# *"Good dredging practices" : the place of traditional eco-livelihood knowledge*

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# "Good dredging practices": the place of traditional eco-livelihood knowledge

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**Abstract**

Livelihoods of most residents of rural communities in developing countries are often dependent on surface water resources. The use and management of this vital resource should be as much as possible equitable for sustainable development to be achieved at local levels in these countries. Inland river dredging is a water resources management strategy usually aimed at improving water courses for navigation, land reclamation and or mitigate flood in the dredged catchment. Dredging operations like most development projects have impacts that are often localised, and benefits that could be local, regional or national. "Good dredging practices", GDP, in industrialised countries have been aimed at balancing national/regional economic benefits, technical feasibility and environmental protection. These practices rely heavily on the quality, and quantity of relevant base-line data available. In most developing countries there is a dearth of baseline data, and most often national/regional economic gains do not necessarily translate into local livelihood benefits. Hence, the basis of GDP should be extended to incorporate local livelihoods priorities, without ignoring the relevance of scientific data when it is available, the issue of technical feasibility, environmental sustainability and economic viability. This approach is relevant to the demand for equitable development in the developing world; could be used in conjunction with traditional eco-livelihoods knowledge (TELK) in developing or determining appropriate approaches for sustainable surface water resources management, as well as reducing environmental conflicts between stakeholders.

Key words: dredging; equity; livelihoods; sustainable development; traditional eco-livelihoods knowledge (TELK), "Good dredging practices" (GDP).

## 1.0 Introduction

Countries all over the world, industrialised and developing alike require programmes that have the potential of bringing about national/regional economic development. Enhancement of navigation channel, land reclamation and flood mitigation through inland river dredging has been an operation that could bring about regional/national economic growth, which makes it an issue of interest in water resources management if development projects are to be equitable to all stakeholders. Equitable development implies identifying ways in which localised impacts of development can be appropriately reduced or

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mitigated as well as enhancing the localised benefits of development projects; in essence such an approach encourages fair opportunities to access, use and preserve natural resources. Water resources play a key role in influencing population distribution and development of settlements, because of its inherent benefits to humans. The structural modification of river courses by dredging has both benefits and costs (some of which have long-term impacts), which are usually not equitably distributed particularly in most rural areas of the developing world. The adverse impacts of inland dredging operations are often localised and in most situations borne by the rural populace whose livelihoods are dependent on the surface water resources. Equity should be an integral component of sustainable development (United Nations, 2002). Therefore, the benefits of planning development projects aimed at achieving intra-generational equity have the potential of reducing conflicts between stakeholders, as well as favours incorporating mitigation options that can reduce the adverse consequences of development.

National economic growth does not necessarily result in equitable development. Economic growth may result in profits for a company or government, and it may generate some jobs, but that alone is not sufficient for furthering development, because it does not necessarily imply poverty alleviation in the developing world (FoE, 2000). Obviously, Friends of the Earth is not an impartial source but there is a wealth of academic literature that has buttressed the above statement. For example, some research by the World Bank acknowledges that economic growth and poverty alleviation are not necessarily linked. In a study of its lending in the poorest countries, the Bank acknowledges that poverty rates increased between 1987 and 1993 from 29% to 33% in spite of increased economic growth rate (World Bank, 1997).

Furthermore, prior to the early 1970s, the Swampy Cree community of Southern Indian depended on commercial fishery. In 1970, the outflow of the lake was dammed, raising the water level by several metres and the original location of the community is now submerged. Commercial fishery was adversely affected and there has been low fish catches. The community was relocated to a place with modern houses and a recreational complex and the constructed brought about national economic benefits. However, the recreational facilities developed to mitigate the localised impacts of the dam do not seem to have replaced fishing, trapping, and hunting as a centrepiece for these people's lives. Poverty, depression, and alcohol abuse have resulted (Rosenberg, *et al.* 1995). Similarly, despite the fact that petroleum contributes over 90% of Nigeria’s foreign earnings, the Niger Delta that bears this vital resource is the most improvised, underdeveloped and has the highest unemployment rate in Nigeria. The situation in the Niger Delta has given rise to agitation for a fair share of the benefits from petroleum resources to the people of the Niger Delta. Perhaps one of the reasons why current development paradigms have failed to meet the tenets of sustainable development is that the current approaches are not holistic (Orr, *et al.* 2008).

Therefore national economic development alone is not a sufficient end goal for delivering development that is equitable (WCED, 1987; FoE, 2000). This calls for “Good dredging practices” (GDP), in developing countries that could facilitate the equitable distribution of the benefits and costs of dredging among the stakeholders. Hence, it is necessary that GDP be developed that are appropriate to the developmental aspirations and livelihoods situations in the developing world rather than GDP focused primarily on balancing environmental impacts, technical efficiency and economic benefits. Such an approach requires the collection of relevant information / data that take local livelihood priorities into consideration in the planning and management of dredging operations.

GDP are approaches aimed at making dredging less detrimental to the environment as well as optimising the benefits from dredging operations. The justification for advocating good dredging in industrialised countries has been for optimising a balance between potential national/regional economic growth, technical feasibility and environmental protection (CIRIA, 1997; Bray, 1998; Reine and Clark, 1998; Riddell, 2000; Vellinga, 2002; WODA, 2004). “Hard science” information concerning rates of siltation, sediment characteristics, hydrological characteristics, riparian components and ecosystem structure have been used in determining good dredging practices in industrialised countries.

The inadequacy or unavailability of baseline data (Long term scientific data and comprehensive information) in most developing countries could be one of the constraints to achieving GDP as currently practised in industrialised countries. Despite the constraints of inadequacy or absence of baseline data, it will be feasible to achieve GDP in the developing world if an integrated approach is adopted in the planning of dredging projects. The integrated approach advocated by WODA (2004), canvasses the need for open lines of communication between all stakeholders, which take into consideration the full range of environmental, technical and economic issues related to the project and proposed dredged catchment. WODA’s integrated approach also encourages the exploration of the knowledge of different stakeholders. This therefore calls for a paradigm shift and basis for the planning and execution of dredging projects in the developing world. Such an approach should be appropriate to localised livelihoods priorities, ensure that as much as practicable relevant data collection approaches are explored.

Historically livelihood issues, traditional knowledge (TK) and traditional eco-livelihoods knowledge (TELK) are often ignored during baseline data collection and in determining GDP. TK is a form of logical, systemic and reliable knowledge gained through residency and intimate contact by local residents peoples with their environment, and are inter- and intra-generationally exchanged and shared (Gadgil and Berkes, 1991; Gadgil and Berkes, 1993; Nabhan, 1997; UNEP, 1998; Ferbadez-Gimenez, 2000; Huntington, 2000; Olsson and Folke, 2001). TK is synonymous with local knowledge, which is simply an experiential knowledge about a geographic area gained by residency. Generally, TELK refers to the long standing experience, understanding and knowledge of people about their local environment, which have been used to earn or win livelihoods. However, livelihoods issues and TELK have been perceived not to have a place in water resources management based on “hard science”. This calls for the introduction of survey approach(es) that allows for rapid data gathering, analysis and interpretation that explores TELK, and that is/are relevant to livelihoods most residents of rural communities of developing countries. Some of the approaches that have been successfully used for capturing and documenting TK, TEK as well as TELK are: questionnaire survey; participatory observation; focus group discussions; workshops; interviews; and documentary evidences.

This paper is aimed at advocating that there is need to explore the TELK in planning for sustainable development if GDP are to be achieved in developing countries and under similar circumstances. Such an approach should ensure that livelihoods priorities and TELK of those potentially at risk of the impacts of dredging in these countries are taken into consideration when designing and implementing inland river dredging projects where and whenever baseline data are unavailable or inadequate and particularly where surface water resources plays a key role in sustaining local livelihoods.

## 2.0 Livelihoods and water resources

Historically and to date, rivers offer routes for navigation and river fishery (Gore and Petts, 1989), while river modifications have served as the bases for socio-economic development (CEDA, 1999; Stolpe, 2001). The importance of aquatic resources to the rural people of the developing world is very clear, because these systems provide drinking water, hydroelectric power, water for irrigation, and fishery (Crisman, *et al.* 2003). The importance of surface water resources can be linked to the crucial role it plays in rural livelihoods as well as in the national economy. Livelihoods are the means or processes by which people earn a living.

There is increasing societal demands on the services that rivers provide for both residents of rural communities whose livelihoods depend on this resource and for national/regional economic benefits. Surface water resource is a vital common pool resource (CPR) in most rural communities in the developing world. These resources have significantly contributed to the income and offer some cushioning to the residents of rural communities, particularly during periods of economic stress in several direct and indirect ways of residents of rural areas of the developing world. Such contribution of CPRs depends on the availability and quality of these resources and their importance varies from region to region and from social group to social group (Jodha, 1990; World Bank, 1999; Adolph, *et al.* 2001; Anwar, *et al.* 2001; Osman, *et al.* 2001). Approximately 95% of those involved in agriculture are inhabitants of rural communities in developing countries (Castillo, 2000). The Ecosystem management approach is one developing strategy that is aimed at achieving long-term ecosystem protection and sustainability by integrating social, biological and natural dimensions (Pavlikakis and Tsihrintzis, 2000). Hence, the integration of research techniques that has been successfully used in natural and social sciences into water resources management could be an option for sustainable water resources management (Mylopoulos, *et al.*

2008). Any attempt to generate effective solutions for today's environmental problems will benefit from the inclusion of TK in the creation of a fully integrated systems model, from which integrated solutions can be found (Sullivan and Meigh, 2007). Therefore, the inclusion of livelihoods priorities of residents of rural communities in the developing world could be an essential prerequisite for equitable development.

The anthropogenic effects of dredging on surface water resources still remain very qualitative and descriptive, due to the complexity of ecological systems and the absence or inadequacy of baseline data in most sub-Saharan countries. However, there exists a rich TELK base of local/indigenous/rural people, which offers historical, seasonal, spatial and temporal eco-livelihoods information. Nevertheless, TELK still remains understudied, under-documented and highly descriptive, which offers an area to be exploited for sustainable inland river dredging, as well as other water resources management approaches.

## 3.0 Dredging and habitat readjustment

River modification dates back from the earliest days of human settlement along rivers and on the floodplains of the Nile, the River Niger, the Mississippi and other large rivers in the USA, The River Trent and other large rivers in the UK, the Burnaby Lake Canada, Indus, the Mesopotamian rivers, and human occupation and settlement on floodplains has increased steadily throughout history (Brookes, 1988; Environment Canada, 1997b; Abam, 2001; Environment Agency, 2005). About 2.5 km of the riverbed stretching from Asamabiri to Agbere-Odoni of the River Nun was dredged in the late 1990s and between the 1980 and 1988 over 30 km of canal networks has been created as a result of dredging in the Niger Delta (Abam, 2001). Similarly, 4.5 km of the Boro River, Okavango Delta, Botswana was dredged between June 1971 and December 1974 (Lubke, *et al.* 1984). There are however, no comprehensive database that contains statistics of dredged rivers or catchments, despite the increasing demand of dredging in industrialised and developing countries.

Appropriately designed studies to assess the impact of dredging are very limited. Until adequate and appropriate data are available, assessment of potential impacts associated with dredging would unfortunately remain subjective, because of the lack of relevant quantitative data (Clarke and Wilber, 2000). Dredging and disposal of dredged material constitute environmental impacts (Bray, *et al.* 1998), however, under the right circumstances, dredging could be necessary for development, despite the very long periods required for significant natural habitat readjustment to occur post-dredging.

Despite readjustment the recover may be long term and the system may not return to its formal status. Hence, care should be taken be when designing or planning dredging operations so that the impacts on localised livelihoods should be dully incorporated.

### 3.1 Natural habitat recovery / re-adjustment

Streams and rivers have considerable natural recovery powers (Swales, 1989). McCauley (1977), proposed that the term "recovery" is not scientifically appropriate when studying re-colonisation processes after cessation of dredging. This is based on the premise that "recovery'" implies a return to prior ecological abundance levels and pathways, which may have taken years to develop and attain, and cannot be reversed.

Changes induced by dredging may significantly alter the pre-dredging ecological status; even if the resulting aquatic biota return to its pre-dredging species abundance and diversity state, it may never return to its pre-dredging structure and internal integrity. Therefore, the term re-adjustment has been used in this paper in preference to "recovery". However, in some cases recovery has been used for specific reference to research outcomes by other researchers, for the purpose of not losing the information from these publications.

A study by Ellery and McCarthy (1994), shows that very little natural 'recovery' of the Okavango Delta floodplain, following the dredging of the Boro channel has taken place after two decades. Similarly, the ecological conditions of the Niger Delta are continuously adjusting to the changing patterns of discharge that has resulted due to dredging (Abam, 2001).

Most of the existing literatures on natural recovery of dredged inland rivers have been focused on fishery resources. Table 1 shows a summary of research outcome on the degree of re-adjustment that has been attained after channel modification (Brookes, 1988). From this summary, it could be inferred that there is yet to be complete ecological re-adjustment even 86 years post-modification. In the author's opinion, such long recovery or ecological re-adjustment periods after river modification imply a significant long-term impact on livelihoods. This is especially likely in rural riverine communities such as in rural communities of developing where residents depend on subsistence fisheries as a major source of their livelihood and primary source of protein in their diet.

**Table 1 Summary of recovery periods after channelisation**

| River | Time elapsed since channel modification | Observation |
|---|---|---|
| Yankee Fork, Idaho | 30 years | 3% reduction in the productivity of bio-diversity compared to non-channelised sections of the same stream |
| North Carolina | 40 years | 20% difference in fish populations compared to non-channelised sections. |
| Blackwater River, Missouri | 50 years | 23% difference in fish population compared to unaltered rivers |
| Portneuf River, Idaho | 86 years | 17% reduction in fish population compared to unaltered river section |

(Brookes, 1988) pp 140

"Recovery" of fish populations is longer compared to invertebrates. This is probably attributable to the relatively longer generation time of fish, their diverse habitat requirement and their large scale distribution. The result of a number of studies suggests that in many cases, fish populations may never completely "recover" without some form of mitigation being undertaken (Swales, 1989). Such long "recovery" periods after river modification, implies significant long-term livelihoods consequences.

The shallow sub-tidal macrobenthos at Port Valdez, Alaska, was examined to assess faunal adjustment following disposal of dredged sediments over a three-year period. Prior to sediment disposal, resident fauna consisted of a relatively highly diverse species assemblage dominated by sessile polychaetes and bivalves. Six months after the disposal of dredged material, virtually all taxa present prior to the dredging operations became rare or absent while opportunistic taxa became dominant. Surveys performed eighteen months after sediment disposal indicated faunal re-adjustment was in progress; large, sessile polychaetes and bivalves were still present in low numbers after two and half years. The composition of a re-adjusted benthic community is influenced by the timing and severity of disturbance as well as by the reproductive biology and motility of the resident fauna (Blanchard and Feder, 2003). Under the right circumstances, dredging may play a useful role in human developmental aspirations. However, the negative impacts of dredging are most often localised (Bray, *et al.* 1998). Therefore, the identification and determination of dredging consequences should transcend technical, economic and environmental indicators; and should go further to address the issue localised livelihoods status that may be compromised by dredging projects.

## 4.0 Baseline data and good dredging practices

Historically, the primary objective of dredging practices was to meet the target of technical efficiency of dredging operations and economic benefits with little regard to the environment. GDP are aimed at reducing the potential adverse effects of development projects on the environment as well as optimising the benefits from these operations (NRA, 1994; UK Marine, 2002a; UK Marine, 2002b). However, a precautionary approach should be considered in cases where adverse effects have been anticipated, to reduce or mitigate the environmental consequences of dredging operations.

Human welfare is continuously dependent on sustainable and equitable management of water resources and its watershed. Sustainable water resources management entails good practices aimed at reducing the likely adverse effect of river modification could have on the environment, and optimising the economic benefits from these operations (NRA, 1994).

GDP, generally rely on the quality and quantity of baseline data available. For example, the level of suspended solids in freshwater has been recommended by (Environment Canada, 1997a), not to exceed more than 10% of the pre-dredging concentrations, and not more than 30% of the benthic population to be removed during dredging operations. For these requirements to be met there must be pre-dredging data on suspended solid concentration, abundance and distribution of benthic organisms in the dredged catchments as well as data of other aquatic biota. However, the knowledge base of African rivers is presently highly localised, inadequate and sometimes unavailable. This implies that data needed for formulations of appropriate water resources management strategies are also largely absent in many Africa countries. Furthermore, the present lack of systematic study and lack of a core body of reference information of African rivers is a serious constraint to assessing anthropogenic impacts on African rivers (Crisman, *et al.* 2003), as well as developing appropriate water resources management approaches.

Even in the USA where substantial dredging projects are annually executed, there is a paucity of data in most regions. Inherent difficulty in accurate sampling of biological resources during large-scale dredging projects has been a major logistical factor responsible for the dearth of ecological data in some regions in the USA (Ault, *et al.* 1998).

### 4.1 The concept and relevance of GDP

The realisation that the aquatic biota of rivers has been adversely altered has resulted in a greater concern for ecologically sound river management. Much has been written about the ecological changes that have resulted from river regulation. However, given appropriate management approaches, both economic and environmental management goals can be simultaneously pursued within the context of sustainable development (Gore and Petts, 1989). However, such sound appropriate management approaches should extend beyond economic and environmental goals, and should take localised livelihoods priorities in rural communities in the developing world into consideration. The integration of livelihoods priorities into sound management approaches could make the benefits of development more equitably distributed across all stakeholders. In the context of this paper such sound management approaches have been termed GDP.

The dredging industry in industrialised countries has been affected by two major but often opposed factors; market and the environment. The changes and development of dredger types over the past 20 years have been market driven (Bray, 1998). Environmental protection has also been one of the emerging criteria influencing the selection of dredgers. However, in developing countries, selection of dredging technique without regard to local livelihoods priorities could fail the test for equitable development. Generally government and river authorities are responsible for making decisions on dredging projects, while environmental assessment are often contracted to private environmental consultants but often supervised by the governments department or ministry of environment. A typical case is the contract that has been awarded for dredging the lower Niger Delta, Nigeria (PTF, 1999). Local communities are generally not represented in the decision making process but usually have opportunities of making comments on the environmental impact assessment (EIA) report of the proposed dredging project that are often ignored.

### *4.1.1 Optimum dredging Intervals*

The determination of optimum technical targets is important during the planning of dredging works. Such as the difference between the maximum and minimum acceptable bed levels of aquatic waterways, when divided by the average annual rate of loss of depth due to siltation, will give the optimum interval between dredging campaigns. This may be very variable, especially in water courses which receive substantial sediment input following heavy rainfall or where sediment deposition is relatively localised (CIRIA, 1997). This implies that the optimum interval between maintenance dredging is dependent on local site conditions, hence catchment should be separately assessed to determine the most appropriate interval between maintenance dredging campaigns.

In the developing world, a possible option to determining optimum dredging intervals, to identifying operational efficiency (economic and technical) and local eco-livelihood situations and the localised use of the proposed dredged surface water catchments. Information, such as localised livelihood significance of the proposed dredged river sections could be accessed by exploring TELK of people residents along the local catchments which could help determine appropriate dredging intervals.

### *4.1.2 Environmental Windows*

The temporal constraints placed on dredging or dredged material disposal for the purpose of protecting biotic resources or their habitats is termed Environmental Windows. Environmental Windows are usually based on the logic that potential detrimental effects can be avoided by preventing dredging or disposal during times when biological resources are most abundant or most sensitive to disturbance (Dickerson, *et al.* 1998). Window periods differ by region and population type, but are formulated to coincide with times when dredging activities are least likely to adversely affect the aquatic biotic community of interest.

For several decades in the USA, there have been routine requests that various aspect of dredging projects be restricted to specified time periods known as Environmental Windows (Reine, *et al.* 1998). Whenever possible in the UK, dredging is planned to minimise adverse impact on the local environment, such as the avoidance of the nesting season of waterfowl, or the growing season of arable crops (CIRIA, 1997). Table 2 contain a summary of sensitive periods in the UK that has determined the restriction of development activities that could adversely impact on aquatic biota.

In the USA, the majority of Environmental Windows constrain dredging operations during spring and summer months (March – September) to avoid potential conflicts with biological activities such as migration, spawning, and nesting. Consequently, many dredging projects in the USA have been restricted to winter months (Reine, *et al.* 1998; Aldridge, 2000).

For appropriate Environmental Windows of sites to be established, the spawning grounds and periods of sensitive biological activity of ecological components at risk should be determined, as well as migratory periods and pattern. Environmental Windows has been aimed at ensuring that valuable natural resources receive adequate protection. In rural communities in developing countries, aquatic biota and surface water resources are usually of livelihood significance such as for fisheries, irrigation, drinking and domestic purposes.

**Table 2 Examples of sensitive periods for aquatic biota in the UK**

| Type of organisms | Sensitive stage in life cycle | Period |
|---|---|---|
| Benthic animals | Spawning. | Spring. |
| | Highest growth rates (shellfish). | Early summer (May-July). |
| | Highest number of eggs and larvae stages (shellfish). | Early summer (March-July). |
| Fish | Migration of salmon and sea trout young (smolt) from rivers to the sea. | Spring and early summer. |
| | Highest numbers of eggs and larval stages. | Early summer. |
| Microalgae (Phytoplankton) | Highest growth rates (highest potential for algal bloom formation). | Between April and July. |
| Seals | Breeding. | Summer. |

(UK Marine, 2002c).

The determination of Environmental Windows in the developing world should take this important socio-economic dimension into consideration so that dredging as a development project would be of less adverse impacts on those directly dependent on ecological resources for their livelihoods. Therefore, there is the need for the application of Environmental Windows in the execution of dredging projects that avoids the destruction of fishing grounds or access to project sites that could adversely impacts on rich agricultural lands in areas where farming and fishing represent a major livelihood source.

### *4.1.3 Selection of dredging technique*

Appropriate dredging techniques could optimise the benefits from projects as well as minimise environmental impacts. Factors that are usually considered for the selection of appropriate options in the UK are: task definition; access; vegetation cover; season; quantities and sediment characteristics; disposal; security of machinery during dredging; and environmental issues. However, no dredging technique is appropriate for all situations, and time of proposed dredging is a determinant of the most appropriate technique that should be used (CIRIA, 1997). In the developing world, the determination of appropriate dredging technique should transcend economic priorities and environmental protection, because dredging has been associated with impacts on localised livelihoods particularly in rural communities. The above statement implies that the selection of dredging technique for equitable development should include taking localised livelihoods priorities such as agricultural land and fishing patterns into consideration in the developing world.

#### *4.1.4 Alternate dredging*

Enlargement of channels by modifying only one bank while leaving the opposite bank almost entirely untouched, is a common practice in many industrialised countries (Dickerson, *et al.* 1998). Adverse environmental consequences could be minimised by dredging river banks alternatively and allowing the re-vegetation of disturbed areas before any maintenance dredging is done.

If dredging operations are alternated from one bank to the other, the aesthetic appearance may be improved and impacts on sensitive habitats can be avoided. Retention of tall vegetation will shade out aquatic vegetation and thereby reduce maintenance costs. If the channel is widened, then clearly all vegetation on the working bank will be lost. However, where widening is not significant, it is beneficial to retain as much vegetation as practicable on the modified side. Damage can be minimised by using small equipment and by revegetating impacted areas (Brookes, *et al.* 1989).

Inland river dredging carried out alternatively allows for faster habitat re-adjustment, without adversely affecting local ecosystem and livelihoods dependent on such ecological systems. Alternate dredging could be explored to avoid the adverse destruction of fishing grounds and rich agricultural lands in areas where these ecological resources are of livelihoods significance. This approach if appropriately implemented could favour sustainable livelihood particularly in rural communities in developing countries, as well as enhance natural ecological re-adjustment.

#### *4.1.5 Dredge material treatment and disposal*

The disposal of dredged material is a technically more challenging and expensive task than the dredging process. Whenever appropriate, treatment and disposal must be considered simultaneously if acceptable good approaches are to be implemented. For example, if dredging is by floating cutter suction dredger, which discharges via a pipeline, then the operations of dredging and disposal are a single continuous process, which must be considered as such (CIRIA, 1997)

Materials arising from the inland river dredging are most commonly disposed of by spreading on the adjacent bank, or on adjoining agricultural land. Therefore, in situation where important species are present or in large numbers, the “rinsing” dredged materials has been carried out before disposal on the river bank. For example dredging beds of reed sweet-grass from the River Beane in Hertfordshire, UK, by using the “rinsing” technique resulted in a 40% reduction in the number of crayfish being removed (RSPB, 1995).

Furthermore, in the UK, the use of dredged materials for construction purposes has been illustrated by beneficial use schemes undertaken by the Port of Truro in the Fal and Helford rivers, in the county of Cornwall UK. The feasibility of mixing de-watered dredged material with china clay waste sands and other waste substances for composting to cap derelict land on two sites of former arsenic works has been investigated. Vegetation became established at both sites where no plants had grown before the placement of dredged material (Brigden, 1996).

Appropriate treatment and disposal of dredged material that takes localised livelihoods situation in rural communities of the developing world into consideration could reduce the impacts of dredging on ecological resources that are of localised livelihoods significance. A typical example of such good practice is the use of dredged materials in coastal fishing communities in the Niger Delta to support farming, because dredged materials has been found to support a wide range of agricultural crops. In addition, canal backfilling with dredged materials has been variously tested and found to be effective in mitigating dredged material impacts and wetland loss, as this has encouraged natural mangrove restoration in the Niger Delta (Ohimain, 2004).

There are no universal treatment methods that would be appropriate for all situations. The quality of the dredged material, the value of the proposed disposal sites or its surrounding and the potential or anticipated use of the dredged spoils have conventionally determined the most appropriate treatment and disposal methods for dredged material. Therefore, treatment and disposal option of dredged material should be considered before dredging sites, dredging seasons, or the selection of appropriate dredging techniques. In developing countries, major farm crops, and localised livelihoods sustenance are major priorities that should be taken into consideration during the planning of dredging projects and disposal of dredgeates.

### *4.1.6 Channel maintenance and mitigation*

Habitat protection or enhancement is likely to be a more successful mitigation measure than species introduction, which would depend on the precise habitat being available (RSPB, 1995). Channel mitigation measures have been effective in providing fish habitat comparable to the unaltered sections (Brookes, *et al.* 1989). Maintaining natural river courses by appropriate designs has given rise to the preservation of the natural biotic community of dredged rivers with minimal effect on the biota.

Habitat lost or degraded through channelisation can be restored and rehabilitated using habitat improvement techniques. Mitigation through habitat protection and restoration has gained much wider acceptance, while traditional forms of river channelisation are increasingly being replaced by alternative approaches, such as stream renovation, which aim to harmonise the priorities of river communities with the use for other purposes (Swales, 1989).

Enhancement may not be connected to environmental mitigation, but may be provided to please a local community that have permitted a development to take place for the benefit of the region, but are not going to benefit much from it themselves. When a fishing area is affected by dredging and a significant drop in the value of future catches is predicted. Monetary compensation could be given to fishermen who use the affected area to earn their livelihoods (Bray, *et al.* 1998).

Mitigation attempts to reduce the adverse impacts of dredging on those most vulnerable to alterations of local ecological systems. The participation and use of the TELK of fishermen and women and those whose livelihoods are affected by dredging projects in the evaluation and mitigation process could make this strategy more effective in reducing inequity associated with the impacts of dredging, particularly in rural communities in developing countries.

## 5.0 TELK and good dredging practices

The destruction of local environmental resources may have adversely affected local culture and livelihood. Presently, development strategies such as inland river dredging have been driven by market economies that most often favour national and regional economic growth at the expense of local livelihood (Turner, *et al.* 2000). However, most of the world's biodiversity occurs on or adjacent to traditional indigenous territories (Nabhan, 1997), from which some of these local and rural people earn their livelihood (Tamuno, *et al.* 2003). It is very unfortunate that the concerns, experience and knowledge of local and rural peoples have often been ignored in the formulation of environmental and water resource policy; rather most development policies and projects has solely relied on data from "hard science".

TK is similar to western science because it is knowledge that is acquired by local people through observation, the accumulation of experiences and informal experiments, and through an intimate understanding of the environment in a given socio-geographical context (Warren and Rajasekaran, 1993; Berkes, *et al.* 2000). However, TK is different from science because science is perceived to be concrete, while TK abstract (Berkes, *et al.* 2000).

TK is a concept that describe knowledge specific to a geographical location or society (Warren and Rajasekaran, 1993). TK is generally much more than information which people have about their local environment. TK is an established body of knowledge about life and living close to nature and interdependence on the environment (Bielawski, 1992). The documentation of TK has not in most cases been fragmented rather than holistic.

TK is non-documented, primarily entails qualitative observations, and it is based on oral tradition. Gathering information about the local socio-political, economic and ecological information can best be accomplished through involving people and participatory observation (Johnson, 2003). In the words of Forrest (2000), "*aboriginal knowledge is not learnt from a book; it is oral and it is passed on; it is about feeling and it is about studying and it is about learning from each other*". Furthermore, the understanding of how local people perceive societal issues is a crucial element in the design of projects aimed at encouraging and supporting community-based management regimes that supports sustenance of rural livelihoods as well as protection of the ecological resources on which these people depends for their livelihoods (Quinn, *et al.* 2003).

Huntington (2000), reported that the knowledge and insights of local people that they have acquired through experience has been successfully used to understand and predict environmental events upon which localised livelihood depends and have been adapted for centuries for survival in marginal areas. Interest in TK has been growing since the early 1990s, partly in recognition that such knowledge can contribute to the conservation of biodiversity, rare species, and ecological processes (Gadgil, *et al.* 1993; Berkes, *et al.* 2000). Although the value of TK in scientific research, environmental assessment, and conservation monitoring has become more apparent and accepted, wider application of TK-derived information is still perceived to be elusive (Huntington, 2000).

TELK is a blend of knowledge generated locally through practice and experience, and external source of knowledge, such as scientific knowledge and or knowledge from other geographical location (Tengö and Belfrage, 2004). The experiences, skills and locally adapted knowledge acquired by professionals such as fishermen, hunters and farmers that have been acquired by living in close contact with the environment have been used for livelihood sustenance. Such knowledge should be explored in planning for sustainable development.

Baseline data (long-term scientific information) are highly desirable but often lacking or inadequate in most developing countries is inadequate and in most cases unavailable (Agarwal, 1997; Terano, *et al.* 1997; Kwak, *et al.* 2002; Coates, *et al.* 2003; Tamuno, 2006). There is therefore the need to develop and use appropriate methods for determining environmental baselines, as well as better approaches of sharing and disseminating research results. Therefore, carefully documented basic studies are needed for evaluating anthropogenic impacts on terrestrial and aquatic ecosystems (Landers, *et al.* 1995). In Indonesia, rapid rural appraisals have been used to gather information about local land and fire use over time, recent fire patterns and their underlying causes, major developments, ecological conditions, and livelihood sources. These information have been accessed from interviewees in all the villages that participated in the study (Chohhalingam, *et al.* 2005). Similarly, qualitative and semi-structured interviews have been used in Belize to provide detailed accounts of change in fishery, as well as used in understanding major past events that may have affected fishery resources (Huitric, *et al.* 2005).

Statistical tests have been used in Mexico to analyze the responses from sample communities, in the study using ethno-botanical assessment of the effect of changes in mangrove forest in the Navachiste-San Ignacio-Macapule lagoon complex, Sinaloa. The result shows that 72% of interviewees have a very good knowledge of mangrove forest, which has been used as a basis for mangrove forest evaluation and management (Hernández-Cornejo, *et al.* 2005). Similarly, the people of the Bulamogi communities, Uganda, have good knowledge about cattle diseases and their treatment. 33 different cattle diseases have been identified by the Bulamogi people, of these, the people can successfully locally treat 9 of these diseases as well as improve lactation in cattle by the use of herbal plants (Tabuti, *et al.* 2003). Local knowledge has been identified as a significant contribution to increased understanding of ecosystems (Coates, *et al.* 2003). TELK of residents of rural communities in the Central Niger Delta have been used to understand the coping strategies of residents of the Niger floodplains (Tamuno, 2001); as well as used to develop a resultant vulnerability matrix for the Central Niger Delta, which has a place in planning for development that is equitable in rural communities on a floodplain (Tamuno, et al. 2003). Similarly, the TELK of residents of the Kolo and Otuoke Creeks have been used in determining the ecological impacts of inland river dredging that are of livelihoods significance, and have been used to identify the season of the year in which inland river dredging could be executed with minimal eco-livelihoods consequences (Tamuno, 2006).

In addition to providing important information that have helped to increase the relevance of scientific research, the use of TK has facilitated developing environmental policies in Canada that recognise and incorporate cultural values. Moreover, the use of TK in scientific investigations gives local stakeholders an opportunity to be members of a team responsible for addressing shared conservation objectives. Such an approach is generally more productive than the sole use of scientific studies (Gilchrist, *et al.* 2005). Similarly, in India, the chances for success of water harvesting have been greater whenever scientific knowledge is integrated with TK (Machiwal, *et al.* 2004).

Exploring TK and TELK in planning dredging in the developing world for equitable development entails involving those most at risk of the detrimental impacts of dredging. Such involvement could lead to implementing GDP that would reduce as much as possible the localised ecological and livelihoods consequences of dredging projects. Information or data alone cannot make dredging equitable but the appropriate use of such information or data could result in GDP that are relevant to residents of rural communities in developing countries. There are however, constraints to accessing and applying TK, or TELK in environmental management for equitable development because of divergent priorities (which may be contrasting) among holders of this type of knowledge. Such a limitation can be surmounted by involving more of the target population through stratified sampling as well as statistically representation of the results of such consultation in the light of existing scientific understanding as well as knowledge from similar or other related geographical locations. However, the main constraints to public participation at the local level are: overlapping or unclear jurisdictions led to distinct actions lacking integrating approach; lack of synergy and an unclear division of responsibility among the different institutions often exacerbates these problems and inhibits reforms from reaching the local level (Mylopoulos *et al.*, 2008). Moreover, the difficulty in establishing a universal approach to capturing and codifying TK, as well as the varying service value local people place on natural resources are major constraints to the use of TK in planning for sustainable development.

## 6.0 Conclusion

GDP as practiced in the industrialised countries, have been aimed at balancing national/regional economic growth and sustainable environment that has relied on the availability and quality of baseline data. The GDP reviewed in this paper attempt to reduce the environmental consequences of dredging as well as maximising the economic gains from dredging operations, hence have a place in water resources management in developing countries for sustainable development.

The need for baseline data in determining GDP as well as the cost associated with obtaining this scientific information cannot be overemphasised. However, the absence or inadequacy of baseline data requires approaches to accessing relevant historical and seasonal environmental information. The use of the TELK available in most rural communities in the developing world could be a very appropriate option to identifying and developing cost-effective and livelihoods sensitive dredging approaches that could make dredging more equitable particularly to those whose livelihoods are at risk of the localised consequences of dredging projects. Nevertheless, TELK should be critically scrutinised, used in conjunction with available scientific data and applied in planning for GDP in situations that TELK can enhance the achievement of sustainable development that is equitable.

The focus, therefore, of GDP, in developing countries, should be aimed at optimising the balance between national/regional economic growth and the enhancement of livelihoods of those vulnerable to the potential impacts of dredging. This focus does not in any way imply that environmental protection is not relevant to sustainable development in developing countries. It does however; advocate that localised livelihood priority should be taken into consideration if GDP is to become relevant to those residing along dredged or proposed dredged river catchments. There is also an urgent need for developing countries to develop appropriate database on aquatic biota, which could also be used for planning for equitable development and for sustainable water resources management.

GDP are achievable in developing countries irrespective of the fact that there is dearth of “hard science” data, if TELK is appropriately explored in identifying eco-livelihoods priorities, whenever dredging operations are to be executed. The use of TELK also entails the active participation of holders of

TK, and TELK in the planning of dredging projects in the developing world. In conclusion, the increasing number of research and academic publications that explores TK and TEK, shows that this knowledge system is valid and has a place in planning for sustainable development.

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## References

Abam, T. K. S. (2001). "Regional hydrological research perspectives in the Niger Delta." *Hydrological Sciences*. **46**(1): 13-25.

Adolph, B. Butterworth, J. Conroy, C. and Morris, M. (2001). *Common Pool Resources in Semi-arid India Problems and Potentials*. Natural Resources Institute (NRI), Chatham, UK. Synthesis Report CRIDA / CWS / AKRSP (I) WRM Ltd. / MSU / NRI Common Pool Resources Research Project Report No. 4 (NRI Report No. 2650).

Agarwal, A. (1997). "Environmental pollution due to urbanisation in developing countries." *New Scientist*. **154**(4): 51-54.

Aldridge, D. C. (2000). "The impacts of dredging and weed cutting on a population of freshwater mussels (Bivalvia: Unionidae)." *Biological Conservation*. **95**: 247-257.

Anwar, S. K. Sastri, M. V. Rama Rao., K. Venkateshwarlu, D. and Srinivas, K. (2001). *Common Pool Resources in Semi-arid India: Andhra Pradesh Regional Report.* Natural Resources Institute (NRI), United Kingdom. NRI Report No. 2648. 64.

Ault, J. S. Lindeman, K. C. and Clarke, D. G. (1998). *FISHFATE: Population dynamics models to assess risks of hydraulic entrainment by dredges*. DOER Technical Notes Collection (TN DOER-E-4), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Berkes, F. Colding, J. and Folke, C. (2000). "Rediscovery of traditional ecological knowledge as adaptive management." *Ecological Applications*. **10**(5): 1251-1262.

Bielawski, E. (1992). "Inuit Indigenous knowledge and science in the Arctic." *Northern Perspectives*. **20**(1): 8.

Blanchard, A. L. and Feder, H. M. (2003). "Adjustment of benthic fauna following sediment disposal at a site with multiple stressors in Port Valdez, Alaska." *Marine Pollution Bulletin*. **46**: 1590-1599.

Bray, R. N. (1998). "A review of the past and a look to the future." *Terra et Aqua*. **70**(March).

Bray, R. N. Bates, A. D. and Land, J. M. (1998). *Dredging A Handbook for Engineers*. John Wiley and Sons, Inc, New York.

Brigden, A. J. (1996). "Used dredged spoil as a topsoil substitute for derelict land reclamation." *The Dock and Harbour Authority*. **77**(869): 85 – 89.

Brookes, A. (1988). *Channelized Rivers: Perspective for Environmental Management*. John Wiley and Sons, Chichester UK.

Brookes, A. (1989). Alternative Channelization Procedures. In Gore, J. A., and Petts, G.E. (Ed.), Alternatives in Regulated River Management. CRC Press, Inc., Boca Raton Florida**:** 139-162.

Castillo, A. (2000). "Ecological information system: Analyzing the communication and utilization of scientific information in Mexico." *Environmental Management*. **25**(4): 383-392.

CEDA. (1999). *Dredging: the facts*. Central Dredging Association (CEDA), Al Deft, The Netherlands. 6.

Chokkalingam, U. Kurniawan, I. and Ruchiat, Y. (2005). "Fire, livelihoods, and environmental change in the middle Majakam Peatlands, East Kalimantan." *Ecology and Society*. **10**(1): 26 [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art26/.

CIRIA. (1997). *Inland dredging - Guidance on Good Practice*. Construction Industry Research and Information Association (CIRIA), Westminster, London. 181.

Clarke, D. G. and Wilber, D. H. (2000). *Assessment of potential impacts of dredging operations due to sediment resuspension*. DOER Technical Notes Collection (ERDCTN-DOER-E9), U.S. Army Engineer Research and Development Centre, Vicksburge, MS.

Coates, D. Bovin, T. Darwall, W. R. T. Friend, R. Hirsch, P. Poulsen, A. F. Quirós, R. Visser, T. A. M. and Wallace, M. (2003). *Review information, knowledge and policy*. Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries, Conference Food and Agriculture Organisation of the United Nations and the Mekong River Commission. Phnom Penh, Kingdom of Cambodia.

Crisman, T. L. Chapman, L. J. and Kaufman, L. S. (2003). *Conservation Ecology, and Management of African Fresh Waters*. University Press of Florida, Florida, USA.

Dickerson, D. D. Reine, K. J. and Clarke, D. G. (1998). *Economic impacts of environmental windows associated with dredging operations*. U.S. Army Engineer Research and Development Center, Vicksburg, MS. DOER Technical Notes Collection (TN DOER-E3).

Ellery, W. N. and McCarthy, T. S. (1994). "Principles for the sustainable utilisation of the Okavango Delta ecosystem, Botswana." *Biological Conservation*. **70**: 159-168.

Environment Agency. (2005). *Fluvial Trent Strategy*. Environmental Agency Midlands Region, Nottingham, UK. 148pp.

Environment Canada. (1997a). *Environmental risk assessments of priority substances under the Canadian Environmental protection Act: Guidance Manual*. Chemical Evaluation Division, Commercial Chemicals Evaluation Branch, Environment Canada (EC), Ottawa, Ontaria, Canada.

Environment Canada. (1997b). *Evaluating the Environmental Impact of Dredging Burnaby Lake*. Environment Canada (EC), North Vancouver, B.C. 107.

Fernadez-Gimenez, M. E. (2000). "The role of Mongolian Nomadic Pastoralists' ecological Knowledge in rangeland management." *Ecological Applications*. **10**(5): 1318-26.

FoE. (2000). *Dubious Development: How the World Bank's Private Arm is Failing the Poor and the Environment*. Friends of the Earth (FoE), Washington, DC. 24.

Forrest, S. (2000). *Indigenous knowledge and its representation within Western Australian's new curriculum framework*. The Australian Indigenous Education Conference, Conference. Fremantle, 3 - 7 April 2000.

Gadgil, M. and Berkes, F. (1991). "Traditional resources management systems." *Resource Management and Optimization*. **8**(3-4): 127–141.

Gadgil, M. Berkes, F. and Folke, C. (1993). "Indigenous knowledge for biodiversity conservation." *Ambio*. **22**(2-3): 151-6.

Gilchrist, G. Mallory, M. and Merkel, F. (2005). "Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds." *Ecology and Society*. **10**(1): 20. [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art20/.

Gore, J. A. and Petts, G. E. (1989). *Alternatives in Regulated River Management.* CRC Press, Inc., Boca Raton Florida.

Hernández-Cornejo, R. Koedam, N. Luna, A. R. Troell, M. and Dahdouh-Guebas, F. (2005). "Remote sensing and ethnobotanical assessment of the mangrove forest changes in the Navachiste-San Ignacio-Macapule lagoon complex, Sinaloa, Mexico." *Ecology and Society*. **10**(1): 16 [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art16/.

Huitric, M. (2005). "Lobster and conch fisheries of Belize: a history of sequential exploitation." *Ecology and Society*. **10**(1): 21 [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art21/.

Huntington, H. P. (2000). "Using traditional ecological knowledge in science: methods and applications." *Ecological Applications*. **10**(5): 1270-4.

Jodha, N. S. (1990). Rural Common Property Resources: Contribution and Crisis. Economic and Political Weekly. **30:** A65 - A78.

Johnson, M. (2003). *Research on Traditional Environmental Knowledge: Its Development and Its Role*. The International Development Research Centre, Canada. http://web.idrc.ca/en/ev-43097-201-1-DO_TOPIC.html [Accessed 22 April 2005].

Kwak, S. J. Yoo, S. H. and Shin, C. O. (2002). "A multivariate index for assessing environmental impacts of regional development projects: A case study of Korea." *Environmental Management*. **29**(2): 301-9.

Landers, D. H. Bangay, G. Sisula, H. Colborn, T. and Liljelund, L.-E. (1995). "Airbone contaminants in the Artic: what we need to know." *The Science of the Total Environment*. **160/161**: 841-8.

Lubke, R. A. Reavell, P. E. and Dye, P. J. (1984). "The effects of dredging on the macrophyte vegetation of the Boro River, Okavango Delta, Botswana." *Biological Conservation*. **30**: 211-36.

Machiwal, P. Jha, M. K. Singh, P. K. Mahnot, S. C. and Gupta, A. (2004). "Planning and Design of Cost-effective Water Harvesting Structures for Efficient Utilization of Scarce Water Resources in Semi-arid Regions of Rajasthan, India." *Water Resources Management.* (18): 219-235.

McCauley, R. W. (1977). "Laboratory methods for determining temperature preference." *Journal of the Fisheries Research Board of Canada*. **34**: 749-52.

Mylopoulos, Y. Kolokytha, E. Kampragou, E. and Vagiona, D. (2008). "A Combined Methodology for Transboundary River Basin Management in Europe. Application in The Nestos-Mesta Catchment Area." *Water Resources Management*. **22**: 1101-1112.

Nabhan, G. P. (1997). *Cultures of habitat: on nature, culture, and story*. Counterpoint, Washington D.C., USA.

NRA. (1994). *Water - Nature's Precious Resource. An Environmental Sustainable Water Resources Development Strategy for England and Wales*. National Rivers Authority (NRA), Bristol.

Ohimain, E. I. (2004). "Environmental impacts of dredging in the Niger Delta." *Terra et Aqua*. **97**: 9-19.

Olsson, P. and Folke, C. (2001). "Local ecological knowledge and institutional dynamics for ecosystem management: a study of Lake Racken watershed, Sweden." *Ecosystems*. **4**: 85-104.

Orr, P. Colvin, J. and King, D. (2008). "Involving stakeholders in integrated river basin planning in England and Wales." *Water Resources Management*. **21**: 331-349.

Osman, M. Mishra, P. K. Mishra, A. K. Dixit, S. Ramachandran, K. Singh, H. P. Rama Rao, C. A. and Korwar, G. R. (2001). *Common Pool Resources in Semi-arid India: a review of dynamics, management and livelihood contributions*. Natural Resources Institute (NRI), Kent, United Kingdom.

Pavlikakis, G. E. and Tsihrintzis, V. A. (2000). "Ecosystem management: A review of a new concept and methodology." *Water Resources Management*. **14**: 257-83.

PTF. (1999). *Environmental Impact Assessment of the Proposed Dredging of the Lower Niger Waterway*. Petroleum (Special) Trust Fund (PTF), Wuse, Abuja, Nigeria. Draft Report. 557.

Quinn, C. H. Huby, M. Kiwasila, H. and Lovett, J. C. (2003). "Local perceptions of risk to livelihood in semi-arid Tanzania." *Journal of Environmental Management*. **68**: 111-9.

Reine, K. and Clark, D. (1998). *Entrainment by hydraulic dredges - A review of potential impacts*. Technical Note Dredging Operations and Environmental Research (DOER)-E1. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Reine, K. J. Dickerson, D. D. and Clarke, D. G. (1998). *Environmental windows associated with dredging operations*. DOER Technical Notes Collection (TN DOER-E2). U.S. Army Engineering Research and Development Centre, Vicksburg, MS.

Riddell, J. (2000). "Dredging: opportunities and challenges for 2000 and beyond." *Terra et Aqua* **78**(March): 3-10.

Rosenberg, D. M. Bodaly, R. A. and Usher, P. J. (1995). "Environmental and social impacts of large-scale hydro-electric development: who is listening?" *Global Environmental Change*. **5**: 127-48.

RSPB (1995). *The New Rivers and Wildlife Handbook.* The Royal Society for the Protection of Birds (RSPB), National Rivers Authority (NRA) and Royal Society for Nature Conservation (RSCN).

Stolpe, N. E. (2001). *Trawling and dredging effects; an industry perspective*. NAS / NRC Committee on Ecosystem Effects of Fishing: Phase 1. Effects of Bottom Trawling on Seafloor Habitats., Conference. New England Aquarium.

Sullivan, C. A. and Meigh, J. (2007). "Integration of the biophysical and social sciences using an indicator approach: Addressing water problems at different scales." *Water Resources Management*. **21**: 111-128.

Swales, S. (1989). The Use of In stream Habitat Improvement Methodology in Mitigating the Adverse Effects of River Regulation on fisheries. In Gore, J. A., and Petts, G.E. (Ed.), Alternatives in Regulated River Management. CRC Press, Inc., Boca Raton, Florida.

Tabuti, J. R. S. Dhillion, S. S. and Lye, K. A. (2003). "Ethnoveterinary medicines for cattle (Bos indicus) in Bulamogi county, Uganda: plant species and mode of use." *Journal of Ethnopharmacology*. **88**: 278-86.

Tamuno, P. B. L. (2001). Flood mitigation: a case study from Bayelsa State, Nigeria. MSc Thesis, Water, Engineering and Development Centre (WEDC), Loughborough University, Loughborough, UK. 161pp.

Tamuno, P. B. L. (2006). Eco-livelihood assessment of inland river dredging of the Kolo and Otuoke creeks, Nigeria. PhD thesis, Department of Civil and Building Engineering, Loughborough University, Loughborough. 328pp.

Tamuno, P. B. L. Ince, M. E. and Howard, G. (2003). *Understanding vulnerability in the Niger floodplain*. Towards the Millennium Development Goals ~ Actions for Water and Environmental Sanitation., Conference Proceedings of the 29th Water, Engineering and Development Centre (WEDC), Loughborough University, UK. Abuja, Nigeria.

Tengö, M. and Belfrage, K. (2004). "Local management practices for dealing with change and uncertainty: a cross-scale comparison of cases in Sweden and Tanzania." *Ecology and Society*. **9**(3): 4. [online] URL: http://www.ecologyandsociety.org/vol9/iss3/art4.

Terano, T. Asai, K. and Sugeno, M. (1997). "The ecological component of environmental impact assessments: A critical review of British environmental assessments." *Journal of Environmental Planning and Management*. **40**: 157-71.

Turner, N. J. Ignace, M. B. and Ignace, R. (2000). "Traditional ecological knowledge and wisdom of Aboriginal peoples in British Columbia." *Ecological Applications*. **10**(5): 127-28.

UK Marine. (2002a). *Environmental impacts of maintenance dredging and disposal.* UK Marine Special Areas of Conservation (SACs) Project, UK Marine. (2002b). *Dredging and Disposal: Contaminated sediments*. UK Marine Special Areas of Conservation (SACs) Project,

UK Marine. (2002c). *Means of avoiding, minimising and assessing the potential impacts of maintenance dredging and promoting benefits*. UK Marine Special Areas of Conservation (SACs) Project,

UNEP. (1998). *Report of the fourth meeting of the conference of the parties to the convention on biological diversity*. United Nations Environmental Programme (UNEP), Nairobi, Kenya.

United Nations. (2002). *Report of the World Summit on Sustainable Development.* The United Nations, New York, USA.

Vellinga, P. (2002). "Dredging in a changing environment." *Terra et Aqua*. **87**(June).

Warren, D. M. and Rajasekaran, B. (1993). "Putting local knowledge to good use." *International Agricultural Development*. **13**(4): 8-10.

WCED (1987). *Our Common Future*. WCED (World Commission on Environment and Development) . Oxford University Press, London.

WODA. (2004). *Hamburg Declaration*. World Organisation of Dredging Associations (WODA), Las Vegas, USA.

World Bank. (1997). *IDA in Action 1994-1996, the Pursuit of Sustained Poverty Reduction.* World Bank, Washington, DC.

World Bank (1999). *India: Livestock Sector Review: Enhancing Growth and Development.* The World Bank and Allied Publishers, New Delhi.