Fish Diversity at Rabi and Gamba, Ogooué-Maritime Province, Gabon

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1 Introduction

Aquatic biodiversity is critical to maintaining landscape ecological processes and the biological function and integrity of aquatic, terrestrial, and interface systems. Aquatic vertebrates, especially fishes, are integral to these ecosystems, not only for natural processes but also as indicators of aquatic condition and sources of local livelihood. This paper reports on a survey of fish and other aquatic vertebrates (reptiles and mammals) in the Rabi oil fields, and on fish diversity in the Gamba area along the Ndogo Lagoon. Both localities are situated in the Gamba Complex of Protected Areas, which belongs to the Gabonese coastal part of the ichthyogeographical province of the Lower Guinea. The Lower Guinean province contains all the Western hydrographical systems between the Cross River basin in the North (Cameroon) to the Chiloango basin in the South (Cabinda) (Thys van den Audenaerde 1966, Roberts 1975). This region is characterised by an important diversity (more than 300 species are mentioned) and a high level of endemism (Teugels and Guégan 1994).

The surveyed zone runs the center of the Gamba Complex, including parts of the Iguéla, Ngové-Ndogo, and Setté Cama Hunting Areas, between Loango and Moukalaba-Doudou National Parks. The hydrographical system of the northern study site, the greater Rabi area, is composed of the upper basins of three coastal rivers: the Mbari River, draining the northern part of this area and eventually flowing to the Fernan-Vaz Lagoon, the Rabi River flowing northwest into the Iguéla Lagoon, and the Echira River, whose system is associated with Lake Divangui, flowing southwest into the Iguéla Lagoon.

The southern study site, the greater Gamba area, encompasses Gabon's largest lagoon, the Ndogo (surface area 487 km^2), and smaller coastal drainages. Its formation seems to be the result of differential erosion with an offshore bar, resulting in an elongate shape coursing parallel to the coast for 40 km, and flowing into the Atlantic Ocean by a narrow north-west facing channel. This narrow channel allows little exchange with the ocean, yielding low salinity (0.5-1.0 g/L, Lomoalle and Albaret 1995) compared with many lagoons of the region such as Conkouati. Brackish and freshwater biotopes can be distinguished from physio-chemical features.

Shores of the Ndogo Lagoon are very denticulate and completely covered with forest (see map on page xxxii). Mangroves (*Rhizophora racemosa* and *Avicennia germinans*) and *Phoenix* palm trees are located near Setté Cama. The main biotopes encountered in and around the lagoon (except open water) are water plant communities including the following species of Angiosperms: *Nymphaea* sp. (Nympheaceae), *Naja* sp. (Najadaceae), *Ceratophyllum* sp. (Ceratophyllaceae), *Alcornia cordifolia* (Euphorbiaceae), *Bergia* sp. (Elatinaceae), *Crinum natans* (Amaryllidaceae), *Pandanus candelabrum* (Pandanaceae), *Cyperus papyrus* (Cyperaceae), *Vossia cuspidata* (Poaceae), *Phoenix reclinata* (Arecaceae) and Pteridophytes: *Ceratopteris sp*. (Adiantaceae), *Bolbitis* sp. (Lomariopsidaceae).

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Table 1. Physical charcateristics of the sampling stations in Gamba.

Stations	pH	T(°C)	Conductivity (µs/cm)	Salinity (mg/l)	Depth (m)
L1	5.52	30.2	18.9	0.2	0.76
L2	5.62	29.7	17.5	0	0.4
L3	5.39	26.0	96.0	0	0.5
L4	6.55	29.3	18.9	0	0.85 – 2.74
L5	5.59	25.9	79.5	0	0.20 – 0.80
L6	5.75	26.2	88.7	0	0.20 – 0.80
L7	5.28	29.3	875.0	0.2	1.43
L8	4.70	26.0	75.0	0	0.20 – 0.80
L9	4.25	26.5	57.4	0	0.20 – 0.80
L10	4.15	29.1	676.0	0.1	0.9
L11	4.50	30.0	18.1	0	0.4
L12	4.29	33.1	604.0	0	1.5
L13	4.48	31.9	354.0	0	1.8
L14	4.76	34.5	355.0	0	0.9 – 2.50
L15	4.81	30.0	549.0	0	2.7
L16	4.62	29.0	57.3	0	0.5
L17	4.14	31.6	40.0	0	0.5 – 1.30
L18	4.72	32.9	528.0	0	1
S1	4.54	32.0	657.0	0.1	0.75
S2	4.25	24.0	61.0	0	2.5
S3	4.36	28.5	768.0	-	2.3
S4	4.10	29.3	950.0	0.2	1.5 – 2.5
S5	3.98	27.0	999.0	0.3	2.5 - 6
S6	4.25	30.0	983.0	0.3	2
S7	4.14	31.6	40.0	-	-
S8	4.20	30.3	49.0	-	0.6
S9	4.40	30.0	425.0	-	1
S10	-	-	-	-	-
S11	-	-	-	-	-

Ichthyological exploration in Gabon started in the 19th Century, concurrent with its geographical exploration. Specimens captured by the first western explorers (Mary Kingsley, Savorgnan de Brazza) served to describe Gabon's first fish species (Gill 1862, Günther 1867a, b, 1871, 1896; Sauvage 1879, 1880, 1883, 1884a, b; Vaillant 1886). Additions to our knowledge of fish diversity continued through the 20th Century by naturalist correspondents (Haug, Cottes, Baudon, Guillaume) who sent many specimens for study to natural history museums in Paris, London and Tervuren (Boulenger 1903a, b, 1904, 1909, 1911; Pellegrin 1900, 1906, 1907a, b, 1908a, b, 1909a, b, 1911, 1924, 1925). Yet, the majority of fishes from the Ogooué basin were unknown until recently. Géry (1964, 1965, 1968) provided knowledge on the Ivindo fish fauna, and Kamdem Toham (1998) on the Ntem River fauna. Finally, recent studies initiated by Carl Hopkins have resulted in a more global vision of fish fauna in Gabon (Hopkins 1981, Hopkins, Sullivan and Lavoué, unpublished results).

Some coastal regions remain unknown, especially outside the lower Ogooué. Chaslerie *et al.* (2000) is the only known report on fishes mainly from the Ndogo Lagoon, and we are not aware of any other aquatic vertebrate surveys in the Rabi area. The present work thus constitutes the first step towards a better understanding of the aquatic ecosystems of this part of Gabon.

2 Materials and Methods

Sampling was conducted in three river systems in the greater Rabi area: the Rabi River system, situated in the oil exploitation zone with 13 stations; the Mbari

Table 2. Fish species recorded during the study.

	Gamba	Rabi
ELOPIDAE		
Elops lacerta Valenciennes, 1847	x	x
MEGALOPIDAE		
Tarpon atlanticus (Valenciennes 1847)	x	
CLUPEIDAE		
Ethmalosa fimbriata (Bowdich 1825)	x	
Odaxothrissa ansorgii Boulenger 1910	x	
Pellonula vorax Günther 1868	x	
Sardinella maderensis (Lowe 1838)	x	
MORMYRIDAE		
Brienomyrus cf. *brachyistius*		x
Brienomyrus kingsleyae (Günther 1896)	x	
Brienomyrus sp.		x
Isichthys henryi Gill 1863	x	x
Marcusenius moorii (Günther 1867)	x	x
Petrocephalus microphthalmus Pellegrin 1908		x
Petrocephalus simus Sauvage 1879		x
Stomatorhinus walkeri (Günther 1867)	x	x
HEPSETIDAE		
Hepsetus odoe (Bloch 1794)	x	x
ALESTIIDAE		
Alestes taeniurus Günther 1867	x	
Brycinus kinsleyae (Günther 1896)	x	x
Brycinus longipinnis (Gunther 1864)	x	x
Nannopetersius ansorgii (Boulenger 1910)	x	x
Phenacogrammus gabonensis (Poll 1967)	x	
Phenacogrammus major (Boulenger 1903)		x
Phenacogrammus sp.		x
CITHARINIDAE		
Congocharax gossei Poll & Lambert 1964		x
Distichodus notospilus Günther 1867	x	x
Nannaethiops unitaeniatus Günther 1872	x	x
Nannocharax fasciatus Günther 1867		x
Nannocharax sp. 1		x
Nannocharax sp. 2		x
Neolebias ansorgii Boulenger 1912	x	x
Neolebias unifasciatus Steindachner 1894		x
CYPRINIDAE		
Barbus holotaenia Boulenger 1904	x	x
Barbus trispilomimus Boulenger 1907		x
Barbus sp.		x
BAGRIDAE		
Anaspidoglanis macrostoma (Pellegrin 1909)		x
Chrysichthys auratus (Geoffroy Saint-Hilaire 1809)	x	x
Chrysichthys nigrodigitatus (Lacepède 1803)	x	
Parauchenoglanis pantherinus (Pellegrin 1929)		x
Parauchenoglanis sp.		x
SCHILBEIDAE		
Pareutropius debauwi (Boulenger 1900)	x	x
Schilbe multitaeniatus (Pellegrin 1913)	x	
AMPHILIIDAE		
Amphilius sp.		x
Phractura brevicauda Boulenger 1911		x

	Gamba	Rabi
CLARIIDAE		
Clarias buthupogon Sauvage 1879	*x*	x
Clarias pachynema Boulenger 1903	x	
Clarias sp.		x
MALAPTERURIDAE		
Malapterurus electricus (Gmelin 1789)	x	x
MOCHOKIDAE		
Microsynodontis batesii Boulenger 1903		x
Synodontis batesii Boulenger 1907		x
SYNGNATHIDAE		
Enneacampus ansorgii (Boulenger 1910)	x	x
Hippocampus algiricus Kaup 1856	x	
BELONIDAE		
Strongylura senegalensis (Valenciennes 1846)	x	
POECILIIDAE		
Aplocheilichthys spilauchen (Duméril 1861)	x	x
Plataplochilus cabindae (Boulenger 1911)		x
Plataplochilus loemensis (Pellegrin 1924)	x	
Plataplochilus ngaensis (Ahl 1924)		x
Plataplochilus sp.		x
APLOCHEILIDAE		
Aphyosemion australe (Rachow 1921)	x	x
Aphyosemion citrineipinnis Huber & Radda 1977	x	
Aphyosemion microphtalmum Lambert & Géry 1968	x	x
Aphyosemion schluppi Radda & Huber 1978	x	
Aphyosemion striatum (Boulenger 1911)		x
Aphyosemion sp.	x	x
Epiplatys huberi (Radda & Pürzl 1981)	x	
Epiplatys multifasciatus (Boulenger 1913)	x	x
Epiplatys sexfasciatus Gill 1862	x	x
Epiplatys singa (Boulenger 1899)	x	
Epiplatys sp.	x	
CHANNIDAE		
Parachanna insignis (Sauvage 1884)		x
NANDIDAE		
Polycentropsis abbreviata Boulenger 1901		x
CARANGIDAE		
Caranx hippos (Linnaeus 1766)	x	
Lichia amia (Linnaeus 1758)	x	
Trachinotus teraia Cuvier 1832	x	
LUTJANIDAE		
Lutjanus agennes Bleeker 1863	x	
Lutjanus dentatus (Duméril 1878)	x	
Lutjanus goreensis (Valenciennes 1830)	x	
GERREIDAE		
Gerres melanopterus Bleeker 1863	x	
Gerres nigri Günther 1859	x	
HAEMULIDAE		
Plectorhinchus macrolepis (Boulenger 1899)	x	
Pomadasys jubelini (Cuvier 1830)	x	
Pomadasys peroteti (Cuvier 1830)	x	

Table 2. *Continued.*

	Gamba	Rabi
SCIAENIDAE		
Pseudotolithus elongatus (Bowdich 1825)	x	
Pseudotolithus senegalensis (Valenciennes 1833)	x	
MONODACTYLIDAE		
Monodactylus sebae (Cuvier 1829)	x	
ARIIDAE		
Arius latiscutatus Günther 1864	x	
CICHLIDAE		
Chromidotilapia elongata Lamboj 1999		x
Chromidotilapia mamonekenei Lamboj 1999	x	x
Chromidotilapia sp.		x
Hemichromis fasciatus Peters 1857	x	x
Nannochromis sp. 1		x
Nannochromis sp. 2		x
Oreochromis macrochir (Boulenger 1912)		x
Oreochromis schwebischi (Sauvage 1884)		x
Pelvicachromis subocellatus (Günther 1872)	x	
Pelvicachromis sp.	x	x
Sarotherodon melanotheron Rüppell 1852	x	
Tilapia cabrae Boulenger 1899	x	x
Tilapia guineensis (Günther 1862)	x	
Tilapia rendalli (Boulenger 1897)	x	x
Tilapia zilii (Gervais 1848)	x	
MUGILIDAE		
Liza dumerili (Steindachner 1870)	x	
Liza falcipinnis (Valenciennes 1836)	x	x
Liza grandisquamis (Valenciennes 1836)	x	
Mugil curema Valenciennes 1836	x	
SPHYRAENIDAE		
Sphyraena afra Peters 1844	x	
Sphyraena guachancho Cuvier 1829	x	
POLYNEMIDAE		
Polydactylus quadrifilis (Cuvier 1829)	x	x
GOBIIDAE		
Bathygobius soporator (Valenciennes 1837)	x	
Chonophorus lateristriga (Duméril 1861)	x	
Periophthalmus barbarus (Linnaeus 1766)	x	
Porogobius schlegelii (Günther 1861)	x	
Yongeichthys thomasi (Boulenger 1916)	x	
ELEOTRIDAE		
Dormitator lebretonis (Steindachner 1870)	x	
Eleotris daganensis Steindachner 1870	x	
Eleotris vittata Duméril 1861	x	
Kribia sp.		x
ANABANTIDAE		
Ctenopoma nanum (Günther 1896)	x	x
Ctenopoma nigropannosum Reichenow 1875	x	x
MASTACEMBELIDAE		
Cœcomastacembelus niger (Sauvage 1879)	x	x
CYNOGLOSSIDAE		
Cynoglossus senegalensis (Kaup 1858)	x	

River system, relatively less disturbed with 6 stations; and the Echira River system, with also relatively low disturbance with 5 stations. In Gamba, sampling in the Ndogo Lagoon included 18 stations covering open water, coastal savanna zones, and stream or river mouths flowing into the lagoon. Eleven stations of natural and man-made streams and marshes separated from the Ndogo Lagoon complex which flow directly into the ocean were also surveyed.

This study used non-destructive methods. Stations were sampled using two multi-mesh gillnets (10-40 mm and 25-50 mm) of 30-m length and 2 m height in Rabi, with two more gillnets (15 and 25 mm) added in the Gamba survey. In Rabi, gillnets were set day and night in each station to catch diurnal and nocturnal species; in Gamba they were set diurnally only. One seine of 10 m length and 2 m high was used in shallow habitats, with 2-3 people holding the seine while 2-3 people drove the fish from upstream toward the seine. Hoop nets were used in marsh or stream biotopes when other means were unsuitable. Fish traps or traditional methods were sometimes used, and in Gamba, inquiries were made among local fishermen to determine their daily catches. In Rabi, electrogenic fish of the family Mormyridae were located with aid of an electrode connected to a bio-amplifier able to detect the electric discharges they produce.

Sampling station descriptions are presented in Appendix 1. For each station, water temperature, pH and conductivity were recorded using a "*Combo pH & EC* model HI98130" multi-parameters analyzer (Hanna) in Rabi and a WWT pH- conducti-oxymeter in Gamba.

Sampled fish were identified in the field using Gilbert *et al.* (1989), Lévêque *et al*. (1990, 1992), Mamonekene and Teugels (1993), Radda and Pürzl (1987), Schneider (1992), Teugels *et al.* (2001), and Thys van den Audenaerde (1966). Species names follow Eschmeyer (2004). Some fish were released when in good condition, and others were preserved

in 10% formalin for collection and further identification. Representatives of most species were photographed alive using a digital camera. Preserved fish specimens have been desposited in the Gabon Biodiversity Program in Gamba, the Smithsonian Institution in Washington, and the Natural History Museum in Paris.

3 Results and Discussion

3.1 Rabi

Sixty-seven fish species were sampled from the greater Rabi area, belonging to 23 families and 44 genera (Table 2). The Cichlidae represented the most diverse family (11 species), followed by the Citharinidae (8 species), the Mormyridae (7 species) and the Aplocheilidae (6 species). We sampled only three species of the Cyprinidae and no freshwater members of the Clupeidae from the genera *Odaxothrissa* and *Pellonula*.

Three marine fish species were sampled including *Elops lacerta* (Elopidae), *Polydactylus quadrifilis* (Polynemidae) and *Liza falcipinnis* (Mugilidae), which are often found in western African lagoons and sometimes in the lower rivers of coastal basins (Lévêque *et al*. 1992).

Compared with similar environments in the coastal region of the Lower Guinean province, the Rabi vicinity was found to be remarkably diverse with 67 species. Sixty-two are freshwater fishes compared to 68 found in a more extensive area of the lower Kouilou River basin in Congo (Teugels *et al*. 1991). Mamonekene and Teugels (1993) reported about 50 species from the upper course of the Kouilou system and the Lomé system (Biosphere of Dimonika, Congo). From collections made in the Cameroonian coastal rivers, Daget (1984) identified 55 species.

Although the survey yield was diverse compared to other studies in the region, it is still largely incomplete. For example, common West African coast freshwater clupeids (*Odaxothrissa* spp. and *Pellonula* spp.) were not captured. *Petrocephalus ballayi* (Mormyridae), a species typical of the coastal area in Gabon (Lavoué and Kamdem Toham, unpub. data), was also absent. Four related observations: (1) although the species-accumulation curve spread towards a plateau, the last two days of field prospecting added seven new species, indicating that there remain a number of species to inventory; (2) non-destructive sampling methods were used, which are inherently selective and ineffective for catching certain species (e.g. the absence of elongate genera of the Clariidae is suspicious); (3) the study took place during the dry season and thus cannot represent the range of seasonal differences in fish distribution (for example, many species, including somespecies of Clupeidae, swim upstream for reproduction during the wet season); and (4) sampling effort was lower on the lower part of these three rivers, although different species assemblages could be found there. For example, only two stations were studied in the lower part of the Echira River, yet six species were only captured at those locations. More complete inventory data would require more sampling effort in different seasonal conditions using different techniques.

The Rabi fauna seems characteristic of the coastal area of Lower Guinea, with the presence of species like *Brycinus longipinnis*, *Brienomyrus cf. brachyistius*, *Polycentropsis abbreviata* and *Kribia* sp. Additionally, species that were until recently considered endemic to the Ogooué basin, like *Stomatorhinus walkeri* and *Petrocephalus simus*, were found in the Rabi vicinity (Lavoué and Kamdem Toham, unpublished data). One possible explanation is that with past marine regression, water in the lagoon became fresher, allowing the spread of some species from the Ogooué basin to mix with lagoon systems and enter smaller streams.

Marsh environments had specific characteristics (Appendix 1) such as high water stagnancy, high temperature, and low dissolved oxygen levels, and were associated with fewer species. Some of these species (like *Clarias* spp., *Parachanna insignis, Kribia* sp. and *Ctenopoma* spp.) are adapted to anoxic environments, with a respiratory organ allowing them to breathe oxygen from the air.

Streams and marshes of the Rabi River system sampled in the dry season appeared to be more diverse than larger rivers. For example, certain stations located in very small streams (<1m) yielded 16 species in only 30 meters. Small streams allow an abundance of hiding places and macrophytic food for small species. Our sampling material was also better-adapted to shallow biotopes and could explain some of the differences in capture. One hypothesis to account for the difference would be shift of the ichthyofauna to the smaller tributary streams in

order to avoid the aquatic pollutants that are concentrated in the main course of the rivers.

The presence of forest cover is a likely explanation for the diversity of cyprinodonts (killifish) of which we have collected about 11 species belonging to 2 families (Aplocheilidae and Poeciliidae). The killifishes belong to a group of fishes living in the the forest; their mouth, located at the upper side of the head, is an adaptation for feeding on the surface of the water as small prey items fall from the vegetation. The disappearance of killifishes parallels the disappearance of the forest. Other fish characteristic of this biotope are the leaf fish *Polycentropsis abbreviata* and some mormyrids (*Petrocephalus* spp. and *Brienomyrus cf. brachyistius*).

Among the other vertebrates, nine species of aquatic or partly aquatic reptiles were found in the Rabi area: *Pelusios gabonensis* (Pelomedusidae), *Crocodylus cataphractus* and *Osteolaemus tetraspis* (Crocodylidae), *Varanus ornatus* (Varanidae), *Python sebae* (Pythonidae), *Grayia caesar* and *G. ornata*, *Hydraethiops melanogaster* and *Natriciteres fuliginoides* (Colubridae) (see Pauwels *et al*. 2003, this volume). During our fish survey, an adult *Pelusios gabonensis* was caught by net at E2 on July 11; another at R10 on July 18. It is obvious that these turtles were attracted by the fish entrapped in the nets; they are most often agile enough to eat fish without being themselves caught, as shown by the number of fish, especially *Hepsetus odoe*, which were found partly-eaten. Both above-mentioned turtles were observed eating trapped fish, and were themselves trapped while trying to escape when we approached to check the nets.

Five adult *Crocodylus cataphractus* were observed at E3 (Lake Divangui) on July 20. Twenty-four specimens were counted in a few minutes, swimming in the lake, the next day, in the afternoon. We had the opportunity to closely examine six specimens which had been caught by net and which were drowned, and to study the fish contained in their stomachs (Pauwels *et al.* 2003). Two adult *Osteolaemus tetraspis* (Crocodylidae, Crocodylia) were active at R7 while the sun was shining. Two others were observed active at R1 and R10 on July 17.

On July 8 we found a juvenile *Varanus ornatus* hidden under the bark of a fallen dead tree overhanging the river at E1. It plunged in the water and reappeared on the bank. Another juvenile was seen by day running among grasses and jumping in the water at R13 on July 18. An individual was observed basking on a branch emerging from the water at M5 on July 19. Another was seen on July 19 at M3 on a branch about 4 m above the water, it let itself fall in the water when we disturbed it. Surprisingly, all observed specimens were juveniles.

An adult *Python sebae*, about 4 m long, was observed at E1 on the bank of the river in the afternoon of July 3. A 3.4 m long python was caught in our net at E4 in the night of July 14. It was still alive and was released. A specimen of similar size, most probably the same one, had been seen just before the nets were set, swimming underwater, in the afternoon. An adult *Grayia ornata* was observed at E2 on a branch about 2 m above the water. When disturbed, the snake dropped headfirst into the river, a confirmation of an observation reported by locals in the Massif du Chaillu, central Gabon (Pauwels *et al*. 2002). A juvenile specimen had been found at R13 during a previous survey (Burger *et al*. 2002). Two adult *Hydraethiops melanogaster* and a juvenile were caught by day with a dip net on July 16 at R6 and on July 18 at R10 respectively. All three specimens were hiding in the vegetation in the water. An adult *Natriciteres fuliginoides* was found active by day at M2 on July 8. Even when roughly handled, it made no attempt to bite.

A giant otter shrew (*Potamogale velox*) was found in our net at M3 at Rabi.

Aquatic or partly-aquatic vertebrates are often ichthyophagous predators, influencing the abundance and variety of fishes. Many vertebrates in Rabi, besides fishes, are at least partly piscivorous. *Grayia ornata* seems to be mainly a fish-eater, apparently preferring catfishes (Pauwels *et al*. 2000, 2002). Although the diet of *Grayia caesar* (found during a previous Rabi survey, see Burger *et al*. 2002 and Pauwels *et al*. this volume) is completely unknown, it is likely to include fish due to its strictly aquatic habit. *Hydraethiops melanogaster* feeds on amphibians and fishes (Chippaux 2001), including Mormyridae (Pauwels, pers. obs.). The diet of Goldie's Tree Cobra *Pseudohaje goldii*, also previously found in Rabi (Burger *et al*. 2002, Pauwels *et al*. this volume), includes fish, as shown by a record of predation on *Xenomystus nigri* Günther 1868 (Pauwels and David 1999). We found several clutches of hatched eggs of an unidentified Trionychid species (either *Cycloderma aubryi* Duméril 1856 or *Trionyx triunguis* Forskål 1775) on the banks of the

Echira River; the diet of those turtles consists mainly of fish. The giant otter shrew *Potamogale velox* feeds on fish among other things (Kingdon 1997). Among the birds found in Rabi (Angehr *et al*. this volume), a number eat fish. Fish are thus an essential component of the food chain in Rabi, as anywhere else.

3.2 Gamba

Eighty-five fish species were found in the greater Gamba area, belonging to 32 families and 58 genera (Table 2). The Aplocheilidae represented the most diversified family (10 species) followed by Cichlidae (9 species).

Salinity affected species distribution on the Ndogo Lagoon, yet some euryhaline species were widely spread including *Elops lacerta* (Elopidae), *Pellonula vorax* (Clupeidae), *Chrysichthys auratus* (Bagridae), *Strongylura senegalensis* (Belonidae), *Gerres melanopterus* (Gerreidae), *Pomadasys jubelini* (Haemulidae), and *Liza falcipinnis* (Mugilidae). Some marine species, though less euryhaline were encountered in the lagoon far from the mouth (*Sardinella maderensis* (Clupeidae), *Trachinotus teraia* (Carangidae)).

Forty-six species (five families) were recorded in the vicinity of Gamba, notably small species without economic importance but reflecting the state of the environment (Table 2).

A study of economic fish species is the only known previous study from the Ndogo Lagoon. During that survey (Pinkston 1997), several marine and brackish fish were recorded that we did not encounter. We found a *Clarias* belonging to the *Brevicephaloides* subgenus and the only *Barbus* caught was *B. holotaenia.* The needlefish *Strongylura senegalensis* appears to be very common in the lagoon.

We did not record some species sometimes found in brackish water such as *Cithrichthys stampflii* (Bothidae), noticed by Pinkston (1997) in the Gamba Lagoon. That same species was recorded in the Conkouati Lagoon in Congo-Brazzaville (Mamonekene *et al*. in press) as well as *Cynoglossus senegalensis.* Presumably a longer and more intensive sampling effort than the present study which was limited to one month, during the rainy season, would yield those species and others. Fish diversity in lagoons depends greatly on water salinity, which varies with rainfall and tide, altering fish community composition throughout the year.

In physical, chemical and vegetation features, the lagoon grades between biotopes along its major axis. Salinity decreases from the mouth at Setté Cama to Malabi cove (beyond Ibouka), confining saltwater-intolerant fishes to the Malabi cove, i.e. schilbeids (*Schilbe multitaeniatus, Pareutropius debauwi*), alestids (*Brycinus kingsleyae, Alestes taeniurus)* and mormyrids (*Marcusenius moorii*). *Distichodus notospilus* (Citharinidae) presents a wider distribution, from the Malabi cove to Gamba, and the killifish *Aplocheilichthys spilauchen* was also encountered all over the lagoon. Frequently-caught species included *Elops lacerta, Pellonula vorax* and *Liza falcipinnis.* Mangrove species such as eleotrids, and gobids are common around Setté Cama. The middle part of the lagoon with mesohaline water constitutes a transition zone, allowing high diversity of euyhaline species. This pattern is however affected by pockets of salinity (meromictic zones).

Freshwater streams flowing in the lagoon provide habitat for species absent in the lagoon that prefer running water or are sensitive to disturbance, such as certain mormyrids like *Stomatorhinus walkeri*.

Observations of local catches indicate two marine species consistently present thoughout the lagoon: *Trachinotus teraia* (Carangidae) and *Arius latiscutatus* (Ariidae). More specimens of *T. teraia* were adult, whereas *A. latiscutatus* was found in juvenile stages at the Gamba wharf. Pockets of salinity could exist in many places of the lagoon, possibly explaining the abundance of *Sardinella maderensis* (many juvenile) in the Gamba Lagoon and coves of the Ndogo Lagoon. Some species are fundamental to lagoon communities, and others just for certain life history periods like reproduction. In West Africa, Albaret (1994) reported that *T. teraia* reproduces in lagoon environments. More research is needed to understand *A. latiscutatus* and *S. maderensis* in the Gamba Lagoon.

Fish distribution in streams and marshes around Gamba seems to indicate that streams without oil waste were more diverse compared to those with oil inflence, yet sample effort was too limited to make causal links. Some species sensitive to environmental changes such as the mormyrids *Stomatorhinus walkeri* are absent from the Ivinga area and the zone between the Mayonami road and the beach. The mastecembelid *Coecomastacembelus niger* was found only in one stream without visible pollution (i.e. NE of the airport). However, other fish such as *Neolebias*

ansorgii, *Clarias* sp., *Epiplatys* sp., *Hemichromis fasciatus,* and *Ctenopoma nanum* were found with some regularity in streams around Gamba, seeming to tolerate certain levels of pollution.

Small cichlids *Pelvicachromis* spp. and *Chromidotilapia mamonekenei* were only present in streams crossing Gamba city, which are presumably disturbed only by organic (not petroleum) pollution. Cichlids are commonly found in organically-polluted environments; indeed *H. fasciatus* is encountered in very polluted urban channels.

When considering the three main environments around Gamba city, Ivinga field (oil exploitation), Camp Sable (habitations), and the periphery of Plaine IV (agriculture), five species were collected in the first two localities and nine in the last locality. A larger inventory effort as part of a sustained survey and monitoring program is necessary to know if the difference in fish richness is due to oil disturbance or not.

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Appendix 1. Description of stations per study site in Rabi and Gamba

A. Rabi

Twenty-seven stations were sampled in river biotopes including flooded forest, natural marshes, and manmade marshes (resulting from landscape engineering works.) Small manmade pools were also sampled. Lake Divangui is the most important water surface inventoried in the area.

Mbari River system (7 stations): Biotopes included flooded forest (M2), streams under forest (M1 and M7) and rivers with shallow and deep parts (M3, M4, M5 and M6). All studies were conducted in July 2002 on dates noted in parentheses.

Sampling Site	Description	Location	Date(s) Sampled in 2002
M1	Marianga River (12 km north of Didjombi on Toucan road)	1º49'16.5" S, 9º52'54.1" E	7 & 11 July
M2	Toucan marshy river	1º 47'43.1" S, 9º53'34.2" E	7 & 8 July
M3	Mbari River (at bridge on the northern road to Ndougou, about 1 km west of Moambatsango Quarry)	1º47'43.1" S, 9º53"34.2" E	19 & 20 July
M4	Mbari River at Gathering Station B	1º52'16" S, 9º51'9.3" E	19 July
M5	Stream between Rabi 106 and Rabi 49	1º52'3.1" S, 9º50'37.9" E	19 July
M6	Stream, upstream of the bridge on the Mbari River	1º47'43.1" S, 9º53'34.2" E	19 July
M7	Toucan downstream of the bridge	1º47'35.5" S, 9º53'36" E	24 July

Echira River system (7 stations): The most extensive system, encompassing the Echira River, the Ngové River, Lake Divangui and its tributary streams. Fast-running rivers with some natural marsh.

Sampling Site	Description	Location	Date(s) Sampled in 2002
E1	Echira River at metallic bridge, 30 km south of Rabi Airport	2º4'43,5" S, 9º50'47.4" E	10 & 25 July
E2	River at bridge of water pumping station, 12 km south of Rabi Airport on Koumaga road	2º00'47.2" S, 9º49'27.4" E	9 & 11 July
E3	Lake Divangui	1º56'28.4" S, 9º59'19.9" E	12, 13, & 21 July
E4	River on the road to Lake Divangui, at the bridge	1º55'14.6" S, 9º58'19.4" E	13,14 & 15 July
E5	Steam tributary of river (cf E4) on road to Lake Divangui, upstream of the bridge	1º55' S, 9º58' E	14 July
E6	Stream at Niungo	2º2'24.9" S, 9º59'36.1" E	25 July
E7	Ngové River, at the bridge on Rabi-Koumaga road	2º8'27.5" S, 9º56'24.5" E	25 July

Rabi River system (13 stations): Encompassing the Rabi River and its streams, it is naturally swampy at its origin, with man-made marshes, swamp forests, and pools resulting from engineering works (the most disturbed system sampled in Rabi).

Sampling Site	Description	Location	Date(s) Sampled in 2002
R1	Marsh 300 m from the large flare at Gathering Station A, near Rabi 17	1º57'39.4" S, 9º52'18.7" E	10 July
R2	Marsh on road between Rabi 133 and Rabi 35	1º57'24.9" S, 9º52'20.7" E	9 July
R3	Rabi River at the bridge of water pumping station near Rabi 125	1º53'48.3" S, 9º51'11.9"	11 & 12 July
R4	Roadside marsh about 300 m north of Rabi 123	1º55'17.2" S, 9º51'11.1" E	12 & 13 July
R5	Rabi River, along the road between Rabi 62 and Rabi 33	1º56'49.5" S, 9º52'2.7" E	16 July
R6	Roadside stream between the main eastern north-south road and Gathering Station C	1º55'48.4" S, 9º52'20.8" E	16 July
R7	Roadside pool, halfway between Rabi 19 and Rabi 55	1º56'7" S, 9º51'51.5" E	16 & 17 July
R8	Marsh on the road to Rabi 56	1º55'58.4" S, 9º51'7.2" E	18 July
R9	Roadside Stream between Rabi 56 and Rabi 72	1º55'56.5" S, 9º50'39.3" E	18 July
R10	Rabi river, on the road between Rabi 146 and Rabi 123	1º55'35.2" S, 9º52'42.9" E	17 July
R11	Small manmade pool along the pipelines, between the main eastern north-south road and Rabi 146, about 400 m west of Didjombi Camp	1º55'35.8" S, 9º52'8.5" E	18 July
R12	Roadside stream between Rabi 46 and Rabi 61	1º52'45.1" S, 9º50'44.0" E	18 July
R13	Roadside marsh between the airport and Ossengué Camp	1º56'34" S, 9º52'52" E	18 & 22 July

B. Gamba

Sampled stations in the Gamba area represent three main typological groups: border and open-water lagoon biotopes, forested marshes on the fringe of the lagoon, and streams situated in the coastal savannas. Lagoon border biotopes are either under forest with a sandy substrate base or covered with Gramineae, Papyrus or ferns (*Bolbitis* sp.). This habitat is often found at the mouths of streams flowing in the lagoon. From Pitonga, the lagoon environment becomes characteristic of mangrove forests (*Rhizophora* spp., *Phoenix reclinata*). Marshes around the lagoon are made of little ponds constituted by lower parts of streams flowing in the lagoon. Much visited by elephants, they have the appearance of muddy, shallow ponds continually moved and covered by litter. Coastal savanna streams run either under gallery forest or in Gramineae fields. They are narrow (<1 m) but relatively deep (sometimes >1 m). In areas with high concentrations of petroleum pits, sometimes oil appears distinctly on the water surface.

The Ndogo Lagoon system was sampled in 18 stations from coast to inland, including river mouths, different proximities to islands, and sub-lagoons of the main body. Physio-chemical parameters are presented in Table 1.

Sampling Site	Description	Location	Date(s) Sampled in 2002
L1	Gamba Lagoon	2º42.245' S, 10º1.646' E	6 & 7 February
L2	Gamba Lagoon	2º42,014' S, 10º0.930' E	6 February
L3	Gamba Lagoon, west Tsongui Island	2º39.074' S, 10º0.343' E	6 February
L4	Gamba Lagoon	2º42.033' S, 10º0.601' E	8 February
L5	Gamba Lagoon	2º43.193' S, 10º0.360'E	9 February
L6	Ndogo Lagoon	2º40.761' S, 10º0.973' E	10 February
L7	Ndogo Lagoon	2º40.131' S, 10º1.555' E	11 February
L8	Ndogo Lagoon	2º41.815' S, 10º2.969' E	12 February
L9	Ndogo Lagoon	2º35.922' S, 10º1.202' E	13 February
L10	Ndogo Lagoon	2º39.413' S, 9º57.103' E	14 February
L11	Ndogo Lagoon	2º37.821' S, 9º56.478' E	15 February
L12	Ndogo Lagoon	2º40.477' S, 10º6.922' E	17 February
L13	Ndogo Lagoon, mouth of Ndogo River	2º33.464' S, 10º8.082' E	18 February
L14	Ndogo Lagoon, Setté Cama	2º28.175' S, 9º45.036' E	20 February
L15	Ndogo Lagoon, Setté Cama	2º31.003' S, 9º44.956' E	21 February
L16	Ndogo Lagoon, Koumaga	2º26.640' S, 9º49.521' E	21 February
L17	Mouth of the Ndogo Lagoon	2º28.834' S, 9º43,331' E	23 February
L18	Ndogo Lagoon near Kimba	2º30.576' S., 9º57.078' E	25 February

Gamba Stream and Marshes (11 stations): characterized by sandy drainages, often in areas of human impact.

Sampling Site	Description	Location	Date(s) Sampled in 2002
S1	Stream Airport 1	2º48.389' S, 10º3.322' E	8 February
S2	Stream Airport 2	2º47.982' S, 10º2.677' E	8 February
S3	Stream Mayonami 1	2º48.115' S, 10º3.449' E	9 February
S4	Stream Mayonami 2	2º48.613' S, 10º3.975' E	9 February
S5	Stream tributary of Pokou River at Gamba	2º44.093' S, 10º2.001' E	1 January 2003 & November 2002
S6	Stream Camp Sable	2º43.437' S, 10º1.176' E	14 February
S7	Stream on the road to Setté Cama	2º42.250' S, 9º56.960' E	14 February
S8	Stream Mpaga	2º30.941' S, 9º46.951' E	22 February
S9	Stream northeast of the Gamba Airport runway	2º47.338' S, 10º3.736' E	28 February
S10	Marsh at the east of Vera Camp	2º39.890' S, 10º12.020' E	18 February
S11	Marsh at the west of Ndogo River mouth	2º35.352' S, 10º8.682' E	18 February