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Non-native fish in Argentina rivers: occurrence, spatial distribution and impact on biota

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Introduction

Context

Santa Fe, capital of the province of Santa Fe, is where I did the internship. It is a very interesting city between the Laguna Setubal and Salado del Norte River where more than half of the population of the province lives. The Laguna Setubal flows into the Coronda River which runs intro the Paraná river, the second largest river of South America considering the catchment area. Since a long time, species from other parts of the world are introduced in the country and in this region. The law in the province of Santa Fe about aquaculture does not prohibit the introduction and farming of non-native species. Only one exotic species is illegal: *Clarias gariepinus* according to the decree n°2410 article 47 in the law 12212. In this way, introduced species of fish can be found in the country and may cause damages in natural systems. Moreover, a lot of references about species introduced in Argentina have been published but there is no review on them.

All around the world, 624 species of freshwater fish were introduced. Species were introduced mainly for aquaculture. Asia is the region with most of introduced species. South America has approximately the same number of native freshwater fish than Asia but a lot less number of introduced species. Asia receives a lot of species from other regions of the world while South America is an important source of fish for other regions (Gozlan 2008).

Objectives

In this context, in agreement with Luis Espínola, my tutor in the laboratory of Ecohydrology of INALI (National Institute of Limnology), we decided to focus the following objectives:

- On Scopus: systematic review of the introduced species in Argentina, identifying the biological communities, the date of publication and the journal
- Systematic review of the no-native fish species in Argentina, review bibliography identifying date of publication, scientific journal and geographical localisation
- Establish spatial patterns of distribution of non-native fish species in the country
- Establish potential impacts on biota in order to establish management policies, present a native candidate to aquaculture
- Show the research work to the members of the laboratory
- Publish the research work

Missions

In order to achieve the objectives above mentioned, a synthetic list of tasks has been established:

- Read about scientometry and impact of introduced species in natural systems
- Review publications on non-native species in Argentina, first in a global way then focusing on fish species
- Form a data set matrix
- Obtain results and statistics for interpretations and implications
- Use those results to suggest management strategies

The researchers and PhD students have different projects which involve sampling field. I went to help during two sampling campaigns. The first was in April 2018. It is part of the doctoral thesis of Florencia Eurich. On river sandbars in the Paraná River, we collected fishes to analyse the fish assemblage. The

second sampling field was on river sandbars too, in Jun 2018. We collected plastics and put traps to capture macroinvertebrates. This campaign is part of the doctoral thesis of Nicolas Garello who works on the ecological role of beaches. The annexe 1 explains the methodology of each sampling period.

Introduction to the topic

Introduction of species occurred since humans started to migrate, as the Romans introduced vertebrates during their colonization of the world (Alcover et al. 1981 apud Moorea et al. 2004). With the globalization and the arrival of new systems of transportation, species were enabled to extend their distribution area. A lot of introductions are intentional. But sometimes, by the air in aircraft and by the sea in the water ballast of ships, species travelled clandestinely and settled in many new places (Ruiz et al. 2000, Bataille et al. 2009) increasing their chances of survival in other regions or countries. But those introductions do not always lead to ecological problems. Indeed, very few introduced species, approximately 10%, become invaders (Williamson and Fitter 1996).

When establishing themselves, introduced species create sensitive situations like homogenization, loss of biodiversity and economic problems. Homogenization occurs when introduced species expend themselves to the detriment of native communities and increase the biodiverse similarity between two or more biota in several part of the world (McKinney and Lockwood 1999). Habitat destruction is one of the main causes of loss of biodiversity. It is especially due to agriculture and industry. Agriculture affects directly the biodiversity by changing completely the landscape and the ecological niches of lots of species. Industries influence this perdition too because factories increase the global climate change, by rejecting CO_2, which impacts the biological communities. Also, rejection of pollutants alters biogeochemical cycles what contributes a lot to habitat destruction (Vitousek 1994). Introduced species and their interaction with native species contribute to decrease biodiversity around the world. Non-native species generally reduce the population of native species and displace them (Vitousek et al. 1996). The economic problems created by biological invasion are important. The United States of America spend each year more than 120 billion of dollars in order to control non-indigenous species and counterbalance the damages of their presence in the territory (Pimentel et al. 2005).

Freshwater habitats are not spared by pathways of invasion. Europe has ten times less native freshwater species of fish than South America but it has a lot more importations of fish than South America (Gozlan 2008). Those introductions are linked to different needs. In South America, the most important reason of introducing fish is aquaculture (Gozlan 2008). Aquaculture started slowly in this region in the 1940's mostly, as sport fishing and other recreational activities, but in the following decades it became a source of food production to feed the local population (Hernández-Rodríguez 2001). Also, introductions of fish occurred for biological control, like *Gambusia affinis* which was introduced for mosquito control in several parts of the world (Fishbase, 2018). According to Gubiani et al. (2018), in the Neotropical region, aquarism trade is the most important vector of introduction for species external to this region.

Argentina is part of the temperate subtropical region with 2,7 million of square kilometres (EWP 2003). It has more than 470 species of fish in its freshwater systems with only 17 introduced fishes according to Liotta (2005). As it is a very long country, there are 90 drainage basins of surface water. The Paraná River is one of the largest rivers with 4000 km long. Its hydrographical basin covers 1,5 million of km² (Bonetto et al. 1975). The Middle Paraná River started at the confluence with the Paraguay river and goes down the city of Diamante (Bonetto and Drago 1968) which includes the Santa Fe province. About 207 species of freshwater fish live in the middle section of Paraná River (Drago et al. 2003).

This paper gives elements to understand the theme of introduced species in Argentina by revising the publications related to the topic. In a first part, we aim to know since how long introductions of species are studied and on which taxonomic groups. In a second part, the review of publications about fishes introduced in Argentina is presented with a cartography of the localisation of those species in the country. Finally, we bring different components to explain how the law about aquaculture could be changed in order to limit the inflows of non-native fish in the province of Santa Fe and promote the production of local species such as the small-scaled pacu (*P. mesopotamicus*).

Presentation of the organization

The INALI laboratory localised in Santa Fe, Argentina, was born in 1962, created by Argentino Bonetto in order to increase the knowledge on freshwater systems. It is the first institute created by CONICET (National Council of Scientific and Technical Research) in Argentina and was the first Institute of Limnology in South America. Studying la fauna and flora and ecological process in continental water is the main objective of the Institute. But the researchers work also on fishery resources to promote a rational fishing and help develop aquaculture in the region. Collections of many of the species living in the Middle Paraná River are created to help with the determination of rare species.

This Institute tries to gather many disciplines to cover better the different topics of research. There are researchers specialized in chemistry, hydrobiology, taxonomy, limnology, etc. Together, they attempt to understand better the Middle Paraná River in its globality and other regions when it's necessary.
In the laboratory where I work, three persons out of nine are in charge of the organisation: Mario Amsler, Water Resources Engineer, Martín Blettler, Doctor of Biological Sciences and Luis A. Espínola, Doctor of environmental Sciences who was my internship's tutor. The seven other researchers are PhD students.

The INALI researchers have a good visibility in South America since they published 2 books, participated in 9 book chapters and have 42 articles in journals for 2017. They also work in international scientific working groups and contribute to a lot of projects in other countries, such as Martín Blettler went to the university pole of Chinon, France, to participate in the project: Ecohydraulics and dams removal.

Methods and materials

a) Back search strategy

In order to understand the theme of introduced species in Argentina, a complete research on the search engine Scopus (https://www.scopus.com) has been done during May 2018. According to Goodman and Deis (2005), it is a better search engine than Web of Science in the field of Sciences thanks to its large coverage of emerging country. Moreover, it covers publications which are not in English.

Searches in English were restricted on the keywords for a better selection. We used the following sequence: "introduction" OR "alien" OR "non native" OR "exotic" OR "introduced" AND "Argentina" OR "Patagonia" OR "Cuyo" OR "Buenos Aires" OR "Northwest Argentinian" OR "Littoral Argentinian" OR "Center Argentinian". All years were included in the search as well as all the topic areas. Then, all articles have been read and a selection done thanks to the abstract, the keywords and when necessary the full text. If the publication was really linked to introduced species in Argentina we kept it. If not, we did not use it. We sorted the documents related to the topic of introduced species depending on the taxonomic groups treated. The classes used are: Fungi, Protozoa, Bacteria, Virus, Invertebrates, Mammals, Amphibians, Birds, Fishes and Vegetation.

We did the same search on Scopus with all the keywords in Spanish and to be sure not forget any paper we chose to search the words in all the possible fields. We put "especies invasoras" OR "especies introducidas" OR "especies exóticas" AND "Argentina" OR "Buenos Aires" OR "Patagonia" OR "Cuyo" OR "Litoral argentino" OR "Centro argentino". The same selection and classification as the search in English have been done.

After a selection in both searches, we gathered the English and Spanish results and took out the duplicated articles. We decided not to integrate 2018 in our graphics because the search on Scopus have been done until May 2018 and other works will probably be published.

b) Introduced fish species

To focus on introduced fish in the country, we worked on Scopus as well. For a finer selection, we choose to restrict the search on the title, the abstract and the keywords, but put no restriction on topic areas and neither on temporal field: all years were analysed. We entered the following sentence: "introduction" OR "alien" OR "no native" OR "exotic" OR "introduced" AND "fish" OR "ichthyofauna" AND "Argentina" OR "Patagonia" OR "Cuyo" OR "Buenos Aires" OR "Northwest Argentinian" OR "Littoral Argentinian" OR "Center Argentinian".

We selected only the articles in relation with introduced fish in Argentina and with a mention of introduced species, or synonyms in the methodology or result parts. At this point we added the articles from the previous search in relation with introduced species in the country. Articles with reference to introduced species only in the introduction were not selected. In case of conflict on the origin of a species, the book of Liotta (2005) “Ditribución geográfica de los peces de aguas continentals de República Argentina” has been taken as reference.
All the publications drawn from this search have been classified by year of publication, journal and by studied species.

To generate maps, when geographic coordinates were given by the authors in the publications, we used them. When it was not the case, we used the software Google Earth Pro to localise the sampling points. Publications without any information more precise than region on the localisation of the fishes were excluded from the map. During the mapping process, geographic coordinate errors were detected and corrected according to the location indications given by the article and using its coordinates given by Google Earth Pro.

Results

a) Back search strategy

In the search in English, 434 documents, with 403 articles, 17 reviews, 8 conference papers, 2 book chapters, 1 editorial, 1 article in press, 1 letter and 1 short survey have been recorded by Scopus. After checking all the papers, only 346 were selected for being related to the search topic: introduction of species in Argentina. The first paper published dates from 1982, as we can see in figure 1, and refers to plants (Barrett and Forno 1982). 356 documents came out the search in Spanish with 316 articles, 23 reviews, 11 book chapters, 2 letters and notes, a book and a conference paper. Only 126 documents were useful, meaning 64% of the results were not conclusive. This is due to the type of search which keeps all documents with one of the keywords in any field including those which are not linked with Argentina or introduced species.
After gathering the results, 29 documents occurred in both searches. We kept only one exemplar in our analysis.

Researches increase in the 2000's and there are three important pics in 2008, 2010 and 2014 with respectively 31, 34, 39 documents for each year (Figure 1). In 2016 and 2017, 40 publications are counted. We can expect an equivalent number of publications for 2018.

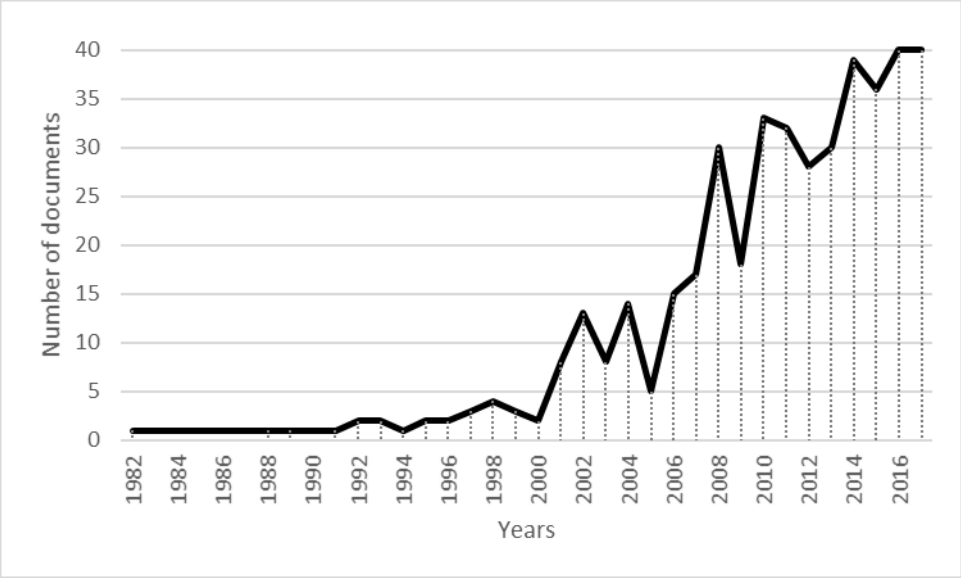

Figure 1: number of documents published per year on biological introductions in Argentina

The classification per year and taxonomic groups (figure 2) reveals most of the researches are about plants: 47% are dedicated to this subject. Then mammals and invertebrates come with around 20% of the papers. 54 documents, which represents 12% of the total, are about fishes introduced in Argentina. Only 7 papers from 2000 to nowadays deal with amphibians and only 3 with both birds and protozoans.

For instants, 2018 counts only 9 documents including 5 related to vegetation, 2 in connexion with mammals, one with invertebrates and one with fish.

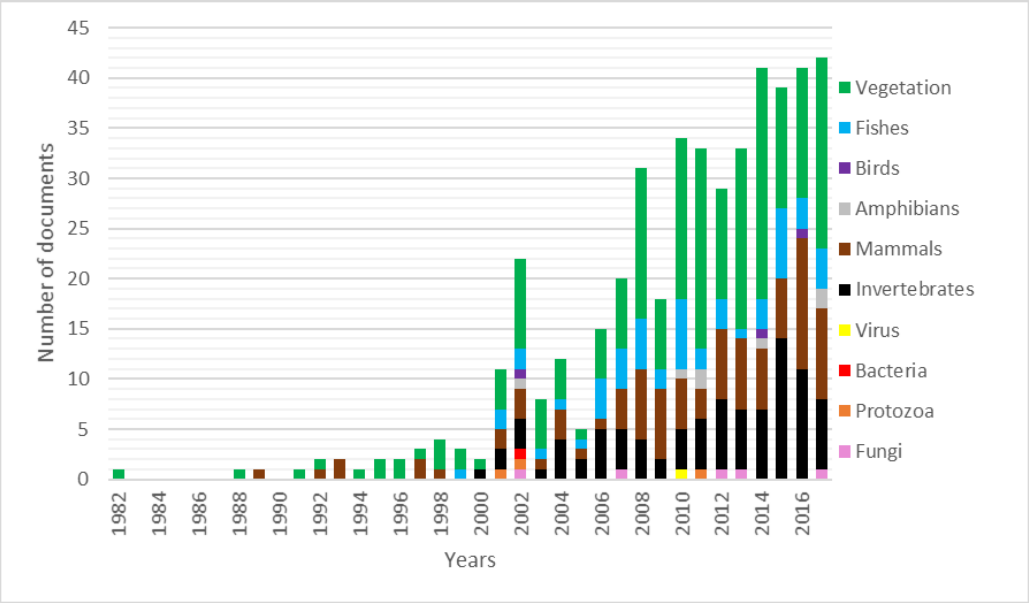

Figure 2: number of documents published on biological introductions in Argentina depending on the taxonomic groups

b) Introduced fish species

From the search on Scopus, 232 publications came out with 206 articles, 11 reviews, 5 book chapters, 5 conference papers, 4 articles in press and a note. Before implementing the selection, we added the 54 articles about exotic fish. 21 did not appear in this second search and duplicates were deleted.

Finally, from the 253 publications, only 83 were categorized as useful. Only 3 species were not included in Liotta's book, neither in the native species nor introduced species, and considered as introduced in Argentina: Oncorhynchus masou (Brevoort, 1856), Oncorhynchus nerka (Walbaum, 1792) and Gambusia holbrooki (Girard 1859) using the Fishbase database (fishbase.org).

The first article on introduced species of fish was not published in 1999 as we believed with the results of the firth search. The second research taught us that the first article on the topic dates from 1940 and talks about salmonids in the Andes of Argentina (Thompson 1940). It was published by the journal Transactions of the American Fisheries Society, which published 6 of the documents found (figure 3). The majority of the journals appear very few times in the results: 27 journals occur once and 5 twice.

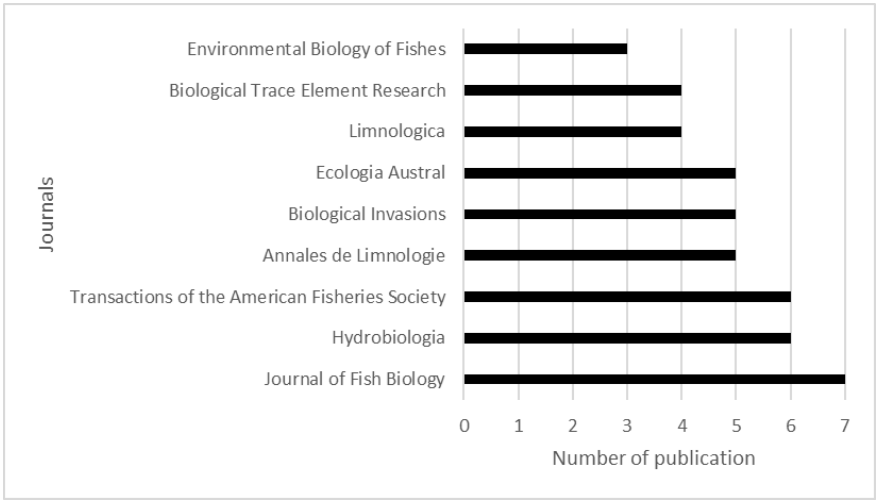

Figure 3: the occurrence of publication in 9 most referenced journals are presented

The journal with most publications is Journal of Fish Biology, a British journal which was part of the 100 most authoritative journals of Biology and Medicine from 1908 to 2008 (FSBI 2016). Hydrobiologia was created in 1948 and, as Transactions of the American Fisheries Society, it published 6 of the publications used in the analysis.

The frequency of appearance of each species in the documents is not always the same as shown in figure 4. *Oncorhynchus mykiss* occurs in 70% of total publications while *Gambusia holbrooki*, *Oncorhynchus nerka* and *Oreochromis niloticus* appear in only 1 article. *Cyprinus carpio*, *Oncorhynchus tshawytscha* and *Salmo salar* are in approximately 16% of the publications. This suggests a greater preponderance of *Oncorhynchus mykiss* in Argentina.

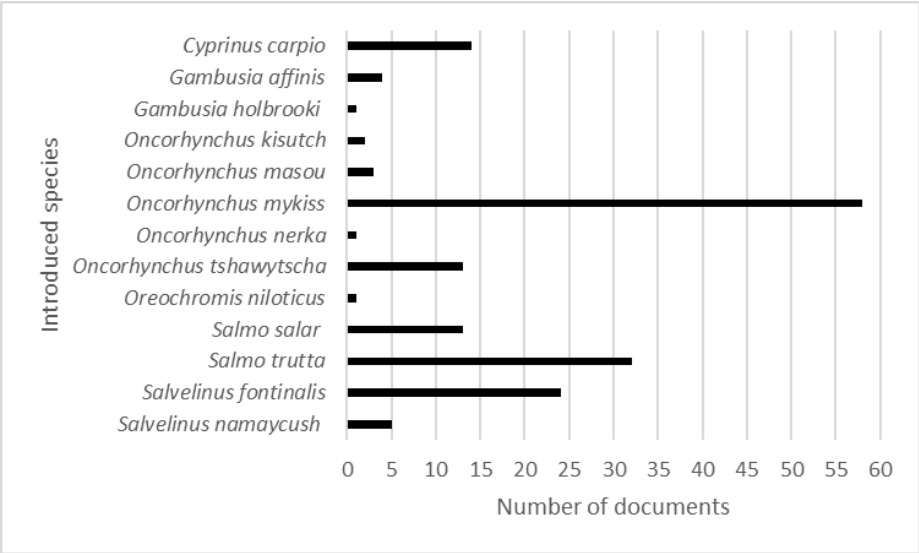

Figure 4: apparition of each introduced species in the 83 publications chosen

In figure 5, we can see the spatial distribution of the species cited in figure 4 in the country. It shows a separation between Patagonia and other ecoregions in the North of the country. *Cyprinus carpio* occupies all the North of Argentina and occurs only in a little part in North Patagonia. Its distribution area seems to be limited. The genus Gambusia occurs only in the North too but *Salmo trutta* and *Salmo salar* are just presented in the Patagonia region, close to Chile, and in the Tierra del Fuego territory. As well as genus *Oncorhynchus* and *Salvelinus* which are mostly in the Southern part, but few localisations in the North show they can support other climatic conditions. *Oreochromis niloticus* appears only one time along the coast of the Buenos Aires Province where there is a concentration of *Cyprinus carpio*. All along the Chilean frontier and especially in the Northwest part of Patagonia, there is also a high density of introduced species. On the contrary, the ecoregion of Chaco does not have any biological invasion by nonindigenous fish.

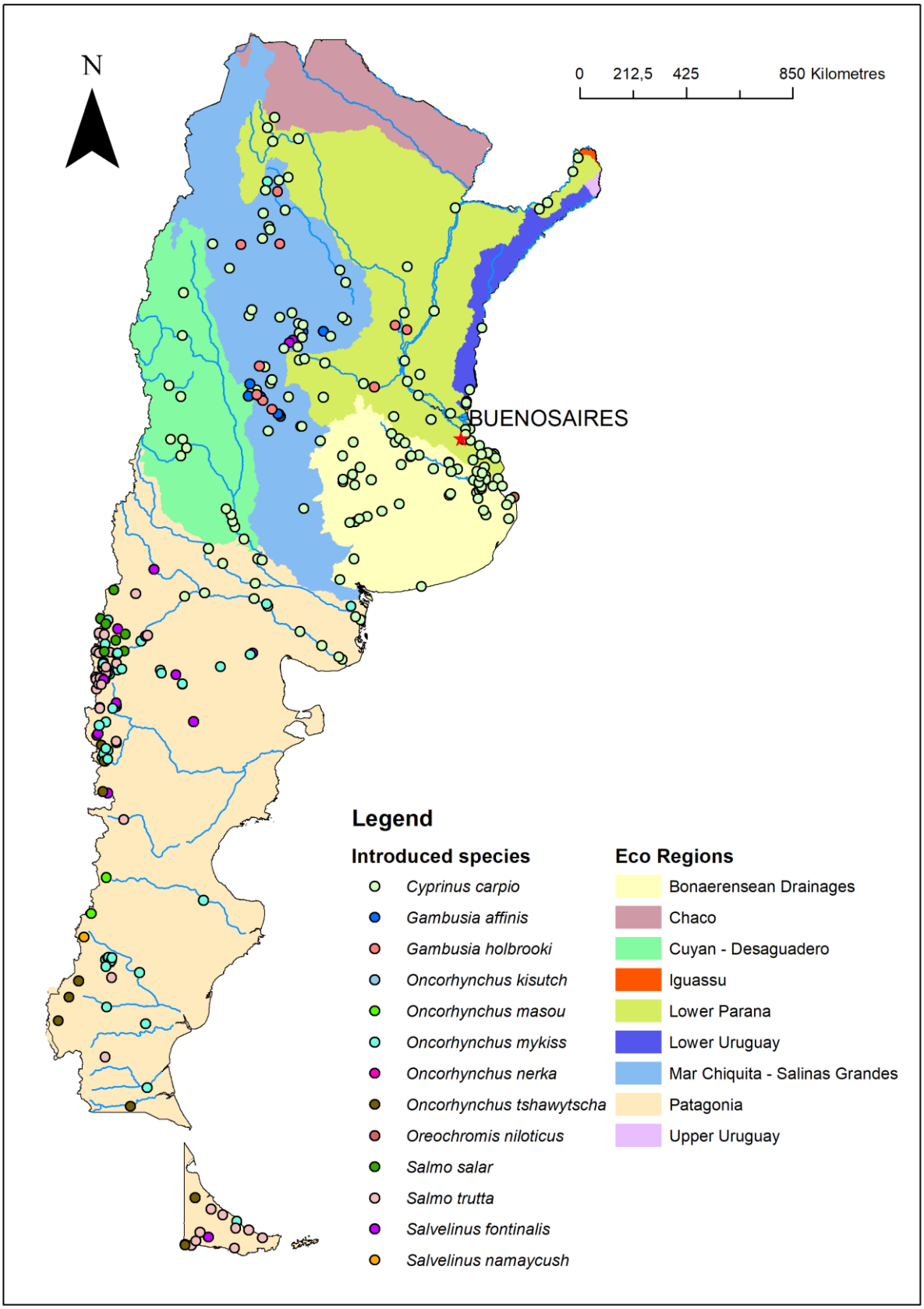

Figure 5: spatial distribution of each no-native species per genus with the representation of the most important freshwater ecoregions in Argentina (WWF and The Nature Conservancy 2015)

In the figure 6, the size of the circle is proportioned with the abundance of exotic fish per province. Provinces in the North of Argentina seem not to have any introduced species: Jujuy, Formosa, Chaco and Corrientes. Only Salta and Misiones Provinces have *Cyprinus carpio* as introduced species. Neuquén Province has the highest density of introduced fish: 189 sampling points where no-native species have been found as we can see in the supplementary material. But Santa Cruz has the highest diversity of introduced fish with 9 species: *Oncorhynchus kisutch*, *Oncorhynchus mykiss*, *Oncorhynchus tshawytscha*, *Salmo salar*, *Salmo trutta*, *Salvelinus fontinalis*, *Salvelinus namaycush*, *Oncorhynchus masou* and *Oncorhynchus nerka*.

In the North of the territory, the diversity of fish is very low in comparison with the Southern provinces. From La Pampa in the South to Jujuy in the North, only 4 provinces have more than *Cyprinus carpio* in their freshwater systems: Buenos Aires, Mendoza, Cordoba and Tucuman. From Neuquén to Tierra del Fuego, there are at least 5 species per province.

As well, in the 5 provinces of Patagonia (Neuquén, Rio Negro, Chubut, Santa Cruz and Tierra del Fuego) the density of fish is more important than in the Northern provinces. Those provinces alone have 74% of the introduced species enumerated.

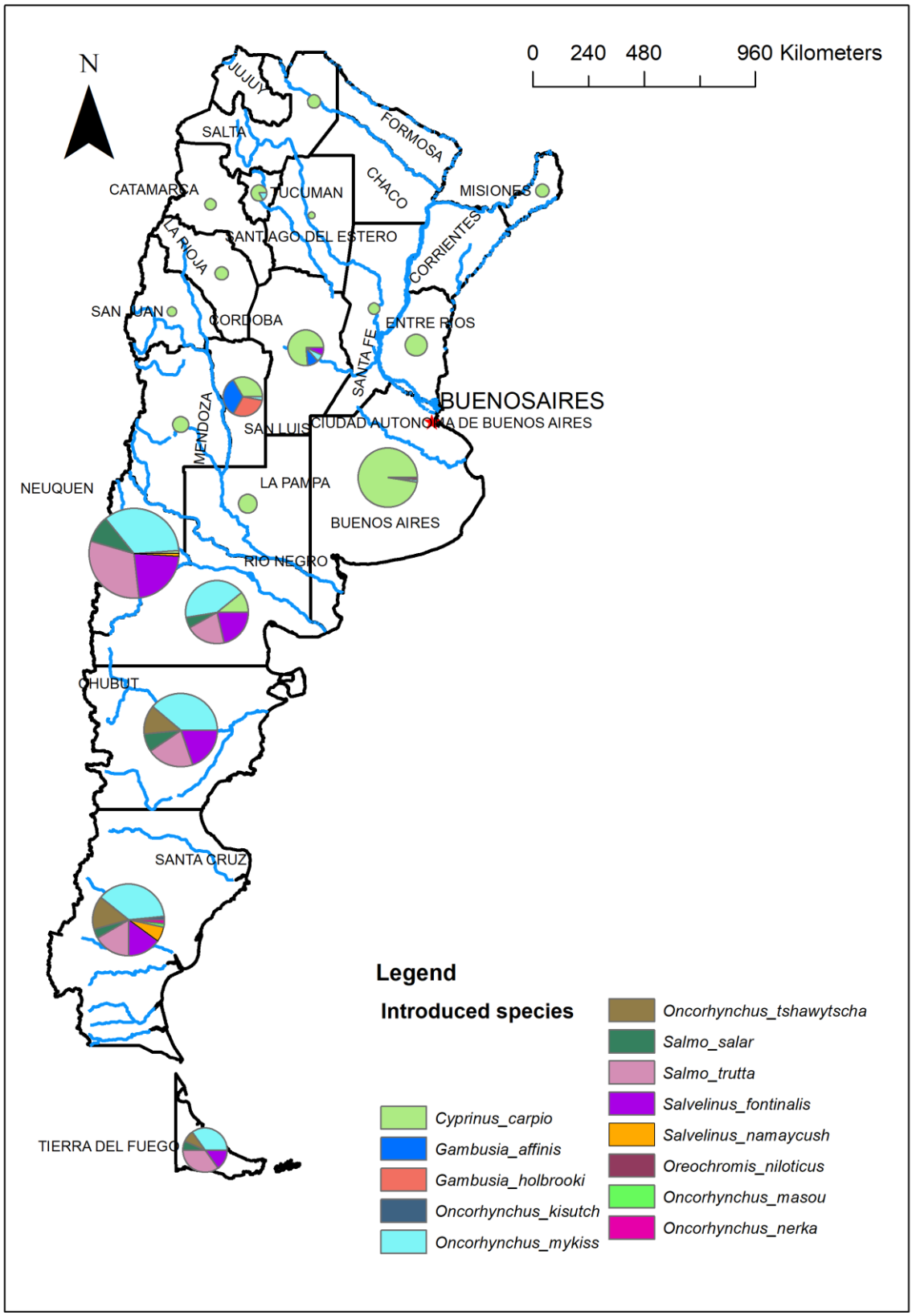

Figure 6: proportion of introduced species per province of Argentina, in blue are represented the more important rivers of the country, the size of the diagrams is proportioned with the density of fish in each province

Discussion and critic

As we can see in figure 1, three periods stand out in the history of publications about introduced species in Argentina. Before 1980, very few studies were found because introduced species were not an important subject at this time. The government started to be concerned about the topic in 1981, when came out one of the founding texts for the management of introduced species in Argentina: the 22.421 law of 1981. In particular Article 5 says : «La autoridad nacional de aplicación podrá prohibir la importación, introducción y radicación de ejemplares vivos, semen, embriones, huevos para incubar y larvas de cualquier especie que puedan alterar el equilibrio ecológico, afectar actividades económicas o perturbar el cumplimiento de los fines de esta Ley», in English : «The national enforcement authority may prohibit the importation, introduction and establishment of live specimens, semen, embryos, hatching eggs and larvae of any species that may alter the ecological balance, affect economic activities or disturb compliance with the purposes of this Law» (InfoLEG 2018). Until 1990, the law is gradually set up in the country. In the 90's, the world begins to see the effects of introduced species and especially the process of homogenization. In this context was signed in 1997 the Resolution 376/97, which deals with the evaluation of the environmental impact of non-native species before their introduction in the country (Argentina Ambiental 2018). These laws create a favourable and promising context for understanding the introduced species in the country. Hence an exponential growth of studies on the topic in the 2000's (figure 1).

Introduced plant species are studied a lot because Argentina has relied heavily on agriculture, whether to feed cattle or to export crops from plantations. Argentina's agri-food sector accounts for 7% of GDP and 36% of jobs. It was the tenth largest exporter country in the world in 2014 with half of the exports dedicated to soya, an introduced plant in the country (Trésor-info 2016).

On the other hand, although the legislative context is more favourable, the number of studies on non-native species of fish, particularly in the province of Santa Fe, is very low (figure 6) whereas it contains the largest fish farm of the country in the city of Rosario. In addition, the freshwater fish production of the country is significantly larger than its marine production. In 2011, only 368 tonnes of marine species were produced compared to 2825 tonnes for continental species (FAO 2018). Furthermore, *Oncorhynchus mykiss* is the most produced species in the country: out of 1556 tons of fish produced in 2003, it represents 80% (1231 tons) (FAO 2018). The strong commercial impact of this species may explain its high occurrence in the Argentine bibliography.

In addition, the list of 17 introduced species written by Liotta in 2005 is outdated as we found 3 other species. It is possible that there is more introduced species of fish in Argentina than we thought.

Prospects

My internship ends the third of August, I already have a month more to achieve my mission here. During this time, I would like to browse the bibliography of the articles used to know if there are other locations of introduced fish in Argentina than the ones I compilated during the mapping process.

As the laboratory focus on the Paraná River and as the only non-native species I found is *Cyprinus carpio*, I would like to do an historical analysis of the common carp and calculate its propagation speed to the North. The point of introduction seems to be the La Plata river. If it is confirmed where exactly and what was its way to the North. Is there a correlation with the construction of dams? Moreover, I would like to know the potential impacts of *Cyprinus carpio* on the local fauna and on ecosystems non-affected by this species yet.

Then, I will begin a detailed analysis of the legislative context in the Santa Fe province about aquaculture, and specially about pisciculture. I will focus on the aspects related with exotic species in order to give suggestions and highlight critical points on the economical management of pisciculture to reduce the potential expansion of exotic species in the province.

Conclusion

Synthesis of the results

Overall, I reviewed all or parts of 993 publications. Only 642 were useful for this study. The taxonomic group of introduced species most surveyed in Argentina is the vegetation. Its study started in 1982 and continues nowadays. The survey of introduced mammals began in 1989 with the exotic deer in Patagonia (Veblen et al. 1989). Only 10 publications talk about the groups of fungi, protozoa, bacteria and virus and 3 studies are about no-native birds in the country. From a second search on Scopus, we learned that non-indigenous fish are studied since 1940 (Thompson 1940). The journal which published most of the articles studied is the British journal named Journal of Fish Biology.

The introduced fish species found in the Argentinean territory are: *Cyprinus carpio, Gambusia affinis, Gambusia holbrooki, Oncorhynchus kisutch, Oncorhynchus masou, Oncorhynchus mykiss, Oncorhynchus nerka, Oncorhynchus tshawytscha, Oreochromis niloticus, Salmo salar, Salmo trutta, Salvelinus fontinalis, Salvelinus namaycush*. The rainbow trout (*O. mykiss*) has the highest occurrence with an apparition in 70% of the total of publications.

We noticed a North/South limitation of the spatial distribution of most of the species previously mentioned, with the North of the Patagonia ecoregion as ecological boundary. *Cyprinus carpio* is only present in the North and the genus *Oncorhynchus* and *Salmo* occupy all Patagonia with Tierra del Fuego included. There is a concentration of introduced species in the Neuquén province and a concentration of *Cyprinus carpio* along the Northern coast of Buenos Aires. The area with the most important diversity of exotic species is the Santa Cruz province with 9 species referenced.

Assessment of skills

For me the three words that describe well my internship are: patience, adaptation and autonomy.

Patience. It was the first time that I did a research task with the intention of a publication. After reading articles on the topic of invasion and introduction of species, I did not really know how to start my work. After doing the same thing several times in order to acquire more components, I obtain a methodology that allows me to retain the elements important for the study. Patience too because you do not know what you are going to find out. For me there were amazing moments when gathering my results I could say “We reveal that point and this one too”.

Adaptation. I did not have only to adapt to a new team but also to a new country. The PhD students and the accomplished researchers are a very good example of a work team. Each PhD student has to investigate on his own thesis but they are present every time when someone needs help, and the researchers too. Argentina is a huge country in comparison with France. Distances are very large and to travel more than 15h in bus is a common thing over there. But it gives advantages to the country in the sense that a multitude of landscapes are there. It was very impressive for me to cross all this diversity in the same territory.

Autonomy. In my opinion this is the point that differs completely with school. My tutor did not say to me at what time I had to go to the laboratory or things I had to discuss with him every week. I was completely free in my work and it was difficult for me at the beginning to acclimatise myself to this new way of studying and learning at the same time. Somehow, my tutor gave me the destination and some steps and I was my own GPS in this itinerary.

It was a pleasure for me to work in the research field, no one is going to pressure you to come at the laboratory at 9 am every day, you organize your time as you want. But I would like to discover (why not during my future internship?), the organisation of a company and the way they work. Thanks to that, I would be able to choose my future professional life without regrets.

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Annexe

Annexe 1: Campaigns of sampling

As my internship was particularly based on bibliography, participate to campaigns of sampling was for me the opportunity to learn how data were collected. I took part in two campaigns that are presented below.

1. Sampling of fishes

For the doctoral thesis of Florencia Eurich, entitled "Dynamics of sandbars the main channel of the Paraná River. Its Importance in structuring Ichthyofaunal patterns" one of the sampling campaigns has been done from 25 to 27 of Abril 2018. During the 3 days, 8 environments were sampled, localized in the figure 1. There were 2 lagoons (laguna 1 and 2) and 3 types of banks that are replicating. The points "Aguas bajo" refer to water under the island, on the opposite side to the current. The 2 places "lateral" are on the side of islands. Last, "Reciente 1 and 2" relate to sedimentary bars free unlinked to islands and more recent.

In each station, we put a battery of 6 nets interrelated as in figure 2, 10 meters long each with different distances between opposite knots: 30, 50, 60, 80, 105 and 120 millimetres. Suspended sediments were tested with a Van Dorn bottle. Through a multi-parameter probe, we noted the following parameters: oxygen, dissolved total solids and pH. Temperature and depth were recorded too. We measured the transparency through a disc of Secchi.

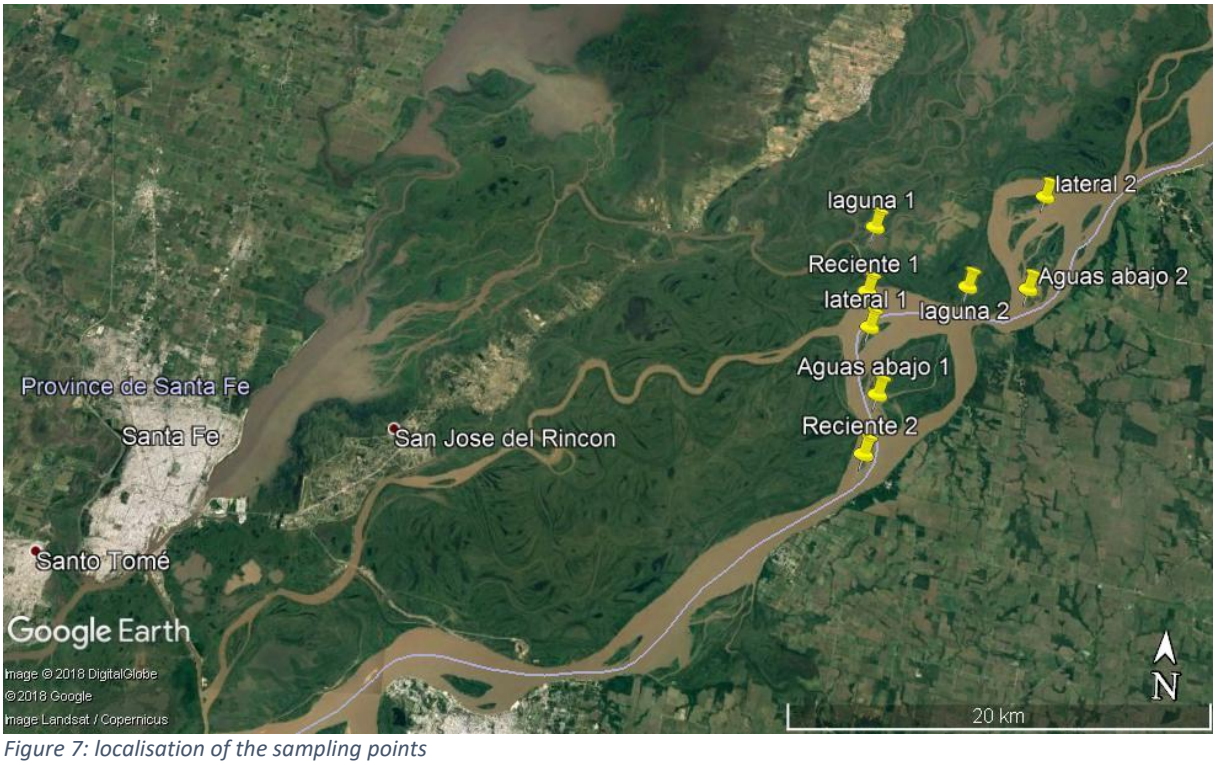

Figure 7: localisation of the sampling points

Captured individuals which were still alive were anesthetized using benzocaine (1 mL of BZ-20 in 5L of water, Piedra et al. 2012). The specimens were identified *in situ*, following keys and bibliography for fish from the Paraná river basin. Total length, length to the last vertebra, weight, gonad identification, gonad weight, stomach weight and stomach filling, means how full is the stomach, were measured in the field (figure3). In a tent appropriate to it.

Figure 8: net interrelated to catch fishes
Picture: Elise Ferlay

b

a

Figure 9: measurement (a) and weighing of the stomach (b) of fish in situ
Pictures: Elise Ferlay

2. Sampling of plastics and macroinvertebrates

Nicolas Garello does a doctoral thesis too on the theme: “The role of the dynamics of the sandbars of the Paraná River on aquatic and terrestrial invertebrates. Approach eco-geomorphological and eco-hydrological”. We were 4 to go in the campaign on the 11 and 12 of Jun 2018 in three places localized in the figure 4. Like for the sample of fish, we noted the following parameters: oxygen, dissolved total solids, pH, temperature and depth and transparency through a disc of Secchi.

Two different types of sampling have been done. One team of two sampled plastics and the other one put traps to catch macroinvertebrates.

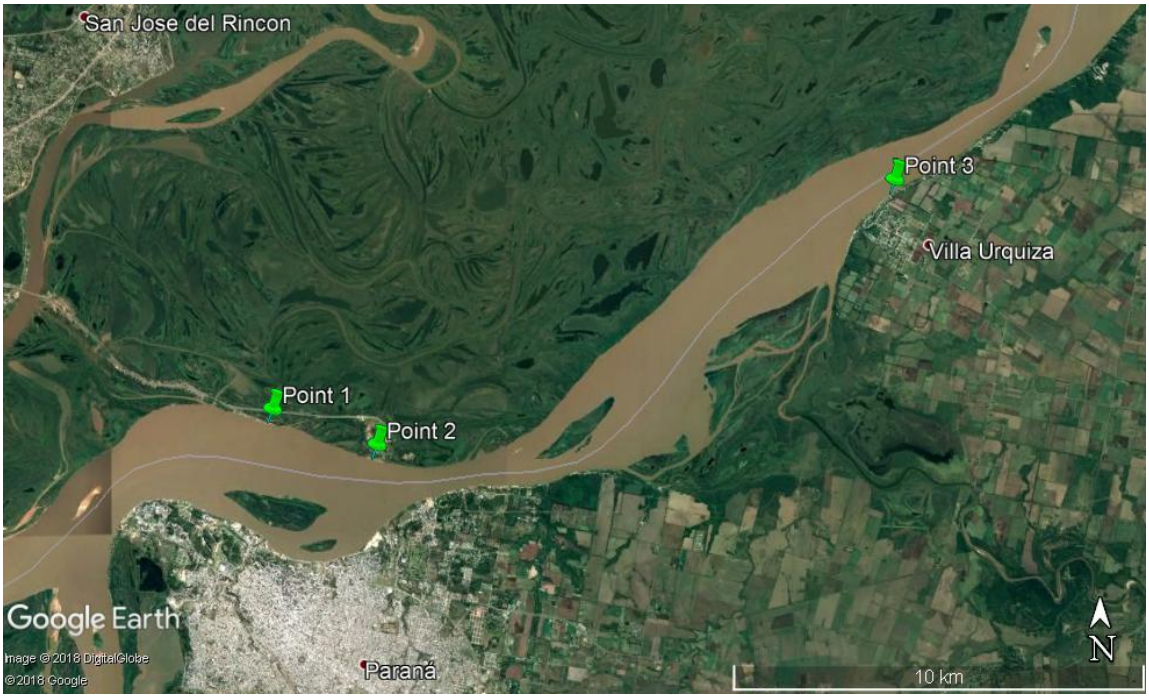

Figure 10: localisation of the sampling points along the Paraná river

a) Plastics

Three different technics were applicated to sample plastics, depending on its size. All the technics were used in both sites in every localisation (figure 4). To sample macroplastics, which is bigger than 2.5 cm, we have defined a research area: 30 meters per 3 meters. Than the two persons gathered every debris they could see in a bag where the characteristics of the area were noted.

To catch mesoplastic, which size is between 5 mm and 2.5 cm, we search in a square of 1m per 1m (figure 5) using a rake to untie the grains of sand and have a better vision of the area. Than like for macroplastic, every particle was gathering in a bag.

To capture microplastic (< 5 mm) a square of 25 cm per 25 cm has been scraped and sample kept in a flask.

a

b

c

Figure 11: collection of macroplastics (a) in an area 30m per 3 m, mesoplastics (b) in an area 1m per 1m and microplastics (c) un a square 25cm per 25cm
Pictures: Elise Ferlay

b) Macroinvertebrates

In totality, 81 glasses with water mixed with detergent have been used to capture macroinvertebrates. In each point of sampling, we sampled three areas. In each area, which goes from the bank of the river to the unsinkable zone, we put 9 glasses: 3 in line at the bank of the river, 3 in triangle in the sand and 3 in triangle too in in insubmersible zone, like figure 6 shows us. The glasses will be picked up 4 or 5 days later.

Figure 12: disposition of the nine glasses with a mix of water and detergent to sample macroinvertebrate on the beach, 3 in green close to the water, 3 in triangle in the sand (red) and 3 in the non-submersible part (blue)
Picture: Elise Ferlay

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Non-native fish in South American rivers: occurrence, spatial distribution and impact on biota

Abstract:
A lot of biological introduction have been recorded in Argentina since 1940. Different taxonomic groups occur in the introduced species of the country. This study examines their proportion through a Scopus search. A finer analyse have been done on the non-native fish and cartographies of their localisations were created. A spatial segregation between Northern and Southern Province is demonstrated.

Key words: introduced species, fish, geographic distribution, invasion, Argentina

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