


PROPOSED FLOOD MITIGATION MEASURES TO BE IMPLEMENTED FOR THE OSHAKATI/ONGWEDIVA AREA

Environmental Impact Assessment (EIA)

Specialist study: WETLAND ECOLOGY AND FISH ECOLOGY SPECIALIST IMPUTS

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PROJECT NAME	Environmental Impact Assessment for the Proposed Mitigation Measures to be implemented for the Oshakati/Ongwediva area
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(a) have knowledge of and experience in conducting assessments (my area of expertise), including knowledge of the Act, these regulations and guidelines that have relevance to the proposed activity;

(b) perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;

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(ii) the objectivity of this report, plan or document prepared in terms of the Act and these regulations.

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EXECUTIVE SUMMARY

The Cuvelai River catchment of 37 000 km^2 is a landlocked endorheic system ending in Etosha Pan, an international Ramsar site. The top reaches in Central Angola are permanent but after fanning out to form a delta and then an inverted oshana system in northern Namibia, it has an unreliable seasonal flow. Large floods called efundja can cause serious flooding as occurred in 2008, 2009 and 2011, flooding large parts of Oshakati and necessitating the design of a flood control system.

Whereas floods are experienced as a disaster by Oshakati and other town dwellers, floods are the life blood of the oshana system and explain the preference of a population of more than 800 000 or 100/km^2 to live in the oshana region. Apart from water, fields and grazing, wetland products such as fruit, frogs and especially fish are of great significance to the rural population. Fish are caught for own consumption using traditional but recently more efficient modern nets and fishing gear. Fish are intercepted during their downstream migration or collected in remaining pools as the iishana dry up.

A normal rich invertebrate and vegetated community develops in the iishana during the flood, that is thereafter heavily grazed upon and invertebrates either aestivate or survive underground or as eggs till the next rainy season.

The iishana all converge at the Omadhiya wetland, a series of semi-permanent pans with the Ekuma River draining excess water to Etosha Pan.

The proposed Dike and deepened channel can have many impacts on oshana functioning and fish life and local subsistence fishing including:

Changing water quality: pollution and salinization of water in iishana

Changing flow patterns affecting fish ecology Omadhiya wetland Etosha Pan and Ramsar site. This can also impact the subsistence fishery

Impacts of flood gates, removal of vegetation, hardening of canal sides, deepening of iishana,

New opportunities are also presented: creation of green space, new borrow pits, new permanent water bodies.

Mitigation of impacts is possible in most cases. General guidelines for mitigation would include decreased disruption of soils during construction phase, confinement of the construction period to dry periods only, timeous replanting of vegetation, landscaping of borrow pits as part of the oshana system, reduction in the area hardened or covered by concrete and development of natural wetlands as filter system for the outflow of drainage water from Oshakati.

The important impacts and proposed mitigations are the following

The identified impacts together with proposed mitigation are listed below.

Water quality deterioration during construction. This can affect iishana life downstream seriously, including fish life and fisheries. Mitigation is possible by ensuring construction is completed before the next rainy season.

Salinisation of iishana. Disturbance of subsurface soils, especially in iishana will take place to construct the dike and to create a wide lowered channel to handle extra flood volumes. Exposure of saline soils can increase the salinity of flood waters and contribute to water quality deterioration further downstream. Limited mitigation is possible by determining subsoils with least salinity and aligning channels there, limiting exposed surfaces and covering opened areas that have saline sub soils with top soil and sand. A monitoring programme downstream to the Omadhiya wetland is advocated.

Nutrient and energy cycles in oshana are affected by removal of soil from bottom, and hardening of channel sides. This will impact on the general functioning of iishana, lower productivity and fish growth and reproduction. Mitigation is possible by covering exposed areas with top soil and sand, placement of hollow brick structures in place of concrete slabs and allowing natural aquatic vegetation to regrow.

Pollution and litter from Okatana River channel, draining the city of Oshakati. Rubbish and leachates from ineffective landfills and sewerage plants pose a risk to the oshana system downstream, including the Omadhiya wetlands. Fish and bird life and fisheries can be negatively affected. Mitigation can prevent pollution if effective artificial wetlands are constructed where runoff from inside Oshakati is treated. All landfill sites and sewage treatment plants have to be upgraded and/or repositioned to prevent any surface or groundwater pollution.

Mixing of Calueque-Oshakati canal water with efundja water. Presently mixing occurs, leading to drinking water deterioration and invasion of Kunene biota and disease agents. Monitoring of further invasions is required. Reconstruction and upgrading of the canal is a priority to prevent negative impacts.

Increased flow rates in channels can impact on biota, including plant life and fish and also the local subsistence fishery. The impact can be lessened by designing and constructing natural sections in the channels with a diversity of habitats where organisms can settle.

Increased flow rates affect erosion and sedimentation balance in the channels themselves but also upstream and downstream, affecting the dynamic balance in iishana down to the Omadhiya wetlands. Increased erosion in the higher velocity zones can initiate erosion and sedimentation changes. This can be prevented by diversifying the channels and creating a system as natural as possible. Monitoring is needed to determine long-term changes.

Decreased surface area of iishana and resulting lower fishing opportunities for communities in Oshakati and also next to the dike and its channel is one of the negative effects of the dike and channel that cannot easily be compensated for. One way would be the conversion of the Okatana River channel and constructed borrow pits near the dike into fish refugia where fish can safely survive dry periods and fishing and repopulate newly flooded iishana in the area the next rainy season, indirectly enhancing local fisheries.

Increased uncontrolled fishing at new and existing bridges, culverts and gates leads to local overharvesting of fish resources. Existing fishery regulations have to be applied to conserve fish stocks.

Wetlands from Ompundja to Omadhiya receive more floodwater as result of faster drainage created by the channels. This has a positive effect on the wetlands and fisheries but hydrological monitoring is essential.

Faster drainage of wetlands around Oshakati has negative effects on iishana and their fisheries. This can be alleviated by reducing the amount of leveling/ deepening of the channel next to the dike to the minimum.

Increased sedimentation in iishana downstream and down to the Omadhiya wetlands can alter functioning of this system negatively, having an effect on pan depth, water retention capacity and fishery. Mitigation measures would include the minimization of flow rate changes and a monitoring programme of sediment loads and sedimentation.

Borrow pits created to provide building material for dike hold a mosquito health hazard. By connecting borrow pits with existing iishana, new fish habitat is created and mosquitoes are biologically controlled. New opportunities for fish farming can also arise in more permanent waters.

Flood dynamics are changed by the diversion wall and channels. Effects can be mitigated by minimizing effects the dike and channels have on the normal hydrological cycle.

Hardening of sides of the channel next to dike wall and channelized Okatana River. This affects biota in channels negatively and prevents regrowth of vegetation. Hollow bricks or similar structures will prevent sealing of the bottom and hyporheos.

Negative effects on giant bullfrogs include hardening of the sides of channels and increase in velocities. Mitigation would include the use of hollow bricks and minimization of hardened surfaces and increased stream flow.

Floodgate operation prevents normal migration of fish and biota down iishana. Mitigation is possible when flood gates are operated in such way as to emulate natural flow and minimize high velocities. Areas of high velocity in the floodgate operation should be minimized and baffles or a fishway constructed to facilitate fish movement if necessary.

High mortality rates of fish attempting to migrate through the sluice gates can be lessened by minimizing such constrictions with high flow and providing cover and shelter to fish from bird predation.

High fish mortality at sluice gates caused by uncontrolled fishing. This should be controlled – sluice gate and bridge areas should be zoned as non-fishing zones. Applicable fisheries legislation already exists.

Controlled water level in Okatana River channel enhances wet periods and aquatic life and fisheries. This is a benefit that should be properly regulated so that conservation of fish is also achieved.

Construction of dike and channels reduces number of fruit trees along existing iishana. This impact can be mitigated by sensitive planning and construction. Fruit and indigenous trees can be planted along all built structures. A community nursery is one of the benefits of this project.

Dumping soil near fruit trees causes tree mortalities. Avoid changing soil levels near trees during construction. Plant new trees where changes are necessitated.

Deepening of Okatana River channel has an effect on the functioning of the oshana and fish life. Negative effects can be lessened by imitating natural flows in the channel draining Oshakati and allowing smaller floods to move through the sluices.

Disruption of normal diversity of iishana and islands by dike construction lowers resilience of oshana system. Follow natural contours, keep long islands in channels and construct new features where possible to maintain hydrological diversity.

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GLOSSARY

Efundja – Irregular large flood event from higher up the Cuvelai bringing with it many fishes

Iishana – Plural of *oshana* – connected grassed depressions in the Cuvelai River system filled regularly with rain water and every second or third year with flood water derived from upstream in Angola.

MFMR – Ministry of Fisheries and Marine Resources of the Government of the Republic of Namibia, responsible for development and management of marine and freshwater fisheries and aquaculture.

Ondombe – Singular of *endombe* – deeper, more open water pools that hold water for longer periods. Several were artificially deepened about 50 years ago to improve water supply in the area.

Oshana region – alternative term used for the middle reaches of the Cuvelai River system where *iishana* type wetlands are found. Not the same as the political Oshana Region as it includes the *iishana* areas only in the Omusati, Oshana, Ohangwena & Oshikoto Regions (Mendelsohn, el Obeid, & Roberts, 2000)

Figure 1-1 EIA team sampling fish in the oshana west of OshakatiK. S. Roberts

1 INTRODUCTION

1.1 BACKGROUND:

This study was undertaken as the wetland ecology and fishery specialist study for the environmental assessment of the proposed flood mitigation measures for the Oshakati/Ongwediva area commissioned by Enviro Dynamics. It includes a literature review of available information on the ecology of the *iishana* wetlands with particular attention to fish and fisheries of the area. Limited fieldwork was conducted in June 2012 to complement earlier work by the authors and colleagues and also to survey the proposed route of the dike and the area likely to receive the diverted floodwaters from south of Oshakati to the Omadhiya lakes complex. Finally potential impacts identified by the scoping exercise as needing further expert attention are assessed.

1.2 SPECIALIST STUDY LEADERS:

Shirley Bethune, Freshwater wetland ecologist and senior lecturer, Nature Conservation at Polytechnic of Namibia. She holds an MSc in Limnology from Rhodes University. 30 years of experience as wetland ecologist in Namibia, first as curator of Water Biology at National Museum, then as fish biologist at Hardap Dam for Ministry of Environment and for 20 years as Chief Hydrologist of the ecological research section at the Department of Water Affairs Namibia. Spent 3 years as Namibia's representative to the UN Convention to Combat desertification (NAPCOD) from 1999 – 2003, before starting to lecture at the Polytechnic of Namibia in 2003. Coordinated research projects for Okacom including Namibia's contribution to the environmental flows of the Okavango River for Okacom. She is the founder and co-chair of the Wetlands Working Group of Namibia and coordinator of a series of water and wetland awareness resource materials since 1992.

Ben C W van der Waal, Fisheries scientist, PhD (fish ecology) University of Johannesburg and 45 years experience. Retired professor in Zoology, University of Venda where he lectured in ecology and fresh water biology. He conducted research on fresh water fish biology, aquaculture with indigenous fish species, wetlands, fish ecology and fisheries in South Africa, Botswana and Northern Namibia. He is well acquainted with the Zambezi, Kavango and Cuvelai river systems and their fish life. He undertook consulting tasks on impacts of development on wetlands in the Oshana region and initiated the fish farming unit at the Rural Development Centre, Ongwediva. From 2007 to 2009 he undertook a fisheries development project titled "Integrated Management of the Zambezi/Chobe River System Fishery Resource Project" in Caprivi, Namibia aimed at improving the fisheries management of the Zambezi fisheries. He has published 28 papers in accredited journals, attended many national and international conferences on fresh water research and aquaculture and participated in more than a dozen short term consultations.

1.3 TERMS OF REFERENCE:

To determine the present fish life in iishana where the dike is planned and to evaluate that.

To evaluate the possible effects of altering the flow of iishana by a dike and channels on the fish life and local subsistence fisheries.

To evaluate the possible effects of a dike and canal and draining system for Oshakati on the fish life downstream and at the Omadhiya wetland and Etosha.

To make recommendation on mitigation measures to lessen he possible negative effects of the dike during building phase and during operation.

To list positive effects and opportunities created by this project.

1.4 METHODOLOGY:

1.4.1 *GENERAL WETLAND ECOLOGY:*

Fieldwork was conducted from 24 – 29 June 2012. The main aim was to follow the proposed route of the dike to see the area it was likely to impact on, to follow the Okatana River through Oshakati and to investigate the receiving oshana south of Oshakati as well as the Omadhiya wetlands as the site where the water would finally converge before continuing to Etosha Pan.

At each of the 18 dike coordinate points, the endpoint and at Hinakulu Yomadhiya Pan, notes were taken of the vegetation, nearby settlements, wetland activities and disturbances and water bodies encountered, were sampled. Drainage patterns, flood lines, erosion and deposition were noted as were the natural contours of the *iishana*. The information collected was compared to the baseline survey data compiled by Clark (1998) and all the plant and aquatic invertebrates noted, correlated with those indicated for similar habitats in the baseline study. This fieldwork exercise served as a reconnaissance of the situation on the ground at the end of the 2012 wet season.

1.4.2 *FISH SURVEYS:*

The main emphasis of the field work was on the fish surveys.

Given that 2012 has been designated as relatively small flood year, the *iishana* were expected to be dry at the time of this field survey towards the end June. Yet, wet and even running *iishana* were encountered during the field trip to dike sites and fish were also still present although not in large numbers, as intensive fishing must have been taking place earlier.

Fish were collected at four locality types relevant to the proposed dike:

Reachable sites on the proposed route of the dike where water was present.

End of the Calueque-Oshakati Canal before the wetland at the NamWater water purification works.

Okatana River draining the town of Oshakati and wetland created by the leaking canal at the NamWater purification work.

Omadhiya Wetland [Hinakulu Yomadhiya Pan], where all *iishana* converge at the lower end of the oshana region north of Etosha National Park.

The selection of sites was done to obtain information on the present occurrence of fish species in the *iishana*, canal and Okatana River *oshana* draining the town. These data were also collected for comparison with previous information on fish diversity, as *iishana* do not have permanent fish populations and are repeatedly colonised anew from either the Cuvelai River reaches higher up, during *efundja* or else locally from survivors from the last flood that survive in deeper, more permanent *endombe* or gravel pits that serve as refugia for them.

The following effective fishing gear was used to collect fish in iishana, pools and the canal:

D-shaped dipnet with a 75 by 45 cm mouth and 80cm deep bag constructed of 8mm meshes to collect small fish.

Seine net 17 by 2.5m with 12mm meshes and supplied by a top line with floats and bottom line with weights.

Inspection of catches of fishers was also investigated where this was possible.

The D-net was drawn from deep towards shallow water by one collector and the seine was used by two persons keeping the bottom line tight between them by hooking the bottom line below one foot. In open water the bottom rope could be pulled up to the surface to capture the fish – a handy technique in shallow open water habitat.

1.4.3 ***STRUCTURED INTERVIEWS WITH WETLAND RESOURCE HARVESTERS/ FISHERS:***

One of the aspects investigated was the use local people made of the available fish as well as their opinions on fish eating and potential impact of the proposed flood protection dike.

Information was collected from local people in each locality while collecting fish. Team members that could communicate in the local Oshivambo language, asked persons and passers-by questions prepared as an open-ended questionnaire. The conversation was often joined by researchers and public as there usually was a lively conversation and interest in what the team was doing and collecting. Summaries of each of the interviews are given in Appendix 3a.

The questionnaire focussed on fish and fishing and the following information was asked:

Characterization of household

Level of education of respondent

Fish eating in household

Fish catching in household

Opinion over last few years for fishing success

Effect of recent high floods on household members

Support by government after flood

Knowledge of proposed dike structure

(See a copy of the questionnaire in Appendix 3b used as a guide to these interviews)

1.5 ASSUMPTIONS AND LIMITATIONS

Assumptions:

We assume there will not be drastic climatological changes and that floods will continue to come down the Cuvelai – not dammed in Angola.

Our samples were representative of fish populations in water bodies.

Limitations:

There is uncertainty about development in Angola.

There is no direct knowledge of salinity of the substrate below iishana and the effect that this will have on water quality when it is exposed by the deepening of the channel.

The Cuvelai River system is extremely unpredictable. Major floods and serious continuous droughts can be expected in future, this is partly the result of global warming and associated features. Future floods and efundja cannot be predicted.

2 LEGAL AND REGULATORY REQUIREMENTS

2.1 The following regulations are of specific relevance to fish protection:

Namibian Government Act No. 1 of 2003: Inland Fisheries Resources Act, 2003.

17 (2) A person who uses a net for fishing may not use the net –

within 100 metres of a bridge, culvert or spillway when water is flowing through such structures;

in a manner that obstructs more than one half of the width of any watercourse where fishing is carried out.

2.2 Namibian Forestry Act

2.3 National Environment /Management Act

2.4 National Water Act

3 THE RECEIVING ENVIRONMENT

3.1 INTRODUCTION:

This study was undertaken as the wetland ecology and fishery specialist study for the environmental assessment of the proposed flood mitigation measures for the Oshakati/Ongwediva area commissioned by Enviro Dynamics. It includes a literature review of available information on the ecology of the *iishana* wetlands with particular attention to fish and fisheries of the area. Limited fieldwork was conducted in June 2012 to complement earlier work by the authors and colleagues and also to survey the proposed route of the dike and the area likely to receive the diverted floodwaters from south of Oshakati to the Omadhiya lakes complex. Finally potential impacts identified by the scoping exercise as needing further expert attention are assessed.

The Cuvelai catchment of 37 000 km^2, is a unique, endorheic wetland wedged between the Kunene River in the west and Okavango River in the east, ending in Etosha Pan, a huge dry salt lake of 4812 km^2 within the Etosha National Park. Etosha Pan was proclaimed as international Ramsar Site in 1995, the first of four Ramsar sites in Namibia and the only inland Ramsar site.

Although originally envisaged to include not only the Etosha Pan but also the 'Oponono' (Omadhiya wetland complex) Pans and the *iishana* of the Cuvelai wetlands to the north, the northern boundary of the Ramsar site is the northern boundary of the Etosha National Park. Etosha Pan was motivated as a Ramsar site because of the large numbers of wetland birds it can support when the shallow, wetland is inundated by rare floods and local rainfall. Then it serves as an important feeding area and breeding site for thousands of birds, supporting more than 1% of the world population of Great White Pelicans, Greater Flamingos, Caspian and Chestnut-banded Plovers (Bethune *et al*, 2007). Furthermore Etosha Pan is important as one of the only two breeding areas for the entire southern African population of Lesser and Greater flamingos.

Other than within the Etosha National Park, the Cuvelai wetland system within Namibia is presently not protected and is inhabited by 800 000 people, many of whom live a largely subsistence life in the oshana region, supported by cash remittances, their livestock, what they can plant and natural products they can harvest such as fish, frogs, reeds, fruit and wild fruit. The continued natural functioning of the Cuvelai wetland is thus important not only in ecological terms but also to a dense population of rural people who rely on natural products such as grazing, fish, fruit, reeds, wood and sedges.

3.1.1 ***CUVELAI WETLAND SYSTEM:***

The Cuvelai Delta, which has a catchment area estimated from 37 000 km^2 (van der Waal, 1999, 2000) to about 40 000 km^2 (Chivell *et al*, 1991). It is formed by the southwards drainage of the perennial Cuvelai River and its two main tributaries the Mui-Muu and Caundo rivers in central Angola, forming a deltaic network of inter-connected streams with a width of 70 km upon reaching a plain in southern Angola before crossing the border into Namibia (Chivell *et al.*, 1991). By the time this network of Cuvelai streams reach Namibia they are no longer perennial, and the seasonal floods or *efundja* do not always extend into Namibia. Even without inflow from Angola, the ephemeral streams and pools called *iishana* in Namibia, can however be filled by local rain. Mean annual rainfall in the area varies from 300 mm/a in the southwest to 550mm/a in the northeast (Chivell *et al.* 1991).

Within Namibia the topography remains very flat, dropping from 1 090 to 1 050 m asl, a gradient of only 1: 2 000, or 50cm/km over the catchment area within Namibia as a whole. According to Clark (1998) the gradient drops to only 15cm/km in the area where most of the *iishana* occur. This flat terrain is an important feature in the shallow flooding of the area. The shallow pools, or *iishana*, and deeper pools, *endombe*, typically dry up each year, becoming increasingly saline and turbid. But while they hold water they are an important surface water source and source of fish to the large rural population. Chivell and colleagues (1991) gave a population estimate of 50 people per km^2, which, given a general doubling of population every 20 years, is now double that (Mendelsohn and Weber, 2011). These people use the *oshana* water both for limited household use, small gardens and for livestock. The population is not evenly distributed as people and their livestock tend to congregate where water is available. This has caused severe overgrazing and trampling in areas close to water points (Clarke, 1998a, Marsh & Seely, 1991). Following the good rain and flood years of this decade, more and more people have moved into previously dry grazing areas, either with their livestock or to fish e.g. around the Omadhiya lakes, at least during the wet-season.

When the *efundja* is sufficiently large to reach Namibia it carries downstream migrating fish along, essential to the livelihoods of people living in the oshana region. The first good rains or floods also trigger the emergence of aestivating African bullfrogs, *Pyxicephalus adspersus*, a seasonal protein source to the dense rural population in the area. With gross evaporation rates of around 2000 mm/year (Chivell *et al,* 1991, Mendelsohn *et al,* 2002) and net deficit of 1500 to 1700mm (Mendelsohn *et al,* 2002), most of the *iishana* dry out by about June each year while the deeper *endombe* and gravel borrow pits may hold water longer, sometimes until the next rains, providing a refuge for the fish and aquatic invertebrate fauna of the system.

Within Namibia the Cuvelai Delta gradually narrows as the *iishana* converge cone-like towards a complex of shallow lakes known as the Omadhiya wetland/lake complex or commonly as the Lake Oponono area named after the best known of the lakes. As the system that will receive the possibly increased floodwaters diverted around Oshakati by the proposed dike as well as the storm water draining from the town via the Okatana River, it is worth looking at the system a little more closely.

The Omadhiya lake complex includes 7 main inter-connected, shallow, ephemeral lakes or pans that dry out every few (2/3) years (van der Waal, 2000a). All the water flowing through the Cuvelai system converges on these pans; from the west via the Etaka oshana water enters Lake Oponono; from the north-west via *iishana* to the west of Ombalantu water enters Uupeke and Korolo (24ha); from Ogongo and Oshikuku in the North water enters Uulidi (100ha), Omanetha (48ha) and Inakulo Yomadhiya (83ha), from Oshakati into UUludi and Korolo and from Ondangwa in the north-east floodwaters enter Onamagwena (507ha). From here water can flow east into Omanetha or south into Inakulo Yomadhiya (grandmother of the lakes) and eventually into Oshituntu (100ha) from which the main outflow is the Ekuma River flowing into north-western Etosha. The lake sizes in brackets are low water sizes calculated from satellite images by Verlinden of the Northern Namibian Environmental Project after the 1995 *efundja*, cited by van der Waal (1999, 2000a). He estimated that the total lake area inundated at low flood was 962ha while at high flood it would be 7430ha, showing the extreme natural variation of the *efundja.* Van der Waal (1999) mentions three sources of input into the lakes: local rainfall (400 mm/a); local floods caused by rain upstream in the oshana region; and floods *(efundja)* from Angola. Based on historical records, information from the Department of Water Affairs and his own observations he calculated that the lakes are likely to be receive some water every two out of three years and that half of these could be from a large *efundja*, i.e. once in three years, but warns that inflows are extremely variable.

Figure 3-1 below is a map of the lakes of the Omadhiya complex, reproduced with permission.

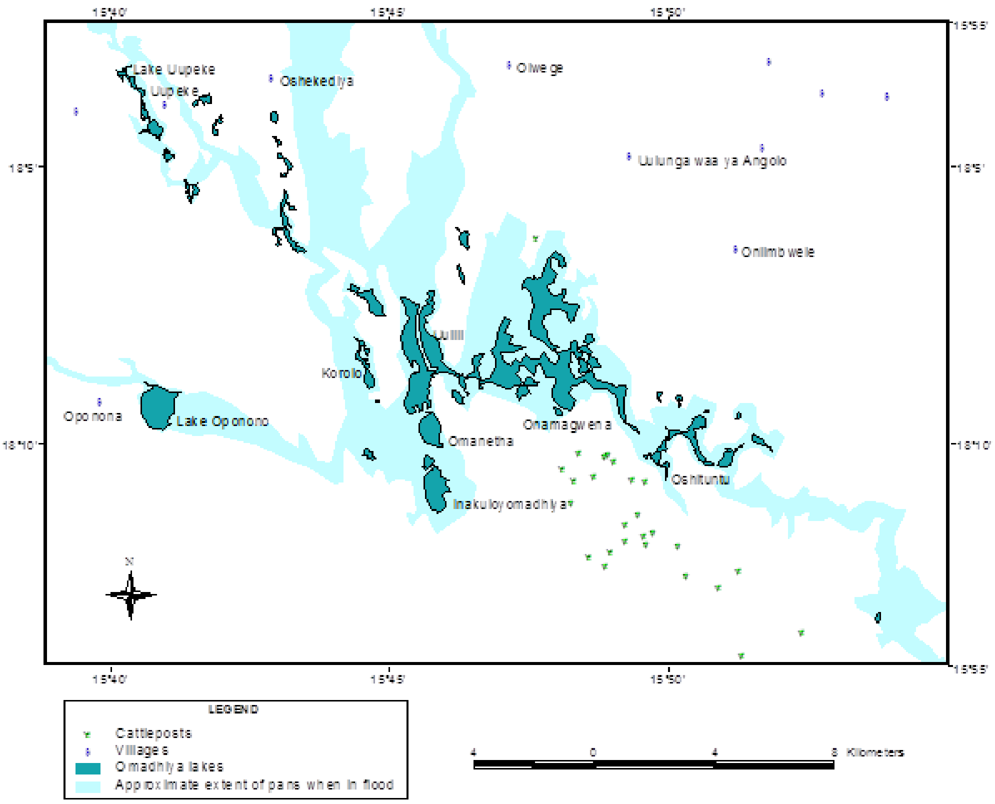

Figure 3-1 Map of the Omadhiya lake complex. Reproduced from van der Waal (2000)

The best defined channel is the Etaka oshana from the west which some think may be an earlier link (paleo-channel) with the Kunene. Interestingly today, the Etaka canal, the main south outflow from Olushanda Dam, which receives water from the Kunene River as part of the inter- basin water supply scheme to the area, is once again linking the Kunene and Cuvelai river basins and like the canal system linking the Kunene via the Calueqe-Oshakati canal (divided into the Etunda canal, the Olushandja – Ogongo canal and the Ogongo-Oshakati canal), it too is a likely conduit for Kunene species to enter the Cuvelai system.

In years of very large *efundja,* water from the Omadhiya lake complex flows southwards via the Ekuma River and enters Etosha in the northwest. A few other ephemeral, drainages such as the Omuramba Oshigambo and Omurambo Ovambo, also drain into Etosha Pan. The frequency of inflows into the Etosha Pan is very variable, calculations range from once in 4 years to reach the top, north western end of the pan to once in 7 to 10 years to fill the pan. (Berry 1972; Simmonds 1996). Local rainfall on the 5 000 km^2 Etosha Pan also contributes water, which is again higher in the east, meaning that Fisher's Pan, close to Namutoni and supplied by runoff from the Omurambo Ovambo from the east, often has water without any inflow from the Cuvelai. The pan in Etosha is extremely saline, with a clay bottom and so supports very little vegetation. The only exceptions are a few salt tolerant grass species such as *Odyssea paucinervis* and halophytic dwarf shrubs like *Sueda articulata, Salsola etoshensis* and several *Monochema* shrubs. This unusual vegetation resulting from the extremely saline pan and area surrounding has been designated as the "saline desert and dwarf shrub savanna fringe' vegetation zone by Geiss (1971). As expected when dry, the pan supports few animals, but is transformed into a rich wetland.

When inundated it is rich in aquatic invertebrates, wetland birds, African bullfrogs, as well as 5 – 14 hardy, saline tolerant fish species (Berry 1972, Curtis et al, 1998, van der Waal 1991).

NamWater currently operates the inter-basin Calueque-Oshakati Canal, a bulk water supply scheme that supplies water from the Calueque Dam on the Kunene River in Angola, via the Etunda canal and a stabilising dam at Olushandja, through 100 km of lined canals to purification works at Ongongo and further to Oshakati where it is purified before being taken further via a network of almost 2 000 kilometres of pipes to towns that including Ondangwa, Oshikango, Eenhana, Okahau, Oshikuku, Okatana and Oshivelo. The scheme also has about 200 km of earth canals that include the unlined Etaka earth canal to transfer "surplus" flows south- eastwards from Olushandja Dam along the Etaka river drainage towards Oponono.

This inter-basin transfer has inadvertently introduced several Kunene River aquatic species that include some 7 documented snail species, including vectors of bilharzia and the Kunene mussel, *Caelatura kunenensis* (Curtis, 1996), several Kunene fish species (van der Waal, 1991) of which at least 10 became temporally established in *iishana* habitats. It is very likely that several aquatic plants, including the *Typha capensis* now forming dense stands near the Oshakati purification works also migrated from the Kunene. Burke (1995a, 1995b) found no alien invasive plant species in Olushandja but did conclude that the vegetation composition around the dam is more closely related to the Kunene River system that to the Cuvelai, suggesting transfer of seeds, plant fragments and even whole plants via the canal. Downstream in the canal plants like oxygen weed, *Lagarosiphon* and pondweed, *Potamogeton,* grow in the canal (own observation).

In the 1950s and 1960s, a programme of deepening more than 100 pools was undertaken by the Department of Water Affairs, to improve water availability in dry months in remote areas. But given the flat terrain, these were only 3 – 5 m deep, (deeper excavation was not possible due to contamination by saline water from the regional saline aquifer that underlies much of the area at depths of about 8 – 10m). Few of the excavated dams held more than 10 000 m^3 of water, while the largest had a capacity of about 30 000 m^2 (Stengel 1963 cited by Chivell, *et a.l* 1991. With one notable exception, at Odibo where the system was maintained by the church, hydrologists investigating surface water resources in the area (Chivell, *et al.* 1991) found that in the years since these dams were excavated, their use for drinking water supply had diminished because most of these excavated dams had partly silted up; the pumps and the fences erected to keep out livestock had both long since disappeared; the high turbidity and fine colloids in the oshana water tended to clog the water purification filters and the availability of piped water provided a more direct source of potable water. These excavations do however still remain important for livestock watering and fishing and many support large fruit trees such as jackalberries, *Diospyros mespiliformis* that have become established on the banks of these *endombe*. The hydrologists, (Chivell, *et al.*1991) recognised their value to augment water supplies especially in remote areas, and recommended their rehabilitation also proposing new sites and designs for new excavation dams, that at 1991 prices would have cost N$ 200 000 each.

Attempts to secure water availability in remote areas are still on-going, current initiatives include the Cuve Waters project, jointly run by the Institute for Social-Ecological Research in Hamburg and the Desert Research Foundation of Namibia (DRFN), that is investigating improving water security in the area through an integrated approach that involves a combination of rainwater harvesting, groundwater desalination, subsurface water storage of *oshana* floodwaters to avoid evaporative losses, and water reuse (Eisold & Benzing, 2010).

3.2 OVERVIEW OF PREVIOUS STUDIES:

3.2.1 *WETLANDS ECOLOGY, VEGETATION, AQUATIC INVERTEBRATES, AMPHIBIANS, BIRDS AND MAMMALS:*

Museum collections:

Although, museum records show that limited collection of plants and animals in the area dates back to the late 1800s, few ecological studies have been undertaken in these very important ephemeral wetlands. Museum records formed the basis of the biodiversity report on the species richness of Namibian wetlands compiled by Curtis *et al*, (1998) which includes a list of the aquatic invertebrates, fish and frogs of the “Cuvelai and Etosha Pan”.

1991 Publications:

Several reports that include ecological aspects appeared in 1991. One by Lindeque and Archibald (1991), which deals with what was then known of the ecology of the Cuvelai but with the emphasis on Etosha. Marsh and Seely (1991) touch on it in their book on the value of oshanas.

Curtis (1991) reports on the aquatic macro-invertebrates and van der Waal (1991) on the fish of the Cuvelai and potential of inter-basin introductions of Kunene species into the system.

Olushandja Dam surveys:

In 1994/5 a series of detailed studies were conducted on Olushandja Dam as part of the EIA linked to the upgrading of the water supply canal and pipeline system. Roberts (1995) looked at the limnology of the balancing impoundment, Burke (1995) at the vegetation, identifying 5 distinct vegetation communities (floating mats, marginal reedbeds, sedge communities, floating-leaved vegetation and fringe vegetation). She listed 120 species of which 22 were grasses and 20 sedges. Curtis (1995) surveyed the snails while Hay and Van Zyl (1995) studied the fish. Biologists from the Department of Water Affairs did the firsts of a series of regular wetland bird counts on the dam (Clarke, 1998a). The counts were done in 1995, January and April of 1997 and in February 1998, showing that 48 wetland bird species occur at the dam. (See Appendix 2c for the list of birds).

Snail surveys:

Following concern about the potential introduction of snail-borne diseases via the interbasin water supply system, a more detailed surveys of snails, particularly vectors of snail-borne diseases, bilharzia in humans and the livestock diseases fascioliasis (liver fluke) and paramphistomiasis (conical fluke), were conducted (Clark, 1997). A nation-wide survey of snails by the State Museum from 1986 to1988 sampled 340 water bodies including several in the oshana region and found neither, *Bulinus globosus* that carries urinary bilharzia, nor *Biomphalaria pfefferi* which carries intestinal bilharzia, anywhere in "Owambo", (Curtis, 1990, 1991). This confirmed the results of earlier health surveys that recorded that these snail vectors were "not prevalent in Owambo" (Pitchard, 1960, 1965, 1966, 1975, cited in Curtis, 1990).

Yet during the survey of Olushandja Dam in March 1995, Curtis (1995a, 1995b) found that both *Bulinus globosus* and *Biomphalaria pfefferi* had colonised the northern section of Olushandja Dam living under the floating stems and leaves of dense stands of the aquatic plant *Ludwigia stolonifera*. None were found in the southern part of the dam. The same survey found 5 more snail species common to Kunene River, which had previously not been found in the Cuvelai system. A follow up health survey of school children confirmed a high incidence of urinary bilharzias in learners at schools near the dam (Curtis 1995b). Thus Olushandja Dam had become a focus of contamination.

Recommendations to the Department of Water Affairs included: removing the plant at the north wall, allowing the water level to drop to let these marginal plants dry out and die, restricting human access to designated plant free areas in the dam and to transfer water by pipeline rather than in open canals. Two years later the situation was again monitored by Clark (1997) who found that the plants removed from the north wall had not regrown and so no snails occurred there, but he found *Bulinus globosus* at the inflow and on plants up to 300 m south of the north wall. None were found lower down or at the southern outflow to the Etaka Canal. He found neither of the vector snails in the canal system taking water to Oshakati nor in any of the *iishana* studied. Yet, records from Ombulantu hospital showed a steady increase of about 50 cases per year from 1994 –1996 (54 cases in 1994, 107 in 1995 and 166 cases in1996). What was of concern was that none of the patients questioned had been to Olushandja Dam. This could only mean that the cercaria (free swimming stages of the bilharzia parasite that infects man) were being transferred along the canal and surviving long enough to infect people downstream. Cercaria are known to survive up to 48 hrs.

Detailed surveys to establish baseline data for ecology of Cuvelai *iishana* and *endombe:*

The most detailed study of *iishan*a and *endombe* was that of Clark (1998a) who over a two year period conducted monthly, scientific vegetation and aquatic invertebrate surveys on 8 *iishana*, 4 *endombe* and a sedge pool near Ehangano. His sites were mainly west and north of Oshakati but his results can be considered typical of *iishana* and *endomb*e in general, as he found little difference between the different *iishana*, or their northern and southern sections (either side of infrastructure such as roads), or between different *endombe*. The vegetation of *iishana* were however clearly distinct from that of *endombe*, and clear vegetation zones could be identified around both types of pools. The aquatic fauna also tended to be similar in different *iishana,* and in different *endombe* but clear habitat preferences could be distinguished in different zones of the pools particulary between shallow marginal areas and the deeper water. His study concentrated particularly on the vegetation and aquatic invertebrate fauna.

Of interest are the distinct vegetation zones of the two different types of pools found. The main distinction between *iishana* and *endombe* were that an *oshana* as a more gradually sloping terrace area of flooded grassland and is generally shallower and much wider than the deeper *ondombe* that have steeper margins and no terrace section, but may support large fruit trees, such as jackalberries, *Diospyros mespiliformis,* brown ivory *Berchemia discolor* and cluster fig *Ficus sycomorus* on the banks.

Vegetation zones identified were:

Woody species at the dry outer edges of the floodplain area that are usually dry; typical plants include:

Acacia hebeclada subspecies tristis, Ziziphus mucronata, (buffalo thorn), Hyphaene petersiana (makalani palm) and Combretum imberbe, (leadwood).

All trees that do not mind standing in water for short periods of time, found at the edges of floodplains.

Terrestrial/floodplain species in the area that is alternately flooded or dry;

typical plants include:

Sedges, grasses like Eragrostris trichophora and lilies e.g. Dipcadi crispum.

Shallow water/pool rooted aquatic plants can be emergent, submerged, or have floating leaves; typical plants include:

Marsilea ferns, *Aponogeton junceus* (waterblommetjies), *Utricularia*, and a variety of sedges (Cyperaceae) and grasses that can grow in water like *Diplachne amboesis.*

Deep water pool species also rooted e.g. *Nymphaea nouchali (*waterlilies).

Saline pool and pan species in areas where little grows due to high salinity;

typical plants include:

Salt tolerant grasses such as Sporobulos iocladus and Odyyssea paucinervis.

In a detailed study of the *iishana*, over two wet seasons, from 1996 to 1997, Clarke (1998a) found that early October rains of as little as 20mm was enough to wet these pools and trigger hatching of Crustacea such as *Triops,* a tadpole shrimp, and *Lovenula falcifera*, calanoid copepods that dominate the crustacean fauna. *Lovenula*, like the other ephemeral pool crustacean are specially adapted to survive in temporary waters, they can tolerate increasing temperature and water chemistry concentrations as the pools dry and even more importantly can complete their life-cycles within 3-4 weeks enabling them to lay drought resistant eggs before the pools dry out (Bethune, 1982). These pools typically dried up within a few weeks, and remained dry until the early January rains, which again triggered crustacea to hatch as well as causing the first emergence of the aestivating bull frogs *Pyxicephalus adspersus*. Some 44 different species of crustaceans occur in these pools, with *Lovenula falcifera*, a calanoid copepod, as the dominant species (Clark 1998a, Clark & Rayner 1999), (See list of Crustacea and where they occur in Appendix 2b). Invertebrate species from the Cuvelai, based on museum records show that 60 crustaceans including16 endemic ostracod species are known from the Cuvelai/Etosha system (Curtis *et al.* 1998). Eleven snail species have been recorded (Curtis, 1991, Curtis *et al.* 1998).

The rains normally continue through January, February and March, keeping the pools filled and with time attracting insect invertebrates too (Clark, 1998b). Some 72 species of aquatic insects including 4 endemic beetles have been recorded from the Cuvelai system (Curtis *et al.* 19980. A more recent study on the aquatic invertebrate fauna by Nakanwe, (2009) confirms the species diversity of aquatic invertebrates and their ecological importance in the *iishana*. Nakanwe regularly surveyed 10 *iishana* and *endombe* from December 2007 to May 2008 to assess the potential of setting up a biomonitoring system to assess river (*iishana*) health that could be used by the Ishana sub-basing management committee in future.

The seasonal floods from Angola via the Cuvelai then add more water and bring fish from Angola. Clarke, (1998 a) noted that the first fish larvae start appearing in the iishana in mid-February and by March *Clarias* had grown to a sufficient size to be caught by local fishermen. Van der Waal (1991) found 17 fish species indigenous to the Cuvelai system and several other species typical of the adjacent Kunene River system occurring lower down in the system that he attributed to introductions via the Calueque-Oshakati Canal water supply network that now links these two river basins.

The exact number of fish species is uncertain, 16 – 18 are considered to be originally from the Cuvelai i.e. occurred there prior to any link with the Kunene River, of these 7 occur frequently in the more saline Omadhiya lakes complex and 5 in Etosha. By 1991 the total number of fish species collected and identified in the iishana, canal, associated ponds and Olushandja Dam rose to 49; the increase ascribed to introductions from the Kunene system (Curtis *et al.*1989, van der Waal, 1991). Further work is needed to establish how many actually succeed in becoming established. The fish, introduced with the annual floods and predatory insect larvae e.g. dragonflies feed on the crustaceans, gradually replacing them as the dominant fauna.

With time the aquatic and marginal vegetation gradually establishes in and around the *iishana,* becoming densest and most diverse in March. Clarke (1998a, 1999) identified 64 species of wetland dicotyledonous plants and 92 monocotyledons of which 39 species were grasses and 38 were sedges (see appendix 2a, for a list of the plant species found). He also published an illustrated field guide to the typical plants of the Cuvelai (Clarke, 1989b). The *iishana* he studied were not linked to the Kunene system so his results can be seen as typical Cuvelai vegetation types. Burke (1995), in contrast, concluded that the plant communities in Olushandja Dam were similar to those in the Kunene, due to introduction of seeds and plants via the water transfer scheme.

Frog, Reptile and Bird surveys:

Fifteen frog species are expected to occur in the Cuvelai system but other than museum collections no detailed studies have been done (Channing & Griffin, 1996, Clark,1998a, Curtis *et al.* 1989, Griffin 1991). The most obvious and economically important amphibian is the African bullfrog, *Pyxicephalus adpersus*. Clark (1989a) noted the first breeding bullfrogs appeared with the early rains, in the first week in January, and the first juvenile frogs a month later. He noted eggs after each heavy rainfall event. Large adult male frogs are a sought after traditional delicacy, particularly by older people.

With the dense rural population, larger animals such as reptiles, birds and mammals are scarce and the area is considered as "depauperate" of wildlife. Only one of the reptiles occurring in the area, the Marsh terrapin, is truly aquatic. Clark, (1998a) lists 65 reptile species known from the area, adapted from the list by Griffin (1991), but did not observe many during his two years of fieldwork.

Regular wetland bird counts were done on Olushandja Dam from 1995 to 1998 (Clarke 1989) giving a species richness of 48 species (see bird count lists in Appendix 2c). The more isolated Omadhiya wetland complex is likely to be an important haven for wetland birds especially those that feed on fish. Berry, Stark & van Vuuren, (1973) estimated that pelicans breeding in Etosha in 1971 must have eaten at least 1000 tons of fish from these pans, the nearest source of fish. The feasibility of establishing a bird sanctuary in the "Oponono-Ekuma area" was investigated by the Ministry of Environment and Tourism (Kolberg, Griffin & Simmons, 1997, Hines 1998) and Etosha Pan at the distal end of the Cuvelai is a Ramsar site, internationally recognised for its importance to birds.

Etosha Pan is one of only two breeding areas for southern African populations of Lesser and Greater flamingos. The only other site where they can breed is Sua Pan in Botswana which is equally unlikely to hold water regularly. Given the extreme variability in both the timing and extent of flows in the Cuvelai system, conditions in Etosha are rarely conducive to breeding. In a 40 year period, investigated by Simmons (1996), the pan only received some water in 17 of those years. Even then this was more often from local rainfall and then mainly in the eastern Fisher's Pan section and not via *efundja* flowing through the Cuvelai. Although breeding was attempted whenever the pan was flooded to a reasonable depth, flamingo breeding was only successful five times in that 40 year period. Either the pan dried out before the eggs could hatch or the fledglings could fly and then became vulnerable to predators such as Black backed jackals or in some cases, continued rain bringing more floodwater caused nests to flood as they were precariously perched on low islands just above the water level. Like the rest of the Cuvelai in Namibia the Pan is extremely flat and small changes in water level can have devastating impacts on the breeding success of the birds.

Last year, following the high floods in the Cuvelai, an estimated 65 000 flamingos were attracted to Etosha Pan and bred successfully (Wilfred Versfeld, Researcher, Etosha Ecological Research Institute, September 2011).

Northern Namibia Ecological Project, Lake Oponono-Ekuma studies:

A series of ecological studies were undertaken by researchers collaborating with the Ministry of Environment and Tourism Northern Namibia Ecological Project (NNEP), these included the bird study by Hines (1998), a fishery survey to determine the fish resources for a potential fishery based on the Omadhiya pan complex (van der Waal, 1999, 2000). He found ten species of hardy fish that could adapt to life in the pans; of these 3 were considered recent introductions from the Kunene system, possibly via the Calueque-Oshakati Canal. The sharptooth catfish, *Clarias gariepinus* dominated fish communities at all sites visited and were likely to be breeding in the pans if they remain wet.

Linked to this was a study of the Turbidity and Conductivity of the pans. The researchers analysed sediment cores taken in different pans (Roberts and Clark, 1999). They investigated claims that seine netting fishing activities and/or trampling by cattle increased turbidity and salinity. Careful readings of turbidity and conductivity were taken at 17 different sites in April 1999 before they deliberately stirred up the sediment to a depth of 10 cm. Interestingly they found this had little impact on the overall turbidity and conductivity of the water in the pan. This led them to conclude that disturbance of the pan bottom by either seine netting or livestock had little additional impact as the conductivity and turbidity in these shallow pans was already similar to that of the first 10cm of substrate but that the fine silt causing the turbidity takes a long time to settle, so that once disturbed it can remain in colloidal suspension for more than a week.

Comparing conductivity changes at 2cm slices of the 50cm deep cores collected, they found a gradual increase in conductivity with depth, with significant correlation of all the cores combined. As soil depth increased conductivity increased exponentially. For the first 10 cm conductivity was similar to the conductivity of the water above it, below 2 000 µS/cm, by 20 – 40cm depth this had increased to 9 000 – 10 000 µS/cm and by half a meter to over 25 000 µS/cm, demonstrating a 10 fold increase within a half meter depth. A typical soil profile from the pans showed black, blocky, crumbly soil in the top layer up to about 20 cm depth, followed by a much more saline whitish/pink calcrete rich more impervious layer extending a further 30 cm down. Exceptions were Oshituntu pan which had darker more clayey soil and Onamagwena Pan which had thick dense brown clay even deep down. Both these pans receive water from the Oshakati/ Ondangwa area.

3.2.2 *FISH ECOLOGY AND FISHERY:*

The fish life of the ephemeral Cuvelai River and Oshana region is not well known, despite the fact that during good rain years (about one in three), local rainfall together with the seasonal floods support a valuable intensive subsistence fishery when *iishana* fill with flood water and migrating fish from more permanent reaches higher up in Angola. Naturally, there are no permanent aquatic habitats in the Cuvelai system in Namibia. Depending on the intensity and duration of the floods and rainfall the water and fish can in some years (about 1 out of 3 years) reach the Omadhiya wetlands, and with a really good *efundja* (one in 4-7 years) continue via the Ekuma River to Etosha itself. During recurring dry years, all these water bodies dry up completely and all fish succumb – no fish can survive the final salty mud or rock hard bottom once dry. The fish life in iishana and pans is thus temporary and relies on repopulation from either the more permanent reaches upstream in Angola or from fish remaining in more permanent man-made deep pools in *iishana* or the canal.

The fish species regularly found in isolated *iishana* and pools is confined to three or four species. This is reflected in catches during the present investigation. During larger floods, a number of more sensitive species also migrate from the permanent rivers and pools in the north and temporarily populate the oshana region during the *efundja*. Two major *efundja* were studied, in 1976 and in 2008-2009, and the higher number of fish species collected then, is reflected in Table 1 (see 4.4.1).

The Inter-basin Water Supply scheme bringing water from the Kunene River via a series of canals has an effect on the fish biodiversity in the *iishana* as fish manage to escape from the canal and then enter *iishana*. Only 16 to 17 of the fish species are thought to be originally from the Cuvelai. By 1991, thirty-nine Kunene fish species that had previously not been regularly collected in the *iishana*, were found in the canal, Olushandja Dam and reservoirs associated with the canal at Ogongo and Oshakati (van der Waal 1991). Some Kunene fish species may now actually have established themselves in some more permanent pools in the Cuvelai particularly after several consecutive years of good rains and/or floods. From a conservation point inadvertently transferring species from one river basin into another where they did not occur, represents an alteration of the natural ecosystem by man and example of transformation.

The subsistence fishery targets fish migrating down the flood-filled *iishana* and all fish remaining at end of the rainy season in pools until they dry up. According to available hydrological information a major *efundja* can be expected once in six years and no flow conditions once in three years (Mendelsohn & Weber, 2011). However, it must be remembered that the flows in this system are extremely variable. Fish are always present in the major floods but with smaller floods this varies, with the result that fish from Angola are probably present in floods about every third year. Nevertheless, fish form an important part of the diet of the population and to birds. Berry and van Vuuren (1973) estimated that pelicans breeding on Etosha in 1972 consumed1000 tons of fish and van der Waal (1991) calculated that 123 fishermen harvesting fish along the Ondangwa-Oshakati road on one day in 1975 caught 4.2 tons of fish. Fish are caught when available, but in the dry season or when *iishana* do not flood and with an increasing cash-based economy, the availability of marine fish is now also commonly eaten.

Traditionally fishing used to be controlled by local chiefs and kings setting a date for fishing as soon as fish size in the *efundja* had reached an acceptable size and most fish had migrated downstream. Traditional traps, baskets and push baskets are now mostly replaced by effective funnel nets, gill nets and large seine nets, able to harvest large amounts of fish for both home consumption and for cash income. This survey revealed that even though June is towards the end of the wet *efundja* season, markets in Oshakati and Ongwediva offered dried fish from *iishana* for sale.

Van der Waal (1999, 2000b) and van der Waal and Ekandjo (2011) conducted and compared the results of two Cuvelai fisheries surveys ten years apart, 1988/89, and again in 2008.

Figure 3-2 Barbus paludinosus caught in iishana alongside Okatana River June 2012.K. Roberts

3.3 FIELD WORK CONDUCTED:

3.3.1 *GENERAL WETLAND ECOLOGY:*

Fieldwork was conducted from 24 – 29 June 2012. The main aim was to follow the proposed route of the dike to see the area it was likely to impact on, to follow the Okatana River through Oshakati and to investigate the receiving oshana south of Oshakati as well as the Omadhiya wetlands as the site where the water would finally converge before continuing to Etosha Pan.

At each of the 18 dike coordinate points, the endpoint and at Hinakulu Yomadhiya Pan notes were taken of the vegetation, nearby settlements, wetland activities and disturbances and water bodies encountered, were sampled. Drainage patterns, flood lines, erosion and deposition were noted as were the natural contours of the *iishana*. The information collected was compared to the baseline survey data compiled by Clark (1998) and all the plant and aquatic invertebrates noted, correlated with those indicated for similar habitats in the baseline study. This fieldwork exercise served as a reconnaissance of the situation on the ground at the end of the 2012 wet season.

3.3.2 *FISH SURVEYS:*

The main emphasis of the field work was on the fish surveys. Given that 2012 has been designated as relatively small flood year, the *iishana* were expected to be dry at the time of this field survey towards the end June. Yet, wet and even running *iishana* were encountered during the field trip to dike sites and fish were also still present although not in large numbers, as intensive fishing must have been taking place earlier.

Fish were collected at four locality types relevant to the proposed dike:

Reachable sites on the proposed route of the dike where water was present.

End of the Calueque-Oshakati Canal before the wetland at the NamWater water purification works.

Okatana River draining the town of Oshakati and wetland created by the leaking canal at the NamWater purification work.

Omadhiya Wetland [Hinakulu Yomadhiya Pan], where all *iishana* converge at the lower end of the oshana region north of Etosha National Park.

The selection of sites was done to obtain information on the present occurrence of fish species in the *iishana*, canal and Okatana River *oshana* draining the town. These data were also collected for comparison with previous information on fish diversity, as *iishana* do not have permanent fish populations and are repeatedly colonised anew from either the Cuvelai River reaches higher up, during *efundja* or else locally from survivors from the last flood that survive in deeper, more permanent *endombe* or gravel pits that serve as refugia for them.

The following effective fishing gear was used to collect fish in iishana, pools and the canal:

D-shaped dipnet with a 75 by 45 cm mouth and 80cm deep bag constructed of 8mm meshes to collect small fish.

Seine net 17 by 2.5m with 12mm meshes and supplied by a top line with floats and bottom line with weights.

Inspection of catches of fishers was also investigated where this was possible.

The D-net was drawn from deep towards shallow water by one collector and the seine was used by two persons keeping the bottom line tight between them by hooking the bottom line below one foot. In open water the bottom rope could be pulled up to the surface to capture the fish – a handy technique in shallow open water habitat.

3.3.3 *STRUCTURED INTERVIEWS WITH WETLAND RESOURCE HARVESTERS / FISHERS:*

One of the aspects investigated was the use local people made of the available fish as well as their opinions on fish eating and potential impact of the proposed flood protection dike.

Information was collected from local people in each locality while collecting fish. Team members that could communicate in the local Oshivambo language, asked persons and passers-by questions prepared as an open-ended questionnaire. The conversation was often joined by researchers and public as there usually was a lively conversation and interest in what the team was doing and collecting. Summaries of each of the interviews are given in Appendix 3a.

The questionnaire focussed on fish and fishing and the following information was asked:

Characterization of household

Level of education of respondent

Fish eating in household

Fish catching in household

Opinion over last few years for fishing success

Effect of recent high floods on household members

Support by government after flood

Knowledge of proposed dike structure

*(See a copy of the questionnaire in Appendix 3b used as a guide to these interviews)

The following points are of interest from this limited survey:

All persons met, lived in households that had no electrical appliances, their extended large families lived mainly from pension and child grants and income sent home from working relatives in cities. They all expressed their interest in both fish eating and in fishing and preferred to eat fish above meat. Tinned or fresh marine and freshwater fish are regularly consumed. Fishing is done when there are fish in the local *oshana,* using the following fishing gear: mosquito nets, traps, push baskets, funnel nets, now often made from small mesh anchovy netting, and fishing lines with multiple hooks, for catfish. During the fishing season they fish daily in the afternoon. One lady came from a distant village specifically to fish a pool close to the Airfield in Oshakati which is known to hold many fish. She expected to spend at least a month harvesting and drying fish from it. Two other respondents were found busy drying their daily catch from a funnel net.

According to all the respondents 2010 was the best year for fishing, in 2011 catches were lower and in 2012 there was some fish, but much fewer and only in some *iishana*. This reflects experimental catches that collected a good number of small fish, mainly *Barbus paludinosus.*

3/8 of the respondents reported actually deriving an income from fish caught. One lady said it's her only income. One man lives from buying and selling fish. But a quarter did not catch any fish in 2012. Only one quarter had heard about the proposed dike and all were unaware their rural life style could be completely changed by the project.

The recent floods in 2010 and 2011 had affected a quarter of the households directly, causing the complete loss of two year's crop, and a neighbour had drowned; Those affected by crop losses due to the floods had received food hand-outs from the Government after the 2010 flood, but some received this very late after the floods. One was disappointed that flood relief was not an annual occurrence even in years of lower flooding such as 2012.

Some concerns expressed by the respondents included the possibility of goats drowning in the proposed channel next to the dike, a request for foot bridges across the channel and a request for relocation close to their original site. Another suggestion was to minimise impacts, by building the dike/ wall right in the *oshana*.

The data collected on fish eating and fishing in 2012 are comparable to two earlier unpublished surveys on fish eating and use by inhabitants of the whole oshana region (van der Waal, 2000b).

As this underlines the importance of fish in the lives of the rural people of the region and justifies the interest fish and fisheries deserves in any resource planning, the following information is given as background:

Two surveys were undertaken analysing 286 completed questionnaires in 1989, and 462 in 1999. Almost all respondents were rural persons living in traditional villages in the Oshana region. In 1989, 100% of respondent's households ate fish. In 1999, this had shrunk to 71% when meat was indicated as first source of protein. This change is probably the result of a series of continued dry years experienced then. *Clarias ngamensis*, not collected during this June survey, and *C. gariepinus* were preferred above small barbs and other freshwater fish which were all preferred above marine fish. Today more people eat 'masbanker' a marine species sold in the market, but still do not prefer it above freshwater fish. The percentage of households catching fish themselves dropped from 87% in 1989 to 60% in 1999. But again1999 followed a series of drier years.

The only, but very prominent, uncertainty/limitation about artisanal fishing as an important economic activity in the area is the varying availability of fish, depending on the size and frequency of the *efundja*. Without a major flood, there is no or little fish available. This uncertainty prevents the local subsistence fishery from being recognised as major sector in the local household economy.

Figure 3-3 Interviewing ladies at their fishing trap near Entembe K. S. Roberts

INTERVIEWS WITH FISHERIES, RURAL WATER SUPPLY AND NAMWATER:

Discussion with officials of the Ministry of Fisheries and Marine Resources at Ongwediva Inland Aquaculture Centre

An appointment was made with Mr Mikael Ekandjo, Senior Fisheries Research Technician, stationed at Ongwediva Fisheries Centre for Wednesday, 27 June 2012. The fish hatchery and centre was visited by the team and a short discussion on monitoring of fish in the *iishana* was followed by an accompanied tour to the modern fish breeding facilities where tilapia, as well as catfish, is produced for aquaculture to supply small-scale, local fish farmers. There are more than 300 people with pools or ponds in the oshana region, who are regularly provided with fish fingerlings, sold at highly subsidised prices of N$0.20 for tilapia (*Oreochromis andersonii*) and N$ 0.30 for catfish (*Clarias gariepinus*). This fish farming sector is slowly expanding whilst the *iishana* are also intensively harvested when there is *efundja* by the whole population.

It was noted that several of the large jackalberry trees next to the fish production ponds had died. Asked about the cause Mr Ekandjo explained that while excavating the ponds and during the construction of the new buildings, the contractors had piled soil around the trees, which effectively killed them. This led to the recommendation that care should be taken that this does not happen when "deepening" the Okatana River in Oshakati or the channel alongside the proposed dike, as large fruit trees are an important natural resource to people living there.

Mr Ekandjo was asked if the MFMR has a research program in place to monitor fish life of *iishana* during the flooding. He replied that:

> The Ministry does not have a regular research or monitoring system in place to monitor fish life of oshana systems. Ad hoc investigations and collections were however recently done, including the surveys conducted by him and van der Waal in the 2008 and him in 2009 and a survey was also undertaken by Mr Albert Mutelo during the 2011 flood. The first two surveys are available as internal reports* (see reference list) but Mr Ekandjo did not know where the third report could be obtained.
>
> He explained that the MFMR focuses on law enforcement and small-scale aquaculture, providing indigenous fish species, advice and fish food to aqua culturists and that local subsistence fishery is not a focal point. This explained the current lack of attention to fish life in the ephemeral *iishana* system.

*The existing reports and previous literature on fish life in *iishana* is dealt with in the next section.

Discussion with Mr L. Hango, Hydrologist at Rural Water Supply

The consultants paid a courtesy call on Mr Leonard (Ronny) Hango at his office at Rural Water Supply on 27 June, to inform him that they were working in the area and would be conducting a site visit to inspect the proposed route of the dike. Permission was asked to be allowed to travel to the lakes complex. Mr. Ashipala of NamWater joined the informal discussions.

Mr. Hango was asked his opinion, as a hydrologist, of the flow patterns in and around Oshakati in recent years and allowed the team to see and photograph the spot satellite image of the 2011 flood at its peak (5 April 2011).

Mr Hango responded that although diverting future *efundja* around Oshakati will have local impacts, especially immediately south of the town and all along the proposed dike, where it is likely to alter flow, sedimentation and erosion, this is a relatively small proportion of the total flood waters of the Cuvelai and the impacts are unlikely to extend as far as the lake complex and definitely should not have any lasting impact on the Etosha Pan.

There was concern that given the small difference in altitude between the town and the end of the dike (1.5m) the diverted water might accumulate and build up a sufficient head to flood back into the town especially if water levels in the Okatana River in town are already high when draining storm-water from the town during periods of high rainfall. Mr Hango was confident that this was unlikely.

Discussion with NamWater Oshakati

An appointment was made with Mr Moses Shakelia, in charge of NamWater, in Oshakati for 28 June to find out more about the Water Supply Scheme that provides water from the Kunene River and possible water quality and ecological impacts that the proposed flood mitigation dike around Oshakati might have. The NamWater representatives included Mr. Shakelia, Mr. Keith Sukuta, the area manager, Ms. Victoria Haikali, a water purification expert as well as Mr. Kapia and Mr Ashipala, who represents NamWater on the Ishana sub basin management committee.

Questions were asked about sections of the Calueque-Oshakati Canal; problems caused to their infrastructure and to water quality by the 2010 and 2011 floods and the proposed upgrading of the system.

Linking this to the proposed dike and channel alongside it questions were asked about how NamWater plans to prevent mixing of Kunene canal water with Cuvelai floodwaters and if the canal section approaching Oshakati was likely to be changed into a siphon or pipe to pass under the proposed dike and its 300m wide channel to divert the floodwaters around the town, crossing the area where the Calueque-Oshakati Canal reaches the town.

NamWater had experienced serious water quality problems with flood water mixing with canal water causing the water to be more turbid and increasing the conductivity, and so also the cost of purification. Following this, NamWater had investigated the feasibility of covering the entire canal to prevent future problems, but as this would prove far too expensive they have decided to invite an investigation to identify critical sections of the Calueque-Oshakati Canal and to replace those sections most prone to flooding, those that required repair and maintenance most often and where mixing problems had occurred, by pipelines or siphons. Two sections that would be looked at, would be at least the final 2 km where the canal approaches Oshakati town from the west and also the section that would have to go under the proposed dike and canal to reach their present infrastructure within the town.

It was evident that although their reasons might differ, both the NamWater officials and the ecologists on the consultant team, did not want *oshana* floodwater to mix with the water supplied from Kunene: NamWater because of the adverse impact on the turbidity, conductivity and possibly also bacteriological water quality and so on the cost of purification, and the ecologists because of the interbasin transfer of Kunene species into the Cuvelai River system of *iishana* and downstream.

The implications of translocation of fish, and on the present artisanal fishery dependent on fish introduced annually from Angola via the Cuvelai, and since the early 1970s, from Calueque Dam on the Kunene, were further discussed. Dr van der Waal explained that when working on the system, soon after the canal was originally built, he predicted the transfer of more than 20 species of fish that did not originally occur in the Cuvelai. Later in 1988 he had surveyed the then Department of Water Affairs holding dam at Oshakati water purification works and found that Kunene fish species had established in the canal and associated dams, validating his concern that Kunene fish species would spread into the *iishana* downstream, via the canal. He suggested continued monitoring of the fish species in Olushandja Dam, Ogongo and Oshikati reservoirs to check for new Kunene species.

The meeting concluded with pointing out the value of the recently established *Typha capensis* (bulrush) wetland behind NamWater by overflow from the canal and that NamWater should consider the value of this wetland as a green area and bird paradise within the city and a benefit that they provide to the citizens of Oshakati. NamWater was informed where to obtain copies of the scoping report of the EIA and permission for the consultants to visit the water treatment plant and slimes dams was granted.

A full record of the discussion held is given in Appendix 1.

Figure 3-4 Typha capensis wetland behind NamWater in Oshakati K S Roberts

3.4 PRESENT SITUATION:

3.4.1 *FISH SPECIES AND CATCHES:*

To facilitate communication a list of fish species in the *iishana* is given in Table 2 below. All species collected since 1975 in *iishana* are listed. For species reported in the canal and associated water bodies and in Olushandja Dam, refer to Hay et al,(1997, 1999) and van der Waal (1991). Table 1 lists the most commonly found fish of the *iishana.*

A summary of fish catches are presented in Table 2 that indicates both the fish species caught during the present survey as well as historical data on fish species collected since 1975 in *iishana*. Table 3 summarizes all known recorded fish from the Cuvelai including those from the June survey. The actual catches at each site during this survey are presented in Appendix 3b.

Table 3-1 Names of fish species commonly collected in iishana (species names based on Skelton 2001)

Fish species	Common English names	Oshiwambo name
Marcusenius macrolepidotus	Bulldog	Enyonyombi
Petrocephalus catostoma	Northern churchill	Onziyanekunkilo
Micralestes acutidens	Silver robber	Oontangu
Brycinus lateralis	Striped robber	Oontangu
Rhabdalestes maunensis	Slender robber	Oontangu
Barbus bifrenatus	Hyphen barb	Oontangu
Barbus paludinosis	Straightfin barb	Oontangu
Barbus poechii	Dashtail threespot barb	Oontangu
Barbus radiatus	Beira barb	Oontangu
Clarias gariepinus	Sharptooth catfish	Ehepala
Clarias ngamensis	Blunttooth catfish	Ombwishi
Schilbe intermedius	Silver catfish	Ombanda
Synodontis cf leopardinus	Leopard squeaker	Ongona
Oreochromis andersonii	Threespot tilapia	Omakende

Oreochromis macrochir	Greenhead tilapia	Omakende
Tilapia rendalli	Redbreast tilapia	Omakende
Tilapia sparrmanii	Banded tilapia	Omakende
Orthochromis machadoi	Kunene dwarf bream	Omakende
Pseudocrenilabrus philander	Southern mouthbrooder	Omakende

Table 3-2 Summary of Fish Catches at Dike Sites, June 2012 and previous fish collections in iishana

Collectioen and date	FISH SPECIES																		
	B. paludinosus	B. poechii	C. gariepinus	C. ngamensis	P. philander\ O. machadoi	O. andersonii	T. rendalli	T. sparrmaniin sit	M. macrolepidotus	P. catostoma	S. intermedius	B. radiatus	P. catostoma	B. bifrenatus	B. lateralis	M. acutidens	O. macrochir	R. maunensis	Synodontis sp
Site 4 DIKE 3 25 June 2012	X				X														
Site 2 DIKE 4 near Okatana crossing 25 June 2012	X		X						X										
Site 3 DIKE 4 at Entembe	X	X			X	X			X										

26 June 2012																			
Site 5 DIKE 10 Oshikuku road 25 June 2012	X		X			X													
Site 7 DIKE 17 28 June 2012	X	X	X			X		X											
FREQUENCY AT DIKE SITES	5	2	3		2	3		1	2										
Site 1 Canal end 25 June 2012	X	X						X											
Site 8 Okatana River south	X				X	X			X		X	X	X						

28 June 2012																			
Site 6 Hinakulu Yomadhiya Pan 26 June 2012	X	X			X	X													
EARLIER COLLECTIONS (Van der Waal 1991)																			
Running oshanas, Oshakati April 1976	X	X	X	X	X	X					X	X	X	X		X			X
Oshanas, Ondangwa December 1984	X		X			X													

Oshanas at end of canal, Dec 1984	X	X	X		X	X	X												
Running oshanas April 2008 and April 2009 floods (Van der Waal and Ekandjo 2011)	X	X	X	X	X	X	X	X	X	X	X		X		X		X	X	X

Table 3-3 Fish species reported from the Cuvelai system, iishana, Calueque-Oshakati Canal and Olushandja Dam. Adapted from Van Der Waal (1991), Hay et al.(1999), Skelton (2001) & Ekandjo and Van Der Waal (2008).

Fish species	Common names	Iishana Before 1970	Iishana after canal connection in 1972	Canal from Kunene + Olushandja Dam 1977-88	Kunene River [upper] (Skelton 2001)	Iishana survey 2012
Hippopotamyrus ansorgii	Slender stonebasher			X	X	
Hippopotamyrus discorhynchus	Zambezi parrotfish				X	
Marcusenius macrolepidotus	Bulldog	X		X	X	X
Mormyrus lacerda	Western bottlenose	X		X	X	
Pollimyrus castelnaui	Dwarf stonebasher	X			X	
Petrocephalus catostoma	Northern churchill	X		X	X	X
Kneria maydelli	Kunene kneria				X	
Kneria polli	Northern kneria				X	
Micralestes acutidens	Silver robber		X	X	X	X
Brycinus lateralis	Striped robber			X	X	X
Rhabdalestes maunensis	Slender robber			X	X	X

Fish species	Common names	Iishana Before 1970	Iishana after canal connection in 1972	Canal from Kunene + Olushandja Dam 1977-88	Kunene River [upper] (Skelton 2001)	Iishana survey 2012
Hepsetus odoe	African pike			X	X	
Hemichrammocharax machadoi	Dwarf citharine			X	X	
Hemichrammocharax multifasciatus	Multibar citharine				X	
Barbus afrovernayi	Spottail barb				X	
Barbus barnardi	Blackback barb			X	X	
Barbus bifrenatus	Hyphen barb		X	X	X	
Barbus breviceps	Shorthead barb				X	
Barbus dorsolineatus	Topstripe barb				X	
Barbus fasciolatus	Red barb				X	
Barbus eutaenia	Orangefin barb				X	
Barbus kerstenii	Redspot barb				X	

Fish species	Common names	Iishana Before 1970	Iishana after canal connection in 1972	Canal from Kunene + Olushandja Dam 1977-88	Kunene River [upper] (Skelton 2001)	Iishana survey 2012
Fish species	Common names	Iishana before 1970	Iishana after canal connection 1972	Canal from Kunene + Olushandja D 1977-88	Kunene River [upper] (Skelton 2001)	Iishana 2012
Barbus lineomaculatus	Line-spotted barb				X	
Barbus matozzi	Papermouth	X		X	X	
Barbus multilineatus	Copperstripe barb				X	
Barbus paludinosus	Straightfin barb	X	X	X	X	X
Barbus cf poechii	hyphen barb		X	X	X	X
Barbus radiatus	Beira barb		X	X	X	X
Barbus kerstenii	Redspot barb				X	
Barbus cf trimaculatus	Threespot barb				X	
Barbus unitaeniatus	Longbeard barb			X	X	
Coptostomabarbus wittei	Upjaw barb			X	X	

Fish species	Common names	Iishana Before 1970	Iishana after canal connection in 1972	Canal from Kunene + Olushandja Dam 1977-88	Kunene River [upper] (Skelton 2001)	Iishana survey 2012
Mesobola brevianalis	River sardine	X		X	X	
Labeo ansorgii	Kunene labeo			X	X	
Labeo ruddi	Silver labeo				X	
Leptoglanis rotundiceps	Spotted sand catlet				X	
Clarias gariepinus	Sharptooth catfish	X	X	X	X	X
Clarias ngamensis	Blunttooth catfish	X	X	X	X	X
Clarias stappersi	Blotched catfish				X	
Clarias theodorae	Snake catfish				X	
Clariallabes sp	Broadhead catfish				X	
Schilbe intermedius	Silver catfish	X	X	X	X	X

Discussion fish survey data:

The fish community of *iishana* consists of five pioneer species also found further south in the Omadhiya wetlands and even Etosha Pan. These species are *Barbus paludinosus, Barbus poechii, Clarias gariepinus, Clarias ngamensis* and *Oreochromis andersonii,* all known to be pioneer, colonising fish species especially successful in unstable aquatic environments. There are few other species collected in 2012, some which were previously regarded as rare, but seem to have colonised some of the more permanent waters around Oshakati in 2012. These other species were only collected in sites associated with the Okatana River and channel including *Marcusenius macrolepidotus*, *Petrocephalus catostoma* and *Tilapia sparrmanii*. These fish were first collected in *iishana* during the 2008 and 2009 floods and now seem to have established themselves in more permanent water bodies. Other fish species not collected during the previous floods may have derived from the Kunene River via the canals of the interbasin water transfer scheme and through connections with the wetlands associated with the canal and Okatana River, establishing populations. This group includes *Barbus radiatus* as well as some other species such as *Tilapia rendalli*. The picture is not clear however, as many species occur in both the upper reaches of the Cuvelai and also in the Kunene River.

The conclusion is drawn that the *iishana* have a low diversity of pioneer fish species during low floods. In good flood years, or *efundja* as happened in 1976 and again in 2008 to 2010, the number of fish species entering the *iishana* from the northern reaches higher up the river increases. Eventually, most fish die as waters dry out during dry cycles.

Another trend in 2012 is that the actual number of fish collected in the shallow, drying out *iishana* was low. Sites associated with the canal and Okatana River fed by overflow from the Calueque-Oshakati Canal, has a greater diversity and higher numbers of fish, partly derived from the canal that is connected directly to the Kunene. From a fish conservation point of view such connection and invasion by foreign fish is not favourable for the integrity of the Cuvelai River and especially not for the Etosha National Park and Etosha Ramsar site. Maintenance of this asset by allowing the original fish species living in the upper Cuvelai and iishana to migrate down the river and *iishana* where they can be harvested by local communities, adding valuable natural resources, would be the preferred natural pattern.

The following sizes of fish were collected in 2012 at the sites near the dike route.

Table 3-4 Ranges of fish sizes, and presence of mature and veryyoung age classes collected.

FISH SPECIES	SIZE RANGE cm [mean]	MATURE FISH present	VERY YOUNG present	TOTAL NUMBER
B. paludinosus	2-9 (6)	YES	YES	709
B. poechii	4-10 [7]	FEW	-	28
C. gariepinus	12-30 [25]	-	-	26
S. intermedius	10-14 [12]	-	-	5
P. philander/ O. machadoi*	2-5 [4]	YES	-	54
O. andersonii	1-12 [9]	-	YES	38
T. sparrmanii	6-12 [7]	YES	-	14
M. macrolepidotus	4-12 [9]	YES	-	83
P. catostoma	5-7 [6]	YES	-	35

*species not always distinguishable in the field

The presented data demonstrate that two of the pioneer fish species, *B. paludinosus* and *O. andersonii*, have succeeded to breed in *oshana* environments recently, i.e. within the last two months. But almost all species were present as half-grown, immature fish that had migrated from higher up the river. The conclusion is reached that local breeding does take place on a limited scale, possibly aided by the many semi-permanent water structures around Oshakati.

It was noted that several of the deeper gravel, burrow pits had clear "No fishing" signs providing a safe place for fish to breed undisturbed. This local breeding must have a positive effect on the availability of fish in *iishana* during years of low rainfall and small floods when fish are not really caught in any large numbers. 2012 was a year of a small flood and no *efundja* took place. Yet the questionnaires reported that fish were harvested this year and we collected fish at many sites and interviews stressed the importance of fish to the local communities.

Comments on the subsistence fishery of *iishana* and Omadhiya wetlands:

Although *efundja* occur irregularly, fishing plays an important role in the lives of the local population. Surveys in 1989 and 1999 showed that almost all households possess fishing gear, consisting mostly of push baskets, traps and fishing lines, enabling every family to harvest fish when available. Fish caught, are consumed fresh and the rest is dried and kept for later. When there is a real, large *efundja*, fish are caught and commonly offered for sale.

Additional to that, there are some dedicated fishers fishing the large pans of the Omadhiya wetlands on a regular basis. These pans contain water and fish in about 3 out of every 4 years and offer the opportunity to make large catches with large seine nets.

At present the artisanal fishery as a whole within the oshana region is not monitored nor controlled. In contravention of the regulations of the National Fisheries Act of the MFMR, waterways are commonly blocked completely by side-to-side set funnel nets, gill nets and traps in fences, making downstream migration difficult; mosquito nets are used and often set covering culverts that are intended to allow water and fish to flow downstream under roads. These fishing activities are specifically common at man-made constrictions in *iishana,* culverts, diversions and bridges.

One interesting observation of wetland natural resource harvesting, other than fishing, was that of a group of women harvesting sedge corms for eating. They wait until the water has dried up and then while the soil is still moist enough to not be too hard, they dig up the corms by hand, clean, and roast them before eating or storing them for later use.

Figure 3-5 Women harvesting sedge corms on edge of oshana K.S.Roberts

4 IMPACT ASSESMENT (OF THE DIKE AND CHANNEL ALONGSIDE IT AND THE DEEPENING AND LINING OKATANA RIVER IN OSHAKATI)

4.1 GENERAL:

This section seeks to evaluate each of the impacts identified during the scoping exercise that relates to wetland ecology and particularly to fish and fishing. Each potential impact is described, giving a brief overview of the impact, its probability, status, what will be affected and how. Each is summed up in a table where an assessment of the extent (EXT), duration, (DUR) and intensity (INT) or magnitude, as well as rating the overall significance of the impact without mitigation and then with mitigation following suggestions on how the impact could be managed, mitigated and monitored.

Criteria used to evaluate impacts:

Extent: Site specific

Local (within 15km)

Regional (within 100km)

National or International

Duration: Very short-term (3 days)

Short-term (3days – I yr)

Medium-term (1-5yrs)

Long-term (5 – 20 yrs

Permanent (20yrs +)

Intensity: No lasting effect

No environmental functions or processes affected

Minor effect

Environment functions but in modified way

Moderate effect

Environment functions but processes altered to cease temporarily

Serious effect

Environment altered, functions and processes cease permanently

Status: Positive (benefit) or

Negative (cost)

Confidence in prediction: High; Medium; Low.

Based on availability of information & specialist knowledge

Overall evaluation of significance of potential impacts: SIGN: N/L/M/H

NONE: No sign of impact at all

LOW: Localised/temporary – No amendment needed to proposed design

MEDIUM Local/regional/short-term – Modify design or mitigate

HIGH: High local or long-term or regional and beyond impacts.

No-go without mitigation.

These impacts are summed up in the attached Tables 5 to 14 and each deals with a separate impact.

4.2 IMPACTS ON NUTRIENT AND ENERGY CYCLES:

(SEE TABLE 5)

With the exception of decades of work done by the University of Witwatersrand, Rhodes University and the Okavango Research Institute of the University of Botswana on how the Okavango Delta functions, succinctly summarised by Mendelsohn, van der Post, Ramberg, Murray-Hudson, Wolski and Mospele (2010) little work has been done on either nutrient or energy cycles in African floodplain wetlands and nothing on the Cuvelai system. Thus only broad impacts based on how wetlands function in general can be made. Wetland productivity depends on the plants and animals it can sustain and how nutrients and energy is cycled between them. Generally a healthy, undisturbed wetland will function better as it can support a diversity of organisms each with its own role in maintaining the ecosystem, e.g. algae and plants forming the basis of the food web with zooplankton i.e. the crustaceans and plants in turn providing food to other aquatic creatures through several trophic levels up to the top predators who in the Cuvelai wetlands are fish-eating birds and man. A second important function of wetland vegetation and filter-feeding invertebrates is water purification, they maintain the water quality.

To maintain a healthy wetland with efficient nutrient and energy cycles, care must be taken to keep the system as natural as possible. The baseline study by Clarke (1998a, 1998b, 1999,) fish studies by van der Waal (1991, 1999, 2000), on snails by Curtis (1990, 1991, 1995a), aquatic invertebrates by Nakanwe (2009), frogs, by

Channing and Griffin (1993) and the biodiversity review (Curtis *et al.* 1998) have proved that the Cuvelai *iishana* support a wide biodiversity.

There are aquatic plants and animals at all trophic level, sufficient to maintain healthy nutrient and energy cycles in this often very variable ecosystem that has evolved over thousands of years. However, disturbance of this by activities such as excavating the bottom or removing marginal sediment and vegetation and thus an important habitat or even worse, by lining the *oshana* and preventing colonisation of the margins and bottom by naturally occurring plants and benthic fauna can seriously impair the natural functioning of this aquatic ecosystem, reducing available food to organisms higher up in the food chain, reducing shelter to fish and reducing the self-cleansing function of the wetland itself.

4.2.1 *IMPACT RELATED TO DIKE AND IT'S CHANNEL:*

During construction there will be serious disturbance where the dike crosses or runs along existing *iishana,* the removal of bottom sediment either for use as building material or to excavate the channel will impact on the bottom functioning and creatures that live or feed there. Productivity will be disrupted reducing food availability and sheltered breeding areas for fish. Tilapia species found in the system include *Oreochromis andersonii* that makes shallow nests in sandy substrate. Lining the sides of the dike with gravel will similarly affect the edge of the channel alongside it.

These impacts are expected to be local, extending for the distance of the dike (23km), medium term, as it will take some time for the vegetation and benthic fauna to recolonize the area, particularly as flows are naturally intermittent, the intensity will be moderate. All this is essentially of low significance. It is expected that turbidity will increase during construction, habitats and food availability will be lost for the duration of construction, but that given the resilience of the system it will recover and the new channel will soon function as the original oshana did.

Suggested mitigation would be to create a rough wall that will provide places where soil can collect again and plants can become re-established in the new channel.

4.2.2 *IMPACT OF DEEPENING AND LINING OKATANA RIVER IN OSHAKATI:*

These impacts are expected to be the same as those for the dike during the process of deepening the channel, depending to what depth it is deepened and how much sediment is removed. As was seen in the core samples from the pans, it is likely that the deeper sediments may be much more saline and could affect water quality and thus what lives there.

More serious though would be the proposed lining of the Okatana River channel through the town; an impervious layer would seriously disrupt the natural functioning of the oshana, reducing the available substrate for aquatic plants and thus the habitat for the invertebrates and fish that live on and amongst the plants and it would impair the self-cleansing ability of the system. If with time the new channel is allowed to build up sediment and colonisation by aquatic and marginal vegetation is allowed the system should be able to recover. Municipalities all over the developed world are spending fortunes "rehabilitating" rivers that flow through their cities by changing channelled rivers some decades ago back to more natural systems. This is done by creating habitats to encourage plants to grow, creating irregularities in flow, backwaters and even waterfalls and islands. Let's not make the same mistake.

The impact of deepening will be mainly local but can extend downstream up to at least the Omadhiya wetlands if saline sediments are disturbed and affect water quality; the impact could continue until after the first good flood after construction and the overall significance would be medium necessitating a careful check of the salinity of the sediment to the depths that will be disturbed. More serious is the impact of lining the channel, if the idea is to line and regularly remove sediment collecting there recolonisation is prevented and the impact becomes permanent and will affect productivity, energy cycles and nutrient cycles locally and downstream.

Figure 4-1 Bulldozed channel in Oshakati, destroying the natural margins. K.S. Roberts

The designers should reconsider changing a natural functioning *oshana* into a canalised ditch and any excavation work should be done sensitively, to not interfere with the natural contours and living margins of the existing oshana. The photograph above shows how not only the marginal zone has been entirely obliterated but the dumping of the soil removed has affected the terrace and banks too.

A) Impact related to dike and its channel

B) Impact of deepening and lining Okatana River in Oshakati

Bold letters refer to confidence in prediction:

L = low as little available information

M = medium based on both available information and specialist knowledge

H = high confidence

Table 4-1 Impact Assesment Summary Table

ISSUE	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A + B Disturbance of bottom by soil removal	Decrease in sediment nutrient levels affects fish feeding and breeding negatively	L	MT	MOD - L	L Con+ FS1-2	Turbidity increase for short construction period only, has little effect on fish life	Cover with original surface material	L
A +B Hardening of sides by lining	Decrease in fish productivity	L	MT	MIN -L	L/M Ong	Fish productivity not affected	Create aquatic plant cover by using hollow structures/bricks filled with soil	L
B Hardening of substrate by lining Okatana channel	*Decrease in cover affects fish survival, breeding, feeding	L	P	SER -M	M Ong	Normal fish biology	Cover lining with original substrate /surface material or allow sediment to collect again naturally and encourage seeding of plants on bottom and along margins	L
	*Reduced substrate for aquatic Plants					Allow plants to re-establish		
	*Reduced natural self-cleansing					Encourage colonisation by plants and benthic filter feeders to		

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	of water					cleanse water		

Note: *Would be permanent and serious if substrate is not replaced or new sediment is not allowed to collect in the lined canal, meaning that plants and benthic fauna will not be able to recolonise the newly deepened and lined channel. It would be even better if the Okatana River channel were not lined but allowed to continue to function naturally as an *oshana.*

Consider designing the new Okatana River channel in Oshakati in a way that keeps it as natural as possible, with a very gradually sloping margin on either side of the main channel, using a hollow brick structure allowing sediment to collect and plants to regrow along these margins and that will make provision for the smaller seasonal flows to flood temporarily into these margins alongside the main *oshana* channel. Be sure to prevent any development, building activity within this flood-plain area. The present design can be adapted by having a very gradual slope extending well away from the main channel to simulate natural marginal flood conditions.

4.3 IMPACTS OF POLLUTION, LITTER AND SUBSTRATE DISTURBANCE DOWNSTREAM

Although not picked up directly during the scoping exercise, the consultants have added the impacts of substrate disturbance e.g. from excavation work at the site of the dike construction or for the channel alongside where a route needs to be cut through ridges and from the deepening of the Okatana River in Oshakati.

Two rather different types of water pollution may arise:

Firstly from contaminated runoff that collects in the storm-water and collects in the Okatana River which is expected to finally collect all the storm-water in the city once this system has been upgraded. In the older parts of the original town near the airfield and hospital there are still wide, shallow ditches alongside the sidewalks that were designed to collect and divert rain water through the town. Unfortunately with the rapid expansion of the town since Independence, large parts of the town particularly the rapidly growing informal settlement areas have no such provision. Rain water will simply collect whatever else has collected within the runoff area and so is very likely to become polluted with biological waste as well as chemicals and oil spill that have collected on the roads. This will enter the Okatana River and flow downstream.

Little organic enrichment does little harm and may be good, adding nutrients (fertilizer) to the floodplains; this only becomes a problem at concentrations of nitrogen and phosphates high enough to promote nuisance algal growth. Such algal blooms and subsequent die off and decay of the algae can cause local anaerobic conditions that could cause fish kills. Of course any broken sewage pipes or flooding of sewage treatment works will also spill into the storm-water as will runoff from ill-sited dump sites; these can cause serious eutrophication and result in algal blooms as has happened in Goreangab Dam in Windhoek and more classically in Nairobi slum suburbs around Nairobi Dam. Both these dams supplied freshwater to their cities and are now too polluted to be used at all (own observation). Algal blooms are common in waterfront developments where canalisation has caused removal of natural fauna and flora responsible for the self-cleansing processes of the wetland.

It is necessary to insure that the sewage and solid waste collection systems in the town are up to standard and will not contribute to pollution.

Two points that need to be given urgent attention to avoid future contamination of water are:

The repositioning and upgrading of sewage treatment systems of Oshakati and all other towns where flooding of sewerage plants occurred during floods.

The recycling of waste in the region. No suitable site for waste disposal exists in the region, nor is the geological structure suitable for dumping. Waste recycling is a must for the region.

Illegal waste dumping on the sides of the bridge on the road south of Oshakati was very evident.

Not only have banks been bulldozed along the middle of an *oshana*, they also cut off the natural flow through the culvert and the bank was covered in litter and alien invasive plants like *Datura*.

Figure 4-2 Bridge on the road south of Oshakati to Ompundja K.S. Roberts

The second type of pollution, already discussed earlier, is that of salinisation of the water due to the disturbance of highly saline substrate layers being dug up. In the Okavango delta saline groundwater being denser sinks more rapidly drawing the accumulated salts down deeper into the substrate (Mendelsohn *et al.* 2010). The Cuvelai may similarly accumulate surplus salts in deeper soil layers beneath the *iishana* as has already been shown for the pans (Roberts and Clarke, 1999).

4.3.1 *IMPACT RELATED TO DIKE AND IT'S CHANNEL*

These are few as the proposed dike route is well north and west of the present town and away from any dense settlements, no evidence of dump sites were found and there are no sewage treatment plants that could be flooded nor sewage pipes that could leak. The only possible contamination could be from earth works linked to construction and excavation of the new channel or for building material for the dike that could be more saline particularly if removed from within existing *iishana*.

Even these impacts will be local, and temporary, only lasting for the duration of the construction period.

B IMPACT OF DEEPENING AND LINING OKATANA RIVER IN OSHAKATI

Storm-water runoff especially from flooded sewage treatment ponds and leaking pipes, or from areas where sanitation is poor or non-existent, can contribute to nutrient loads that can cause eutrophication and algal blooms. Less natural, canalised wetlands are more prone to this. Ensuring that the sewage pipe network is in good repair and sewage treatment ponds are far from flood prone areas will help to prevent this. Grids to block organic waste entering the storm-water drains and prevention of illegal waste dumping will also help avoid downstream contamination of the oshana water. Care must be taken when deepening the Okatana River to prevent salts leaching from the disturbed sediments, digging should avoid disturbing the deeper more saline soil layers. The Okatana River channel should be kept as natural as possible to allow the re-establishment of plants and re-colonisation of the invertebrate fauna that help to keep the water clean.

These impacts can extend as far downstream as the nutrients and salts flow, possibly all the way to the Omadhiya wetlands, in severe cases causing algal blooms and even anaerobic conditions that could cause fish kills. But, with care and good maintenance of services in the town this can be avoided. Waste dumping in and near the Okatana River canal must be prevented and the town dump site well sited and lined to prevent contamination of either the surface or groundwater.

With care and sound planning, pollution, whether caused by eutrophication picked up from sewage or dump site, leaching from disturbed or excavated sediments, or caused by mixing with NamWater supplies from the Kunene system, can be avoided. Care must be taken in the dry months not to allow waste to accumulate where it can be washed into the river.

A) Impact related to dike and its channel

B) Impact of deepening and lining Okatana River in Oshakati

Bold letters refer to confidence in prediction:

L = low as little available information

M = medium based on both available information and specialist knowledge

H = high confidence

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A Possible salinisation due to salts leaching out of disturbed substrate excavated during construction	Increased salinity of water in the channel alongside the dike Most *oshana* creatures have wide tolerance ranges due to variability of the system and high evaporation rates	L	ST	Min -M	L Con	Of limited duration	Check salinity gradient in substrate beneath *iishana* to avoid disturbing saline layers if they occur	0
A + B Mixing with water supplied from Kunene	Introduction of Kunene species (invasion and genetic pollution)	R	LT	Ser -H	M Ong	No chance of canal water (NamWater supply) mixing with *oshana* water	Careful construction, ensures NamWater canals and ponds unable to spill downstream	L
B Reduction in aquatic invertebrates + Fish kills due to eutrophication, algal blooms and resultant local anoxic conditions created in canal in town & downstream	Aquatic invertebrates and Fish die as result of stagnant water that has no oxygen	L	MT	MOD -H	M Ong	No sewage leaks nor leaching from dump sites No algal	Prevent build-up of organic waste in storm- water. Repair sewage pipes and move ponds to	L

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
Impact may extend all the way to Omadhiya wetland Unlikely to affect Etosha	Negative effect on piscivorous birds if fish numbers reduced Fish mortality in Omadhiya Lower bird numbers Lower fishing success downstream to lakes	R	MT	SER -L	M Ong	blooms No fish mortalities Responsibility of Oshakati Municipality No algal blooms No fish mortalities Normal fishing downstream and in lakes	higher ground. Law enforcement on dumping. Use wetlands as green lungs. Keep *oshana* natural. Water quality bio-monitoring of Okatana monthly in summer by town council Annually monitor fish + bird populations in Okatana and downstream to lakes .	L
B Salinisation of water	Increased water salinity in Okatana channel + downstream for first few flood seasons, due to construction	R	MT	Min	M Con+	Can be avoided by careful	Check salinity gradient in substrate beneath *iishana* to avoid disturbing deeper saline layers,	L

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
	disturbance.				FS1-2	excavation	if they occur	

4.4 IMPACTS OF ALTERED FLOWS (VELOCITIES AND VOLUMES) ON SENSITIVE ECOSYSTEMS DOWNSTREAM:

(Oshana receiving diverted water, Omadhiya wetlands, Ekuma River and Etosha Pan)

The main impacts foreseen have to do with increased velocities of flow due to larger volumes of *iishana* water accumulating in the diversion channel alongside the dike, this may also increase drainage from the *iishana* upstream that cause them to dry out sooner. The ecological impacts particularly on fish may extend to the receiving *oshana* south of Oshakati at Ompundja and might even have an effect on fisheries in Omadhiya lakes but given that the *iishana* draining through and around Oshakati make up only a small proportion of the southward flow of the entire Cuvelai system, this impact is expected to be small and is not expected to extend to the Etosha Pan.

This was confirmed during discussion with the Rural Water Supply hydrologist (Leonard Hango, personal communication, June 2012). A more detailed discussion of potential impacts related to fish is given below for completeness, and some recommendations to MFMR are given.

Oshana receiving diverted water: (between Oshakati and Ompundja)

During low to normal flood years, flow will only increase slightly but during high flood years, the water volume will be increased tenfold, and the depth doubled.

The flow velocity will be double during high floods and can have the following effects:

Effects on fish:
Small floods – little impact.

Large floods – fish migrating downstream will move faster downstream than before.

Lower local colonisation and more fish move downstream.

Young of the year - small fish migrating upstream will be negatively affected by increased flow.

Small fish will be more preyed upon at any constriction in the canalised system.

This is an advantage for catfish but serious disadvantage to small barbs and tilapia.

Effects on fishery:
Small floods – little impact

Large floods – fishing is improved in landscaped/channelized oshana and at many new bridges constructed. This overharvesting is detrimental to the fish communities downstream that are reliant on migration from upstream. The fishery requires regulation as is presently not applied in the *oshana* region. Control should consist of ensuring implementation of existing fisheries legislation prohibiting use of any net 30m from any culvert or bridge.

The MFMR has to improve the application of existing legislation. New, more applicable legislation may be required to protect fish at all culverts and bridges where large-scale interception of migrations with modern funnel nets takes place.

Omadhiya lake complex:

The lakes are expected to receive more water as result of the faster drainage around Oshakati. The lakes receiving water most directly from the *iishana* around Oshakati is Onanagwena rom where it spills into adjacent lakes and continues southwards via Oshituntu and the Ekuma River to Etosha. Interestingly the two pans that are furthest north, Uupeke and Korolo have the least compact sediments, interpreted being the result of recent erosion further upstream in the feeder *iishana* west of Ombalantu (van der Waal 2001). It is of concern that further sediment deposition in the pans, possibly caused by increased flow velocities from the channel alongside the dike could threaten the viability of the pans. Increased sedimentation in pans may make them shallower, increasing the surface area of these shallow lakes and so evaporative losses. No mitigation seems possible, as the increase inflow and resultant sedimentation results from ongoing interference, not confined to the diversion channel but caused by general overgrazing, deforestation + trampling:

Effect on fish:
Small floods – no effect

Large floods – increased inflow and longer retention period makes breeding in the pans possible, a positive effect from the point of view of the fishery, but the long-term effect of accumulating sediments in pans can have a severe negative effect on fish and benthos.

Effect on fishery:
Slight positive effect.
If water stays longer than a year, and some protection is provided to the fish in the pans they can breed and provide young that can populate the *oshana* system the next season.

MFMR regulations need revision to enable control of fishing in certain years to curb overfishing.

Figure 4-3 Inakulo Yomadhiya Grandmother lake of the Omadhiya lake complex K.S. Roberts

Ekuma River (Draining Omadhiya Wetland to Etosha):

Possible effects:

Negative: increase in sediment load, can be permanent and of national concern

Positive: increase in flow, permanent, also national value.

Etosha Pan:

Possible effects:

Positive: if inflow is increased, better drainage suggests this, overall impact diluted by other inflows.

Regional, national and international as it is an international Ramsar site.

Effect on fish:

Effect of small floods – none

Effect of large floods – more fish will be able to migrate further down to Etosha.

This will have a positive effect for fish-eating birds like pelicans.

Ultimately all fish in Etosha succumb, either to high salinities or to inevitable drying out.

Effect on fishery:

None, as the fish are not harvested within the Etosha National Park.

4.4.1 *IMPACT RELATED TO DIKE AND ITS CHANNEL*

Flows and velocities are expected to increase by up to twofold during large floods in the new channel next to the dike. The period of flooding will be slightly extended during high flow years but may be shortened during low and medium flow years as result of intervention with the normal flow and facilitating a new, deepened channel that can handle large floods:

Effect on fish life:
Low flow – a decrease in area and time in and around the channel.

High flow – increase in area north and west of channel as well as a longer time water will stand there. This will benefit fish life.

Effect on fishery:

The fishery will benefit from the higher water level standing for a longer time in a larger area to the west and north.

Better catches could be made over a longer period during high floods

In low-flow conditions the situation is reversed. The deepened channel will drain water received from inflowing *iishana* faster with less area, over a shorter period covered leading to lower catches.

Effects on aquatic vegetation and aquatic invertebrates:
Local scouring of *iishana* substrate will form new channels, remove aquatic and marginal vegetation and so remove the marginal vegetated habitat required by some invertebrates, reducing the number and biodiversity of invertebrates and decreasing overall productivity.
Faster drainage of upstream *iishana* will cause them to dry out sooner and so shorten the wet season and increase the dry season wetland habitats, reducing overall productivity. This impact can be mitigated by using the installed sluice gates to retain or allow through small floods essential to the overall functioning of the Okatana *oshana* within Oshakati rather than diverting them around the town and so increasing flow velocity along the dike.

4.4.2 *IMPACT OF DEEPENING AND LINING OKATANA RIVER IN OSHAKATI*

The deepening of the Okatana River in Oshakati and downstream for another 10km will negatively affect fish life by shortening the period the channel carries water. Deepening it will however offer better fish habitat for especially larger fishes like catfish for the period it is filled.

High fishing pressure can be expected in the modified channel requiring regulation and control of fishing activities, especially where fyke nets and funnels are set across the stream. The lining of the channel will not benefit fish life as it offers little hiding place or feeding substrate. Allow as natural a system of floods to flow through the Okatana River in Oshakati as possible.

Basically keep floods as natural as possible, by operating sluices in a way that will allow small floods to continue through Oshakati town within the Okatana River keeping the *oshana* functioning as naturally as possible and avoiding unnecessarily high velocities in the channel.

A) Impact related to dike and its channel

B) Impact of deepening and lining Okatana River in Oshakati

Bold letters refer to confidence in prediction:

L = low as little available information

M = medium based on both available information and specialist knowledge

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A Higher flow rate in channel during high floods	Upstream migration of small fish bred locally is lowered	R	LT	MIN -L	L Ong	No effect on fish migration	Keep velocities in channel sections within the natural velocities of *iishana*	L
	Increased fishing success where fish concentrate in increased velocity areas near structures can lead to overfishing and affect downstream fishery negatively	L	LT	MOD -M	M Ong	Fish are not overharvested at certain points	Apply regulations of fisheries act to protect fish life during migrations – no modern nets allowed that obstruct fish migrations	
	Etosha Pan and Omadhiya wetlands could be negatively affected by increased sedimentation, (higher flow velocity carrying more	N	LT	MOD -M	M Ong	Omadhiya and Etosha wetlands not affected by dike and channels	Design and keep flood velocities below erosion rates Monitor sedimentation rate in *iishana*, Omadhiya pans, Ekuma and	

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
	sediment down), but unlikely.						inflow to Etosha	
	Local scouring of substrate to form new channels, could remove aquatic and marginal vegetation, reducing habitats to aquatic invertebrates, so reducing overall productivity.	L	MT	MIN -M	M Ong	Smaller impact if operation is sensitive to allowing small floods through Oshakati town, to retain habitats.	Keep velocities in channel sections within the natural velocities of *iishana*. Use sluice gates to allow small to medium floods to go through Okatana *oshana* – to allow natural flow regime to maintain natural habitats and functioning. (See comment below Table 3.1)	
	Negative effect on local fishing north of dike, with small floods	L	LT	MIN -L	L Ong	Normal fishing experienced around dike	Avoid disruption of low flow in *iishana* by excavation, keep to natural oshana	L

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
							margins	
	Faster drainage of upstream iishana, decreased time that wetland area remains aquatic increases length of the dry season	L	MT	MOD -M	M Ong	Retain normal wetland cycle. With the exception of really large damaging *Efundja* going through Oshakati town.	Operated sluice gates at dike/road and at culverts to retain small to medium floods at normal level, allow small to medium floods through Okatana in town.	L
	More water received during normal and large floods in wetlands extend period of water retention in Omadhiya wetlands and possibly Etosha. This can benefit fish + all aquatic life.	L	LT	MOD +M	L Ong	No effect	No mitigation needed, May be an advantage to maintain wetlands and refugia for fish and inverts.	0 +
Increased flow causes	Wetlands from Ompundja to	R	LT	MOD	M	No increased	Keep flow rates in channels below	L

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
increased erosion and also increased sediment transport	Omadhiya receive more sediment, causing siltation of pans. This influences water retention periods in pans			-M	Ong	sedimentation	erosion rate level	
	Can smother benthos and so causes less fish in wetlands, decreases overall productivity including lower fish catches	R	LT	MIN -M	M Ong	Normal productivity including fish populations	Keep flow rates in channels below erosion rate level	L

Note: * Basically keep floods as natural as possible, by operating sluices in a way that will allow small to medium floods to continue through Oshakati town within the Okatana river, both to keep this *oshana* functioning as naturally as possible and also to avoid building up unnecessarily high flow volumes and velocities in the channel that diverts the excess flow around the town.

There is likely to be increased silt being carried downstream during the construction phase and just after it and so greater sedimentation and smothering of bottom living plants, invertebrates, and of nests of some fish species such as *Oreochromis andersoni.*

4.5 IMPACTS ON FISH AND WETLAND DIVERSITY AND ON LIVELIHOODS DEPENDENT ON FISH: (

During high floods (*efundja)* the fish diversity in *iishana* depends on what fish species have migrated down the Cuvelai from Angola. An example is the sudden common occurrence of *M. macrolepidotus* in our catches – a fish not collected in *iishana* since 1975. It must have migrated down the Cuvelai from the permanent reaches of the river and established viable populations in Namibia. Continued maintenance of the integrity of the Cuvelai in Angola is an important uncertainty deserving international attention.

During low floods, especially after a long dry period, there is very little fish life in the few open water ponds remaining in the *oshana* system – all fish have died or been caught out by local people.

Permanent waters acting as refugia play a very important role to maintain fish species presence during the recurring dry periods.

Against this background the impact of the dike and associated channels have very little direct impact on fish diversity or the fishery except for those aspects discussed elsewhere.

If the dike and channels are to have a positive impact on the livelihood of the local communities, it has to do with fishery management and specifically with protection of fish life in more permanent water bodies to act as inocula for new populations breeding and distributing in the *iishana* once inundated. This project may convince policy makers that it is worthwhile to invest in education and law enforcement to identify refugia in the *oshana* region where fish can be protected during dry seasons to repopulate the *oshana* system in the next rainy year.

The 'no fishing' signs erected at several of the deeper borrow pits such as the one at the bridge on the Okatana road show that authorities are aware of this and are restricting fishing in these refugia.

Proof of successful breeding of fishes in Namibian *oshana* reaches of the Cuvelai System has been obtained earlier (van der Waal 1991, 2000) and further evidence collected now as juvenile fish.

A) IMPACT RELATED TO DIKE AND IT'S CHANNEL:

The dike and the channel alongside it will not have a large effect on wetland and fish diversity but the fishery locally and further downstream may be affected through any negative effect resulting from altered water quality or flood modification.

The construction phase of the dike may have a serious impact on aquatic life if work is not completed and levelled and compacted and covered in time with suitable sand or other less fine material before the next flood. If not, large scale deterioration of flood water with erosion can be expected, smothering vegetation downstream as well as preventing feeding and breeding of fish.

This will then have a similar negative effect on the fishery around Oshakati as well as the area south as far as the Omadhiya Pans.

How the excavation is done can be critical. The bulldozing procedure should be sensitive to the *iishana* and as far as possible follow the natural contours of the existing *iishana*. Any bulldozing of the oshana floor should not be perpendicular to the flow direction.

Similarly the design and siting of any borrow pits will be crucial and if well placed can be beneficial offering much needed refugia where fish and other aquatic organisms can survive in deeper water through the drier periods. Borrow pits should be sited on the existing ridges and elsewhere interspersed with normal oshana floors and islands to maintain natural flow patterns.

B) IMPACT OF DEEPENING AND LINING OKATANA RIVER IN OSHAKATI:

The effects of the building phase are expected to become more serious if the channel is not constructed and finalised within one dry season. The effect on the fishery downstream may also become serious. Likely impacts include sedimentation due to deepening of the Okatana River smothering the bottom and any benthic organisms living there; it is also likely to cause the removal of marginal vegetation or as was observed on the recent field trip, the dumping of sediment removed on the banks and so smothering the natural marginal terrace and bank vegetation. (Refer to Figure 7). The deepening and lining of the Okatana channel will thus cause the loss of important oshana bottom, marginal, terrace and bank habitats that will lead to an overall decline in productivity including fish breeding. Possible salinisation due to deepening of Okatana channel will cause a decline in water quality that could cause the more saline sensitive species to disappear. It is true that this does happen naturally as *iishana* dry out but the process would be accelerated reducing the productive wet and growing period, affecting overall aquatic productivity.

Sensitive construction and operation of the flood diversion scheme can largely mitigate any impacts and the creation of borrow pits that can serve as refugia for fish and other aquatic life can be positive as the deeper water will allow their survival in the dry periods providing refugia from where the *iishana* can again be colonised the next season.

A) Impact related to dike and its channel

B) Impact of deepening and lining Okatana River in Oshakati

Bold letters refer to confidence in prediction:

L = low as little available information

M = medium based on both available information and specialist knowledge

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A. Water pollution, erosion and sedimentation caused by dike (dealt with in 3.2 + 3.3)	Lower wetland and fish diversity in *iishana* and downstream as far as Omadhiya lakes complex, possibly to Etosha.	R	LT	MOD -M	M Ong	No diversity loss in wetlands	Keep water quality and erosion rates within natural limits by appropriately natural channel design. Sensitive operation of bulldozers (see text)	L
A. Permanent or longer-lasting water bodies created by channels and borrow pits for dike project	New habitat created for aquatic life including fish, that can be used as refugia or fish farming opportunities. Positive impact.	L	LT	MOD +M	M Ong	Permanent water bodies act as important fish refugia to repopulate *iishana* annually. Responsibility of Fisheries	Create connections with borrow pits and *iishana*. Permanent water bodies receive conservation status and fishery regulations are enforced	L +
	Permanent water bodies can enhance fishing in whole region	R	LT	SER +M	M Ong	Opportunity taken to stimulate subsistence fishery. Water bodies act as inocula repopulating *iishana* annually, regional advantage	Connect water bodies to *iishana* and give protection status ito fisheries legislation. Sensitive design of borrow pits.	0 +

						to rural people		
A. Introduction of Kunene river species	Not encouraged in conservation nor health terms, but already occurring and can enhance fishery	N	P	SER -M or + M	H Ong	Can be avoided by careful construction and operation in cooperation with NamWater (responsible)	Take care to avoid mixing of Kunene supply water with oshana floodwaters diverted around town	L
A + B Changed flood dynamics	Lower fish catches in wetlands, affecting fishermen negatively	R	LT	MOD -M	M Ong	Fish catches not affected by dike project	Operate sluices to keep flood dynamics, peak and duration, within natural flow range, through & around Oshakati town	L
ISSUE CONTINUED 3.4	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A,B Hardening of sides of dike next to channel and lining of Okatana canal	No vegetation on hardened channel sides or allowed to grow in lined canal	L	LT	MOD -L	L Ong	Normal vegetation cover for aquatic life	Use hollow bricks in place of solid concrete apron/gravel Replace substrate over lining or allow sediment to collect	L
B. Sedimentation due to deepening	Smothering of benthic organisms and removal	L	ST	MOD	M	Reduce intensity and duration of impact	Construction and excavation sensitive to	L

Okatana channel	of marginal vegetation, due to construction.			-M	Con+ SF1-2	by careful construction	functioning of *iishana*	
B. Habitats lost due to deepening and lining of Okatana channel	Decline in aquatic vegetation, habitats, aquatic invertebrates and fish, general decline in productivity	L	MT LT	SER -M	H Ong	Of limited duration if substrate is replaced or sediment allowed to settle, but permanent if lined channel is to regularly "cleared" of vegetation	Replace substrate Do not clean out sediment Keep *oshana* as natural as possible, keep margins. Allow bottom and marginal vegetation to re-establish	L
	Reduces self-cleansing function of natural wetland fauna and flora	L	LT	MOD -M	M Ong	Natural vegetation cover for aquatic life	Cover lining with original substrate /surface material or allow sediment to collect again naturally and encourage seeding of plants and colonisation by inverts on bottom and at margins	L
B. Salinisation due to deepening of Okatana channel	Decline in water quality that could cause more saline-sensitive species to	R	ST	MOD -M	M Cons+	Limited or no additional salinisation	Check soil profile in *oshana* to determine salinity of	L

	disappear. Happens naturally as *iishana* dry out but would be accelerated, reducing productive wet period and overall productivity				FS1-2		mud and do not excavate to depths that would allow leaching of additional salts	

4.6 IMPACTS ON FROGS (PARTICULARLY PYXICEPHALUS ADSPERSUS) AND AQUATIC INVERTEBRATES:

As the main points relating to impacts on aquatic fauna have been largely covered under the previous point that dealt with aquatic diversity in general and fish diversity in particular, this discussion will confine itself particularly to the aestivating giant bullfrogs, *Pyxicephalus adspersus* and aquatic invertebrates more generally.

The African bullfrog is an important food source to rural communities living in the Cuvelai. These large frogs aestivate in the soil of *iishana* banks in the dry season and emerge with the first good rains to breed in the newly inundated rain pools. Large numbers are harvested each season and care must be taken not to disturb the aestivating frogs or prevent them aestivating.

4.6.1 *IMPACT RELATED TO DIKE AND IT'S CHANNEL AND IMPACT OF DEEPENING AND LINING OKATANA RIVIER IN OSHAKATI:*

The impacts on aestivating giant bullfrogs and aquatic invertebrates are similar for both development, hardening of the dike sides and so of at least one side of the channel that will divert the flow around the town as well as lining of the Okatana channel and hardening its sides can prevent frogs from digging into the substrate to aestivate. Excavation of the channels will dig up and kill buried aestivating frogs. Frogs can be expected to have dug down to 40cm deep. In addition, increased velocity of flows both in the diversion channel and in a lined Okatana river through the town will decrease the suitable spawning habitat as these frogs require standing water to breed. Frog eggs, tadpoles and aquatic invertebrates can further be washed downstream and increase chances of predation.

Other than not lining the Okatana channel, structures such as hollow bricks could be used to encourage re-establishment of vegetation and the substrate could be replaced after lining. Quiet sections could be incorporated in the channel curves to allow safe breeding sites in quiet waters for frogs, fish and aquatic invertebrates. Essentially keeping the system as natural as possible will be the best solution.

No detailed study on the giant bullfrogs in the Cuvelai has yet been undertaken and this offers an interesting natural resource use project to determine criteria for sustainable harvesting and to find out more about the behaviour and requirements of this species in the Cuvelai *iishana* system.

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A + B. Excavation of aestivating adult frogs during construction	Removal and death of adult frogs dug up during construction	L	MT	MOD -M	H Con	Care taken to identify and rescue frogs during excavation	Not at all sure that this would be possible, but can be reduced if excavation activity in deeper sections of existing *iishana* is kept to a minimum. Keep to natural contours.	L/M
A,B Hardening of sides dike on edge of diversion channel and lining of Okatana bottom	Frogs prevented from digging into soil to aestivate where gravel cladding or lining is applied	L	LT	MIN -L	L Ong	Frogs can dig into soil	Use hollow bricks in place of solid concrete apron/gravel and allow bottom sediment re-establish, do not clear.	L
A,B Increased velocity in channel	Tadpoles and aquatic invertebrates washed away by flood current in lined channel	L	LT	MIN -L	L Ong	Normal tadpole and aquatic invertebrate survival	Create places with no flow & growth areas for aquatic plants, monitor tadpole populations annually a month after good inundation.	L
	Increased predation of tadpoles and aquatic invertebrates	L	LT	MIN -L	L Ong	Normal tadpole populations	Monitor tadpole and frog populations annually a month after good inundation	L

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
	in unprotected areas							

4.7 IMPACTS OF CHANGES IN WATER QUALITY (TURBIDITY, SALINITY, NUTRIENT CONCENTRATIONS) ON *IISHANA* HABITATS AND FISH AND FISHERIES:

In all cases where oshana bottoms are disturbed by deepening existing channels, serious negative effects on water quality can be expected over a short-term period, such as one summer season, as loosened silt takes very long to settle out. Fish species of the *iishana* are not sensitive to slight changes and deterioration of water quality and experience serious increases in salinity as the deeper *iishana* and pans of the Omadhiya wetland complex dry out. With ever increasing salinities as the salts become concentrated by evaporation, the fish will eventually all die off. But this is no excuse to hasten the process by careless construction practises or bad timing.

The increasing soil salinity with substrate depth found in these pans has already been discussed.

4.7.1 *IMPACTRELATED TO DIKE AND ITS CHANNEL:*

The dike and channel will have a short-term, one season, and negative effect during construction on water quality and turbidity which will affect fish life by decreasing available food organisms, which will lead to overall loss of condition and so to lower spawning success rates and overall productivity of the system. Over the longer term, rehabilitation of the dike and channel will alleviate these negative impacts. Some erosion and ongoing leaching of salts from disturbed sediments, e.g. sediment taken from the *oshana* bottom and used to build walls/ flood protection banks can however cause water quality deterioration over a longer term, i.e. 10 years. (Refer to photographs in Figures 8 and 10 below).

Figure 4-4 **Bull dozed wall within oshana on outskirts of Oshakati to protect shacks. K.S. Roberts**

4.7.2 *IMPACT OF DEEPENING AND LINING OKATANA RIVER IN OSHAKATI:*

Disturbance of oshana bottom substrate may have a short-term to medium-term negative effect on water quality, aquatic and fish life. Over the longer-term, stabilization and smothering of the bottom by newly transported sediments and the establishment of aquatic vegetation will alleviate this impact. The hardened surfaces of the channel will however prevent any submerged aquatic plant growth or contact with the hyporheos. The impact will however be permanent if accumulated sediment is continuously removed to 'clean' the lined channel. It would be best to keep the Okatana River natural.

Impacts linked to disturbance of substrate for excavation or construction resulting in increased turbidity and salinity and linked to the collection of storm-water drainage into Okatana River are of course similar to impacts on pollution, litter and substrate disturbance as discussed under 3.2.

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A. Removal of material from *oshana* for dike building and channel construction	Turbidity and salinity increase during and after construction	R	ST/MT	MOD -M/ H	M Con+ SF1-2	Difficult to manage , accept some turbidity change during + after construction of dike and channel	Very difficult during construction but will recover if exposed areas are covered with sand or stabiliser	L
	Reduced aquatic vegetation for first few seasons until recolonised		MT		M Con+ SF1-2	Will have impact during construction but allow plant regrowth along margins	Use hollow bricks or rough surfaces to allow regrowth + recolonisation	
	Fish migration, feeding, breeding impacted		ST		M SF1-2	Accept local impact on fish populations and migrations during construction, within a few seasons return to normal fishing in *iishana*	No real mitigation possible	
	Fishing success lowered, community disadvantaged below and next to dike		ST		M Ong		Expect some impact during construction but will recover if exposed areas are covered with sand or sediment is allowed to naturally build up.	
	Fish survival in Omadhiya pans low – pans fill with		MT/LT		H Con+	Omadhiya water quality and fish community will		

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
	sediments and water deteriorates sooner				SF1-2	be temporarily affected		
B. Unpurified street runoff from Oshakati is allowed to collect in storm-water drains and to flow via Okatana River into *iishana* downstream	Water quality and health of *oshana* system and Omadhiya wetland deteriorates	N	LT	MOD -M	M Ong	Water quality in *iishana* downstream of Oshakati is normal and safe. Needs cooperation of Oshakati Municipality to prevent contamination, adhere to MAWF effluent permit requirements + initiate monthly biomonitoring.	Create natural wetland at bottom end of Okatana river to filter runoff. Reposition + upgrade sewerage treatment Enforce water quality/effluent regulations on outflow from industry. Monthly biomonitor ing of water quality + health to test Okatana River outflow	L
	POTENIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
ISSUE CONTINUED 3.6	Fish life in *oshana* system and Omadhiya	N	LT	MOD -M	M Ong	Normal fish life in iishana	Runoff has to be purified before release into *oshana* system, either by creating a natural	L

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
Unpurified street runoff from Oshakati is allowed to collect in storm-water drains and flow via Okatana River into *iishana* downstream	wetland affected					Needs cooperation of Oshakati Municipality to purify stormwater either before entering the new channel or before this water flows out of town.	reedbed at lower end of Okatana River before it exits the town of having a system that collects and at least semi-purifies the storm water entering the channel.	
	Fishery in oshana system and Omadhiya wetland negatively affected	N	LT	MIN -M	M Ong	Fishery not affected by runoff water	As above, filtering of runoff needed to prevent impact on fishery	L

4.8 IMPACTS OF FLOODGATE OPERATION (DURATION AND TIMING OF FLOWS) ON IISHANA AND FISH:

These impacts have to do with the free migration of fish and aquatic invertebrates in this network of inter-connected *iishana* through the system, including the Okatana River to reach other *iishana* and the pans downstream. The broader issue is the migration of fish and other aquatic fauna through infrastructure that could block their route throughout the region. Clarke (1998a) who studied *iishana* found little evidence of such impacts and assumed that enough fish were able to move downstream; however his study was nearly 15 years ago and there has been an increase both in the number of people living and fishing in the area as well as in the availability of fine meshed and mosquito nets often found completely barring bridges and culverts and even siphon entrances. This is an issue that needs to be addressed by MFMR regulations and their enforcement.

4.8.1 *IMPACT RELATED TO DIKE AND ITS CHANNEL:*

Fish migrations down the Cuvelai and its associated *iishana* ending in the channel in front of the dike will all be deflected along the featureless banks of the channel next to the dike. An increase in predation of smaller fish by catfish and piscivorous birds can be expected. When floodgates are opened, some of the dammed water runs down the channelized Okatana River, fish will move through increasing their vulnerable to injury and predation by birds and predatory fish.

Of greater concern is the increased opportunity for fishing by local people using modern day effective fishing gear. The use of long fish funnels and fykes and nets at culverts and bridges is prohibited in the fisheries legislation but little specific law enforcement is taking place to enforce these fishery regulations in the *oshana* region, the argument being that as result of the temporary or ephemeral nature of the fish habitat, all fish will anyway succumb and so are free to be harvested.

For long-term benefit of the fisheries as natural resource, such a *laissez faire* approach is not conducive. Neither is it according to the traditional natural resource management of fish resources in the area where limits were set by traditional chiefs on appropriate fishing times and gear types (van der Waal, 2000). If the optimal benefit of these artisanal fish resources for local communities is a goal of the MFMR, all bridges and culverts and sluices should be no-fishing zones allowing free passage for migrating fish.

4.8.2 *IMPACT OF DEEPENING AND LINING OKATANA RIVER IN OSHAKATI:*

The deepening and straightening of the Okatana River in Oshakati will have a slight positive effect if more water is kept for a longer period of time and if natural vegetation is allowed to grow back in areas where it was disturbed by deepening, compaction and channelization.

There are also negative impacts expected:

Decrease in water surface area by damming and filling in considerable areas and constriction of *iishana* in Oshakati
Disturbance of natural bottom and compacted unproductive surfaces
Increased predation where natural cover has been removed or compaction took place
Removal of diversity of habitats and featureless sides/ margins of the aligned channel
Decrease in vegetation, sheltered margins and so habitat for fish food items
Increased fishing pressure.
This should be monitored and controlled by MFMR if needed.

Depending on how the system of sluices / floodgates on either side of the town are operated, they can either reduce the amount of water entering the town and decrease how long it remains, reducing the habitats available for fishing in town or, by preventing water from leaving town, could increase the time the water remains in the town *oshana*, so locally improving fishing

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A. Upstream fish migration through open gates	Fish cannot migrate upstream due to high velocity rates	L	LT	MOD -M	M Ong	Undisturbed migration	Modify design structure of floodgates or install fish ladder	L
A, B Downstream fish migration through open gates	High mortality at and below floodgates caused by high predation by predatory fish and birds	L	LT	MOD -M	M Ong	Normal fish predation level	Fish predation can only be mitigated by minimising these constrictions in flow. Provide cover for fish at structures.	L
	High mortality where Fishermen concentrate efforts at weirs and floodgates, culverts and along new flood diversion channel	L	LT	MOD -M	M Ong	No mortalities above normal Needs cooperation of Fisheries authority	Create" no fishing" zones at all bridges, culverts, weirs and gates according to existing fishery act regulations.	L
A + B Deepening channels reducing natural	Stopping natural floods and inundation of floodplains from occurring in channel alongside dike and in Okatana *oshana* in town will	L	LT	MIN -M	L Cons+ FS1-2	Minimum disturbance of natural flow and water retention/	Operate sluices in a way that will allow small to medium flows through so as to keep flow regime natural	L

flows through *iishana*	have negative effects on fishing in channel and river					flood time	and to not decrease water retention period	
B *Deepening channels can either decreasing or increasing the time water pools remain in wet season	Shortened period when filled with water affects fish survival	L	LT	MIN -M	L Ong	Normal period with water	Manage flood gates in such way that period of flooding is not affected	L
	Longer period water retained in Okatana *oshana* within Oshakati can improve fishing	L	LT	MIN +M	L Ong	Operation of sluice /flood gates to keep water in town longer, improves fishery **if** vegetation allowed to grow	Modify operation of sluice gates to maximise fishing Allow vegetation to establish	L +

4.9 IMPACTS OF REMOVAL OF VEGETATION, (INCLUDING LARGE FRUIT TREES) AND LINING OF OKATANA RIVER ON THE *IISHANA* HABITATS, FISH AND FISHING:

Important features of the Cuvelai vegetation are the larger riverine trees found on the banks of the larger *endombe* and on the ridges or higher ground alongside the *iishana*.

The groundwater recharged by these wetlands support large fruit trees such as jackalberries (*Diospyros mespiliformis), brown ivory (Berchemia discolour)* or the makalani fan palm (*Hyphaene petersiana)*, sycamore fig trees (*Ficus sycomorus)*, leadwoods (*Combretum imberbe)* as well as some typical riverbank trees like the ana tree (*Faidherbia albida),* woodland waterberries, (*Syzigium guineense)*, and acacia species with nutritious pods, important for fodder, like *Acacia nilotica, A. arenaria* and *A. hebeclada.* All these trees are well established and of value both for their fruit to man, his livestock, and birds, provide shade and serve to stabilise the banks and margins of the wetlands against erosion. The fact that in many places these trees have been left when others like the mopane were removed to clear crop land testifies to their value as a natural resource of the wetland.

Figure 4-5 Makalani Palms, Hyphaene petersiana, alongside Cuvelai oshana. K.S. Roberts

Although only one study on the ethnobotany of the Cuvelai is available (Rodin, 1985), it is well known that wild fruits as well as wetland vegetation is extensively used and collected to sell. This includes reeds and sedges as building material, to make fishing gear and baskets and in the case of the corms of some Cyperaceae species as food. The *iishana* also support large semi-aquatic grasslands in the wet season that provide good grazing in the dry times.

The 2001 Forestry Act specifically makes it illegal to remove or damage any plant that grows within 100m of a watercourse; the *iishana* of the Cuvelai are very wide, braided watercourses.

Any vegetation removal, or indeed disturbance of bottom or marginal soils and covering substrate e.g. by lining of the channel next to the dike or the Okatana River in Oshakati will have a negative effect not only on the vegetation itself but also on fish life in the following ways:

- Removal of protective cover for fish
- Increased predation by birds and predatory fish
- Reduction in surface area for aquatic invertebrates and epiphytic algae and bacteria by emergent vegetation removal
- Increased water velocity in the absence of submerged or marginal vegetation that would otherwise attenuate flow.

4.9.1 *IMPACT RELATED TO DIKE AND IT'S CHANNEL:*

The dike will confine the larger floods to a 300m wide channel alongside it, preventing the natural spreading out of this water across a large area of floodplain and so reduce the surface area of flooded vegetation available for fish considerably, directly and by preventing flooding of areas behind the dike inside Oshakati town. With a projected expected fish biomass of 30kg per ha, 3000 kg fish production and growth is lost for every km^2 of *oshana* surface area that cannot be compensated for in any way.

All along the proposed dike route, several large trees, particularly important fruit trees were noted: In fact each is visible in the large scale aerial photographs used. Care should be taken to avoid any unnecessary removal of these trees. By sensitive alignment of the dike to follow the natural contours of the *iishana* along which it passes, the removal of many of these trees which are all on slightly higher ground, can be prevented and where this is not possible saplings should be replanted on the bank opposite the dike to replace any trees lost.

Important vegetation zones can be protected by creating or leaving some higher lying islands within the deepened channel allowing the flow to naturally braid around it or even by creating long islands as well as some quieter water areas. The focus should be to keep the channel natural.

The dike sides are likely to be compacted and partly covered with concrete affecting adjacent aquatic systems negatively by allowing dirty runoff directly into the water and when the dike is used as main road, the runoff from the road could contribute additional oil and fuel pollution.

Little vegetation is expected to regrow on the sides of the dike or in the channel next to it. This has negative effects on all aquatic life including the fish, causing loss of habitat and shelter or cover to fish and the aquatic invertebrates that are their food source, and can increase water temperatures due to the shallow waters being more exposed to the sun.

Fishing is also expected to be negatively affected by the removal of vegetation and deepening of the channel for a period until the bottom has been stabilised, some growth of emergent and submerged vegetation has taken place and sediments covered the saline bottom soils. This process may take two good flood years and longer, particular if the *efundja* fail to reach so far south and the channel fills only with local rain water.

A positive impact could be that the areas flooded north and west of the dike will increase and if water also remains here longer, with a deepened channel, fish production may increase, partly offsetting the reduction in area caused by cutting off of *iishana* inside the dike.

4.9.2 ***IMPACT OF DEEPENING AND LINING OKATANA RIVER IN OSHAKATI:***

The deepening of the channel may be advantageous in terms of keeping water for longer but if the intention and design aim to drain Oshakati completely, or require regular removal of accumulated sediment and vegetation, this will counteract this expectation, so in reality the benefits will be very small and insignificant.

Care should be taken to minimize any disturbance to the marginal and terrace vegetation alongside the town *oshana,* and once constructed the channel should be re-habilitated to encourage regrowth of vegetation in and alongside it. Care must be taken not to remove any large trees or to dump soil near them which was shown to kill jackalberry trees at the Fishery institute in Ongwediva. To maximise the fishing potential within the town, vegetated habitats needed by the fish for shelter, feeding and breeding should be retained or re-created and smaller floods should be allowed through the town each year with sufficient capacity of shallow sections in the Okatana River channel to absorb these floodwaters. Thus design of the route within the town should move away from the idea of a canalized ditch confined to its banks that will move water away as quickly as possible, to a more natural braided system flowing around islands and at times allowed to flood shallow areas adjacent to the main canal. There is a vast amount of literature available on river rehabilitation using natural features to maintain functions that can be consulted.

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A. Flooded wetland area downstream of dike is reduced	Reduced productivity and lower fish catches in Okatana *oshana* as much of the floodwater is diverted away reducing area of flooded vegetation where invertebrates, frogs and fish can breed, shelter and grow	L	LT	SER -M	M Ong	Natural flooded wetland area and fish productivity restored	Operate sluices in such a way as to allow small to medium floods into Okatana *oshana* Design waterway in town to accommodate these floods Allow marginal vegetation to re-establish. Keep trees	L
A. Increased flooded wetland area to N + W	Creates new vegetated, flooded wetlands N + W of dike	L	LT	MIN +M	0 Ong	Improved fishery production could compensate for losses downstream	None, mainly positive impact	0 +
A and B Removal of economically important trees	Important food supply to people, livestock, birds and even fish gone, effect people harvesting plant resources, livestock eating nutritious pods	L	LT	MIN -M	L Perm	Important vegetation resource retained or replanted.	Start nursery and plant local fruit trees on channel banks Avoid dumping soil	L

particularly fruit trees	and fish that feed on fallen fruit, so also the fishery					Large trees, particularly fruit trees kept.	near trees Where possible align dike and channels to follow natural contours and avoid large trees	
	Shading of pools removed. Affects water temperature + fish survival	L	LT	MIN -M	L Perm	Water temperature maintained	Plant trees back on channel banks and at pools	0
A and B Removal of island or river bank tree vegetation	Excavation + construction work destroys island and bank habitats and removes veg + large trees	L	LT	SER -M	H Ong/ Perm	Islands retained Follow natural contours of *iishana* and go around trees	Leave long islands along deepened channels to retain viable trees + bank vegetation	L
B. Smothering of trees growing on *iishana* banks	Large fruit trees on *iishana* banks and excavated channels, die	L	P	SER -H	H Perm	Trees survive as care taken not to dump substrate nearby	Strictly avoid dumping substrate removed by excavations near trees	0
B. Loss of marginal, terrace and bank vegetation	Important *iishana* habitats destroyed + productivity impaired	L	P	SER -H	M Ong/ Perm	Retaining margins and Rehabilitation of habitats allows regrowth of plants	Consider channel design sensitive to retaining wetland margin, plants + functions	L

4.10 IMPACTS OF DEEPENING THE CHANNELS, EXCAVATION OF MATERIAL (E.G. FROM THE RIVER TO THE NORTH OF OSHAKATI) TO CONSTRUCT THE DIKE AND THE CREATION OF NEW BORROW PITS ON FISH AND *IISHANA* HABITATS:

As discussed earlier under 4.2 excavation of the *iishana* can seriously affect water quality. Disturbance of the very fine, saline silt forming the bottom of *iishana* has a negative effect on the water quality in terms of increased turbidity, increased erosion rate and increased salinity. Each year there is a serious dispute between stock farmers and fishers using seine nets when a particular pan or *oshana* starts drying out, the stock farmers allege that disturbance of the bottom by men pulling heavy seine nets, increases turbidity and salinity rendering water later unsuitable for their cattle (Roberts & Clarke, 1999, van der Waal, 2000a). It is true that as the *iishana* dry they become increasingly turbid and saline and that once disturbed the turbidity takes a long time to settle out. Disturbance by construction activities is similarly expected to have a negative effect on water quality. Based on the findings of Roberts and Clark (1999) who tested sediment cores from the Omadhiya wetlands, concern was expressed at the scoping meeting for this Flood mitigation project, that prior to excavation of any *oshana* or the deepening of the Okatana River in Oshakati, sediment cores be tested for salinity at depth, as there is a real likelihood of stirring up salt-rich sediments that can contaminate the water and *iishana* habitats downstream. Although the system is naturally variable, there does seem to be a mechanism of “locking away” salts in the sediment to reduce salinisation of the water, and construction activities may severely impair this.

4.10.1 *IMPACT RELATED TO THE DIKE AND ITS CHANNEL:*

A considerable amount of material has to be excavated from *iishana* to lower levels suggested for the channel, likely to be 300 to 400m wide. Some of this material can be used to construct the dike, adding material from the borrow pits. This disturbance of such wide areas in *iishana* may have a very negative impact on water quality in the channel as well as on groundwater replenishment.

Fish will be negatively affected by such deterioration of water quality. It must however be noted that the main fish species found in the iishana *B. paludinosus, C. gariepinus* and *O. andersonii* are all extremely hardy fish that can survive high turbidity and salinity values. There is more concern over the potential negative impact on the water received by the proposed Ramsar site at the Omadhiya wetlands and designated Etosha Pan Ramsar site. Over a long period this added load of salts and fine sediments may negatively affect functioning of these wetlands, production of algae and other food, fish life and wetland birds supported by these pans.

Existing and new borrow pits if landscaped properly and connected to the *oshana* network, can become valuable assets in the landscape by providing water during dry periods for man and beast and act as refuges for fish and other aquatic fauna. Extensive fish farming could also be practised in such pits. If done sensitively, the excavation work during construction can be done to allow “landscaping” of the new diversion channel and to include islands to protect trees and other important natural resources including areas of reed and sedge communities (see Figure 6). This will allow a more natural wetland system to re-establish itself afterwards. It is important to follow as far as possible the natural contours of *iishana* to retain the habitats and functioning of these important wetlands as well as their fish productivity.

4.10.2 *IMPACT OF DEEPENING AND LINING OKATANA RIVER IN OSHAKATI:*

As mentioned previously, disturbance of bottom sediments of the channel will have immediate negative effects which will lessen over time, about 2 -3 years, as new sediments cover the soils and if vegetation grows on it. The lining of the channel with hardened surfaces and concrete will remove and prevent regrowth of vegetation and have a negative impact to aquatic and fish life.

The Okatana River should follow the natural contours of the oshana and allow for small floods and a variation of habitats to be retained within the system to keep it functioning.

The borrow pits needed to obtain material for construction can be turned into fish refugia or even fish ponds for aquaculture as long as they are connected to open water and landscaped for this.

Figure 4-6 Okatana oshana channel north of proposed dike, note natural contours. K.S. Roberts

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
ISSUE	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A + B Excavation of channels can expose saline substrate	Leaching from exposed saline substrates can increase water salinity and impair water quality	R	MT	MOD +M	M Con+ SF1-2	Salinity downstream not increased. Impact mainly limited to construction.	Test *iishana* substrates cores along entire route. Take care not to excavate to deeply	L
A. Opportunity to rehabilitate gravel pits to link to *oshana* system	Unproductive and spoilt feature in landscape, permanent damage	L	LT	MOD +M	M Perm	Turned into productive part of *oshana* and fish refugia	Landscaping of gravel pit sides and connection with *oshana* system to allow flood water connection.	0 +
B. Opportunity to sensitively create new gravel pits with potential as fish ponds or refugia	More unproductive holes in land-scape, permanent damage No fish ponds created No refugia to retain fish and other aquatic fauna to restock *iishana*	L	LT	MOD +M	M Perm	Existing and new gravel pits turned into fish ponds that provide job opportunity + Create refugia for fish and other aquatic organisms	Create gravel pits designed to be suitable for fish production, Modify to link to *oshana* system for floodwater supply Deep enough to retain water through dry season or even two consecutive dry seasons	0 +

A + B. Opportunity to create long islands within new diversion channel alongside Dike wall	Loss of marginal and river bank vegetation and habitats Loss of overall wetland productivity	L	MT	MOD +M	M Ong	Creation of islands to assist with rehabilitation of *iishana* habitats alongside dike route and to protect large trees.	As part of dike construction and excavation of diversion channel alongside dike use some material to create islands or leave some long islands to aid rehabilitation	0 +
A + B Dike and proposed channels not sensitive to natural contours of *iishana*	Loss of essential *iishana* habitats alongside newly created channel, loss of overall wetland productivity and fish production Loss of natural functioning and self-cleansing property of wetland	R	MT	MOD -M	M Perm	Dike and diversion channel alongside it follow the natural contours of the *iishana* as far as possible and so remains a functioning wetland system	Take care to align dike route along natural contours of *iishana*. Allow natural flood regime along and across natural margins	L

4.11 HEALTH IMPACTS/SPREAD OF BILHARZIA AND MALARIA ASSOCIATED WITH SLOW FLOWING WATER

As mentioned earlier in this report, bilharzia and the snails that serve as vectors to this parasite were unknown in the Cuvelai prior to 1990 (Curtis, 1990, 1991). Since then with the introduction of Kunene river water via the inter basin water supply scheme operated by NamWater, both host snails have been found on vegetation, mainly on floating leaves of *Lugwigia stolonifera* in the northern section of Olushandja Dam (Curtis, 1995a, 1995b, Clark, 1997, 1998b) but not anywhere else in the system at that time. Yet, cases of bilharzia were increasing at Ombalantu hospital each year even though many of the patients had never been to Olushandja Dam suggesting that the cercaria (the free-swimming life-stage that infects people in the water) had managed to survive in the canal downstream. Given that the snails and the disease managed to spread from the Kunene, it would be wise to once again conduct a snail survey to determine its further spread in the last 14 years and to check with hospitals in the area if new cases occur.

Some simple practical precautions to prevent the spread of bilharzia and contamination by people are given in the reports by Curtis (1990, 1995a, 1995b) and by Clark (1997). Bilharzia snails live in well vegetated, quiet waters. Such conditions could exist on the quiet margins of *iishana* systems and in isolated pools as waters begin to dry out. At places where such conditions are likely it would be advisable to create vegetation-free access points for people using resources from the wetland.

As these conditions can occur both in the diverted channel around the town and within pools in the Okatana *oshana* the recommendations apply equally to both impacts A and B.

Malaria is endemic (in the medical sense) in the Cuvelai, as drying *iishana* pools provide foci for the insect carriers, *Anopheles* mosquitoes to breed. They too prefer standing water. It does not make any sense to eliminate these habitats from the *iishana* system as they also support many beneficial creatures. Several fish species are known to eat mosquito and provided they occur naturally within the Cuvelai system could be introduced into for example the pools created within burrow pits. Otherwise the precautions advocated by the Ministry of Health should be followed and care taken in the application of DDT that this bioaccumulative poison that targets all insects including beneficial ones, be done in a way that will not contaminate *iishana*.

Similarly awareness that mosquito nets are for sleeping under and not for fishing needs to be done.

4.11.1 ***IMPACT RELATED TO DIKE AND ITS CHANNEL AND IMPACT AND DEEPENING AND LINING OKATANA RIVER IN OSHAKATI:***

Isolated, standing water pools within the *iishana* can harbour both mosquitoes and bilharzia snails although the current distribution of the snails beyond Olushandja Dam is not known. Sensible precautions need to be taken, one natural way of dealing with mosquitoes is to allow insect eating fish to migrate into the pools during floods and to work with the Ministry of Health and Social Services to create awareness, but to be cautious of the ecological implications of the use of DDT near wetlands and the illegal use of mosquito nets for fishing especially when used over culverts to catch everything trying to move downstream.

The snail surveys of 1991 and 1997 need to be repeated and become part of a regular, annual, ecological monitoring programme of the water supply scheme and any *iishana* inadvertently linked to it, including the new diversion channel alongside the dike, the Okatana River in Oshakati and the receiving *iishana* (not the Omadhiya lakes as suitable vegetation is unlikely to occur). The best time to monitor would be towards the end of the wet season when isolated pools remain. The hospital records should be regularly checked. Should vector snails be found, recommendations for Olushandja should be applied e.g. having vegetation-free access points for people to use.

Summary of the evaluation of the impacts

Tables 5 to 14 sum up the impacts discussed and should be read together with the preceding text.

In addition to this evaluation of the impacts raised, the consultants were asked to comment on the potential for fish farming and based on the experience gained on the field trip would like to also comment on the green space created by the *Typha* wetland behind NamWater in Oshakati, the importance to keeping the Okatana River in Oshakati and the diversion channel alongside the proposed dike as natural as possible and the prevention of potential erosion, sedimentation and salinisation.

ISSUE	POTENTIAL IMPACT UNMANAGED					MANAGED IMPACT		
	POTENTIAL IMPACT UNMANAGED	EXT	DUR	INT	SIGN	MANAGED IMPACT	MITIGATION	SIGN
A + B. Rain-fed borrow pits and quiet pools offer habitat for mosquitoes	Malaria mosquito populations develop and malaria breaks out in population Already happens in quiet, standing waters without fish, e.g. gravel pits	L	LT	MOD -M	M Ong	No build up of mosquito populations in any isolated pools or gravel pits Requires cooperation Health departments' malaria awareness and control campaigns.	Connect borrow pits with *oshana* system so fish can migrate into pools. Monitor pools for malaria mosquito larvae. Active malaria control +campaigns in whole region	L
A + B Fishing with mosquito nets Inappropriate use of malaria control tool	Illegal fishing with mosquito nets sometimes even cutting off movement of all aquatic fauna downstream by blocking culverts and narrow channels Decreases productivity of *iishana*	R	LT	MOD -M	M Ong	Smaller fish, snails and other aquatic fauna not held back or killed by small mesh nets	Fisheries to strictly impose penalties (fines and confiscation of mosquito nets) at all culverts, sluices, bridges constrictions in channels	L

A + B. Vegetated margins of deeper quiet waters could provide habitat for bilharzia vector snails	Continued mixing with Kunene supply water could introduce bilharzia vectors to *iishana*	L	LT	MIN -M	M Ong	Prevention of bilharzia In cooperation with Health Department, NamWater and Dept of Water Affairs	Avoid any mixing with water supplied from Kunene syst. Vegetation-free access points to water for people to use Snail surveys annually at the end of the wet season of all water associated with flood diversion scheme both inside and outside town. Annual check of hospital records for cases of bilharzia.	L

4.12 COMMENT ON POTENTIAL FOR FISH FARMING IN THE NEW CHANNEL:

The proposed channelization in association with the dike will offer a temporary aquatic habitat as it will actually increase flood water movement down the Cuvelai system. It will thus not offer permanent fish habitat and thus limited opportunities for fish farming. But where water is dammed, the extended area and period offers habitat and growth opportunities for fish.

Some fish farming opportunities could be developed as part of the proposed channel where portions are deepened or borrow pits are dug to be converted into fish ponds or in rehabilitated and new borrow pits created during the excavation and construction work for this project. Fish farming in cages in deeper sections with suitable flow rates is another possibility. Advice from MFMR should be sought on the appropriate design of ponds suitable for aquaculture. Even if not used to farm fish, borrow pits that are deep enough to retain water through one or even two dry seasons can serve as important refugia for fish and other aquatic fauna.

There are a number of factors to be considered when planning fish ponds in an *oshana* environment:

- high evaporation rates [200cm/a]
- soil structure and salinity of *oshana* soils
- high turbidity
- vegetation to provide suitable marginal habitats where fish can shelter
- suitable feed for fish
- security and flood risks

The proposed Okatana River channelization will similarly not provide direct fish farming opportunities, for the same reasons as above. Deteriorating water quality is a further factor to be considered.

4.13 COMMENT ON POTENTIAL OF GREEN SPACE LINKED TO TYPHA WETLAND NEXT TO NAMWATER:

The existing bulrush *(Typha capensis)* swamp created from regular overflow of the canal near the Namwater purification plant (See photograph in Figure 5) could be maintained as part of the Okatana drainage and kept wet with regular overflows from the purification plant as is currently done. It has a threefold function benefitting the developing city and region:

Act as green lung in the middle of a built-up area. It provides a habitat for fish and wetland birds and could become a recreational attraction if developed for hiking, picnics and bird watching.

Act as refugium for fish species. Fish could survive the dry-season and low flood years to breed early in the summer season and young fish could colonise the filling *iishana* once rains start. This has a beneficial effect on the natural control of mosquitos and on the subsistence fishery downstream in the system.

Wetlands act as water purification systems, helping to counteract the negative impact of urban impacts on water quality.

4.14 COMMENT ON ADVANTAGES OF KEEPING OKATANA RIVER IN OSHAKATI AND THE DIVERSION CHANNEL ALONGSIDE THE PROPOSED DIKE AS NATURAL AS POSSIBLE:

As is shown clearly in the ecological baseline study on *iishana* and *endombe* of the Cuvelai by Clark (1998a), these important seasonal and ephemeral wetlands support a wide diversity of plants and animals within a healthy diversity of habitats, each with its community of plants and animals that function together to maintain the health and productivity of these wetlands. Although seasonal and at times extremely ephemeral, they harbour a robust wetland community, including fish able to withstand very variable environmental conditions to which they have adapted over thousands of years.

Like all wetlands, the *iishana* systems provide both goods, in the form of water, sedges, edible plants and fruits, grazing, snails, frogs, fish and wetland birds and essential ecological services that include self – purification of water, vegetation that attenuates floods and prevents erosion, plankton at the base of the aquatic food chain and the full spectrum of viable trophic levels to support this productive ecosystem that in turn supports a dense rural community supplementing the food and security of the most vulnerable members of the population (Bethune *et al.*2007). Nearly half of all Namibians live in this area many of whom rely at least for part of each year on wetland resources and whose livestock graze on grasses supported by regular flooding.

For this reason it is important to be careful not to impair ii*shana* functioning and to maintain as far as possible the natural habitat, plants and animals and water flows of the system to enable it to continue to provide the ecological services it does. Thus as outlined in the section dealing with impacts and their possible mitigation care must be taken to keep the Okatana River, the diversion channel alongside the dike as well as the receiving *iishana,* as natural as possible.

This includes following the natural contours of the *iishana* as closely as possible, avoiding removal of vegetation and hard linings, allowing natural rehabilitation to take place, and where necessary creating islands to protect trees and other vegetation and to encourage re-establishment of communities and habitats after construction. Having learnt that canalising rivers and interfering with natural flow patterns, leads to the irreversible loss of ecological services, municipalities and governments elsewhere in the world are spending time and money on rehabilitating these rivers to become more "natural". Operation of the sluices should as far as possible mimic flow pattern and at least allow small floods through the town of Oshakati where the waterways should be designed to cope with this.

4.15 COMMENT ON PREVENTION OF EROSION, SEDIMENTATION AND SALINISATION DURING CONSTRUCTION AND OPERATION:

Erosion caused by construction activities can be mitigated by planting indigenous fruit trees along banks of constructed channels and allowing marginal vegetation to re-establish.

Signs of active erosion are plentiful in many *iishana* south of Oshakati. Sand bars are common in many *iishana* after the recent large floods with braiding in others, signs of considerable sediment load and movement. The impact of the increased flow in constructed channels can be considerable and especially in the very flat area south of the channel and inflow sections of the Omadhiya wetland.

Hydrological and sedimentological investigation and regular monitoring is required to determine to what extent erosion and sedimentation rates are likely to be affected by the dike project.

Increased salinisation by disturbed sediments particularly from depths below 10cm and particularly from *iishana* and pan beds must be further assessed and avoided. All along the proposed dike route soil samples sites were noted, but all these had been surface samples; what is needed is detailed core samples tested for conductivity and salinity.

Possible actions:

Create more permanent wetlands with aquatic vegetation to act as filtering system at the end of the dike.

Annual monitoring of sedimentation above and below the dike, as well as at fixed locations downstream of the dike and at the Omadhiya wetlands.

Testing of substrate salinity and conductivity, wherever excavation work is proposed to the maximum depth likely to be disturbed.

4.16 COMMENT ON RECONSTRUCTION OF CULVERTS ON EXISTING ROADS:

It was observed that many culverts and even bridges (Figure 13) have floors now raised above oshana floor level causing water to dam up above the causeways and roads. This may have actually contributed towards the flooding experienced in Oshakati.

It is suggested to inspect all bridges and culverts on roads in the region for this aspect and to rectify floor depths when replacing structures.

Figure 4-7 Raised floor of bridge over Oshikuku oshana illustrates the raised floor levels of many structures, adding to the flooding risk.

5 CONCLUSIONS AND RECOMMENDATIONS

Overall there is no reason, that if done with care, taking the value and nature of the *iishana* ecosystem into consideration, the dike and its diversion channel and the Okatana River through Oshakati town should have lasting environmental impacts that cannot be mitigated, and in some cases as with the borrow pits providing refugia to wetland species can be beneficial. But care must be taken to keep the system as natural as possible, to retain its functions and productivity.

Most impacts are likely to be local some extending downstream at least as far as the Omadhiya wetland but not likely to affect the Etosha Pan Ramsar site.

Several of the impacts are associated with the construction phase and are expected to not last more than one, possibly two wet seasons after completion of construction. In fact some construction activities can be modified to be beneficial to the wetland, e.g. creating islands to protect trees and "landscaping" to create a variety of habitats within the new diversion channel.

Operation of the sluice gates sensitive to the natural flow and flood patterns of the system will be important as will be following the natural contours of the existing *iishana*. For example some sections of the proposed dike down the middle of the *oshana* to the west of Oshakati should rather follow the eastern bank of this *oshana* to keep the full width available for the flow of the diverted water.

On the western side of the channel natural gradual banks should be kept rather than creating steep banks to retain the marginal habitat and allow overflow of floods. By keeping the system as natural as possible and allowing it to re-establish itself in a way that will retain a variety of habitats and communities, any long-term and permanent impacts envisaged can be solved.

Effects on fish life by the dike are limited. The modified Okatana River draining Oshakati can become an asset in terms of fish if proper fisheries management according to the existing fisheries regulations are enforced. The wetland and channel can be declared a fish conservation area in terms of which fish life is protected. Regular monitoring of hydrological changes and sedimentation and of fishery activities is required.

Detailed ecological studies of the *iishana* system are few, and the monitoring programme suggested by Clark (1998a) and Nakanwe (2009) and regular monitoring of the fish and artisanal fishery needs to be implemented.

Much of the available information has been gleaned from the "grey literature" i.e. unpublished government and project reports. This information should be published to be more accessible for studies such as this.

Certain aspects of natural resource use such as the value and ecology of the edible *Pyxicephalus adspersus* frogs is needed.

Consideration should be given to extending the Etosha Ramsar site northwards to include the *iishana* wetlands.

Thus the main recommendations can be summed up as:

Careful planning and construction.

Operate sluice gates to mimic natural flow patterns.

Avoid exposing saline substrate that could leach salts into system.

Be sure to avoid any mixing of *oshana* floodwaters and Kunene water to avoid further interbasin transfer of organisms, particularly disease vectors and fish.

Fix up storm-water and sewage systems in Oshakati and ensure no dumping where runoff can enter *iishana* system.

Keep *iishana* as natural as possible to retain important wetland functions and services like the self cleansing property of the water and productivity of these wetlands.

Do not disturb banks, margins and terraces, retain vegetation and fruit trees and replant if removed.

Create habitats that might otherwise be lost e.g. islands with trees within new channel.

Ensure that construction is sensitive to natural contours of *iishana.*

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APPENDICES

APPENDIX 1 Record of Interviews

A) RECORD OF DISCUSSION HELD WITH NAMWATER IN OSHIKATI ON IMPLICATIONS OF PROPOSED FLOOD MITIGATION DIKE ON WATER AUTHORITY INSTALATIONS – THURSDAY 28 JUNE, 2012:

PRESENT: NamWater Consultants team:

Mr Moses Shakelia, Chairman Dr Ben van der Waal (Fish specialist)

Mr Ashipala Ms Shirley Bethune (Aquatic ecologist)
Polytechnic of Namibia (Natural Resource Management)

Mr Martin Kapia Mr Kevin Roberts (Chief Hydrologist, DWAF, Water Environment)

Ms Victoria Haikali Mr Jonas Hausiku (Enviro Dynamics)

Mr Keith Sukuta (Area Manager) Ms Emelia Sende and Mr Joseph Kaudinge (Research Assistants) Nature Conservation students, Polytechnic of Namibia.

The meeting started promptly at 8:30 in the NamWater Boardroom in Oshakati on Thursday 28 June. All present were introduced and Dr van der Waal explained that the consultants were conducting a survey to assess the possible impacts of the proposed flood mitigation dike around Oshakati on the wetlands / *iishana* and particularly on fish communities and annual artisanal fishery on which so many people living in the Cuvelai depend.

He added that he was concerned about potential ecological impacts of flood water mixing with the NamWater Ogongo-Oshakati open canal and asked if there was any concern that the water channelled around Oshakati by the dike might mix with canal water where it crosses the large *iishana* just west of Oshakati where it crosses the Oshikuku road, as the proposed dike is expected to divert water through there in a 300 m wide channel flowing southwards.

Dr van der Waal outlined his concerns regarding the continuous mixing of Oshana (Cuvelai) water with canal (Kunene) water and impacts on water quality that could well increase the costs of purification. He asked what plans NamWater has to prevent such mixing and if those present agreed that the proposed dike may pose an increased risk of mixing water supplied from the Kunene River via the canal and the often more turbid waters of the *iishana*.

Mr Shakelia responded that the feasibility of covering the entire length of the water supply canal from Olushandja Dam to Oshakati, to prevent contamination by floodwaters had been recently assessed but was found to be too expensive; however it had been agreed that the most vulnerable sections should be identified and could in future be replaced by siphons. Several such sections occurred along the Oshakati-Ogongo section of the canal. He added that the project intends to look at the canal, identify critical areas and provide practical solutions that will prevent flood water entering the canal. Mr Hausiku asked what the criteria for "critical" were. He was told that these were, for example: areas where the surrounding land is higher or nearly as high as the canal; those sections where expensive repairs had been necessary in the past, e.g. after the *efundjas* of 2010 and 2011; areas within town; and sections where canal water had been contaminated by floodwaters making it expensive to clean the water prior to supply via the pipe line system to Oshakati, and all the other towns supplied by the existing network of pipes. Mr Roberts commented that it was evident that NamWater too did not want *oshana* flood water in the canal, and that the water quality was very different, with *oshana* water often having very high conductivities (>150 µS/m) and high turbidity.

Mr Shakelia referred the consultants to the water engineers at NamWater in Windhoek for further details about the canal upgrading, repairs, the sections to be piped and the advertised tender, suggesting that they speak to Mr Martin Harris.

One concern however is that people all along the route use and benefit from the canal and would not be able to do this if sections of the canal are replaced by sections of pipeline. One section that will be looked into to be changed into a pipeline or siphon is the section from 2km west of Oshakati where the canal nears the large *oshana*, where the Oshikuku road crosses it. The consultants were assured that sections vulnerable to flooding, and those that often required repair would be identified and prioritized. These would in future be piped to prevent mixing. The implications of this on the fish, and on the present artisanal fishery dependent on fish introduced annually from Angola via the Cuvelai and also from Calueque Dam on the Kunene, were further discussed.

Dr van der Waal explained his concerns related to the inter-basin transfer of water and fish, as a result of mixing of Kunene and Cuvelai waters. Dr van der Waal explained that when working on the system, soon after the canal was originally built, he predicted the transfer of more than 20 species of fish that did not originally occur in the Cuvelai. He was concerned that Kunene fish species would spread into the *iishana* downstream, via the canal. In 1988 he had surveyed the then Department of Water Affairs holding dam at Oshakati treatment works and found that Kunene fish species had established in the canal and associated dams, proof that they had moved along the canal.

He was now curious to find out if any of these species, for example *Tilapia rendalli* and *Tilapia sparrmanii*, had become established in the *iishana* of the Cuvelai system. He felt it important to consider a follow-up survey to investigate this. Permission was asked to view the water treatment ponds after the meeting. At some future date, Dr van der Waal would be interested to again sample the ponds, both at Ogongo and Oshakati, and if possible also Olushandja Dam, to investigate fish species brought down by the canal now.

Dr van der Waal enquired about the new *Typha capensis,* (bulrush) wetland between the NamWater purification works and the end of the Ogongo - Oshakati canal near the site of new market and congratulated NamWater on sustaining a green area within the city. He was impressed to see the variety of birds attracted to the wetland and said that efforts must be made to maintain this potential green lung and tourist attraction. He asked if NamWater considered the maintenance of this wetland as part of their corporate social responsibility towards the citizens of Oshakati.

Both groups agreed that it was in the interest of NamWater to prevent mixing of Kunene supply water with the floodwaters of the Iishana and that this should be taken into consideration in the EIA on potential impacts of the proposed flood mitigation dike and the canal alongside it to divert waters south-westwards around Oshakati town. Mixing would have serious cost implications to NamWater in terms of higher cost of purification of the water and to conservationists, ecologists and fisheries biologists in terms of the spread of Kunene species into the Cuvelai system and the effects on local biodiversity.

A brief discussion followed on the proposed future water supply from the Okavango River an impacts of water abstraction and transfer of organisms would have on the ecosystem lower down in the river and especially on the aquatic systems of Namibia, if raw water is transported from one river basin into another.

It was agreed that a record of the discussion would be sent to NamWater. Mr Hausiku explained that the scoping report of the EIA was now available and NamWater can download it from the Enviro Dynamics website. The link is http://www.envirod.com/pdf/proposedfloodmitigationmeasurements/OFM%20scoping%20report%2030_05_2012%20to%20DEA.pdf. He explained that the results of the ecological studies including the fishery survey would be reported to the Draft Environmental report to be compiled by Enviro Dynamics. He added that if NamWater Oshakati want to register to receive the proceedings this is possible via Carla@envirod.com

Permission was requested to visit the water treatment ponds and this was granted with Ms. Petrina Amesho as guide. Ms Amesho kindly showed the consultants around the plant and slime dams and explained the purification process. It was noted that when the quality of the receiving water is good, water can be discharged directly into the *Typha* wetland instead of the slimes dams. Dr van der Waal expressed his appreciation for the tour adding that at some future date he would be very interested to again survey the fish population in the holding ponds to compare with his earlier studies to see which Kunene fish species had now become established within the Cuvelai catchment.

B) RECORD OF DISCUSSION HELD WITH MR LEONARD HANGO AT RURAL WATER SUPPY –OSHAKATI WEDNESDAY 27 JUNE, 2012: 9:00.

The consultants paid a courtesy call on Mr Leonard (Ronny) Hango at his office at Rural Water Supply to inform him that they were working in the area and would be conducting a site visit to inspect the proposed route of the dike. Permission was asked to be allowed to travel to the lakes complex. Mr Ashipala of NamWater joined the informal discussions. Mr Hango was asked his opinion as a hydrologist of the flow patterns in and around Oshakati in recent years and allowed the team to see and photograph the spot satellite image of the 2011 flood at its peak (5 April 2011). He believes that although diverting future *efundja* around Oshakati will have local impacts, especially immediately south of the town and all along the proposed dike, where it is likely to alter flow, sedimentation and erosion, this is a relatively small proportion of the total flood waters of the Cuvelai and the impacts are unlikely to extend as far as the lake complex and definitely should not have any lasting impact on the Etosha Pan. There was concern that given the small difference in altitude between the town and the end of the dike (1.5m) the diverted water might accumulate and build up a sufficient head to flood back into the town especially if water levels in the Okatana River in town are already high when it is to channel storm water from the rest of the town during periods of high rainfall. Mr Hango was confident that this was unlikely.

APPENDIX 2 Species lists

A) Plants found in *iishana* and *endombe* by Clarke (1998)

Family/Order	Name
Charophyta	Nitella hyaline
Pteridophyta	
Marsileaceae	Marsilea nubica
Marsileaceae	Marsilea vera
Marsileaceae	Marsilea sp
Dicotyledonae	Angiospermae
Polygonaceae	Oxygonum alatum
Aizoaceae	Limeum viscose
Aizoaceae	Mollugo cerviana
Aizoaceae	Sesuvium sesuvioides
Portulacaceae	Portulaca collina

Amaranthaceae	Gomphrena celosioides
Nymphaeceae	Nymphaea nouchali var caerulea
Vahliaceae	Vahlia capensis subsp vulgaris
Fabaceae	Aeshynomene indica
Fabaceae	Indigofera charlieriana
Fabaceae	Neptunia oleracea
Fabaceae	Sesbania pachycarpa
Geraniaceae	Monsonia angustifolia
Euphorbiaceae	Chamaesyce prostrate
Elatinaceae	Bergia spathulata
Lythraceae	Ammania baccifera
Gentianaceae	Nymphoides indica
Rubiaceae	Kohautia aspera
Rubiaceae	Kohautia subverticillata
Convolvulaceae	Ipomoea aquatic
Boraginaceae	Heliotropium ovalifolium
Scrophulariaceae	Bacopa floribunda
Scrophulariaceae	Cycnium tubulosum
Scrophulariaceae	Lindernia parviflora
Acanthaceae	Blepharis sp
Acanthaceae	Hypoestes forskaolii
Lentibulariaceae	Utricularia stellaris
Asteraceae	Cotula anthemoides
Asteraceae	Dicoma anomola
Asteraceae	Eclipta prostrate
Asteraceae	Emilia ambifaria

Asteraceae	Epaltes gariepina
Asteraceae	Geigeria ornativa
Asteraceae	Hirpicium gorterioides
Asteraceae	Nicolasia costata
Asteraceae	Sphaeranthus peduncularis subsp rogersii
Asteraceae	Vernonia poskeana
Monocotyledonae	
Alismataceae	Burnatia enneandra
Hydrocharitaceae	Lagarosiphon cordofanus
Hydrocharitaceae	Ottelia exserta
Aponogetonaceae	Aponogeton junceus
Liliaceae	Camptorrhiza strumosa
Liliaceae	Dipcadi crispum
Liliaceae	Eriospermum rautanenii
Liliaceae	Ornithogalum rautanenii
Liliaceae	Scilla sp
Liliaceae	Trachyandra arvensis
Amaryllidaceae	Crinum rautanenianum
Commelinaceae	Commelina subulata
Eriocaulaceae	Eriocaulon cinereum
Poaceae	Andropogon eucomus
Poaceae	Aristida adscensionis
Poaceae	Aristida stipoides
Poaceae	Brachiaria deflexa
Poaceae	Brachiaria humidicola
Poaceae	Brachiaria schoenfelderi

Poaceae	Brachiaria xantholeuca
Poaceae	Dactyloctenium aegyptium
Poaceae	Digitaria milanjiana
Poaceae	Diplachne cuspidate
Poaceae	Diplachne fusca
Poaceae	Echinochloa colona
Poaceae	Echinochloa holubii
Poaceae	Echinochloa stagnina
Poaceae	Elytrophorus globularis
Poaceae	Eragrostis biflora
Poaceae	Eragrostis cylindriflora
Poaceae	Eragrostis gangetica
Poaceae	Eragrostis inamoena
Poaceae	Eragrostis lappula
Poaceae	Eragrostis membranacea
Poaceae	Eragrostis rotifer
Poaceae	Eragrostis viscose
Poaceae	Microchloa kunthii
Poaceae	Odyssea paucinervis
Poaceae	Oryza longistaminata
Poaceae	Oryzidium barnardii
Poaceae	Pogonarthria fleckii
Poaceae	Setaria pallide-fusca
Poaceae	Sporobolus coromandelianus
Poaceae	Sporobolus fimbriatus
Poaceae	Sporobolus ioclados

Poaceae	Sporobolus spicatus
Poaceae	Tragus racemosus
Poaceae	Urochloa brachyuran
Poaceae	Wilkommia sarmentosa
Lemnaceae	Lemna aequinoctialis
Cypercaeae	Abildgaardia sp
Cypercaeae	Bulbostylis hispidula
Cypercaeae	Bulbostylis sp
Cypercaeae	Courtoisia cyperoides
Cypercaeae	Cyperus articulatus
Cypercaeae	Cyperus compresseus
Cypercaeae	Cyperus difformis
Cypercaeae	Cyperus esculentus
Cypercaeae	Cyperus haspan
Cypercaeae	Cyperus imbricatus
Cypercaeae	Cyperus longus subsp tenuiflorus
Cypercaeae	Cyperus procerus
Cypercaeae	Cyperus schinzii
Cypercaeae	Cyperus sphaerospermus
Cypercaeae	Cyperus sp
Cypercaeae	Eleocharis atropurpurea
Cypercaeae	Eleocharis limosa
Cypercaeae	Fimbristylis complanta
Cypercaeae	Fuirena angolensis
Cypercaeae	Isolepis setacea

Cypercaeae	Kyllinga alba (Cyperus cristatus)
Cypercaeae	Kyllinga albiceps (C. merxmuelleri)
Cypercaeae	Lipocarpha hemisphearica
Cypercaeae	Mariscus aristatus
Cypercaeae	Pycreus chrysanthus
Cypercaeae	Pycreus macrostachyos
Cypercaeae	Pycreus pumilus
Cypercaeae	Rhynchospora holoschoenoides
Cypercaeae	Schoenoplectus corymbosus
Cypercaeae	Schoenoplectus erectus
Cypercaeae	Schoenoplectus maritimus
Cypercaeae	Schoenoplectus muricinux
Cypercaeae	Schoenoplectus roylei
Cypercaeae	Scleria foliosa
Cypercaeae	Volkiella disticha

B) Crustacea found in *iishana, endombe* and other Cuvelai water bodies by Clark (1998)

Habitat:	Oshana	Ondombe	Olushandja	Reservoir	Earth
			dam		canal
Class: Ostracoda					
Family: Cyprididae					
Plesiocypridopsis cf aldabrae	x				
Pseudocypris gibbera Sars 1924	x				
Sclerocypris dumonti	x				x

Martens 1988					
Sclerocypris exserta Sars 1924	x				
Class: Copepoda					
Order: Calanoida					
Family: Diaptomidae					
Lovenula falcifera (Loven 1845)	x	x		x	
Metadiaptomus colonialis (van Douwe 1914)	x				
Metadiaptomus meridianus (van Douwe 1912)	x	x			
Paradiaptomus schultzei van Douwe 1912	x				
Thermodiaptomus congruens (Sars 1927)	x	x	x		
Tropodiaptomus capriviensis Rayner 1994					x
Tropodiaptomus schmeili (Keifer 1926)	x				x
Order: Cyclopoida					
Family: Cyclopidae					
Mesocyclops major (Sars 1927)	x		x		x
Microcyclops inopinatus (Sars 1927)			x		
Microcyclops sp	x				
Thermocyclops emini (Mrazek 1895)	x				x
Thermocyclops sp	x				

Class: Branchiopoda					
Order: Anostraca					
Family: Branchipodidae					
Branchipodopsis cf wolfi Daday 1910	x				
Family: Streptocephalidae					
Streptocephalus indistinctus Barnard 1924	x	x			
Streptocephalus macrourus Daday 1907	x	x			
Streptocephalus ovamboensis Barnard 1924	x				
Streptocephalus proboscideus (Frauenfeld 1873)				x	
Streptocephalus cladophorus Barnard 1924				x	
Order: Notostraca					
Family: Triopsidae					
Triops granarius (Lucas 1864)	x	x			
Order: Conchostraca					
Family: Cyzicidae					
Caenestheriella australis (Loven 1847)	x	x			
Family: Cyclestheriidae					
Cyclestheria hislopi (Baird 1859)	x	x			x

Family: Leptestheriidae					
Leptestheria rubidgei (Baird 1862)	x				
Leptestheria striatoconcha Barnard 1924	x				
Family: Lynceidae					
Lynceus pachydactylus Barnard 1929	x				
Lynceus truncatus Barnard 1924					x
Habitat:	Oshana	Ondombe	Olushandja	Reservoir	Earth
			dam		canal
Order: Cladocera					
Family: Chydoridae					
Euryalona colleti Sars 1895	x	x			
Family: Daphniidae					
Ceriodaphnia rigaudi Richard 1894			x		
Daphnia barbata Welthner 1897	x	x	x		
Simocephalus capensis Sars 1895	x				
Simocephalus exspinosus (Koch 1841)		x			
Family: Macrothricidae					
Echinisca capensis Sars 1916		x			
Macrothrix propinqua	x				

Sars 1909					
Macrothrix spinosa King 1852	x				
Leydigia macrodonta Sars 1916	x	x			
Family: Moinidae					
Moina micrura Kurz 1874	x	x			x
Moina tenuicornis Sars 1896	x	x			
Moina sp			x		
Family: Sididae					
Diaphanosoma brachyurum (Lieven 1848)	x				
Diaphanosoma excisum Sars 1886			x		x

C) Bird counts done on Olushandja Dam 1995 – 1997 by Clarke and Roberts

Jan-95	Jan-97	Apr-97		Common Name	Scientific Name
0	1	1		Little Grebe	Tachybaptus ruficollis
4	3			Great White Pelican	Pelicanus onocrotalus
4	6	13		White-breasted Cormorant	Phalacrocorax carbo
13	5	1		Reed Cormorant	Phalacrocorax africanus
0	4	39		African Darter	Anhinga rufa
5	5	1		Grey Heron	Ardea cinerea
8	5	19		Purple Heron	Ardea purpurea
14	10	1		Great White Egret	Egretta alba
0	0	13		Intermediate Egret	Egretta intermedia
0	0	1		Green-backed Heron	Butorides striatus
0	9	0		Black Egret	Egretta ardesiaca
51	25	4		Little Egret	Egretta garzetta
8	19	480		Cattle Egret	Bubulcus ibis
9	6	3		Squacco Heron	Ardeola ralloides
118	35	0		African Spoonbill	Platalca alba
2	0	0		Greater Flamingo	Phoenocopterus ruber roseus
6	0	0		Lesser Flamingo	Phoenocopterus minor
0	3	0		Spur-winged Goose	Plectropterus gambensis
53	0	1		Egyptian Goose	Alopochen aegyptiacus
50	0	0		Red-billed Teal	Anas chrythrorhyncha
0	3	0		Hottentot Teal	Anas hottentota

7	1	0		Osprey	Pandion haliactus
6	3	1		African Fish Eagle	Haliaeetus vocifer
0	1	1		Black Crake	Amaurornis flavirostris
0	3	0		Moorhen	Gallinula chloropus
0	0	2		Purple Swamphen	Porphyrio porphyrio
50	0	0		Red-knobbed Coot	Fulica cristata
25	7	0		African Jacana	Actophilornis africana
1	0	0		Painted Snipe	Rostratula benghalensis
48	0	0		Black-winged Stilt	Himantopus himantopus
28	11	0		Blacksmith Plover	Vanellus armatus
0	0	6		Wattled Plover	Vanellus senegallus
82	18	0		Kittlitz's Sandplover	Charadrius pecuarius
0	1	0		Three-banded Plover	Charadrius tricollaris
8	0	0		Marsh Sandpiper	Tringa stagnatilis
84	2	0		Greenshank	Tringa nebularia
7	1	0		Wood Sandpiper	Tringa glarcola
0	1	0		Common Sandpiper	Actitis hypoleucos
29	3	0		Ruff	Philomachus pugnax
6	1	0		White-winged Black Tern	Chilidonias leucopterus
4	8	4		Pied Kingfisher	Ceryle rudis
0	3	0		Malachite Kingfisher	Alcedo cristata
0	0	118		Red Bishop	Euplectes orix
730	204	709		Number of Birds	
28	30	19		Number of Species	

	43			Total Species recorded	

APPENDIX 3: Field Notes

FIELD NOTES OSHIKATI FLOOD PREVENTION WETLAND AND FISH SURVEY:

24 – 29 JUNE 2012

A) FISH USE INTERVIEWS / SUMMARY OF RESPONSES

Interview 1 - 26 June Dike 5 – Okatana stream

7 in household, 3M, 4F ages 6-90, Income NDF and Pension – no household appliances.

2 ladies walking to Okatana, completed Grade 12, Dike site 5 Okatana stream,

Eat tinned fish, marine fish mostly and prefer fish to meat.

Catch fish using mosquito net for *eenhango* (small fish), baskets, and *oshongo* (push basket).

Best time to catch is in afternoons when water is getting low.

Use cleaned mussel shells (*onkosa*) to pour water to treat small children.

2010 was best year for fish, 2011 good but not better than 2010, 2012 not that high but plenty of *eenhangu* (small fish).

2010 + 2011 flood too high (family member drowned), High until June. 2012 flood low.

Government provided food after flood as little food from own crops, some people relocated,

This year food from own crops.

7. Did not know about proposed wall, no clear idea of it or likely impacts.

Interview 2 – 26 June Dike 3 – Entemba stream

11, 4M,7F, 9 months – 60 yrs, Pension and MP – no appliances near Ondjandja.

Man with traps across stream Completed Grade 10, at Dike site 3 – 26 June.

Mainly eat fish they catch themselves. Buy marine fish when iishana dry up, prefer fish to meat.

Catch fish Feb – Aug, use nets, hooks and *oshongo* + baskets. Catch enough to eat, when eaten, catch again.

2010 + 2011 a lot, 2012 less, daily catches decreased (number of fish caught per day).

2010 was best flood, 2011 + 2012 floods were high too, water depth up to neck height.

Food from GRN after floods only, "getting few months late" Not informed about wall.

Impacts likely to reduce fishing, goats may drown in channel north of proposed wall. Afraid people may not be able to cross to other side.

Care should be taken not to damage any houses during construction of wall, will need bridges to cross safely to shops and schools.

Interview 3 – 26 June Dike 4 – Entemba stream

8, 2M, 5F, 24 – 40, Income selling fish, one works, no appliances. 26 June.

Completed Grade 12, Dike site 4, Entemba stream – 2 ladies drying fish trap across stream.

Eat all kinds of fish, including those sold in shops, main daily diet is mostly fish they catch and dry or buy. Meat usually eaten after rainy season when fish is scarce.

Catch with nets and fish hooks, start catching at beginning of rainy season, March – June, depends on time of floods and flow. Fish throughout the day – no specific time.

2010 + 2011 had a lot of fish compared to 2012 mainly because of good rains.

Better floods in past years than this year due to poorer rain this year.

Government helped to relocate people, provided food only to people affected by floods, They have heard about the wall on the radio last year, but do not have a clear idea of how everything will work, Do not foresee any impacts of wall on fishing, except that people may need to be relocated, animals may drown, and drinking points may be disturbed.

Wall needs crossing points for people and animals, relocation should take care to relocate people closer to their old places.

Interview 4 – 28 June Dike 17 – Onendongo – rainwater pool

12, 2M, 10F, 2 months – 50 yrs, pension, no household appliances.

Elder, near Dike 17, 9 ladies harvesting sedge corms in wet sand at Onendongo, 28 June. Rainwater fed pool on higher "island" ground near large homestead.

Prefer flood fish but eat marine fish and meat when fish not available from iishana.

Fish with baskets, when they have time, from Feb to June.

A lot of fish in 2010 +2011. 2012 no fish in comparison.

2012 flood was less, our crops were not flooded at all.

Nothing, we were not even relocated, Had not heard about any wall at all.

It will affect crops and fishing, not ready to relocate, would not be able to collect eendago anymore.

Suggest the wall be built in the oshana and not near houses or in the village.

Interview 5 – 28 June – Kingfisher pool, oshana receiving canal water at end of siphon

29 dependents, 3 sisters + children, ages sisters 50 – 60 yrs, income: selling fish for mahangu

Lady fishing with funnel trap at Kingfisher pool behind airfield, no appliances. Come all the way from Onendongo to fish for a month, catch and dry fish to take home.

Yes eat fish and depend on fish sales for their livelihood.

Come once a year for up to 2 months, when water had dried near village they move to where water remains – even to Oponono and lakes.

2010 + 2011 fish were a lot, 2012 fish numbers went down.

2011 flood was too much, More than 2012, no need to move out of houses at all.

Sometimes received food from Government but not every rainy season, They depend on fish that depend on the floods for both selling and eating.

She lives far from where the wall will be but thinks that it might affect fishing on which she depends.

Depends on fish for her whole life and fears the wall would reduce fish numbers and so would be against it.

Interview 6 – 28 June, Kingfisher pool

7, 2M,5F, 1yr – 35, self employed selling fish, no appliances.

Man and wife who have house near Kingfisher pool, completed Grade 12, informed us that fish in pool come from Ruacana via canal.

Prefer fish to meat; the more the flood the more fish available.

Catch a lot, particularly Feb to June, every day for eating and selling.

2010 + 2011, fish numbers were very high 2012 they did not catch much fish.

2012 flood was less then recent years and did not destroy crops.

Government provided food for a few months after floods, but did not compensate for flood damage: Have not heard about any wall.

B) FISH SURVEY RESULTS – ACTUAL FISH CATCHES RECORDED AT EACH SITE SURVEYED IN JUNE 2012

Site 1 Monday 25 June End of Canal at siphon entrance under *Typha* wetland near NamWater.

In Oshakati. S 17 46 28.7 E 15 42 02

Gear	Species	Size range (cm)	Total no
D – net 10 scoops	T. sparrmanii	6	1
	B. poechii	6	2
	B. paludinosus	3 – 5	58

Site 2 Monday 25 June 'No fishing' pool Okatana Gravel pit 3 ha, 2m deep, gravel sand

N of Oshakati S17 23 59.8 E 15 42 35.2

Gear	Species	Size range (cm)	Total no
D-net 10 scoops	M. macrolepidotus	4-7	2
	C. gariepinus	26	1
	B. paludinosus	7 – 9	73
Seine net	M. macrolepidotus	6 – 12	7
	C. gariepinus	26 – 28	2
	B. paludinosus	7 – 9	8
	S. intermedius	10 – 14	4

Site 3 Tuesday 26 June Dike 4 Entembe stream (near man with traps). Very shallow slow flow

S 15 43 15.3 E 17 43 31.3 (pigs eating mussels)

Gear	Species	Size range (cm)	Total no
Seine net	O. andersonii	5 – 9	2

	P. philander	4 – 5	2
	B. poechii	7 – 10	5
	M. macrolepidotus	4 – 8	6
	B. paludinosus	4-5	4
D –net	O. andersonii	1	2
	B. paludinosus	1 – 3	9

Site 4 Dike 3 Tuesday 25 June Two ladies drying fish – sub sample of their catch of previous night in trap across shallow slow flowing stream. Total catch about 800 fish

Gear	Species	Size range (cm)	Total no
Trap across stream	P. philander	2 – 5	50
	B. paludinosus	2 – 6	39

Site 5 Tuesday 25 June, Dike 10 pool in large oshana west of Oshakati on main road to Oshikuku

Near Omugongo estate - Oshakati Oshana north of tar road 3 ha pool, 50m x 350 m, pond fished

S 15 40 0.2 E 17 45 51.2

Gear	Species	Size range (cm)	Total no
D- net 5 scoops	B. paludinosus	2 – 7	11
Seine net	B. paludinosus	3-8	31
	O. andersonii	9-11	4
	C. gariepinus	12 – 16	2

Site 6 Wednesday 26 June Lakes – Grandmother lake- Hinakulu Yomadhiya lake.

Gear	Species	Size range (cm)	Total no
D – net 50m walk	B. paludinosus	2 - 4	7
Seine net 30 m			
Catch A	B. paludinosus	4 - 7	5
	B. poechii	9	1
Catch B	B paludinosus	3 - 7	37

	B poechii	4 - 7	3
	O. andersonii	7 - 12	4
	P. philander	3	1
Catch C	B. paludinosus	3 - 5	8

<u>Site 7</u> Thursday 28 June – Deep pool en route to Dike 17 (lunch stop) Snake 1.6 km from Dike 17

S 17 50 18.1 E 15 41 05.8 on edge of large oshana west of Oshakati SW of airfield

Gear	Species	Size range (cm)	Total no
Seine net	T. sparrmanii	7 - 12	13
	O. andersonii	1 - 5	23
	C. gariepinus	12 - 30	20
	B. paludinosus	4 - 9	205
	B. poechii	8	1

<u>Site 8</u> Thursday 28 June – Kingfisher pool. Pond at causeway west of airfield Oshakati

1.2 m deep 30 x 25 m in size

Lady caught two catfish in funnel net in 5 min. Trap on opposite side of causeway

Gear	Species	Size range (cm)	Total no
Seine net			
Catch A	C. gariepinus	29	1
	B. radiatus	5 -6	19
	S. intermedius	10	1
	O. andersonii	6 - 10	4
	P. philander	3 -	
	M. macrolepidotus	7 - 10	6
	B. paludinosus	4 - 6	66
Catch B	P. castostoma	5-7	35
	B. radiatus	4-6	24 + 47
	O. andersonii	6 - 12	3
	P philander	4 - 5	2

	M macrolepidotus	8 - 11	62
	B. paludinosus	3 - 8	205
	B. poechii	5 - 10	20