Journal Pre-proof

Recovery of local dragonfly diversity following restoration of an artificial lake in an urban area near Buenos Aries

Federico Lozano , Alejandro del Palacio , Lia S. Ramos , Lucas Granato , Andrea Drozd , Javier Muzón

PII: S1439-1791(21)00182-1
DOI: https://doi.org/10.1016/j.baae.2021.11.006
Reference: BAAE 51423

To appear in: *Basic and Applied Ecology*

Received date: 1 June 2021
Accepted date: 21 November 2021

Please cite this article as: Federico Lozano , Alejandro del Palacio , Lia S. Ramos , Lucas Granato , Andrea Drozd , Javier Muzón , Recovery of local dragonfly diversity following restoration of an artificial lake in an urban area near Buenos Aries, *Basic and Applied Ecology* (2021), doi: https://doi.org/10.1016/j.baae.2021.11.006

Recovery of local dragonfly diversity following restoration of an artificial lake in an urban area near Buenos Aries

Federico Lozano [a], Alejandro del Palacio [a], Lia S. Ramos [a], Lucas Granato [a], Andrea Drozd [bc] and Javier Muzón [a]

[a] Laboratorio de Biodiversidad y Genética Ambiental (BioGeA), Universidad Nacional de Avellaneda

[b] Departamento de Ambiente y Turismo, Universidad Nacional de Avellaneda

[c] Laboratorio de Biología y Sistemas del Centro Regional de Estudios Genómicos de la FCE - UNLP

Corresponding author Javier Muzón – jmuzon@undav.edu.ar

Abstract

Urban lakes are environments prone to severe environmental deterioration if an effective management policy is not carried out by local governments. However, management aimed only at facilitating access and recreation for citizens can negatively affect the environmental health of these ecosystems since the pristine ecosystem structure is not recovered. In this paper we present early results of a governmental restoration program based on pond cleaning and native vegetation recovery at an artificial lake of the city of Avellaneda (Saladita Norte Reserve), part of the Metropolitan Area of Buenos Aires, one of the largest urban areas with the highest concentrations of inhabitants of the world. We used odonates as indicators because of their quick response to changes in environmental quality. Besides, we tested if the NDVI can be used as a surrogate to monitor changes in dragonfly diversity in managed areas. Since the intervention was carried out during the winter and there were no previous data on the richness or diversity of odonates, we analyzed their response to the intervention comparing it with a lake of similar origin and characteristics but with a different use and management (Saladita Sur Reserve). We recorded in Saladita Norte 81% of the regional diversity, including three newly recorded species, while the lake Saladita Sur , only amounted to 21% of the regional diversity. The NDVI did not reflect the observed changes in the structural complexity of the vegetation and therefore could not be used as a surrogate. These early results indicate that management practices such as the increase of native vegetation on the banks (especially in grassland areas), keeping a diverse floating vegetation and the cleaning and removal of wastes from the water, promote a significant and rapid increase in the levels of biodiversity.

Keywords: Urban lakes; restoration; Odonata; Argentina; Avellaneda

Introduction

Urban blue space improvement is a desirable objective in order to mitigate negative impacts of urbanization processes that affect aquatic biodiversity. Nowadays, there is an increasing number of studies focusing on the improvement of management practices for urban wetlands and strategies for biodiversity conservation. One of the main objectives of those studies is to improve environmental quality and increase the ecosystem services they provide.

Although it is known that urban development negatively affects natural wetlands, reducing their number, size and heterogeneity, on occasions, also generates a local increase in the availability of artificial wetlands. These wetlands can partially mitigate the loss or decline of biodiversity (Schnack et al. 2000; Kadoya et al. 2004; Fontanarrosa et al. 2009; Holtmann et al. 2017). If these artificial environments are not adequately managed from the environmental point of view (e.g., low water quality, absence or reduction of native vegetation, shoreline rectification, incorrect waste disposal, etc.) they will only offer habitat for generalist or urban native species, and invasive alien species (Goertzen & Suhling, 2013).

Avellaneda city is located within the Metropolitan Area of Buenos Aires (AMBA), one of the largest urban areas with the highest concentrations of inhabitants of the world. The AMBA is the most politically complex urban area in Argentina, integrating 40 municipalities, one province, one autonomous City and one federal state. It is a dynamic area, undergoing constant expansion, which occupies approximately 2400 km^2 on the western margin of the Río de la Plata. It has a population of more than 15 million people, which represents 35% of the country's total, incorporating approximately 1 million people every 10 years. This demographic expansion occurs without an effective urban planning and without the proportional increase in basic urban infrastructure, which for example, reaches 60% coverage in drinking water and 38% in sewers. The climate of the region is subtropically humid, with long warm summers and mild winters. The landscape is characterized by horizontal plains or very soft undulations, dominated by grasslands of *Stipa*, *Poa*, *Piptochaetium*, and *Aristida*; it has a gentle slope towards the east and well defined streams that flow into the Paraná

River and Río de la Plata estuary (Brown et al. 2006, Faggi et al., 2008). Two eco-regions coexist in the AMBA, Pampa and Delta and the Paraná Islands; their interaction made this region extremely rich in plant and animal diversity. The increasing urbanization of the area has left only a few remnants of the historic landscape..

The aquatic habitats in this area are diverse and numerous. Among the lentic environments, the most typical ones are lakes which are identified as third order lakes (Hutchinson 1957). These are shallow water bodies, with low volume, without slopes and well-defined ellipsoidal basins without differentiation between a coastal zone and a deep zone (Baigún & Lombardo 2017). Besides, the "Bañados" are very common and are small shallow temporary bodies of water, which usually occupy wind-made land depressions (Baigún & Lombardo 2017). Both types generally lack arboreal and shrub vegetation on their margins. Within urban areas, their banks are highly modified since there is periodical removal or cutting of tall grass, planting of exotic and native trees, so that the public has comfortable access and shade. The streams are usually shallow and can be temporary or permanent, collect rainwater or hyporheic flow, and can be integrated into the drainage network in periods of heavy rains (Baigún & Lombardo 2017). These streams generally present a wooded gallery formation in the last hundred meters before the mouth. However, in the urban context streams are highly polluted, mostly rectified or piped, and their wooded vegetation is extirpated.

The city of Avellaneda, with a long history of industrial development, is partially developed on the Buenos Aires coastal plain, a flooded strip of variable width that extends parallel to the Río de la Plata coast to approximately 5meters above sea level. The district has a shortage of green space, with a ratio of 0.62 m^2 of green spaces per inhabitant; this is significantly under the 10 m^2 recommended by the World Health Organization.

At present, in Avellaneda, areas of notable biological value persist on the floodplain of the Río de La Plata, and artificial lakes such as Saladita Norte and Saladita Sur (Fig. 1). These date from the late nineteenth century when they were excavated as part of the construction of the Dock Sud port channel. Both represent currently isolated artificial lakes, which receive their main contributions from rainfall and groundwater. Due to their location, and given the added value of the ecological support and regulation services that they provide to the population, these lakes constitute a strategic ecosystem, both for the city and the region.

The use of aquatic insect assemblage structure is an important tool in monitoring successional changes during restoration (Heino, 2009) since aquatic insects use a wide variety of habitats during their life cycle, and respond to the vegetation structure in each habitat they occupy (Gómez-Anaya &

Novelo-Gutiérrez, 2014). Odonata in particular, are well-documented as good bioindicators (Samways & Simaika, 2016; Vorster et al. 2020); they are sensitive to successive changes in plant regeneration (both in structure and abundance), their diversity being positively correlated. This correlation can be interpreted as a successful wetland management (Gómez-Anaya & Novelo-Gutiérrez, 2014).

In August 2019, the Matanza-Riachuelo Watershed Authority (ACUMAR) conducted an environmental recomposition project in Saladita Norte lake in order to improve its habitat quality, and thus enhance the life quality of the surrounding residents. The intervention was carried out in three days, and included cleaning the water and its banks, planting native species around the lake, placing informative signs, painting a mural, and sowing seeds.

This research resulted from a concrete request from ACUMAR to the Laboratorio de Biodiversidad y Genética Ambiental (BioGeA); ACUMAR needed to assess if the environmental intervention process, especially the changes in the vegetation structure and specific composition, had any effects on the diversity of odonates, which can be used as wetland health indicators. The main obstacle for this research was that the intervention took place in winter and there were no data on the Odonata diversity in Saladita Norte prior to it. Therefore, it was impossible to compare Odonata diversity before and after the intervention. However, the surrounding area was well known and sampled (BioGeA 2017; Ramos et al., 2016; Weigel Muñoz et al., 2019), and we decided to use Saladita Sur as a reference wetland with which to make the comparisons. This decision was rooted in two assumptions, on the one hand, data from Saladita Sur evidence that there have not been any significant changes in the Odonata diversity since 2017. On the other hand, both lakes are very similar in size, history and location, so any difference between the two of them should be related to the environmental management of the area. The NDVI is a simple numerical indicator that can be used to analyze the remote sensing measurements, from a remote platform and assess whether the target or object being observed contains live green vegetation or not. This index is sensitive to changes in pleustonic and bank vegetation which are important features determining diversity of Odonata.

Therefore, the research hypotheses were:

H_1: Small and directed restorative intervention measures in Saladita Norte increase significantly the biodiversity of the Odonata; and

H_2: The Normalized Difference Vegetation Index (NDVI) can be used as a surrogate to monitor changes in dragonfly diversity in managed areas.

Material and methods

Study Area

Both artificial lakes, Saladita Norte and Saladita Sur, are urban reserves surrounded by median-low and low class neighborhoods and container deposits. Most of the total area of these reserves are occupied by the lakes, being the distance to the surrounding streets very short (between 2 and 40 m). The distance between the two lakes is extremely short (200 m), separated by a highway. Both surrounding areas are equally served by waste collection. Main difference between both lkes is the closeness of Saladita Norte to the petrochemical port of Dock Sud (Fig. 1).

Saladita Sur 34°40'22.55''S 58°20'25.37''W

The Saladita Sur (Fig. S1) was designated an Ecological Reserve in 1994. It has a rectangular lakeof eight hectares and 15 m depth. The main objectives of this reserve are to allow the recovery and preservation of the urban wetland with a low-impact use of natural resources for tourism, recreational and educational purposes. The local government has promoted different activities in order to improve the knowledge and public awareness of the biodiversity of this area. The flora consists mainly of a combination of native trees (*Erythrina crista-galli*,) and shrubs (*Solidago chilensis*, *Eryngium paniculatum*, *Schoenoplectus californicus*, *Passiflora caerulea*, *Cortaderia selloana*), which were planted by man, and exotic vegetation (*Vachellia caven*, *Prosopis alba*, *Bauhinia forficata*, *Ricinus communis*); the riparian herbaceous vegetation is continuously managed to facilitate public access to the lake and it consists mainly of grass. The fauna is that of the Pampa region; previous studies with Odonata on the area showed that this Reserve is eusynanthropic and has a very low diversity value compared to other areas in the region (Ramos et al. 2017).

The perimeter of the reserve is fenced. It functions mainly as a recreational area. There is a canoeing club and an educational center, besides there are scattered benches facing the lake and a set of outdoor park games for children. Therefore, the vegetation is managed as an urban park, promoting homogeneity of the bank with poor development of the structural complexity of the herbaceous component of the vegetation. There is scarce development of aquatic vegetation, which is also managed in order to improve canoeing activities (mainly *Ceratophyllum demersum*). The odonate diversity is well-known since there have been surveys in the area since 2012; it is very low with only eight species, which represents 21% of the total Avellaneda species richness (Ramos et al. 2017).

Saladita Norte 34°39'54.27''S 58°20'24.74''W

The Saladita Norte lake (Fig. S2) was designated an Ecological Reserve in 1999 with the same objectives as the Saladita Sur. It has a sub-rectangular lake of 3.5 ha and 7 m depth. Unlike the Saladita Sur, the area has not been promoted and so there is little information on its flora and fauna. In fact, past lack of systematic controls allowed the area to become a dumping site for domestic wastes and fill materials both in the body of water of the lake and on its banks. Until the intervention performed by ACUMAR, its riparian vegetation had been affected by the general lack of care; there were no concrete management measures on its vegetation, except for the cutting of the grass on the margins and afforestation on its extreme north.

The ACUMAR intervention took place in August 2019. During the first day cleaning activities were carried out in the water and in the surrounding areas. A total of six cars in addition to various bulky wastes were removed from the water; in the riverbank and surrounding areas a total of 210 tons of waste were removed. During the next day, native herbaceous plants were planted on the banks of the lake (*Lippia alba*, *Verbena bonariensis*, *V. montevidensis*, *Eryngium paniculatum*, *Dysphania ambrosioides*, *Baccharis trimera*, *Solidago chilensis*, *Austroeupatorium inulifolium*, and *Ludwigia bonariensis*), together with several specimens of native trees which were planted 2 m apart from the edge around the lake (i.e., *Erythrina crista-galli* and *Solanum granuloso-leprosum*). Besides, during this day indicative posters of the Reserve and different signs were placed around the lake to inform about their species and their ecological importance. Finally, on the last day seeds of *Bromus unioloides* were sown, especially where the bank was devoid of vegetation. Then, a mixture of black soil with mulch was added to improve soil fertility and promote plant and seed growth.

The perimeter of the reserve is not fenced. The area is mainly used by surrounding residents and occasionally by members of the canoeing club of the Saladita Sur. There are a lot of domestic wastes within the water, which suggest that the area is still being used as a dump area for surrounding residents. The herbaceous vegetation used to be homogenous and cut regularly. Since the intervention the marginal vegetation has grown considerably, showing more structural complexity of this component (see Results and Discussion). There is a lot of floating vegetation which extends up to 4 m from the margin, mainly *Egeria densa*, *Azzolla filiculoides*, *Ludwigia peploides*, *Ceratophyllum demersum*, *Eichhornia crassipes*, *Hydrocotyle bonariensis*, and *Lemna* sp.; this is not managed and follows its natural cycle. At some points, floating vegetation close to the bank evolved in more complex associations called "*embalsados*" in Argentina, giving more heterogeneity to the lake. The "Embalsados" or floating islands are a common vegetal formation in the Parana basin, formed form a root cluster of a few dominant hydrophytes, as for example the water hyacinth (*Eichhornia crassipes*), with high amount of organic matter. Depending upon the water level of the river, lakes or lagoons, they can rest on the bottom or float, acting as filters and trap particulate matter (Benzaquen et al., 2013). At high water levels, Paraná embalsados float and show increased macroinvertebrate abundance and diversity (Poi de Neiff & Carignan, 1997). There is no information on the Odonata of the Reserve before the intervention.

Sampling procedures

The accessible perimeter of each of the lakes was divided into sections of 10 m in length. On each sampling date, 10 transects were randomly selected, using a random number generator in which adult Odonata were counted with the aid of close-focus binoculars; when necessary adults were collected with aerial nets, fixed by injection with 96% alcohol and then dehydrated with silica gel; once dry they were stored in plastic envelopes in the Laboratorio de Biodiversidad y Genética Ambiental (Universidad Nacional de Avellaneda) collection. Collections were made from November 2019 until March 2020, and from November 2020 until January 2021, between 10:00 and 14:00 on sunny days when adults are more active. Sampling had to be interrupted from March to November 2020 due to the COVID-19 pandemic.

Satellite Image - remote sensing methods

Forty Sentinel 2 L2A images were processed for water and pleuston areas estimation between 2018-12-15 and 2020-11-04. First the lakes were delimited through polygons over high-resolution images of Google Earth and then all Sentinel 2 images were clipped to that area. The normalized difference vegetation index (NDVI) was subsequently estimated (Jensen 1996). The NDVI is widely used and has a long history of use in remote sensing, geography and ecology, to study characteristics of vegetation, including amount (biomass), type, and condition and delineate the distribution of vegetation, water and soil (Huang et. al. 2021). The NDVI is calculated as NDVI = (NIR - RED) / (NIR +RED) were $-1 < NDVI < 1$.

The spectral reflectance responses of water have a typical behavior in the optical spectrum. These responses have a low reflectance throughout the spectrum range, and it decreases further towards infrared (Fig. S3). Therefore, NDVI values are often below 0. Phytoplancton abundance also may change the response of water by increasing the NIR reflectance (Drozd et al. 2019) and so, the NDVI also increases. After field validation, a 0.35 NDVI threshold was selected to detect presence of pleuston. Any value above 0.35 was considered related to pleuston biomass, and values below this threshold were considered water.

For each image, the NDVI threshold was applied and water bodies were classified into water cover or pleuston. At last, both cover areas were calculated.

A similar methodology was applied in order to measure vegetation cover in shores. We digitalize a polygon of 60 m width around the water bodies and estimated NDVI mean for the area of each image.

The applied softwares and platforms were QGIS 3.10.6 and Google Earth Engine (Gorelick et al. 2017)

Data analysis

In order to assess if there were significant differences in terms of species richness and Shannon diversity index a T-test was carried out using Past v 4.0 (Paleontological Statistics)

Results and discussion

The number of Odonata species in Saladita Norte has proven to be really high. A total of 31 species were recorded, which represent 81% of the species registered for the district of Avellaneda (Table 1). It is worth highlighting the presence of *Acanthagrion cuyabae*, *Erythrodiplax pallida* and *E. paraguayensis* (Fig. S4A-C), since they constitute new records for Avellaneda city, and are the southernmost records of each of these species. *Acanthagrion cuyabae* and *Eryhtrodiplax paraguayensis* are typical species of lentic habitats, both permanent and temporary, with a regular or abundant presence in the provinces of Corrientes, Chaco, Santa Fe and Entre Ríos (Lozano et al. 2020). *Erythrodiplax pallida*, on the other hand, is a rare species with scarce and sporadic records in Argentina all of them in natural environments of the Esteros del Iberá and the Lower Delta of Paraná (del Palacio & Muzón, 2016); its presence in an urban wetland such as Saladita Norte, more than 100 km south of the southernmost locality known for the species, is an unexpected and a remarkable record. On the contrary, the species richness in the Saladita Sur lake remained low. Surveys in the area in 2019 and 2020 showed similar numbers to those observed during 2017.

Despite that odonate species richness in both areas shows that there is a fluctuation over time (Fig. 2), Saladita Sur does not show an improvement in the overall richness (the mean number of species recorded since 2016 is 5.1). On the contrary, Saladita Norte shows a clear increase in the number of species over time (the number of species is larger than the same period of time the year before). The Shannon diversity index shows a similar pattern as the species richness, with a strong fluctuation in both areas, but showing a gradual increase in Saladita Norte (Fig. 2).

Analysis of the diversity patterns of the two lakes shows that species richness and Shannon diversity are significantly different (Species richness: $T=7.498$, $DF=17$, $p <0.001$; Shannon: $t=6.099$, $df=17$, $p <0.001$), since the probability of chance to explain the observed variation was very low. On average, the observed difference between species richness was 7.98, and the observed difference between Shannon diversity index was 0.87.

Although we do not have data prior to the intervention, and therefore we do not know the previous values of odonate richness and diversity, we could assume with enough confidence that the values of richness and diversity after the intervention are likely to have increased. There are some reasons to assume this: the high percentage of regional specific richness found in only one lake (the species richness is notably higher in the study area compared to similar ecosystems nearby and has increased in a two-year period since the intervention; Saladita Norte has 81% of all the known species for the whole district whereas Saladita Sur has only 21%), the new record of three species in a fairly well sampled region in the last 10 years (*Acanthagrion cuyabae*, *Erythrodiplax pallida* and *E. paraguayensis*), and the significant increase in richness five months after the intervention, coinciding with the growth of bank native herbaceous vegetation (Fig. S5).

The bank vegetation, as a result of the planting activities, has shown a steady increase in complexity since the intervention (Fig. S5). The vegetation structure of the shore changed differently around the lake. The eastern margin was the one with the greatest observable changes (Fig. S5) because the reforestation activities were mainly concentrated in this margin. The vegetation grew considerably, forming a dense heterogeneous stratus of about 1.80 m high and 1.5 m wide parallel to the coastline. This provided a physical barrier to the wind and a great variety of micro-habitats where odonates, especially the Zygoptera, found refuge, perching sites, and copulation sites. The northern margin of the lagoon did not undergo major structural changes. However, this margin contained a large number of species due to the fact that there is a large tree cover. The western margin did not show great modifications in terms of the herbaceous vegetation, therefore it was the margin chosen by the neighbors for recreational activities. In addition, it is worth mentioning the establishment of a stable 2-4 meters wide stripe of “embalsados” around the lake which contributed to the increase of heterogeneity within the lake.

The same period in Saladita Sur shows no floating vegetation in the water. During the first three months of this study species richness and Shannon diversity in Saladita Norte did not increase significantly, probably because it is the same period in which the bank vegetation (planted in August) had not grown significantly.

Considering the maximum levels of specific richness reached in Saladita Norte compared to Saladita Sur, it is possible to assume that a significant part of this increase is related to the increase in environmental heterogeneity due to the intervention carried out by ACUMAR, especially the heterogeneity generated by the increase in plant diversity on the banks of the lakes, and the observed differences in the floating carpet and the resulting new micro-habitats.

The NDVI for the water of Saladita Sur shows very low values (near 0) throughout the whole period. On the contrary, Saladita Norte shows a tendency to decline from December 2018 to December 2020, which seems to be even greater since the intervention in August 2019 (Fig. 3A). This might be reflecting the change in the structure of the aquatic vegetation, due to the waste removal from the water. Specifically, NVDI from the lakes from December 2018 to August 2020 shows that the natural evolution of the floating vegetation in Saladita Norte is extremely variable due to both, wind drive movements and the regular succession of the pleustonic community; contrastingly to Saladita Sur which does not show floating vegetation in the water (Fig. S6).

The NDVI for the shore of the Saladita Norte shows a seasonal pattern coincident with the seasonality of the vegetation being the NDVI larger between October and May (Fig. 3B). These results do not reflect the increase in complexity and height of the bank vegetation observed. The marked peaks observed are moments of overflow of the lake or a lot of waves due to wind. The presence of water on the shore greatly decreases the spectral response in general, which gives an abrupt decrease in the index (Fig. 3B).

Conclusions

The effectiveness of odonates as monitors is due to the fact that their species, and the assemblage that they comprise, are sensitive to changes in the landscape such as alterations in the structure of the environments they inhabit, and changes of the physicochemical conditions of the water (Simaika

& Samways, 2009). Odonates respond quickly to environmental changes, being able to colonize favorable environments in a short time or retreat when they are no longer favorable. For this reason, we can evaluate both the decrease in environmental quality and its increase (e.g., restoration), ideally comparing the specific cast in relation to a previous or pristine situation (Muzón et al., 2019).

The recent management of the Saladita Norte has proven to be successful, satisfying the first research hypothesis. In this sense, the implementation of management practices such as the increase of native herbaceous vegetation on the banks (especially in grassland areas like the Pampa ecoregion), keeping a diverse floating vegetation within the lakes, the stopping of pruning activities, and the cleaning and removal of wastes from the water, promote a significant increase in the levels of biodiversity of the fauna, represented in this study by a difference of almost 400% in the specific richness of odonates. These results indicate that the environmental health status of the Saladita Norte has improved since the beginning of the monitoring and that adult Odonata respond rapidly to improvements in the habitat quality.

The NDVI was useful to compare the modification of floating and bank vegetation in both lakes along two consecutive years. On the shore, the NDVI showed the seasonality of the vegetation, but did not change according to the increase of the structural complexity observed in the field after the intervention. On the water the NDVI decreased, possibly reflecting the changes in the aquatic vegetation and location due to wind. Therefore, the second hypothesis was not satisfied because the NDVI did not prove to be an efficient tool to monitor changes in dragonfly diversity in managed areas, since it did not reflect the increase in complexity and heterogeneity of the vegetation. However, this could be related to the resolution of the images used. Further research is needed to assess the value of the NDVI.

Finally, it is worth noting that revegetation practices to restore urban blue spaces' health are important, as long as the pristine ecosystem structure is recovered. Sometimes, as in this case, small, low-cost man-made interventions can improve, in short periods of time, the environmental conditions of urban wetlands, partially restoring ecosystem services to the society.

Acknowledgements

We want to acknowledge to the Directorate of Environmental and Social Impact Assessment (DEIAS) of the he Matanza-Riachuelo Watershed Authority (ACUMAR) for their assistance during the monitoring process.

Funding: This work was supported by the Matanza-Riachuelo Watershed Authority (ACUMAR)

References

Baigún, C., & Lombardo, R. (2017). 8a. Subregión Lagunas de la Pampa Húmeda. In: Benzaquen, L., Blanco, D.E., Bo, R., Kandus, P., Lingua, G., Minotti, P. & Quintana, R. (Eds). *Regiones de Humedales de la Argentina* (pp. 207-222). Ministerio de Ambiente y Desarrollo Sustentable, Fundación Humedales/Wetlands International, Universidad Nacional de San Martín y Universidad de Buenos Aires.

Benzaquén, L., Blanco, D.E, Bó, R.F., Kandus, P., Lingua, G.F., Minotti, P., Quintana, R.D., Sverlij, S. & Vidal. L. 2013. *Inventario de los humedales de Argentina: sistemas de paisajes de humedales del corredor fluvial Paraná Paraguay*. Secretaría de Ambiente y Desarrollo Sustentable de la Nación, 376 pp.

BioGeA (2017). *Biodiversidad en Humedales Urbanos. Las libélulas como indicadoras de calidad ambiental en humedales de Avellaneda*. https://doi.org/ 10.13140/RG.2.2.29000.57607.

Brown, A., Martinez Ortiz, U., Acerbi, M., & Corcuera, J. (2006). *La Situación Ambiental Argentina 2005*, Fundación Vida Silvestre Argentina, Buenos Aires.

del Palacio, A., & Muzón, J. (2016). Redescription of *Erythrodiplax pallida* (Needham, 1904) (Odonata: Libellulidae). *International Journal of Odonatology*, *19*, 1-2. https://doi.org/10.1080/13887890.2016.1143408

Drozd, A. A., & Fernández, V. (2016). Monitoreo Satelital de las Aguas del Río Uruguay Análisis del patrón de firmas espectrales para cianobacterias y dinoflagelados en el embalse Salto Grande entre los años.

Drozd, A., Tezanos Pinto, P., Fernández, V., Bazzalo, M., Bordet, F., & Ibañez, G. (2019). Hyperspectral remote sensing monitoring of cyanobacteria blooms in a large South American reservoir: high- and medium-spatial resolution satellite algorithm simulation. *Marine and Freshwater Research, Special Issue*. https://doi.org/https://doi.org/10.1071/MF18429

Faggi A.M., Krellenberg K., Castro R., Arriaga M., & Endlicher W. (2008). Biodiversity in the Argentinean Rolling Pampa Ecoregion: Changes Caused by Agriculture and Urbanisation. In: Marzluff

J.M. et al. (eds) *Urban Ecology*. Springer, Boston, MA. https://doi.org/10.1007/978-0-387-73412-5_25

Fontanarrosa, M., Collantes, M. B., & Bachmann, A. O. (2009). Seasonal patterns of the insect community structure in urban rain pools of temperate Argentina. *Journal of Insect Science*, *9*(10), 1-18.

Goertzen, D., & Suhling, F. (2013). Promoting dragonfly diversity in cities: Major determinants and implications for urban pond design. *Journal of Insect Conservation*, *17*, 399-409. https://doi.org/10.1007/s10841-012-9522-z.

Gómez-Anaya, J. A. & Novelo-Gutiérrez, R. (2015). A case of successful restoration of a tropical wetland evaluated through its Odonata (Insecta) larval assemblage. Revista de Biología Tropical, 63(4), 1043-1058. https://www.redalyc.org/journal/449/44942283013/html/

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). *Google Earth Engine: Planetary-scale geospatial analysis for everyone*. Remote Sensing of Environment.

Heino, J. (2009). Biodiversity of aquatic insects: spatial gradients and environmental correlates of assemblage-level measures at large scales. *Freshwater Reviews, 2,* 1-29. https://doi.org/10.1608/FRJ-2.1.1

Holtmann, L., Philipp, K., Becke, C. & Fartmann, T. 2017. Effects of habitat and landscape quality on amphibian assemblages of urban stormwater ponds. *Urban Ecosystems*, *20*, 1249–1259. https://doi.org/10.1007/s11252-017-0677-y

Huang, S., Tang, L., Hupy, J. P., Wang, Y. & Shao, G. (2021). A commentary review on the use of normalized difference vegetation index (NDVI) in the era of popular remote sensing. *Journal of Forestry Research*, *32*(1), 1–6. https://doi.org/10.1007/s11676-020-01155-1.

Hutchinson, G. E. (1957). *A treatise on limnology: 1. Geography, physics and chemistry*. New York, Wiley.

Jensen, J. (1996). Introductory Digital Image Processing A Remote Sensing Perspective (2nd Edition). Prentice Hall, Inc., Upper Saddle River, NJ.

Kadoya T., Suda S. I., & Washitani I. (2004). Dragonfly species richness on man-made ponds: effects of pond size and pond age on newly established assemblages. *Ecological Research*, *19*, 461–467. https://doi.org/10.1111/j.1440-1703.2004.00659.x.

Lozano, F., del Palacio, A., Ramos, L., & Muzón, J. (2020). The Odonata of Argentina: state of knowledge and updated checklist. *International Journal of Odonatology*, *23*(2), 113–153. https://doi.org/10.1080/13887890.2020.1737585.

Muzón, J., Ramos, L. S., & del Palacio, A. (2019). Urban aquatic insects. In : Del-Claro K., Guillermo R. (eds) Aquatic Insects (pp. 349-364). Springer, Cham. https://doi.org/10.1007/978-3-030-16327-3_14

Poi de Neiff, A. & Carignan, R. 1997. Macroinvertebrates on *Eichhornia crassipes* roots in two lakes of the Paraná River floodplain. *Hydrobiologia* 345: 185-196.

QGIS.org. (2021). QGIS Geographic Information System. QGIS Association. http://www.qgis.org

Ramos L. S., Lozano F., & Muzón J. (2017). Odonata Diversity and Synantrophy in Urban Areas: A Case Study in Avellaneda City, Buenos Aires, Argentina. *Neotropical Entomology*, *46*, 144-150. https://doi.org/10.1007/s13744-016-0443-5

Samways, M. J., & Simaika, J. P. (2016). Manual of Freshwater Assessment for South Africa: Dragonfly Biotic Index. In SURICATA 2. Retrieved from http://biodiversityadvisor.sanbi.org/wp-content/uploads/2016/07/Suricata_2_2016.pdf

Schnack, J. A., De Francesco, F. O., Colado, U. R., Novoa, M. L., & Schnack, E. J. (2000). Humedales antrópicos: Su contribución para la conservación de la biodiversidad en los dominios subtropical y pampásico de la Argentina. *Ecología Austral*, *10*, 63–80.

Simaika, J.P. & Samways, M. J. 2009. An easy-to-use index of ecological integrity for prioritizing freshwater sites and for assessing habitat quality. *Biodiversity and Conservation*, *18*, 1171-1185.

Vorster, C., Samways, M. J., Simaika, J. P., Kipping, J., Clausnitzer, V., Suhling, F., & Dijkstra, K.-D. B. (2020). Development of a new continental-scale index for freshwater assessment based on dragonfly assemblages. *Ecological Indicators, 109* (September 2019), 105819. https://doi.org/10.1016/j.ecolind.2019.105819

Weigel Muñoz, S., Ramos, L., & Muzón, J. (2019). La Reserva Costera Municipal de Avellaneda (Buenos Aires, Argentina), una nueva área protegida dedicada al estudio de los odonatos. *Hetaerina, 1*, 12-14.

Table 1: Species list of the Avellaneda district and records for the two study ponds. Species inventory of the city of Avellaneda was obtained from previous studies (BioGeA 2017; Ramos et al., 2016; Weigel Muñoz et al., 2019)

Taxon	Saladita Norte	Saladita Sur	Avellaneda district
Zygoptera			
Acanthagrion cuyabae	x	-	x
Acanthagrion lancea	x	x	x
Argentagrion ambiguum	x	-	x
Cyanallagma bonariense	x	x	x
Homeoura chelifera	x	-	x
Ischnura capreolus	x	-	x
Ischnura fluviatilis	x	x	x
Oxyagrion terminale	x	x	x
Telebasis willinki	x	-	x
Lestes spatula	x	-	x
Lestes undulatus	-	-	x
Anisoptera			
Brachymesia herbida	-	-	x
Brachymesia furcata	x	-	x
Erythemis attala	x	-	x
Erythemis peruviana	x	-	x
Erythemis plebeja	x	-	x
Erythrodiplax melanorubra	x	-	x
Erythrodiplax nigricans	x	x	x
Erythrodiplax corallina	x	-	x
Erythrodiplax media	x	-	x
Erythrodiplax pallida	x	-	x
Erythrodiplax paraguayensis	x	-	x
Miathyria marcella	x	-	x
Micrathyria hypodydima	x	x	x
Micrathyiria longifasciata	x	-	x
Orthemis ambinigra	-	-	x
Orthemis nodiplaga	x	-	x
Pantala flavescens	x	-	x
Perithemis icteroptera	x	x	x
Perithemis mooma	x	-	x
Planiplax erythropyga	x	-	x
Tauriphila risi	x	-	x
Tramea cophysa	-	-	x
Rhionaeschna absoluta	-	-	x
Rhionaeschna bonariensis	x	x	x
Rhionaeschna confusa	x	-	x
*Rhionaeschna planaltica**	-	-	x
*Triacanthagyna nympha***	?	-	x
Totals	**31**	**8**	**38**

* A characteristic marginal forest-dwelling species (we do not expect it occurs in these lakes).

** Crepuscular species (all our samplings were done at noon).

Comment [H1]: We consider that t column is important to discuss the species composition within the area.

Legends and figures

Fig. 1. Location of Saladita Norte and Saladita Sur reserves, Avellaneda, Buenos Aires province, Argentina. Aerial photography downloaded from Google layer in QGIS 3.10.8.

Fig. 2. Species richness (S) and Shannon diversity of two water reserves in both lakes. Arrow indicates the beginning of the intervention.

Fig. 3. NDVI changes over time in Saladita Norte and Sur. Arrows indicate the start of the intervention. (A). NDVI changes in the water of the lake. (B). NDVI changes in the shore of the lake. Circles mark moments of overflow of the pond or a lot of waves due to wind which decreases the spectral response.

Appendix

Supplementary Fig. 1. Saladita Norte reserve and lake.

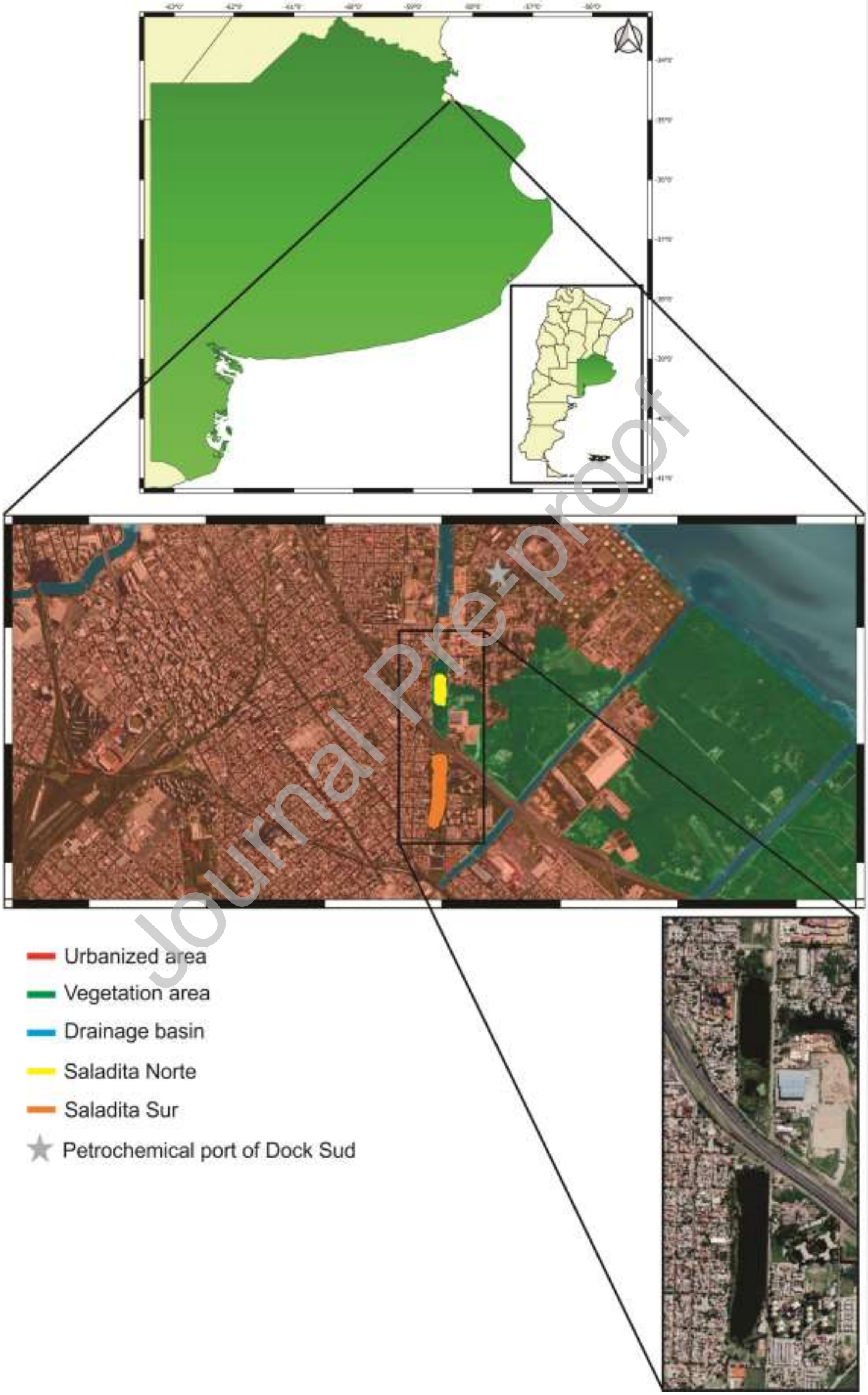
Supplementary Fig. 2. Saladita Sur reserve and lake.

Supplementary Fig. 3. Spectral signature of clear water body (from Drozd & Fernandez 2016)

Supplementary Fig. 4. Odonate species recorded for the first time in Avellaneda. (A) *Acanthagrion cuyabae*; (B) *Eryhtrodiplax paraguayensis*; (C) *Erythrodiplax pallida*.

Supplementary Fig. 5. Changes of the vegetation structure observed since the intervention in the shore of Saladita Norte. (A) August, 2019; (B) January, 2020; (C) March, 2020; (D) October, 2020.

Supplementary Fig. 6. Changes in NDVI over time. (A) December, 2018; (B) March, 2019; (C) June, 2019; (D) August, 2019; (E) December 2019; (F) March 2020; (G) June 2020; (H) August 2020.


Urbanized area
Vegetation area
Drainage basin
Saladita Norte
Saladita Sur
Petrochemical port of Dock Sud