the area fishery can be calculated (Table 6). Using individual gear CPUE the total catch estimated (402,879 kg) varies from the blanket estimate in Table 3 (376,423 kg). The high usage and CPUE of bunduki makes it the largest contributor to catch in the area, providing 33% of all fish caught in Diani-Chale and Gazi. Hook and line fishing contributes the next highest proportion of catch, at 15%. Beach seines (juya), because of their low CPUE, prohibition from most of Diani-Chale area and seasonally restricted use in Gazi, contribute 12% of all catch, in third place.

DISCUSSION

The combination of religious and lunar/tidal calendars results in a very strong cyclical pattern in fishing (Fig. 2), and the monsoon seasons strongly influence the amount of fishing during the year (Figs. 4, 5). Access to the sea is restricted by strong wind and waves, so fishing activity is lower during the southeast monsoon (SEM). Nevertheless, the fringing reef structure of the Diani-Chale coastline results in lagoon waters being sheltered from ocean waves for 4-6 hours during low tide each day so some access to the sea and to intertidal exposed reef flats is possible under almost any conditions, and fishing during the SEM is only slightly below levels in the NEM. At the short-term sights of Mvumoni and Mkwakwani there was no difference in fishing between seasons, and the former even showed higher fishing activity in the SEM. Gazi bay is a more open and exposed system than the fringing reef at Diani-Chale, and a larger increase in fishing during the NEM is clearly seen (Fig. 5).

During both seasons cyclical fishing activity by tidal and lunar phase was recorded (Fig. 6) however this was much less so during the NEM than during the SEM. Lower fishing activity during 'msindizo', or neap tides, was reported by fishers as being due to low tide falling in the late afternoon. During neap tides the lagoons are more exposed to ocean conditions as the higher low tide height results in the reef crest not being fully exposed – and during the SEM rougher conditions are experienced in the lagoon. Thus rougher conditions in the SEM appear to accentuate the lunar pattern of less fishing activity during neaps/ msindizo. It was interesting though, that while the lunar/tidal cycle in fishing activity was strong at the long-term sites (Diani-Chale) in the NEM, it was weaker with all sites considered (Fig. 6). This breakdown in the cycle may be dominated by fishing activity at Gazi, which is known for a larger proportion of migrant fishers, and for young men (who may be inexperienced) joining fishing crews as casual labour, for beach seines and ring nets. They may be less tied to traditions of fishing by the lunar and Islamic calendar, and the gears they operate, particularly ring nets (which may be used floating or on the bottom) in the NEM may be less dependent on tidal cycles that affect water depth and the use of bottom-dependent gears.

This study estimates a total population of 570 fishers operating in the 7 landing sites in Diani and Gazi, with daily numbers averaging 27.3±8.9 to 42.2±6.6 fishers per site, in the SEM and NEM, respectively. These fishers exert a pressure of 85,551 fisher-days per year in Diani-Gazi (Table 3). Using the mean CPUE for the area (Maina et al. 2008) we estimate a total catch of 376,423 kg of fish from the reef system, though using a more accurate method based on gear-specific CPUE, the total catch is 10% higher, at 402,879 kg (Table 6). A number of factors in the census method used tend to under-estimate the number of fishers each day. These include the activity of night-time fishers, who are common, avoidance of data collectors by fishers using illegal gears and fishers uncomfortable with research and monitoring for various reasons, and fishers operating from locations other than the 7 landing sites. Additionally, some of the landing sites, such as Mwanyaza, extend over several hundred meters of beach, and fishers may be missed. Factors that lead to over-estimating effort generally do not apply to the counting of fishers, but may occur in weighing and reporting of catch such as rounding up errors, related to pride in reporting high numbers. The method used to arrive at the total number of 570 fishers in the area may result in over-estimation, as the same individuals may be double-counted on different days if they fish with different captains, and some captains may work as crew on some days. However this does not affect the daily counts and total catch estimates.

Non-fishing activities and opportunities may influence fishing patterns noted here. The sites showing the least difference between NEM and SEM fishing effort, or a reversal of the expected pattern of less fishing during the SEM, are Mvuleni, Mwaepe, Mvumoni and Mkwakwani. These are the northern sites in the area (Fig. 1) and the most closely associated with the tourism industry in Diani. Gazi, Chale and Mwanyaza are all more isolated from tourism. The high season for tourism falls mainly in the NEM in December-March, and many fishers may either be employed in other tourism-related work, or opt to take tourists to the reef as this earns more than fishing, thus decreasing fishing effort.

Overwhelmingly the most important gear in the Diani-Chale fishery is the speargun (bunduki), operated by 30% of all fishers and catching 33% of all fish caught. The next dominant gears are far behind, with hook and line and beach seines more or less equal at about 15% of fishers using them and 12-15% of total catch. Fishers depend on spearguns and hook-and-line almost equally throughout the year, but beach seine use is highly seasonal, supporting 25% of fishers during the SEM (predominantly in Gazi, when other options are limited) but only 10% in the NEM. Both spearguns and beach seines are illegal gears in Kenya. Their combined importance in the artisanal fishery, supporting 37% of fishers in the NEM and 57% in the SEM, poses significant challenges for rational management. Both are gears of last resort in that they require minimal investment and experience of the fisher (Obura et al. 2002). Their greater use during the SEM when traditional gears are harder to operate, requiring more experience, emphasizes their importance as a last-resort source of income and protein.

The damaging effects of beach seines on fish populations has been amply demonstrated due to their high juvenile and by-catch rates (McClanahan, 2005), and the destructive effects of their use on corals and seagrass beds is clear from trampling by the operators to snagging and breakage when the nets are dragged. Less emphasized but increasingly apparent is their destructive impact on social structures. Welcomed early on because of their large overall catches and employment of local youth (Obura et al. 2002), they soon deplete fish populations locally and out compete other gears (McClanahan, 2004). The low per-fisher catch rate of beach seines (Table 6, Maina et al. 2008) does not appear to deter fishers from using it. This may be because the low individual catch is masked by the large overall catch, or individuals accept this trade-off as they do not have to invest in gear or preparation of their own. In some areas beach seine captains are exclusively outsiders, and ownership of the gear and boats is by the captains or non-fishing entrepreneurs (CORDIO/FAO, in prep). Thus from being independent fishers owning and operating their own traditional gear, and earning both cash and protein for home consumption, fishers become day-labourers. In the most extreme cases beach seine crews may carry home only their share of sales, without a share of low-grade fish which traditionally may be the main source of household protein (CORDIO/FAO, in prep).

Spearguns were banned by decree due to claims from fishing elders that they are destructive. However scientific evidence for this has not been shown, and the conflict between speargunners and other fishers is reminiscent of age-class and other social conflicts rather than fishing effects (Obura et al. 2002). The value of spearguns as an entry-level gear for inexperienced young fishers is clear. Because of this the social costs of their being illegal are potentially high, as strict enforcement would deprive one third of all Diani-Gazi fishers of their livelihood. The inconsistency in tolerating an illegal gear can be highly damaging to rational management, particularly at this time when authority and responsibility are being delegated to Beach Management Units, and fishers will have to face the multiple dilemmas of tolerating infringements or enforcing the law on their colleagues and relatives. Conflict among fishers, whether by age-class, social standing, origin or other internal division will most likely be aggravated by this dilemma resulting in worsening, not improved, fisheries management.

Based on the numbers of fishers dependent on the illegal gears, and the degree of evidence supporting those designations, we recommend:

-Strengthen efforts to enforce and rationalize beach seine regulation and enforcement. This will remove a destructive gear from both fishery and social perspectives, affecting about 17% of total fishing effort by either encouraging alternatives to remove this effort, re-assigning the effort to non-destructive and less conflictual gears, and/or redesigning the gear and its use to be less destructive;

-Rescind the ban on spearguns but devise alternative management options, through the BMUs. This will affect one third of all fishers. For example, by restricting spearguns to entry-level fishers (e.g. less than five years) and/or by zonation of fishing sites or times, the total effort by spearguns may progressively be reduced and that of other gears increased. Achieving this will require technical improvements to other gears that have lower catch rates than spearguns (Table 6) as well as establishment of formal training courses to attract fishers away from spearguns, perhaps through the Fisheries Department, BMUs or both. Additionally, focused investment and promotion of alternatives to fishing are required.

Scaling up these results to the national level can be done through a simple extrapolation of these results, assuming the area, landing sites and BMUs are representative of those nationally. Three of the landing sites reported here are formally gazetted by the Fisheries Department as BMUs. The fisheries Frame Survey of 2006 (GOK 2006) reported 31 landing sites in Kwale District, which was 26.9% of the total of 115 coastal landing sites. Thus from numbers reported here for Diani-Gazi (570 fishers and 403 tonnes annual catch) we estimate the Kwale District totals to be 5,890 fishers and 4,164 tonnes/yr, and the national totals to be 21,900 fishers and 15,481 tonnes per year, respectively. The number of fishers is over twice the Frame Survey results of 2,986 (Kwale) and 10,154 (national), and the total catch is double the level reported for 2005 of 7,605 tonnes (GOK 2005). Differences in methodology may account for some of the discrepancy. However considering that this study does not include the higher-productivity catch estimates of offshore fisheries common on the northern coast (e.g. tuna trolling and large bottom nets, jarife) and included in Fisheries statistics, the under-estimation of national marine catch and its socio-economic importance may be more than indicated. A detailed census of fishing effort as done here, combined with accurate catch per effort records and local frame surveys should be carried out at a more representative selection of landing sites to achieve a more accurate estimate of these parameters.

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REFERENCES

Alidina, H.M. (2004). Prospects for improving artisanal fisheries management in Diani Chale, Southern Kenya. MSc Thesis. Dalhousie University, Halifax Nova Scotia.

Alidina, H.M. (2005). Local Level Fisheries Management in Diani-Chale, Kenya: Current Status and Future Directions. *Ocean Coastal Management,* 33:459–470.

Glaesel, H. (1997). Fisher, parks and power: the socio-environmental dimension of marine resource decline and protection on the Kenyan Coast. PhD dissertation. University of Wisconsin. Madison.

Government of Kenya. (2006). Marine Waters Frame Survey 2006 Report. Ministry of Livestock and Fisheries Development. Fisheries Department. Republic Of Kenya.

Government of Kenya. (2005). Annual Report. Ministry of Livestock and Fisheries Development. Fisheries Department. Republic Of Kenya.

Jiddawi N.S and Ohman M.C. (2002). Marine fisheries of Tanzania. *Ambio* 31, 518-527.

Khamala, C.P.M. 1(971). Ecology of *Echinometra mathaei* (echinoidea-echinodermata) at Diani beach, Kenya. Marine Biology 11, pp.167-172.

Maina G.W., D.Obura H.Alidina and B.Munywoki. (2008). Increasing catch in an over-exploited reef fishery - Diani-Chale, Kenya, from 1998 to 2006. In: Ten years after bleaching – facing the consequences of climate change in the Indian Ocean. CORDIO Status Report 2008. Eds. Obura, D.O., Tamelander, J., & Linden, O. CORDIO (Coastal Oceans Research and Development in the Indian Ocean)/Sida-SAREC. Mombasa. http//:www.cordioea.org . Pp 309-320.

Muthiga, N. and McClanahan, T.R. (1987). Population changes of sea urchin *Echinometra mathae* on an exploited fishing reef. *African journal of ecology* 25, pp. 1-8.

McClanahan, T.R., Glaesel H., Rubens J. and Kiambo R. (1997). The effects of traditional fisheries management on fisheries yields and the coral-reef ecosystems of southern Kenya. Environmental conservation, 24, 105-120.

McClanahan, T. R., Maina, S. and Davies, J. (2005). Perception of resource users and mangers towards fisheries management options in Kenyan coral reefs *Fisheries Management and Ecology.* 12: 105-112.

Obura, D. O. (2001). Participatory monitoring of shallow tropical marine fisheries by artisanal fishers inDiani, Kenya. *Bulletin of Marine Science* 69:777–792.

Obura, D.O., Wanyonyi, I., Mwaura, J. (2002.) Participatory monitoring of an artisanal Fishery in Kenya. CORDIO status report 2002. pp. 70-82.

Ochiewo, J. (2004).Changing fisheries practices and their socio-economic implications in South coast Kenya. *Ocean Coastal Management,* 47:389–408.

Rubens, J. (1996). An analysis of the benefit and costs of marine reserve regulations at Diani, Kenya: The socio-economic context of resource conflicts between fishing communities and wildlife authorities. MSc Thesis. University of Newcastle.

Tobisson, E., Anderson, J., Ngazi, Z., Rydberg, L. and Cederlof U. (2008). Ambio 27,677-685.