Ecohydrology & Hydrobiology 13 (2013) 135–147

Contents lists available at SciVerse ScienceDirect

Ecohydrology & Hydrobiology

journal homepage: www.elsevier.com/locate/ecohyd

Original Research Article

Public perceptions of papyrus: community appraisal of wetland ecosystem services at Lake Naivasha, Kenya

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ARTICLE INFO

Article history:
Received 30 October 2012
Received in revised form 20 March 2013
Accepted 25 March 2013
Available online 9 April 2013

Keywords:
Cyperus papyrus
Riparian communities
Provisioning services
Consumptive use values
Ecological restoration
Lake Victoria

ABSTRACT

Papyrus wetlands form ecological buffer zones, protecting lake shallows from sedimentation and open water from eutrophication. Multiple wetland processes and functions also support the livelihoods of adjacent riparian communities. However, ecohydrologists have in the past typically placed insufficient emphasis on social and cultural factors operating within the catchments that they study. Here we outline a process that better integrates social science research methods within ecohydrology, using the 'language' of ecosystem services to prioritise objectives for the rehabilitation of papyrus wetlands at Lake Naivasha in Kenya. Reference is made to Lake Victoria for comparison and to illustrate how and why stakeholders' perceptions of wetland services may vary over even short distances.

1. Introduction

Studies of papyrus wetlands are attracting renewed attention from ecologists, economists and social scientists owing to their key role in maintaining the health of aquatic ecosystems and supporting the livelihoods of people living close to them (Harper et al., 2011; Maclean et al., 2011; Morrison et al., 2012; Terer et al., 2012a). The emergent macrophyte *Cyperus papyrus*, L. (hereafter 'papyrus') is a giant member of the sedge family which typically outcompetes coexisting wetland species, forming vast monotypic swathes of swamp in wet parts of central, eastern and southern Africa (van Dam et al., 2011). In Kenya, papyrus wetlands occur along the shores of Lake Victoria (Balirwa, 1995), around the inflowing rivers of Lake Naivasha (Harper, 1992) and, to a lesser extent, within smaller freshwater bodies of the Rift Valley (Terer et al., 2012b).

Papyrus wetlands form ecological buffer zones at the land–water interface, protecting lake shallows from sedimentation (Kansiime et al., 2007) and allowing excess nutrients arriving from the catchment to be efficiently assimilated and recycled into plant biomass (Gaudet, 1977), thereby reducing the risk of eutrophication in open water. Jones and Muthuri (1997) calculated the net primary production of a papyrus swamp at Lake Naivasha to be >6 kg dry weight m^{-2} yr^{-1}, making it one of the most productive natural ecosystems on record. Being fast growing and high yielding, papyrus forms a readily renewable source of plant fibre, something upon which humans have long capitalised since ancient Egyptians began to make the first forms of paper c. 5000 years ago (Bell and Skeat, 1935). Today, many communities living near papyrus swamps, particularly in East Africa, continue

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1642-3593/$ – see front matter
http://dx.doi.org/10.1016/j.ecohyd.2013.03.008

to derive socioeconomic benefits from these highly productive habitats (Gichuki et al., 2001): tall stems are harvested for the production of mats, baskets and furniture (both for subsistence and for sale); rhizomes are uprooted for cooking fuel when alternatives are scarce and the wetland habitat as a whole is prized for hunting opportunities and as a store of traditional medicines (Morrison et al., 2012).

The future ability of these wetlands to continue delivering such a wide array of ecosystem services is uncertain, however. As with other wetland types around the world (Mitsch, 2010), papyrus swamps in East Africa are experiencing severe stress from a combination of: human population pressures (Balirwa, 1995); drainage in favour of agriculture (Schuyt, 2005); over-harvesting (Osumba et al., 2010); ineffective management (Hartter and Ryan, 2010); destruction by large mammals (Morrison and Harper, 2009) and the effects of climate change (Odada et al., 2009). Calls have been made for over a decade in Kenya for the restoration (Zalewski and Harper, 2001), protection (Kiwango and Wolanski, 2008) and future wise use (Terer et al., 2012a) of these important habitats. Morrison et al. (2012) provide an example of community-led rehabilitation and management of papyrus wetlands at Lake Victoria that – in spite of its apparent success – has so far only been achieved on a small scale and is yet to be replicated elsewhere. Larger scale restoration now seems possible at Lake Naivasha, given the support of local and national governance agencies as well as international donor assistance (Harper et al., 2011).

The ultimate beneficiaries of papyrus wetlands are riparian communities ('*wetlanders*': Coles and Coles, 1989), whose livelihoods depend, to varying degrees, on the direct and indirect benefits arising from wetland processes and functions, including access to clean drinking water and the provision of fish and fibre (MA, 2005). We can therefore expect that the attitudes and behaviours of these groups in relation to the wetlands will, to a considerable extent, determine the state and structure of the ecosystem over time, while taking due account of wider processes such as climate change. Ecohydrologists designing and implementing proposed wetland restoration measures thus require a nuanced understanding of the ecosystem from the perspectives of these key stakeholders, in order that they may strike a balance between enhancing the biophysical and ecological state of the wetlands and addressing the needs of the people who use them.

Hiwasaki and Arico (2007, p. 4) contend, however, that:

> "...the trend of past activities conducted under UNESCO's ecohydrology theme shows that emphasis placed on social and cultural factors has been insufficient. An important aspect that has yet to be fully addressed by ecohydrologists is the one related to people's relationship to water and the surrounding environments."

The authors discuss the need to integrate concepts and methodologies from the social sciences into ecohydrological research in order to "overcome the gap" separating its practitioners from the multiple social, cultural, political and economic interactions critical to effective water resources management (Hiwasaki and Arico, 2007). We agree that concerted efforts to integrate the social sciences into ecohydrological projects are crucial in the search for sustainable solutions to issues connecting water, the environment and people. At Lake Naivasha, an 'Ecohydrology Demonstration Site' since 2005 (Harper et al., 2011), a detailed analysis of people's values and beliefs regarding papyrus is currently missing. Closer integration of social and cultural considerations with ecohydrological research is particularly warranted in the case of Lake Naivasha since management plans for the ecosystem are presently under review, partly in response to claims of exclusion of certain stakeholder groups (Harper et al., 2011).

The aim of the present study, then, is to begin to overcome this knowledge gap, using the 'language' of ecosystem services to establish informed social and ecohydrological objectives towards the successful rehabilitation and future wise use of Naivasha's wetlands. A comparative analysis with riparian communities at Lake Victoria is made in an attempt to reveal how and why different stakeholders' perspectives may differ between sites and to consider the implications of this variation for wetland management.

1.1. Study areas

Lake Naivasha (0° 45′ S, 36° 20′ E) is Kenya's second largest freshwater body (surface area c. 140 km^2, max. depth c. 6 m) lying at an elevation of 1890 m.a.s.l. in the Rift Valley province, with a surrounding catchment area of around 2150 km^2 (Harper et al., 2011). Much of Naivasha's ecological history has been summarised in Harper et al. (2002). The lake is unusual in being one of only two freshwater bodies in a system of otherwise alkaline-soda lakes (Harper and Mavuti, 2004). This freshwater system is used for drinking, washing and livestock-watering by some 800,000 people (KNBS, 2012) living throughout the catchment whilst, at the same time, supporting geothermal power industries (generating c. 15% of Kenya's total power production, projected to rise to c. 39% by 2014: Afara Global, 2012) and irrigated vegetable and flower-growing – the latter being Kenya's top foreign-exchange earner and thereby making the Lake Naivasha ecosystem a critical component of the national economy (Harper et al., 2011).

Lake Victoria (1° 0′ S, 33°, 0′ E) is the world's second largest freshwater body (surface area c. 68,500 km^2, max. depth c. 84 m) lying at an altitude of 1133 m.a.s.l., with a surrounding catchment area of some 185,000 km^2 (Balirwa, 1995). Aspects of its ecological history have been summarised in Witte et al. (1999). The Kenyan part of Lake Victoria, roughly 6% of its total surface area, fringes Nyanza province (with a population of around 5 million people: KNBS, 2012) in the southwest of the country. In addition to fishing (the region's principal source of protein), subsistence agriculture and local craft industries, Nyanza's natural resources provide raw materials for textile and paper mills, rice plantations, sugar refineries, leather tanneries, cement plants and agrochemical factories (Kairu, 2001).

Despite differences in scale and economic functions, both lakes depend on papyrus wetlands to help regulate the aquatic environment in order to provide essential ecosystem services to local, regional and international populations.

2. Materials and methods

All 'known' human welfare benefits associated with papyrus wetlands (hereafter 'PWs') in East Africa were listed and then grouped into similar sub-sets following an extensive literature review. The resulting table formed the basis of a comparative tool to be used during data analysis. A pilot study was then conducted at Dunga beach, near Kisumu on the shore of Lake Victoria (see Morrison et al., 2012), in order to assess the completeness of this table, as well as to provide a training opportunity for enumerators prior to actual data collection. Through informal interviews, the pilot study revealed the existence of several benefits attributed to papyrus not recorded from the literature that were therefore added to the list. The final table thus consisted of 27 sub-sets of benefits organised into 4 groups, corresponding to the major categories of ecosystem services (provisioning, regulating, cultural and supporting) as defined by the MA (2005), with between 6 and 8 sub-sets in each category.

Semi-structured interviews were subsequently conducted at 8 different sites (varying in size between c. 5 and 15 ha) around Lake Victoria during August 2011 over the course of one week, from 07:00–14:00 h. The month of August was chosen since riparian communities are particularly active at this time between Kenya's long and short rains, after which many wetland sites become inaccessible due to flooding. Each site was randomly selected from a list of locations with known public access to wetlands compiled by field assistants. Individuals encountered close to PWs within the riparian zone (defined for the purposes of this study as land lying between the lake edge and up to 500 m inland) were then approached in a haphazard fashion at each site. If found to be a willing participant, open-ended questions were asked – such as "*do the papyrus wetlands here hold any value for you?*" or "*do you think the swamps are important for the environment in any way?*" – and responses written down verbatim. Demographic (e.g. gender, age, highest level of formal education) and life history data (e.g. sources of income, duration of residence around the lake, frequency of visits to the wetlands) were also collected, in an attempt to situate different perceptions within explanatory social and cultural contexts. All information was recorded in situ by the enumerators. Having established a methodology with which we were satisfied and a target number of respondents (118) at which it was deemed that a point of saturation in the answers being received had been reached, we proceeded to conduct a further 118 interviews at 8 different sites, randomly selected in the same manner, around Lake Naivasha the following week during the same time of day.

Responses provided by participants were assigned to appropriate sub-sets of services within the table described above (hereafter 'TOKS': Table Of Known Services) upon returning from the field. For example, if a respondent stated that he or she valued papyrus for its perceived medicinal properties, that citation would be assigned to the sub-set entitled "source of biochemical resources", under provisioning services. In this way, each of the 236 interviews could be allocated an individual TOKS 'score' (the theoretical maximum being 27, should all sub-sets be cited), serving as an initial quantitative representation of stakeholders' responses for the purposes of statistical comparison between sites. The relative percentage weighting (by citation) of each sub-set was then calculated in order to reveal which services might be regarded as priority from a management perspective.

Focus group discussions (lasting between 30–45 min and attended by 8–10 individuals) were also held at two sites chosen at random (Ramula, Lake Victoria and Kamere, Lake Naivasha) in addition to the interviews, with efforts made to ensure a balanced representation of gender and age. These sessions allowed for greater depth of expression and insight than the one-on-one interviews alone and contributed important information to the study, particularly concerning values associated with heritage, spirituality and other such 'cultural' services.

Finally, papyrus wetlands at each of the 16 sites were allocated a 'site quality score' on a scale of 1–10. Starting from a hypothetical score of 10 ("pristine" wetland), a point was then deducted for any of the following disturbance characteristics: evidence of clearance from burning or overharvesting; signs of uprooting; habitat patchiness; stunted growth; missing umbels (flower heads); signs of trampling; presence of large numbers of livestock and proliferations of climbing weeds. The same individual surveyed each site in a systematic fashion for each of these characteristics prior to the collection of qualitative data. These scores were compared with TOKS scores in order to discern what relationship, if any, exists between local habitat quality and levels of environmental awareness.

The limitations of assigning numeric values in this way were fully considered in both of the above instances. In particular, the figures for the TOKS scores reflect the number of different ecosystem services recognised as important by the respondents but they are not indicative of economic or other quantitative aspects of value attributed by the authors or by participants to different services. The values assigned to, and the valuation of, ecosystem services – especially with reference to cultural services and to economic/non-economic valuation – is currently an issue of much debate and contention (Gomez-Baggethun and Ruiz-Perez, 2011; Potschin and Haines-Young, 2011; Busch et al., 2012). These issues will be explored further in the contexts of Lakes Naivasha and Victoria as part of our ongoing research. For the current study, the TOKS data represent an initial indication and point of comparison as to the nature and range of important ecosystem services at and between the two lakes.

3. Results

3.1. Demographic data

A typical cross-section of the Lake Naivasha and Lake Victoria riparian community is shown in Table 1. The ratio of male (81/118) to female (37/118) individuals interviewed at

Table 1
Summary demographic data from participants ($n = 236$) in the study for Lakes Naivasha and Victoria. Key – *Gender*, number of females (♀) and males (♂); *Age*, age (cohorts); *Education*, highest level of formal education; *History*, life history (*Resident*, number of participants who were local residents; *Birth*, % resident since birth; *Outside*, % born outside the region); *Duration*, length of time settled in region (years); *Distance*, distance of residence from wetland; *Frequency*, frequency of visits to wetland (e.g. '> 1/decade' = once every ten years or more). 95% confidence intervals are shown in parentheses for numerical means and nominal modes (expressed around proportions).

		Lake Naivasha	Lake Victoria
Gender	♀	37	59
	♂	81	59
	n	118	118
Age	Min.	<18	<18
	Max.	>55	>55
	Mode	19–35 (0.7 ± 0.1)	19–35 (0.4 ± 0.1)
Education	Min.	None	None
	Max.	University	University
	Mode	Primary (0.4 ± 0.1)	Primary (0.7 ± 0.1)
History	Resident	90/118	118/118
	Birth	28.8%	88.1%
	Outside	71.2%	11.9%
Duration	Min.	1	6
	Max.	41	69
	Mean	9.1 (±2.1)	35.1 (±2.7)
Distance	Min.	101–500 m	101–500 m
	Max.	>5.1 km	>5.1 km
	Mode	>5.1 km (0.6 ± 0.1)	0.5–1.0 km (0.3 ± 0.1)
Frequency	Min.	>1/decade	1/month
	Max.	2–3/day	2–3/day
	Mode	1/day (0.3 ± 0.1)	1/day (0.6 ± 0.1)

Naivasha was roughly 2:1 and the predominant (proportional mode 0.7 ± 0.1) age group 19–35 years old. There was a fairly even spread among respondents in terms of their highest level of education: a small majority (35.6%) had only reached primary school, 22.9% had completed secondary school, 20.3% were college graduates and 16.9% were enrolled in or had graduated from a university, with 4.2% having no formal education. Just over 75% (90/118) classed themselves as residents of Naivasha, the remaining 28 being temporary visitors to the region. The majority of the residents (56/90) had recently immigrated (arriving on average 9 years ago), with only 34 born in the region itself. Over half (56.7%) those who had immigrated had done so in search of employment, around one quarter (26.7%) to escape conflicts elsewhere, and the remainder variously to join friends/family, with the aim of acquiring land, or for medical reasons. Most people (0.6 ± 0.1) resided over 5 km away from the wetland area where the interview took place and around one third (0.3 ± 0.1) visited the site on average once a day. Twenty ethnicities were recorded in the survey sample, the majority (80.5%) being Kenyans, comprising 13 different (traditionally tribal) communities, the remaining 19.5% representing 7 other nationalities (American, Australian, British, Canadian, Danish, German and Zimbabwean)[1]. A total of 21 different categories of employment were recorded, ranging from flower farm workers and fishers to teachers and tradesmen, among many others. Their single stated livelihood was the sole means of income for the majority (87.3%) of individuals.

The gender ratio of the riparian community interviewed around Lake Victoria was 1:1 with the majority of individuals aged between 19–35 years old, as at Naivasha. However, nearly twice as many (68.6%) participants had left education following primary school, only 14.4% had completed secondary school and there were only two college students and a single university graduate among the survey pool, with 14.4% having no formal education whatsoever. Every individual ($n = 118$) interviewed was a local resident, the vast majority (88.1%) since birth. With only 10/118 participants having immigrated to the region, the mean residence time was over 35 years (almost four times that of Naivasha). A small majority (proportional mode 0.3 ± 0.1) lived close (i.e. between 0.5–1.0 km) to the wetland where the interviews took place – around three times the number at Naivasha – and twice as many people (0.6 ± 0.1 compared to 0.3 ± 0.1) visited the site once a day. Over 99% of respondents represented the Kenyan Luo community, with just one other ethnicity (Luhya) stated. Only 9 different categories of employment were recorded around the lake (compared to 21 at Naivasha), the majority (39.8%) of participants being papyrus mat-makers and subsistence farmers (34.7%) in addition to fishers, tradesmen and others. In contrast to Naivasha, the majority (73.7%) of respondents pursued multiple livelihood strategies by having two or more jobs.

3.2. TOKS and site quality scores

The maximum 'TOKS score' at Naivasha was 13/27, with a mean score of 3.4 (±0.4) (Table 2). The average site quality score (SQS) recorded, rounded to the nearest whole number, was 5/10, although this varied between sites from a minimum of 1 to a maximum of 7. There were no significant differences between the 8 sites in either TOKS or site quality scores; although the number of participants between each site varied, this was not highly significant and no correlation was found between number of participants (n) and TOKS scores.

The maximum TOKS score recorded around Lake Victoria was similar to Naivasha (15/27), yet the overall mean was exactly double at 6.8 (±0.6). The average site quality score for the 8 sites surveyed was equally comparable at 6/10 – although this varied over a narrower range of between 5 and 8 (Table 2). As at Naivasha, there were no significant differences between the 8 sites in either TOKS or site quality scores, the number of participants did not vary significantly between sites and there was no correlation between number of participants and TOKS scores.

3.3. Comparisons between lakes

No significant differences ($p = .05$, Mann–Whitney U-test) between Victoria and Naivasha were detected with respect to variations in the number of participants at each location (n: Table 2) nor their associated site quality scores; likewise no association was found between n and TOKS scores for either lake. The variance in TOKS scores between the lakes, however, was highly statistically

[1] Non-Kenyan visitors were included in the survey pool since tourism plays an important role in the management of the Lake Naivasha ecosystem.

Table 2
Summary of TOKS (Table of Known Services) scores and site quality scores (SQS) for each location surveyed around Lakes Naivasha (top panel) and Victoria (bottom panel), ranked in decreasing order of mean TOKS score. Site codes correspond to data points in Fig. 2; *n*, number of participants at each site; *Mode* refers to the most frequently identified service at each site (and for the lake as a whole *); 95% confidence intervals shown in parentheses for location means and modes (expressed around proportions).

Rank	Code	Site	*n*	TOKS score			Mode	SQS
				Min	Max	Mean		
1	YM	YMCA Beach	8	0	8	4.9	Clean water supply*	4
2	KB	Karagita Beach	15	1	5	4.4	Clean water supply	1
3	KA	Kamere Beach	24	0	8	4.3	Clean water supply	2
4	CV	Crescent View	8	1	5	4	Clean water supply	5
5	TB	Town Landing Beach	15	1	13	3.5	Clean water supply	6
6	FE	Fish Eagle Inn	18	0	6	3	Biodiversity support	7
7	CA	Carnelley's	10	1	5	2.4	Biodiversity support	7
8	FC	Fisherman's Camp	20	0	7	1.2	Aesthetic values	7
		Lake Naivasha	**118**	**0**	**13**	**3.4** (±0.4)	* **0.4** (±**0.1**)	**5** (±2)
1	NK	North Kabodho	15	2	15	9.6	Fibre for commodities*	5
2	NY	Nyalenda	21	4	12	8.6	Fibre for commodities	6
3	KG	Kamagaga	10	6	13	8.5	Clean water supply	5
4	WK	West Kabodho	12	4	12	8	Fibre for commodities	7
5	RA	Ramula	16	1	9	5.8	Fibre for fuel	5
6	KO	Kakola-Ombaka	16	1	10	5.4	Fibre for commodities	8
7	WK	West Kabar	16	1	8	4.1	Fibre for commodities	7
8	KM	Kamuga	12	1	9	4	Local climate control	8
		Lake Victoria	**118**	**1**	**15**	**6.8** (±0.6)	* **0.9** (±**0.1**)	**6** (±1)

significant [$F(117, 117) = 2.171$, $p < .01$], the mean score at Victoria being twice that of Naivasha.

This variance in TOKS scores is reflected in the differences between the number of participants (absolute values) who recognised benefits falling within the 27 sub-sets of services, being statistically significantly higher at Victoria for provisioning [χ^2 (1, Yates' correction) = 110.04, $p < .01$], regulating [χ^2 (1) = 56.02, $p < .01$] and supporting [χ^2 (1) = 15.40, $p < .01$] services, with only recognition of cultural services showing no significant difference [χ^2 (1) = 0.01, $p < .01$] between the two lakes (Fig. 1).

Plotting TOKS scores against site quality scores (Fig. 2) reveals a negative correlation between the two factors at both lakes, the relationship between the data sets being stronger for Naivasha ($r^2 = 0.574$) than for Victoria ($r^2 = 0.442$), and a Spearman Rank Correlation Coefficient (two-tailed test) showing the relationship to be highly significant in both cases ($r_s = -857$, $p = .02$ for Naivasha and $r_s = -.893$, $p = .02$ for Victoria).

At Lake Naivasha, the largest proportion (42.1%) of perceived benefits associated with PWs related to provisioning services; over a quarter (27.9%) corresponded to cultural services and the remainder were split evenly between regulating (15.0%) and supporting (15.0%) services; rather different divisions were recorded around Lake Victoria (50.9, 13.8, 21.6 and 13.7% respectively) which illustrate that, there, provisioning > regulating > cultural > supporting services, whilst at Naivasha provisioning > cultural > regulating = supporting services (Fig. 3).

The data become most instructive when assigned their relative weighting. Nullifying sub-sets whose proportional citation within the survey pool falls below 5% presents a clearer picture of which services are most widely valued and might thus be assigned priority from a governance perspective. Table 3 lists all the services recorded at each lake with a relative value above this threshold (i.e. where proportion > .05), ranked by decreasing order of percentage weight based on that classification. The most commonly identified service around Lake Naivasha is an association of PWs with a 'clean water supply' (this does not necessarily imply recognition that the papyrus itself is responsible for 'water purification', a regulating service), followed by support for biodiversity and appreciation of their aesthetic qualities (Table 3). A different pattern emerges for Lake Victoria, where the provision of fibre for the manufacture of commodities is of primacy, followed by biodiversity support and the provision of fibre for fuel. Both locations have sub-sets of services not found at the other above this threshold, each group of which accounts for a similar proportion of that lake's priority services, i.e. Naivasha (*): aesthetic values, fishing/hunting opportunities, social relations and sense of place (combined weighting 43.8%); Victoria (+): fibre for commodities, fibre for fuel and fibre for livestock (44.0%).

The 3 sub-sets of priority services uniquely identified at Lake Victoria represent 'consumptive use values' (CUVs) characterised by direct utilisation of papyrus fibre – in the manufacture of marketable products, for burning as a domestic fuel, or as livestock fodder when fresh. Each of these services was also recognised at Lake Naivasha (Fig. 1), although their proportion among all citations there fell below 5%, hence their exclusion from Table 3. However, irrespective of locality, a strong positive correlation ($r^2 = 0.976$) exists between the number of CUVs cited (divided into four cohorts, comprising individuals who recognised either 0, 1, 2 or 3 CUVs) and the mean TOKS scores of individuals within each cohort[2]. The

[2] For each record, the number of CUVs cited by an individual was discounted from their TOKS score so as not to bias the relationship, e.g. if a respondent only recognised the value of papyrus for fuel and nothing else, his or her TOKS score was treated as '0' for the purposes of this analysis.

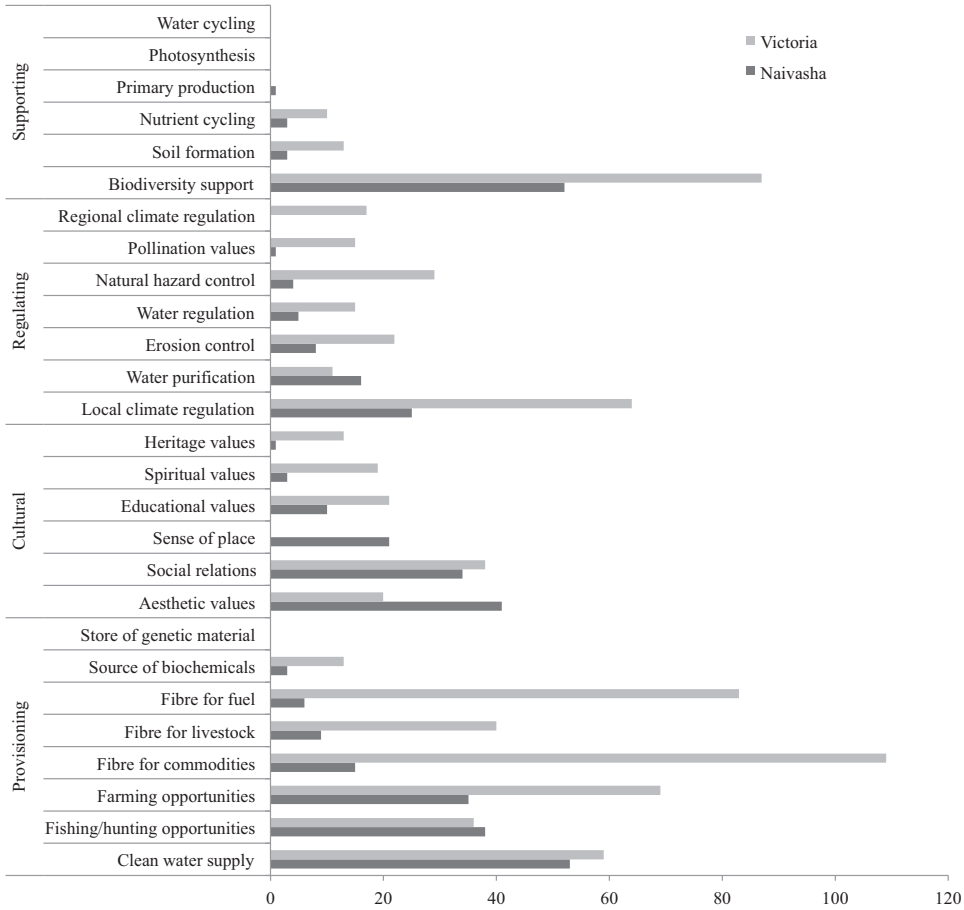

Fig. 1. Number ($n = 236$) of participants (absolute values) who recognised benefits of papyrus wetlands within the 27 sub-sets of services identified at Lakes Naivasha and Victoria.

mean TOKS score of respondents who recognised one or more CUVs was found to be strongly significantly higher [$F(176, 58) = 3.034$, $p < .01$] than that of those who recognised none (Fig. 4).

3.4. Demography and TOKS scores

At Lake Naivasha, the 28 participants whose livelihoods centred in or around the riparian zone (comprising

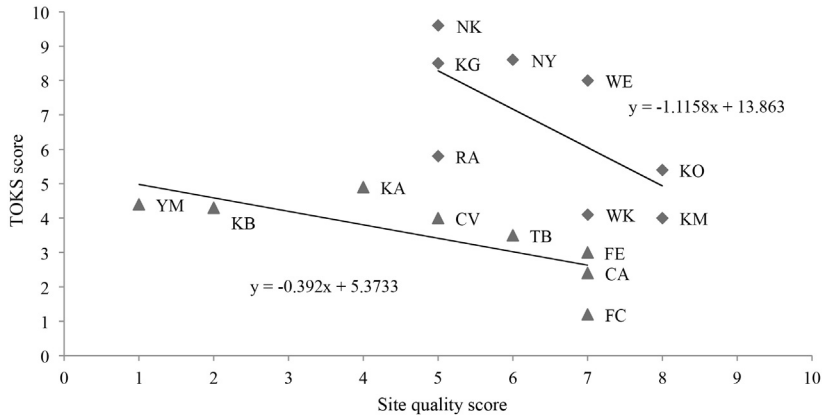

Fig. 2. Scatter plot showing negative correlation between TOKS and site quality scores for Naivasha (triangles) and Victoria (diamonds); for site codes see Table 2.

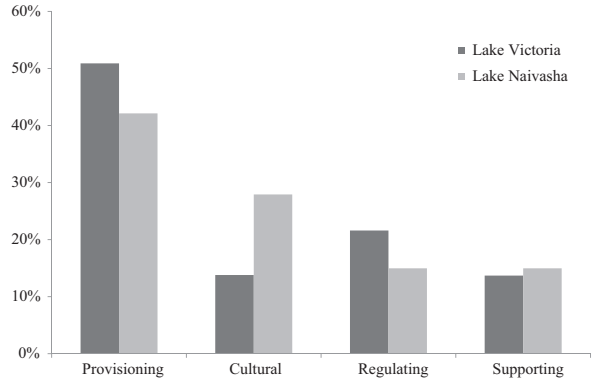

Fig. 3. Relative percentage weighting of benefits associated with papyrus wetlands from the perspectives of respondents interviewed around Lakes Victoria and Naivasha.

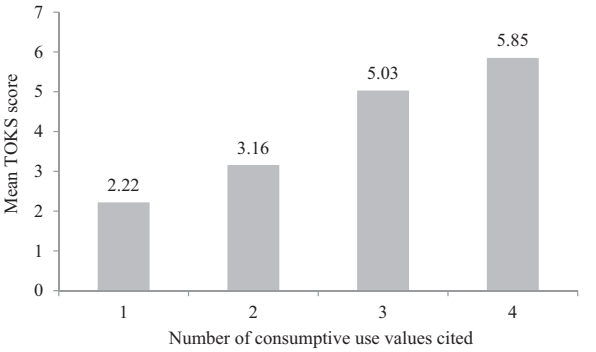

Fig. 4. Mean TOKS scores of individuals who recognised 0, 1, 2 or 3 consumptive use values of papyrus.

papyrus mat-makers, fishers, coxswains, tour guides, subsistence farmers and herdsmen) had significantly higher ($z = 1.810$, $p < .05$) TOKS scores (mean 3.9) than those with livelihoods centred away from the riparian zone (3.2). There were no significant differences in this regard at Lake Victoria, however, where the vast majority (100/118) of respondents pursued riparian livelihoods.

Residents at Naivasha had significantly ($z = 6.104$, $p < .01$) higher TOKS scores (mean 4.2) than non-residents (mean 1.8); at Victoria all participants were residents. No significant association between number of years settled and TOKS scores was detected for either lake.

In terms of gender, there were no significant differences ($z = 0.739$) between the mean scores of men (7.0) and women (6.5) at Victoria, whilst at Naivasha men scored significantly ($z = 3.870$, $p < .01$) higher (3.9) than women (2.2). This observation may be linked to income-generating activities, in that women comprised only 16.7% of those with riparian livelihoods (with statistically higher scores) at Naivasha in contrast to 81.8% of women at Lake Victoria.

The difference in TOKS scores between Kenyan nationals and foreigners was strongly significant ($z = 7.799$, $p < .01$) at Naivasha, Kenyans scoring higher (4.0) on average than foreigners (1.2). There were no foreigners among the survey pool at Lake Victoria.

There was no significant difference at Naivasha ($z = 1.860$) between participants with > 1 job and those with a single job, both groups having similar mean scores (4.2 and 3.2 respectively); the difference at Victoria, on the other hand, was highly significant ($z = 6.134$, $p < .01$), those with multiple jobs scoring higher (7.9) than those with just one (3.7).

The distance between participants' homesteads and local wetlands had a significant [ANOVA, $F(5, 112) = 3.464$, $p < .01$] effect on TOKS scores at Victoria; post hoc comparisons (Tukey HSD test) indicated that the mean score for those residing < 100 m away (8.7) was significantly different from those living between 501–1000 m away (5.1). The effect at Naivasha was also significant [ANOVA, F (4, 113) = 2.899] at $p < .025$, Tukey tests indicating TOKS scores to be significantly different between two sets of cohorts: 501–1000 m (4.5) and > 5.1 km (2.8) and between 3.1–5.0 km (4.6) and > 5.1 km (2.8).

There were no statistical differences in scores between different age groups at Naivasha, unlike at Victoria where the differences were significant [ANOVA, $F(3, 114) = 3.047$, $p < .05$], participants < 18 years tending to have lower scores (mean 3.5) than those aged 19–35 years (7.1) and 36–54 years (7.4).

The relationship between participants' highest level of formal education and TOKS scores was significant [ANOVA, F (4, 113) = 3.216, $p < .05$] at Naivasha only; post hoc comparisons revealed significant differences between primary school (mean 3.6) and secondary school (4.2) cohorts and university (1.9) cohorts.

Finally, frequency of visits to the wetland had a highly significant [ANOVA, F (8, 109) = 3.259, $p < .01$] effect on participants' scores at Naivasha, those who visited the site several times a day scoring higher (mean 4.0) than those

Table 3
Relative percentage weighting of priority (proportional citation >.05) ecosystem services associated with papyrus wetlands around Lakes Naivasha and Victoria; * and + indicate service is uniquely recognised around that lake.

Rank	Lake Naivasha	%	Lake Victoria	%
1	Clean water supply	19.6	Fibre for commodities +	21.5
2	Biodiversity	17	Biodiversity	19.3
3	Aesthetic values *	13.3	Fibre for fuel +	14.1
4	Fishing/hunting opportunities *	12.5	Farming opportunities	12.8
5	Farming opportunities	11.5	Local climate regulation	12.2
6	Social relations *	11.2	Clean water supply	11.7
7	Local climate regulation	8.1	Fibre for livestock +	8.4
8	Sense of place *	6.8		

who visited once every 10 years or more (1.9). There were no significant differences in this regard at Victoria.

4. Discussion

The demographic data collected around Lake Naivasha describe an ethnically heterogeneous, recently settled riparian community with a high rate of immigration and reasonably high levels of formal education. Taken as a whole, participants recognised a wide array of ecosystem services associated with papyrus wetlands across the four categories (Fig. 1). Looking more closely however, levels of individual awareness were generally very low, with a mean TOKS score of 3.4/27 (Table 2), equating to recognition of just c. 13% of all 'known' services. The corresponding data for Lake Victoria, on the other hand, describe a more homogeneous and longer-settled riparian community with a low rate of immigration and lower levels of formal education. As at Naivasha, most services (22/27 sub-sets) were recognised by the collective survey pool; levels of individual awareness were twice as high on average however, with a mean TOKS score of 6.8/27 (c. 25% of all services); a highly significant difference.

Differences between the lakes regarding the perception of benefits associated with PWs may be partly explained by differences in both geography and demography[3]. Below we discuss these two sets of factors in relation to different 'priority' services (Table 3) identified – those common between lakes as well as those unique to either Naivasha or Victoria.

4.1. Commonalities between lakes

4.1.1. Clean water supply

At Lake Naivasha, the most frequently identified service associated with PWs was a supply of clean water for drinking, washing and livestock watering. The Malewa and Gilgil rivers, which together supply most of the inflow to the lake, are bordered for much of their lower courses by private horticultural enterprises and cattle ranches, with limited public access points for the collection of water for domestic use (D. Kimani, personal communication). Hence the few accessible parts of the lake edge known as 'public beaches' – especially those that are still fringed by papyrus – seemingly constitute the most favoured sites for the collection of clean water. Furthermore, borehole water around Lake Naivasha contains concentrations of fluoride up to eight times higher than the World Health Organisation limit (1 mg L^{-1}), causing malformations and weakness in bones and teeth, whereas lake water fluoride concentrations are half this limit (N. Pacini, unpubl.).

At Lake Victoria, a similar number of respondents cited a supply of clean water as a benefit associated with PWs (Fig. 1), yet its relative weighting among priority services was lower than at Naivasha (Table 3). This may be for one or more of the following reasons: (1) a greater number of rivers and distributaries drain into Lake Victoria to which there is generally greater access, reducing the need to visit lake edge sites in order to collect water; (2) since PWs are typically more common within the riparian zone (and generally more intact, with site quality scores in the range of 5–8: Table 2) their ability to trap sediments and improve water quality may be more obscured from the perception of local stakeholders (or, in other words, taken for granted); (3) whilst valued for this service at certain sites, significantly greater benefits are derived from other services, such as the provision of plant fibre (see Section 4.3).

4.1.2. Biodiversity

The role that PWs play in supporting biodiversity constitutes a similar proportion of priority services identified at each lake (Table 3). Indeed, both Naivasha and Victoria are renowned for their high levels of (particularly faunal) species richness, attracting local holidaymakers, international tourists and researchers to their shorelines (Bugenyi, 2001). The wetlands themselves provide critical breeding grounds and nursery refugia for fish species (Hickley et al., 2004), as well as valuable habitat for mammals (hippopotamuses, sitatunga), birds (including some papyrus endemics: Maclean et al., 2006) and invertebrates. Whilst forming a similar relative proportion of each lake's priority services, in absolute terms (Fig. 1) a significantly [χ^2 (1, Yates' correction) = 8.82, $p < .01$] higher number of people around Victoria recognised biodiversity support as a benefit associated with PWs. This observation may be partly explained by the fact that a greater proportion of the survey pool at Victoria: (a) pursued riparian livelihoods and (b) lived closer to the wetlands than at Naivasha (Table 1), factors that are likely to have imparted greater knowledge of their associated biodiversity.

4.1.3. Farming opportunities

Benefits relating to farming opportunities refer to the high agricultural potential presented by the riparian zone more generally, being land of gentle gradient with good access to fresh water and enhanced by nutrient-rich, peat-like deposits within the wetland created by the decomposition of papyrus biomass. Often parts of the wetlands are cleared, either by uprooting rhizomes or else through the setting of fires during the dry season, in order to convert this productive land to agriculture. This had recently happened at one site around Lake Victoria (Ramula) where an increase in food prices had prompted local residents to clear the papyrus for conversion to rice paddies, both in order to feed their families more cost-effectively and to benefit from the profitability of the price hike (the most commonly-cited benefit of papyrus at that location was 'fibre for fuel': Table 2). As above, a significantly [χ^2 (1) = 11.13, $p = .01$] greater number of people around Lake Victoria cited farming opportunities as a sub-set of services than at Naivasha, a fact that may be explained by a greater proportion (34.7% compared to 10.2% at Naivasha) of participants at Victoria being

[3] Seasonal variations in hydrology will also have an impact on the range and value of ecosystem services from PWs and correspondingly on the perception of these from local stakeholders. However, having conducted the research over a 2-week period, we assume no significant differences between the two lakes in this regard – all wetland sites having been in a non-flooded state.

subsistence farmers themselves. What's more, access to the lake edge at Naivasha is limited to a handful of public beaches where use of the riparian zone for farming is (theoretically, if not practically) prohibited by environmental law.

4.1.4. Local climate regulation

A further shared appreciation for the wetland environment of both lakes stems from its regulating effects on local climatic conditions: the air around the swamps typically reported as being cooler thanks to the shade of tall papyrus stands, as well as a belief among respondents that wetland areas produce more reliable rainfall than surrounding regions (those cleared for agriculture). A significantly [χ^2 (1) = 17.10, p = .01] higher number of people cited local climate regulation as a benefit attributed to PWs at Victoria, for which similar reasons as outlined for biodiversity (Section 4.1.2) may be given by way of explanation, in addition to the observation that average daytime temperatures there are typically higher and thus the shade of the papyrus more likely to be appreciated. What's more, a number of respondents at Victoria talked of a spiritual/religious practice linking wetlands with local precipitation levels, wherein dry papyrus stems are burnt in order that the ash rising from the fire may return to the land "as raindrops" encouraging the onset of the wet (growing) season. No such spiritual practice/custom was encountered at Naivasha, on the other hand.

4.2. Services unique to Naivasha

Values relating to aesthetic qualities, social relations and one's 'sense of place' together accounted for almost one-third (31.3%) of all priority services at Naivasha (Table 3). These 3 sub-sets correspond to the benefits local residents (as well as outsiders) feel when visiting the wetlands to collect water, wash their clothes or simply to meet and relax with others during their free time. Whilst access to the lake's shoreline is limited, a number of public beaches (such as Kamere) remain open and are frequented by congregations of school children, church parties and tourist groups eager to witness the natural beauty of the riparian zone (E. Morrison, personal observation). The unique significance of these services at Naivasha may arise from the fact that many residents live in densely-populated informal settlements set within the denuded (deforested, heavily eroded) landscape of the lake's hinterland at sites often >5 km away from the riparian zone (Table 1), making a visit to the more verdant shoreline an attractive proposition.

Such benefits did not rank as priority services at Victoria, where the majority of respondents lived much closer (<1 km) to the wetlands and visited them more regularly as a consequence of their livelihood strategies. Further, the typically warmer and wetter climate of the Lake Victoria region produces a more fecund landscape away from the lake as well as close to it, whilst population densities around Lake Victoria appear somewhat lower, with the majority of local residents living within traditional Luo homesteads close to sites settled by their ancestors. Some or all of these factors may combine to explain why significantly [χ^2 (1) = 7.25, p = .01] fewer people at Victoria recognised the wetlands for their aesthetic qualities and none at all for contributing to their sense of place. In absolute terms, however, maintenance of social relations was cited by a comparable number of respondents as at Naivasha (Fig. 1), likely stemming from the fact that a many people spent their working days in and around the riparian zone (see Section 4.3 below); that said, it did not constitute a priority service when assigned its relative weighting (Table 3).

The remaining priority service identified at Naivasha but not Victoria was fishing (and to a lesser extent hunting) opportunities provided for by the physical complexity of the wetlands, creating ideal refugia for juvenile fish that can be easily (if illegally) caught using seine nets. Naivasha lacked both a target fish species (Hickley et al., 2008) and a traditional fishing community until a group of Luo immigrants arrived from Lake Victoria in the course of the last century. Today, Naivasha's moderately sized fishery is restricted to 50 licensed fishing vessels, with further restrictions placed on crew sizes and the type of nets that may be used; what's more, following a collapse of the fishery in 2001, a closed season now operates between 1st June and 31st August each year (Kundu et al., 2010). These regulations, despite being only weakly enforced, drive those who are unable (or else unwilling) to comply towards fish poaching in the lake shallows (V. Kinyua, pers. comm.).

Benefits pertaining to fishing opportunities presented by PWs were perhaps less frequently cited at Lake Victoria during this study for one or more of the following reasons: (1) thicker bands of papyrus hid those that do in fact fish within the wetlands from view; (2) the vastly superior fishery compared to Naivasha permits more reliable catches in the open lake (whether boats be licensed or not, the size of Lake Victoria making it even more difficult to regulate than Naivasha) and (3) fishers may have been underrepresented within our survey pool (comprising just 11/118 respondents) precisely because they were engaged in fishing away from the riparian zone whilst the surveys were being carried out.

4.3. Services unique to Victoria

At Lake Victoria, 3 unique services constitute nearly half (44%) of all priority services identified, each being characterised by direct consumption of papyrus (fibre) itself – whether it be used for producing commodities, as biomass for domestic fuel, or for feeding to livestock (Table 3) – and all recognised by a statistically significantly [χ^2 (1) = 71.27, 66.63 and 19.63 and respectively, p = .01] greater number of people than at Naivasha. The delivery of each of these services involves some degree of harvesting effort on behalf of the riparian community and, as such, we might regard their relationship with the wetlands as an 'active' association. At Naivasha, on the other hand, delivery of *all* priority services implies only a more 'passive' association; rather than being 'consumptive use values' (Turner et al., 2011), the sub-sets listed in Table 3 (e.g. clean water supply, biodiversity support, aesthetic

values) are conversely 'non-use values' involving not harvesting of the papyrus itself, but rather utilisation of other biotic (e.g. fish) or abiotic (soils) components associated with it.

Again, reviewing the demographic data may provide some of the explanation behind these differences:

1. Whilst the average (modal) age-range of respondents at both lakes was 19–35 years old, the proportion of the total survey pool falling within this range was lower for Victoria (0.4 ± 0.1) than for Naivasha (0.7 ± 0.1), where 16.9% of the survey pool were aged 55 or above, compared to only 6.8% at Naivasha.
2. Over three times the number of participants at Victoria (104 compared to 34/118 at Naivasha) had been resident since birth and, as highlighted above, a greater proportion of participants lived closer to the wetlands and tended to visit them more frequently.
3. At Victoria, 84.7% of the survey pool pursued livelihood strategies based in or around the wetland itself, compared to only 23.7% at Naivasha.

With a greater number of elders (with statistically higher TOKS scores) living and working within the riparian zone over a longer period of time, we postulate that the accumulation and transfer of 'traditional ecological knowledge' (Berkes et al., 2000) surrounding papyrus plays a more significant role in the present perception of wetland ecosystem services amongst Lake Victoria's riparian communities than is the case for Naivasha. Our previous research in the region (Morrison et al., 2012) revealed that younger generations typically learn how to make use of papyrus (e.g. in the manufacture of everyday necessities such as mats, baskets, ropes, brooms and furniture) from the experiences of older generations, the outcome being that wetlands are often valued first and foremost for their known human welfare benefits, such as those listed in Table 3 – i.e. for producing commodities, as fodder for livestock (particularly during the dry season) and for burning as a domestic fuel.

Almost three-quarters (73.7%) of participants at Lake Victoria stated that they had two or more jobs, compared to only 12.7% at Lake Naivasha. Diverse livelihoods have been described (Francis, 2000) as common in rural African societies heavily dependent on natural resources where, "*apart from a regular wage income, it is very likely that none of the activities from which people construct livelihoods can on their own provide a secure living*" (Francis, 2000, p. 57). Certain wetland sites visited around Lake Victoria typify such scenarios (with many livelihoods closely tied to papyrus), whereas at Lake Naivasha the data suggest a community less concerned for, or aware of, the broad range of services and values emanating from local wetlands. As Clewell and Aronson (2013) recently surmised: "*rural residents... are likely to be much more knowledgeable [about ecosystem services] because they are directly dependent on natural goods and services for their survival and well-being*" (Clewell and Aronson, 2013, p. 22). This difference is clearly reflected in the different TOKS scores recorded, the average score at Naivasha being half that of Victoria (Table 2).

4.4. Other services of significance

Spiritual and/or religious values related to PWs were recognised by a significantly [χ^2 (1) = 11.68, $p = .01$] higher number of people at Victoria. For example, several respondents during interviews and, more so, as part of the focus group discussion held at Ramula, made mention of a traditional belief in Luo culture concerning the practice of *nyawawa*, which is the chasing away of supposed spirits or ghosts (*jochiende*). The belief is that, prior to flooding, papyrus wetlands were the sites of plantations used by ancient Luo. On occasions when deceased ancestors reappear in spirit form searching the villages for food, a great cacophony ensues (caused by the sound of clapping, drumming or the beating of pots) by members of the community fearing the dreadful moans of the *mumbo* (lake *jochiende*: Harries, 2001). The sound is intended to drive their ancestors away from the village towards the wetlands, which are regarded as the "gateway" through which *mumbo* leave the living world; the papyrus is thus afforded sanctity by some members of the riparian community who would not allow it to be cleared completely for fear of losing their means of dispelling perceived evil spirits.

No such belief system was spoken of during the equivalent group discussion at Kamere, nor at any of the 8 sites around Naivasha (although mention was made of baptisms being performed in the lake, this relied not so much on the papyrus as the open water). However, one shared 'cultural service' between the lakes did exist, namely appreciation of the opportunities presented by papyrus for remaining concealed when having sex with one's (or, as was often recounted, someone else's) partner – a practice known colloquially as "green lodging".

In view of the above spiritual/religious connotations and the aforementioned transfer of traditional ecological knowledge between generations, it is perhaps not surprising that values relating to one's heritage were recognised by a significantly [χ^2 (1) = 10.36, $p = .01$] higher number of people at Victoria. Educational opportunities presented by PWs, whilst poorly recognised in general, were also identified by a statistically [χ^2 (1) = 3.94, $p = .05$] greater proportion of respondents at Victoria. As well as learning from family members engaged in wetland livelihoods, this trend may be due to the efforts of environmental education organisations active in the Lake Victoria region, disseminating information specifically related to papyrus through radio broadcasting, wetland ecotourism and research. It may be partly because of these activities that the wider impacts of PWs on regional climate regulation and primary production were uniquely recognised by participants at Victoria, whilst their contributions to erosion control [χ^2 (1) = 6.52, $p = .05$], natural hazard (e.g. flooding) regulation [χ^2 (1) = 18.97, $p < .01$], groundwater recharge [χ^2 (1) = 5.05, $p = .05$], nutrient cycling and soil formation [χ^2 (1) = 3.85 and 6.31, $p = .05$ respectively] were all recognised by a significantly higher number of people than at Naivasha.

4.5. Concluding remarks

We postulate that chief among the reasons for lower levels of awareness regarding the full range of potential benefits from PWs at Naivasha are:

1. Lack of a recognised consumptive use value for papyrus limiting people's awareness of, or concern for, its wider social and environmental benefits: Naivasha has a high rate of immigration into its expanding heterogeneous communities, wherein stores of traditional ecological knowledge in general may have been diminished, or else are less relevant to livelihoods characterised by "regular wage incomes" (Francis, 2000) in what is becoming an essentially peri-urban district.
2. Lack of access to sites where wetlands remain intact: land use within Naivasha's riparian zone is dominated by commercial flower and vegetable farms, tourist lodges and large colonial-era private properties, essentially preventing local residents from accessing the lake edge, save for the few public beaches that remain open.
3. Lack of papyrus itself: Naivasha has lost much of its former wetland area over the last four decades (Harper and Mavuti, 2004), the reasons for which are summarised in Morrison and Harper (2009); given a limited amount of a resource to begin with, we can expect public awareness surrounding it to be correspondingly low.

Whatever the reasons for the lower levels of awareness surrounding wetlands at Lake Naivasha, the overall implication is a paucity of identifiable 'stewards' among the general public who are concerned with, or accountable for, the protection and management of papyrus. Morrison et al. (2012) argued that riparian communities pursuing livelihoods based on papyrus around Lake Victoria constitute the de facto wetland managers there, since resource conservation is inherently within their (socio-economic) interests. Whilst the sustained efforts of the Lake Naivasha Riparian Association and other local environmental organisations (see Harper et al., 2011) deserve wide recognition, especially at the policy level, Naivasha's wetlands require engaged managers at the community level with vested interests in the sustainable use and management of papyrus.

In view of the above, scientists, policy makers and conservation practitioners at Naivasha are presently pursuing, inter alia, the following three lines of applied socio-ecohydrological research:

Development of a novel, consumptive use value for papyrus: in particular we seek to assess the suitability for local wetlands to be used as a source of domestic fuel in the form of biomass briquettes (see Jones, 1983), both to raise awareness among stakeholders regarding the potential values of papyrus (consumptive or otherwise) and, from a governance perspective, to encourage community engagement in wetland restoration and management.

Participatory and GIS mapping of the riparian zone, in order to: establish which of the several putative public access points remain open; assess the extent and quality of remaining wetlands by developing a 'lakeshore functionality index' and to use this information to guide legislation for the riparian zone currently under review.

Restoration of catchment and river mouth papyrus: to enhance the ability of wetlands to trap inflowing sediments and provide cleaner, clearer water for domestic use – in response to the supply of clean water being the highest priority service associated with wetlands cited by local stakeholders, but above all for the improved delivery of all ecosystem services (and, in particular, those less frequently recognised or valued, such as nutrient cycling) for the enhancement of the entire socio-eco-hydrological system.

In view of the first point, we recognise the need to exercise caution when advocating for any form of wetland exploitation; our ultimate aim is to strike a balance between ecohydrological restoration and *sustainable* utilisation of papyrus, founded upon increased environmental awareness and governed by principles of 'wise use' (Ramsar, 2012). Indeed, from this study it can be seen that greater awareness surrounding papyrus often correlates negatively with local habitat quality (Fig. 2): sustainable consumption of resources is thus a critical and central tenet of any human-wetland interaction. That said, it is noteworthy that at Lake Victoria – where consumptive use values of papyrus are well known – the general picture is one of 'mere' resource degradation (Thenya et al., 2006), whilst at Naivasha, where consumptive uses for papyrus are virtually unheard of, the picture is one of near-complete resource destruction (Harper and Mavuti, 2004). This trend would suggest that at least *some* level of resource utilisation (or valuation) is important for the conservation of papyrus. In other words, when communities recognise the value of a local wetland resource they may rationally act to maintain, or even enhance, its existence – providing that the wider political, socio-economic and governance contexts enable them to do so. Such was the case with ancient Egyptians concerned with, and engaged in, the manufacture of papyrus scrolls for over a thousand years or more (Bell and Skeat, 1935). This study has shown that levels of awareness surrounding the wider benefits of PWs are higher among those who recognise consumptive use values (Fig. 4).

We recognise that stakeholders' perceptions of ecosystem services are biased by a number of factors and cannot constitute the sole basis for improved livelihoods support, since there are likely to be stark inconsistencies between people's expectations and sustainable development. At Naivasha, papyrus wetlands perform important regulatory services (filtering sediments, absorbing nutrients, mitigating lake shore erosion, etc.) of great relevance to local livelihoods, whose full description and quantification remain a considerable challenge. Yet, relatively few people showed awareness of these.

However, despite a bias towards economic activities and provisioning services, people's perceptions ought to be carefully considered, disclosing as they do local stakeholder needs and values, indicating which forms of ecohydrological management will be met by a positive response from society and which forms may instead fail. This type of approach to knowledge creation is particularly key to the development of ecological restoration projects,

wherein: "*local residents... need to know how the restored ecosystem can benefit them personally... if they are unaware of the restoration and its public benefits, they may vandalise or otherwise disrespect it*" (Clewell et al., 2005, p. 11).

Here we hope to have demonstrated that this type of inquiry, which draws on both scientific and social scientific insights, can contribute to the development of ecohydrology as a contemporary and more integrated field of research. This is particularly warranted in cases where environmental management plans are being created ab initio or, as in the context of this study, being redrawn following feelings of stakeholder exclusion (Harper et al., 2011).

In developing a novel approach (the TOKS tool) to ecosystem services evaluation, we have shown that attitudes and behaviours towards papyrus wetlands can vary significantly between stakeholders even over short distances. As well as studying the role of wetland ecosystem services in sustaining livelihoods, there is much further work to do in understanding local perspectives and values, how they are shaped and translated into action. Nonetheless, we contend that this represents an important initial step. The Lake Naivasha ecosystem, part of the global network of 'Ecohydrology Demonstration Sites' as well as a UNESCO 'HELP' (Hydrology for the Environment, Life and Policy) basin (Harper et al., 2011), is an ideal arena in which to attempt such closer integration of the social sciences with ecohydrology.

Conflict of interest

None declared.

Funding streams

Thanks to the Natural Environment Research Council and the Economic and Social Research Council, U.K, for financial support to E. Morrison. The authors thank the Kenyan Ministry of Education, Science and Technology for research permission to D. Harper. The ESPA (Ecosystem Services for Poverty Alleviation) programme also supported the fieldwork of D. Harper and C. Upton. Thanks also to COOP (Switzerland) and REWE (Germany) for supporting our ongoing research at Lake Naivasha.

Acknowledgments

Sincere thanks to all who gave their time to talk to us and participate in the study, to our research assistants Beatrice, Benter, Dave and Joel at Lake Victoria, and to Chege, Dominic, James, Reuben and Victoria at Lake Naivasha. The authors thank the Kenyan Ministry of Education, Science and Technology for Research Permission to D. Harper. The Natural Environment Research Council and the Economic and Social Research Council provided financial support to E. Morrison, their ESPA (Ecosystem Services for Poverty Alleviation) programme also supported the fieldwork of D. Harper and C. Upton. We thank Mrs. Sarah Higgins for her commitment to the conservation of Lake Naivasha and the generous support that she and Mrs. Velia Carn provide for our research there.

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