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Structure and diversity of fish communities in man-made ponds of the Niger Delta (southern Nigeria)

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ABSTRACT

1. A survey of eight local earthen hand-dug ponds located within the freshwater swamps of a Niger Delta area (southern Nigeria) was conducted over a period of 3 months. A total of 4,313 fishes representing 19 species from 12 families were recorded.
2. The most abundant species was *Xenomystus nigri* (905 individuals), whereas the least common was *Protopterus annectens* (13). Cichlidae and Clariidae counted three species each, whereas Anabantidae, Hepsetidae, Mochokidae, Protopteridae, Phractolaemidae, Malapteruridae and Gymnarchidae were represented by a single species each.
3. A lotic species, *Synodontis* sp., was recorded possibly as a result of the episodic flood of 2012.
4. The Engenni swamps harbour a moderately diverse ichthyofauna. Regulations should be put in place to further enhance the fisheries potential of these local ponds.

KEYWORDS

Ichthyofauna, Floodplain ponds, Species diversity, Conservation, Engenni, Niger Delta.

INTRODUCTION

Freshwater fish communities are an essential component of aquatic ecosystems (e.g. Albaret et al. 2004; Mann 2009) and play a crucial role in local subsistence economies in most tropical regions of the globe (e.g. FAO 1990; Moses 1992; Sikoki et al. 1998; Lévêque and Paugy 2006). The extensive flooded forests of Central and West Africa (such as along the Congo River and in the delta of the Niger) are major hotspots of fish biodiversity (Olson and Dinerstein, 1998; Elaikhame, and Sikoki, 1998; Carr et al., 2014; Mallon et al., 2015). These large forested floodplains are characterised by long periods of inundation and extensive marginal wetlands (Niger Delta Environmental Survey, 1998) and tend to host high species numbers with a large proportion of endemic species (Roberts and Kullander, 1994). However, because of their economic relevance, fish communities have been heavily altered by human intervention also in these megadiverse habitats of tropical Africa. In a recent meta-analysis, Amadi et al. (2019) showed that in wetlands associated to the Niger delta, fish assemblages were generally characterised by low evenness, with 90% of specimens belonging to over a quarter of the overall number of taxa, and were strongly dominated by species of aquaculture interest (especially tilapiine cichlids).

In the swamps and flooded forests of the Niger Delta, fish farming is an important source of business (Abowey 2000; Amadi et al. 2019). Man-made ponds, more or less isolated from the river, are stocked with dense fish biomass and supply markets mainly with farmed catfish and tilapia (Akari 1992; Abowey 2000; Allison et al. 2007). At the same time, in many rivers such as Brass (Sikoki et.al. 1998), Nun (Abowei 2000), Kolo Creek (Alfred-Ockiya et al. 1998), Bonny (Chinda and Osuamkpe 1994) and Orashi (Akari 1982), native fish communities are depauperated by overfishing and show typical signs of "fishing-down" as anticipated by Lae for the Niger Delta (Laë 1995) and described in greater detail for the Ouémé River in Benin (Welcomme 2001). These altered fish communities are characterised by a preferential loss of large-size species leading to a dominance by 0 and 0+ cohorts, with an increase in secondary productivity, but with an overall reduction of the value of the fish catch.

In this paper, we assess fish diversity in eight man-made ponds of the Niger Delta subject to traditional fishing activities by the Engenni indigenous community, believed to belong to the very early settlers of the Niger Delta, and to concomitant environmental stress because of industrial activities and oil spillage (Niger Delta Environmental Survey, 1998). We aim at characterising their diversity metrics and their community structure.

1. MATERIALS AND METHODS

1.1. Study area

The study was conducted in eight randomly selected man-made ponds in Engenni, Rivers State, Nigeria. The Engenni community resides along the Orashi River, running from Oguta in Imo States up to Akpedan in central Abua (Abua/Odual Local Government Area, Rivers State). In the area where the eight ponds are located, the Orashi River current is sluggish and its banks are mostly covered by gallery forest (Niger Delta Environmental Survey, 1998). The Orashi is a hard whitewater tributary of the Niger and is one of the most important areas for the biodiversity conservation in the region (e.g. see Akani et al. 2014; Luiselli et al. 2015), with a typical fish community characterised by Nilo-Sudanian savannah species and less forest species (Teugels and Powell 2004). Its waters are less acidic, have higher conductivity, have higher nutrient content and are less transparent than the blackwater tributaries that characterise the eastern portion of the Niger system (i.e. Sombreiro and New Calabar rivers; Thieme et al. 2005).

The eight sampling ponds (Figure 1) are situated within a floodplain forest that has been inhabited for about a millennium by the Engenni ethnic group (Ahoada-West Local Government Area of Rivers State). The Engenni floodplain is located within the Guinea-Congolian rain forest zone (White 1983) and constitutes the northern portion of the Niger Delta at the boundary between Rivers and Bayelsa States.

The tropical climate of the study area is characterised by a relatively well-marked alternation between a dry and a wet season. The dry season extends from November to April, whereas the wet season lasts from May to October, with a high rainfall peak in July. Mean monthly maximum temperature ranges between 27 and 34°C, whereas the mean monthly minimum varies between 22 and 24°C (NDES 1998). The region is one of the wettest of the world, with an average yearly rainfall above 3,000 mm year^{-1}. Vegetation within the floodplain forest includes emergent trees measuring 12–16 m high, such as *Terminalia ivorensis*, a hardwood species subject to overexploitation, *T. superba*, *Irvingia gabonensis, Elaeis guineensis*, with an understorey dominated by *Raphia* palms (*Raphia vinifera, R. hookeri*), *Alchornea cordifolia*, *Ficus exasperata* and *Bambusa vulgaris*. The huge *Terminalia* trees shelter the ponds from di-

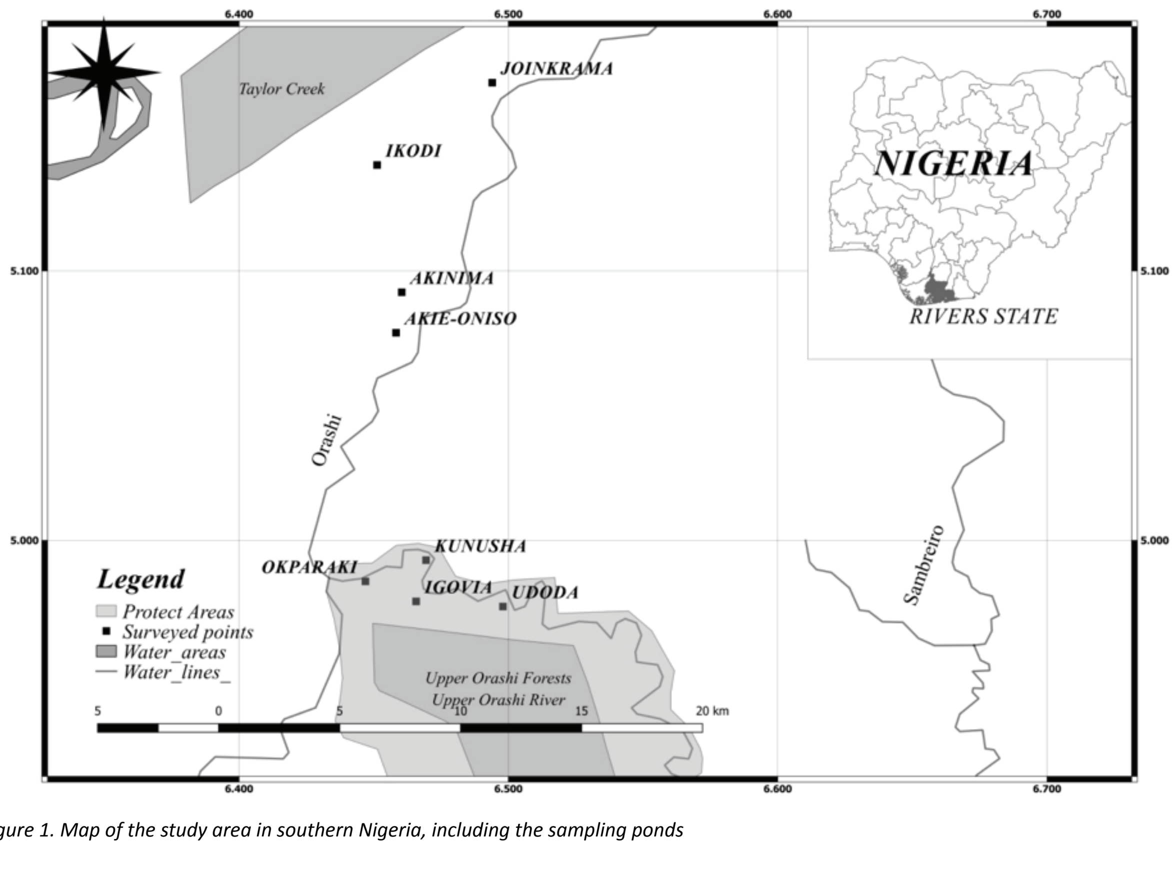

Figure 1. Map of the study area in southern Nigeria, including the sampling ponds

rect irradiance and reduce air movement, moderating evaporation. Floating macrophytes, particularly *Pistia stratiotes*, *Ceratophyllum demersum*, *Azolla* sp. and *Lemna* sp., typically cover the pond surface, whereas water hyacinth *Eichhornia crassipes* is becoming common while it increases in distribution and abundance across the region.

1.2. Fish stock harvesting protocol

Clarias and tilapias were the fish species usually introduced by humans for pisciculture practices in the ponds of the study area (our unpublished observations). Fish stocks were harvested during the 2016 dry season, while the Orashi River overflow was receding, and until the beginning of the 2017 wet season (from February to late May). Fish harvesting was conducted by scooping water out of the ponds for several hours using various sizes of buckets, until fish became exposed, lying on the clayey substrate. Fishes were caught mostly alive, collected by hand or lifted in basket traps; in all cases, the entire available stock was harvested at the end of operations.

In February 2017, before ponds were emptied, pre-arrangements were made with the pond owners for allowing us to assist during the stock harvest operations and to record fish catch data. Measurements such as length, width and depth of the various ponds were taken to determine pond volume and size. Collectively the ponds surveyed covered a surface of 162 m^2 and a volume of 262 m^3 (see Appendix 1). Pond VII was the largest in size, with a surface of 35 m^2 and a volume of 59.5 m^3, whereas the smallest pond was no. V with an area of 17.3 m^2 and a volume of 27.3 m^3.

Individuals of each fish species that were caught from each pond were recorded and identified to species level using Reed *et al.* (1967), Gourène and Teugels (1991), Lévêque et al. (1990) and Idodo-Umeh (2003).

1.3. Statistical analyses

In order to illustrate patterns of species composition, evenness and dominance, and to interpret diversity patterns among the 8 stations, the following indices were calculated (Magurran 1988): (1) number of species observed; (2) number of individuals harvested; (3) dominance index, that is, 1–Simpson's index, ranging from 0 (all species are equally abundant) to 1 (one species dominates the entire community); (4) Simpson's diversity index, also ranging from 0 to 1; (5) Shannon's index, varying from 0, for communities with only a single taxon, to high values, for communities characterised by many taxa but each having few individuals; and (6) Buzas and Gibson's evenness (Harper 1999). Bootstrap analysis was applied to generate upper and lower confidence intervals of all indices, with 9,999 random samples, each with the same total number of individuals as in each original sample being generated (Harper 1999).

A paired group (UPGMA) dendrogram, with Euclidean distances as similarity index, was used in order to show the dissimilarities among ponds in terms of fish community composition and abundance of the various fish species.

The data distribution of each variable was tested for normality by the Shapiro–Wilk test, and when normality was rejected ($P < 0.05$) a log transformation was applied before performing parametric statistics. Correlation analysis between two log-transformed variables was carried out by Pearson's correlation coefficient. Alpha was set at 5%, and all tests were performed with PAST 3.0 version statistical software.

2. RESULTS

From the 8 ponds, 19 species belonging to 12 families were harvested, for a total of 4,313 individuals (Table 1). Saturation curves revealed that all study areas were accurately sampled (Figure 2A), and that their diversity profiles were similar (Figure 2B). The African knifefish *Xenomystus nigri* (Notopteridae) was the commonest species in terms of individual counts and represented almost 21% of the total number of individuals. The least common was *Protopterus* sp. (Protopteridae, only 0.3% of the total). Overall, the families Cichlidae and Clariidae were the most harvested, followed by Channidae, Notopteridae and

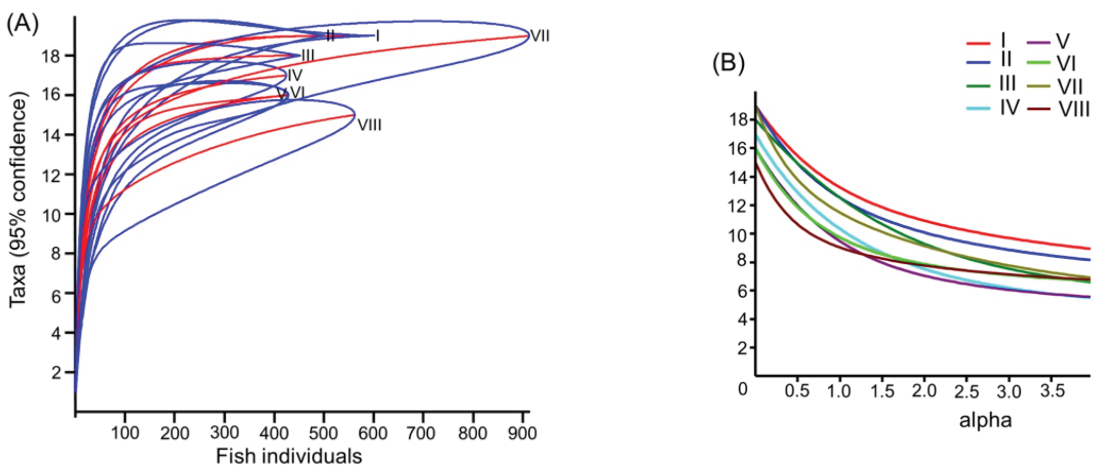

Figure 2. *(A) Saturation curves (with 95% confidence intervals after 9,999 bootstraps) and (B) diversity profiles (95% confidence, after 9,999 bootstraps), for the community diversity of fish in the eight stations at the southern Niger Delta. Symbols: I to VIII = study ponds*

Table 1. Summary of the various fish species harvested from each of the studied artificial ponds in the Upper Orashi area, southern Nigeria.

				Ponds					
FAMILY/SPECIES	I	II	III	IV	V	VI	VII	VIII	TOTAL
Anabantidae/*Ctenopoma kingsleyae*	10	3	2	1	0	0	30	1	47
Cichlidae/*Hemichromis fasciatus*	30	25	30	26	20	28	60	33	252
Tylochromis sp.	20	15	10	7	11	5	45	2	115
Hemichromis bimaculatus	10	5	15	0	10	8	3	8	59
Clariidae/*Clarias macromystax*	50	40	37	20	7	15	50	42	261
Clarias camerunensis	52	32	21	14	20	36	39	22	236
Gymnallabes typus	5	3	7	2	0	1	9	0	27
Channidae/*Parachanna africana*	49	54	32	27	45	60	80	49	396
Parachanna obscura	20	14	12	20	11	8	32	50	167
Gymnarchidae/*Gymnarchus niloticus*	5	3	8	7	4	2	1	0	30
Hepsetidae/*Hepsetus odoe*	60	71	49	54	71	62	102	93	562
Mochokidae/*Synodontis* sp.	73	48	55	63	71	82	105	107	604
Notopteridae/*Papyrocranus afer*	32	20	15	33	26	21	53	51	251
Xenomystus nigri	104	92	107	114	109	76	205	98	905
Malapteruridae/*Malapterurus electricus*	15	10	14	8	7	12	10	2	78
Phractolaemidae/*Phractolaemus ansorgii*	52	42	20	3	0	8	82	3	210
Polypteridae/*Polypterus* sp.	7	8	11	15	1	0	1	0	43
Erpetoichthys calabaricus	6	15	9	10	11	2	3	1	57
Protopteridae/*Protopterus* sp.	3	2	0	0	5	0	3	0	13
TOTAL	603	502	454	424	429	426	913	562	4,313

Table 2. Summary of the diversity indices calculated from each pond.

Pond	No. species	No. individuals	Dominance	Simpson	Shannon *H*	Evenness
I	19	603	0.09	0.91	2.58	0.70
II	19	502	0.10	0.90	2.53	0.66
III	18	454	0.11	0.89	2.53	0.70
IV	17	424	0.13	0.87	2.34	0.61
V	16	429	0.14	0.86	2.25	0.59
VI	16	426	0.13	0.87	2.28	0.61
VII	19	913	0.11	0.89	2.44	0.60
VIII	15	562	0.13	0.87	2.20	0.60

Polypteridae (Table 1). The harvested amount varied remarkably across ponds. Fish catch was most abundant in pond VII (21.2% of the total fish harvested), whereas the least productive was pond IV (9.8%).

(Log)-transformed pond surface area positively influenced the (log) number of harvested fishes ($r = 0.953$, $n = 8$, $P < 0.001$), and the same was true for (log) pond volume against (log) number of harvested fishes ($r = 0.947$, $n = 8$, $P < 0.001$). Inter-pond variations in diversity index value were relatively minor (Table 2) and diversity indices were not significantly influenced by pond size. For instance, the dominance index did not correlate significantly with pond surface ($r = -0.242$, $P = 0.563$) or pond volume ($r = -0.206$, $P = 0.624$), and Simpson's index had opposite direction in its correlation with pond size, but with no statistical significance (pond area: $r = 0.261$, $P = 0.532$; pond volume: $r = 0.223$; $P = 0.594$).

UPGMA dendrogram showed that only pond VII (Akinima) was considerably different from the other ponds in terms of fish community composition and abundance of the various species (Figure 3). Interestingly, Akinima was by far the largest of the eight investigated ponds (Appendix 1).

3. DISCUSSION

The present study recorded a lower species diversity than previously recorded in other man-made ponds in the Niger delta

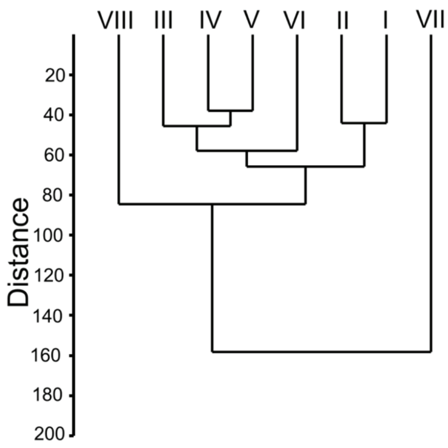

Figure 3. UPGMA dendrogram, with Euclidean distances as similarity index, showing dissimilarities among ponds in terms of fish community composition and abundance of the various species

(for instance, Ezekiel [2002] in 10 local fish ponds in Odiokwu Ekpeye recorded 24 species belonging to 16 families), and obviously a much lower diversity than the one observed in natural water bodies from the same area; Alfred-Ockiya [1998] in Kolo creek in Bayelsa State recorded 41 species from 28 families; Nwadiaro [1989] in Oguta Lake identified 98 species; Alison et. al. [1997] in Elechi creek identified 37 species from 22 families; and Ibim *et. al.* [2016] recorded 61 species belonging to 54 genera in New Calabar River Niger Delta.

Differences in fish assemblages have been attributed to differences in physico-chemical characteristics, water body size, nature and composition of the bottom substrate, choices of gear used during the survey, as well as conservation status (White 1983; Ezekiel 2002). The fish community composition in our floodplain ponds was heavily influenced by fishermen who frequently introduce fingerlings of commercial species in the attempt of increasing ecosystem productivity. At the same time, it was modulated by the periodic addition of native species introduced by seasonal floods as the ponds become inundated by River Niger tributaries during the tropical rainy season.

As discussed by Jackson et al. (2013), pond communities undergo an environmental filtering caused by the restrictive physico-chemical conditions that typically develop within floodplain ponds that become disconnected from running waters. These are high daily excursions in dissolved oxygen with potentially lethal minima, occasional high temperatures and low transparency. During the receding limb of the hydrograph, fish species that are able to adapt to the disappearance of lotic habitats and to the ensuing physico-chemistry will prosper and grow rapidly under the highly productive conditions that are typical of the floodplains of whitewater rivers such as the Orashi (high temperature and high nutrient levels). As the drawdown continues, predation will tend to progressively establish as a second factor of selection that will eventually dominate the fish community. Predation will be exerted in particular by lentic predators that do not only rely solely on vision, but that are also adapted to sub-optimal oxygenation. Members of the Channidae family, in particular the snakeheads *Parachanna*, are good candidates in matching these biological traits. Predictions made by this mixed model determined by environmental filtering + predation were largely confirmed by our recordings, albeit with few surprises.

The most abundant species (*X. nigri,* Notopteridae) recorded in our survey was a swamps dweller, very common in shallow ponds all over the Niger Delta area and also in the ponds studied by Ezekiel (2002) at Odiokwu, Rivers State. It is known to rise to the surface and gulp air; it can then absorb oxygen using a dedicated gas bladder lined with a highly vascularised epithelium (Greenwood 1963 Jackson et al. 2013). Another species that could have been expected in the eight ponds was *Protopterus sp.* (Protopteridae), characterised by a paired heavily vascularised and elongated cylindrical organ serving as 'lung', which allows members of this family to breathe atmospheric air. Similarly, well adapted to low oxygen environments were the Clariidae and the Anabantidae, some of which, such as *Ctenopoma kingsleyae*, possess supra-branchial organs, whereas the hingemouth *Phractolaemus ansorgii* (Phractolaemidae) displays a ventral modified swim bladder that can function as a lung. Despite their adaptations, *Protopterus* and *Gymnallabes typus* (Clariidae), known to breed and feed within floodplains, were the least common in our pond records, possibly because both species tend to aestivate by digging deep holes within the pond substrate, and can remain unnoticed by fishermen until the next season (Holden and Reed 1972). Additional air-breathers included another Clariidae (*Clarias* sp.), other Cichlidae (*Hemichromis fasciatus, Tylochromis* sp.), as well as the Channidae *Parachanna sp.* Species of Channidae and Anabantidae are able to dig burrows within the wet sediment to resist drought and to move overland in search for more convenient habitats (Jackson et al. 2013 and references therein).

Most fish species encountered in our study ponds, such as *H. fasciatus* (Cichlidae), *Tylochromis* sp. (Cichlidae), *Parachanna* spp. (Channidae), *X. nigri* (Notopteridae), *Papyrocranus afer* (Notopteridae), *Malapterurus electricus* (Malapteruridae), *Clarias* sp. (Clariidae), *Gymnarchus niloticus* (Gymnarchidae), *C. kingsleyae* (Anabantidae), *Protopterus* sp. (Protopteridae) and *Phractolaemus ansorgii* (Phractolaemidae), were also frequently observed in the ponds of Odiokwu (Ezekiel 2002) and are widespread within Niger Delta area (Amadi et al. 2019).

Interestingly, we also recorded the presence of a *Synodontis* catfish (Mochokidae), a typical riverine taxon rather than a pond dweller. It was present in all eight ponds, accounting for 14% of the total fish population harvested. Most of the individuals were juveniles, 7.8–8.2 cm long. Their presence suggests that adults could have been spawning within the ponds during the rainy season and receding back to the river during drawdown. Local fishermen reported that *Synodontis* had not been seen within the ponds before 2012, the year characterised by an exceptional flood that catastrophically affected wide areas in the Niger Delta region. In this regard, Osuamkpe (2014) predicted that altered flood pulses could result in changes in the fish community composition in the Orashi River area, and this would also affect man-made ponds that are heavily inundated during the flood period.

3.1. Implications for the local economy

Better knowledge of the community composition of natural and man-made aquatic ecosystems will allow greater insight in planning fishery exploitation in the Niger system. The Engenni Floodplain is undergoing severe deforestation and pollution; only two forest reserves exist along the Orashi River (Upper and Lower Orashi); even here, heavy logging and degradation are escalating (Thieme et al. 2005). The consequences of floodplain forest destruction on the local hydrology and local climate change are poorly understood and generally underestimated, despite their potentially severe negative impact on freshwater productivity. The 2012 flood event, which caused a 2.4-m high tidal flow in the lower Orashi Province lasting nearly 5 weeks, was recorded as the most destructive in the last three decades (Mmom and Aifesehi 2016). This particular event was triggered by a dam failure on the Benue River in Cameroon, concomitant with high water levels in the Orashi itself. According to recent projections, in the near future the region will experience higher rainfall frequency (5–6% increase of rainfall by 2030; IPCC 2007) such that the relevance of the riparian floodplain forest for moderating flood peaks and for enhancing water infiltration could become even more important than it is felt now.

Results obtained from our survey provided useful information for a prediction of annual fishery catch from local manmade ponds in the Niger Delta area. Our data could serve to establish a compensation baseline in case of a pollution outbreak in the area. The study region has been frequently affected by oil spillage, and local fishermen have frequently requested compensation from governmental institutions or from multinational oil companies.

The results obtained from our study underpin the following recommendation:

- Local man-made ponds should be allowed to fallow so as to enhance fishery production.
- Industrial and anthropogenic activities that lead to a fragmentation of freshwater swamps should be avoided not to affect aquatic habitats.
- The use of biological chemicals like gammalin 20 for fishing within swamps should be prohibited.
- Government should deploy agricultural extension officers to rural areas to instruct artisanal fisherfolk about sustainable and productive fishing practices, including ways to enhance local ponds farming in order to boost protein availability in rural areas.

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Appendix 1: *Geographic location and size of the studied ponds*

Pond	Stations	Latitude	Surface (m^2)	Volume (m^3)
I	Ikodi	4° 68’ 21.534	20.3	32.4
II	Udoda	4° 58’31.704	18.1	29.0
III	Kunusha	4° 59’ 33.666	16.1	24.1
IV	Okparaki	4° 59’5.394	16.8	26.4
V	Igovia	4° 58’ 38.556	17.3	27.3
VI	Akie-Oniso/(Oruama)	5° 4’37.452	18.2	29.2
VII	Akinima	5° 5’ 31.548	35.0	59.5
VIII	Joinkrama	5° 10’ 11.592	20.0	34.0