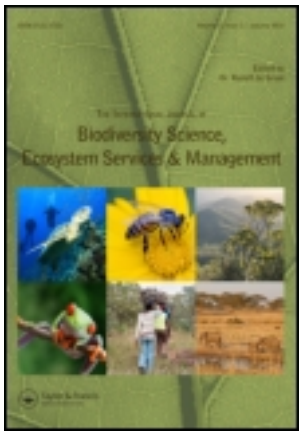

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The Niger Delta wetlands: threats to ecosystem services, their importance to dependent communities and possible management measures

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REVIEW ARTICLE

The Niger Delta wetlands: threats to ecosystem services, their importance to dependent communities and possible management measures

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The Niger Delta wetlands are changing rapidly, raising concern for the wetlands' health and for communities relying upon its ecosystem services. Knowledge on ecosystem service provision is important for effective ecosystem and livelihoods management, but is currently lacking for the Niger Delta. We synthesised literature and used the 'Drivers–pressure–state–impact–response' (DPSIR) framework to structure information on changes in the wetlands' ecosystem services and implications for dependent communities. The wetlands' ecosystem services are being eroded through oil and gas exploration, dredging, invasive plant infestation and wetland reclamation. This is exacerbated by rising demand for oil, population growth and weak governance. Mass fish migration, water pollution and reduction of wetland area are also evident, impacting ecosystem services and traditional livelihood systems. This has caused poverty; people have to buy goods that previously could be obtained from the wetlands. Effective wetland management will be aided by: recognition of ecosystem services' contributions to community well-being; understanding how benefits are distributed over time, space, stakeholder; and how these changes in response to pressures. Since key pressures in the wetland are anthropogenic, understanding the role of institutions in relation to the Niger Delta's ecosystem services is imperative.

Keywords: Niger Delta; ecosystem services; threats; wetlands; DPSIR

1. Introduction

Wetland ecosystems are among the most important in the world, providing a diverse range of ecosystem services[1] vital to human well-being (Barbier et al. 1997; RCS 2007). They gave rise to the first modern global nature-conservation convention[2] (Matthews 1993) and remain the only single group of ecosystems with their own international convention (Turner et al. 2000). Dugan (1990) points out that there are about 50 definitions of wetlands in use. The Ramsar Convention on Wetlands provide the most widely used, defining wetlands as

> areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres

in addition, they 'may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands' (RCS 2007).

Globally, wetland is estimated to cover 5–10% of the earth's terrestrial surface (Mitsch and Gosselink 2007; RCS 2007), some 1280 million hectares, although, it is believed that this is an underestimate (MEA 2005). Some estimates put the global loss of wetlands at about 50% (Barbier 1994; Rijsberman and Silva 2006; ICSU et al. 2008). However, this is speculative, being based on extrapolation of wetland loss during the twentieth century of some types of wetlands in areas that have been best documented, including North America, Europe, Australia and New Zealand (MEA 2005). There are no reliable figures on the global extent of wetland loss, but there is good evidence for dramatic loss of individual wetlands (see MEA (2005) for global examples, and below for Africa). This wetland loss is associated with loss of vital ecosystem services, and so has made places and people more vulnerable to environmental, economic and socio-political perturbations with significant impacts on biodiversity and community livelihood (ICSU et al. 2008; Odada et al. 2009).

Interest in wetlands of tropical Africa has heightened (Dugan et al. 2006) because of their importance as hot spots for the development and maintenance of biodiversity (Renema et al. 2008; Keddy et al. 2009); their vital role in providing food, water and livelihood security to the mainly poor people living around them (Adams 1993; Silvius et al. 2000; Schuyt 2005; Rebelo et al. 2009); and most recently for their ability to sequester atmospheric carbon (Ringius 2002; Loiselle et al. 2006). Whilst the value of tropical African wetlands is being increasingly recognised, Thiombiano and Tourino-Soto (2007) point out that there is an increasing trend in severity and extent of degradation in African environments, from the humid zones of the Congo and Zambezi basins to the dry areas of the Nile, Niger and Lake Chad basins. For instance, half of the Usangu Plains, Tanzania, were lost between 1984 and 2000 (Kashaigili et al. 2006); and 15% of wetland area

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in Tunisia and 84% of wetland in the Medjerdah catchment (Algeria and Tunisia) has been lost (Hollis 1992). Similarly, Lake Chad, one of the largest in the world when first surveyed by Europeans in 1823 (Johnston 1908), has shrunk considerably (Favreau et al. 2008). In 1963, it was about 25,000 km^2 in surface area, but Coe and Foley (2001) found it to be about one-twentieth the size it was in the mid-1960s. This is having serious ecological and socio-economic implications for the region, including a reduction in availability of fresh water resulting in conflicts and migrations (Guganesharajah and Shaw 1984; Nnoli 1990; Coe and Foley 2001).

Providing data and information about the values of wetlands is a major way to ensure their wise use and stem their conversion and development (Turpie et al. 1999; Balmford et al. 2002; Mmopelwa 2006). However, in comparison to wetlands elsewhere, there is a general lack of information on wetlands in Africa, including those of Nigeria's Niger Delta where various pressures bring about ecological changes at a drastic rate thereby threatening the wetlands' ability to continually provide ecosystem services. There is a clear need to promote the sustainable use of the Niger Delta. This requires an understanding of the ecosystem services provided, and the threats that the wetland is exposed to. However, good information on this wetland area tends to relate largely to the substantial deposits of crude oil and gas, and not its rich ecological endowment. Knowledge on wetland ecosystem services, drivers of change and subsequent impacts is reasonably well understood at an aggregate level, but to develop a sustainable use strategy, such knowledge is required specific to the region of concern (Boavida 1999; Ostrom et al. 2007). Such information is currently lacking for the Niger Delta wetlands, hence we synthesise what is known of the ecosystem services provided by the Niger Delta wetland, and within the framework of the widely used 'drivers–pressure–state–impact–response' (DPSIR) model, explore the major issues confronting the sustainable use of the wetlands. In addition, we identify knowledge gaps which if addressed should improve management of the wetland.

2. Methods

2.1. Study area

The Niger Delta is the third largest wetland in the world (Uluocha and Okeke 2004; Umoh 2008), and the largest river delta and mangrove ecosystem in Africa (Dupont et al. 2000; Ajonina et al. 2008), with the greatest extension of freshwater swamps (Ogon 2006). The Niger Delta is located in southern Nigeria, in the lower reaches of the Niger River (Figure 1), and extends between latitudes 4°2′ and 6°2″ north of the equator and is 5°2″ east of the Greenwich meridian (Davies et al. 2009). The wetland is formed by the accumulation of sedimentary deposits transported by the rivers Niger and Benue (World Bank 1995), which discharge water, sediment and other loads across southern Nigeria, and beyond into the Atlantic Ocean. Over many years, this has resulted in the formation of this complex and fragile delta with a rich biodiversity (Abam 2001).

Figure 1. Nigeria and the Niger Delta states (indicated with grey shade)
Source: Idemudia and Ite (2006).

Over 50% of the delta is water, with thousands of creeks (Ikelegbe 2006), and collectively, the delta accounts for 55% of all fresh water swamps in Nigeria (Umoh 2008). Annual rainfall ranges from 3000 mm to 4500 mm, with a wet season between July and September, and a dry season from December to February. Average monthly temperature is 27°C (World Bank 1995).

The Niger Delta forms an integrated mosaic of aquatic, semi-terrestrial (mangrove and freshwater swamps) and terrestrial habitats (Bisina 2006), which is highly diverse and supportive of numerous species of terrestrial and aquatic flora and fauna (Uyigue and Agbo 2007). The delta has the richest biodiversity in Nigeria (Ebeku 2004), and is an area of international importance for its ecological riches which include several IUCN 'Red List' species including some endemic or near endemic mammals (such as *Kinixys homeana*, Home's hinge-back tortoise) (Luiselli et al. 2006; Obot 2007). A recent survey revealed that the delta has several previously unknown species, including the Niger Delta Red colobus (*Procolobus badius epieni*), new to science (Ebeku 2004; McGinley 2008).

When defined based on human geography and hydrology, the delta region consists of present-day Bayelsa, Delta and Rivers States and covers an area about 20,000 km^2 (World Bank 1995; Uyigue and Agbo 2007), but the broader Niger Delta region, which includes all the oil-producing areas and others considered relevant for reasons of administrative convenience, political expedience and development objectives, extends the land area to 75,000 km^2 (Ighodaro 2005). Defined in this way, the Niger Delta consists of nine states (Figure 1), with over 30 million inhabitants, about 22% of Nigeria's population.[3] The region is ethnically very varied, typifying the diversity and plurality that gives Nigeria its socio-political strength. Ethnic groups include Bini, Efik, Ibibio, Ijo, Isoko/Ukwani, Itsekiri and Urhobo. Despite its vast oil resources, the region remains poor with high levels of unemployment (Agbogidi and Ofuoku 2006; Idemudia 2009). Unemployment and underemployment – at 8.8% and 26.2%, respectively – are higher in the Niger Delta than in other regions of Nigeria (Ukiwo 2009). Social issues presently confronting this region include cases of hostage taking, kidnappings and pipeline vandalisation (Peterside 2007; Watts 2008). These are viewed as a response of the people to the perceived injustice in the distribution of costs and benefits of oil exploration. They believe that while local communities directly bear the environmental consequences of oil development, such as loss of biodiversity (Uluocha and Okeke 2004; James et al. 2007; Phil-Eze and Okoro 2009) and pollution of the water supply (Okoh et al. 1996; Ekundayo and Fodeke 2000), other regions of the country enjoy the economic benefits.

2.2. Data sources

The synthesis of Niger Delta wetlands ecosystem services, and threats to them, was developed through analysis of secondary source data (the outcome of the study is being used to inform ongoing primary data collection in the delta). These sources included peer reviewed materials presented in journals, books and international and national conference presentations, supplemented by non-peer-reviewed literature from a wide range of other sources, including international and national non-governmental organisations, national and local government bodies, academic institutes and some commercial organisations. These sources were collected through comprehensive and extensive literature search using academic reference databases including Web of Knowledge, Science Direct and Cambridge Scientific Abstracts (including databases such as Aqualine, Aquatic Sciences and Fisheries Abstracts, Biological Sciences, Conference Papers Index for life, environment and aquatic sciences, GeoRef, International Bibliography of the Social Sciences, Oceanic Abstracts and Sociological Abstracts). Internet-based search engines (e.g. Google scholar, scirus.com) were also used to identify relevant 'grey literature' and, in addition, relevant conference and workshop papers and newspaper articles were acquired directly from contacts in Nigeria.

A structured search using Boolean logic was conducted using a wide range of terms. These related to the geography of interest (e.g. Niger Delta, Niger wetland), natural components of the delta (ecosystem, wetland, mangrove, biodiversity, etc.), characterisation of Niger Delta condition (ecosystem status, ecosystem condition, environmental assessment, etc.), stresses (pollution, development, degradation, impact, etc.) and human value (livelihood, use, benefit, value, economic benefit, etc.). Sources were investigated, and information collated, with particular reference to the principle ecosystem services provided (provisioning, regulating, cultural, supporting; MEA (2005)) and the DPSIR framework, which is discussed further below. It was not practical to systematically test the veracity of information presented in the available sources, but we did seek to ensure that, wherever possible, results were based on data presented across multiple sources.

2.3. Drivers–pressure–state–impact–response framework

In the 1990s, the Organisation for Economic Co-operation and Development developed the pressure–state–response model as a means of selecting and organising indicators and associated data in a way useful to decision-makers and the public. The model was further expanded by the European Environment Agency by the addition of steps addressing drivers and impacts, thus creating a more widely applicable framework that considers the behavioural factors underlying the pressures. Drivers are the socio-economic and socio-cultural forces behind human activities, and also include any natural factors, such as climate change, which can modify pressures on the environment. Pressures are the stresses that human activities place on the environment. State reflects the condition of the environment, whilst impact denotes the consequences

of that environmental status for people, the economy and the ecosystem. Response refers to the responses by society to the environmental situation.

DPSIR has been widely used for assessing the causes, consequences and responses to environmental change in a holistic way and for organising information about the state of the environment (European Economic Area 1995; Smeets and Weterings 1999). More recently, DPSIR has been applied in assessment of the impacts of environmental change drivers on ecosystem services (Lin et al. 2007; Harrington et al. 2010; Atkins et al. 2011). However, its adoption and use is still in its infancy with respect to African countries (Agyemang et al. 2007). The DPSIR model has its critics, who point to the assumption of deterministic causal relationships (overly simplistic and which give insufficient attention to secondary effects and complicating external factors), and that one to one relations are rarely dealt with in practice (Niemeijer and de Groot 2008; Maxim et al. 2009). However, we use the model as a convenient organising framework tool for systematically structuring environmental information. We focus on the first four steps, as the final 'response' step is subject to current primary field research.

The results of our analysis are presented below – Section 3.1 summarises the ecosystem services provided by the Niger Delta, based upon a synthesis of the source material, whilst Section 3.2 describes these services within the context of the DPSIR model. The remaining sections provide further discussion, and draw conclusions.

3. Results

3.1. Ecosystem services provided by Niger Delta wetlands

Wetland ecosystems provide many services that are important for human well-being (de Groot et al. 2002; MEA 2005). Wetlands harbour vast biological riches, purify air and water; provide food, medicines, energy and raw materials. They also regenerate soils and pollinate crops, regulate the climate, control floods and offer opportunities for recreation and spiritual renewal (Mitsch and Gosselink 2000; Brander et al. 2006). The MEA (2003) classifies such goods and services as provisioning, regulating, cultural and supporting services. Although, all wetlands have the potential to contribute many of these services, different wetlands are noted for one or more major service. Generally, wetlands in less-developed societies are mostly noted for their direct benefits such as for cropping, collection of reed, sedge and firewood and also fishing and game hunting (see Emerton et al. 1999; Schuyt 1999; Turpie et al. 1999; Turpie 2000; Mmopelwa 2006), while wetlands in more developed societies are noted for their indirect benefits such as aesthetics and biodiversity (International Water Management Institute 2006). Table 1 summarises the key ecosystem services derived from the Niger Delta wetlands.

Prior to the advent of multinational oil exploration in the Niger Delta, inhabitants made their living from the

Table 1. Major ecosystem services provided by or derived from Niger Delta wetlands.

General ecosystem services[a]	Niger Delta ecosystem services[b]
Provisioning	
• Food	• Timber products: saw logs, transmission poles, bamboo, building poles, fuelwood and chewing sticks (World Bank 1995; NDDC 2006; Alogoa 2005; McGinley 2008)
• Fresh water	• Agricultural and tree crops: cassava, yam, cocoyam, rice, maize, ogbono, cocoa, etc. (World Bank 1995; Umoh 2008; Omofonmwan and Odia 2009)
• Fibre and fuel	• Fish and other aquatic food such as barnacles, crabs and other invertebrates (Nwadiaro 1984; Fentiman 1996; Davies et al. 2009)
• Biochemical	• Aquatic insects (Arimoro and Ikomi 2009)
• Genetic materials	• Medicinal species (Ndukwu and Ben-Nwadibia (2005)
• Other products	• Bush meat (Luiselli 2003; Luiselli et al. 2006)
	• Other products including raffia, snail, spices, mangrove salts, reeds and sedge (World Bank 1995; UNDP 2006)
Regulating	
• Climate regulation	• Provides a good sink for greenhouse gases of CO_2 and CH_4 (Brooks et al. 2000)
• Water regulation (hydrological flows)	• Provides buffer against natural disaster including coastal erosion and regulates flood (Cugusi and Piccarozzi 2009; Sanford 2009)
• Water purification and waste treatment	• Regulates water movement, quality and volume (Abam 2001; Uluocha and Okeke 2004)
• Erosion regulation	• Habitat for pollinators (Dupont et al. 2000)
• Natural hazard regulation	• Natural attenuation (Benka-Coker and Ekundayo 1995; Abu and Dike 2008)
• Pollination	
• Salinity control	
Cultural	
• Spiritual and inspirational	• Source of spiritual inspiration (Isichei 1982)
• Recreational and tourism	• Site for fishing festivals (Jonathan 2006)
• Aesthetic	• Spiritual and sacred sites (Anderson and Peek 2002; Bisina 2006)
• Educational	• Vast biodiversity (indicative of tourism) (World Bank 1995; Ebeku 2004)
Supporting	
• Soil formation	• Supports delta's biodiversity (Ejechi 2003)
• Nutrient cycling	• Soils support nitrogen mineralisation (Iwegbue et al. 2006)
	• Supports transportation (inland ports) that link places (Wolf et al. 2002; NDDC 2006; Egbagbe 2009)

Notes: [a]Based on MEA (2005).
[b]Some Niger Delta wetlands ecosystem services, such as sacred sites, are little known and subject to ongoing research.

wetlands as farmers, fishermen and hunters (Aprioku 1999; Alogoa 2005). Just like other wetlands in developing societies, the Niger Delta is noted for its provisioning services which include timber, and food from both terrestrial and aquatic systems. Major timber species found in abundance in the wetlands are Abura (*Hallea ledermannii*), Cotton tree (*Ceiba pentandra*), Iroko (*Milicia excelsa*), Mahogany (*Khaya* sp.), Obeche (*Triplochiton scleroxylon*) and Red mangrove (*Rhizophora* sp.). These are notably used as sawlogs, transmission poles, bamboo, building poles, fuelwood and chewing stick (World Bank 1995). Fuelwood is an important source of domestic energy, especially for cooking (Chinweze and Abiola-Oloke 2009), and chewing stick sourced from the roots, twigs or stems of wetland plants are as effective as toothbrushes in maintaining oral hygiene (Ndukwe et al. 2005). The World Bank (1995) estimated the total annual value of Niger Delta timber products in the region of N500 million ($22.8 million).[4] Sapele (in Delta state) was the first port to export timber from Nigeria, around 1900. Today, there are hundreds of small- and large-scale timber enterprises in the Niger Delta. The rubber tree (*Hevea brasilensis*) is a major source of latex for the production of plastics and glue for the wood, paper and tyre industries.

The Niger Delta is equally an important ecosystem at ensuring food security through the provision of various crops (Umoh 2008). The rich soil resource in the wetlands supports agriculture, with cultivation of important food and cash crops including rice, plantain, pineapple, yam, cassava, cocoyam, oil palm, raffia palm, potatoes, coconut, cocoa, mango and groundnut. These crops form the basis of household food consumption in the delta. Cassava (*Manihot esculenta*) is edible and is a major source of carbohydrate, often processed to produce other staple foods such as garri, fufu, starch and tapioca. Oil palm (*Elaeis guineensis*) is a major source of edible vegetable oil. Plantain (*Plantago* sp.) is a staple food. Raffia palm (*Raphia* sp.) is a source of palm wine, a traditional drink. These crops equally have high industrial potential. Cassava serves as a raw material for industrial starch production. Oil and kernel derived from the oil palm are raw materials in high demand for production of foods, cosmetics, detergents and industrial oils. The Raffia palm is essential in distillation of export-quality gin and industrial alcohol, and also in dry yeast production for baking and medical applications. There are a number of soft drink, brewery, distilleries, food processing, footwear and other economic activities all of which depend on agricultural products from the wetlands.

Aquatic life in the Niger Delta is very rich (Ebeku 2004; Uluocha and Okeke 2004). The wetlands provide fish, a common source of animal protein for most households (Chindah and Osuamkpe 2008; Davies et al. 2009), and a rich source of amino-acids, vitamins, minerals and poly-unsaturated fatty acids (Allison and Okadi 2009). The waters of the Niger Delta have a high abundance and diversity of fish with about 200 species (Nwadiaro 1984; Fentiman 1996). Of these, 16 species have been identified as endemic to the region, and another 29 are near endemic (Moffat and Linden 1995; Ebeku 2004). Common species in the delta include cat fish, tilapia, shell fish, fin fish, coroackers, barracuda, denticle herring and hingemouth (Eboh et al. 2006; Oribhabor and Ansa 2006; Ekeke et al. 2008). Other aquatic foods in the delta include crabs, barnacles, periwinkles and other aquatic invertebrates (World Bank 1995). In addition, there are about 57 taxa of aquatic insects, some of which are edible and important bio-indicators of water quality in the Niger Delta (Arimoro and Ikomi 2009). This aquatic richness supports a thriving commercial fishery in the delta, serving as a major source of employment and income to many households (Davies et al. 2009).

Other important provisioning services derived from the Niger Delta include Ogbono, also called bush mango (*Irvingia gabonensis*) cooked as soup. Giant snails (*Archachatina marginata*) are served as a delicacy; these are rich in meat protein and nutrients (Fagbuaro et al. 2006). The wetland also provides a variety of fauna, some of which are hunted as bush meat including squirrels, grass cutters, antelopes, bears and hares. Others are monkeys, otters, marsh mongoose and hinge-back tortoise (*Kinixys erosa*, *K. homeana* and *K. belliana nogueyi*) (Luiselli 2003). Medicinal roots, leaves, barks, fruits, canes and ropes, honey, spices and mangrove salts are equally important services from the wetland (World Bank 1995). Ndukwu and Ben-Nwadibia (2005) identified a total of 24 species in the Niger Delta wetlands having varying applications in ethno-botany and ethno-medicine. Such medicinal species have an important healthcare role in the lives of rural people particularly in remote parts of the developing world (Levingston and Zamora 1983).

These provisioning ecosystem services are notable for household consumption, income generation and fulfilment of social and cultural obligations. These services are equally important source of raw materials for both local and export needs to a variety of cottage and other medium- and large-scale industries operating in the region. Hence, various employment opportunities are made available to local communities. Although, the exact contributions (in terms of number of jobs and cash income) of these services from the wetland is not known, available evidence underscore the importance of the Niger Delta wetlands to livelihoods of the locals.

The Niger Delta also provides substantive and significant regulating services. It regulates the movement of essential water and sediments in the region (Abam 2001). It regulates surface water quality and volume, and replenishes and sustains groundwater (Uluocha and Okeke 2004). It provides a sink for greenhouse gases of carbon dioxide (CO_2) and methane (CH_4) (Brooks et al. 2000). Flood control is a further essential regulatory service performed by the Niger Delta, a region where rainfall is high, and flood control is essential (Oladipo 1995; Uluocha and Okeke 2004). The importance of such regulation is appreciated when it is considered that a metre sea-level rise would flood 18,000 km^2 of land, damage assets worth about

9 billion dollars and force relocation of about 4 million people (World Bank 1995). Although the degree of mitigation of these impacts offered by the Niger wetland ecosystem components is not known, it is known that mangroves can provide a natural buffer against flood, hurricane, tsunami and climate change–induced sea-level rise to which deltas are vulnerable as well as combating coastal erosion (Cugusi and Piccarozzi 2009; Sanford 2009).

Salinity control and purification by removal of nutrients and other pollutants is also provided by the Niger Delta wetlands (Uluocha and Okeke 2004). There are a number of microorganisms in the wetlands which are important in the bioremediation of crude oil–polluted environments (Benka-Coker and Ekundayo 1995). Their importance to natural cleaning processes specifically photo-oxidation, volatilisation, evaporation and biodegradation in the removal of crude oil is also emphasised (Abu and Dike 2008).

The delta vegetation makes good habitat for wildlife (Hamadina et al. 2007) such as large Hippopotamuses and the rare Pygmy Hippos (McGinley 2008), whilst the wetlands are also a stronghold for the rare West African manatee. The only mammal species endemic to Nigeria, the monkey Sclater's guenon (*Cercopithecus scateri*), is found only in the Niger Delta (Ebeku 2004). Over 330 different species of birds have been identified in the delta (World Bank 1995), among which are parrots and the palm-nut vulture. In addition, some species classed as vulnerable, such as the Hammer kop (*Scopus umbretta*), which are rare over much of their ranges; remain abundant in the Niger Delta (Ebeku 2004). The delta is also an important habitat for trans-hemispheric migratory bird species (World Bank 1995). This rich biodiversity indicate a potential for eco-tourism, although this remains relatively undeveloped, and the potential has been greatly diminished by the deteriorating ecological health, insecurity and social conflicts in the region.

Cultural services address spiritual and inspirational, recreational and educational functions. Some communities in the delta worship crocodiles and hinge-back tortoises found in the delta (Isichei 1982). These are regarded as 'holy animals', reported to bring happiness, and they are believed to be a symbol of peace or a sign of abundant children (Akani and Luiselli 2001). Other cultural services of the wetland include its use for fishing festivals such as the Opuaduno Lake and Seigbein fishing festivals (Jonathan 2006). Very little is written of the spiritual values and sacred sites in the Niger Delta wetlands. This is likely due to the secrecy that surrounds these services in most African society (Speranza et al. 2008). However, it is known that the wetland has many essential spiritual and sacred sites (Anderson and Peek 2002; Bisina 2006).

The Niger Delta wetlands are also noted for their supporting services, that is, those services that underpin the provision of other categories of ecosystem services detailed in Table 1 and discussed above. These include nutrient cycling, oxygen production and soil formation, which act to support the delta's biodiversity (Ejechi 2003); nitrogen mineralisation (Iwegbue et al. 2006); and contribute to carbon sequestration and climate regulation (Uluocha and Okeke 2004). One often overlooked service is that the wetlands provide vital support by providing rapid transport routes in an otherwise difficult terrain, with many urban and rural settlements accessible only through the wetland (Wolf et al. 2002).

3.2. Niger Delta wetlands ecosystem services in a systems context

3.2.1. Driving forces increasing or mitigating pressures on the Niger Delta wetlands

The RCS (2007) identified drivers of change in wetland ecosystems. The indirect drivers include demographic; economic (e.g. trade, subsidies, markets); socio-political (e.g. governance, institutional and legal framework); science and technology; and cultural and religious (such as choices about what and how much to consume). Direct drivers include changes in local land use and land cover, species removal and/or invasive introductions, eutrophication and pollution, hydraulic infrastructure development, water abstraction and climate change.

There are some clear direct drivers relevant to ecosystem change in the Niger Delta wetlands, not least the invasive Nypa palm. However, the indirect factors are arguably more significant. Of these, population growth, which has been rapid, is clearly very significant (Hamadina et al. 2007). In 1963, the population of the region was about 9 million, this increased to 12 million in 1973 (Ahonsi 1988), 20 million in 1991 and 30 million in 2006. By 2015, population is projected to be 41.5 million in the region (National Population Commission 2006; NDDC 2006). The implication of such rapid growth is high demand for agricultural, residential, industrial and other space and increased demand for wetland resources such as bush meat, timber and fuelwood. Past and current governance structures have proved ineffective in managing such growth pressure sustainably (Olujimi 2009). Rising local and international demand for crude oil which is abundant in the Niger Delta is also driving environmental change through a high demand for wetland area for oil exploration and exploitation. In addition, existing institutional and legal frameworks have given priority to oil exploration over protection of the wetland (Ebeku 2004), and government interventions, such as agricultural subsidies and policies (e.g. 'Operation Feed the Nation') have distorted the relative costs and benefits of ecosystem services in favour of massive wetland conversion from mangrove to agricultural (rice) production. There are few studies on natural drivers of change in the Niger Delta, but those available suggest that temperatures are rising in the region, and rainfall declining (Awosika 1995; Oladipo 1995; Odjugo 2010). Whilst there is evidence that such climatic change can trigger major change in ecosystems (Walther et al. 2002; Alley et al. 2003), there is no strong evidence this is currently occurring in the Niger Delta.

3.2.2. Pressures on the Niger Delta wetlands

Wetlands face different pressures, dependent on the nature of driving forces at play. Uluocha and Okeke (2004) identified that wetland changes in Nigeria as a whole were the consequence of rapid urbanisation, mining, oil and industrial waste pollution, uncontrolled tilling for crop production, overgrazing, logging, unprecedented wetland reclamation, construction of dams, transportation routes and other physical infrastructure. Natural pressures included marine and coastal erosion, subsidence, ocean water intrusion, invasion by alien floral and faunal species, sand storm, desertification and droughts. Our review, specific to the Niger Delta, identified ten pressures (Table 2) of which four appear particularly problematic, as judged from the literature and personal observations in the field. These four, discussed further below, comprise oil and gas exploration and development; wetland reclamation for housing and infrastructural development; dredging activities; and invasive plant species, especially the Nypa palm. These are outcomes of the driving forces described above (see Figure 2). Dredging in the delta is strongly influenced by government policies aimed at making waters navigable for transportation, especially for oil and gas products. Weak institutions ensure that dredging activities by government agencies and private organisations go unquestioned. Government policy aimed at promoting plantations in the delta is responsible for the introduction of invasive species which is further promoted by lack of institutional procedures for dealing with alien species. Oil and gas exploration and wetland reclamation is strongly driven by the rising demand for crude oil and weak institutions. The influence of a rising population strongly linked to oil industry related migrations is note worthy.

3.2.2.1. Oil and gas exploration and development. The Niger Delta has one of the best quality crude oils in the world (Omotola 2006). Commercial exploitation started in 1956 and today, this oil accounts for about 90% of Nigeria's foreign earnings (Odulari 2008). The scale of the operation is large, with over 1500 oil wells drilled in 159 oil fields and more than 7000 km of pipelines over the Niger Delta region (Ene-Ita 2009). Shell Petroleum

Table 2. Pressures and impacts on the Niger Delta wetlands.

Pressure	Major service at risk/impact	Source
Aquaculture	Loss of mangrove with its rich biodiversity and attendant impact on livelihoods	Davies et al. (2009), Zabbey et al. (2010)
Oil exploration and exploitation activities	Narcotic effects and mortality of fish and other faunal organisms/dynamite shooting causes increases in turbidity, blockage of filter feeding apparatuses in benthic (bottom dwelling) fauna and reduction of plant photosynthetic activity due to reduced light penetration.	Ekundayo and Fodeke (2000), Uluocha and Okeke (2004), Twumasi and Merem (2006), James et al. (2007), Uyigue and Agbo (2007), Obot (2007), Ugochukwu and Ertel (2008), Watts (2008), Luiselli (2009), Phil-Eze and Okoro (2009), Zabbey et al. (2010)
Dredging	Direct burial and destruction of fringing mangroves and associated fauna/changing topography and hydrology/increased erosion and siltation/excessive flooding and ponding of the backswamp/estuarine acidification and heavy metal pollution/succession to freshwater vegetation	Ohimain et al. (2004), Rim-Rukeh et al. (2007), James et al. (2007)
Invasive plants (Nypa palm)	Decrease in genetic diversity through loss of genetically distinct populations and hybridisation with native species	James et al. (2007), Phil-Eze and Okoro (2009), Zabbey et al. (2010)
Damming activities	Top of form reduction in water flow and sediment	Abam (1999), Uluocha and Okeke (2004)
Human activities (such as deforestation unsustainable hunting, overfishing, logging)	Loss of flora and fauna	Luiselli (2003), Luiselli et al. (2006), Phil-Eze and Okoro (2009)
Wetland reclamation (agricultural and urbanisation)	Loss of flora and fauna	Wolf et al. (2002), Twumasi and Merem (2006), James et al. (2007), Phil-Eze and Okoro (2009)
Climate change	Sea-level rise, flooding, loss of lives and properties	Uyigue and Agbo (2007)
Other industrial and domestic effluents	Soil and water pollution	Ugochukwu and Ertel (2008)
Indiscriminate use of fertiliser	Water pollution	Obire et al. (2008)

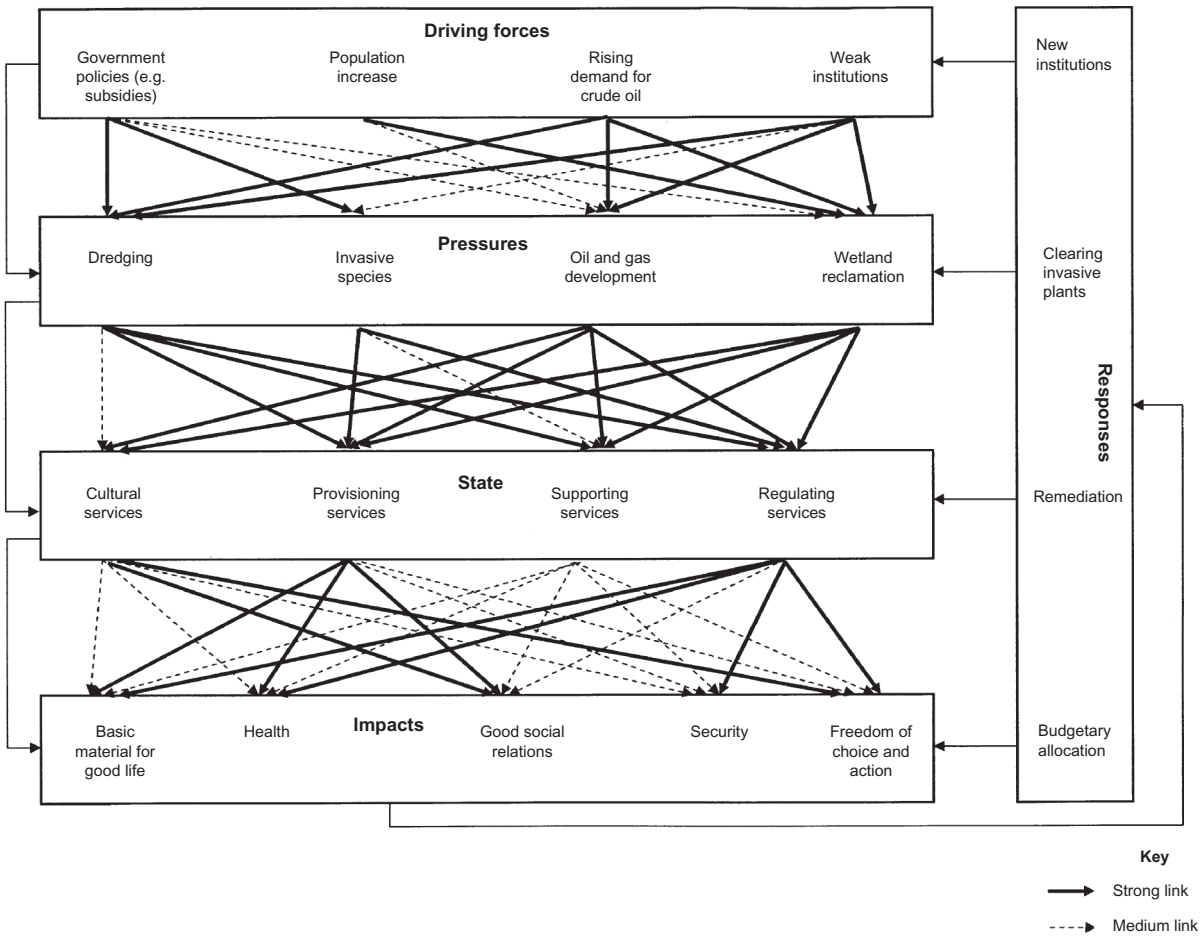

Figure 2. Niger Delta ecosystem services within the DPSIR framework (indicating significant links).
Note: Absence of a link does not imply no influence, only that linkage is weak at best. Some links are not shown but assumed. For example, supporting services are linked to other ecosystem services as it underpins their province; it is possible that rising demand for oil drives government polices and weakens institutions; freedom of choice and action also depends on the other four constituents of human well-being.

Development Company alone operates in over 31,000 km^2 (AIP 2009). The Niger Delta, a fragile environment very sensitive to natural resource exploitation (Ogon 2006), has been highly stressed through these activities. The consequence of exploitation of oil and gas exploration in the Niger Delta has been widely blamed as a main threat to the integrity of the wetland (Uluocha and Okeke 2004; Zabbey 2004; Obot 2007). The process involved in oil and gas exploration in the delta involves sophisticated technology to detect and determine the extent of deposits. The process involves clearing seismic lines of any patch of wetland and dynamiting for geological excavation. The detonation of dynamite in an aquatic environment produces a narcotic effect and mortality in fish and other faunal organisms. Destabilisation of sedimentary materials associated with dynamite shooting causes water turbidity, blockage of filter feeding apparatuses in benthic fauna and reduction of photosynthetic activity due to reduced light penetration (Zabbey 2004).

Oil spills routinely occur in the Niger Delta as part of the oil and gas exploration process (Zabbey 2004; Obot 2007). According to Obot (2007), recent estimates are that between 9 million and 13 million barrels (1.5 million tons) of oil has spilled in the Niger Delta ecosystem over the past 50 years. Two states in the delta, Rivers and Delta, suffer about 300 major oil spills per year (O'Hara 2001). Between 1976 and 1997, there were 5334 reported cases of crude oil spillages releasing about 2.8 million barrels of oil into the land, swamp, estuaries and coastal waters of Nigeria (Dublin-Green et al. 1998). Sources of these spills include pipeline leakage and rupturing, accidental discharges, discharges from refineries and sabotage (illegal bunkering). When it comes into contact with water, oil forms a layer which prevents oxygen dissolving in water and so interferes with the healthy functioning of the ecosystem. Crude oil also contains toxic components, which can cause outright mortality of plants and animals as well as other sub-lethal impacts (Zabbey 2004).

Like oil spillage, gas flaring associated with oil production continued unabated in the Niger Delta. Gas flares contain over 250 toxins such as benzene (Zabbey 2004) which are responsible for loss of vegetation and total burning of the delta's mangrove vegetation that include population of endangered and endemic species (Obot 2007). Flaring

natural gas from oil fields as a by-product of crude oil production is also a common sight that dominates the skyline in the Niger Delta. Local people have complained of respiratory problems such as asthma and bronchitis – health conditions caused by physical or chemical agents associated with crude oil production. The flares also contribute to acid rain and have contributed more greenhouse gases than all of sub-Saharan Africa combined (Friends of the Earth International (FOEI), 2004). However, community efforts to halt or reduce gas flaring in the delta have proved unsuccessful (Bienen 2005).

3.2.2.2. Wetland reclamation. Population increase, industrialisation and urbanisation resulted in an increased demand for space for housing and other infrastructure. Consequently, government have been forced to reclaim marginal lands in the swamps of the Niger Delta (Abam and Okogbue 1993). Wetland reclamation remains one of the top developmental priorities for states in this region (Wolf et al. 2002). Central government support for reclamation is also strong: a past president of Nigeria was recently asked how to create space in the Niger Delta; he simply said 'drain the swampy areas' (Oyatomi and Umoru 2009). Multinational companies, particularly those in the oil and gas industry, also reclaim wetland for their use (Etuonovbe 2007). Reclamation activities change the area from its natural state, radically affecting the provision of ecosystem services and impacting upon the flora and fauna in the delta. Extensive pressure is also exerted on the wetland from road building and forest clearing for agriculture. For example, there is plan to develop about 30,000 hectares of land in the wetland for mechanised farming for large-scale commercial rice, cassava and other associated crop production and processing (UK Trade and Investment 2011). Information on the exact extent of wetland reclaimed is scarce.

3.2.2.3. Dredging. Dredging involves the relocation of underwater sediments and soils. In the delta it is carried out for various social and economic development reasons such as construction and maintenance of waterways, transportation infrastructures and for reclamation and soil improvements. Some of these activities are very large scale. The impending dredging of the river Niger from Baro in Niger state to Warri in Delta State would see over 570 km of channel dredged (Ogah and Odita 2009). During dredging, sediment, soil, creek banks and vegetation along the way are removed and deposited as dredge spoils. Government and oil companies are mainly responsible for dredging (Ohimain et al. 2004), some local businesses are also involved (Etuonovbe 2007). Although, dredging is variously regarded as a major problem confronting the delta (Ohimain et al. 2004; James et al. 2007), little information is available on the exact extent of the problem. Ohimain et al. (2004) indicated that a major oil-producing company generated approximately 20 million m^3 of spoils between 1990 and 1996. Dredging significantly degrades water quality and can harm fisheries. Rim-Rukeh et al. (2007) and Ohimain et al. (2008) showed that dredging is responsible for physico-chemical changes in water of the delta, particularly pH, total dissolved and suspended solids (TDS and TSS), conductivity, turbidity, sulphate, dissolved oxygen, oxygen demand (as biological oxygen demand (BOD) and chemical oxygen demand (COD)). These activities can cause removal of sub-tidal benthic species and communities (such as reduction in the population density and taxa of zooplankton); release of organic matter, nutrients and/or contaminants on aquatic organisms; and disrupt the ambient chemical/physical conditions (such as reduction in light penetration and primary production) (Nayar et al. 2007).

3.2.2.4. Invasive species. Nypa palm is a widespread invasive species introduced from Singapore into the Niger Delta as part of a trial plantation in 1906 (King and Udo 1997; Enemugwem 2009). The plant outcompetes, preys upon, parasitises or otherwise displaces a number of indigenous species (Laë et al. 2004) reducing their growth and survival rate and causing decline and extinction of indigenous plant populations in large areas of the mangrove ecosystem. The Nypa palm has led to decrease in genetic diversity through loss of genetically distinct populations and hybridisation with native species. It has assumed a dominant status in the creeks especially in such areas as the basin of Idua, Assang (Oron Bar), Jaja Creek, Ikineto Creek, Parrot Island, Alligator Island, Strong Face Creek, Uya Oro Creek, Ikot Abasi, Andoni and Bonny Rivers (Federal Environmental Protection Agency 1999). It has also impacted adversely on the socio-economic activities of coastal communities, as it hinders fishing, navigation and fuel wood supply (Isebor et al. 2001). The habitat for migrant marine turtle in Alaska beach, one of the known turtle nesting areas is infested with the weed which sheds leaves and fruits in such abundance that it constitutes and obstacle to the turtle population in surrounding water (United Nations Environment Programme 2007). The local use and economic benefit of the plant is minimal (Udofia and Udo 2005). Hyacinth (*Eichhornia* sp.) is another invasive species in the delta; however, its pressure is minimal compared to Nypa palm, especially towards the coast because it is intolerant to salt water (Akinyemiju 1987).

These four main pressures vary in importance across the Niger Delta. Oil development pressures are most prevalent in oil-producing communities such as Bonny, Ogoni and others along the creeks, whilst reclamation activities are most common in urban centres such as Yenegoa and Port Harcourt. Other pressures highlighted by the review (Table 2) include, perhaps most notably, the indiscriminate use of fertiliser resulting in eutrophication (Obire et al. 2008); the rapid growth of aquaculture (fish, snail, crabs) which will convert mangrove area to shrimp ponds as an economic activity, with consequent wetland impacts (Davies et al. 2009; Zabbey et al. 2010); climate change (Uyigue and Agbo 2007); industrial and domestic effluents

(Ajao and Anurigwo 2002); unsustainable hunting and overfishing (Luiselli 2003; Phil-Eze and Okoro 2009); and damming activities (Abam 1999). According to Abam (1999) there are impoundment of 49 dams in the Niger Delta catchment area with a combined reservoir capacity of 36 million cubic metres which has a direct impact on the wetland. Table 2 shows how these pressures impact upon the main wetland ecosystem services, and indicates their relative importance based on citation and discussion in the literature.

3.2.3. State of the Niger Delta wetlands

The pressures discussed above have contributed to changes in the ecology (state) of the wetland. It is a combination of these pressures impacting the health and the integrity of the wetland that increase the likelihood of abrupt changes in its ecosystem with significant consequences for human well-being (MEA 2005). Although, the rate and extent of changes resulting from each of these pressures is not exactly known, it is very clear that the wetland is being degraded as a result (Twumasi and Merem 2006; James et al. 2007; Coleman et al. 2008). Coleman et al. (2008) reported wetland loss resulting from agriculture and urbanisation to be at a rate of about 5 km^2/year, a figure supported by Ainodion et al. (2002). The World Bank (1995) had earlier estimated that about 10% of the Niger Delta mangroves have been lost due to deforestation from oil exploration and exploitation activities of big multinational oil corporations. Another study has revealed that over 21,000 hectares of the mangrove in the region has disappeared between 1986 and 2003 (James et al. 2007).

Apart from reducing habitat area, clearing of pipeline track delineates natural populations, which in turn distorts biological breeding (Obot 2007). The unique biodiversity of the region has changed drastically and many important species have been lost. Important turtle communities are currently experiencing local extinctions due to catastrophic effects of oil exploration (Luiselli 2009); while hippopotami previously seen in the Bonny area have recently vanished, either deceased or forced on an ecologically destructive migration (Zabbey 2004; Ugochukwu and Ertel 2008). The rich agricultural soils are not spared, as they have been polluted beyond internationally acceptable standards. According to Ana et al. (2009), the physicochemical characteristics of soils in part of the delta indicated that most parameters, such as pH and organic carbon content were at critical levels – eroding important soil nutrients, such as algae (Nwankwo 2001). Due to oil extraction, the Niger Delta has significantly subsided (Ibe 1996). This state of the Niger Delta wetlands ecosystem is so poor that it was recently declared one of the most endangered ecosystems in the world (Nigerian Conservation Foundation 2006). As the state of this ecosystem changes through loss of mangroves and reduction in extent and quality of wetland, ecosystem services are eroded, either directly, or via the interlinking of ecosystem services (ICSU et al. 2008). The ability to provide one group of services depends on the proper functioning of the others (MEA 2005), hence a problem with one will affect the others.

Regulating and provisioning services face the greatest change with all four of the major pressures directly threatening their flow (Figure 2). The link between invasive plant infestation and supporting services is not very clear, which may be connected with the fact that supporting services are less obvious than others. Cultural services appears to be least changed with medium pressure from dredging and no established pressure from invasive species infestation.

3.2.4. Impact on dependent communities in the Niger Delta

There is an inextricable link between healthy natural systems and human well-being (ICSU et al. 2008), and it is evident that the loss of wetland area can result in abrupt changes in ecosystem service provision, with significant consequences for human well-being (MEA 2005). The changes observed in the Niger Delta wetlands have seen a decreased flow of ecosystem services to dependent communities, particularly the destruction of traditional livelihood systems, causing economic harm and human suffering (UNDP 2006).

Impacts on provisioning services are very evident in the Niger Delta. The destruction and death of agricultural and tree crops (Daniel-Kalio and Braide 2002) have denied communities food and a major source of income. A significant relationship between gas flaring and food resources has also been observed: there is premature abortion of fruit and colour changes in leaves contributing to poor crop yields; while fish catches on which inhabitants depend are low due to mortality or migration (Iyayi and Agbeboh 2007). Moffat and Linden (1995) noted that annual fish catch per fisherman fell from 1.88 tons in 1983 to 0.7 tonnes in 1989, and these catches are likely to be lower still today. Communities have also been exposed to pollutants with health implications (Avwiri and Nte 2003), particularly that from polluted freshwater streams and rivers (Ajao and Anurigwo 2002). A June 2001 oil spill in Ogdobo community destroyed the only source of drinking water for 150,000 people and children reported skin and eye problems after swimming in the oil-contaminated river (FOEI 2004; AIP 2009). Fish contaminated with oil and other toxins also pose significant health risks (Fentiman 1996). The loss of important biodiversity (Ugochukwu and Ertel 2008; Omofonmwan and Odia 2009; Phil-Eze and Okoro 2009) including medicinal flora and fauna (Ndukwu and Ben-Nwadibia 2005) have deprived the delta's communities a host of benefits (direct and indirect) with further significant implications for health.

The changes in the wetland have also resulted in communities been exposed to natural hazards (Olajire et al. 2005; Omeje 2006). There have been recent reports of unprecedented flooding in the delta, inundating thousands of homes and businesses, and forcing families to relocate (Oyadongha 2009). According to Opukri and Ibaba (2008),

there are strong links between oil-based environmental degradation and displacements in the Niger Delta. A local commentator noted that sacred shrines and places of worship have been opened up for drilling and exploration for oil, and ancient landmarks pulled down and in some cases destroyed: 'We are now like a people without a past' (Bisina 2006). This illustrates a significant loss of cultural value to local communities. Moreover, employment and job opportunities (as fishermen, farmers, hunters, ferry men, etc.) have declined, and intense poverty is becoming entrenched (Aluko 2004). Degradation in the delta is also lowering the resilience of people to climate change impacts (Uyigue and Agbo 2007).

The adverse impacts (costs and risks) of changes to Niger Delta ecosystem services is increasing, and most worryingly, the impacts fall disproportionately on the poor (Jike 2004). Aluko (2004) noted that most of the oil activities are located in the rural area, far from the urban centres. The rural poor are more directly dependent on natural resources than the rich urban dwellers that often have the means to provide substitutes. Thereby, the already high poverty level in the delta is exacerbated as poor communities loose livelihood resources. They must obtain cash to buy some of the services they previously (before the discovery of crude oil in 1956) would have collected for free from the wetland, or be forced to engage in unsustainable practices by exploiting marginal lands. Loss of medicinal species will inevitably put community health at risk and as cultural heritage is lost, communities become dejected. Social consequences of wetland degradation thus include poverty and frustration, resulting in communities lashing out at one another or at national and regional government or even at the multinational corporations and foreigners. In summary, the implication of the changes in the state of the Niger Delta wetland is inability of the wetland to (continually) support the basic constituents of human well-being (basic material for good life, health, good social relations, security and freedom of choice and action) identified by MEA (2005).

The importance of the Niger Delta wetlands transcends national to global significance. In the same vein, impacts of pressures may be transmitted several hundred kilometres to regional and even global scale. Scheren et al. (2002) point to the movement of pollutants from the wetland into regional water (Gulf of Guinea), and according to FOEI (2004) the flares from the Niger Delta have contributed more greenhouse gases than all of sub-Saharan Africa combined. This underscores the importance and relevance of researching and managing wetlands on a regional scale.

3.2.5. Responses to DPSI

Government responses have targeted some of the problems discussed above, although such measures are often ineffective with respect to the Niger Delta. For example, in 2001, Nigeria signed the Ramsar Convention on Wetlands of International Importance. International funding and conservation projects followed, but these were focussed on the Hadejia-Nguru wetland in northern Nigeria, stopover point for birds migrating from Europe. Despite being more fragile and most important to the survival of Nigeria, the numerous laws and institutions in place to address the objectives of the Ramsar Convention appear to have achieved little for the Niger Delta wetlands. This is largely due to the nature of the indirect driving forces discussed above. One important institution – the National Environmental Standards and Regulations Enforcement Agency – was established to regulate and enforce environmental standards through protection and development of the environment, biodiversity conservation and sustainable development of Nigeria's natural resources. The act establishing the agency stipulates that National Environmental Standards and Regulations Enforcement Agency has powers to evolve and review existing guidelines, regulations and standards on the environment except with respect to the oil and gas sector. Making the oil and gas industry exempt in this way has sent the wrong signal to operators in the sector, and indicates that the government is willing to dispense with conservation objectives when they challenge economic objectives. Such lack of ambition and foresight on the part of the government is not helping management of the Niger Delta wetlands.

Clearing invasive plants is the main response to the fourth dominant pressure described above, yet even here, adequate funds and manpower are not provided. Efforts at remediation are also costly and with weak institutional arrangements, oil companies are less accountable. Some federal, state and local government institutions do recognise the seriousness of the declining status of the Niger Delta wetlands and make conservation funds available but corruption often mean such monies are diverted. Moreover, some ecosystem services, such as sacred groves have no substitutes/alternatives that can be purchased with any monies made available. Overall, most government responses to ecosystem decline have been half-hearted, causing local communities to respond by campaigning and drawing global attention to the un-remediated environmental damage in the delta. This started as a peaceful agitation, but has since turned violent (O'Hara 2001).

4. Discussion

Using frameworks such as the DPSIR to analyse changes in ecosystem services is now gaining ground as a way to evaluate ecosystem changes and their implications for human well-being. The DPSIR framework has potential as an important tool in communicating with and amongst the policy community in developing societies like Nigeria. However, the framework is only able to capture the key relationships between society and the environment, and is arguably too simplistic to capture other interactions whilst also acting as an effective analytical and communication tool. Interactions between drivers are not visible; neither is the fact that other categories of services depend on supporting services and other constituents of human well-beings are important for freedom of action and choice.

Nevertheless, our study was able to use the framework to identify the ecosystem services provided by the Niger Delta wetlands, and the major pressures that threaten their continued supply, considering particularly the benefits that flow to local wetland users. Overall, we find that the Niger Delta wetlands provide a diverse range of ecosystem services that are important to the livelihood of local people. Key ecosystem services include resource provision (particularly timber, salt and raffia), food (fish, snail, spices, Ogbono), buffering against natural disasters, provision of medicinal plants important for healthcare and support of cultural fishing festivals. The wetlands also provide a major sink for greenhouse gases, providing benefits beyond the region. However, the ecosystem has experienced major changes due to development pressures, particularly those from oil and gas exploitation, dredging, land reclamation and introduction of invasive species.

The main pressures on the Niger Delta wetlands are similar to in some respects to those widely blamed for wetland loss internationally and elsewhere in Africa (Emerton et al. 1999; Schuyt 1999; Turpie et al. 1999; Turpie 2000). Conversion to agricultural and urban land is responsible for the loss of about half of all wetlands globally in the twentieth century (Bruland et al. 2003; Rijsberman and Silva 2006). In the Niger Delta, conversion to agricultural lands is minimal, but conversion for urbanisation, that is wetland reclamation for residential, industrial and other developments, is prevalent. In addition, the Niger Delta is similar to other mineral-rich wetland ecosystems where mining activities are a pressure (Castilla and Nealler 1978; Parulekar et al. 1986; Holopainen et al. 2003). We also find that, for the most part, the principal pressures are those which do not derive directly from local community activity, which must go some way to explain why these communities perceive themselves as 'victims' of environmental change in the delta. However, the role of local communities in contributing to such pressures has been given little attention, and research is needed to better understand how such communities contribute to the changing provision of wetland ecosystem services. For example, one cannot dismiss the impact of acts of sabotage which often result in spills, such as the 1998 Jesse community pipeline explosion that claimed over 2000 lives (Onuoha 2006). The exact proportion of oil spills in the Niger Delta caused by sabotage (bunkering and vandalising pipelines), as opposed to equipment failure or human error on the part of oil multinationals is unknown because data on the causes of oil spills in the Niger Delta has never been subject to independent or effective monitoring or verification.

Of the principal ecosystem service groups, we find that provisioning and regulating services are under the most pressure, being affected by all four of the key pressures identified in the review. Cultural services appear to be the least impacted, principally under pressure from oil and gas exploration activities and wetland reclamation (Figure 2). Literature on the link between ecosystem services and human well-being in the delta is sparse, and characterising this link has necessarily relied to some extent on personal observations to support evidence drawn from the literature. With this caveat, we conclude that the loss of provisioning and regulating services will have the greatest impact on livelihoods in the Niger Delta, although the other services are clearly also important for human well-being. This is consistent with studies of other African wetlands which have noted the importance of wetlands to provisioning (Eaton and Sarch 1997; Adekola et al. 2008; Lannas and Turpie 2009) and regulating services (Acharya and Barbier 2000; Dixon and Wood 2003), whilst not denigrate the importance of cultural or supporting services.

Our study characterises how the pressures on Niger Delta wetlands will change the supply of ecosystem services. The little evidence on cultural services may be a result of the lack of knowledge of the status and value of most cultural ecosystem services. Some cultural services are poorly understood as they are shrouded in secrecy. Provisioning and regulating services are better understood, and are mostly strongly connected to human well-being. The link between provisioning services and good social relations is very evident too, as in the Niger Delta; lack of access to provisioning services is a major source of tensions. For example, Naagbanton et al. (2009) note that trans-boundary wood exploitation (i.e. one community pushing into another community mangrove area) seems inevitable, and has the potential to trigger inter-communal conflict. The importance of provisioning services to human well-being have often led to societies trading-off other services such as supporting services, even though, by definition, they are necessary for the production of the other service types. They differ from provisioning, regulating and cultural services in that when degraded, their impacts on people are often indirect and/or occur over a very long time, whereas changes in the other service types have relatively direct and short-term impacts (MEA 2005). This explains the seeming medium linkage of supporting services to all constituents of human well-being (Figure 2).

Our analysis indicates that weak governance in administrative and legal institutions leads to ineffective alleviation of pressures on the wetland. This is consistent with the recognition of institutional factors as important drivers of environmental change (Young 2002). Thus, governance must be regarded as a key driver of ecosystem change in the Niger Delta. Many studies, including the MEA (2005), emphasise the political drivers of wetland change. This is very evident in most Niger Delta research, which clearly displays a lack of research into the socio-political drivers of wetland change. Greater attention on the indirect drivers of change in the delta is needed, including the use of approaches that link the social and ecological sciences, to enable the examination of the full causal chain running from the indirect drivers through the direct drivers to ecosystem change (ICSU et al. 2008).

From our review, several knowledge gaps can be identified, which if addressed, would enable a more complete understanding of Niger Delta wetlands ecosystem services, and their sustainable management. First, a more detailed understanding of the principal threats to the Niger

Delta wetlands identified in this review is needed. Unlike most wetlands, whose principal threat comes from agriculture (Tiner 1984; Rijsberman and Silva 2006), oil and gas exploration, reclamation for residential, industrial and other purposes, dredging activities and invasive plant infestation emerge as prominent threats eroding the Niger Delta wetland. Whilst we know these are the most prominent threats, we do not know the extent to which each threat has changed wetland ecosystem services; where the threats mostly occur and the ecosystem services most affected. An empirical study to ascertain these will be necessary for planning and management of the Niger Delta wetlands.

Second, a lack of research and documentation means that the extent to which each ecosystem service contributes to human well-being is not sufficiently understood (World Bank 1995; Ebeku 2004). This lack of information constrains management decision-making, as connections between ecosystem services and human well-being are not always clear, and the value of the ecosystem services are usually unknown (and hence are excluded from cost–benefit appraisals). Further key information on Niger Delta ecosystem services, needed to support sustainable resource management, is thus urgently needed. These needs include information on the value placed on different ecosystem services by various user groups; the quantity of ecosystem services collected/used and how and for what purpose they are used. Such information will serve to improve the general understanding of ecosystems and their values in the Niger Delta and to extend the evidence base that characterises connections between ecosystem services and human well-being. Until such information is generated, the nature of the contribution that Niger Delta ecosystem services make to human well-being in the region will remain highly uncertain.

Third, there is a need to understand more fully the nature of the ecosystem services benefits flowing to communities. Ecosystem services can be valued (Bingham et al. 1995; Howarth and Farber 2002), with some authors emphasising the importance of economic valuation as a means of assessing the contribution of wetlands to human well-being (see Turpie et al. 1999; Balmford et al. 2002; Mmopelwa 2006). However, commoditisation of ecosystem services in such an African setting in which ecosystem services are essential beyond their economic value will be misleading and may not yield the required management outcome. An income-dominated perception will focus only on the cash income that can be generated from an ecosystem. A socio-cultural view of ecosystem services such as medicinal plants moves beyond simply the economic value, to the health impacts and importance for traditional rituals. Therefore, employing the different perceptions of economic, ecological and socio-cultural values (Farber et al. 2002) is essential to better understand the contribution that wetlands and their ecosystem services make to human well-being. Such information can, among other things, aid development of a framework for compensation for damage to natural resources in the Niger Delta wetland region and aid evaluation of alternative development options by quantifying the full costs and benefits associated with different wetland use options. To begin with, there is need to identify and understand those people (individuals and groups) using and benefiting from the wetland. This is the type of information Coomes et al. (2004) advocated as essential to aid effective targeting of conservation-development initiatives by understanding, with whom specifically, conservation efforts should be focused.

A fourth knowledge gap relates to the actual operation of institutions (formal and informal), with respect to Niger Delta wetlands ecosystem services. Although, there are numerous legal regimes to protect several aspects of the Niger Delta ecosystem (Ebeku 2004; Ugochukwu and Ertel 2008), destructive activities still continue. One would imagine why threats to such an important ecosystem persist despite availability of formal institutional frameworks. According to Blaikie (1985), answers lie in a political-economic context. A possible explanation is that, since crude oil from the delta is the economic lifeblood of Nigeria, economic, political and administrative measures ensure that exploration and production activities are screened from *hostile* interventions (Ebeku 2004). Thus, legal and formal institutional frameworks are rendered ineffective, through the adoption of informal institutions. This underscores the need to explore the political dimensions of Niger Delta wetland change. It is analysis of this aspect of ecosystem change that political ecologists argue for (Bryant and Bailey 1997; Forsyth 2004; Robbins 2004).

While the prominent threats identified in this review implicate oil multinationals, elites and the political class, this should not take attention away from possible eroding activities of local communities. Studies from other parts of Africa have suggested that very often wetlands are degraded by the same people whose livelihoods depend on them (Schuyt 2005). In the Niger Delta there is evidence of communities engaged in unsustainable hunting, overfishing and excessive logging for fuel wood (Luiselli 2003; Luiselli et al. 2006; Phil-Eze and Okoro 2009; Zabbey et al. 2010). Therefore, emphasis on oil multinationals, elites and the political class, whilst neglecting the probable degrading actions and institutions of local communities will prove detrimental to wetland management in the long run. All these users of the wetland operate within informal institutions in addition to any formal ones they belong to, but it is not very clear how these informal arrangements amongst users affect the formal institutions. An important line of enquiry is to understand how formal and informal institutions governing the use of the Niger Delta wetlands interact and give rise to various outcomes. Understanding this process can then lead to knowledge about what type of interventions might result in sustaining ecosystem services. Study of institutions may also help reveal existing indigenous knowledge governing the use of Niger Delta wetlands, which should promote improved decision-making with respect to wetlands ecosystem services (Speranza et al. 2008).

Many researches present African communities as though they are homogeneous, but in reality institutions in Africa are diverse and fragmented (Elbadawi and Sambanis 2000). Failure to recognise this heterogeneity has led to generic recommendations, most of which have failed to achieve their intended objectives. This means that the use of the term *community* in its geographical context as though such *community* are homogeneous may not hold for African societies. The truth is that homogeneous communities necessary for such generalisation barely exist in Africa (Booth 2009). To promote effective management and develop an effective evidence base, it is important to revisit the concept of community, describing how things work in an African context. The Niger Delta is suitable site to generate such knowledge considering the varying interests, views, perceptions, institutions and uses of the wetland.

Finally, a major knowledge gap revealed by this review is a lack of adequate evidence to characterise the beneficiaries and losers as ecosystem services change in space and time. Many studies have taken a global approach in this respect, and have generally viewed multinational oil companies, government and elites as winners and the local communities as losers (FOEI 2004; AIP 2009). While this may be correct, evidence to support this is insufficient. Besides, most of these studies have focused on the broad-scale inequality and have neglected possible inequality existing at the local level, such as within a community. Mapedza (2006) warned that research should not be blind to the autocratic and biased nature of some traditional leaders, and the implications this will have for distribution of ecosystem services at a local level. A characterisation of the distribution of access to, and benefit from, ecosystem services (in time, space and by user at global to local scales) will enhance our understanding of the complex social and political dynamics that are key determinants on the ability of wetlands to continually provide ecosystem services, and hence sustain livelihoods.

5. Conclusion

Our study has reviewed the ecosystem services provided by the Niger Delta wetlands within the context of the DPSIR framework which, although has its limitations, proved to be a useful framework for structuring the analysis. We find that the key services are those relating to provisioning (food, physical resources, medicinal products), and regulating services (particularly a buffer against natural disasters) although significant cultural services are also evident. The main threats to the wetland are oil and gas exploration, dredging, reclamation and introduction of invasive species. There is a strong link between these four main pressures and changes in provisioning and regulating services of the Niger Delta wetlands.

A series of knowledge gaps are evident, which hamper development of sustainable management. These relate to more detailed knowledge of how and where the four main development pressures affect the distribution of ecosystem services in space and time; how, precisely, ecosystem services contribute to human well-being in the delta; characterisation of the full value of Niger Delta wetland ecosystem services, recognising both its economic and non-economic components; how formal and informal institutions operate to modify the flow of ecosystem services benefits; and finally, how such benefits, or loss of such benefits, are distributed amongst such groups and communities, within and without the delta.

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Notes

1. Ecosystem services are the benefits provided by ecosystems to humans (Millennium Ecosystem Assessment 2005).
2. The Convention on Wetlands of International Importance especially as Waterfowls Habitat (the Ramsar Convention on Wetlands).
3. Computed from 2006 census data available from www.population.gov.ng/.
4. At a 1995 official exchange rate of N22 = $1.

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