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PONDS: CONSERVATION THROUGH A BETTER MANAGEMENT OF ENVIRONMENTAL IMPACTS
DIVERSION: AN OPTIMAL MANAGEMENT? THE CASE OF LOIRE HEADWATER CATCHMENT (FRANCE)

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Abstract
French ponds suffer from bad press regarding their environmental impact. In the context of aquatic environments protection, their survival is in jeopardy. Their management in order to reduce the hazard seems the only way to ensure their maintenance. To achieve this, water managers advocate the diversion described as the best way. But no scientific study corroborates their statements. That is why we propose a thermal study in the long-term of three ponds in the Loire headwater catchment. Indeed, temperature is a key parameter in water quality and a remarkable indicator. Given the results from more than 51,000 unpublished data, we argue that in this time scale, regardless of types of diversion ponds, this management can reduce or even remove the thermal impact ponds.

Keywords: diversion ponds, environmental impacts, management, temperature, water quality, Loire headwater catchment

1 BARRAGE PONDS: NEGATIVE CRITICISM OF ENVIRONMENTAL IMPACT AND DEVELOPMENT OF DIVERSION

Barrage ponds, enjoying a fairly succinct regulation, depend mainly on the aquatic environments legislation and even more particularly, on the river legislation (Millot 2014). Essentially, it is the European Water Framework Directive (WFD, 2000) and the Law on Water and Aquatic Backgrounds (LEMA, 2006). The main objective is protecting watercourses from both a quantitative and qualitative point of view, to achieve "good ecological status" (WFD, 2000). In this context, the deleterious picture of ponds is a threat to their durability as the main evidences against ponds concern the impact on the physicochemical quality of rivers and the severance of ecological continuity, defined as "sufficient transport of sediment and living species" (Sido, 2006). The threat of elimination, said “erasing” (Etablissement Public du Bassin de la Vienne, 2010), is real. It is more for leisure ponds since only economic use is seen as justifying the presence of a pond: "works without economic use will preferably be erased (or leveled)" (DREAL Centre, 2014). Therefore, it seems that better management of the environmental impact of ponds is a necessary condition to the preservation and perpetuation of ponds.

Until not so long time ago, different arrangements of water outlet (monk, spillway, bottom valve) were variable by which managers influenced to reduce the hazard. But now it seems that their effectiveness is no longer sufficient. Now water managers promote an expensive alternative management, the diversion, as the best one. By dividing the stream between the supply of the pond and a bypass channel, the idea is allow ecological continuity and reduce the physicochemical impacts of ponds.

In this context of threat and given the cost of a diversion (at least EUR 12000), a scientific study is needed to clarify this almost dogmatic discourse of water managers. Is diversion an optimal management to reduce environmental pollution and this, irrespective of types of ponds? To study its effectiveness, we focus here on the thermal study at a long time scale of three diversion ponds located at Loire headwater catchment.

2 STRATEGY OF SELECTION FOR STUDY SITES AND ITS EQUIPMENT: RELEVANCE AND REPRESENTATIVENESS

From national to local scale, the study area is scientifically relevant and humanly necessary. The study sites were selected based on their characteristics and representativeness in order to clarify a possible typology of diversion ponds. The equipment and instrumentation have been put in place in order to highlight a trend of the average annual thermal impact, while being able to extrapolate these results to other ponds and ponds regions.

2.1 Selection of study area and test ponds: numerical, surface, use and developments interest

Centre and Limousin regions are among the two most important areas of ponds in France, both for density and for stagnucity (Bartout, 2014). Considering logic basin as well as national importance in terms of ponds of Cher, Creuse and Indre departments (Table 1), the headwater catchment of Loire is a study site that is more than suitable.

Table 1. Cher, Creuse et Indre, three departments among the most important in the national scale, as much by the number of ponds that the water area

	Area1* (km²)	Water area (km²)	Nbr of ponds* (>0,1ha)	Density (/km²)	Stagnucity* (%)
Cher	7 289	58,3	5 086	0,7	0,8
Creuse	5 584	36,6	3 498	0,6	0,66
Indre	6 879	121,9	7 504	1,09	1,77
France	560 680	4 506,9	249 788	0,44	0,8

* data (2005) from Bartout, Unpublished ; vocabulary from Bartout & Touchart, 2013

Furthermore, the study area also has the distinctive feature of majority harboring of leisure ponds, that is to say the least studied and most sensitive ponds face with political management of aquatic environments.

We identified and observed twenty diversion ponds in the study area (Figure 1). It doesn't seem much among over 16,000 ponds in the region. Diversion, as a bypass, has existed for a very long time. However, its use as management to regulate impact ponds is recent. This explains why the territorial presence is still low. In addition, the lack of information on facilities ponds limits the achieving of an exhaustive unpublished census of diversion ponds, which would probably be more important than what is brought to our attention today.

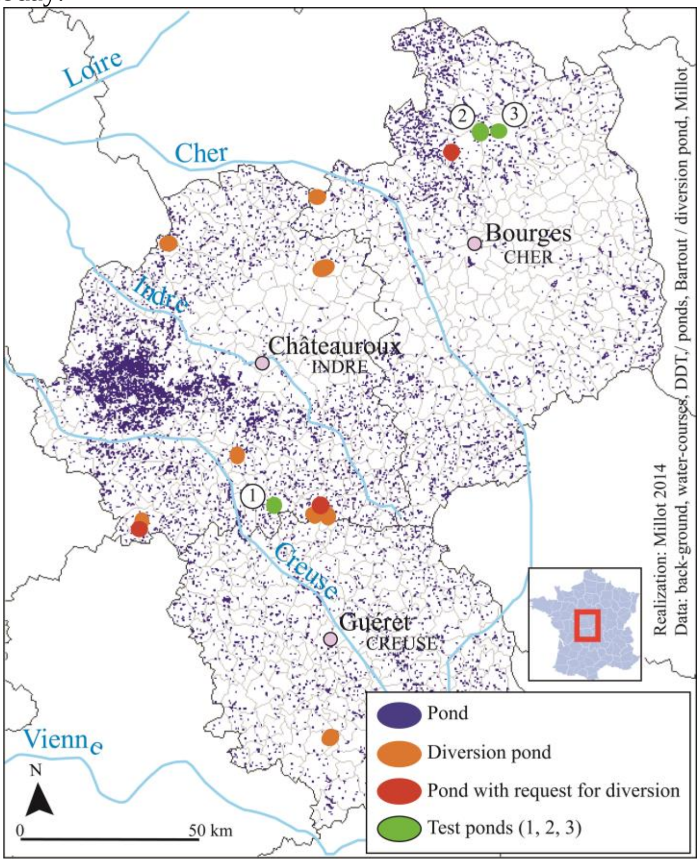

Figure 1. Localization of diversion ponds and test ponds in the study site

After some preliminary studies (observation of the characteristics and general functioning, physicochemical measurements), we focused on detailed study of three ponds (Figure 1). These offer a wide range of observable characteristics on diversion ponds, and most of all, those considered as the three main factors which can have a role in the functioning and impact of diversion ponds (Table 2): the type of distributor and the induced distribution of watercourse, the watercourse's rank and the type of water output.

Table 2. Diversion ponds characteristics, possible factors of influence on their functioning and/or efficiency

	Diversion fitting out					*Upstream or downstream environment*			*Pond fitting out*	
	Creation	Type	Lenght (m)	Distri-butor	Conflu-ence (m)	Rank W-C	Another pond (<20m)	Tributary (before confluence)	Area (ha)	Water output
"Gâte-souris" (1)	2008	With	330	Grate	0	1	P	Abs	2,15	Spillway
"des Barres" (2)	2006	On	374	Grate	530	4	Abs	P	16	Valve bottom
"la Verrerie" (3)	1965	With	444	Plank	150	2	"P"	Abs	0,86	Monk

The pond "Gâte-souris" is a small leisure pond located in headwater catchment, with a spillway and damming a stream of rank 1. Thus it is part of typical ponds that are in the crosshairs of environmental criticisms. In such a way, following a drain incident, a diversion was imposed in 2008. Distributor is a small concrete structure with a grate, oriented at about 100° to watercourse. Due to the orientation of the distributor and plant debris accumulating on the grate, the watercourse mainly flows into the bypass.

The pond "des Barres" is much larger than others in the region with its 16 ha (median of ponds in the department is 0,47 ha) and a depth at the sluice gate of about 4 m. This is interesting because it is often accepted that ponds in large volume are more impacting, thermally speaking, due to a residence time of water which should be longer. Moreover, this is its size which was an argument to derive. Today, the pond is administratively "on diversion". Distributor is a concrete structure provided with a grate, oriented at about 60° to watercourse. As at "Gâte-souris", only a small part of the river flows into the pond. But the flow is more important here, due to the rank.

The pond "la Verrerie" is interesting because it presents one of many facets which are less typical than diversion ponds as they are conceived by water managers. Here, diversion was originally built to provide drinking water to the house nearby. This "diversion" of "Petite Sauldre" (rank 2) flows a second small waterbody and that doesn't follow the current logic in making diversion. The distributor, oriented at about 110° to the watercourse isn't fitted with level control system. Planks on "diversion" side act as level control. Thus, the volume of water is more equitably distributed between pond and "diversion" than in the first two ponds.

2.2 The temperature as a key parameter of physicochemical quality: tools and measures

To understand the role of the diversion in the ponds impact on the downstream environment, we chose to focus on the study of the temperature. Indeed, it is an outstanding indicator because it is the one among all of the physicochemical parameters which propagates the further in the water and whose impact is the most observable in the water quality, due to its influence on the biological and chemical processes of the watercourse and on the solubility of oxygen (Williams, 1968). Thermal study on a long-time scale (annual cycle) has several interests. Firstly, we can highlight a trend of overall average impact of diversion ponds between upstream and downstream. Secondly, it allows the study and comparison of the more complex impact at all time scales: seasons, months of stronger or weaker impacts, daytime, etc. Finally, this study provides a reliable basis for further regional studies.

Thermal study of ponds on the long-term has been permitted by using underwater thermometers (Tynitag Data Loggers). Specifically, we used TG- 4017 PLUS 2 and TG- 4100 models. The internal CTN sensor may register values between -40°C and 85°C (TG-4017 PLUS 2) and between -40°C and 70°C (TG-4100), the whole being protected by a housing IP -68 resisting shocks. The main interest of these thermometers is their own power supply (lithium battery) and their capacity to 32,000 readings. If functioning of watercourses and ponds doesn't warrant a study on a second scale, we can enjoy a very precise study of the hour scale. Even if the piezoelectric sensor doesn't provide an accuracy with good quality such as a resistance thermometer with Pt100 4 wire captor, these devices are ideal for our field. According to a calibration performed between the two devices over eight years (Touchart & Bartout, 2011) and because we use new or 5 years old maximum devices, we can estimate a minimum accuracy of 0.28°C and an average accuracy of 0,19°C.

Thermometers were placed at the surface as much as possible, 50 meters upstream of the distributor, at the water output – when it was technically possible - and 50 meters downstream of the diversion-stream confluence. Thus, from 2012 to 2014, we equipped the three study sites with thirteen different thermometers on seven places of measurements. All in all, more than 51,000 unpublished data are analyzed here.

3 DIVERSION PONDS: A POSITIVE BALANCE ON A LONG TIME SCALE

Because the environment and management of diversion ponds involve different functions, impacts may not be identical. To understand in which case diversion is interesting, three typology criteria and three ponds were selected. The analysis of 51,192 unpublished data shows that in the long term, the diversion can fade pond thermal impact on downstream, but differently depending on ponds.

3.1 Pond type with a spillway: a full effectiveness for a very impacting pond

Analyzed data are the hourly temperatures from midnight April 20, 2012 to midnight April 19, 2013. During this period, the thermometer downstream was probably taken in ice for several days, which disrupted the results. Thus, the data between February 13 and March 16, 2013 have been excluded from all thermometers for instance 2301 data. This results in a slight overestimation of the annual average temperature. However, that does not change trends of the 23,976 remaining temperatures.

According those data, we can say that the pond warms water tributary of 2.93°C on average, but that diversion allows thermal recovery which limits the final warming (50 meters downstream) to 0.35°C on average (Figure 2).

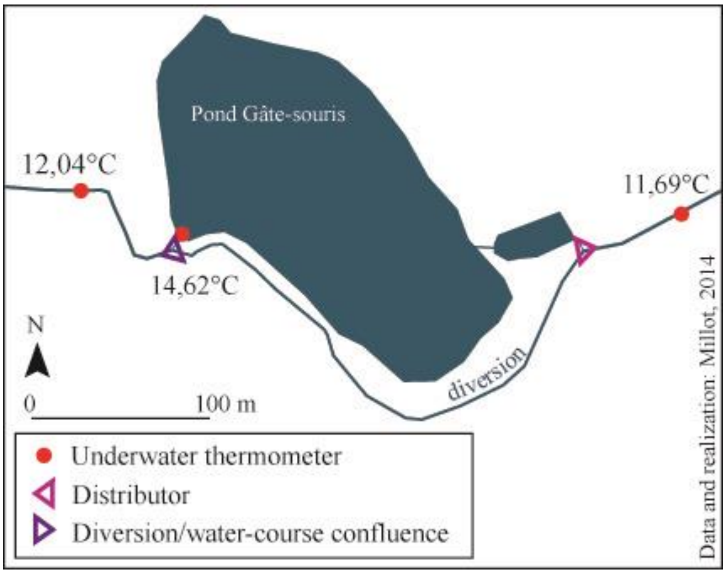

Figure 2. Thermal balance sheet for pond "Gâte-souris" (Montchevrier, 36), from April 20, 2012 to April 19, 2013

To this interesting finding may be added two points. The first is to not forget the accuracy of 0.19°C thermometers. Then what can be seen as a warming of 0.35°C on average over the year actually represents a decrease in water temperature as it could theoretically be without a pond. Indeed, if we consider water temperature's evolution in a linear appearance – +0.2°C every 100 m in headwater catchment (Touchart, 2002) – we can say that this diversion pond has reduced the classic warming water to 0.31°C. This is even more interesting than the spillway has an impact almost 1°C higher than the average of pond with spillway impact, which is +2°C (Touchart, 2002). This is due to the thin layer of water at the outlet, especially sensitive to sunlight.

At first sight, this diversion pond has no impact on downstream's watercourse. Management with diversion seems to allow a rapid thermal recovery of the water flowing of the pond.

3.2 Large pond “on bypass” bit fed

From October 24, 2012 to October 23, 2013, 9696 temperatures allow the assessment of the annual average. Both regular attendance of this communal pond and layout of the bottom valve haven’t allowed placing a thermometer at water output. Downstream, the digger regulating water level and race feeding have induced loss of data. We excluded 7824 data, either for their inconsistency or as a precaution. The average is overstated by approximately 3°C upstream and downstream. But it doesn’t change our analysis conclusions. Thus, during the period, downstream temperature is averaged 0.54°C warmer (Figure 3). For the same reasons as for the pond "Gâte-souris", we can’t really consider this as an increase.

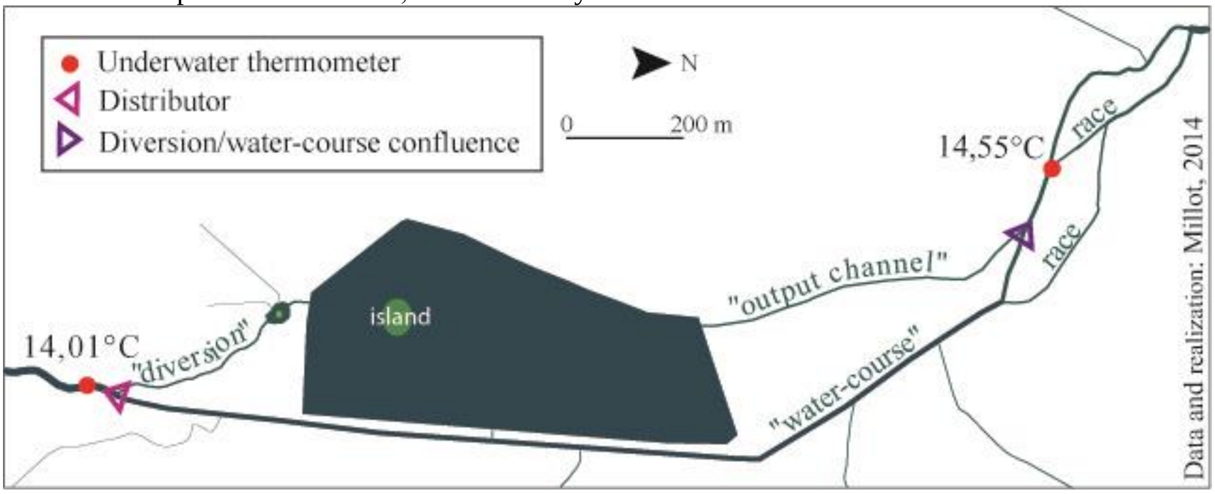

Figure 3. Upstream-downstream thermal balance sheet of pond "des Barres" (La Chapelle d'Angillon, 18), from October 24, 2012 to October 23, 2013

Unlike pond "Gâte-souris", output channel of more than 500 meters surely allows thermal recovery. However, considering the large size of the pond, its limited feeding because of the diversion, and valve bottom, comparable to the monk as used today, which indicates an annual average increase of 1°C downstream, these results are quite staggering. They allow refuting two major arguments in pond criticism. A large pond has not necessarily thermal impact on downstream environment and the diversion is not only a substitute less efficient in reducing thermal hazard than erasing it (ONEMA, 2010).

3.3 Pond with "diversion" with no real distributor and disrupted downstream

For the pond “la Verrerie”, we have all data per hour from April 16, 2013 to January 15, 2014, as 17,520 data for upstream and downstream (as on the pond “des Barres”, the layout of the monk didn’t allow an installation of a thermometer). These indicate an average warming of 1°C between upstream and downstream (Figure 4), that is to say the annual average warming of a pond with a monk.

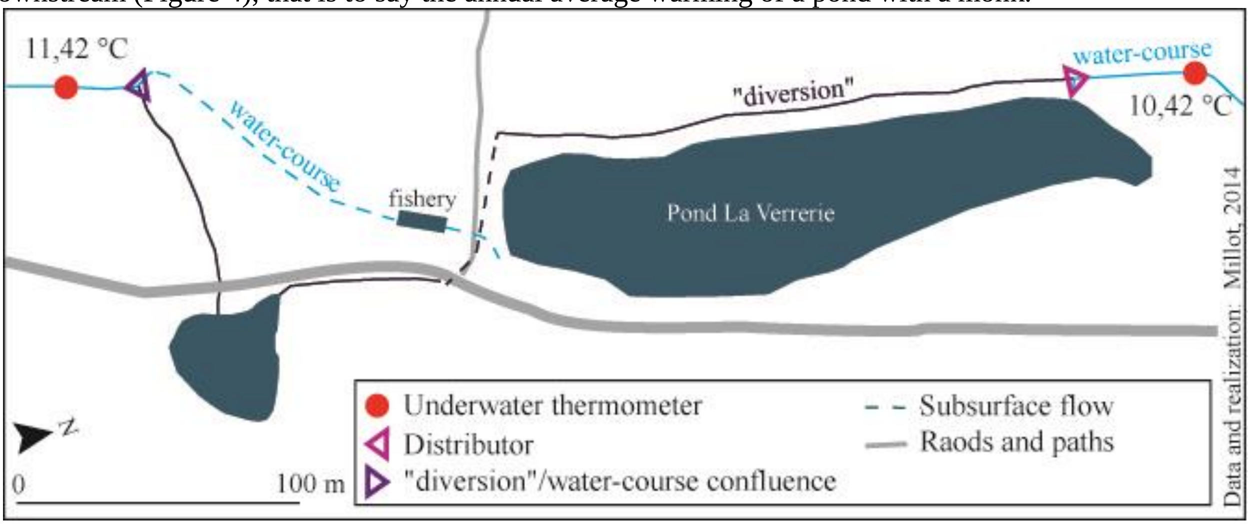

Figure 4. Pond “la Verrerie”, Ivoy-le-pré (18), annual average temperatures, from April 16, 2013 and January 15, 2014

In the light of previous results, it seems that it is the second pond presence, with a spillway, which interferes with the diversion effectiveness. Diversion isn't useful for the pond "la Verrerie" in itself but it is for this grouping in "chain". Indeed, if we consider the annual average warming of a pond with a spillway and the one of a pond with a monk as well, it is clear that the diversion remains useful even to a lesser extent.

At last, water managers convey another idea that a chain of ponds is more harmful than some individual ponds. It is therefore interesting to compare these results with those of pond "Gâte-souris". This allows us to theorize that, considering thermal aspect, two diversion ponds in one chain are less impacting than two separate ponds with no diversion, even when they are fed by a watercourse undisturbed in its linear upstream. Considering work on the thermal impact of ponds (Touchart, 2002) shows that in a chain, thermal downstream increase is mainly due to the first pond, this theory is even more justified.

4 CONCLUSION

Anthropic creation necessarily has impacts on its environment and its development aims to reduce them. Considering the context of aquatic environments protection, the threat of erasing leisure ponds and the development of diversion by water managers, diversion pond as optimal management should be studied. On this scale time, it appears that characteristics of diversion ponds doesn't seem to unduly influence the effectiveness of diversion, whether upstream environment or type and development of pond and diversion. However, they can explain the differences, particularly the juxtaposition of ponds in a "chain" of which one of them isn't derivated. But in all cases, diversions have erased the thermal impact of the pond or reduced it to something akin to a pond with a monk. Diversion may well be of interest to a pond whose configuration doesn't allow the development of a monk, as the pond "Gâte-souris".

With this study, diversion seems to be an optimal arrangement to reduce thermal hazard ponds, and through this, reduce the broader environmental hazard and allow pond conservation. However, we have to be careful. On daily and seasonal scales, more consistent with aquatic life, the influence and usefulness of diversion ponds can be more complex. Finally, for a more complete study, it will also be interesting to examine the impact of diversion on other important impacts, such as dissolved oxygen, sediment transport or residence time in pond.

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