Pyrex Journals 2035-7789

Pyrex Journal of Ecology and the Natural Environment
Vol 1 (4) pp. 055-062 September, 2015
http://www.pyrexjournals.org/pjene

Original Research Article

Population structure of fish from the Serra do Mar, Paraná, Brazil: a comparative analysis of environments affected and by oil spills and unaffected areas

A Ostrensky[1*], RM Neto[2], GG Castilho-Westphal[2], TO Zeni[2], V Abilhoa[3] and A Horodesky[2]

[1]Departamento de Zootecnia, Universidade Federal do Paraná, Rua dos Funcionários, 1.540, Juvevê, CEP 80035-050, Curitiba, PR, Brazil.
[2]Grupo Integrado de Aquicultura e Estudos Ambientais, Universidade Federal do Paraná, Rua dos Funcionários, 1.540, Juvevê, CEP 80035-050, Curitiba, PR, Brazil.
[3]Museu de História Natural do Capão da Imbuia, Laboratório de Ictiologia, R. Prof. Benedito Conceição, 407 - Capão da Imbuia, Curitiba - PR, 82810-080, Brazil.

Accepted 22nd September, 2015

The rupture of the OLAPA (Oleoduto Araucária-Paranaguá) pipeline in February 2001 caused a spill of approximately 52,000 litres of diesel oil that reached rivers in the Serra do Mar region, in part, of the Atlantic Forest, which is one of the most important and fragile biomes in Brazil. The aim of the present study was to determine whether, 10 years after the rupture of the Oleoduto Araucária-Paranaguá pipeline, the fish populations at sites exposed to the spill showed changes in structure that may be correlated with the oil spill. Five rivers were selected for assessment of their ichthyofauna: the Meio and Sagrado rivers (treatment), which were exposed to oil, and the Pinto, Passa Sete and Marumbi Rivers (control), which were selected because they present environmental characteristics similar to those of the exposed rivers and are located in the same geographic region. A comparison of biometric variables between the treatment and control groups showed greater mean values for the total length, standard length and total weight of the fish captured in the treatment group. The analyses indicated no difference between the treatment and control groups in relation to the number of significant differences previously reported for the biometric variables of each studied species. These findings indicate biometric similarity between the fish populations inhabiting rivers exposed to the oil spill and those in unexposed rivers. There was no evidence of changes in the population structure of fish in the environments affected by the oil spill.

Key words: Environmental impacts, freshwater, ichthyofauna, petroleum, south of Brazil.

INTRODUCTION

On February 16, 2001, the rupture of the OLAPA (Oleoduto Araucária-Paranaguá) pipeline in the Serra do Mar, Paraná State, Brazil, resulted in the release of 52,000 litres of diesel fuel. A total of five containment barriers was installed along the stretches affected by the spill to minimise oil dispersion and facilitate its removal. Despite these containment efforts, some of the oil reached the rivers and streams of the region, dispersing over approximately 28 km in one of the most important and fragile biomes of Brazil, the Atlantic forest, and reaching the estuary of the bay of Paranaguá. Once in the environment, petroleum-derived hydrocarbons undergo various processes, including volatilisation, hydrolysis, photolysis, biodegradation, biotransformation, physical degradation and dissolution (Pedrozo *et al.,* 2002). The extent of the impact generated and the rate of each of these processes varies according to the intrinsic conditions of each environment, making it difficult to predict the breakdown of petroleum and the composition of the resultant degradation by-products as well as to infer their ecotoxicological potential (French-MaCay *et al.,* 2009).

Diesel fuel, which is composed of carbon and hydrogen atoms together with low concentrations of sulphur, nitrogen and oxygen, is a compound that is considered moderately to highly toxic to aquatic biota (Alvez 2008).

Corresponding Author: ostrensky@ufpr.br

Fish come into contact with the oil via different routes, mainly through gas and ionic exchange, with a consequent contamination of the gills, as well as trophic routes (Filho 2006). This contamination temporally influences all levels of biological organisation, from individuals to the highest levels (ecosystems) (Cajaraville *et al.,* 2003). According to Lawrence & Elliott (2003), the effects of oil on fish depend mainly on the organism's developmental stage as well as its mode of interaction with the environment. These responses are not always specific. In addition to contaminants, fish tend to respond simultaneously to the environmental changes caused by the physical and chemical conditions of the water. Variations of these natural factors can often induce subcellular and physiological responses in fish similar to those caused by exposure to contaminants (Hewitt & Thrush 2007).

At the individual level, the effects of environmental stress can manifest at various levels of biological organisation (ranging from the organelle to organismal scale). However, the response rate at each level decreases as the level of organisation becomes more complex (Hylland *et al.,* 2003). In turn, when fish communities are exposed to environmental stress, they may undergo a selection process favouring more tolerant species or species that are capable of more rapid self-detoxification, making them more capable of surviving in the impacted region. When the environmental stress is reduced, populations of aquatic organisms tend to recover through recruitment, recolonization and immigration (Lawrence & Hemingway 2003). This capacity of the system to return to its previous state (before the accident) is known as resilience (Bown *et al.,* 2013). The present study aimed to assess whether the population and biological structures of the fish species found in rivers exposed to the OLAPA pipeline oil spill are similar to the structures found in rivers with similar environmental characteristics in the same geographic region that were not exposed to oil, 10 years after the accident.

Materials and Methods

Five rivers in the region affected by the OLAPA accident were analysed. As there were no available data on the structure of the biological system from the period prior to the accident, a comparative approach was adopted based on an analysis of environments that were exposed to oil as well as unexposed areas. In addition to the system affected by the accident (the Meio and Sagrado rivers), three other rivers (Pinto, Passa Sete and Marumbi) (Figure 1) were identified. The unaffected rivers selected for the present study are located in the same geographic region and present physiographic characteristics that are very similar to those of the system exposed to the oil. Thus, the rivers exposed to the oil were considered to represent the treatment condition and the unexposed rivers to represent the control.

To achieve a more accurate comparative analysis, three sampling sites were established in each of the monitored rivers. However, it was only possible to establish a single site in the Meio River due to its characteristics (i.e., its greater slope, smaller dimensions, homogeneity of habitats and low mean flow). Samples were collected between April 2010 and January 2011. Characterization of the population structure of the ichthyofauna was performed with the aid of electronarcosis equipment (electrofishing). This apparatus consists of two dip nets connected to a power generator (Honda EB 1000) that emit electrical discharges of approximately 120 Volts into the water. The discharges were applied in a downstream-upstream direction, with the dip nets travelling in parallel relative to each other through a predetermined area corresponding to a water surface area of 250 m², comprising backwaters and rapids, during a one-hour period.

During the discharges, unconscious fish were captured with the aid of a hand net and kept in a container with river water until the end of collection and the beginning of the sorting stage. At each sampling site, the temperature, dissolved oxygen concentration (mg / L) and saturation (%), pH and conductivity were measured throughout the sampling period (Table 1). After sampling, the fish were sacrificed by severing the spinal cord, fixed in 10% buffered formalin (the fixative was injected into the coelomic cavity, followed by immersion in the same solution) and stored in barrels. The material was then sent to the laboratory of the Ichthyological Research Group of the Capão da Imbuia Natural History Museum (Museu de História Natural do Capão da Imbuia), where species were identified based on specialized literature in the catalogues from Lucena & Lucena 2002; Pereira & Reis 2002; Reis & Schaefer 1998; Kullander & Lucena 2006; Menezes *et al.,* 2007; and Lucinda 2008 and Buckup *et al.,* 2007. The fish was subsequently sent to the Laboratory of Histology and Microbiology of the Integrated Group on Aquaculture and Environmental Studies at the Federal University of Paraná (Universidade Federal do Paraná - UFPR).

In the laboratory, the following biometric parameters were determined in the sampled animals: total length (TL)/cm; standard length (SL)/cm and total weight (TW)/g. A random sample of 30 specimens of each species was analyzed from each sampling site. When the number of captured specimens was less than 30 for a given species, biometric measurements were taken from all specimens. Statistical analyses were performed using Statsoft Statistica™ 8.0 software. A comparative assessment of the abiotic variables measured in each river was carried out using comparative tests of multiple independent variables via the Kruskal-Wallis method. A multivariate cluster analysis of the sampling sites was performed using the simple Euclidean distance method.

Analyses comparing the biometric variables obtained from the treatment and control group specimens were performed using the Kolmogorov-Smirnov test. Next, a ratio test was conducted using Chi-square analysis to assess the significance of the number of differences observed between the fish from the treatment and control groups. The constancy of occurrence (C) of the different species was determined based on the percentage of the study period in which each species occurred and calculated for each analyzed river using the following formula:

$$C = \frac{pi}{P} X\, 100$$

Where, pi equals the number of samples containing species i, and P is the total number of samples collected.

The calculated values of C enabled species to be grouped into three categories: (i) constant (C > 50%), (ii) accessory (25% < C < 50%) and (iii) accidental (C < 25%).

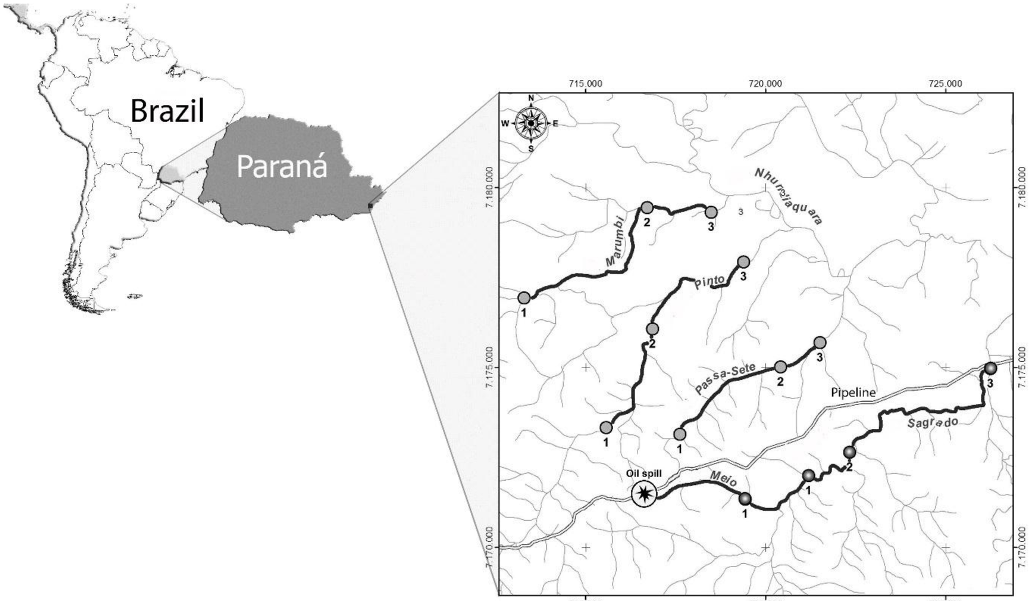

Figure 1: Monitored Rivers and respective sampling sites. Highlight of the pipeline and location (*) of the accident

Figure 2: Cluster analysis grouping sampling sites from different rivers based on abiotic characteristics

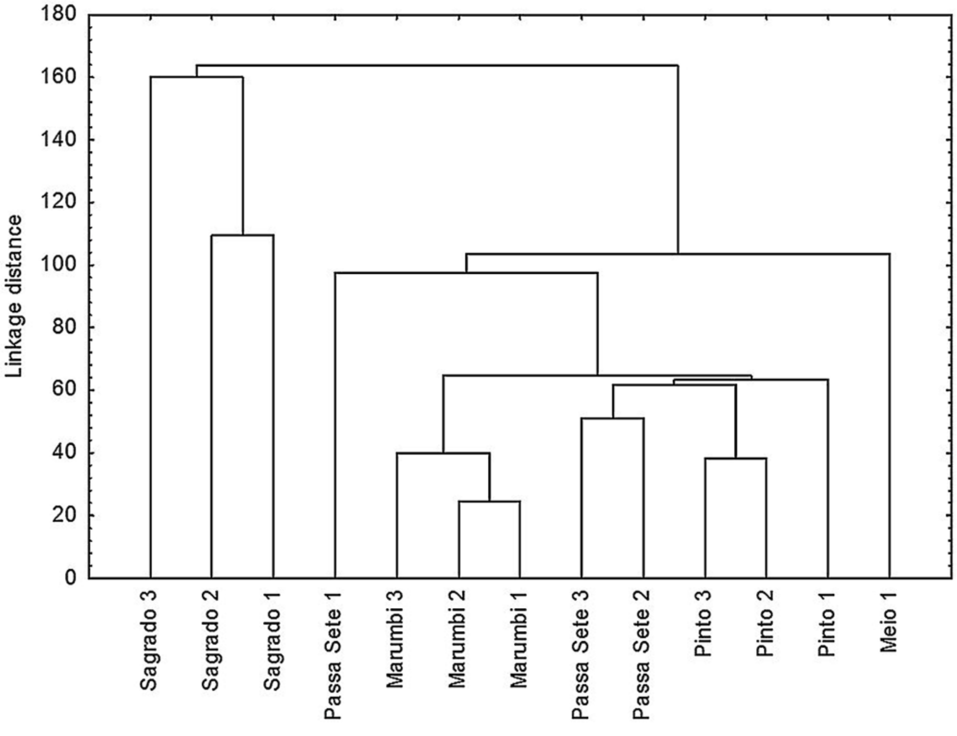

Table 1: Physical and chemical parameters analyzed. TW (total weight, g)

Parameters	Unit	Equipment	Model
Temperature	˚C	Oximeter	YSI550
Dissolved Oxygen	mg/L and %	Oximeter	YSI550
pH	-	Portable pH Meter	HI8424
Electric Conductivity	µS	Conductivity Meter	pHtek

Table 2: Mean values of abiotic parameters measured at each sampling site for each river. T (temperature), DO (dissolved oxygen), EC (electric conductivity). Different letters indicate significant differences (p<0.05) between sites

Factor	**Meio**	**Sagrado**			**Passa Sete**			**Pinto**			**Marumbi**		
	1	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
T (°C)	20.7 (19-22.2)	21.2 (19-23.2)	22 (19.6-24.2)	21.4 (19.1-23.7)	21 (20-22)	21.6 (19.6-23.5)	22 (20.1-23.7)	20.7 (19-22.3)	21.5 (19.5-23.3)	22.5 (20-24.8)	20.2 (18.2-22.1)	20.7 (18.5-22.7)	21.6 (19.4-23.6)
OD (%)	88.3 (82.4-94.2)	83.1 (74.5-91.5)	80.8 (68.8-92.7)	88.1 (83.7-92.3)	87.6 (82-93.2)	82.8 (74.7-90.7)	78.6 (73.4-83.7)	88.1 (79.3-96.8)	84.2 (76.8-91.5)	87.5 (79.8-85)	88.7 (82.1-95.2)	87.6 (82.7-92.4)	90.2 (82-98.2)
OD (mg/L)	8.1 (7.2-9)	7.7 (6.8-8.4)	7.2 (6.2-8)	7.7 (7.2-8.2)	7.8 (7.3-8.2)	7.2 (6.2-8.1)	6.7 (6.0-7.3)	7.8 (7-8.6)	7.8 (7.2-8.3)	7.2 (6.2-8.1)	7.8 (7.3-8.2)	7.8 (7.3-8.2)	7.9 (7.2-8.5)
pH	7.7 (7.4-8)	7.5 (6.7-8.3)	7.5 (7.1-7.9)	7.4 (6.9-7.9)	7.6 (7.4-7.8)	7.4 (7.1-7.6)	7.2 (6.8-7.5)	7.6 (7.2-7.9)	7.7 (7.2-8.1)	7.4 (7.1-7.8)	7.7 (7.4-8.1)	7.6 (7-8.1)	7.6 (7.2-7.9)
EC (µs)	90.2^{a} (72-108.3)	69.5^{ab} (41.5-97.4)	49.8^{bcd} (46-56.4)	49.4^{bd} (44.5-54.3)	79.6^{ac} (73-86.1)	70.8^{ad} (66.2-75.3)	72.4^{ad} (63-81.8)	51.4^{bcd} (46.5-56.2)	54.1^{ab} (51-57.5)	56.2^{ab} (52.7-60)	35.3^{b} (30.3-40.2)	36.1^{b} (30.5-41.6)	38.5^{b} (33.5-43.4)

Table 3: Distribution and abundance of individuals in the different families collected in the studied rivers

Family	**River**												
	Meio	**Sagrado**			**Passa Sete**			**Pinto**			**Marumbi**		
	Sampling sites												
	1	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Callichthyidae	4	12	52	1	0	29	11	39	22	66	8	18	40
Characidae	58	39	62	85	87	290	254	33	101	39	27	36	74
Crenuchidae	0	18	15	11	18	26	47	163	284	70	97	147	318
Cichlidae	7	10	25	3	0	10	5	3	2	4	2	3	16
Curimatidae	0	0	0	0	0	2	2	0	0	0	0	0	0
Erythrinidae	0	1	1	0	0	6	3	0	2	0	3	0	9
Gymnotidae	8	2	2	2	2	3	6	3	2	1	0	1	10
Gobiidae	0	2	3	18	0	0	0	0	2	3	0	0	8
Loricariidae	0	35	114	93	0	58	36	16	191	268	75	69	216
Pimelodidae	7	7	6	1	18	17	20	59	16	8	63	23	11
Poecicliidae	43	13	24	6	4	4	12	1	8	37	1	6	59
Synbranchidae	8	16	4	1	0	2	2	7	17	1	9	8	8
Pseudopimelodidae	0	0	0	0	0	0	0	0	0	1	0	0	1
Trichomycteridae	0	0	0	0	0	0	0	2	0	0	1	1	1

Table 4: Frequency of occurrence of species captured in the studied rivers

Frequency	**Species**
Frequent	*A. leptos*, *A. multispinis*, *A. altiparanae*, *A.* cf. *ribeirae*, *A. janeiroensis*, *A. tajasica*, *B. microcephalus*, *C. callichthys*, *C. lanei*, *C. pterostictum*, *C. facetum*, *C. tingui*, *C. sanctacatarinae*, *D. langei*, *G. brasiliensis*, *G. carapo*, *G. pantherinus*, *H. leucofrenatus*, *H. multifasciatus*, *H. malabaricus*, *H. reticulatus*, *K. lacerta*, *M. microlepis*, *O. hepsetus*, *P. splendens*, *P. harpagos*, *P. pappenheimi*, *P. obtusa*, *R. quelen*, *R. transfasciatus*, *Rineloricaria* sp., *S. barbatus*, *S. marmoratus*, *Trichomycterus* sp.
Accessory	*Characidium* sp., *C. nattereri*, *H. bifasciatus*
Accidental	*Astyanax* sp., *B. saporator*, *G.* cf. *oceanicus*, *Gobionellus* sp., *H. graciosa*, *Hypostomus* sp., *Microglanis* sp., *P.* cf. *azygolechis*, *P. steindachneri*, *P. alessandrae*, *S. guntheri*

Table 5: Mean values and confidence intervals of biometric variables of the species captured in the studied rivers. TL (total length, cm); SL (standard length, cm); TW (total weight, g); C (Control) and T (Treatment); Different letters indicate significant differences ($p<0.05$) between Treatment and Control by Kolmogorov Smirnov Test

Species	**TL**		**SL**		**TW**	
	C	**T**	**C**	**T**	**C**	**T**
Characidium lanei	5.0^{b} (4.9-5.0)	5.9^{a} (5.0-6.7)	3.9^{b} (3.8-4.0)	4.8^{a} (4.0-5.4)	1.4^{b} (1.3-1.5)	2.5^{a} (1.5-3.5)
Deuterodon langei	7.2^{a} (6.9-7.4)	4.2^{b} (3.1-5.2)	5.6^{a} (5.4-5.8)	2.8^{b} (2.2-3.3)	6.7^{a} (6.1-7.2)	1.7^{b} (0.04-3.3)
Hisonotus leucofrenatus	5.3 (5.2-5.3)	5.4 (5.2-5.6)	4.0^{b} (3.9-4.0)	4.1^{a} (3.9-4.2)	1.3^{b} (1.3-1.4)	1.5^{a} (1.4-1.7)
Hollandichthys multifasciatus	7.0^{a} (5.8-8.1)	5.2^{b} (4.2-6.0)	5.3^{a} (4.1-6.4)	4.0^{b} (3.2-4.7)	4.5^{a} (2.4-6.7)	2.8^{b} (1.4-4.2)
Mimagoniates microlepis	3.8^{b} (3.6-3.9)	4.8^{a} (4.4-5.1)	2.8^{b} (2.7-2.9)	3.6^{a} (3.3-3.7)	0.5^{b} (0.5-0.6)	1.2^{a} (0.9-1.4)
Oligosarcus hepsetus	3.7^{b} (2.9-4.6)	7.8^{a} (5.0-10.5)	3.0^{b} (2.5-3.5)	6.3^{a} (3.9-8.5)	0.5^{b} (0.3-0.8)	4.7^{a} (0.6-9.1)
Rineloricaria sp.	8.1^{b} (7.7-8.3)	8.7^{a} (8.1-9.2)	7.0^{b} (6.7-7.2)	7.5^{a} (7.0-8.0)	3.3^{b} (2.9-3.7)	4.7^{a} (3.7-5.6)
Scleromystax barbatus	6.1^{a} (5.8-6.2)	5.1^{b} (4.6-5.6)	4.6^{a} (4.4-4.7)	3.8^{b} (3.3-4.1)	3.8^{a} (3.6-4.1)	2.7^{b} (2.0-3.5)

Table 6: Ratio Test regarding the number of significant differences obtained through the Kolmogorov-Smirnov statistical test applied to the biometric variables analyzed in fish from treatment (Meio and Sagrado) and control (Pinto, Passa Sete and Marumbi) rivers. TL (total length, cm); SL (standard length, cm)

Biometric variable	**Number of significant differences**		**Total number of differences analyzed**	***p***
	Control	Treatment		
TL	3	4	48	0.71

SL	3	5	45	0.49
TW	3	5	48	0.49

Results

Abiotic factors

The abiotic characterization of each sampling site is described in Table 2. Multiple comparison analysis showed that only the electrical conductivity was significantly different between the rivers and their respective sampling sites. Sites 2 and 3 in the Pinto River and site 1 in the Sagrado River were the only sites that did not differ in terms of conductivity when compared to the other sites. The Meio River showed the largest differences. Multivariate cluster analyses were performed, grouping sampling sites according to the monitored abiotic factors. Thus, it was established that despite the initial attempt to identify and define the groups of sampling sites that were most similar to each other in the studied rivers, the linkage distances calculated via cluster analysis were generally shorter between the sites in the same river than between sites that were presumably similar, but located in different rivers (Figure 2).

Biotic factors

To conduct an analysis of population structure, a total of 4,831 fish was collected, which belonged to six orders, 14 families and 48 species. As a maximum of 30 individuals from each species was analyzed, the total number of fish processed was 4,619. The orders Characiformes and Siluriformes were the most abundant, being represented by 2,428 and 1,970 individuals, respectively. Characidae was the most abundant family, with 234 individuals being captured, followed by Loricariidae, with 196 individuals, and Crenuchidae, with 140 individuals (Table 3).

Based on the frequency of occurrence of the 48 species captured, it was found that the species considered to be constant were the most abundant (69.3%) in all of the monitored rivers, followed by accidental (22.4%) and accessory (8.1%) species (Table 4).

The control group showed the greatest percentage of constant species, which contributed 41.9% of the catches. This category accounted for 14.7% of the treatment group. Species considered to be accessory constituted 11.8% of the treatment group and 6.9% of the control group, while accidental species were more common in the control group compared with the treatment group, accounting for 18.8% and 5.6% of these groups, respectively.

The analysis of the biometric parameters obtained for each species captured in the assessed rivers determined the differences between the treatment and control groups, based on comparison of the mean values of each parameter and their respective confidence intervals (Table 5). Comparative analyses of the studied biometric variables between the treatment and control groups showed significant differences for the variables (TL, SL, TW) among eight of the 48 species captured. The number of species that presented significant differences between the treatment and control groups was 7 for total length, 8 for standard length and 8 in total weight, with greater mean values being detected in the treatment group. Following comparative analyses of the biometric variables between the treatment and control groups using the Kolmogorov-Smirnov test, any parameters that showed significant differences were subjected to a ratio test (Table 6). This test showed that there was no statistically significant difference ($p > 0.05$) between the control and treatment groups in relation to the number of previously quantified significant differences in the biometric variables of each species analyzed.

Discussion

Fish populations are selected by the physiographic, physical and chemical conditions found in aquatic systems (McCormick *et al.,* 2000; Herlihy *et al.,* 2006). Therefore, according to Onorato *et al.,* (1998), fish species are not randomly distributed, but, rather, occupy specific habitats within each aquatic environment. Thus, changes in environmental conditions tend to cause a restructuring of fish assemblages, reflecting the prevailing conditions of the habitat in which they live. According to the American Petroleum Institute (1994), changes in aquatic environments caused by petroleum hydrocarbons induce a set of responses at the individual, population and community levels. Small-sized rivers with a low water flow exhibit a high sensitivity to the impacts of oil spills because of the lower rates of pollutant dilution observed in these waterways (French-McCay *et al.,* 2009).

Among the hydrological parameters analyzed in the present study, only the electrical conductivity of the water showed significant differences between the established sampling sites. Several authors have described the direct influence of conductivity on the dynamics of fish communities, which can alter the population structure, richness, diversity and distribution of species in the environment (Casatti *et al.,* 2001; Pessano *et al.,* 2005; Felipe & Súarez 2010). In addition to the presence of pollutants, electrical conductivity can be directly influenced by factors such as the chemical composition of the soil and the size of the river (Kney & Brandes 2007).

The grouping of rivers, according to the quantified abiotic factors showed that the sites within the same river, despite being found at different altitudes and different locations, were highly similar to each other, while sites in different rivers, even with similar altitudes, showed a greater degree of dissimilarity. According to Winkelmann *et al.,* (2003), abiotic indices in natural environments, especially streams, rarely exhibit high similarity values. Due to its low water flow and reduced dimensions, the Meio River was shown to be morphologically similar only to site 1 in the Passa Sete river. In comparison, the other sites in the Passa Sete river (sites 2 and 3) exhibit larger dimensions and greater water flows, therefore not showing a correlation with site 1.

The three sampling sites in the Sagrado, Pinto and Marumbi rivers were morphologically similar. Site 1 for each river exhibited large-sized rocks in the river bed, a high water flow and a broad width. Sites 2 and 3 in the three rivers were composed primarily of silty and sandy sediments and were located in more lentic river stretches, which allows the formation of different habitats for the different species found in these stretches. However, despite showing physiographic similarities with the Marumbi and Pinto rivers, the Sagrado river distinguishes itself due to a greater degree of human disturbance, being subjected to constant anthropogenic interference (bridge building, crop cultivation along its banks and channel widening to avoid flooding) at all sample sites. Many studies have been performed to analyze the causes of changes in the environmental conditions of ecosystems and their biological communities (Araújo 1998; Cunico *et al.,* 2006; Ferreira & Cassati 2006). These studies assume that the communities present in different environments responds to external impacts through changes in their structural and functional characteristics (Ferreira & Cassati 2006).

In the present study, the orders Characiformes and Siluriformes dominated both the treatment and control groups, representing approximately 91% of all individuals captured. According to Reis *et al.,* (2003), in freshwater Neotropical regions, the order Siluriformes is the group showing the greatest abundance of species, followed by the order Characiformes, which displays a high prevalence in the ichthyofauna of South America, especially in flowing waters. Ferreira (2007) also analyzed streams in the Serra do mar (though in the state of São Paulo) and found a high species richness distributed among the orders Characiformes and Siluriformes. In addition to this study, several other studies have found a predominance of these two orders in streams located in the coastal areas of the serra do mar in the states of Rio de Janeiro and São Paulo (Teixeira *et al.,* 2005; Mazzoni *et al.,* 2006; Guimarães *et al.,* 2010). According to Gaston (1994), the importance of a species in the population can be attributed to its frequency of occurrence in aquatic environments, or representable in terms of body mass or numbers of individuals. The constancy of occurrence of fish species is an important factor for characterizing all sites along a stream and is considered a qualitative measure that identifies the migrant or resident species of a community as well as the effect of seasonal variations and environmental changes on communities (Teixeira & Gurgel 2005).

The findings of the present study showed that the identified constant species (n = 34) were the most abundant in the five assessed rivers, representing about 69% of the total recorded occurrences. This group was comprised mainly of Characidium lanei, Deuterodon langei, Hisonotus leucofrenatus, Rineloricaria sp, and Characidium pterostictum. These records corroborate the findings of Guimarães *et al.,* (2010) in the Pinto River, in which the authors found 15 constant species, representing approximately 45% of the total, and the species Characidium pterostictum, Characidium lanei and Rineloricaria sp were predominant.

According to Flores-Lopes *et al.,* (2006), when there is a predominance of constant species in streams contaminated with pollutants, the impacted environment is considered to be in a state of ichthyofaunal recovery. This situation arises because after stressful pollution events, species tend to disperse to locations where there is no significant influence of the contaminant. The observed predominance of constant species, therefore indicates that the ichthyofauna of the rivers exposed and not exposed to oil have stabilized. According to Lowe-McConnell (1975), the resident communities of a river can be increased numerically by the entry of immigrant fish joining residents for a certain period time to feed or reproduce. However, this phenomenon was observed among only a few of the species caught during the sampling campaigns conducted in the present study, as there was a greater frequency of constant species in the five rivers evaluated.

The chronic effects observed in fish populations exposed to hydrocarbons may translate into decreases in their survival ability and reproductive success, which may lead to a decline in the population density and reduced genetic variability within populations (Weis *et al.,* 2001). Comparison of the biometric variables examined in the present study showed few significant differences between the treatment and control groups. However, increased mean values were found for the total and standard length and the total weight of fish caught in the treatment group. Adams *et al.,* (1993) reported that, depending on the severity of an oil spill in an environment, the physiological systems of fish can be impacted, reducing their growth as well as the amount of fat and glycogen stored in their livers and, consequently, affecting reproduction. However, the results obtained in the present study showed no evidence of a reduction in the growth or weight of the fish from rivers exposed to oil. Although the observed biometric differences could be related to the low number of specimens collected in the Meio and Sagrado rivers (treatment), or even intrinsic characteristics of the studied species or environments, the ratio test performed to analyze the significance of the differences found between the fish from the two groups (treatment and control) showed that they were not significant. These results indicate the existence of biometric similarity between the fish populations that inhabit the rivers exposed to oil spills and those in unexposed rivers.

Acknowledgements

The authors thank the Universidade Federal do Paraná - UFPR for the support provided during the development of the study as well as Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES for the scholarship provided for the masters dissertation at the Zoology post graduate program of UFPR.

References

Adams J K, A J He lkamp & R P. Hannah (1993). Method for ranking biological resources in oil spill response planning. Proceedings Oil Spill Conference, 159-164.

Alvez M V. (2008). Estabilidade e filtrabilidade de óleo diesel. Rio de Janeiro. Dissertação (Mestrado em Engenharia Química do Instituto de Química), Universidade Estadual do Rio de Janeiro, RJ. 102 p.

American Petroleum Institute. (1994). Options for minimizing environmental impacts of freshwater spill response. Hazardous materials response & Assessment division, 23-119.

Bown N K, T S Gray & S M Stead (2013). Co-management and adaptive co-management: Two modes of governance in a Honduran marine protected area. Marine Policy, 39: 128-134.

Buckup P A, N A Menezes & M S Ghazzi. (2007). Catálogo das espécies de peixes de água doce do Brasil. Rio de Janeiro, Museu Nacional, 195 p.

Cajaraville M P, L Hauser, G Carvalho, K Hylland, I Olabarrieta, A J Lawrence, D Lowe & A Goksoyr. (2003). Genetic damage and the molecular/cellular response to pollution. In: Effects of pollution on fish molecular effects and population responses. Blackwell Science Ltda, Blackwell Publishing Company, 2-161.

Casatti L, F Langeani & R M C Castro. (2001). Peixes de riacho do Parque Estadual Morro do Diabo, bacia do Alto rio Paraná, SP. Biota Neotropica, 1: 1-15.

Felipe T R A & Y R Súarez. (2010). Caracterização e influência dos fatores ambientais nas assembleias de peixes de riachos em duas microbacias urbanas, Alto rio Paraná. Biota Neotropica, 10: 43-151.

Ferreira F C. (2007). Ictiofauna de riachos na planície costeira da bacia do rio Itanhaém, litoral sul de São Paulo. Dissertação (Mestrado em Ciências Biológicas – Zoologia), Universidade Estadual Paulista. 126 p.

Flores-Lopes F, L R Malabarba, E H L Pereira & J F P Silva. (2001). Alterações histológicas em placas ósseas do peixe cascudo Rineloricaria strigilata (Hensel) (Teleostei, Loricariidae) e sua frequência no lago Guaíba, Rio Grande do Sul, Brasil. Revista Brasileira de Zoologia, 18(3): 699-709.

French-McCay D, C J Beegle-Krause, J Rowe, W Rodriguez & D S Etkin. (2009). Oil spill risk assessment – Relative impact indices by oil type and location. AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, 655-681.

Gaston K J. 1994. Rarity. London: Chapman & Hall, 205 p.

Guimarães A T B, M S Menezes & A C Peret. (2010). Composição da ictiofauna em função da fisiografia de um riacho costeiro de Floresta Atlântica – Brasil. Biota Neotropica, 10(2): 57-65.

Herlihy A T & R M Hughes, J C Sifneos. (2006). Landscape clusters based on fish assemblages in the conterminous USA and their relationship to existing landscape classifications. In: Hughes R M, Wang L, Seelbach P W. (Eds.) Landscape influences on stream habitats and biological assemblages, 87-112.

Hewitt J E & S F Thrush. (2007). Effective long-term ecological monitoring using spatially and temporally nested sampling. Environmental Monitoring and Assessment, 133: 295-307.

Hylland K, S Feist, J Thain & L Forlin. (2003). Molecular/Cellular processes and the health of the individual. In: Effects of pollution on fish molecular effects and population responses. Blackwell Science Ltda., Blackwell Publishing company, 2-161.

Kney A D & D Brandes. (2007). A graphical screening method for assessing stream water quality using specific conductivity and alkalinity data. Journal of Environmental Management, 82: 519-528.

Kullander S O & C A S Lucena. (2006). A review of the species of Crenicichla (Teleostei: Cichlidae) from the Atlantic coastal rivers of southeastern Brazil from Bahia to Rio Grande do Sul States, with descriptions of three new species. Neotropical Ichthyology, 4: 127-146.

Lawrence A J & M Elliott. (2003). Introduction and conceptual model. In: Effects of pollution on fish molecular effects and population responses. Blackwell Science Ltda., Blackwell Publishing company, 2-161.

Lawrence A J & K Hemingway. (2003). Effects of pollution on fish, Molecular effects and population responses. Blackwell Science Ltda, Blackwell Publishing company, 2-161.

Lowe-McConnell R H. (1975). Fish communities in tropical freshwaters. Their distribution, ecology and evolution. London and New York, Longman, 303 p.

Lucena Z M S & C A S Lucena. (2002). Redefinição do gênero "Deuterodon" Eigenmann (Ostariophysi: Characiformes: Characidae). Comunicações do museu de ciências e tecnologia da PUCRS, 15: 113-135.

Lucinda P H F. (2008). Systematics and biogeography of the genus Phalloceros Eigenmann, 1907 (Cyprinodontiformes: Poeciliidae: Poeciliinae), with the description of twenty-one new species. Neotropical Ichthyology, 6: 113-158.

Mazzoni R, N Fenerich-Verani, E P Caramaschi & R Iglesias-Rios. (2006). Stream-Dwelling fish communities from an Atlantic Rain Forest drainage. Brazilian Archives of Biology and Technology, 49(2): 249-256.

McCormick F H, D V Peck & D P Larsen. (2000). Comparison of geographic classification schemes for Mid Atlantic stream fish assemblages. Journal of the North American Benthological Society, 19: 385–340.

Menezes N A, S H Weitzman, O T Oyakawa, F C T Lima, R M C Castro & M J Weitzman. (2007). Peixes de água doce da Mata Atlântica, Museu de Zoologia da Universidade de São Paulo, São Paulo, Brazil. 405 p.

Onorato D P, P A Angus & K R Marion. (1998) Comparasion of a small-mesh seine and a backpack eletroshocker for evatuating fish populations in a north-central Alabama stream. North American Journal of Fisheries Management, Bethesda, 18: 361-373.

Pedrozo M F M, E M Barbosa, H X Corseuil, M R Scheneider & M M Linhares. (2002). Ecotoxicologia e Avaliação de Risco do Petróleo, Centro de Recursos Ambientais, Salvador. 13-41.

Pereira E H L & R E Reis. (2002). Revision of the Loricariidae genera Hemipsilichthys and Isbrueckerichthys (Teleostei: Siluriformes) with description of five new species of Hemipsilihthys. Ichthyological Exploration of Freshwaters, 13 :97-146.

Pessano E F C, C L O Azevedo, M V M Querol, E Querol, L G Brasil, L R B Castro, T B Pinto & F V Corrêa. (2005). Ictiofauna do arroio Quarai-Chico, bacia do médio rio Uruguai, no interior do Parque Estadual do Espinilho, Rio Grande do Sul, Brasil. Biotemas, 18(2): 143-153.

Reis R E & S A Schaefer. (1998). New cascudinhos from southeastern Brazil: Systematics, edemism and relationships (Siluriformes, Loricariidae, Hypoptopomatinae). American Museum Novitates, 3254: 1-25.

Reis R E, S O Kullander & C J Ferraris. (2003). Check list of the freshwater fishes of South and Central America. Editora da Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brasil. 729 p.

Teixeira J L A & H C B Gurgel. (2005). Ocorrência e distribuição temporal da ictiofauna do açude riacho da Cruz, no Rio Grande do Norte. Revista Ceres, 52(300): 317-324.

Teixeira T P, B C T Pinto, B F Terra, E O Estiliano, D Gracia & F G Araújo. (2005) Diversidade das assembleias de peixes nas quatro unidades geográficas do rio Paraíba do Sul. Iheringia, Série Zoologia, Porto Alegre, 95(4): 347-357.

Weis J S, G Smitht, I Zho, C Sastllo, B Lsassi & P Veis. (2001). Effects of contaminants on behavior: biochemical mechanisms and ecological consequences. BioScience, 31: 209-217.

Winkelmann C, J H E Koop & J Benndorf. (2003). Abiotic features and macroinvertebrate colonization of the hyporheic zones of two tributaries of the river Elbe (Germany). Limnologica, 33: 112-121.