Environmental variability and the fishery dynamics of the Okavango delta, Botswana: the case of subsistence fishing

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Abstract

The hydrological regime of the Okavango River Basin is the main driver of ecological change in the delta. The delta supports a small-scale fishery which is a source of livelihood for communities within its fringes. The fish resource is particularly important to subsistence fishers, who have limited access to socio-economic opportunities. However, fish availability is subject to 'concentration and dilution' effects because of the hydrological regime. As a copying strategy, fishers use a variety of fishing methods to effectively harvest the delta's fish community across all its trophic levels. This exploitation regime helps to maintain the delta's species diversity and only reduces fish biomass proportionally across the different trophical levels. Furthermore, fishers have developed different fish-processing techniques to preserve their harvest for low fishing season periods to cope with low food availability. The aim of this paper therefore, was to explore spatio-temporal variations in fish availability and to show how the delta's subsistence fishers cope with this dynamicity.

Key words: environmental variability, rural livelihoods, subsistence fishing

Introduction

The Okavango delta, the world's largest Ramsar site (22,000 km^2), originates in the Angolan highlands, flows through Namibia before entering Botswana at the Panhandle where the floodplain is relatively narrow (McCarthy, Bloem & Larkin, 1998; Government of Botswana, 2003). The hydrology of the delta is very dynamic and annual inundation varies as a result of the magnitude of the flood discharge and local rainfall and to a less extent to antecedent effects and evaporation (McCarthy *et al.*, 1998). The spatial variation and duration of inundation leads to some areas being permanently flooded, while distal areas become flooded infrequently, and then for a relatively short period (McCarthy *et al.*, 1998; Gumbricht *et al.*, 2004). According to McCarthy *et al.* (1998), evaporation varies throughout the year, but not at the same magnitude like annual inflow and rainfall.

The Okavango delta supports a small-scale commercial and subsistence fishery (Rothert, 1997; Mosepele, 2001; Ashton, Nordin & Alonso, 2003; Mmopelwa, Segametse & Mosepele, 2005), where potential annual fish yield is estimated at 5000–8000 tones (FAO, 2003). Generally, floodplain fish populations undergo *inter* and *intra* annual variations driven by the hydrological regime (Welcomme, 1985). Consequently, the resultant longitudinal and lateral fish migrations (Merron, 1991) effected by these variations result in spatio-temporal variations in fish availability (Mosepele, 2000). This has implications on households to whom fishing is a major livelihood activity. However, in these variable environments, subsistence fishing households have always coped with and adapted to spatio-temporal variations in fish availability. Coping mechanisms refer to short-term responses to situations that threaten the livelihood systems of individuals, while adaptive strategies are long-term ways or responses by which individuals/households change their productive activities and modify local rules and institutions to secure a livelihood (Berkes & Jolly, 2001; Maltimore & Adams, 2001; Topkins & Adger, 2004; Marschke & Berkes, 2006). In the Amazon (for instance), Cerdeira, Ruffino & Isaac (2000) found that subsistence fishers use a variety of different fishing gears at different spatial scales to effectively harvest the fish resource. No research has been undertaken to investigate how fishers respond to variations in fish availability because of environmental variability in the Okavango delta.

The aim of this paper was to highlight the impact of the delta's variability on subsistence fishing and how fishing

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households respond to these variations. Therefore, this paper's objectives were to analyse spatio-temporal variations in fish availability in the delta; the significance of fish to rural livelihoods of communities on the fringes of the delta; coping strategies of communities in a dynamic ecosystem; and monitoring strategies of fisheries as a way to inform decision making/policy.

Materials and Methods

Description of study area

The study area is the Okavango delta in Botswana, the largest inland wetland known in Africa for its large quantities of fresh water spreading over lagoons and channels (Ashton *et al.*, 2003) (Fig. 1). The mean annual rainfall over the Okavango delta is 513 mm, with a rate of evapotranspiration as a result of high temperatures (Snowy Mountains Engineering Corperation, 1989). The dominant vegetation in the perennial swamps is papyrus (*Cyperus papyrus*) while vegetation in the dry-land areas is characterized by mixed stands of trees and a variety of grasses and sedges. Seasonally flooded areas are characterized by submerged plant species such as *Schoenoplectus corymbosus* and *Cyperus articulatus*, while intermittently flooded areas may contain both dry-land and swamp plant species. In the small islands, the vegetation types include tall broad leaved evergreen trees (e.g. *Ficus natalensis*), while the large islands are characterized by woodland vegetation.

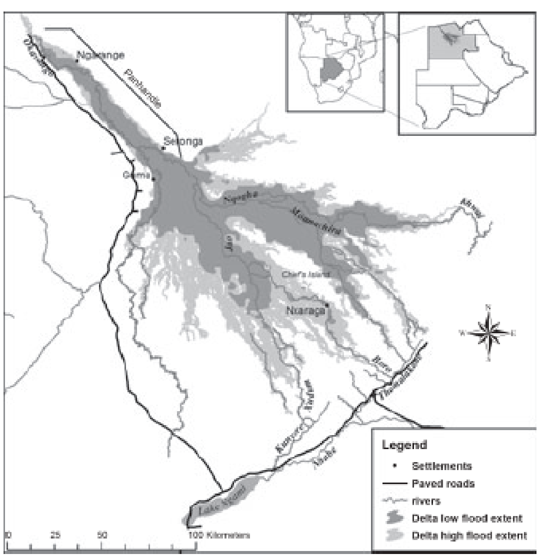

Fig 1 Map of the Okavango delta showing the four experimental fishing stations around the delta

Materials

Data collection. As a result of the multidisciplinary nature of this study, several kinds of data were used: hydrological data, experimental fishing data, socio-economic data and data from traditional/subsistence fishers.

Hydrological data for the mean daily discharge in m s^{-1} were collected at a hydrological station in the upper panhandle of the delta.

Experimental fishing data were collected in four study sites: Ngarange and Seronga, both situated on the upper panhandle of the delta; Guma Lagoon, situated in the lower panhandle, and Nxaraga, situated in the seasonal part of the delta (see Fig. 1). Multi filament, multi-panel nets were set in all available habitats in the study sites. These nets were 90 m long, with 9, 10 m panels of different mesh sizes (22, 28, 35, 45, 53, 75, 86, 93, 118 and 150 mm stretched mesh). Nets were set overnight for approximately 12 h (this is a standardized time used for experimental fishing techniques using gill nets) and removed from the water every morning. These standardized fishing methods are described in Mosepele (2000) and Mbewe (2000). This sampling regime ensures that the observations made on the fish populations are representative of the delta.

Data were collected using creel surveys conducted in the villages around the delta's panhandle by randomly selecting fishermen to analyse their catches.

Data were collected from a socio-economic survey of subsistence fishing households in 22 villages from around the delta using a structured questionnaire. Following training of field staff, 10% of subsistence fishers in the 22 selected fishing villages were surveyed in 2004. Households were selected in a systematic random manner where each second household in the sampling frame was selected. Face-to-face interviews were conducted in a total of 248 subsistence fishing households.

Methods

Data analysis. Experimental fishing data were packaged and analysed in PASGEAR (Kolding, 1989). Relative fish biomass (g per set) was calculated in PASGEAR and tested against the mean monthly water flow discharge in STATISTICA (1995, STATISTICA for Windows, 2nd Edition StatSoft Inc. Tulsa, OK, USA) using the non-parametric Spearman correlation to test for significance and nature of relationship.

Relative fish biomass (kg per set) was also calculated for several habitats around the delta. A pair-wise student's *t*-test for independent samples in STATISTICA was then calculated to test for differences in fish availability between different areas in the delta. The efficiencies of the different fishing gears were determined by calculating catch per unit of effort (c.p.u.e) based on numbers (of fish) per gill net (or any other fishing gear) set (i.e. Nos per set) for each of the different fishing gears used by subsistence fishers. An index of relative importance implemented in PASGEAR was used to determine the most important species in each fishing gear. Shannon's Index and the Evenness Index, also implemented in PASGEAR were used to determine species diversity for each of the different fishing gears used.

For the socio-economic data, SPSS (2006; SPSS version 16. SPSS Inc. Chicago, IL, USA) was used to calculate frequencies and percentages to determine the significance of fish to rural communities.

Results

Catch composition and species diversity

The highest species diversity (and richness) was observed in Nxaraga while Guma had the lowest species diversity. The lowest species richness was observed in Seronga. According to the relative evenness index, Guma fish community was dominated by few fish species compared with Nxaraga and Seronga which had a slightly more even distribution of fish species in the fish community. The highest relative biomass (15.877 kg per set) was observed in Nxaraga while the lowest was observed in Ngarange (Table 1).

Spatio-temporal variations in fish availability

Figure 2 shows that fish availability in the delta undergoes seasonal variations, where the highest biomass is available between August and November while the lowest biomass is available between March and May. A Spearman correlation showed that there is a significant ($P = 0.004$) negative correlation between relative fish biomass and mean monthly water discharge (−0.365) in the delta. Table 2 shows that there are significant differences in fish relative biomass between several different areas in the delta except for Nxaraga and Guma. This suggests that fish availability is subject to spatial variations.

Significance of fish on rural communities living on the delta's fringes

Subsistence fishing has socio-economic, socio-cultural and food security values to the delta's subsistence fishermen (Table 3). As a socio-economic activity, subsistence fishing was reported by majority (47%) of respondents to be a major livelihood activity from a total of 17 possible livelihood activities. Fish is either consumed at home or bartered for other commodities. As shown in Table 3, most subsistence fishermen barter fish for grain, while others barter it for goods from shops (e.g. sugar, cooking oil, etc.) and other kinds of meat. While the primary socio-economic value of fish may be bartering, 18% of some 39 respondents also indicated that they purchase food from fish sales.

As summarized in Table 3, subsistence is a social activity where a higher proportion of women, girls and boys normally fish in groups. On the other hand, a high proportion of men fish alone, although some proportion of men also fish in groups.

The food security value of fish is reflected by the fact that most of the households (68%) consume more than half of their catch. This suggests that the contribution of fish to household diet is significant. Asked about the three most important ways or strategies of ensuring food supplies to the household during periods of shortage, 27% of the fishing households ranked 'increasing fish catches' as their most important strategy, while 22% ranked 'increasing fish catches' as their second most important strategy. Twelve per cent of the households ranked 'increasing fish catches' as their third most important strategy.

Coping strategies of communities in a dynamic ecosystem

The different fishing gears used in the delta are both habitat and time specific (Table 4). The use of different fishing gears is a household response to cope against spatio-temporal variations in fish availability in the delta. Gill nets and hook and line are generally used in relatively deep water (i.e. >1.5 m). Conversely, fishing baskets, barrage traps, fishing spears and mosquito nets are used in shallow

Table 1 Species composition, diversity and relative biomass based on experimental fishing data collected between 2000 and 2005 from four main areas in the Okavanogo delta

Species	Ngarange	Seronga	Guma	Nxaraga
Aplocheilichthys hautereaui				x
Aplocheilichthys johnstoni	x		x	x
Aplocheilichthys katangae	x			x
Barbus afrovernayi	x	x	x	x
Barbus barnardi	x		x	x
Barbus bifrenatus	x	x	x	x
Barbus eutaenia	x			x
Barbus fasciolatus	x	x	x	x
Barbus haasianus			x	x
Barbus multilineatus	x			x
Barbus paludinosus		x	x	x
Barbus poechii	x	x	x	x
Barbus radiatus	x	x	x	x
Barbus thamalakanensis			x	x
Barbus unitaeniatus	x			x
Brycinus lateralis	x	x	x	x
Clarias gariepinus	x	x	x	x
Clarias liocephalus				x
Clarias ngamensis	x	x	x	x
Clarias theodorae	x	x	x	x
Hemichromis elongatus		x		
Coptostomabarbus wittei			x	x
Ctenopoma multispine			x	x
Cyphomyrus discorhynchus				x
Hemigrammocharax multifasciatus				x
Hepsetus odoe	x	x	x	x
Hippopotamyrus ansorgii	x	x		x
Hippopotamyrus discorhynchus	x	x	x	
Hydrocynus vittatus	x	x	x	
Labeo lunatus	x	x	x	
Leptoglanis cf dorae	x			
Marcusenius macrolepidotus	x	x	x	x
Micralestes acutidens	x			
Momyrus lacerda	x	x	x	x
Nannocharax macropterus		x		x
Oreochromis andersonii	x	x	x	x
Oreochromis macrochir	x	x	x	x
Parauchenoglanis ngamensis	x	x		
Petrocephalus catastoma	x	x	x	x
Pharyngochromis acuticeps	x	x	x	x
Pollimyrus castelnaui	x	x	x	x
Pseudocrenilabrus philander	x	x	x	x
Rhabdalestes maunensis	x		x	x
Sargochromis carlottae	x	x	x	x
Sargochromis codringtonii	x	x	x	x
Sargochromis giardi	x	x	x	x
Sargochromis greenwoodii	x	x	x	x
Schilbe intermedius	x	x	x	x
Serranochromis longimanus	x			
Serranochromis altus	x	x	x	x
Serranochromis angusticeps	x	x	x	x

Table 1 (Continiued)

Species	Ngarange	Seronga	Guma	Nxaraga
Serranochromis longimanus				x
Serranochromis macrocephalus	x	x	x	x
Serranochromis robustus	x	x	x	x
Serranochromis thumbergi	x	x	x	x
Synodontis leopardinus	x	x	x	x
Synodontis macrostigma	x	x	x	x
Synodontis macrostoma	x	x	x	x
Synodontis nigromaculatus	x	x	x	x
Synodontis thamalakanensis	x	x	x	x
Synodontis vanderwaali	x	x	x	x
Synodontis woosnami	x	x	x	x
Tilapia rendalli	x	x	x	x
Tilapia ruweti	x			x
Tilapia sparrmanii	x	x	x	x
Species richness	53	46	48	57
Shannon's diversity index	2.48	2.47	1.83	2.67
Relative evenness index	0.61	0.64	0.47	0.64
Mean relative biomass (kg per set)	5.544	8.375	I 1. 848	15.877

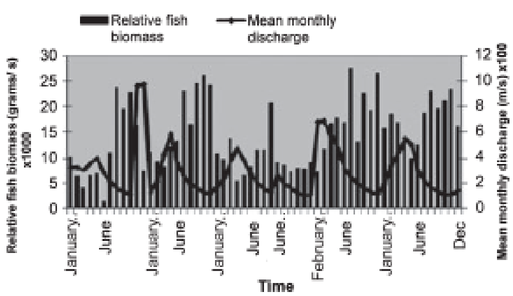

Fig 2 Illustration of temporal variations in fish relative biomass (g per set) and mean monthly discharge (ml s^{-1}) in the Okavango delta. The fish data are based on experimental fishing done between 2000 and 2005

Table 2 A pair-wise summary of *t*-test for fish relative biomass between different areas in the delta where *P*-values marked with an asterisk indicate a significant difference in relative fish biomass between the different areas at a 95% confidence level

Test	*P*-value
Nxaraga versus Guma	0.172
Nxaraga versus Seronga	0.019*
Nxaraga versus Ngarange	0.002*
Guma versus Seronga	0.007*
Guma versus Ngarange	0.000*
Seronga versus Ngarange	0.044*

seasonal floodplains (i.e. <1.5 m), usually when the floods arrive or recede.

Table 5 shows that there are different types of fishing gears adapted to harvesting the fish community at different trophic levels. Mosquito fishing nets and fishing baskets harvest some of the smallest fish species in the delta (e.g. *Aplocheilichthys johnstoni*), while barrage traps, hook and line, and gill nets harvest the largest fish species (*Clarias* spp.). Traditional hook and line generally catches big fish, while mosquito nets catch small fish. Fishing baskets are nonselective fishing gear because they harvest the largest number of fish species while barrage traps are more selective because they harvest the lowest number of fish species (Table 5).

Another important coping strategy of subsistence fishers in the delta is postharvest preservation of fish. Sixty-five per cent of respondents in the socio-economic survey indicated that they either sun-dry or smoke their catch to peddle it or keep it for periods of reduced fish availability.

Discussion

Fish availability in the Okavango delta has spatio-temporal variations, similar to what has been observed elsewhere (e.g. Kolding, 1994; Welcomme, 2001). The observed negative correlation between the flood regime and fish availability from this study is based on a 'dilution and

Table 3 Summary of socio-economic variables that highlight the significance of fish on rural livelihoods of the subsistence fisher communities living on the fringes of the Okavango delta

Variable	%	n
Socio-economic value		
Fishing as a major socio-economic activity[a]	47	247
Purchase food from fish sales	18	39
Barter for goods and services using fish	45	245
Barter for grain using fish	58	180
Barter for other kinds of meat	5	180
Barter for goods from shops (e.g. sugar, cooking oils, etc.)	1	180
Socio-cultural value		
Women who fish alone	70	247
Women who fish with female relatives or friends	72	174
Girls who fish alone	61	247
Girls who fish with female friends or relatives	66	95
Boys who fish alone	58	246
Boys who fish with male siblings and or friends	61	107
Men who fish by themselves	52	246
Food security value		
Households who consume more than half of the catch	68	234
Households who rate 'increasing fish catches' as first strategy to offset decreased food supply[b]	27	248
Households who rate 'increasing fish catches' as second strategy to offset decreased food supply[b]	22	248
Households who rate 'increasing fish catches' as third strategy to offset decreased food supply[b]	12	248

[a]These include formal sector wages; temporary jobs; running a street vendor; carpentry; thatching; brick making; blacksmith, etc. from a total of 17 possible economic activities.

[b]These include cutting down on meals; reduce food portions; look for paid work; gather wild fruit; barrow food from relatives; borrow cash; receive food rations; sale of baskets or handicrafts; sell traditional beer; ask for food from relatives; use/sell grain from previous harvest; sell livestock and livestock products, etc. from a total of 21 possible strategies.

concentration' effect that has been described before for floodplain systems (Welcomme, 2001). Because of this dynamic effect, fish availability/catchability is highest during low floods when fish are 'concentrated' and lowest during high floods because fish are dispersed over a wide area and are hence' diluted'. Variations in space can occur either because of spatial differences in fish production (Silvano & Begossi, 2001) or fish migrations (Merron, 1991) which may either be due to breeding or feeding. Fox (1976) observed differences in spatial fish production where some peripheral lagoons in the southern and western portions of the delta have higher fish production as a result of water enrichment from cattle dung. Temporal and spatial variations in fish availability to rural communities have also been observed by Cerdeira *et al.* (2000) in the Amazon.

While subsistence fishers typically fish for home consumption (e.g. Cerdeira *et al.*, 2000), this study has shown that the delta's subsistence fishers consume and sell part of their catch. This study also revealed that female fishers, who predominantly use basket and mosquito fishing nets, harvest the smallest fish species (e.g. *A. johnstoni*), which also agrees with Mosepele, Mmopelwa & Mosepele, 2003 observations. However, these have little or no market value and are therefore, mostly consumed at home. Consequently, catches from female fishers become a major source of protein for rural households (Crespi, 1998; Cerdeira *et al.*, 2000). However, the seasonality of basket fishing indicates that fish protein availability is possibly highest between August and February and scarce at other times of the year. Larger fish with a good market value are harvested by male fishers using gill nets, hook and line, and barrage traps, and these are either bartered or peddled around the village for other household needs. Notwithstanding, Mosepele (2003) indicated that market value is species specific.

The Okavango delta's subsistence fishers have developed coping strategies based on gear technology to ensure continued fish availability despite the observed ecosystem variability. As an important coping strategy, multi-gear fishing is used by the delta's subsistence fishers to optimize fish utilization. In the Amazon, Batista *et al.* (1998) observed that gill nets are used throughout the year, while other gears are used seasonally. These coping strategies ensure that fish can still be available to rural communities even when other fishing gears cannot be used anymore. The delta's multi-gear fishery is also a common strategy in other African inland fisheries (Welcomme, 1985; Kolding, Ticheler & Chanda, 2003) and the Amazon (Batista *et al.*, 1998; Cerdeira *et al.*, 2000). According to Mosepele *et al.* (2003), a multi-gear fishery is the best approach to effectively utilize the delta's fishery without any significant

Table 4 Summary of the different fishing gears used by subsistence fishers in the delta showing major habitat where the gear is used and the main season when the gear is used

Fishing gear	Major habitat	Main season of use
Gill nets	River channels, lagoons, floodplains	Throughout the year
Hook and line	Margins of river channel, lagoons	Throughout the year
Fishing baskets	Seasonally flooded floodplains	August–February
Barrage traps	Seasonally flooded floodplain river channels	August–February
Fishing spears	Seasonally flooded floodplains	August–February
Mosquito nets	Seasonally flooded floodplains	August–February

Table 5 Summary of catching efficiency (c.p.u.e), species diversity and the most important fish species per fishing gear used by subsistence fishers in the Delta

Fishing gear	c.p.u.e (Nos per set)	Species richness	Mean fish size (mm)	Shannon's index	Evenness index	Most important species
Mosquito nets	3.8	22	38	2.26	0.73	*A. johnstonni*
Gill nets	4.8	43	259	2.29	0.61	*Clarias* spp.
Fishing baskets	19	46	57	2.62	0.68	*T. sparrmanii*
Hook and line	21.1	24	261	2.31	0.73	*O. andersonii*
Barrage traps	58.5	17	228	2.36	0.83	*C. gariepinus*

impact on fish biodiversity. Jul-Larsen *et al.* (2003) points out that a multi-species fishery can only be optimally harvested through multi-gears that harvest the fish community at different trophic levels. Therefore, the multi-gear fishery is not only the best coping strategy towards fish availability in the delta, but subsistence fishers are also inadvertently conserving fish biodiversity through this exploitation regime.

Postharvest technologies (i.e. smoking and sun-drying the catch) are also used to ensure that fish is available during periods of scarcity. These practices are consistent with Tlou's (1985) observations that smoked or sun-dried fish is either bartered or consumed in times of scarcity. Maar (1965) made a similar observation about this postharvest technology. According to Welcomme (2001), smoking fish in developing countries increases its postharvest shelf life, while Welcomme (1985) indicated that smoking fish is the commonest method of preserving fish in Africa.

The observation that women use traditional fishing equipment in social groups suggests that female fishers continue to pass cultural knowledge (e.g. weaving fishing baskets; the art of basket fishing, etc.) to posterity. Therefore, female fishing is not only a source of livelihoods, but is also a form of socio-cultural identity. McGoodwin (2001) points out that fishing is not only a means of ensuring livelihoods for rural fishers, but also a way of life of the rural fisher-folk. Fish has also been shown to have a social safety value mainly because fishers turn to it during lean periods (see Mosepele, 2000). Consequently, fishers engage in other economic/livelihood activities (e.g. livestock sales, formal sector employment, etc.) during good economic times and resort to fishing as a major livelihood activity in difficult economic times (Mosepele, 2000).

Conclusion

This paper has shown that while fish availability in the delta is subject to spatio-temporal variations, it remains a key resource used by rural communities living within the fringes of the delta to alleviated poverty. In response to these variations, subsistence fishers have devised coping mechanisms such as using multiple fishing gears to harvest different fish species in different habitats at different periods; and postharvest technology to preserve fish for lean times.

Understanding and appreciating the value of fish and fishing to rural communities by fisheries managers, requires consideration of the biological, physical and social dimensions of subsistence fishing. This will assist policy makers/managers in making well-informed decisions regarding the management of subsistence fisheries. For instance, there is need to initiate long-term monitoring strategies to study the effect of multi-gear exploitation regime on the long-term sustainability of the fishery as the use of this technology may be a result of considerable cumulative experience (McGoodwin, 2001). Classical fisheries management paradigms are normally based on gear restriction (Welcomme, 2001) that may inadvertently result in loss of culture and social customs if these are implemented without a comprehensive and holistic understanding of traditional/subsistence fisheries. Clearly, African freshwater fisheries and small-scale inland fisheries are complex entities which need integrated approaches to capture their intrinsic value to rural fishing communities.

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Conflicts of interest

The authors declare no conflicts of interests.

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