Integrated data for integrated planning for the Okavango Ramsar site: challenges and prospects.

by Cornelis VanderPost,
Harry Oppenheimer Okavango Research Centre,
University of Botswana, Pr Bag 285, Maun, Botswana. Tel 6861833, email:cvanderpost@orc.ub.bw).

Abstract

An integrated management plan is a requirement for a Ramsar site. Plan development for the Okavango site by the Government of Botswana was supported by construction of a simple but integrated GIS-database that combines available data and allowed cross-disciplinary issues –such as human-elephant conflicts- to be more readily examined by stakeholders. Data challenges included data-sharing-problems, data incompatibilities, inaccuracies and gaps. A major challenge was the promotion of the realistic use of cross-disciplinary data by government departments at district level. Some of these challenges were overcome by the development of a user-friendly interface and through training of stakeholders.

The integrated data allowed the Okavango plan to contain a fair degree of cross-disciplinary initiatives, although sectoral approaches remain quite prevalent. The prospects for future plan implementation depend on the efficient use of integrated data and enhanced attention to cross-disciplinary issues as a strategy toward solving land-use conflicts that may otherwise undermine conservation targets.

Using existing integrated data to guide the comprehensive monitoring of environmental conditions is also crucial for feedback concerning the plan's major objective of reconciling development and conservation objectives.

Integrated data for integrated planning for the Okavango Ramsar site: challenges and prospects.

Introduction

According to 'Wiktionary', the free online dictionary, integration refers to "The act or process of making whole or entire." (http://en.wiktionary.org/wiki/integration). One generally talks of integration when resource decisions and actions all support organization-wide goals. Planning for wetland conservation requires an integrated approach that takes into account plans, processes, resource decisions and actions by many different actors simply to avoid a situation where the action of one actor (lets say the construction of a road) impacts negatively on the action of another actor (e.g. the protection of an important bird breeding area).

Human impacts that potentially impact on wetlands must be considered in the broader context of the socio-ecological complex (Haberl et al., 2006), the conceptual framework that places people within -and not outside- the ecological systems that make up our environment. From that perspective, people's activities impact upon and are themselves impacted by ecological variables. The concept of ecosystem services (Millennium Ecosystem Assessment, 2005) embodies this interdependence. The ecosystem services of wetlands include provisioning, regulating, enriching and supporting services. According to the Millennium Ecosystem Assessment (2005) as many as 15 of the 24 recognised ecosystem services are undergoing degradation worldwide. These include typical wetland services such as fresh water provision, water purification and natural hazard flood regulation.

The 'Wise Use' of wetlands –particularly when they are officially protected- implies the maintenance of their ecological processes to ensure the sustainability of services derived from them. Failure to maintain crucial ecological processes will lead to loss or degradation of the ecosystem services provided by wetlands and will affect people's wellbeing (Finlayson, 2003). 'Wise Use' of wetlands thus requires wise management which in turn requires adequate data and information for appropriate decision making (Cassettari, 1993).

In Africa, wetlands occupy a mere 1 per cent of the continental area and undisturbed wetlands in Africa are thus especially valuable. Where they also play a role as world level wildlife habitats and pools of biotic diversity in addition to their function as sources of water for a growing population, their conservation is of paramount importance (Mitsch and Gosselink, 2000).

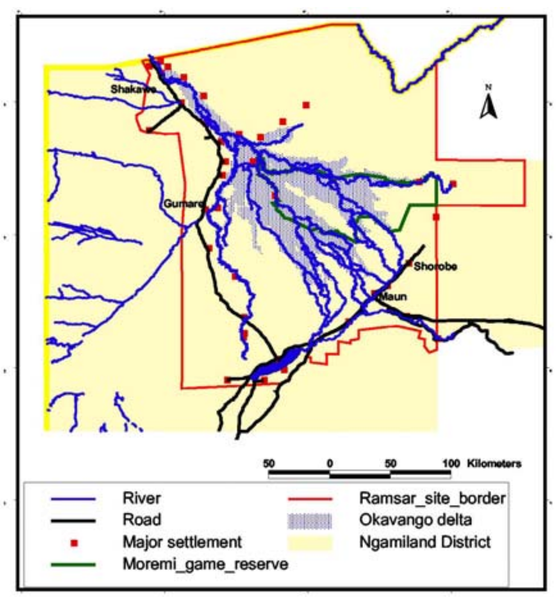
In order to classify wetland areas accurately for the purpose of conservation, basic data are required on their structure and composition (Finlayson, 2002), a challenge particularly for African wetlands. A further necessity for good data stems from the need to manage wetlands and to monitor change. This focuses, for example, on the feasibility of detecting ecological or flow changes, for instance by using different satellite sensor systems (Goward and Williams 1997).

The unique Okavango Delta in north-western Botswana (Figure 1), an internationally important wetland and wildlife concentration in semi-arid southern Africa, was proclaimed as an international Ramsar site in April 1997. The Convention on Wetlands of International Importance (or ‘Ramsar Convention’) advocates for the wise use of wetlands and their sustainable utilisation for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem. The requirements of the Ramsar convention include the development of a management plan that should be integrated into the public development planning system at local, regional or national level. This integration into spatial and economic planning at the appropriate level is assumed to ensure implementation, public participation and local ownership and to enhance the possibility of local as well as external funding (Ramsar Convention, 2008).

The ‘New Guidelines for management planning for Ramsar sites’ suggest that Ramsar site management needs to be integrated into ‘Integrated River Basin Management’ which itself is complementary to ‘Integrated Water Resource Management’ (IWRM), which, again, is part of the proposed implementation strategy of Agenda 21. This implies that both water quantity and quality aspects must be considered and that the multi-sectoral nature of water resources development (for water supply and sanitation, agriculture, industry, urban development, hydropower generation, inland fisheries, transportation, recreation and other activities) in the context of socio-economic development must be recognized (Ramsar Convention, 2008).

Figure 1a. General location in Africa of the Okavango Ramsar site.

Figure 1b. Okavango Ramsar site in Ngamiland District



Achieving adequate allocation of water to sustain wetland ecological functions requires that such water needs are defined and communicated to other stakeholders, while it is also essential that the benefits of wetlands, such as their hydrological and ecological functions and their provision of goods and services, are determined in order to justify the required water allocations (Ramsar Convention, 2008).

The Okavango Delta Management Plan (ODMP) is Botswana's response to the Ramsar convention requirements. It is a comprehensive effort to manage in a wise manner the resources of the Okavango wetlands and surrounding areas. At the start of the plan development process it was realised that for sound decision making aimed at wise use, sound information and data is needed. This paper discusses the efforts to provide such data for that purpose.

The ODMP integrated plan

The ODMP planning approach made use of the Ramsar Planning Guidelines and the Ecosystem Approach to wetlands management and was further guided by the need to address key management issues experienced by diverse stakeholders. For the latter, several rounds of traditional public village meetings (known as kgotla) were conducted for stakeholder consultation (Bendsen, 2005). The overall goal of the Okavango Delta Management Plan is to integrate resource management for the Okavango Delta that will ensure its long-term conservation and that will provide benefits for the present and future well being of the people through sustainable use of its natural resources (Dept. of Environmental Affairs, 2008).

The diverse and complex nature of the Okavango Delta in terms of its natural resources, its wide range of users and uses, its multiple managers (including communities) and an array of national laws, policies and guidelines as well as regional and international conventions, agreements and protocols are all factors that dictated the need for an integrated management planning process for the area. Examples of policies and plans that ODMP needed to integrate with include the list in Table 1 below, a daunting task indeed.

Table 1. Policies and plans that ODMP needs to integrate with

NATIONAL PLANS AND POLICIES

1.Vision 2016 – A Long Term Vision for Botswana
2.Draft National Wetlands Policy and Strategy, 2000
3.National Policy on Natural Resources Conservation and Development, 1990
4.National Biodiversity Strategy and Action Plan 2004
5.Tourism Policy of 1990
6.Wildlife Conservation Policy of 1986
7.National Water Conservation Policy and Strategy Framework of 2002
8.National Settlement Policy of 1998
9.The Revised National Policy on Rural Development of 1997
10.National Development Plan 9 (NDP 9)
11.Ngamiland District Development Plan 6 (NDDP 6)
12.Botswana Tourism Master Plan of
13.National Water Master Plan of 1991
14.Ngamiland District Settlement Strategy 2003 - 2027

INTERNATIONAL PLANS AND POLICIES

15.Permanent Okavango River Basin Agreement of 1994
16.Southern African Community (SADC) Shared Watercourse Systems Protocol of 1995.
17.SADC Protocol on Fisheries
18.SADC Protocol on Development of Tourism
19.SADC Protocol on Wildlife Conservation and Law Enforcement
20.The Convention on Wetlands of International Importance (Ramsar Convention)
21.United Nations Convention on Biological Diversity
22.Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
23.United Nations Convention on Combating Desertification (UNCCD)
24.United Nations Framework for Convention on Climate Change (UNFCCC)
25.United Nations Convention on the Law of Non-navigational use of International Watercourse

Source: Dept. of Environmental Affairs. 2008.

Management of the Okavango Ramsar site is complicated by its large size: at 55,374 km^2 it is the second largest Ramsar site in the world. It includes an area of permanent swamp of approximately 6,000 km^2 in addition to drylands and seasonal swamps that vary between 4,000 and 10,000 km^2. Within the Okavango Ramsar site itself, therefore, the most important task was the integration of resource decisions and actions by the different government divisions, both regional and national. This required pooling of relevant data and consultations between diverse departments (listed in Table 2) across several ministries. Consultations were also necessary with non-governmental organisations and private sector interests. During plan development the Okavango Wetland Management Committee provided a forum for these necessary consultations.

Table 2 Project Components ODMP and responsible government departments

Component	**Responsible Institution**
Policy, planning and strategy – including project management, co-ordination, integration and technical assistance: DEA and IUCN.	Department of Environmental Affairs
Communication	Department of Environmental Affairs
Research, data management and participatory planning:	Harry Oppenheimer Okavango Research Centre (HOORC).
Hydrology and water resources:	Department of Water Affairs (DWA).
Wildlife management:	Department of Wildlife and National Parks (DWNP).
Sustainable tourism and CBNRM:	Department of Tourism (DoT) and North West District Council (NWDC).
Fisheries management	DWNP, Division of Fisheries
Vegetation resources management	Department of Forestry and Range.
Physical planning	NWDC, Physical Planning Unit (PPU).
Land use planning and land management	Tawana Land Board (TLB) in association with DLUPU
Waste management:	NWDC, Environmental Health Department (EHD).
Sustainable livestock management	Department of Animal Health and Production (DAHP).

Source: Dept. of Environmental Affairs. 2008.

Construction of a simple but integrated GIS-database

To facilitate the development of an integrated plan, data from all appropriate sectoral interests needed to be combined into an integrated database. The best possible environment for this was an integrated Geographic Information System (GIS) database that employed geographic referencing as the integrating mechanism (Cassettari, 1993).
For its development, decisions were required about all the various aspects of the GIS database, including data gathering, data storage, data standards, etc. The important steps are listed in Table 3 below.

Table 3. Important steps in the GIS database implementation process.

1. Clarification of the stakeholder's information strategy.
2. Existing data
    2.1. Inventory of existing data
    2.2. Conversion of existing data
    2.3. Development of meta-data
3. New data
    3.1. Inventory of new data needed
    3.2. Collection of new data
4. System design
    4.1. Outputs (in relation to the information strategy)
    4.2. System functionality and design
    4.3. System development, test and installation
    4.4. Network considerations
5. System Set Up
    5.1. Software
    5.2. Data
    5.3. Output design (map layouts and reports)
6. User training
    6.1. Development of tailored training courses and manuals
    6.2. Comprehensive training of System Administrator
    6.3. Training of users
7. User support

Source: Dept. of Environmental Affairs. 2008.

During the preparation stages for management plan formulation, the immediate role of the GIS was to visualise the various combinations of sectoral data sets and to be an integration tool for topographic and sectoral data. The GIS also played a crucial role in data generation and enhancement through the application of mostly simple GIS procedures such as display, GPS-data downloads, buffering, classification, overlay, query and contouring (Ormsby et al., 1998).

Base-map construction involved the transformation of all available and newly generated digital data to the regional standard map-projection and datum, i.e. UTMZone 34, WGS84 Datum, even though a narrow strip east of longitude 24E belonged technically to UTM-Zone 35. Also, all data were converted to shapefiles for use in relatively low-cost off-the-shelve GIS software.

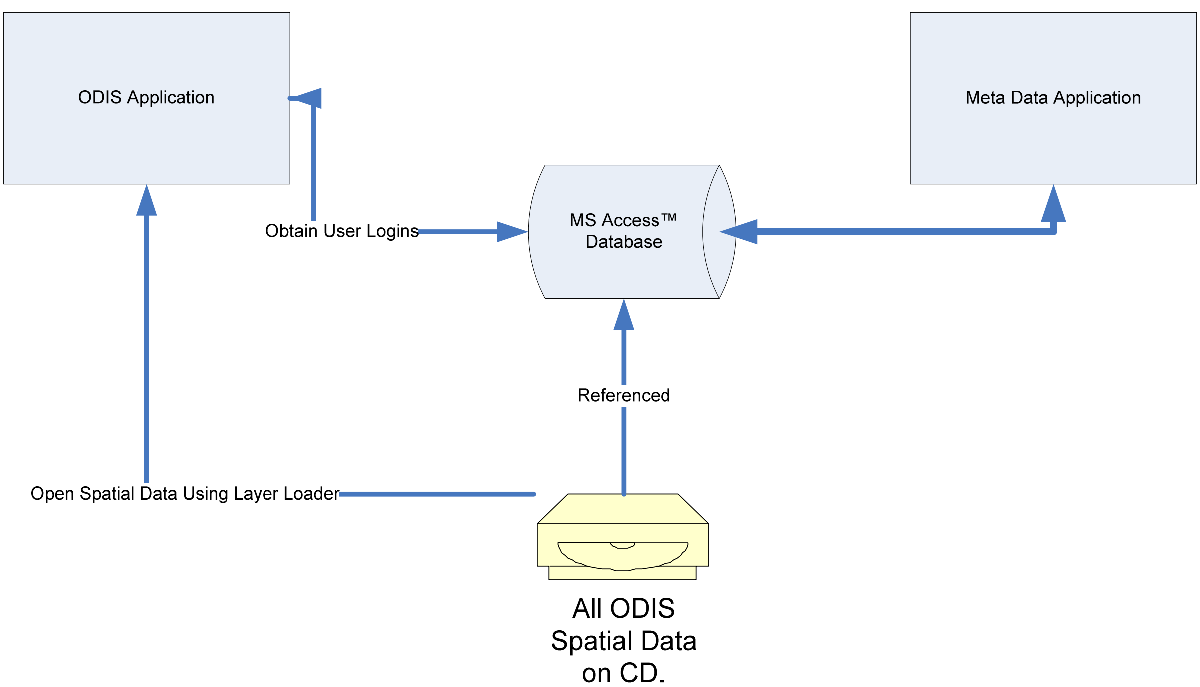
Existing digital data sets were combined with data specifically generated for the study. Settlement locations, for example, were mostly updated by identifying them from the most recent population census listing and recording coordinates with hand-held global positioning system (GPS) equipment during field visits. Newly constructed roads were plotted from centre-line coordinates obtained from road construction companies and older roads by driving along them with GPS equipment. The coordinates were downloaded and converted to shapefiles using the common map-projection and datum.

The challenge for data-management was to integrate the existing data in meaningful ways and to fill the data gaps identified by the government departments participating in the ODMP process. The original data integration aim was to incorporate all categories of data, including grey and other literature, herbarium-plant data, statistical and other research data, information from community consultations as well as maps, aerial photos and satellite images. Compiling such data into an integrated geographic database allowed for relationships to be made visible, such as, for example, between water, wildlife and tourism or between vegetation, crop-lands and people–wildlife conflicts.

However, the total integration of all data was not achieved. Plant-herbarium data could not be integrated with the other data and only partial integration of literature and geographic data could be achieved. Only limited digital satellite image data could be integrated due to data volume restrictions at government departments. However, other data was successfully integrated into a simple GIS environment.

The resulting product was named the Okavango Delta Information System (ODIS) and consisted of a simplified GIS-like interface based on a tailor made Arc Mapobject application working in tandem with a project specific Access metadatabase that provided a link to the actual data (Figure 2). These two products together with the data were distributed on cd's free of charge to all participating partners.

Figure 2. Okavango Delta Information System structure.



The product so developed met the requirements that the application be built to be ‘stand alone’ and be not reliant on commercially available packages. With respect to ODIS this means that as long as they register as users, stake holders have access to GIS functionality in an easy-to-use format without having to purchase costly software.

Okavango Delta Information System Data challenges

ODIS was developed to support the Okavango Delta Management Plan by facilitating access to relevant data for planning purposes. This was done by providing a central data access point for data available at various government and non-government organizations, by ensuring compatibility of data formats, by promoting data integrity and by providing training on working with the data for various applications.

Central point for data access

Many data about the Okavango region were scattered at various locations making it difficult to access for stakeholders. Typically, for example, reports were kept on shelves in government offices, while GIS data often resided with consultants that had worked on government consultancies. Environmental monitoring data was often with safari companies involved in hunting or photographic safaris.

Most organisations were not unwilling to share and to allow for centralizing of the data in one place to facilitate sharing and access. Thus, the University library (at the Harry Oppenheimer Okavango Research centre (HOORC)) made a collection of all available grey literature, mostly government and consultancy reports, while the University GIS lab collected all available GIS data.

The amount of work involved in compiling all data was substantial and more complex than anticipated. One of the more common problems was for data custodians wishing to improve their data (correcting mistakes, adding recent records from handwritten forms, etc) before sharing the data with other parties. In other cases, data were available only in software specific formats and could not be easily exported from such software. In some cases, data was available only in hand-written form. For the purpose of data documentation, basic metadata about all available data was compiled in a specially designed Access database, which also provided a link to the actual data locations.

Data compatibility

All data that was location specific, was transformed into simple shapefiles (Ormsby et al., 1998). Data was standardized to the UTM-Zone34-WGS84 projection but was stored in decimal degrees. A standard nomenclature for GIS shapefile data was developed loosely based on the Spatial Data Standard for Facilities, Infrastructure and Environment (SDSFIE: https://tsc.wes.army.mil/products/tssds-tsfms/tssds/projects/sds/default.asp).

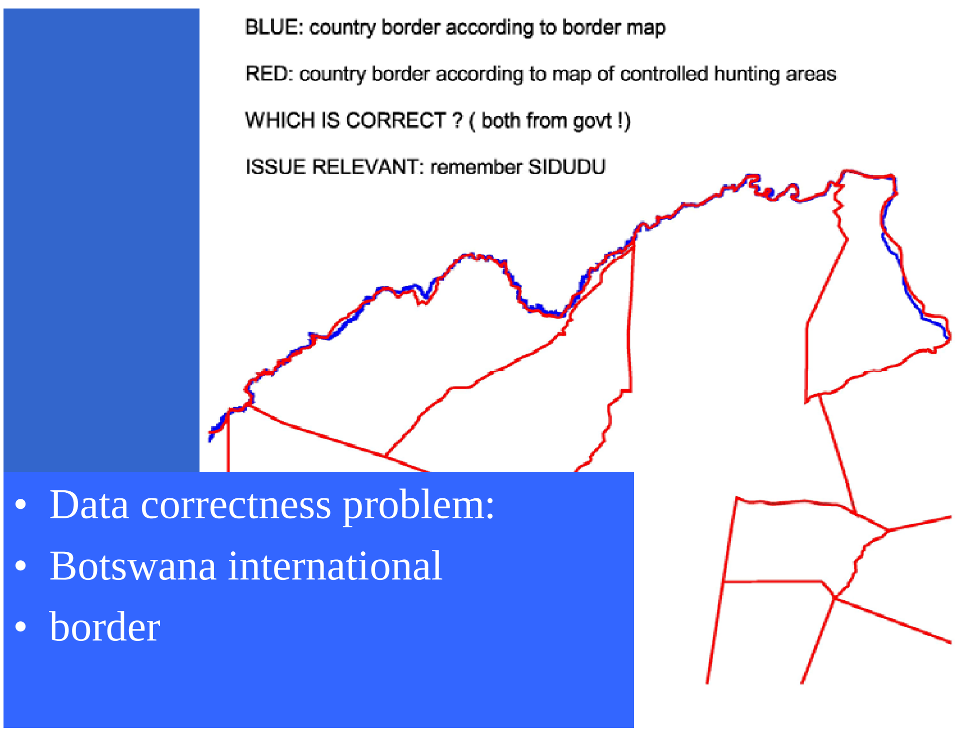
The basic set of metadata was created to maintain essential information (data originator, last update, etc) about the data. Where possible, attribute data was organized in the most simply structured database files, maintaining the original variable field nomenclature where possible. In some cases additional or summary tables were constructed, e.g. daily rainfall data were summarized into monthly and annual rainfall data sets.

Data problems

Where possible, the various data problems encountered were resolved or at least recorded for action at a later stage. Problems included missing or incorrect data, incomplete data, and outdated or inadequate data (Aronoff, 1989). For example, no data existed on frog distributions, often regarded as important in wetland ecology monitoring (Tiner, 1999).

There were also many data correctness problems, some more easily resolved than others. For example, borehole locations obviously situated across the border in Namibia could be corrected or deleted. More complicated were border accuracy problems as illustrated in Figure 3. Different government sources distributed differently aligned national and district boundaries.

Figure 3. Example of data correctness problems: official data distributed by different government departments do not match.



An example of incomplete or inadequate data related to the data on human-elephant conflicts. Although incidents were reported to the authorities, the records did not include details about the exact locations of the incidents. For conflict management purposes it was, however, quite important to know where exactly conflicts occurred.

Promote use of cross-disciplinary data by government departments at district level

While access to the data was improved by pooling all data in a central location and developing the user friendly ODIS data interface, the actual use of data by the various stakeholders was further promoted through user training and the development of an ODIS user manual. In addition complete prepared issue maps were made available for various topics that could be used as baseline maps for specific applications (e.g. wildlife conflicts, tourism).

During training workshops it became obvious that many government participants had very little information about the data that was available even in their own field. It also became clear that many had not worked much with even their own data. For example, participants quite often reported errors in the data (e.g. a lodge or airstrip located wrongly). They were then surprised to learn that it concerned the very data submitted by themselves. They had either never displayed the feature locations geographically or not in the context of other data such as rivers or roads which –if done- would have highlighted the wrongness of the location (e.g. airstrip on wrong side of river).

Participants very quickly became interested in examining their own data in relation to data from other departments. For example, comparing wildlife distributions with the distribution of large and small settlements or comparing the locations of crop fields with average or maximum flood levels.

In some cases government departments were not set up with the right computer hardware and software to allow proper examination of their data (hence the need for the ODIS interface). In other cases, responsibility for the data was transferred to headquarters in Gaborone (at 1000 km), sometimes not even copies of data being retained at local level. Between the 11 government departments participating in the ODMP there were virtually no cases of data sharing and in some cases data were not even shared between different sections in the very department, mostly because they were not aware of each others activities.

At the end of their training, course participants –mostly middle-management level government officials but also some NGO and private sector representatives – were supplied with the complete ODIS package (ODIS interface software, Access-database and the data) to allow then to install and use the database at their department. For specific applications such as tourism, wildlife management and water resources ready made issue maps were prepared that pulled together the most relevant data for that application. Users could then add additional data to the base-set and manipulate the mapped data for various printing options. Documents linked to specific locations could also be consulted directly from within ODIS, although the facility created for this tended to suffer from technical difficulties.

By comparing data across disciplines, participants also often started to note the need for additional data. For example, when examining human elephant conflicts, it was useful to examine data about the distribution of elephants (from bi-annual aerial counts) and the distribution of crop-lands. It would then have been useful to compare data about reported crop damage events by elephant. Unfortunately, such data was recorded at wildlife offices in the larger settlements without specific details about the location of the incident.

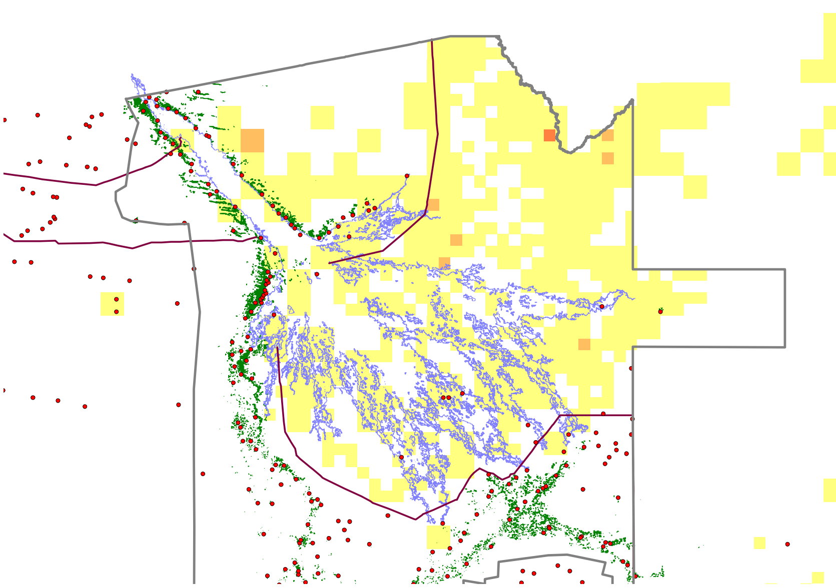
Solving land-use conflicts that may otherwise undermine conservation targets.

One of the aims of the database was to provide support to the ODMP process with respect to land-use conflicts that might impact negatively on conservation targets. Many of such conflicts, especially at village level, were identified through several rounds of community (kgotla) consultations.

Absence of a safe water supply was frequently raised as one of the main problems people faced (Bendsen, 2005). In small settlements there are no standpipes and children are exposed to crocodiles when they fetch water from the river. Pollution of drinking water was in certain cases blamed on elephants since sometimes drinking water sources are shared between communities and wildlife. To reduce this problem, communities requested that boreholes be drilled elsewhere for elephants, far away from the villages.

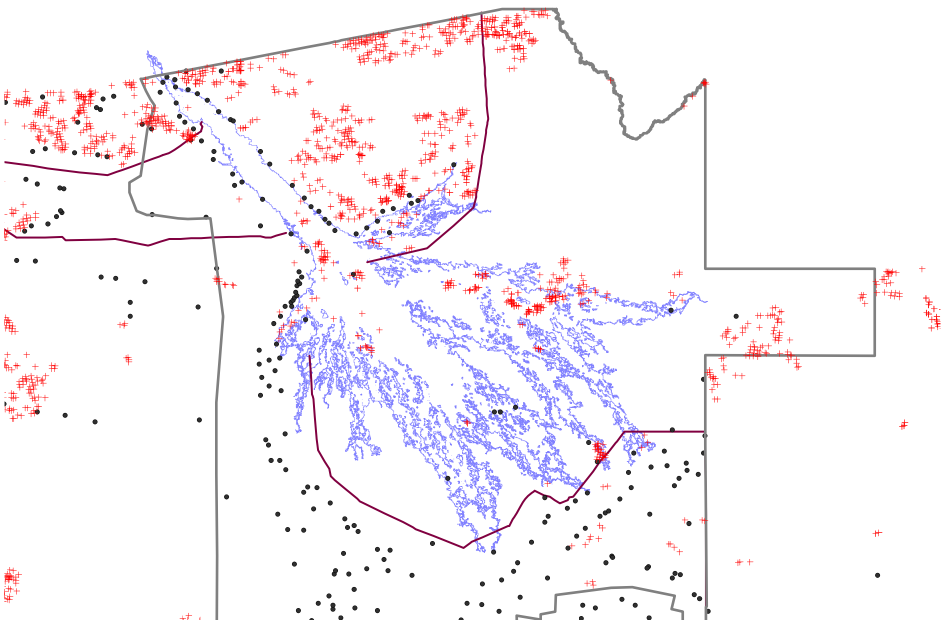
Human-elephant conflict resolution benefits from data about elephant distribution (routinely collected by the department of wildlife) in combination with data regarding the distribution of arable lands and settlement locations. A map that combines these data brings out the most important conflict regions and also shows the location of the few remaining potential elephant migration corridors that would allow them to access both the waters of the Okavango and the nutritious grazing in western Ngamiland (Figure 4).

Figure 4. Arable fields (green) in relation to elephant distribution (yellow) in the Okavango Ramsar site.



Plotting the distribution of bush fires, likewise, reveals that they occur more frequently in semi-protected areas and less in areas where people keep livestock and where preserving grazing and browse is important (Figure 5).

Figure 5. Distribution of bush-fires (red) in relation to settlement (black).



Monitoring of changing environmental conditions

It was realized that integrated data is also a necessity for environmental monitoring during ODMP plan implementation. The objectives of the ODMP implementation include fairly complex issues including the securing of the integrity of water resources and the protection of biodiversity. To secure the functioning of all essential biophysical (ecological) and hydrological systems and to optimise the socio-economic potential of the Ramsar site through the sustainable use of natural resources are additional high powered objectives (Dept. of Environmental Affairs, 2008.).

This obviously raises the question as to how we will know that these objectives are being met. In order to 'secure the integrity of water resources' it is, for instance, imperative to monitor water quality. This requires the development of water quality indices or indices of biological integrity. On the other hand, to 'protect, maintain and improve biodiversity' requires the measurement of biodiversity over time, using some agreed measure of overall biodiversity. Similarly, to 'optimise the socio-economic potential of the Ramsar site through the sustainable use of natural resources' necessitates the monitoring of socio-economic conditions.

These issues require substantial detailed data to be collected according to agreed protocols that address representative spatial distribution and adequacy of the measurement procedures. In addition, appropriate feedback to management implementation is required.

The University of Botswana is in this respect expected to implement the recommendations of the ODMP research strategy, which acknowledged and emphasized the importance of directed and long-term monitoring activities to inform on-going management, record the state of the environment and list implications for communities that depend on this environment (Ashton et al., 2006). This is because it was realized that an effective system of monitoring is critically important in providing information to the management decision-making processes of the ODMP. While research helps to define the criteria for successful management interventions, monitoring allows the success or failure of management actions to be evaluated (Ashton et al., 2006).

So, the University of Botswana (with partners) is in the process of designing a water quality monitoring programme with chemical and biological components and with the objective to:

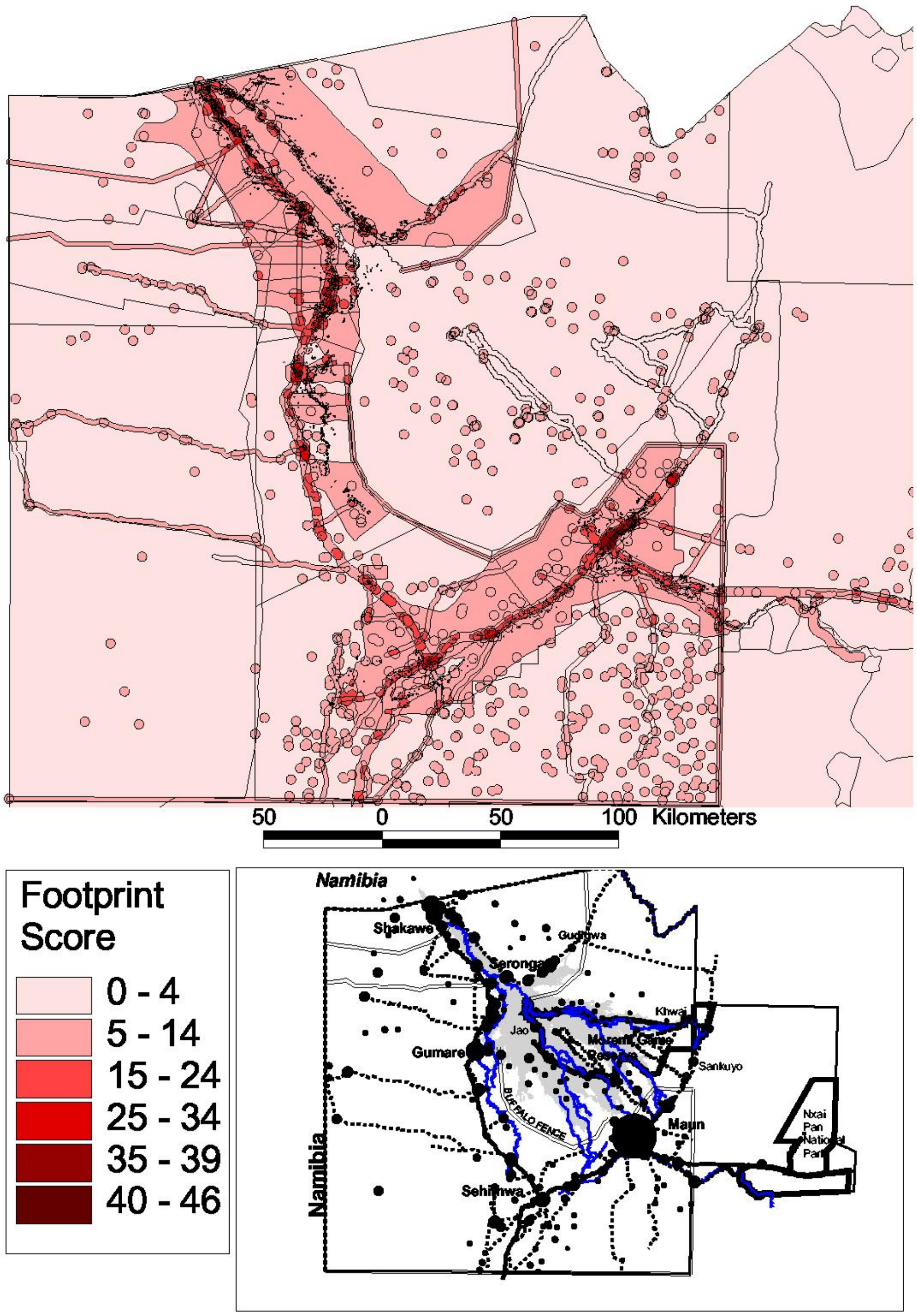
- Measure, assess and report on the ecological state of aquatic ecosystems
- Detect and report on spatial and temporal trends in the ecological state of aquatic ecosystems
- Identify and report on emerging problems.

While details have yet to be finalized, probable indicators (besides basic chemistry data) may include aquatic invertebrates, fish diversity, change in riparian vegetation and diatom diversity. Obviously, major efforts are required to gather sufficient baseline data (Dallas and Mosepele, 2007).

On the other hand, the overall human impacts on the environment can be monitored and visualised by regular mapping of the ‘human footprint’ as a quantitative measure for the level of human influence on the land surface. Using methodology similar to that used for the global ‘human footprint’ project -a world-scale attempt to map the level of human disturbance by producing a world map of human influence on the land surface (Sanderson et al. 2002)- the human footprint was reformulated more precisely for the Okavango Ramsar site by Vanderpost (2007), applying locally available data.

Measurement of the human footprint involves the allocation of scores to land areas on the basis of population density, land transformation characteristics, human accessibility and power infrastructure (Sanderson, 2002). This was adapted to local conditions for example by including cattle-grazing (mostly on communal lands) and borehole construction as additional elements of land transformation (Vanderpost, 2007). GIS buffering and overlay techniques were used to allocate scores to land units and create a compounded scores map for the region. Scores for individual land units vary between 0 and 46. The resulting footprint map is reproduced in Figure 6.

Figure 6. Human Footprint map of Okavango Ramsar site



The map shows a ‘light’ human footprint for the Moremi game reserve and its buffer zone because few people live there permanently, although there are many activities, including tourism, hunting and fishing that reduce their ‘last of the wild’ characteristics and impact on the natural waters of the area. A substantial population is resident just outside the Moremi buffer zone with the human footprint particularly strong along the western and southern margins of the Okavango wetlands (Vanderpost, 2007).

These monitoring applications of the ODIS database provide new challenges as increasingly more specific and detailed data are required for effective monitoring and related feedback to management planning.

Conclusion

The development of the ODMP integrated database with the simplified independent GIS-like ODIS interface has greatly contributed to inter-sectoral data sharing in the Okavango Ramsar site and has thereby contributed to the development of the management plan for the Ramsar site. The challenge now is to fruitfully utilize inter-sectoral data for plan implementation, an important aspect of which is environmental monitoring.

The use of data for management implementation and environmental monitoring requires increasing levels of data analysis and thus increasing quality and detail of the data themselves. For example, the management of fish stocks through regulation of fisheries requires good data on fish stocks and fish catches. To determine minimum flow requirements (after water abstraction) for ecological wetland functions requires detailed ecological data to determine ecosystem resilience, while water quality monitoring requires adequate sampling techniques and effective indicators. In short, when it comes to database applications for monitoring purposes, the goalposts appear to be constantly changing.

In the Okavango Ramsar site, the most important framework relevant to management and environmental monitoring is the fact that they take place within a protected area. This implies that the ecosystem services required for the maintenance of the ecological functioning of the protected area need to be given adequate attention even given the multiple and potentially conflicting uses of the Delta waters upon which people's wellbeing depend. This has implications for both the quantity of water abstraction and the resulting remaining flow that can support such services as well as the quality of water that is needed to maintain ecological health. These therefore need to be adequately monitored on the basis of representative data.

If the management of the Ramsar site is to ensure long-term future fresh water availability as well as maintenance of other wetland ecosystem services, then it needs to be an integrated effort at wetland ecosystem management. The Okavango Delta Management Plan provides a framework that allows this and the ODIS database has elements that can support this. The challenge is to effectively integrate the policy and institutional framework of the institutions responsible given that each has its own limited sectoral mandate and that each government department faces serious human and financial resource constraints, while all departments respond to policy fashioned at central state level with little scope for addressing local issue. This may result in alienation of the residents of the Ramsar site and create resentment toward ODMP implementation rather than cooperation.

References

Aronoff, S, 1989. Geographic information systems : a management perspective. Ottawa, Ont., Canada : WDL Publications

Ashton, P.J., Turner, S.D., Jensen, K.H., Mundy, P.J. and Neergaard Bearden, B. 2006. The development of a five-year research strategy for the Okavango Delta Management Plan (ODMP). Report: Maun, Okavango Delta Management Plan Project.

Bendsen, H., 2005. Results and Analysis of the Feedback Community Consultation Process on the ODMP. Harry Oppenheimer Okavango Research Centre, Maun.

Cassettari, S. 1993. Introduction to Integrated Geo-Information Management. London, Chapman&Hall.

Central Statistics Office (CSO), 2002, *2001 Population and Housing Census: Population of Towns, Villages and Associated Localities* (Gaborone: CSO).

Dallas, H.F., Mosepele, B. 2007. A preliminary survey and analysis of the spatial distribution of aquatic invertebrates in the Okavango Delta, Botswana. African Journal of Aquatic Science, 32, 1, 1-11.

Dept. of Environmental Affairs. 2008. Okavango Delta Management Plan**.** Dept. of Environmental Affairs, Gaborone, Botswana. xxiv, 190 p.

Finlayson, C.M. 2003. Integrated inventory, assessment and monitoring of tropical wetlands. In: C. VanderPost, (Okavango Report Series Editor), T. Bernard, K. Mosepele, L. Ramberg (eds), (2003), Environmental monitoring of tropical and subtropical wetlands. Proceedings of a conference in Maun, Botswana, December 4-8, 2002. ISBN 99912-949-0-2, Okavango Report Series Nr 1. Harry Oppenheimer Okavango Research Centre, Maun. 102 pp.

Goward, S. N., and Williams, D. L., 1997, Landsat and earth systems science: development of terrestrial monitoring. Photogrammetric Engineering and Remote Sensing, 63, 887–900.

Haberl, H., V. Winiwarter, K. Andersson, R. U. Ayres, C. Boone, A. Castillo, G. Cunfer, M. Fischer-Kowalski, W. R. Freudenburg, E. Furman, R. Kaufmann, F. Krausmann, E. Langthaler, H. Lotze-Campen, M. Mirtl, C. L. Redman, A. Reenberg, A. Wardell, B. Warr, and H. Zechmeister 2006. From LTER to LTSER: conceptualizing the socioeconomic dimension of long-term socioecological research. *Ecology and Society* **11**(2): 13. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art13/

Kgomotso, P.K. and Swatuk, L. A. 2006. Access to water and related resources in Ngamiland, Botswana: Toward a more critical perspective and sustainable approach. Physics and Chemistry of the Earth, 31, 659–668.

Millennium Ecosystem Assessment (2005). Ecosystems and human well-being: synthesis. Washington, DC: Island Press.

Mitsch, W.J. and Gosselink, J.G. 2000. **Wetlands.** New York : John Wiley.

Kgathi, D., L., Ngwenya, B., N. and Wilk, J. 2007. Shocks and rural livelihoods in the Okavango Delta, Botswana. Development Southern Africa, 24:2, 289 - 308.

Ormsby, T., Eileen Napoleon, E., Pat Breslin, P., Nick Frunzi, N., 1998. Getting to Know ArcView GIS 3.x., The Geographic Information System (GIS) for Everyone. ESRI, USA.

Ramsar convention 2008. The New Guidelines for management planning for Ramsar sites and other wetlands suggest that ramsar site management need to integrated into http://www.ramsar.org/key_guide_mgt_new_e.htm

Sanderson, E.W., Jaiteh, M., Levy, M.A., Redford, K.H., Wannebo, A.V. and Woolmer, G., 2002, The human footprint and the last of the wild. *BioScience,* **52**(10), 891–904.

Tiner, R.W. 1999. Wetland indicators : a guide to wetland identification, delineation, classification, and mapping. Boca Raton, Fla. : Lewis Publishers.

VanderPost, C., 2007. Protected areas in Ngamiland, Botswana: investigating options for conservation-development through human footprint mapping. *International Journal of Environmental Studies,* Vol. 64, No. 5, 555-570.