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What urban lakes and ponds quality is about? Conciliating water quality and ecological indicators with users' perceptions and expectations about urban lakes and ponds quality in urban areas

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ABSTRACT
Urban lakes and ponds (L&Ps) provide numerous ecological and social services for local populations living in urban areas. Their monitoring and management are mostly based on water quality and ecological indicators and poorly consider public preferences and expectancies related to these artificial ecosystems. Even fewer studies bring together expert indicators and public expectations to inform management objectives for urban lakes. Based on an interdisciplinary study, this paper compares an expert assessment of the ecological quality of three urban L&Ps located in the Ile-de-France area with the public perception of these lakes. This approach permits us to explore the compatibilities and incongruences between the various ways in which scientists, managers and urban users assess urban L&P quality. Based on these data, we discuss how it could be possible to define management objectives that integrate quality indicators and expect these objectives to be used in a territorial approach that might allow to obtain a better adequacy between social users' expectations and the ecological status of these L&Ps.

Introduction

As recently shown by Oertli and Parris (2019), an increasing amount of attention is being paid to urban lakes and ponds (L&Ps) in relation to the expansion of urbanization worldwide. Most of the time, these L&Ps have an anthropogenic origin or are ancient natural habitats that have been strongly modified by urban planning politics. Additionally, these ecosystems also known as 'retention basins' play an important role in urban stormwater management (Hassall et al., 2015; Sender & Malslanko, 2014). Because of their main characteristics (small, shallow, highly artificial shorelines, concentration of contaminants, often hypertrophic tendency), they are usually considered to have less ecological importance than nonurban and natural lentic ecosystems (Brucet et al., 2013; Clifford & Heffernan, 2018). In particular, the levels of biodiversity found in urban L&Ps appears to be lower than those in nonurban area even if, depending on the local conditions and the management of these ecosystems, these ecosystems can reach similar levels of biodiversity than those of nonurban area (Céréghino et al., 2008; Hill et al., 2017; Naselli-Flores, 2008; Oertli & Parris, 2019; Williams et al., 2004). Consequently, these L&Ps are increasingly integrated into ecological networks for biodiversity conservation in Europe, such as Natura 2000 and Blue and Green Corridors. Urban L&Ps are also widely recognized by local actors and users as providing a large range of vital ecosystem services for cities (Amigues & Chevassus-au-Louis, 2012; Bolund & Hunhammar, 1999; Lundy & Wade, 2011). In addition to their primary hydraulic regulation function, urban L&Ps contribute to climate change mitigation (Amigues & Chevassus-au-Louis, 2012) and provide appealing landscapes (Bonnin & Clavel, 2010; Boutefeu, 2011; Hill et al., 2017), spaces for physical and recreational activities important to human health and well-being (Mishra et al., 2020; Völker et al., 2016), and

social interaction and environmental educational areas (Blicharska & Johansson, 2016). Due to the coexistence of these numerous ecological and social services provided by urban L&Ps, the managers of these ecosystems must deal with conflicts of use and incompatibilities between the water quality criteria needed for these various uses (e.g. a protected bird nesting area deteriorates the water quality, which has consequences for recreational activities). They also need to consider the particular urban characteristics and pressures (Schueler & Simpson, 2001) and the diversity of meanings associated with small ponds in urban landscapes (Clifford & Heffernan, 2018). Based on interdisciplinary research conducted on 49 urban L&Ps in the Ile-de-France area, we choose to focus on three lakes that are representative of the wide variety of situations encountered, to explore the relationships between (i) their characteristics in terms of integration in the urban landscape, water quality and ecological status, and (ii) the perceptions by various actors (visitors, managers, etc.) of the general state of these ecosystems and of their usefulness and (iii) the related management practices. We discuss how different knowledge and evaluation methods of urban lake quality (developed by scientists, managers and users) can enlighten L&P management to strengthen the synergies between ecological conservation goals, multiple social uses and amenities in an urban context. To address conflicts of use and incongruencies between various goals, the current paper suggests that the management of urban lakes should be envisaged not at the scale of each individual pond but rather at territorial scales including a few L&Ps that can accomplish various functions according to their ecological status.

Theoretical background

Challenges for defining and managing urban L&P

Despite the numerous studies that have been performed by various disciplines (such as hydrology, ecology, microbiology, limnology, geography) on urban and peri-urban L&Ps, our knowledge of their functioning and management remains limited (Birch & McCaskie, 1999; Céréghino et al., 2008; EPCN, 2008). These ecosystems are subjected to multiple anthropogenic pressures and to management strategies that can dramatically change their ecological state (e.g. control of flows, dredging, etc.) (Clifford & Heffernan, 2018). Another difficulty in producing relevant knowledge about these ecosystems is disciplinary fragmentation (i.e. each discipline adresses a particular aspect and develops its own quality indicators) and management fragmentation. For example, management responsibility for urban lakes is frequently shared by various municipal services and institutions, which are in charge of a particular use or function (Birch & McCaskie, 1999; Blicharska & Johansson, 2016; Wagner & Oglesby, 1984). Incompatibilities in the management priorities of these various actors comprise a major issue of urban L&P conservation (Wagner & Oglesby, 1984; Oertli et al., 2009). Finally, Brucet et al. (2013) have shown that managers are confronted with a great variety of expert criteria to assess the water quality and ecological status of these ecosystems, and that there is a need for the development of cost-effective diagnostic tools able to disentangle the effects of complex multiple pressures and their mitigation. The main regulatory framework for the assessment of water bodies in Europe – Water Framework Directive (WFD) – is minimally relevant for assessing artificial urban L&Ps, either because most of them are too small (i.e. only L&Ps larger than 50 ha are monitored, according to WFD procedures), or because they are too artificial and strongly impacted by urban pressures and uses. The WFD defines indicators of ‘good ecological state’ (i.e. biological quality, physico-chemical quality and hydromorphological criteria) and threshold values independently of any reference to social uses (Carré et al., 2017); however, managers still try to refer to this regulatory framework when defining their management objectives (Steyaert & Ollivier, 2007). If these 2 V. MITROI ET AL. indicators are pertinent for evaluating sanitary risks and ecological status (such as eutrophication), then they are less appropriate for considering the diversity of social uses

and amenities of urban ponds. Consequently, institutional actors in charge of the management of urban L&Ps face numerous questions that are related to the multiplicity of valuing and evaluation criteria that can be deployed to characterize L&P quality. For example, how is the ecological state of urban L&Ps affected by their urban characteristics? Should they be considered and managed as important 'spots of urban nature' even when their ecological and sanitary quality is very poor? How they can integrate into their management plans, the criteria used by residents and users of urban ponds to appreciate the overall quality of these ecosystems?

Social perceptions of L&P quality and users' aesthetic preferences

Usually located within parks or surrounded by green belts and vegetation, urban L&Ps are considered as 'green areas' and 'blue areas providing important amenities for cities' habitants' (Mishra et al., 2020; White et al., 2010). Compared with terrestrial green ecosystems in urban areas (i.e. forests, parks and gardens), very few investigations have been achieved on the way in which urban L&Ps are perceived by urban residents and users. Nevertheless, the literature informs on their aesthetic appeal (Gao et al., 2018; Hassall et al., 2015; Sender & Malslanko, 2014), their positive impact on well-being and health (Higgins et al., 2019; Völker et al., 2016) and their contribution to sense of place and neighborhoods' identity (Decamps, 2001). Although they are generally highly appreciated in urban landscapes, some negative aspects are also identified as being related to urban L&Ps, such as unwanted and invasive species or cyanobacteria blooms that affect people's ability to enjoy water bodies (Brisson et al., 2017). The aesthetic and visual preferences of users (neighbors, visitors, etc.) are important issues to be taken into consideration for the definition of conservation scenarios of urban water bodies. The theory of cultural sustainability suggests that when ecosystems and landscapes are perceived as attractive, people are more likely to have sustainable behaviors over the long term (Decamps, 2001; Nassauer, 1992, 2004). This propensity for ecosystem pro-conservation attitudes is directly related to their appearance:

When the appearance of the landscape elicits human perceptions and behaviors that maintain its ecological health, the landscape could be described as culturally sustainable; a landscape that people enjoy or are proud of is more likely to be culturally sustainable. (Nassauer, 2004)

In the field of urban water, public perception and aesthetic values are indeed considered as key issues for the sustainable management of urban wetlands (Kaplowitz & Kerr, 2003; Nassauer, 2004), river restorations (Junker & Buchecker, 2008) and urban stormwater management practices (Apostolaki et al., 2006; Gao et al., 2018). Nevertheless, there is no conclusive evidence about the concordance between the public perception of the quality of aquatic ecosystems and their ecological richness (or water sanitary quality, as judged by experts). Some landscape ecology investigations have shown that what people enjoy as the appearance of nature may have little inherent relationship with its ecological quality measured according to species richness or abundance criteria (Dallimer et al., 2012; Hassall et al., 2015). Nevertheless, few studies have shown that even if people may not explicitly recognize (or quantify) biological diversity, the subjective perceptions of species diversity may reflect objective measures. The presence of charismatic species (e.g. kingfishers, dragonflies) considered by experts in ecological inventories is very positively interpreted by people (McGinlay et al., 2017) because it allows them to connect with biodiversity in a tangible or emotional way (Higgins et al., 2019). If some concordances can be established between the visible (macro-) biodiversity and social appeal of urban L&Ps, then the relation between water quality and social perception of the quality of these ecosystems is even less investigated and difficult to capture. This is not surprising if we consider that water quality refers in a large part, to various invisible contaminants (i.e. micropollutants, heavy metals, fecal bacteria, etc). Other visual criteria, such as water color and turbidity can nevertheless be shared indicators between expert and profane grids of water quality

lectures. Some interesting citizen science experiences have confirmed that citizens can inform cyanobacteria blooms on lakes and shallow waterbodies in relevant ways (Castilla et al., 2015;

Mitroi et al., 2020), thereby complementing the institutional monitoring of the trophic status of these aquatic systems (Hadj et al., 2017). In addition to the aesthetic and visual criteria, other factors play a role in the public perception of hardly transformed ecosystems such as the health benefits related to the possibilities offered by these water bodies to enjoy nature or to provide recreational activities (angling, swimming, boating) (Junker & Buchecker, 2008). This is about the 'functional level of landscape' (Nassauer, 1992, 2004), which refers to the accessibility to infrastructures for walking and recreational activities or the possibility of visually enjoying related landscapes. The public safety feeling that emerges in these landscapes also play a role in their appreciation by users. This is directly related to the social frequentation of L&P surroundings as open public places that can easily be occupied by unwanted populations with unappropriated behaviors (i.e. noisy, potentially dangerous, etc.). Finally, a place that is well cared for (i.e. trash-free water and shorelines and infrastructures that are well maintained) contributes to the security and well-being that a water body can provide (Nassauer, 2004). Because these last features have little to do with the water quality or ecological value of a lake they are often neglected by managers; however, they are very important indicators for urban L&P users. Not addressing social perceptions about L&P quality may lead to a clash between public perception and public action concerning urban L&P conservation.

Case study

The Ile-de-France region is one of the most populated metropoles in Europe and the most urbanized areas of France (IAURIF, 2016). The urban area was extended through a suburbanization process initiated in the late 1960s, which included the construction of new cities (so-called villes nouvelles). Many artificial ponds and lakes were created as a result of the sand and gravel extraction used for new urban planning during the 1970s and 1980s. These water bodies were integrated into the urban landscapes for different assigned functions such as stormwater outlets, urban landscape, and recreational activities (e.g. sailing, swimming, fishing, etc.). Currently, the Ile-de-France region contains approximately 1,000 L&Ps, 250 of which have an area >5 ha (Catherine et al., 2008). The ecological and sanitary states of these L&Ps, which are subject to various and combined anthropogenic pressures and pollution, are very little known and represent a real challenge in regard to understanding their ecological functioning. Local authorities, national agencies, and user associations (e.g. fishermen, naturalists and local residents) acknowledge urban ponds as increasingly important elements of the urban landscape and human wellbeing and lately as important 'biodiversity spots' to preserve.

Material and methods

Study sites

To better understand the diversity of the ecological state of L&Ps in Ile-de-France, 49 lakes in the Ile-de-France region were monitored between 2011 and 2013. These 49 lakes were representative of the 250 lakes in the Ilede-France region displaying a >5 ha surface by their hydrogeological and limnological characteristics and by the various land-uses and population densities around these lakes (Catherine et al., 2008). Among these 49 lakes, we chose to focus on three lakes located on the outskirts of Paris (Créteil: 11 km from Paris, 48°46′ N 02°27′ E; Enghien-les-Bains, 13 km from Paris, 48°58′ N 02°18′ E and Saint-Quentin-en-Yvelines, 24 km from Paris, 48°47′ N 02°01′ E). These lakes displayed contrasting characteristics in terms of history, landscape evolution, watershed size, shoreline artificialization and land-use profiles in the 1 km area around the lake, which reflect their diversity. For example, there is a green area around the lake of St-Quentin-en-Yvelines, while in

Enghien-les-Bains, there is just a very small green area in the southeastern part of the lake. Finally, in Creteil, the western part of the lake is green while the eastern part is very urbanized (Table 1).

Table 1. Main characteristics of the three lakes and their surrounding areas.

	Enghien-les-Bains	Créteil	Saint-Quentin-en-Yvelines
Lake surface (ha)	33.8	40.8	120.0
Average depth (m)	1.25	4.63	1.63
Watershed surface (km^2)	53.7	1	40.6
Urban areas of the watershed (%)	59.2	56.4	22.0
Agricultural areas of the watershed (%)	1.0	0.0	37.1
Natural spaces areas of the watershed (%)	37.8	20.5	34.5
Urban areas (1 km) (%)	90.0	71.5	36.00
Agricultural areas (1 km) (%)	0.0	0.0	50.0
Natural spaces areas (1 km) (%)	10.0	18.5	8.0

Digital orthophotograph interpretation

The landscape evolution related to the three selected lakes during the past 65 years, was assessed using digital orthophotographs within a 1-km area from the lakeshore. This distance was determined through a compromise between ecological criteria (i.e. lake catchments) and landscape criteria (i.e. the visual perceptions of users). This analysis was based on four aerial missions conducted between 1949 and 2014. The oldest photographs were georeferenced from the orthophotograph of 2014. Using MapInfo software, we built a database and produced twelve descriptive land use maps for each lake at different time periods, which generated land use evolution maps for each of the studied lakes. These maps were then used to quantify the evolution of land use between 1949–1950 and 1971–1972; between 1971–1972 and 1991–1992, and finally between 1991–1992 and 2014. The interpretation of the orthophotographs was completed with some bibliography concerning the evolution of the three concerned cities and the initial landscape of the lakes.

Constructing a regional reference framework for the ecological status of urban lakes

The data used for the assessment of the lake ecological status were based on three sampling campaigns performed during the summers of 2011–2013 on 49 lakes of the Ile-de-France region. These data were used to set up a regional frame of reference for the ecological status of the lakes in Ile-de-France (Mitroi et al., 2016). The ecological quality of the three lakes considered in this article is therefore presented not only in a comparative perspective between the three lakes, but also in reference to this regional framework. The ecological indicators used for the assessment of the ecological status of the lakes are the result of a consultation process between the researchers and L&P managers and their operational needs. These indicators allow us to characterize (i) the trophic status of the water bodies, (ii) their microbiological quality and (iii) their level of contamination by anthropogenic contaminants. Twenty parameters considered by Carr and Rickwood (2008) to reflect the ecological functioning of water bodies, were used to estimate four indices: the water quality index (WQi), the microbiological index (Mi), the trace metals index (TMi), and the polycyclic aromatic hydrocarbons index (PAHi) (Table 2). The value of these indices for each lake was calculated as the average of the deviations from the guideline value for all selected parameters. Thus, an index could reach a value of 100 only if the entire set of parameters included in the index indicated a good status for the water body. Finally, the global quality index (GQi) of each water body was calculated as the average of the different quality indices (WQi, Mi, TMi, PAHi). Similarly, this index could only be set to 100 if all the different quality indices had a maximum value (i.e. good status). In addition to their contribution to a global characterization of water bodies, some indices were also used to evaluate whether a water body was suitable for human activities. For example, the microbiological index (Mi) was used to assess whether a water body was suitable for recreational activities, particularly swimming.

Sociological approaches for the assessment of the representation of uses and lake quality

A sociological survey was conducted on various social actors (neighbors, visitors, planners, and managers), to identify public perceptions (Barnetta et al., 2018; Gao et al., 2018) of the global quality of the three lakes and their 'naturalness'. We conducted 26 interviews with lake managers from the Ile-de-France region, and 159 questionnaires were administered during the summer of 2013 to users of the three selected lakes (Enghien-les-Bains: 41; Saint-Quentin-en-Yvelines; 43; and Créteil: 75). The survey was performed 'au fil de l'eau' by varying the days of the week and the hours of the day to cover a wide and diverse panel of participants. The panel of users was relatively well balanced by age but women were generally overrepresented (Table 3). We used questionnaires with both closed-ended questions (with a single possible answer between a few already codified) and open-ended questions (where people could express themselves by using their own words). All data were statistically treated by using specific sociological methods for qualitative and quantitative codification and analyzed with XLStat software.

Table 2. Parameters used for the calculation of indices and guiding values expressing a 'good ecological status'

Indicators and indices	Units	Guideline values	Source of the guideline values
WQi			
Dissolved Oxygen	mg/L	>9.5	UNEP, 2008
pH	SI unit	6–9	UNEP, 2008
Conductivity	µS/cm	<500	UNEP, 2008
Total Nitrogen	mg/L	<1	UNEP, 2008
Total Phosphorus	mg/L	<0.05	UNEP, 2008
Mi			
Chlorophyll a	µg/L	<50	European Directive: 2006/7CE and 2014/101/UE; Circular for the bathing and nautical activities area, 25.01.2010 of the Ministry of Ecology, Sustainable Development and Energy (DGS/SD7A 2003/270, 2004/364, 2005/304).
% Cyanobacteria	%	<50	
Microcystins	µg/L	<13	
E. coli	UFC/ 100 mL	<900	
Fecal enterococci	UFC/ 100 mL	<330	
TMi			
Lead	µg/L	<1.2	European Directive 2013/39/UE.
Nickel	µg/L	<4.0	
Chrome	µg/L	<3.4	Order of 25 January 2010, Ministry of Ecology, Sustainable Development and Energy.
Zinc	µg/L	<7.8	
Copper	µg/L	<1.4	
PAHi			
Anthracene	ng/L	<100	European Directive 2013/39/UE of European Parliament and Council.
Fluoranthene	ng/L	<120	
Benzo[a]pyrene	ng/L	<270	
Benzo [b]fluoranthene	ng/L	<17	
Benzo[g,h, i]perylene	ng/L	<8.2	

Table 3. Composition of the respondent community by gender and age group.

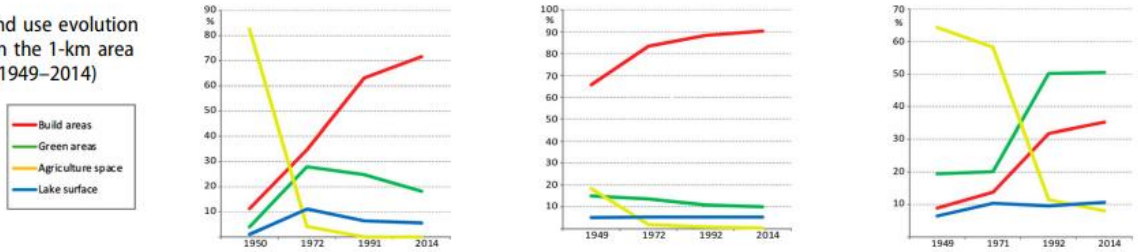
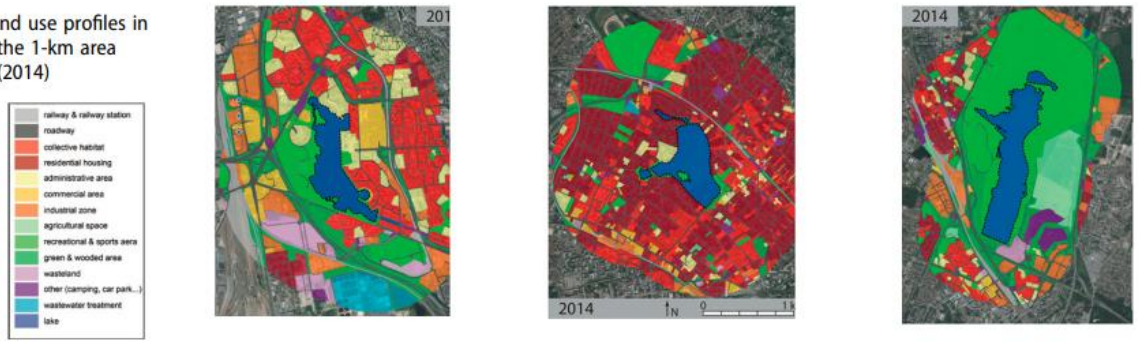
		Age range						
Lakes	Gender	15–17	18–24	25–34	35–49	50–64	65+	Total
Enghien	Male	0	0	2	2	3	6	13
	Female	0	12	6	6	2	2	28
Créteil	Male	0	1	7	5	8	7	28
	Female	2	7	15	9	8	6	47
St-Quentin	Male	0	1	6	5	6	1	19
	Female	0	3	7	9	4	1	24
Total		2	24	43	36	30	23	159

Results

Urban profiles of lakes – landscape and uses

Concerning the urban patterns, the strong densification of urban areas is apparent for each of the three lakes during the studied period (1949–2014), but the urbanization timelines and ratios between built and green areas of the shorelines are very different (Table 4):

Table 4. Various uses of the lakes and evolution of the landscape occupation around them.

	Creteil	Enghien-les-Bains	Saint-Quentin-en-Yvelines
Lake creation	1976	eighteenth century	seventeenth century
Land use evolution in the 1-km area (1949–2014)			
Land use profiles in the 1-km area (2014)			
Shoreline urbanization	< 50% Collective housing, leisure and sportive installations, administrative city center>50% Green areas	< 70% Cultural city center (public establishments, casino, water games)> 30% Private houses (some with gardens on the lakes)	100% free of buildings, green area outside the city, boating center
Users' residential place	< 75% locals> 25% occasionally passers	< 60% locals< 30% neighboring cities> 10% occasionally passers	Very mixed, with people coming from long distances and Paris
Users' frequency at the lake	Very regular attendance (several times a week) all throughout the year, with peaks in summertime	Regular attendance (more or less frequent), but also people just 'passing by' all year round	Many come 1–3 times a year while some come for the first time; very concentrated on good weekdays
Main uses	Same as for an urban park (lawns, play areas, etc.); sailing school; nature observation and education; fishing	Sailing school; cultural events; walking; meeting place, and rest.	Lots of leisure activities and sporting events; school and leisure center activities; barbecue and picnic areas; nature observation and education; fishing

• Built at the end of the eighteenth century, Lake Enghien (36 ha) is a historical lake that was landscaped by the construction of a dam on the marshy area of the Montmorency Valley. In the first half of the nineteenth century, the place became a leisure destination for the Parisian bourgeoisie (Neu, 1994) and residential buildings began to be built on the lakeshore. In 1949, the urbanization level of this space was already high (65.8%) and consisted mainly of individual residential housing (44%). The city continued to expand and become denser until the 1970s with the development of collective housing. By 1972, nearly 85% of the 1-kilometer surrounding area was already built. The remaining green and woodland areas (approximately 10% in 2014) are mainly situated on private properties that are not accessible to the public.

• For Creteil Lake, cartographic data indicate that this lake (40.8 ha) was landscaped in 1976 as part of the Park of General Interest of 23 ha dedicated to recreational activities for the 'ville nouvelle' de Créteil, which was built between 1950 and 1972. Massive urbanization started in 1950 and continued between 1972 and 1991. The eastern part of the lakeshore is strongly urbanized and occupied by

collective housing and administrative buildings, while the western bank has preserved green spaces and leisure establishments.

• Lake Saint-Quentin-en-Yvelines was originally built in the seventeenth century inside a complex hydrological network meant to supply water to the fountains of Versailles. Located 24 km southwest of Paris, the lake area remained very rural until 1971, when the construction of the new town of Saint-Quentin-en-Yvelines began. This new city led to the disappearance of important agricultural land (from 59% to 11%), but the landscape around the lake remained very 'green' since a significant part of the agricultural land was converted into green and wooded areas (19.4% in 1949–50.1% in 1992). An outdoor recreational space of 600 ha was created in 1969 around Lake Saint-Quentin-en-Yvelines, which became an important leisure location for the new city as well as for the entire region.

The users of Lake Creteil are mostly locals (only 16 of 80 come from neighbor municipalities), while in Enghien-les-Bains and Saint-Quentin, more than half of the users are inhabitants of neighbor cities, including Paris. We also found some differences between the three lakes regarding the frequency of visits and indirectly, the degree of familiarity of the users with the lakes. While in Creteil there are mainly regular users (up to 40% visit several times per week), in Saint-Quentin, the majority of users (40%) visit the lake only two to four times in their lifetime, while only 30% frequent the lake more regularly (one or more times per month). In Enghien, people's presence on the lake's banks is very diverse, ranging from daily attendance for those living in the city to less frequent visits for those living in neighbor districts.

Despite different landscape patterns and degrees of urbanization in the surrounding areas of these lakes, all of them have experienced a similar evolution toward a diversification of their original landscape functions. For instance, they all provide stormwater storage and recreational functions for riparian populations, in addition to landscape and urban biodiversity functions.

Water quality and ecological status of the three lakes

Based on the quality indices, none of the three lakes can be considered to have a good ecological status, but for different reasons. The weak GQi of Lake Enghien-les-Bains is mainly due to the high degree of contamination by PAHs, while Lake Creteil is mostly downgraded by the WQi and TMi indices and Saint-Quentin is primarily downgraded by the WQi index (Table 5). Compared to the 49 lakes monitored in the Ile-de-France region, Enghien-le-Bains is the most degraded on the basis of the GQi (and mostly due to PAHi), while Créteil and Saint-Quentin-en-Yvelines lakes are characterized by better GQi values though they display the lowest values for WQi (Table 5).

Table 5. Quality index values for the three lakes compared to the values found for the 49 lakes of Ile-de-France.

		WQi	Mi	PAHi	TMi	GQi	Urban areas (1 Km) %
Enghien-les-Bains		90.7	95.6	40	99.7	81.6	90.0
Créteil		80.7	100	100	85.6	91.6	71.5
Saint-Quentin-en-Yvelines		84.0	100	100	98.7	95.7	36.0
Ile-de-France (49 lakes)	Minimum	42.9	69.4	40	71.4	81.6	
	1st quartile	87.4	95.0	100	99.3	93.8	
	Median	92.0	100	100	100	96.6	
	3rd quartile	95.7	100	100	100	98.8	

WQi: water quality index; Mi: microbiological index; PAHi: polycyclic aromatic hydrocarbons index; TMi: trace metals index; GQi: general quality index.

When considering these characteristics, it appears that the lake with the lowest GQi (Enghien-les-Bains) is the shallowest and the smallest of the three lakes and the lake with the most urbanized direct watershed within its 1-km area (90%). In contrast, the lake with the best water quality (Saint-Quentin-en-Yvelines) is the largest lake with the less urbanized watershed within its 1-km area (35%).

Public perceptions of the naturalness and quality of urban ponds

Among the large number of social uses that were identified for the three lakes (boating, swimming, fishing, observation of nature, etc.), relaxation/evasion is the most often cited use for the three lakes (Figure 1A). Although it is difficult to precisely quantify the use of 'relaxation', it appears that most people visit the lakes' banks primarily to 'relax', 'get some fresh air' and 'to escape from urban pressures' (35% in Saint-Quentin, 60% in Enghien and 70% in Créteil). These answers are coherent with users' vision about the main function of urban lakes, which provide relaxing places where they can escape urban pressure (Figure 1B). Lakes and the surrounding green areas are mainly seen as places to play sports, go on outings with children, have a picnic, or engage in other social activities.

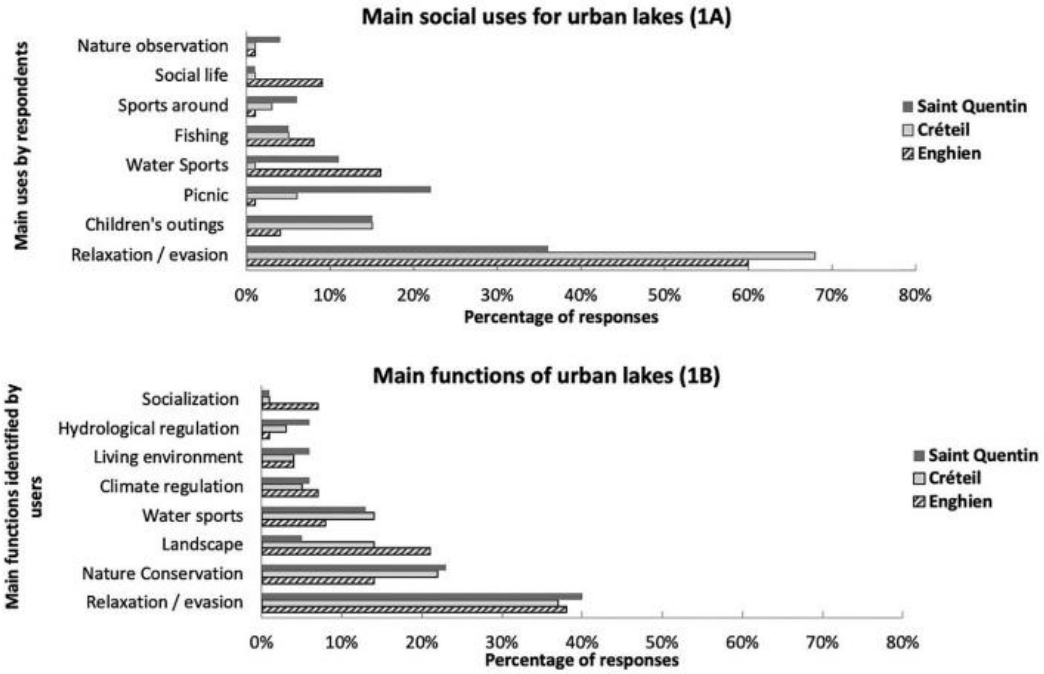


Figure 1. User answers on the main uses (1A) and functions (1B) of the urban L&Ps.

If we consider the degree of urbanization of the 1-km areas surrounding the lakes, it is interesting to see that the more the surrounding environment is urbanized, the more the landscape function is appreciated (Figure 1B). In Lake Enghien, which is the most urban of the study, more than 20% of the users consider the lake to have a major landscape function for the city while for the lake of Saint-Quentin-en-Yvelines, which is located in a green area outside the residential neighborhoods, the landscape function is not perceived as important (only 5% of the answers). On the other hand, the lakes of Saint-Quentin-en-Yvelines and Creteil are perceived as having an important ecological function of nature protection (24% and 22% respectively), while in Enghien, only 15% of the respondents cited this function (Figure 1B).

Even if a larger proportion of the respondents in Creteil considered that the lake was artificial, there was no significant difference (chi-2 test) concerning this criterion of the natural/artificial lake character (Figure 2A) when comparing the respondents from the three lakes. In the same way, there was no significant difference (chi-2 test) in their responses concerning the ecological state of the lakes, even if those of Creteil provided the lowest proportion of the good state (Figure 2B). Finally, no significant difference (chi-2 test) was detected in regard to the age and gender of the respondents concerning these two criteria.

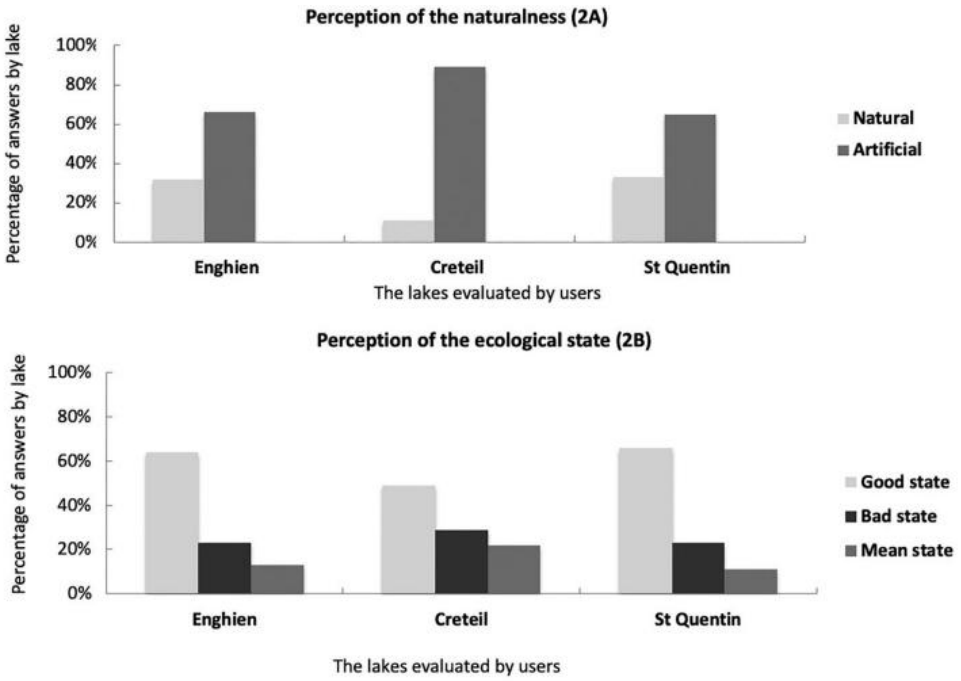


Figure 2. Perceptions of the naturalness (2A) and ecological status (2B) by users of the three lakes (Créteil, Enghien-les-Bains and Saint-Quentin-en-Yvelines).

Users were asked to freely name three main criteria they employed to evaluate the 'naturalness' and the 'ecological state' of the lakes. For 'naturalness', they evoked a patrimonial relationship with the lakes, referring to the 'social origin' of these water bodies. The 'social origin', meaning that the lakes were landscaped through the process of urbanization, largely dominated the biophysical (e.g. the aspect of the banks and level and aspect of the water) and morphological (e.g. size) criteria (Figure 3). This is less the case for Lake Saint-Quentin, where many users come from other cities of the region and therefore know less about the social history of the lake. The degree of greening/artificiality of the lake's shoreline was the second criterion mentioned by users to evaluate the naturalness of the lake. Other criteria do not seem to be important in their assessment of naturalness, excepted the size of the lake for users in Enghien-les-Bains.

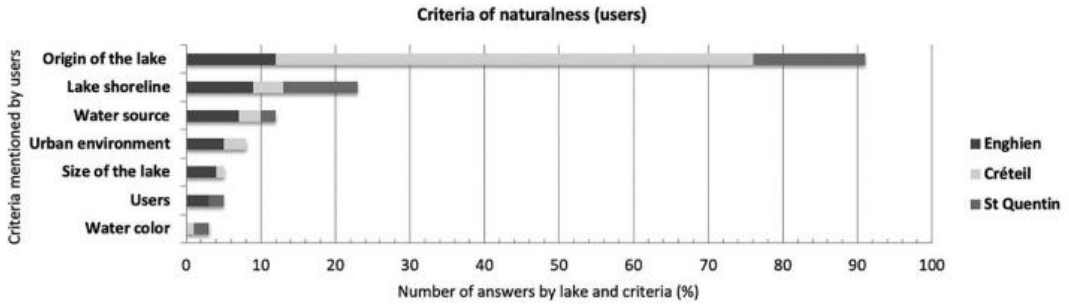


Figure 3. Criteria mentioned by users for their evaluation of the naturalness of the three lakes.

Table 6. Key criteria mentioned by users and managers for evaluating the lake ecological quality.

Key criteria	Users' answers ($N = 120$)	Key criteria	Managers answers ($N = 26$)
Cleanliness and maintenance	48	Water quality (pollution)	11
Water appearance	39	Biodiversity	8
Natural appearance	11	Microbiological quality	5
Leisure facilities	5	Nutriment inputs	4
Fish and fishing activities	5	Invasive species	3
Urban pollutions	3	Landscape criteria	3
		Users Attendance	3
		Cleanliness and maintenance	2
		Cleanliness and maintenance	2

Concerning the criteria used to assess the lake ecological quality, the most important for users were the 'cleanliness' and 'maintenance of the lake' (the water and its surroundings) (Table 6). When users mentioned 'water appearance', this primarily referred to hygiene (e.g. no trash or pollution residue) or the healthy aspect of the water (e.g. 'clean water', 'no algae', 'transparent water'). The natural aspect of the lake and its environment (e.g. the presence of vegetation, birds, fish, etc.) was ranked in third position. However, the relationship between these two major categories of judgment ('cleanliness' and 'natural appearance') differed according to the surrounding environment. For Saint-Quentin, which is located in a vegetal environment, users considered the 'natural appearance' to be a more important criterion than 'cleanliness', which was the first criterion for the users of Enghien and Créteil, which are located in a more urban environment. For many users of Saint-Quentin, the 'green and blue' image of the area is seen as a guarantee of biodiversity and hence a criterion by which to assess lake quality. For the users of Creteil and Enghien, which are located in a much more urbanized landscape, the criterion of 'leisure facilities' was much more important than the 'natural appearance' and refers to the presence of leisure facilities, accessibility, walking paths, etc. Surprisingly, pollution was a very secondary concern for users of the three lakes.

The key criteria used by managers for the assessment of the ecological quality of lakes were very different from those of users. Managers mainly mentioned 'water quality', followed by 'biodiversity'. Landscape and visual criteria, including those of cleanliness and maintenance of lakes and shorelines were rarely mentioned by managers.

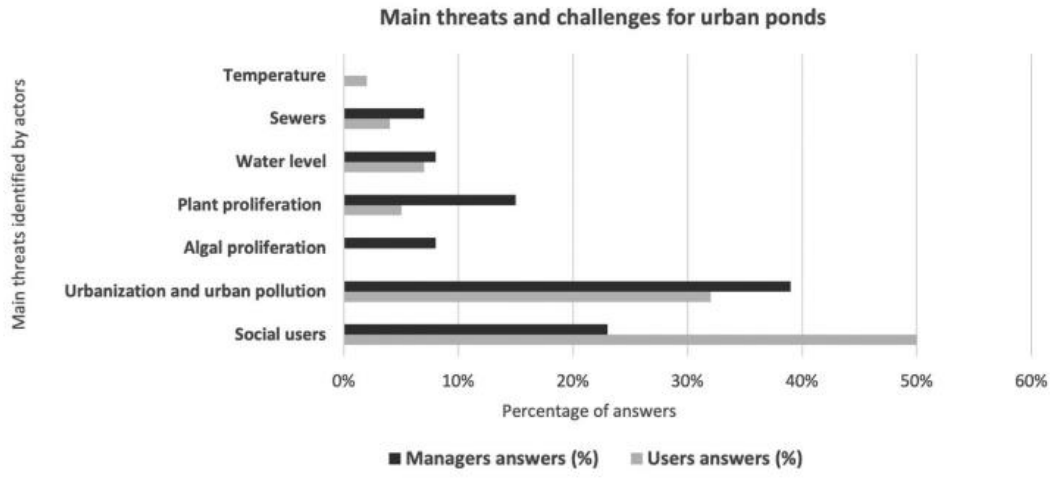


Figure 4. Main threats and challenges for urban lakes mentioned by users and managers.

Main threats identified by actors

As shown in Figure 4, the main threat reported by the users for the ecological quality of the lakes consisted in 'the other users' (50% of respondents), while managers identified users as the second major degradation factor (23% of respondents). The idea that too many users are a threat to lake

quality is associated with users who exhibit problems related to cleanliness, insecurity and the deterioration of the 'social ambiance'. This can be linked to very high visitation levels (especially in Créteil and Saint-Quentin), particularly during weekends and sports or cultural events. For managers, 'urbanization and associated pollution' was the first major degradation factor (39%), while this criterion was the second one for the users (32%) (cf. Figure 4).

These perceptions of the threatening factors were directly related to the actions that are considered necessary to improve or conserve lake quality. Users considered that the most important action is to better control users. First, they proposed more education-, information- and awareness-raising measures for all categories of users. Second, they requested action to better regulate and control user practices including better supervision and the limitation of users (e.g. number of visitors, boats, 'selective' access, contraventions for noncompliant activities). Another type of action frequently cited by users concerned the 'maintenance' of water bodies and their banks. Other improvements concerned the necessity to assign additional spaces for nature and protect the environment from urban pressure. A similar importance (approximately 7%) was given to water quality, whether through dredging or filtering, decanting or purification.

Discussion

The impact of the urban environment on L&P quality – ecological indicators and public expectations

The effects of urbanization on the evolution of urban L&Ps are quite contradictory when considering both ecological (and water quality) indicators and public expectations. The ecological indicators suggest that the urbanization of the 1-km surrounding area of the L&Ps is an important source of pollution pressures for these ecosystems (e.g. nutrients, PAHs, heavy metals, microbes). If the size of the watershed and its degree of urbanization is considered a good proxy for assessing the nutrient and pollution fluxes to the L&Ps (Catherine et al., 2013), several studies have shown that the land use in the area adjacent to a lake (between 500 m and 1 km) has a more significant impact on the water quality and the trophic status of these lakes than does the whole catchment land use (Akasak et al., 2010). As suggested by our data, this could be because the degree of urbanization in the 1-km area is frequently more important than that in the whole catchment.

In contrast, the sociological investigation of public perceptions of urban L&P quality shows that they are highly appreciated by users, regardless of their ecological status or urbanization degree in the 1-km surroundings. This outcome is in accordance with recent works on users' perceptions of urban nature and blue spaces, which show that users tend to adapt their expectations and quality evaluation criteria according to the uses they envisage and to their urban location (manicured urban park, green area, residential area) (Junker & Buchecker, 2008; Sender & Malslanko, 2014; White et al., 2010). For example, in the particular case of the lake of Enghien-les-Bains (a very urbanized and residential water body), users do not expect high level of biodiversity but rather aesthetic characteristics for the urban landscape and assets for open space activities. In contrast, for users of the lake of Saint-Quentin (located in a green area outside the city), the lake's quality is mainly judged on environmental criteria, including the presence of birds and vegetal varieties and the green aspect of the shoreline. This adaptation of quality criteria to the surrounding landscape probably explains why, from the users' point of view, the evaluation of the quality in the Enghien and Saint-Quentin lakes appears to be very similar. These results must be interpreted since we know that we focused our survey on direct users of these green and blue spaces instead of on all residents living around these lakes, which could have more negative perceptions or weak interest levels for them.

In terms of management objectives, the fact that no significant relationship was found between the ecological quality of these lakes and the social perception of their quality and wellbeing amenities opens up new considerations about the possible pathways of bridging together social and ecological targets in management practices. If managers focused their actions on the protection/restoration of a good ecological state, then their choices must also include users' perceptions and expectations to be able to mutually assure a diversity of uses and a good ecological functioning of these urban lakes.

Of course, we are aware that these data obtained on the three lakes are probably nonrepresentative of the great diversity of the situations that could be encountered in the urban L&Ps of the Ile-de-France area. However, during the data presentation of our findings to the managers of numerous of these L&Ps, which was performed at the end of the research program, most of the managers shared our analyses built on the data recorded from the three lakes. In the same way, one potential bias in this study concerns the fact that in this study, we were not able to consider people who choose to avoid these urban L&Ps because they have a negative point of view about them. This omission could lead to an overrepresentation of people who have a good opinion about the quality of these ecosystems.

Defining management objectives within a diversity of meanings

The first consideration is about the acknowledgement of the diversity of meanings encompassed by urban L&P quality. Frequently, managers have the tendency to refer to standardized quality indicators and threshold values to evaluate urban L&P quality. Even when not concerned with the WFD institutional monitoring, managers are often attached to the idea of 'reference status', because standardized indicators help them set quality objectives and define action plans. Consequently, they tend to homogenize the quality management objectives to get closer to 'good ecological status' standards (Carré et al., 2017; Steyaert & Ollivier, 2007). Moreover, in the framework of ecosystem services approaches, a better ecological quality of lakes could allow for the maximization of ecosystem services, but this is not sufficient to prevent the existence of conflicts of use and some incompatibilities between the various uses and the water quality required for them (Bolund & Hunhammar, 1999; Lin & Ueta, 2012; Lundy & Wade, 2011).

This approach eludes the incoherencies between various management objectives (Blicharska & Johansson, 2016; Wagner & Oglesby, 1984) and fails to address the problem of trade-offs within various ecosystem services (Janssen et al., 2020; Schueler & Simpson, 2001). In some shallow lakes located in Ile-de-France, it has been found that the bird population is an important source of nutrients that contributes to the eutrophication of lakes and affects their capacity to provide other ecosystem services, such as recreational activities (i.e. that are disturbed for example by cyanobacterial blooms due to the eutrophication) or stormwater storage (i.e. that necessitates a different management of water level than the one appropriated to bird nesting needs). This situation shows that for each urban lake, managers are inevitably confronted with choices of quality criteria and quality objectives that should be explicitly discussed to clarify which ecological and social functions can be privileged and which functions will be affected or impossible to accomplish.

From a diversity of meanings to a diversity of water bodies at the regional scale

To address the conflicts between management objectives and the incompatibilities between the multiple expected ecosystem services, we propose that management practices need to evolve from a focus on each individual L&P to a consideration of the management of urban L&Ps at a larger territorial scale. Despite the small size of numerous urban L&Ps and the 'bad' quality values obtained by some of them, all these water bodies provide social and cultural amenities and are rich in terms of biodiversity when they are considered all together. Following recent research results on the

biodiversity richness of small pond networks (Hill et al., 2017; Oertli & Parris, 2019; Williams et al., 2004), we consider that at the neighborhood and city scales, it may be interesting to maintain a diversity of L&Ps with various trophic states via a 'pondscape approach' (Boothby, 1997; Hassall et al., 2015) focused on the management of lake networks rather than individual entities.

In this framework, the key issue of this approach will be to know how to improve the coordination of social uses and amenities with the various ecological statuses of urban L&Ps. Instead of considering that a single lake can answer to all ecological and social quality criteria, we suggest that a diversity of lakes with various ecological statuses can better support a large diversity of social uses and amenities. Consequently, the water quality targets for each urban lake will be different based on the accordance between their intended uses (recreation, water supply, flood control, biodiversity, etc.) and their trophic state (Figure 5).

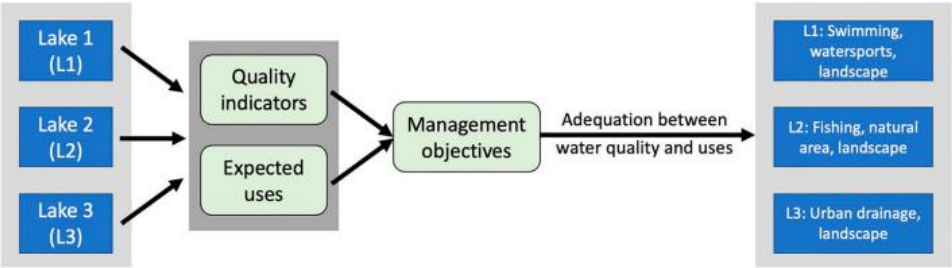


Figure 5. Territorial planning of proximate lakes by reorganizing and distributing compatible uses on different lakes according to their water quality/ecological state.

For example, eutrophic lakes could be oriented toward environmental and educational uses (e.g. natural areas dedicated to bird resting and nesting, mini-natural parks landscaped for environmental observation, etc.), while lakes displaying a good microbiological quality could be primarily dedicated to recreational uses (e.g. swimming, boating, etc.). As a matter of consequence, lake management should prioritize restoration actions on the ponds where they can obtain the best results in terms of water quality. This will particularly concern the control of pollutant inputs (organic and inorganic).

Such a territorial approach should also permit the avoidance of the application of remedial methods to try to maintain some uses in aquatic ecosystems, regardless of the water quality (Humbert & Quiblier, 2019). For example, short-term solutions based on the application of chemicals (copper sulfates, hydrogen peroxide, etc.) and/or on the use of ultrasonic device are frequently used to kill cyanobacteria, which are dangerous for humans and consequently disturb recreational activities in water bodies. Knowing that cyanobacterial blooms are mainly due to eutrophication, the application of short-term solutions is frequently chosen by managers rather than sustainable solutions for the control of nutrient loads, which take time to have visible effects. Knowing also that there are many uncertainties about the environmental impacts of these short-term solutions and on their applications in the field, a territorial management approach to urban L&Ps should permit a better adequation between water quality and the uses that are required by these ecosystems (Humbert & Quiblier, 2019).

The choice of the most appropriate uses for each ecosystem should not be considered to be definitive; a revision of these uses should be periodically performed based on the evolution of the water quality and on the users' capacity to adapt their practices to a given environment.

Of course, this territorial management approach raises many questions, including: the relevant territorial unit (which is not necessarily the watershed scale), the likely acceptance of management choices concerning the use of spatial organization, the possible obstacles for its implementation, and

the difficulty of capturing and dealing in an inclusive way with various stakeholders' expectations and values (Chan et al., 2012). Moreover, a water body that offers the possibility of specific uses does not have the same value if it is part of the 'reference territory' of an individual (i.e. close to his or her home, work, or usually used for accessing services and leisure) or if it is outside of this territory. From a territorial and land-based perspective, uses are quite incommensurable, and when a spatial variable is introduced, we cannot determine the equivalence of a use in two distinct places. Thus, the users' capacity to adapt their practices and evaluation criteria from one environment to another must be taken into account.

For all these reasons, the territorial distribution of ecosystem services should be balanced between different lakes based on their specific quality and particular urbanization conditions (i.e. nearby water bodies with similar access conditions). In any case, this reorganization of water body ecosystems services must consider the following factors together: the sociohydraulic constraints (related to the history of urban development), the ecological quality of the lakes (measured according to the parameters of the environmental regulation), and the social demand as expressed by various users and managers.

Conclusion

Organizing the multifunctionality of urban L&Ps is a core issue for the management of their ecological quality. Many urban planning schemas worldwide include the creation of small urban ponds (Boix et al., 2012; EPCN, 2008; Oertli & Parris, 2019) that are intended to provide various urban and ecological functions. This article suggests that a more integrative management of the existing and future urban L&Ps and water bodies (such as Stormwater Drainage Utility System (SDUS) must be organized at the city (or neighborhood) scale, including various waterbodies. This article shows that managing urban shallow L&P quality is not only about improving the ecological and water quality indicators of each lake but also better coordinating the various ecological statuses of L&P and their social uses (ecosystem services, benefits, values and expectations). Consequently, to provide the various uses and services that are expected from urban L&P, it is necessary to conserve or promote a diversity of ecosystems regarding their ecological status.

As shown in our paper, public perceptions about lake quality can provide some interesting understandings of the role of urban L&P, their expected functions and quality indicators. Despite the fact that users' valuations of urban L&P quality are mainly based on aesthetic aspects (i.e. the 'natural' and 'green' appearance) rather than on clearly established ecological values in terms of biodiversity for example, users' preferences are not necessarily incompatible with ecological quality objectives. We show that user expectancies can be an important driver of L&P preservation, mainly via blue–green landscape conservation, which can provide important well-being amenities within cities. This advocates for the preservation of the vegetal coverage of lake shorelines and of the green surrounding areas, which are strongly appreciated by the public and will have a positive impact on biodiversity and water quality by reducing anthropic urban pressures.

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