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Importance of gravel pits for the conservation of waterbirds in the Garonne river floodplain (southwest France)

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Abstract. The loss of natural wetlands throughout the World has made created habitats such as gravel pits, reservoirs or rice fields potentially important for waterbird conservation. In southwest France, the increasing abundance of gravel pits has allowed several bird species to colonize the region. The avian community was studied from 1996 to 1998 in six gravel pits in the Garonne floodplain. A total of 39 species of waterbirds were recorded, with higher abundance during the winter and post-breeding periods. We analyzed habitat use to identify key environmental factors determining the temporal and spatial distribution of the avian community. The presence of submerged macrophytes was found to be the most important factor influencing the distribution of waterbirds. The presence of paths in the vicinity of the areas reduced both the total number of birds and species richness owing to human disturbance. Gravel pits have an increasingly important role in the conservation of bird biodiversity. By controlling disturbance and management of vegetation, managers can enhance this role.

Introduction

Human activities result in the destruction of natural wetlands, but also the creation of 'artificial' habitats such as rice fields, gravel pits or reservoirs. Over time, these 'new' wetlands become important alternative habitats for wildlife (Senra and Ales 1992; Pandey 1993; Blanco and Marchamalo 1999; Parejo and Sanchez-Guzman 1999). During the last century, the extraction of gravel in European river floodplains created 'new' wetlands (gravel pits). In England, the value of these aquatic ecosystems for waterbirds has been well documented (Keywood and Melluish 1953; Glue 1970; Hughes et al. 1979; Tydeman 1982; Andrews 1990; Phillips 1992; Fox et al. 1994). In Slovakia, 33% of birds censused in midwinter were present in gravel pits (Kalivodova and Feriancova-Masarova 1998). In France, gravel pits cover an area of about 90 000 ha, with an estimated 5000 ha added each year (Barnaud and Le Bloch 1998). However, little is known about interactions between environmental factors and waterbirds in gravel pits. For example, disturbance from human activities is common at gravel pits, and studies in other wetlands suggest that this can locally affect the temporal and spatial distribution of waterbirds (e.g., Burger and Gochfeld 1991; Cayford 1993; Klein 1993; Fox and Bell 1994; Madsen 1994).

In this paper, we assess waterbird abundance and diversity in gravel pits from southwest France, study the influence of different habitat features on these variables, and propose management measures to improve the quality of gravel pits for waterbird conservation.

Study site

In the Midi-Pyrénées region of France, most gravel pits are situated near Toulouse in the central part of the Garonne floodplain. The oceanic influence predominates in the whole basin, but less so in the southeast where there is a Mediterranean influence causing dry winds and lower rainfall. The annual average air temperature is 12.7 °C with 672.6 mm of precipitation. For this study we selected six gravel pits, as follows (Figure 1):

– Four unmanaged gravel pits (nos. 1–4) at Saint Caprais about 25 km north of Toulouse (Figure 1) created from 1982 to 1997. The total surface area is 71 ha with a mean depth of 3 m.
– Two gravel pits (nos. 5–6) at Lavernose-Lacasse southwest of Toulouse. One is managed by an anglers association and the second unmanaged (created in 1983 and 1993, respectively). The total surface area is 39 ha with a mean depth of 3 m.

Six species of submerged macrophytes were present in the gravel pits: *Myriophyllum spicatum, Najas major, Nitella* sp., *Potamogeton natans, Ranunculus trichophyllus* and *Veronica anagallis*. However, only the charophyte *Nitella* sp. is abundant and present especially in gravel pits 1 and 4. Fish were present in all the pits (Santoul 2000).

Methods

Censuses were carried out weekly from October 1996 to October 1998 using binoculars (8×30) and a telescope (20×60). The small surface area and open character of the gravel pits permitted a full census of the population (Tamisier 1972). The number and distribution of all waterbirds in each gravel pit were recorded and their position was noted on a map, identifying 13 zones in the six pits (Figure 1 and Table 1), according to the variation in the major environmental variables analyzed (for method see Borowiec 1975; Santoul and Tourenq 2002).

For each zone where waterbirds were counted, several environmental parameters were recorded: surface area, water depth (<1 m, 1–3 m, 3–4 m), submerged macrophytes (presence, absence), and presence of paths close to the banks.

We identified four seasonal periods following Joachim et al. (1997): the wintering period from October to February; pre-breeding from March to April; breeding from May to July and post-breeding from August to September. The

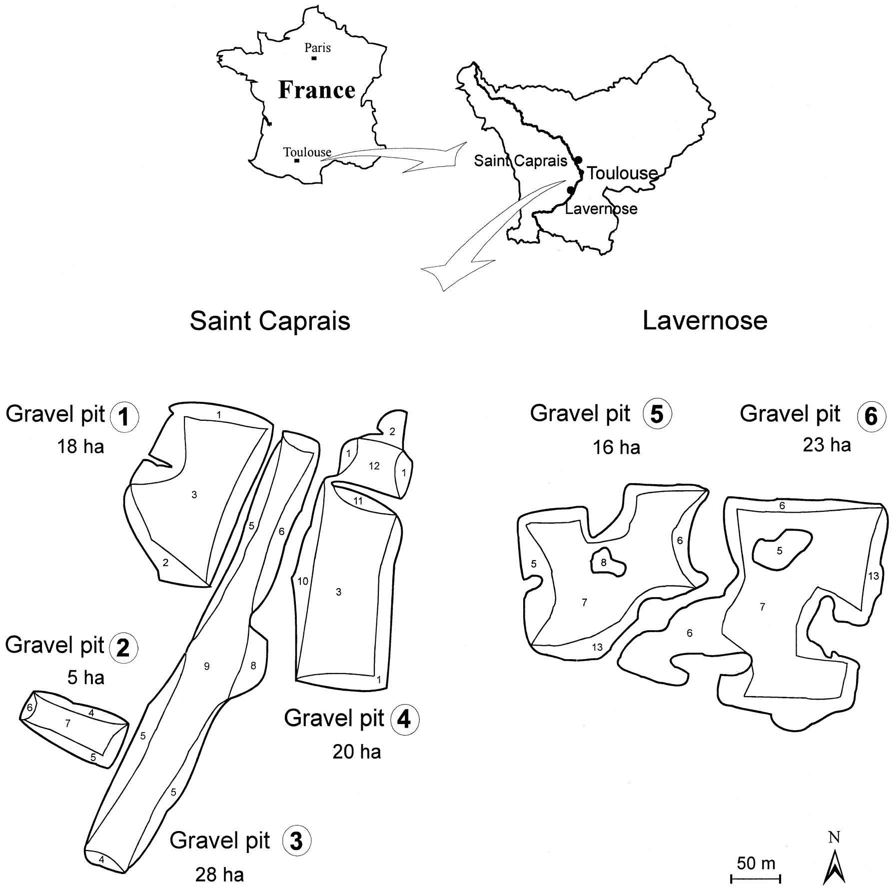

Figure 1. Location of the gravel pits studied. The small numbers indicate separate zones.

Table 1. Characteristics of the different zones.

Zone	Path	Macrophytes	Water depth
1	0	1	2
2	0	1	1
3	Open water	1	3
4	0	0	1
5	0	0	2
6	1	0	2
7	Open water	0	2
8	0	0	3
9	Open water	0	3
10	1	1	3
11	0	1	3
12	Open water	1	2
13	1	0	3

Table 2. List of waterbird species censused on gravel pits, their maximum and mean counts for different periods and their European threat status.

Family	Species	Scientific name	European threat status	Phenological categories*		
				Wintering	Migrants	Breeding
Podicipedidae	Great creasted grebe	*Podiceps cristatus*		10 (<10)	19 (<10)	15 (<10)
	Little grebe	*Tachybaptus ruficollis*		25 (<10)	68 (23)	53 (<10)
	Slavonian grebe	*Podiceps auritus*		3 (<10)	3 (<10)	
Phalacrocoracidae	Great cormorant	*Phalacrocorax carbo*		333 (94)	58 (<10)	1 (<10)
Ardeidae	Grey heron	*Ardea cinerea*		43 (12)	23 (<10)	10 (<10)
	Night heron	*Nycticorax nycticorax*	Declining		5 (<10)	
	Purple heron	*Ardea purpurea*	Vulnerable		5 (<10)	2 (<10)
	Cattle egret	*Bubulcus ibis*		319 (56)	70 (<10)	
	Little egret	*Egretta garzetta*		4 (<10)	16 (<10)	6 (<10)
Threskiomithidae	Spoonbill	*Platalea leucorodia*	Endangered			1 (<10)
Anatidae	Mallard	*Anas platyhynchos*		322 (103)	430 (90)	111 (31)
	Teal	*A. crecca*		123 (13)	20 (<10)	
	Wigeon	*A. penelope*		6 (<10)	6 (<10)	
	Gadwall	*A. strepera*	vulnerable	10 (<10)	10 (<10)	
	Shoveler	*A. clypeata*		60 (17)	40 (<10)	
	Pintail	*A. acuta*	Vulnerable	9 (<10)	2 (<10)	
	Garganey	*A. querquedula*			10 (<10)	
	Pochard	*Aythya ferina*		364 (147)	72 (<10)	2 (<10)
	Tufted duck	*A. fuligula*		77 (29)	55 (<10)	
	Scaup	*A. marila*	Localized		1 (<10)	
	Red-crested pochard	*Netta rufina*	Declining	2 (<10)	1 (<10)	1 (<10)
	Shelduck	*Tadorna tadoma*		8 (<10)		
	Smew	*Mergus albellus*	Vulnerable	3 (<10)		

Table 2. (continued)

Family	Species	Scientific name	European threat status	Phenological categories*		
				Wintering	Migrants	Breeding
Rallidae	Coot	*Fulica atra*		594 (327)	665 (203)	204 (60)
	Moorhen	*Gallinula chloropus*		2 (<10)		
Gruidae	Crane	*Grus grus*	Vulnerable	1 (<10)		
Recurvirostridae	Black-winged stilt	*Himantopus himantopus*			1 (<10)	
Glareolidae	Collared pratincole	*Glareola pratincola*	Endangered			1 (<10)
Charadriidae	Little ringed plover	*Charadrius dubius*	Declining		8 (<10)	4 (<10)
	Lapwing	*Vanellus vanellus*			4 (<10)	4 (<10)
Scolopacidae	Redshank	*Tringa totanus*	Declining		10 (<10)	
	Greenshank	*T. nebularia*			3 (<10)	3 (<10)
	Common sandpiper	*Actitis hypoleucos*			3 (<10)	
	Snipe	*Gallinago gallinago*			4 (<10)	
	Bar-tailed godwit	*Limosa lapponica*	Localized		1 (<10)	
	Dunlin	*Calidris alpina*	Vulnerable		1 (<10)	
	Sandpiper unidentified			1 (<10)		
Laridés	Yellow-legged gull	*Larus cachinnans*		35 (<10)	21 (<10)	31 (<10)
	Black-headed gull	*L. ridibundus*		190 (31)	272 (33)	17 (<10)
Sternidés	Common tern	*Sterna hirundo*			2 (<10)	12 (<10)

*Maximum number (mean counts).

Table 3. Significance of partial effects in the model analyzing total number of bird individuals, controlling for gravel pit and zone as random factors. Significance of factors was estimated by comparison with the distribution of the *F* statistic, where df indicate the degrees of freedom of the test.

Factor	*F*	df	*p*
Surface	0.61	1327	0.43
Depth	0.49	2327	0.61
Period	53.24	3327	< 0.0001
Macrophytes	1.87	1327	0.17
Path	6.14	1327	0.01
Depth × macrophytes	4.94	2327	0.008
Period × macrophytes	3.08	3327	0.03
Not in the model			
Depth × period	1.23	6321	0.29
Depth × path	0.62	1327	0.43
Period × path	1.09	3324	0.35
Macrophytes × path	0.07	1326	0.79

numbers of waterbirds and species recorded in each of the 13 zones were averaged for all the censuses in a given period and year. To control for the effects of spatial pseudoreplication, two random factors controlling for the effects of gravel pits and zone within the gravel pits were included in the analyses. Data were analyzed with the GLIMMIX macro for SAS 8.2 (SAS Institute 2000), fitting a mixed effects General Linear Model with Poisson errors due to the nature of the count data (Crawley 1993). Main effects and two-way interactions were fitted using type III sum of squares. A backward removal procedure was used to obtain a final model containing only significant factors plus those non-significant factors included in two-way interactions that significantly improved the fit of the model. The surface area of each zone was controlled for in all analyses.

Results

A total of 39 bird species were recorded, representing 13 families and 27 genera. Anatidae (13 sp.), Scolopacidae (8 sp.) and Ardeidae (5 sp.) were the most abundant families (Table 2). Fourteen species that are of conservation concern in Europe (Tucker and Heath 1994) were recorded. During the study period, four bird species nested on the gravel pits: *Anas platyrhynchos, Fulica atra, Podiceps cristatus* and *Sterna hirundo*.

Birds were more abundant during the winter, with a mean of 830 individuals per count, than in the other periods ($F_{3,327} = 53.24$, $p < 0.0001$, Table 3, Figure 2). Abundance was also high during the post-breeding period with a mean of 530 birds. Anatidae and Rallidae species (especially coot, mallard and pochard) were most

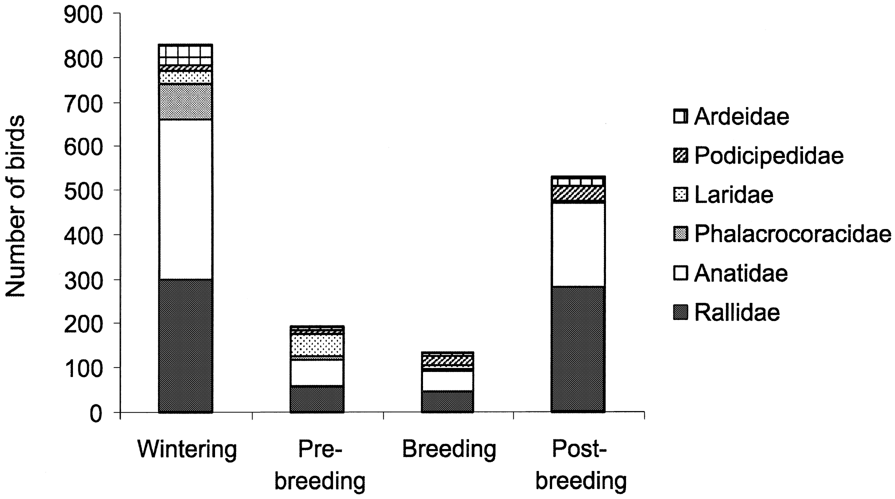

Figure 2. Bird numbers for each waterbird family (average count for each period).

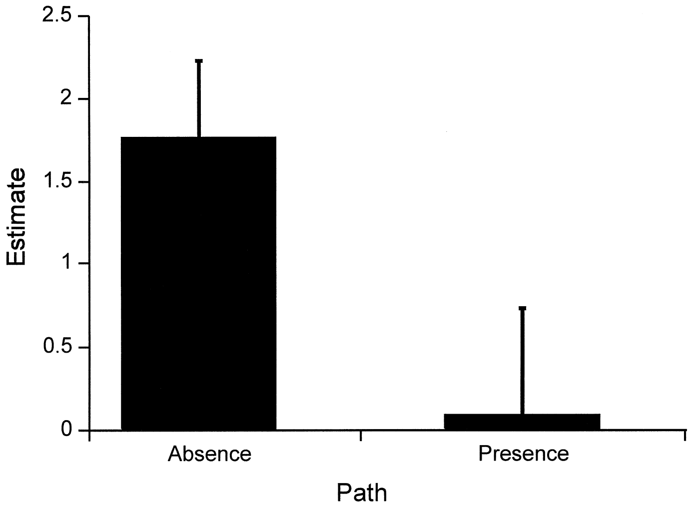

Figure 3. Influence of the presence of paths on total bird numbers, based on the partial effect of paths in the model of Table 3.

abundant during these periods. Difference in waterbird abundance was not statistically significant between the breeding and pre-breeding period (mean counts of 133 and 195 waterbirds). Waterbirds were more abundant where no paths were present close to the bank ($F_{1,327} = 6.14$, $p = 0.01$, Figure 3). During the post-breeding period, waterbirds were more abundant in areas with macrophytes, but no significant differences occurred during the other seasons (Figure 4). Furthermore, a

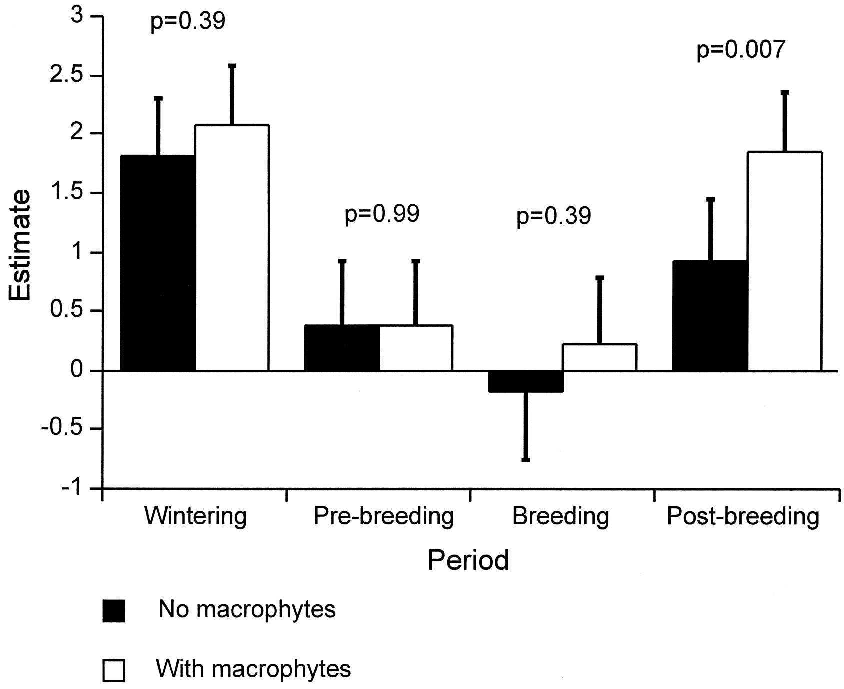

Figure 4. Influence of submerged macrophytes on the abundance of birds in different periods, based on the model of Table 3.

significant partial effect of the presence of macrophytes was found in zones 3–4 m deep ($p < 0.0001$), but not at other depths (Figure 5).

Species richness was highest during the post- and pre-breeding period with a maximum of 19 species recorded in April 1997 (see Table 4). Species richness was larger in areas without nearby paths ($F_{1,333} = 10.47$, $p = 0.01$, see Table 4).

Discussion

Our study shows that, in southwest France, gravel pits are particularly important for waterbirds during the post-breeding and wintering periods when provision of additional, suitable habitat is likely to reduce population mortality and increase the size of the overall waterbird populations (Jorde et al. 1983; Batt et al. 1992; Zorn et al. 1995; Dehorter and Tamisier 1996; Hafner 1997; Sutherland 1998). The comparison of our results with data available for the Midi-Pyrénées area shows that our gravel pits are one of the principal wintering sites for waterbirds in this region (Bugnicourt 1988; Joachim et al. 1997). The geographical location of the gravel pits near the Pyrenees mountains also makes the Midi-Pyrénées region important as a stop-over for migrant birds (Hoyer 1994). Although the number of birds recorded

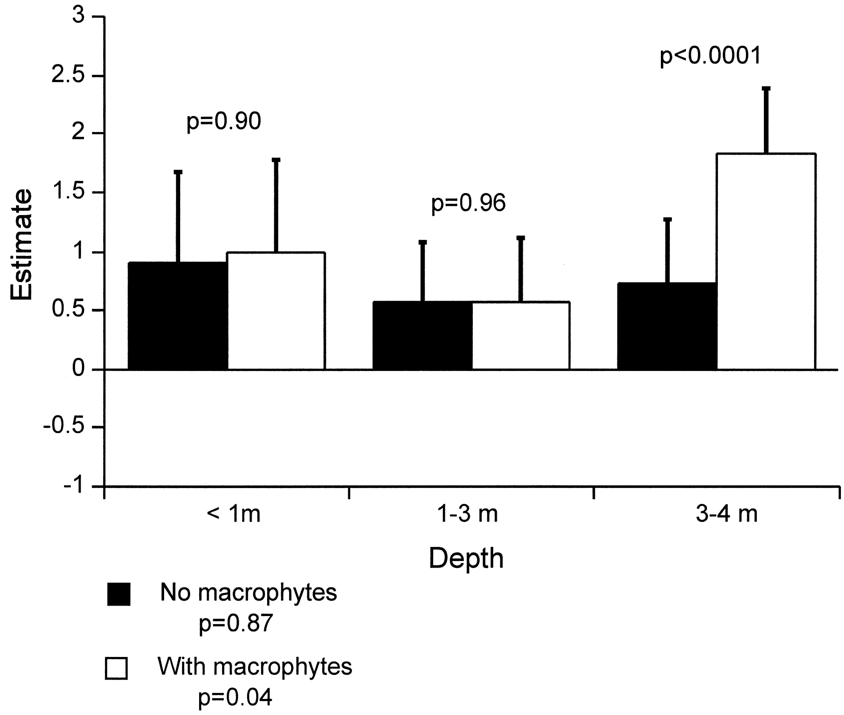

Figure 5. Influence of submerged macrophytes on the abundance of birds in zones of different depths, based on the model of Table 3. Probabilities correspond to the statistical significance of differences in means of areas with and without macrophytes while controlling for depth.

Table 4. Significance of partial effects in the model analyzing species richness, controlling for gravel pit and zone as random factors and forcing surface of zones into the model. Significance of factors was estimated by comparison with the distribution of the *F* statistic, where df indicate the degrees of freedom of the test.

Factor	*F*	df	*p*
Surface	7.02	1333	0.009
Period	11.92	3333	<0.0001
Path	10.47	1333	0.001
Not in the model			
Depth	0.82	2333	0.44
Macrophytes	0.31	1332	0.58
Depth × period	1.38	8327	0.20
Depth × macrophytes	0.58	5330	0.72
Depth × path	1.25	3333	0.29
Period × macrophytes	0.30	4329	0.88
Period × path	1.83	3330	0.14
Macrophytes × path	0.16	2331	0.85

on our study site averaged less than 1000 in any season, we studied less than 0.2% of the total surface area of gravel pits in France.

In our gravel pits, we found that paths in the vicinity reduced both the numbers and diversity of waterbirds owing to human disturbance, mainly from walkers, often accompanied by dogs. Similarly in a gravel pit complex in southern Britain, wintering Pochard concentrated on reserves where human access to bank-sides was restricted (Fox et al. 1994). Work in other wetlands shows that disturbance is one of the most important factors explaining the distribution of waterbirds (Prigioni and Galeotti 1989; Bousquet 1994; Santoul and Tourenq 2002). Disturbance reduces feeding opportunities of waterbirds and is equivalent to habitat loss, although its effects are reversible. Human disturbance loads ought to be incorporated in gravel pit management decisions at local and regional scales. Wildlife managers are encouraged to carefully evaluate whether visitor presence could disrupt bird behavior, density and species richness, and then seek short and long term solutions (e.g., setting buffer zones for visitors, restricting access to areas with high diversity value and at times of peak use by birds).

Our results show a strong influence of the availability of submerged macrophytes on the presence of birds during the post-breeding period, but this effect was not significant during the other periods. Charophytes and the many invertebrates that live on them (Marklund et al. 2001) provide food for ducks, coots, grebes and other waterbirds (Knapton and Petrie 1999; Blindow et al. 2000). In English and German gravel pits, Pochards and Coots prefer areas rich in charophytes and other macrophytes where they dive for food, and numbers of diving birds increase as nutrient inputs lead to an increase in macrophyte biomass over the years following excavation (Fox et al. 1994; Küsters 2000). We found that the influence of submerged macrophytes on waterbird numbers was only significant at depths of 3–4 m, probably because this was the depth at which greatest biomass of vegetation was attained, thus attracting diving ducks, coots and grebes. We suggest that the seasonal effect was found because we only censused birds during daylight, and waterbirds are generally diurnal during the post-breeding period and thus concentrated in feeding areas. In winter when days are shorter, diving ducks and some other waterbirds are nocturnal, concentrating in suitable areas for roosting (those free from disturbance) during the day and in suitable feeding areas at night (McNeil et al. 1992; Guillemain et al. 2002).

The lack of an effect of submerged macrophytes on waterbird abundance in the pre-breeding and breeding periods may be influenced by the relative abundance of fish-eating birds in these periods, since cormorants and other fish-eating species may find more food in areas free of submerged vegetation. In order to increase the value of gravel pits for waterbirds, fish should not be introduced. Santoul (2000) showed that in some gravel pits indirect competition between fish and waterbirds can occur (Street 1982). Cyprinids like carp (*Cyprinus carpio*) increase water turbidity (Crivelli 1983), and can reduce plant and invertebrate populations (Mallory and Blancher 1994). On our gravel pits, the origin of fish stocks is unknown; however, releases by humans and transport during river floods are likely to be the main sources of these stocks (Santoul 2000). Management of fish stocks to enhance macrophyte development in gravel pits can favor the development of the waterbird community.

Even small artificial wetlands such as our gravel pits can have a major benefit for waterbird populations by enabling connectivity between larger wetlands well separated in space (Bournaud et al. 1980). Such connectivity also ensures the maintenance of bird-mediated dispersal of plants and invertebrates between wetlands (Amezaga et al. 2002). Gravel pits are very interesting for the protection and reproduction of many species, but the lack of management usually limits their ecological development. Restoration is generally carried out to transform gravel pits into recreational areas or fishing lakes, and only rarely into habitats favorable to waterbirds. Owing to the continuing loss of natural wetlands, there is a need to enhance the contribution of artificial wetlands such as gravel pits to future conservation of waterbird species and communities. The results of this study suggest that reducing human access and increasing the development of macrophytes are suitable management practices to increase waterfowl abundance and diversity in gravel pits (see also Andrews 1990).

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