

An indirect assessment of the effects of oil pollution on the diversity and functioning of turtle communities in the Niger Delta, Nigeria

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Abstract

An indirect assessment of the effects of oil pollution on the diversity and functioning of turtle communities in the Niger Delta, Nigeria.— There are many documented cases of oil spillage in the Niger Delta region, southern Nigeria (West Africa). Due to both habitat characteristics and omnivorous habits, the freshwater turtles are important vertebrates species in the trophic chain. They are therefore considered to play a significant role as ecological indicators for areas subjected to oil spillage events. The aim of this study was to evaluate the effects of oil spillage and consequent pollution on the abundance, complexity and functioning of freshwater turtle communities of the Niger Delta, by comparing the turtle fauna found in two areas with similar environmental characteristics, one unpolluted and the other polluted by a case of oil spillage in 1988. A total of 510 turtle specimens belonging to four different species (*Trionyx triunguis*, *Pelusios castaneus*, *Pelusios niger*, and *Pelomedusa subrufa*) were captured in the unpolluted area, whereas 88 specimens, from two different species (*P. castaneus* and *P. niger*) were captured in the polluted area. The dominant species was *P. castaneus* followed by *P. niger* in the unpolluted area, and *P. niger* in the polluted area. A marked shift in habitat use was observed in one species (*P. niger*) after the oil spillage event. This study revealed both direct and indirect effects of oil pollution on the complexity and habitat use of Nigerian freshwater communities of turtles. The main direct effect was a considerable reduction in the specific diversity of the turtles; 50% of species were lost after oil spillage and there was a very strong decline in the numbers of turtle specimens also for those species which were able to survive the catastrophic pollution event. The shift in habitat use after oil spillage by *P. niger* may have a significant effect on the long-term persistence of this species, independently of the pollution effects of the oil spillage event, because it considerably reduced habitat niche separation between this species and the closely related *P. castaneus*, a potential competitor. It is therefore stressed that eco-ethological modifications in populations of animals subjected to catastrophic events such as oil pollution should be taken into account when evaluating the long-term effects of these devastating phenomena.

Key words: Turtles, Community ecology, Habitat, Pollution, Oil industry, Tropical, Nigeria.

Resumen

Evaluación indirecta de los efectos de la contaminación por petróleo en la diversidad y funcionamiento de las comunidades de tortugas del delta del Níger, Nigeria.— Existen numerosos casos documentados de vertidos de petróleo en la región del delta del Níger, al sur de Nigeria (África Occidental). Tanto por las características del hábitat como por sus costumbres omnívoras, las tortugas de agua dulce constituyen importantes especies de vertebrados en la cadena trófica. Por consiguiente, se considera que desempeñan un papel fundamental como indicadores ecológicos en las áreas sujetas a vertidos de petróleo. El presente estudio tiene por objeto evaluar los efectos de los vertidos de petróleo y la consiguiente contaminación en la abundancia, complejidad y funcionamiento de las comunidades de tortugas de agua dulce del delta del Níger. Para ello se han comparado con las especies de tortugas halladas en dos áreas con características medioambientales muy similares, una no contaminada y la otra contaminada, tras un caso de vertido de petróleo en 1998. En el área no contaminada se capturaron un total de 510 ejemplares de tortugas pertenecientes a cuatro especies distintas (*Trionyx triunguis*, *Pelusios castaneus*, *Pelusios niger* y *Pelomedusa subrufa*), mientras que en el área

contaminada se capturaron 88 ejemplares procedentes de dos especies (*P. castaneus* y *P. niger*). La especie dominante en el área no contaminada fue *P. castaneus*, seguida de *P. niger*, y en el área contaminada fue *P. niger*. En una de las especies (*P. niger*) se observó un pronunciado cambio en el uso del hábitat tras el vertido de petróleo. Este estudio revela los efectos directos e indirectos de la contaminación por petróleo en la complejidad y uso del hábitat de las comunidades de tortugas de agua dulce de Nigeria. El principal efecto fue una considerable reducción en la diversidad específica de las tortugas; el 50% de las especies se perdieron, produciéndose una importante disminución en el número de ejemplares de las especies que lograron sobrevivir a la catastrófica contaminación. Es posible que el cambio en el uso del hábitat experimentado por *P. niger* repercuta de forma significativa en la persistencia a largo plazo de esta especie, con independencia de los efectos de la contaminación provocada por el vertido de petróleo, puesto que se redujo considerablemente la separación del nicho ecológico entre esta especie y otra especie estrechamente relacionada con ella y posible competidora, *P. castaneus*. Por consiguiente, se destaca el hecho de que para evaluar los efectos a largo plazo de fenómenos tan devastadores como los causados por los vertidos de petróleo y la subsiguiente contaminación, habría que tener en cuenta las modificaciones ecoetológicas generadas en poblaciones de animales sometidas a episodios catastróficos.

Palabras clave: Tortugas, Ecología de comunidades, Hábitat, Contaminación, Industria petrolera, Trópico, Nigeria.

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Introduction

With a crude oil production of 2.04 mb/d, the Federal Republic of Nigeria is an Oil Producers Economic Community (OPEC) country, and is the main oil producer country in sub-Saharan Africa. Most of the oil-related industry of Nigeria is found in the Niger Delta region (DE MONTCLOS, 1994; EMBASSY OF NIGERIA, 2001). Natural environments of crucial ecological relevance such as swamp-rainforest and large portions of mangrove forest, as well as many endemic species of divergent faunal and floral groups (KINGDON, 1990), are found within the Niger Delta region. There is no doubt that the oil-related industry may be a prominent cause of habitat loss and a threat to the conservation of many important plant and animal species. Therefore, the impact of oil-related industries on the natural ecosystems of Niger Delta merits careful research. However, the constant friction between the main oil companies operating in the region and the local inhabitants has led to chronic civil instability which in turn has caused further political problems. For example, at the time of Ken Saro Wiva's execution by the military regime of the late General Sani Abacha (1995) [Ken Saro Wiva was an internationally famous Nigerian writer who defended the opinion of the Niger Delta inhabitants (mainly the Ogoni tribe) who claimed they were the rightful owners of the crude oil. The Federal Government was accused of stealing their oil to sell to companies (Agip, Shell, ExxonMobil, etc). The late General Abacha ordered the execution of Ken Saro Wiwa and youth groups protested by destroying pipelines, causing significant economic loss to the oil companies] demonstrators broke oil pipelines to steal crude oil and petroleum, frequently causing oil spillage and pollution.

As for cases of oil spillage, the "Niger Delta Environmental Survey" (NDES, 1998) and environmentalists such as Odu et al. (1989) have documented evidence of oil spillage in the region, especially in mangrove zones with brackish water rivers. The following cases are examples of temporal constancy of spillage events, which may have adversely affected the ecosystems and ecological biodiversity of the Niger Delta region: Bonny oil spillage (1993; brackish water), Rumuekpe oil spillage (1995; freshwater swamp), Bille oil spillage (early July, 2000; brackish water, with over 250,000 barrels lost), and the Ogbodo-Isiokpo oil spill (2001; freshwater stream). Unfortunately, many other spillage events have occurred and their impact on the fragile ecosystem of the region has not yet been documented.

Despite previous studies on the effects of oil spillage on natural ecosystems and their plant and animal communities, no scientific research is available for the Niger Delta other than relatively terse comments available in local grey literature [mainly Environmental Impact Assessment (EIA) studies conducted by local industries].

Due to both habitat characteristics and omnivorous habits, the freshwater turtles are important vertebrates species in the trophic chain (AKANI et al., 2001). They are therefore considered to be significant ecological indicators for areas subjected to oil spillage events. In this regard, it is unfortunate that chelonians have not been popular subjects for community ecology studies (e.g., TOFT, 1985). Little is known on the organisation of their communities or assemblages of species (but see WILLIAMS & CHRISTIANSEN, 1981; VOGT & GUZMAN, 1988; MOLL, 1990; STONE et al., 1993; TERAN et al., 1995; KENNETT & TORY, 1996; ALLANSON & GEORGES, 1999; PRITCHARD, 2001).

The aim of this study was to evaluate the effects of oil spillage and consequent pollution on the abundance, complexity and functioning of freshwater turtle communities in the Niger Delta. The methodology compares two very close turtle communities (a polluted area and a non-polluted area) with very similar ecological conditions. In particular, in the above-mentioned comparative approach, the following issues were addressed:

1. Is there any loss in terms of specific turtle diversity and abundance after oil spillage events?
2. Is there any species-specific change in habitat selection after oil spillage events? If so, which habitats are favoured by surviving turtle populations?

Materials and methods

Study areas

Two study areas were used for our comparisons, both with similar environmental conditions (i.e. a main river tract with banks covered by dense gallery forest, and with seasonal swamps into the riverine forest, and almost permanent marshes with rich aquatic vegetation). Among the plant species found in both areas, we may cite *Pterocarpus* sp., *Raphia* sp., *Triumfetta eriophlebia*, *Mitragyna stipulosa*, *Triplichiton scleroxylon*, *Khaya* sp., *Terminalia superba*, *Mitragyna ciliata*, and others. The linear distance between the two areas was approximately 20 km. Both areas presented very similar surfaces (1 km of main river tract with its forested banks), to avoid eventual differences in terms of the numbers of observed specimens being caused by a different surface surveyed.

Both study areas appeared to have adequate micro-habitats (i.e. forested banks, spots with rich aquatic vegetation, and a number of basking sites) to house rich populations of semiaquatic chelonians.

Unpolluted area

The unpolluted study area was situated along a tributary of Sambreiro River (Rivers State), approximately 7 km east of Degema town (Kula,

Degema Local Government Area). There is no data about the water volumes of this site. This area was characterized by a portion of shallow, lentic, seasonally flooded, galloping swamp forest with several mounds, and by a deeper river with forested banks.

Polluted area

The polluted study area was situated along Sakie Stream and Baki Creek (Bayelsa State), where a well-known case of oil spillage had occurred. On January 27th, 1988, a spillage of crude oil (estimated at about 1,026 barrels) was detected along the Nun River delivery line of Shell Petroleum Developmental Company. This was the result of a pipeline burst caused by an internal tear. The oil flowed down an area of seasonally flooded galloping swamp forest (Sakie Stream) into the Baki Creek which links up to the Nun River into Igeibiri Creek during the rainy season (ODU et al., 1989). There are no data about the water volumes of the Sakie stream and Baki Creek. The Sakie stream is a shallow, lentic, seasonally flooded, galloping swamp forest with several mounds. Baki Creek, on the other hand, is deeper and tidal. According to ODU et al. (1989) report, oil pollution affected the galloping forest to a width of about 12–25 m and a length of about 350 m. Only the bottom sediment of the Baki Creek was affected but not the banks, while the banks of Eniwari Creek and aspects of Igeibiri Creek were oiled. The vegetation affected was heterogeneous and consisted of broad leaved, tall trees like *Mitragyna stipulosa*, *Harungana madagascariensis*, *Atiopicus communis*, *Musanga cercopoides*, *Eupatorium odoratus*, *Costus afer*, *Alchornea* sp., *Triumphetta eriophlebia*, etc, all characteristic of freshwater swamp. In Baki Creek the damaged vegetation was predominantly mangrove, dominated by *Rhizophora racemosa* and *Avicennia africana*. Around Igeibiri Creek some fallow species showed chlorotic symptoms, and phytoplankton abundance and productivity as well as a number of benthic organisms were adversely affected in the high and impacted areas of the galloping forest as well as the Baki and Eniwari Creek areas (ODU et al., 1988).

Four different species of freshwater turtles (*Trionyx triunguis*, *Pelusios niger*, *Pelusios castaneus*, *Pelomedusa subrufa*) were found in this river before the spillage, but their relative abundance was not studied (POLITANO, 1985; ODU et al., 1989). During 30 days of field work in 1984, a team of scientists headed by Dr Edoardo Politano recorded 48 *Pelusios niger*, 31 *Pelusios castaneus*, 4 *Pelomedusa subrufa* and 2 *Trionyx triunguis* (POLITANO, 1985), from exactly the same study area. It should be pointed out that these scientists did not specifically study freshwater turtles, and came across these animals purely by chance. Several specimens were collected at that time, and they are now stored in the collections of the Environmental Centre "Demetra", Rome.

Table 1. Summary of the data on total hydrocarbon content (THC, in ppm), in surface as well as in bottom water, measured at the site of oil spillage for the "polluted study area", and at some neighbouring localities along the River Nun (Bayelsa State, southern Nigeria). See also the study by ODU et al. (1989): ND. Not detected. (For more details on the methods, see the text.)

Tabla 1. Resumen de los datos sobre contenido total en hidrocarburos (THC, en ppm), tanto en la superficie como en el fondo del agua, medido en el emplazamiento donde se produjo el vertido de petróleo para el "área de estudio contaminada", así como en algunas localidades vecinas situadas a lo largo del río Nun (estado de Bayelsa, sur de Nigeria). Véase también el estudio de ODU et al. (1989): ND. No detectado. (Para más detalles acerca de los métodos empleados, consultar el texto.)

Location	THC	
	Top	Bottom
Aguobiri	0.3	ND
Ekowe	1.3	3.2
Eniwari	0.5	1.2
Nangigbene	2.5	2.4

The spillage event at this site was devastating, resulting in crude oil pollution upstream up to a distance of 1 km. Total hydrocarbon content for several sites along the River Nun, where this oil spillage event occurred, are presented in table 1 (see also ODU et al., 1989). Water Samplers were used to sample the surface and bottom water at each station. Aliquots of each sample were collected in plastic bottles and transported to the laboratory in ice-loaded chambers. The oil spill occurred on 27th January, 1988 and on the following day, "Shell Petroleum Development Company" sent containment booms and anchors to check the flow of oil into Igeibiri Creek. However, before this could be done, crude oil had escaped into the creek. Post-Impact Studies of the spill (aimed at quantifying the extent and degree of pollution and damage) were carried out over the period, September 10–22, 1988. Laboratory analysis of Total Hydrocarbon content (THC) in the soil and water samples were carried out by extraction method using toluene and the extracted oil determined by the absorbance of the extracts at 420 nm in a spectronic 70 Spectrophotometre. The concentration was consequently read off from a standard curve and multiplied by the appropriate dilution factor.

Methods

Data were gathered mainly during the years 2000 and 2001, but some additional observations were also made in the two study areas between 1996 and 1999. In total, these two study areas were surveyed for 20 field days at each locality, both in dry and in wet seasons. Each field day lasted at least 12 hours. Thus, in total, 80 field days (40 in dry and 40 in wet seasons) were done. The search for free-ranging turtles along non-linear transects was conducted along three main habitats, known to be frequented by these species (see LUISELLI et al., 2000): main river tract, forest swamps, and permanent marshes surrounded by grassy vegetation. Several standard turtle-collecting techniques were used, including baited hoop traps, dipnetting, trawling [see also GIBBONS et al. (2001) for a similar procedure], and many additional specimens were brought in by local villagers specifically employed for the purpose of this research project. The numbers of villagers employed at the two sites and also the number of traps (200 at each site, all situated along the main rivers) was standardized to avoid any potential bias in the methodology.

Once the turtles were captured, they were measured (plastron length), sexed, identified to species, and permanently individually marked by unique sequences of notches filed into the marginal scutes.

To avoid statistical problems due to "pseudo-replication" of the data (MATHUR & SILVER, 1980; HURLBERT, 1984), data (on habitat use, diet, etc) was recorded only once from individual turtles, i.e. the recaptured turtles were never used again for data recording and analyses. For uniformity, data relative to the first time a given specimen was encountered were recorded.

Quantitative biodiversity analyses were made according to the following indexes: species diversity was calculated using Margalef's Diversity Index (MAGURRAN, 1988):

$$D_{Mg} = (S - 1) \ln N$$

where S is the total number of species and N is the total number of individuals.

Species dominance was assessed using the Berger-Parker index (MAGURRAN, 1988):

$$d = N_{\max} / N$$

where N_{\max} is the total number of individuals of the most abundant species. An increase in the value of the reciprocal form of the index ($1/d$) indicates an increase in diversity and reduction in dominance (MAGURRAN, 1988).

Evenness index was calculated using Pielou's formula:

$$E = H / \log S$$

with H representing Shannon's index and S the total number of species. Shannon index is:

$$H = - \sum [n / N \log (n / N)]$$

where n is the number of individuals observed for each species and N is the total number of individuals observed in each study area.

Habitat niche breadth was assessed by the Simpson's diversity index (SIMPSON, 1949):

$$B = 1 / \sum (pi^2)$$

where pi is the frequency of utilization of the i th resource.

All data were statistically analysed by STATISTICA (version 5.0, for Windows) PC+package (STATSOFT INC., 1996), with all tests being two-tailed and alpha set at 5%.

Results

Community composition in pristine habitat and in oil-polluted habitat

A total of 510 turtle specimens, belonging to four different species (*Trionyx triunguis*, *Pelusios castaneus*, *Pelusios niger*, and *Pelomedusa subrufa*), were captured in the unpolluted area, whereas 88 specimens, belonging to two different species (*Pelusios castaneus* and *Pelusios niger*), were captured at the polluted area. The dominant species was *Pelusios castaneus* followed by *Pelusios niger* in the unpolluted area, and *Pelusios niger* in the polluted area. In the villages around the polluted area smoked shells of both *Trionyx triunguis* and *Pelomedusa subrufa* were found, which testifies that these two species were certainly also present in this latter area before the various pollution events. The values of the biodiversity indexes calculated for both the unpolluted and the polluted areas are given in table 2. A linear correlation Mantel test revealed that D_{Mg} was significantly higher in the unpolluted area ($P < 0.0001$), and that E was significantly higher in the polluted area ($P = 0.038$), whereas no statistical difference was found between areas regarding the indexes d ($P = 0.352$) and H ($P = 0.117$).

Habitat use

The distribution of captured species in three different habitats at both the unpolluted and the polluted areas is presented in figure 1. The percentage of occurrence of turtles (all species cumulated) in the three habitats is presented in figure 2. Values of niche breadth, calculated for each species both in the polluted and unpolluted environments are presented in table 3. In both species of *Pelusios* there was a significant (at least $P < 0.005$, Mantel test) reduction in the

Table 2. Values of the biodiversity indexes calculated for both the unpolluted and the polluted areas: S. Total number of species; N. Total number of individuals; N_{max} . Total number of individuals of the most abundant species; D_{Mg} . Margalef's diversity index; D. Berger–Parker's dominance index; E. Pielou's evenness index; H. Shannon's index.

Tabla 2. Valores de los índices de biodiversidad, calculados tanto para las áreas no contaminadas como para las contaminadas: S. Número total de especies; N. Número total de individuos; N_{max} . Número total de individuos de la especie más abundante; D_{Mg} . Índice de diversidad de Margalef; D. Índice de dominancia de Berger–Parker; E. Índice de uniformidad de Pielou; H. Índice de Shannon.

	S	N	N_{max}	D_{Mg}	D	H	E
Unpolluted area	4	510	314	18.703	0.616	0.387	0.643
Polluted area	2	88	57	4.477	0.648	0.281	0.937

habitat niche breadth at the polluted area in comparison with the unpolluted area.

A factorial plan of a Principal Component Analysis (PCA) on the habitat similarities across turtle species [VARIMAX standardized rotation model; \log_{10} det. Corr. Matrix = -46.977 , eigenvalues: 3.656 (60.9% of total variance explained), 1.842 (30.7% of total variance explained)] based on the proportion of specimens found in each habitat type, including in the analysis only the adults (fig. 3), showed that: 1. *Pelusios castaneus* in polluted area, *Pelusios*

niger in polluted area, and *Trionyx triunguis*, are arranged in the same zone of the multidimensional spacing; 2. *Pelusios castaneus* in unpolluted area, *Pelusios niger* in unpolluted area, and *Pelomedusa subrufa* are arranged in divergent zones of the multidimensional spacing each another; 3. Factor 1 correlated significantly with *Pelusios niger* in unpolluted area, *Pelusios niger* in polluted area, and *Pelusios castaneus* in polluted area; 4. Factor 2 correlated significantly with *Pelusios castaneus* in unpolluted area, and *Pelomedusa subrufa*.

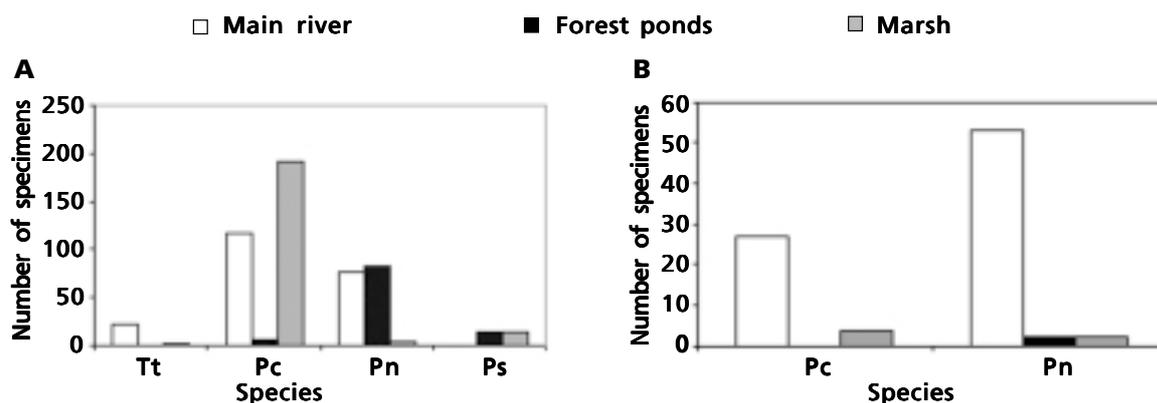


Fig. 1. Number of turtle specimens observed in the unpolluted area (A) and in the polluted area (B) during the present research study, in the three different habitat types. For this figure, the various species are entered separately: Tt. *T. triunguis*; Pc. *P. castaneus*; Pn. *P. niger*; Ps. *P. subrufa*.

Fig. 1. Número de ejemplares de tortugas observados en el área no contaminada (A) y en el área contaminada (B) durante el presente estudio, en los tres tipos de hábitat distintos. En esta figura, las distintas especies se indican por separado. Tt. *T. triunguis*; Pc. *P. castaneus*; Pn. *P. niger*; Ps. *P. subrufa*.

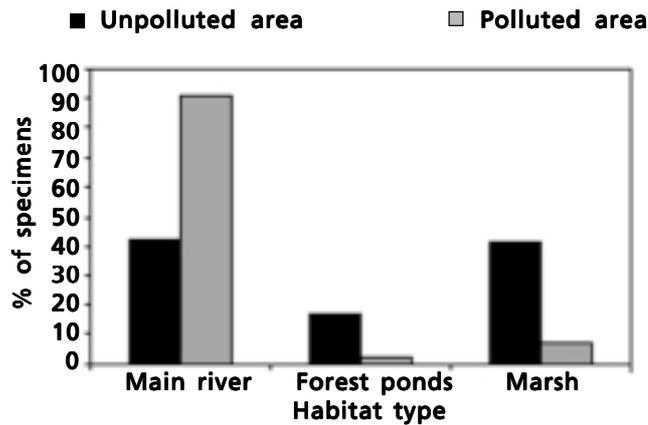


Fig. 2. Percent of occurrence of turtles (all species cumulated) found in the three different habitat types in the unpolluted area ($n = 510$) and in the polluted area ($n = 88$).

Fig. 2. Porcentaje de la presencia de tortugas (todas las especies acumuladas) halladas en los tres tipos de hábitat distintos del área no contaminada ($n = 510$) y de la contaminada ($n = 88$).

Table 3. Values of the Simpson's niche breadth indexes calculated for all the study species in both the unpolluted (Unpoll) and the polluted (Poll) areas.

Tabla 3. Valores de los índices de amplitud de nicho de Simpson, calculados para todas las especies del estudio, tanto en las áreas no contaminadas (Unpoll) como en las contaminadas (Poll).

Species	Unpoll	Poll
<i>Trionyx triunguis</i>	1.189	***
<i>Pelusios castaneus</i>	1.965	1.280
<i>Pelusios niger</i>	2.075	1.156
<i>Pelomedusa subrufa</i>	1.000	***

Discussion

Our study revealed both direct and indirect effects of oil pollution on the complexity and habitat use of Nigerian freshwater communities of turtles, even though over ten years had elapsed between the pollution event and the present study.

The main direct effect was a considerable reduction in the turtle specific diversity, with 50% of the species being lost after oil spillage, and with a very strong decline in the numbers of turtle specimens also for those species which were

able to survive the catastrophic pollution event. It should be pointed out that the two species which disappeared were the largest one (*Trionyx triunguis*), with a basically carnivorous diet (AKANI et al., 2001), and the smallest one (*Pelomedusa subrufa*), which is typically a savanna species, and which only marginally enters the swamp-forest habitat of Niger Delta (IVERSON, 1991, 1992; LUISELLI et al., 2000). Thus, it seems likely that extinction of these two species occurred mainly due to a decline also in prey species (mass mortality of fish caused by the oil pollution of waters) in the case of the former species, and due to a suboptimal adaptation to forest environments, aggravated by the catastrophic oil spillage event, in the case of the latter species.

Another direct consequence of the oil spillage event is that the habitat use changed considerably in one species, i.e. *Pelusios niger*, which shifted from an intensive use of swamps into the rain-forest before spillage to an almost complete abandonment of this habitat type after the spillage event. It was most probably a consequence of the fact that at least several of the swamps became strongly polluted after the oil spillage event, with nearly complete extirpation of the flora and small fauna inhabiting them. Unfortunately, there are no contaminant analytical data available to confirm this, but only a number of empirical evidences (ODU et al., 1989).

The shift in habitat use by *Pelusios niger* may have strong effects on the long-term persistence of this species, independently of the pollution effects of the oil spillage event. Indeed, this species is certainly a strong competitor with *Pelusios castaneus*, a species which is phylogenetically closely

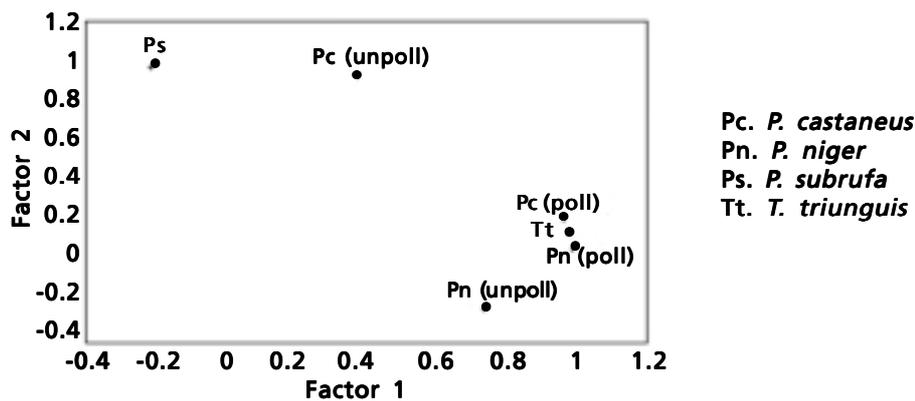


Fig. 3. Factorial plan of a Principal Component Analysis (PCA) on the habitat similarities across turtle species (VARIMAX standardized rotated model), based on the proportion of specimens found in each habitat type, including in the analysis only the adults, selected after Fisher exact test across species: (unpoll). Sample observed in the unpolluted area; (poll). Sample observed in the polluted area.

Fig. 3. Plano factorial de un análisis de componentes principales (PCA) sobre las similitudes que presentan los hábitat de distintas especies de tortugas (método normalizado de rotación VARIMAX), basado en la proporción de ejemplares hallados en cada tipo de hábitat, incluyendo en el análisis sólo los ejemplares adultos, seleccionados tras el test exacto de Fisher realizado en distintas especies: (unpoll). Muestra observada en el área no contaminada; (poll). Muestra obseveda en el área contaminada.

related, of similar size, and with similar dietary habits (LUISELLI et al., 2000). Based on observations and statistical modelling of the distribution of these species, LUISELLI et al. (2000) concluded that the most likely niche difference between these potential competitors is divergent habitat use, with one species being more linked to permanent water bodies than the other, which is conversely linked to seasonal swamps and marshes. Presently in our study area, the oil spillage event constrained the two species to coexist on the same habitat resource (as clearly explained by the factorial plan of PCA in fig. 3), and thus to strengthen their competitive relationships. It is likely that, under these conditions, the species least adapted to permanent water bodies would decline, thus augmenting the direct negative effects of the pollution event. Apart for direct killing to adults and juveniles, it is most likely that oil contamination had serious effects also on the eggs. Turtles lay their eggs on sandy beaches (LUISELLI et al., 2000), which are common around this area in focus, and oil readily permeates into sandy beaches. It implies that turtle eggs could easily be destroyed by this contaminant. Our study fully reinforces the few published observations on mortality of herpetofuna following oil spills. For instance, BURY (1972) observed that after a diesel oil spill into a Californian stream, 36 garter snakes and a single pond turtle of the genus *Clemmys* were killed, while others were in a moribund state. Following a huge oil spill on St. Lawrence River,

many frogs and turtles were also found dead (PALM, 1979; ALEXANDER et al., 1981).

A significant implication of this study is that eco-ethological modifications in populations of animals subjected to catastrophic events of oil pollution should always be studied in order to properly understand the long-term effects of these devastating phenomena.

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References

AKANI, G. C., CAPIZZI, D. & LUISELLI, L., 2001. Diet of the softshell turtle, *Trionyx triunguis*, in an

- Afrotropical forested region. *Chel. Cons. Biol.*, 4: 200–201.
- ALEXANDER, M. M., LONGABUCCO, P. & PHILLIPS, D. M., 1981. The Impact of oil on marsh communities in the St. Lawrence River. In: *Oil Spill Conference*: 333–340. American Petroleum Institute, Washington D.C.
- ALLANSON, M. & GEORGES, A., 1999. Diet of *Elseya purvisi* and *Elseya georgesii* (Testudines: Chelidae), a sibling species pair of freshwater turtles from eastern Australia. *Chel. Cons. Biol.*, 3: 473–477.
- BURY, R. B., 1972. The Effects of Diesel Fuel on a Stream Fauna. *Calif. Fish Game*, 58: 291–295.
- DE MONTCLOS, M.-A., 1994. *Le Nigéria*. Kurthala, Paris.
- EMBASSY OF NIGERIA, 2001. Nigeria's profile: political and economical. *Embassy of Nigeria Italy Quarterly Newsletter*, 3(2000): 11–12.
- GIBBONS, J. W., LOVICH, J. E., TUCKER, A. D., FITZSIMMONS, N. N. & GREENE, J. L., 2001. Demographic and ecological factors affecting conservation and management of the Diamondback Terrapin (*Malaclemys terrapin*) in South Carolina. *Chel. Cons. Biol.*, 4: 66–74.
- HURLBERT, S. H., 1984. Pseudoreplication and the design of ecological field experiments. *Ecol. Monogr.*, 54: 187–211.
- IVERSON, J., 1991. Global correlates of species richness in turtles. *Herpetol. J.*, 2: 77–81.
- 1992. *A revised checklist with distribution maps of the turtles of the world*. Privately Printed, Richmond.
- KENNETT, R. & TORY, O., 1996. Diet of two freshwater turtles, *Chelodina rugosa* and *Elseya dentata* (Testudines: Chelidae) from the wet-dry tropics of northern Australia. *Copeia*, 1996: 409–419.
- KINGDON, J., 1990. *Island Africa*. Academic Press, New York.
- LUISELLI, L., POLITANO, E. & ANGELICI, F. M., 2000. Ecological correlates of the distribution of terrestrial and freshwater chelonians in the Niger Delta, Nigeria: A biodiversity assessment with conservation implications. *Rev. Ecol. (Terre et Vie)*, 55: 3–23.
- MAGURRAN, A. E., 1988. *Ecological diversity and its measurement*. Princeton University Press, Princeton (New Jersey).
- MATHUR, D. & SILVER, C. A., 1980. Statistical problems in studies of temperature preferences of fishes. *Can. J. Fish. Aquat. Sci.*, 37: 733–737.
- MOLL, D., 1990. Population sizes and foraging in a tropical freshwater stream turtle community. *J. Herpetol.*, 24: 48–53.
- NDES, 1998. *Environment and Socio-economic Characteristics*. Vol 1. Niger Delta Environmental Survey, Port Harcourt.
- ODU, C. T. I., NWBOSHI, L. C., FAGADE, S. O. & AWANI, P. E., 1989. *Final Report on Post-Impact Study of SPDC "8" Nun River Delivery Line Spillage*. Report to Shell Petroleum Developmental Company, Port Harcourt.
- PALM, D. J., 1979. *Damage Assessment Studies Following the NEPCO-140 Oil Spill on the St. Lawrence River*. EPA 600/7-79-256. Industrial Environment Research Laboratory EPA, Cincinnati, Ohio.
- POLITANO, E., ED. 1985. *Studio dell'ecosistema di un'area del Delta del Fiume Niger, Nigeria, con riferimento allo sfruttamento industriale petrolifero*. ENI S.p.A., Rome.
- PRITCHARD, P. C. H., 2001. Observations on body size, sympatry, and niche divergence in softshell turtles (Trionychidae). *Chel. Cons. Biol.*, 4: 5–27.
- SIMPSON, E. H., 1949. Measurement of diversity. *Nature*, 163: 688.
- STATSOFT INC., 1996. *STATISTICA for Windows, release 5.0*. Statsoft Inc, Tulsa.
- STONE, P. A., HAUGE, J. B., SCOTT, A. F., GUYER, C. & DOBIE, J. L., 1993. Temporal changes in two turtle assemblages. *J. Herpetol.*, 27: 13–23.
- TERAN, A. F., VOGT, R. C. & GOMEZ, M. F. S., 1995. Food habits of an assemblage of five species of turtles in the Rio Guapore, Rondonia, Brazil. *J. Herpetol.*, 29: 536–547.
- TOFT, C. A., 1985. Resource partitioning in amphibians and reptiles. *Copeia*, 1985: 1–21.
- VOGT, R. C. & GUZMAN, S., 1988. Food partitioning in a neotropical freshwater turtle community. *Copeia*, 1988: 37–47.
- WILLIAMS, T. A. & CHRISTIANSEN, J. L., 1981. The niches of two sympatric softshell turtles, *Trionyx muticus* and *Trionyx spiniferus*, in Iowa. *J. Herpetol.*, 15: 303–308.