Increasing Catch in an Over-exploited Reef Fishery: Diani-Chale, Kenya, from 1998 to 2006

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keywords: Artisanal, fishes, catch per unit effort, catch composition, fishing gears, Diani-Chale

ABSTRACT

Artisanal fisheries are an important economic activity of the coastal communities in Kenya. In this paper fish landing data collected through participatory monitoring from seven sites was analysed to determine trends in catch per unit effort (CPUE) in the artisanal catch for the period 1998-2006 in the Diani-Chale area. The catch from a subsample of fishermen was recorded at the landing site level on two days each week. Results indicate a general increase in catches over the period with annual average minimum in 1999 (3.1 kg/fisher/trip) and maximum in 2006 (6.2 kg/fisher/trip). Catch varied significantly through the year with a monthly minimum of 3 kg/man/trip in June and a maximum of 5 kg/man/trip in March. A total of 64 fish families were recorded whereby Siganidae, Scaridae, Lethrinidae, Scombridae, Sphyraenidae, Lutjanidae and Acanthuridae accounted for 77% of the total catch. Landed fish catches showed a high degree of temporal and spatial variation, and is also likely affected by many factors, including monsoon seasonality, habitat health, fishing gear, fishing pressure, fishers' preferences, and choice of fishing site among others.

INTRODUCTION

Coral reef fisheries provide income, food security and employment to a large number of people throughout the tropical and subtropical seas. Along the Kenyan coast, marine fishery resources have remained underutilized despite efforts to stimulate the fishing industry and maximize fish catches. Nonetheless, along with the expansion of the fishery, it is required that catches remain at sustainable levels. The coastal artisanal fisheries mainly comprises of the brackish water fisheries with fishing limited to creeks, estuaries and inshore waters of less than 40 m depth. The latter constitutes the Kenyan south coast fishery characterised by small traditional non-motorized canoes with a few semi-industrial fleets.

Inshore and brackish water artisanal fisheries contributes about 90% of marine fish landings which accounts for less than 5% of total declared national fish landings (Obura 2001, GoK, 2004). Marine fishery in Kenya supports about 10,000 fishermen, half of whom operate in Southern Coast (Ochiewo 2004) and approximately 600 fishers in Diani-Chale (Malleret-King *et al* 2003). During the dry and relatively calm season (Northeast monsoon-November

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

to April), the small traditional vessels mainly operate within the inshore coral reef areas and inside the estuaries and creeks whereas the few motorized canoes fish in the open sea. The rainy season with storms extends from May to October (Southeast monsoon-SEM). These rough sea conditions restrict fishing operations of canoe fishermen from the open sea resulting in a high fishing effort at the shallow coral reef waters during the period.

The increasing fishing pressure on near shore waters has resulted in overexploitation and extensive degradation of coral reef ecosystems as in the case of Diani-Chale which remains among the heavily exploited reefs (McClanahan 1995, McClanahan *et al.,* 1997, Obura *et* 2002), while off shore resources remain largely untapped.

The Diani-Chale, arstisanal fishery has experienced a decline in diversity and abundance and there are indications that some species are overexploited well beyond maximum sustainable yield - MSY (McClanahan, 1992) and require prompt management measures. Intense fishing, including of trigger fish (Balistidae) has resulted in an increase of sea urchin populations increasing competition with herbivorous fish (McClanahan and Shaffir 1990; McClanahan and Muthiga 1998). During the 1995-1999 period an overall decline in catches was reported (McClanahan and Mangi 2001) but since then catch rates and abundance of predominant fish groups appear to have been stable, with minor variation among gear types (Obura 2001, Kanyange and Obura, 2003).

The artisanal fishery of Diani-Chale is multi-species and multi-gear, employing traditional dugout canoes propelled by either poles or sails. The gears used include basket traps, handlines, spear guns, gill nets and cast nets among others. Even with the existing fisheries management measures, there has been unregulated gear use although elders and fisher folks have in the past played a big role in eliminating use of destructive gears such as beach seines from some fish landing sites (McClanahan and Mangi 2001). The gears target different species and fishers have preference for certain fish and fishing sites with most-

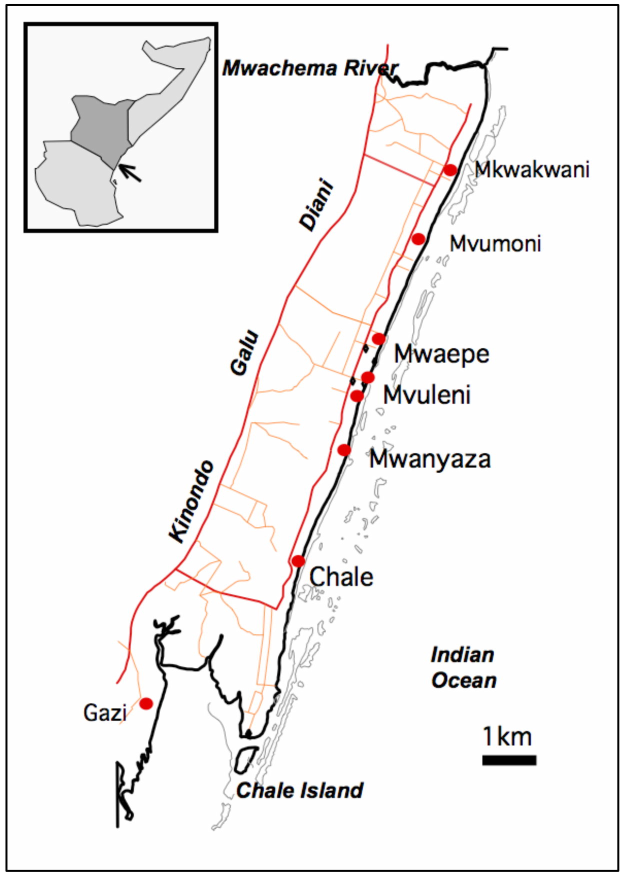

Figure 1. Map of the Diani-Chale reef area, showing the landing sites.

visited sites having the highest catch rates. Fishermen work individually or in pairs and at times in small groups and fishing is characterized by low catches hence poor incomes and living conditions.

To manage fisheries, information about fishers, catch and effort, fish stocks, fish processing and trade is vital. Such information forms the basis for policy choices, management plans and evaluations, and has to be sufficient, of good quality and up-to-date. The magnitude, spatial and temporal distribution of fishery resources (catch records and catch per unit effort) is required to give indications of effort, biomass and potential yield to enable evaluation of long-term cyclic variations.

It has become increasingly important to actively involve local communities in resource management from research or monitoring stage to formulating management policies. In Diani-Chale efforts have been made to increase the fishers' involvement in monitoring of fishery resources and the environment (Obura 2001, Obura et al. 2001, Obura et al 2002). The participatory monitoring program initiated in 1998 aimed at (1) introducing a community based monitoring program to track trends in resource use and condition benefit management agencies simultaneously; (2) engaging the fisher groups, community institutions and other stakeholders in resource management; and (3) use the monitoring programme as a tool for education and capacity building among fishers.

The findings of the participatory data collection process from seven fish landing stations for the period 1998-2006, were used to provide a better insight into the importance of the Diani-Chale fisheries. The study evaluates the level of exploitation of the artisanal fishery in Diani-Chale and Gazi fishing grounds highlighting seasonality and fluctuations in catch landings focusing on: catch rates (CPUE kg/man/trip), composition of landed stocks, and fishing strategies used. Overall, the report gives an overview of a typical artisanal fisheries catch profile of Kenyan reef fisheries at the same time demonstrating the fishers' capability to monitor the fishery. The data discussed will be useful in making management decisions for sustainable artisanal fisheries and will also add to the existing knowledge of the artisanal reef fisheries of Diani-Chale and Diani marine reserve.

MATERIALS AND METHODS

Study Site

Diani-Chale area is located 30 km south of Mombasa in Kwale District (Fig. 1). Data is analyzed from 1998 to 2006 from seven artisanal fish landing stations namely; Mwaepe, Mvuleni, Mwanyaza, and Chale, and from 2004 to 2006 from Gazi, Mkwakwani and Mvumoni. All the landing sites except Gazi are located within a continuous fringing reef system with a reef crest about 0.5 to 1.5 km from the shoreline sheltering sea grass beds in the lagoon with a maximum depth of 5-6 m. Gazi is in a bay covering some 18km^2 but is sheltered from strong waves by the Chale peninsula and island to the east and a fringing coral reef to the south. With a fisher density of about 15-20 fishers/ km^2 in a 30-40 km^2 area (Alidina, 2005) Diani-Chale coral reefs are characterized by low coral cover, low fish abundance and high abundance of sea urchins (McClanahan *et al* 1994, McClanahan & Obura, 1995).

Catch Monitoring

The daily catch of individual fishermen was monitored twice per week at each fish landing site by a trained fisherman. Units of measurement were discussed and selected in community meetings and tailored to meet fishermen's local knowledge, practices and needs of the catch assessment systems (Obura 2001). Recorded data included: name of the captain, number of crew, gear used, vessel or means of transport, fishing site, total catch (kg- estimated wet weight using a spring balance) and catch composition (taxa and number of fish). Focusing on representation among the main gear types, emphasis was always placed on adequately surveying the different gear types used, with a separate census exercise undertaken to enable extrapolation from catch per fisher to total catches (see Tuda et al, 2007). The results of the monitoring work were shared on a regular basis in the presence of fisherfolks, community leaders, fishery resource managers and other stakeholders with the fishery trends shown and discussed openly in community meetings.

Data Analysis

The data were analyzed to estimate daily, monthly, seasonal and yearly averages of the catch per fisher, catch per gear and landing site and composition of the landed catch. The catch per unit effort (CPUE) was based on the weight of fish caught during a fishing trip or day (kg/man/trip). All data were tested for

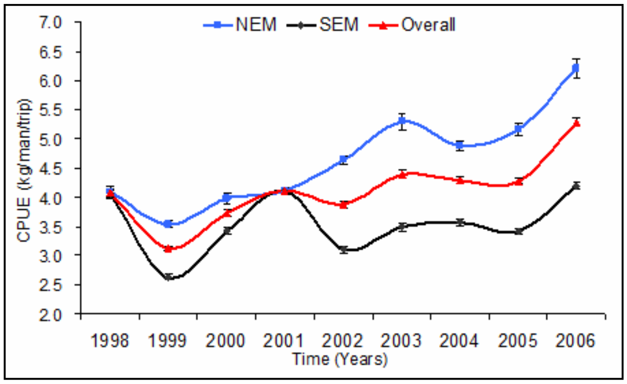

Figure 2. Annual and seasonal trends of CPUE (kg/man/trip) in Diani-Chale from 1998-2006; error bars indicate standard error of the means.

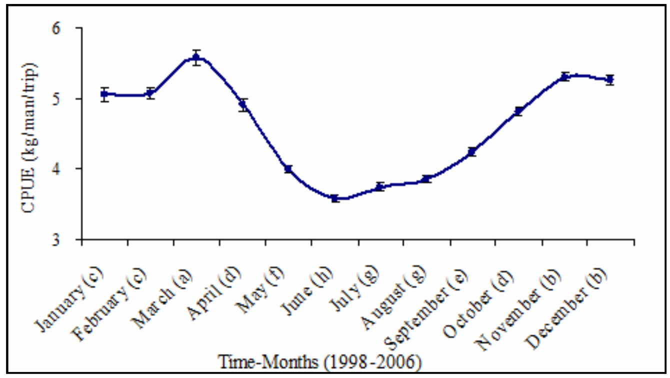

Figure 3. Monthly variations in catch per unit effort (CPUE) in Diani-Chale, error bars indicate standard error of the means while letters in brackets indicate post hoc results. Months with the same letter were not significantly different from each other.

normality using a KSL test. Since the data was not normally distributed even after several transformations, non-parametric Wilcoxon and Kruskal-Wallis tests were used.

RESULTS

Catch per Unit Effort (CPUE)

The estimated annual and seasonal CPUE for all gears from 1998 to 2006 ranged from 2.6 kg/man/trip to 4.2 kg/man/trip during SEM and between 3.5 kg/man/trip to 6.2 kg/man/trip during the NEM with the minimum recorded during 1999 and the maximum in 2006 (Fig. 2). Following a decline from 1998 to 1999, annual catch showed a steady increase from 2000 to 2006. Including the 1998 points, a linear regression slope of 0.165 (r^2 = 0.5834) was obtained, giving an overall increase of 165 g per fisher per year.

The CPUE in Diani- Chale was significantly higher during the NEM as compared to the SEM (Wilcoxon, Z=-35.87, p<0.0001). Similarly, significant differences in CPUE among years was noted except for 1998/2001 and 2004/2005 (Kruskal-Wallis c= 1033.69, p<0.0001). Within an annual cycle, catch rates were minimum in June and during the SEM (May – August, 3 to 3.7 kg/man/day) and maximum in March and during the NEM (3.7 to 5 kg/man/trip) with the differences among months being significant (Kruskall-Wallis c=1825.21, P<0.05, Fig. 3).

Annual mean catch rate was lowest in 1999 at Mwaepe (1.5 kg/man/trip) and highest in 2004 at Gazi (6.4 kg/man/trip, Fig. 4). However there was considerable variation in CPUE between years at each landing site and each year between landing sites (Table 1). For all years combined, catch rates differed significantly between landing sites (Kruskall-Wallis c=1033.69, P<0.05) except for Chale and Mkwakwani ,while for all sites combined there were significant differences over the years (P<0.0001, Kruskall-Wallis c-3735.15) except in 2004/2005 and 1998/2001. An upward trend in CPUE was recorded from five out of seven landing sites with Mvuleni recording the steepest trend (Table 1). Gazi and Mvumoni showed a gradual declining trend from 2004 while Mwaepe, Mwanyaza and Chale recorded slightly increasing trends with a peak CPUE in 2006.

Fishing Gear

Traditional fishing gears dominate the Diani-Chale fishery (Table 2), with some being modified with new materials and/or adoption of new designs from other communities. In this dataset, the main contributors to the total catch in the area were bunduki and malema with 22% and 19% respectively, while amongst the least important are mkondzo, kimia kigumi , kimia chachacha, juya, shomo, nyavu ya kutega and zonga which scored less than 2% (Table 2). The contribution of gears to the total catch fluctuates over time (Fig. 5). Juya, beach seines, were banned in Diani since 2000 as they are illegal gear and destructive. However they are common in Gazi and are among the top gears used by number of fishers.

Catch rates for the gears ranged from a minimum of 1.7 kg/man/trip for kimia kigumi to 9.4 kg/man/trip for kimia and ring net (Table 2). Jarife (6.2 kg/man/trip), bunduki (4.7 kg/man/trip) and malema (4.2 kg/man/trip) recorded relatively higher catches as compared to other gears (< 2.7 kg/man/trip). An increase in CPUE over the years was observed from the majority of gears (Table 2). The fastest increases recorded (Table 2) are for gears with few data points, to these high rates of rise are not realistic. For gears sampled from 1998-2006, the rise in catch was between 0.13-0.53 kg/fisher/year on the high side (jarife, bunduki, mshipi, juya, shomo, kimia kigumi) and 0.03-0.08 kg/fisher/year on the low side (malema, mkuki, nyavu and mshipi).

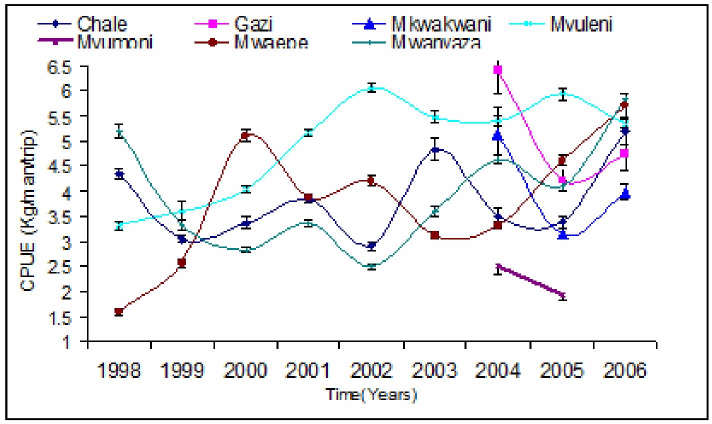

Figure 4. Annual variations in catch per unit effort (CPUE) by fish landing site in Diani-Chale, error bars indicate standard error of the means.

Gear use varies considerably between landing sites. The four commonest gears in the fishery are malema, bunduki, nyavu and mshipi as they are widespread and used at almost all landing sites (Table 2). Some gears are only used at specific landing sites; kimia kigumi,

Table 1. Annual catch per unit effort (CPUE, (kg/man/trip) by fish landing site in Diani-Chale, 1998-2006 (means, ± standard deviation) and annual increase for longer-term sites given by linear regression of catch on year for each landing site. Kruskal-Wallis (KW) nonparametric ANOVA for differences in CPUE between landing sites: * p < 0.01, ** p < 0.001, *** p < 0.0001.

Year	Chale	Gazi	Mkwak-wani	Mvuleni	Mvu-moni	Mwaepe	Mwan-yaza	All sites	KW
1998	4.3±4.3			3.3 ±2.4		1.6 ±1.2	5.2±2.6	4.1±3.8	**
1999	3.0±3.0			3.6 ±5.6		2.6 ±2.2	3.3±2.7	3.1±3.6	***
2000	3.4±5.3			4.0 ±2.0		5.1 ±3.4	2.8±1.5	3.7±4.1	***
2001	3.8±4.0			5.2 ±2.6		3.9 ±1.6	3.4±2.1	4.1±3.1	***
2002	2.9±3.6			6.1 ±3.1		4.2 ±3.4	2.5±1.8	3.9±3.5	***
2003	4.8±9.1			5.5 ±3.9		3.1 ±2.0	3.6±2.9	4.4±5.9	***
2004	3.5±4.7	6.4±8.7	5.1±3.6	5.4 ±3.5	2.5±1.9	3.3 ±2.1	4.6±2.9	4.3±4.2	***
2005	3.4±3.8	4.2±9.5	3.1±2.6	5.9 ±4.2	1.9±1.4	4.6 ±3.8	4.1±3.0	4.3±5.2	***
2006	5.2±7.7	4.7±9.4	4.0±4.4	5.4 ±2.9		5.7 ±8.7	5.8±3.3	5.3±6.9	***
All years	3.7±5.2	4.7±9.4	3.5±3.4	5.1 ±3.6	2.1±1.6	4.0 ±4.2	3.9±2.8	4.1±4.7	***
c-Value	489.92	81.27	21.99	1098.88	11.13	1645.45	1493.15	1033.69	
P-Value	0.0001	0.0001	0.0001	0.0001	0.0008	0.0001	0.0001	0.0001	
Regression slope (r^2)	0.100 (0.118)			0.307 (0.668)		0.300 (0.411)	0.1433 (0.127)	0.165 (0.583)	

Table 2. Catch performance of fishing gear used at the study sites in Diani-Chale from 1998-2006. CPUE measured in kg/fisher/day and regression slope (i.e. change in catch) in kg/fisher/year. Percentage of total catch contributed by the gear. Kruskal-Wallis (KW) nonparametric ANOVA for differences in CPUE for each gear between landing sites: * p < 0.01, ** p < 0.001, *** p < 0.0001. + - gears recorded over 2004-6 giving only 3 points for regression.

Gear type		Catch statistics			KW	Long term trend	
Local name	English Name	CPUE	sd	%	*p*	*Slope*	*r2*
Kimia+	Cast net	9.4	21.5	11	***	-1.426	0.0660
Ring net	Ring net	9.4	15.9	9	-	1.747	0.8410
K. chachacha+	Cast net	6.9	21.0		***	1.465	0.8812
Jarife	Shark nets	6.2	11.1	11	-	0.527	0.2450
Bunduki	Spear gun	4.7	3.4	22	***	0.210	0.6132
Mshipi	Hand line (hook and line)	4.2	5.3	14	***	0.273	0.7340
Malema	Basket traps	3.7	2.8	19	***	0.082	0.1969
Mkondzo/ mkuki	Spear	3.3	1.9		***	0.053	0.2020
Nyavu	Gill net	3.3	4.6	14	***	0.035	0.0110
Juya+	Beach seine net	3.0	3.3		-	0.399	0.2670
Nyavu ya kutega	Bottom set net	2.8	2.7		**		
Shomo	Harpoon	2.6	1.9		**	0.171	0.6650
Kimia kigumi+	Beach seine net	1.7	1.9		-	0.132	0.9750
Zonga		1.5	1.7		*		
Uzio	Stake traps						

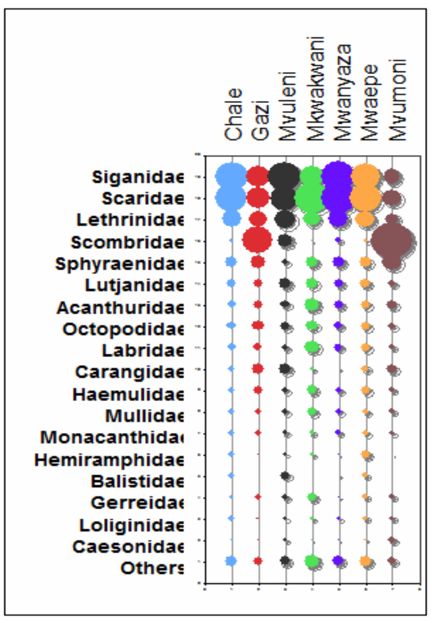

Figure 5. The major fish families harvested in Diani-Chale and the percentage catch composition by landing site. Families contributing less than 1% are summed as "others". Circles are scaled by area, largest circle = 43% (Scombridae, Mvumoni).

kimia chachacha, and ring nets were only recorded in Gazi, juya from Chale and zonga was recorded from Gazi and Chale. In Gazi, ringnets, mshipi and jarife recorded the highest catch rates. Mwanyaza recorded peaks in the use of jarife (17 kg/man/trip) and nyavu (8 kg/man/day) while Mvuleni recorded maximum CPUE from bunduki (6 kg/man/trip) and nyavu ya kutega (7.3 kg/man/trip). Variation in catch rates from malema, bunduki and mkondzo between landing sites was slight.

Catch Composition

A total of 1,106,749 individual fishes from 64 families were recorded from all landing sites over the 7 year period (Table 3). By abundance the Siganidae and Scaridae dp,omated at 25.5 and 24.9% respectively, followed by Lethrinidae (10.2%), Scombridae (5.2%), Sphyraenidae, Lutjanidae and Acanthuridae. Altogether, these families accounted for 77% of the total catch. The was primarily typical reef fishes although reef associated and pelagic piscivores such as Scombridae, Sphyraenidae, Octopodidae and

Table 3. Catch composition by fish family and landing site.

Species group	Habitat	Catch composition (%total catch) per landing site							
		Chale	Gazi	Mvuleni	Mkwak-wani	Mwan-yaza	Mwaepe	Mvu-moni	OVER-ALL
Siganidae	Reef	28.1	15.1	28.7	15.8	29.8	23.6	8.7	25.5
Scaridae	Reef	27.4	15.4	20.0	29.5	31.0	26.8	9.3	24.9
Lethrinidae	Reef	10.5	8.7	11.5	8.3	10.4	9.9	5.4	10.2
Scombridae	Pelagic	0.8	24.0	6.9	0.1	1.1	0.7	43.9	5.2
Sphyraenidae	Reef associated	5.3	7.4	1.5	5.0	4.9	4.5	9.4	4.5
Lutjanidae	Reef	3.2	3.4	4.6	4.0	3.3	3.8	2.3	3.6
Acanthuridae	Reef	2.4	3.1	2.6	6.9	3.2	3.1	3.4	3.0
Octopodidae	Reef associated	2.6	4.2	2.8	4.1	2.5	3.1	2.0	2.9
Labridae	Reef	2.3	2.4	2.1	6.1	2.5	3.0	1.2	2.5
Carangidae	Reef associated	1.6	4.0	4.4	0.8	0.5	2.2	3.4	2.4
Haemulidae	Reef	2.0	2.8	1.6	3.7	2.0	3.0	1.5	2.2
Mullidae	Reef	1.9	2.1	1.8	2.9	1.8	2.1	1.3	1.9
Monacanthidae	Reef	1.6	1.6	1.4	1.2	1.5	1.8	1.0	1.6
Hemiramphi-dae	Pelagic	1.6	0.1	0.6	0.9	0.2	3.4	0.1	1.3
Balistidae	Reef	1.6	0.0	2.5	0.0	0.4	1.3	-	1.3
Gerreidae	Coastal	0.6	1.9	1.6	2.8	0.3	1.1	1.2	1.1
Loliginidae	Reef associated	1.5	0.5	0.6	0.8	0.8	1.2	1.3	1.0
Caesonidae	Reef	0.5	0.3	1.0	0.1	0.2	0.5	2.3	0.6
Others		4.4	3.2	3.8	6.9	3.7	5.0	2.4	4.2
# of families	-	60	55	57	53	58	60	47	64
Total # of individuals		270,422	100,732	227,534	33,201	202,338	247,280	25,241	1,106,749

Hemiramphidae (1.3%) formed a substantial portion. Many families were rare and grouped into "others", accounting for 4.2% of the total catch. There were slight differences between the composition of catch between landing sites (Fig. 5). The families Scombridae and Sphyraenidae dominated the catches landed at Mvumoni (43.9% and 9.4%) and Gazi (24% and 7.4%) while other landing sites landed typical reef fishes. Mwanyaza recorded the highest percentage of Siganids (29.8%) and Scarids (31%).

Catch composition varied by fishing gear (Fig. 6). Siganidae dominated jarife, juya, zonga, mkondzo, malema, ring net and speargun catches (41%-26%) whereas Scaridae was the leading catch in juya, zonga and malema (34%-26%). Kigumi and nyavu ya kutega catches were dominated by Scombridae (44% and 41% respectively) while mkondzo and shomo were dominated by Sphyraenidae (22.6% and 14.2% respectively). Carangidae accounted for 42% of the kimia chachacha catch. The percentage composition for dominant fish families for various gears showed some slight variation over the monitoring period.

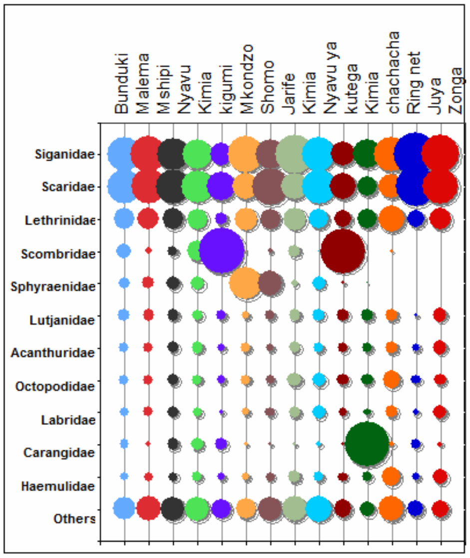

Figure 6. Percentage composition of most abundant fish families harvested by fishing gear in Diani-Chale. Families with less than 2% summed as "others". Circles are scaled by area, largest circle = 45% (Scombridae, kigumi).

DISCUSSIONS

Overall Catch per Unit Effort (CPUE) Trends

The yearly CPUE (kg/man/trip) in Diani-Chale shows an increasing trend from 3.1 kg/man/trip in 1999 to 6.2 kg/man/trip in 2006 (Fig. 1), due to a broad increase in catch rates among almost all gears in the fishery (Table 2). This increase is corroborated by independent data over the same period and is in contrast to declining trends recorded from 1995-1999 where habitat degradation and excessive effort were held responsible for catch declines (McClanahan and Mangi 2001). The lowest catch rate in 1999 falls in the year after the 1998 coral bleaching and mortality event in which shallowest portions of Diani reef suffered 60-80% mortality (DO, unpublished data). Reef recovery has occurred from about 2000 to the present (pers. obs.), and the banning of beach seines from most of the Diani landing sites may have contributed to the recovery of the fishery (McClanahan and Mangi 2001). Interestingly Mvuleni, Mwanyaza and Mwaepe landing sites have shown the strongest signs of improvement, and are the three sites that most aggressively expelled beach seines.

However beach seines are not totally removed from the reef as fishers can only stop others from landing fish at their beach, but traditionally have few powers to control activities in the water. Thus beach seine crews have continued to operate from Kinondo Mgwani landing site, which has refused to allow monitoring since 1997 and Mkwakwani, which refused monitoring up until 2004. Additionally, beach seine teams operating from Gazi share fishing grounds with those from Chale landing site, around Chale Island.

The higher catch rates in the NEM (<6.2 kg/man/trip) over the SEM (<4.2 kg/man/trip) are likely due to calm weather conditions, the rough weather during the SEM reducing fishing effort during this season (Obura 2002). Seasonal to monthly differences were documented in the composition of the catch and it may be that fish migrations, decreased density and activity due to a deeper thermocline in the SEM (Obura 2001b) and different seasonal reproduction patterns for both pelagic and demersal fish (Okera 1974, Kaunda-Arara and Ntiba 1997, and Kulmiye et al. 2002) may influence catch rates in the different seasons.

Mvuleni, Gazi and Mwaepe have above-average CPUE (Table 1). Differences in CPUE between landing sites could be associated with the extent and condition of the reef and lagoon, fishing effort, withdrawal of destructive gear and nearby commercial markets (Obura 2001, McClanahan *et al* 1996). The high catch for Mwaepe is surprising, as it is adjacent to the most degraded reef studied in Kenya (McClanahan and Muthiga 1998 and McClanahan *et al* 1997) and is reported to have recorded extremely low catches. The reef south of Mwaepe is less degraded however, and Mwaepe is located at the main break in the Diani fringing reef, which often has aggregations of schooling fish in it (e.g. chubs, DO pers. obs.).

Occasional catches from the channel and outer reef increase the mean catch rate considerably. Likewise Gazi has open access to a more extensive bay system, and this attracts migrant fishers from Vanga and Pemba (Tanzania) who use motorized boats and ring nets during the NEM (Ochiewo 2004, CORDIO unpublished data), contributing to high catches there. Also in Gazi, extensive mangrove systems may increase the biomass of fish locally through export of detritus and nutrients and provision of refugia and/or food that increase the survivorship of the juveniles (Mumby *et al* 2003, Ogaden 1997,Laegdsgaard and Johnson 1997).

The four most common gears in the fishery: malema, bunduki, nyavu and mshipi are widespread and used at almost all landing sites thus their contribution to the total catches is high while others such as kimia kigumi, kimia chachacha, and ring net were only recorded in Gazi (Table 3 and Fig. 4). This confers with earlier work where they were found to contribute between 16-31% to the recorded landings. This explains why contribution of ring net to the overall catches is lower. The decline in the contribution of bunduki and juya over time could be associated to change in gear use (Fig. 5).

Among gears, bunduki and malema were most commonly recorded and the main contributors to the total catch with 22% and 19% of landings respectively. Interestingly data collection from bunduki fishers declined gradually from 31% in 2002 to 18% in 2006. Bunduki was declared illegal in 2001 and sensitivity from the young fishermen who normally use it, and conflict with their elders and those in authority (e.g. supporting monitoring for management) is likely to have led to this decline. By contrast, the overall numbers of fishers using bunduki did not change over this time (Tuda et al., 2007).

Catch per Unit Effort by Fishing Gear

Among the main gears used, two are illegal in Kenya - spearguns (bunduki) and beach seines (juya). In 1995-6 bunduki and juya contributed 38% and 39% to the total catches respectively at Diani (McClanahan *et al* 1996). The use of beach seines has dropped as a result of exclusion, close to zero within Diani sites, but at about 12% of overall catch including Gazi (Tuda et al., 2007). Within this dataset, the proportion of bunduki dropped from 31% in 2002 to 18% in 2006. A full census indicates that bunduki are the most common gear in Diani-Chale, being used by 30% of the fishers, and contributing 33% of the total catch (Tuda et al., 2007). The decline in bunduki catch being recorded here is likely due to stigmatization of the fishers after the gear was banned in 2001, and their increasing unwillingness to participate in monitoring.

The fishing techniques and gears have changed with time , which is likely to continue given the increasing demand for fish and marine products.. Acquisation of modern fishing vessels at Mvuleni and Mwaepe landing sites may have contributed to the shift in gear use enabling fishermen to extend their fishing range. However, local knowlegde about the fish behaviour, seasonal variation and periodicity remains important in adoption of newer methods.

The overall average CPUE for different fishing gears in Diani-Chale and Gazi bay varied widely with lowest and highest catches recorded for kimia kigumi (1.7±1.9 kg/man/trip) and kimia and ring net (9.4 ± 2.5 kg/man/trip) respectively (Table 3). The most popular gears, malema, mshipi, nyavu and bunduki, had relatively moderate to low CPUE of 2-5 kg/man/trip.

Catch Composition

The total number of fish families (64) recorded during the present study is greater than those recorded previously in the same sites. Thirty seven families were landed from seagrass, sand and coral habitats (McClanahan and Mangi 2004), 40 families from seagrass and un-vegetated areas were sampled by experimental beach seine fishing in Gazi bay (De Troch *et al* 1996), and 50 families were reported from the same bay (Kimani *et al* 1996). The scale of sampling in this study – twice weekly at all major landing sites for almost 10 years is likely the reason for the higher diversity reported here. This is also in opposition with the common criticism that participatory monitoring does not sample diversity as well as scientific/technical monitoring (see Obura et al. 2002, Muhando 2007).

The dominance of low trophic level families and relative absence of top predators confirms over fishing and 'fishing down the food chain'. Top predators are often the preferred fish and slow to recover as they grow slowly and mature late. The families Siganidae, Scaridae and Lethrinidae accounted for 60.6% of the landings, dominating all landing sites except in Gazi and Mkwakawani where family deeper and net-based fishing (ring nets, etc) target Scombridae (Fig. 5). This corroborates earlier studies which reported dominance of sea grass and coral reef-associated species with small number of species contributing largely to the total captures (McClanahan and Mangi 2004). Rabbitfish dominate catches from heavily exploited reefs while small Lethrinids dominate catches from moderately exploited reefs. Studies done at the fished Mpunguti Marine Reserve and unfished Kisite Marine Park showed Lethrinids as the dominant family for 37% from each protection area and generally higher fish biomass in unfished reefs as compared to fished ones (Samoilys 1988, McClanahan and Mutere 1994, Watson 1996). With the same three families dominating most gear catches, there are likely to be high levels of competition, and therefore conflict, among different gear users.

CONCLUSIONS

Overall catch per unit effort (CPUE, kg/man/trip) in Diani-Chale appears to be increasing from a low of 3.1±3.6 kg/man/trip in 1999 to 5.3±6.9 kg/man/trip in 2006, with higher catches during the NEM than SEM. There are significant differences in monthly CPUE with catches ranging from 3.07±2.79 kg/man/trip in June to 5.07±6.47 kg/man/trip in March. The upward trend in CPUE was recorded from five out of seven landing sites with Mvuleni recording the steepest trend while Gazi and Mvumoni showed a gradual declining trend from 2004 to 2006. Within these overall patterns, catch rates are characterized by high variability, as catch is affected by local site characteristics, gear use patterns, seasonal and other patterns in fish abundance and factors that affect catchability.

Kimia and ring nets recorded the highest catch rates (9.4 kg/man/trip) while juya, nyavu ya kutega, mkondzo and kimia kigumi and juya recorded the lowest (<3 kg/man/trip). The fish catch of Diani-Chale shows a high level of dominance by the Siganidae, Scaridae and Lethrinidae which together with Scombridae, Sphyraenidae, Lutjanidae and Acanthuridae, account for 77% of the total catches.

Improvement of Diani-Chale fishery may entail retiring and phasing out destructive fishing gear classes (gear shift), change in fishers perception and behaviour about fishery management, improving technology and increasing incentives to limit habitat damage besides development of alternative livelihood activities.

REFERENCES

Alidina HM (2004). Prospects for Improving Artisanal Fisheries Management in Diani-Chale, Southern Kenya. Dalhousie University, Halifax, Nova Scotia (72).

De Troch, M. et al. (1996). Fish communities in a troical bay (Gazi Bay, Kenya): Sea grass beds vs. unvegetated areas. Neth. J. Zool. 46(3-4): 236-252.
Fisheries Department. 2004. Annual report. Mombasa, Kenya.

Kanyange, W.N., Obura, D.O. (2003). Fish catch monitoring: a participatory approach in Diani-Chale, Kenya. CORDIO-EA, Mombasa, Kenya.

Kaunda-Arara, B. and M. J. Ntiba. (1997). The reproductive biology of *Lutjanus fulviflamma* (Forsskal, 1775) (Pi: Lutjanidae) in Kenyan inshore marine waters. *Hydrobiologia* 353(1-3): 153-160. Kluwer Academic Publishers.

Kimani E N., K G Mwatha., E. O. Wakwabi, J. M. Ntiba & B. K Okoth, (1996). Fishes of a shallow tropical mangrove estuary. Gazi, Kenya. *Marine and fresh water Research:* 47: 857-868.

Kulmiye, A. J., M. J. Ntiba and S. M. Kisia (2002). Some aspects of the reproductive biology of the thumbprint emperor, *Lethrinus harak* (Forsskal, 1775), in Kenya Coastal waters. *Western Indian Ocean Journal of Marine Science*. 1(2): 135-144. Western Indian Ocean Marine Science Association.

Laegdsgaard, P. & Johnson, C. (2001). Why do juvenile fish utilise mangrove habitats? J. Exp. Mar. Biol. Ecol. 257, 229–253.

Malleret-King D, King A, Maghubhai S, Tunje J, Muturi J, Mueni E, Onganda H (2003). Review Of Marine Fisheries For Kenya: Understanding Fisheries associated livelihoods and the Constraints to their Development in Kenya and Tanzania(FMSP project R8196).

McClanahan T, Obura D (1995). Status of Kenyan Coral Reefs. Coastal Management 23: 57-76.

McClanahan T, Mutere J (1994). Coral and sea urchin assemblage structure and inter-relationships in Kenyan reef lagoons. Proceedings of the 7th International Coral Reef Symposium.

McClanahan T, R, Kaunda-Arara (1995). Fishery recovery in a coral reef marine park and its effect on the adjacent fishery. Conservtion biology 10: 1187-1199.

McClanahan TR, Mangi S (2001). The effect of a closed area and beach seine exclusion on coral reef fish catches. fisheries management and ecology 8: 107-121.

McClanahan T, R, Muthiga N, A (1998). An ecological shift in a remote coral atoll of Belize over 25 years. Environmental conservation 25: 122-130.

McClanahan, T & S Shafir (1990). Causes and consequences of sea urchin abundance and diversity in Kenyan coral reef lagoons. Oecologia 83:362-370.

McClanahan TJ, Mutere J (1994). Coral and sea urchin assemblage structure and interrelationships in Kenyan reef lagoons. Hydrobiologia 286: 109-124.

McClanahan TR, Kamukuru AT, Muthiga NA, Yebio MG, Obura D (1996). Effect of sea urchin reductions on Algae, coral and fish populations. Conserv. Biol. 10: 136-154.

McClanahan TR, Glaesel H, Rubens J, Kiambo R (1997). The effects of traditional fisheries management on fisheries yields and the coral-reef ecosystems of southern Kenya. Environ. Conserv. 24: 1-16.

McClanahan T. (1992). Resource utilization, competition and predation: a model and example from coral reef grazers Ecol. Modelling (pp).

Muhando, C.A. (2008). Approaches to coral reef monitoring in Tanzania. 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.cordio.org. Pp.129-138.

Mumby, P.J., Edwards, A.J., Arias-Gonzalez, J.E., Lindeman, K.C., Blackwell, P.G,.Gall, A., Gorczynska, M.I., Harborne, A.R., Pescod, C.L., Renken, H., Wabnitz, C.C.C., Llewellyn, G., (2004). Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427, 533-536.

Obura, D. (2001b). Kenya. Marine Pollution Bulletin 42: 1264-1278.

Obura, D. (2001a). Participatory monitoring of shallow tropical marine fisheries by artisanal fishers in Diani, Kenya. Bulletin of Marine Science 69: 777-791.

Obura D, Wanyonyi I, Mwaura J (2002). Participatory Monitoring of an Artisanal Fishery in Kenya. In: Linden O, Souter D, Wilhelmsson D, Obura D (eds.) Coral Reef Degradation in the Indian Ocean. Status Report 2002. CORDIO, Kalmar (pp 108).

Obura D, Wells S, Church J, Horrill C (2001). Monitoring of fish and fish catches by local fishermen in Kenya and Tanzania. Marine and Freshwater Research 53: 215-222.

Ochiewo, J. (2004). Changing fisheries practices and their socioeconomic implications in South Coast Kenya. *Ocean & Coastal Management* 47: 389- 408. Elsevier.

Ogden, J. C. in Life and Death of Coral Reefs (ed. Birkeland, C.) 288–297 (Chapman and Hall, New York, 1997).

Okera, W. (1974). Morphometrics, 'Condition' and gonad development of the East African. *Sardinella gibbosa* (Bleeker) and *Sardinella albella* (Valenciennes). *Journal Fish Biology* 6: 801-802. The Fisheries Society of the British Isles.

Samoilys M (1988). Abundance and species richness of coral reef fish on the Kenyan coast: the effects of protective management and fishing. Proceedings of the 6th International Coral Reef Symposium, Townsville Australia. 2: 261-266.

Tuda, P., Nyaga, W., Maina, G.W., Wanyonyi, I. & Obura, D.O. (2008). Estimating total fishing effort over tidal to annual periods in the Diani-Gazi reef fishery in Kenya. 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.cordio.org . Pp 321-334.

Watson M (1996). The role of protected areas in the management of Kenyan reef fish stock. University of York.