

Long-term changes in agricultural practices and wildfowling in an internationally important wetland, and their effects on the guild of wintering ducks

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Summary

1. The Marais Poitevin, one of the principal wintering and passage sites for ducks and waders in the East Atlantic flyway, underwent agricultural intensification in the 1980s. The numbers of ducks declined in the period 1979–96 in the main roost, Baie de l'Aiguillon; this was a site-specific phenomenon for which local factors were responsible. We describe here long-term changes in some key characteristics of the wetlands, paying particular attention to the principal factors affecting the quality of waterbird habitat: the area of semi-natural grasslands, water management and wildfowling.

2. The area of grasslands declined by 50% between 1970 and 1995, principally as a result of conversion to arable farmland. The pattern was observed over the whole area and was slightly more marked close to the day-roost of the ducks. The rate of change was greatest in the 1980s. Water levels, and therefore the flooded area, were reduced over the study period during the months of May to November. The numbers of wildfowling declined from the 1970s, but the number of artificial wildfowling ponds increased, especially after 1980. The number of birds killed did not decline and may have increased. The quality of the ducks' habitat therefore declined by all three measures.

3. Four species, mallard, shoveler, teal and gadwall, showed an increase in other sites in north and west France either over the whole period or over the last part (1984–96), while declining (shoveler and mallard) or remaining stable in the Baie de l'Aiguillon. Pintail remained stable in the other sites, while showing a long-term decline (over 30 years) in the Baie. Wigeon did not use the Baie in large numbers in the 1996 cold spell as they did until the 1980s.

4. The uncoupling of the trends for these species in the Baie from their trends in the other sites may reflect the loss of grassland feeding habitat in the Marais Poitevin. However, for mallard, pintail and shoveler the declines in the Baie were much stronger than the 50% loss of grasslands so other factors, such as the reduction in autumn flooding and/or shooting, are likely to have played a part.

5. Since the three measures of long-term trends in duck habitat co-varied it was not possible to separate their effects statistically. The hypotheses arising from this study need to be tested: this should be done using comparative and experimental approaches. Suggestions are made for the management of water levels and shooting in the feeding habitat close to the Baie de l'Aiguillon.

Key-words: *Anas*, drainage, grassland, hunting, intensification, wetlands.

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Introduction

The ecological functioning of many wetlands has been altered since the 1950s, particularly in the western hemisphere (Dugan 1990). Their landscapes have been transformed by land reallocation, changing agricultural practices and construction of buildings for industry and tourism; their hydrological functioning has been altered by drainage; and leisure uses, including wildfowling and boating, have increased, leading to more disturbance for wildlife. Such changes have had profound effects, particularly in Europe, where a half to two-thirds of wetlands have been lost (CEC 1995; see also Finlayson, Hollis & Davis 1992 for data on Mediterranean countries). In the Camargue, the most important wetland site in France for wildlife conservation, 40% of the semi-natural habitats have been turned over to agricultural or industrial uses (Tamisier & Grillas 1994), while in Greece, Handrinos (1992) estimated that 300 000 ha (61%) of wetlands have been lost since 1920. One of the principal causes of these changes has been identified as intensive agricultural practices (CEC 1995), which have been promoted by post-war European and national policies of agricultural intensification (CIEPP 1994).

Wetlands are essential stopover and wintering habitats for waterbird populations, and the loss of suitable wetland habitat is likely to have severe consequences for them (Bautista, Alonso & Alonso 1992). In North America many migratory shorebirds have declined in number (Howe, Geissler & Harrington 1989; Morrison, Downes & Collins 1994) and these negative trends are probably due to some extent to losses of wetland habitat, which may affect different species to varying extents depending on migration patterns and habitat preferences (Bildstein *et al.* 1991). In the UK, reclamation of intertidal feeding grounds is a potential threat to shelduck *Tadorna tadorna* and shorebird populations.

Ducks migrating in the East Atlantic flyway are restricted geographically into a 'bottleneck' through the Netherlands, Britain and France, where these birds track wetlands, principally along the coasts. The Marais Poitevin (96 000 ha) is the largest wetland on the Atlantic coast of France, and the second in the country after the Camargue. With its coastal part, the Baie de l'Aiguillon, this wetland is one of the principal wintering and passage sites for waterbirds (Spitz 1964; Brosselin 1972; Saint-Gérard 1985) in one of the most important flyways in the western Palaearctic region. The Marais provides important habitat for many protected species listed by the Bonn and Berne Conventions, and by the European Council Directives on the conservation of wild birds (79/409/EEC) and of natural habitats and wild fauna and flora (92/43/EEC). Part of the Marais Poitevin has been designated under the 'Wild Birds Directive' as a Special Protected Area. At the national level the Marais contains 64 Zones Nationales d'Intérêt Ecologique

Faune et Flore (the equivalent of Sites of Special Scientific Interest), covering 12 000 ha, listed in the 1991 national survey.

As the largest wetland on the French Atlantic coast, the Marais Poitevin underwent agricultural intensification in the 1980s (Schéma d'Aménagement des Marais de l'Ouest; CIEPP 1994). This agricultural development included an explicit attempt to integrate conservation and development in this wetland, with the creation of a Parc Naturel Régional in 1979 whose charter included a clear brief to conserve wildlife and semi-natural habitats, particularly the grasslands, within the context of agricultural development. Since 1980, agricultural intensification through drainage and land reallocation, with levelling of smaller canals and hedges, financed to a large extent by public funds (national and European), has resulted in a transition from beef to arable production (principally wheat, sunflowers and maize) over much of the area. We have documented a decline in the dabbling duck community wintering at the Baie de l'Aiguillon; over the last 15 years, trends in duck numbers at this site were disconnected from trends at the regional level, and were unrelated to patterns of cold weather movements (V. Bretagnolle, unpublished data).

We analyse here long-term changes in some key characteristics of this wetland during the period 1967–96 (the area of semi-natural grasslands, water levels and wildfowling activity), and evaluate the consequences of these changes for the guild of dabbling ducks, mallard *Anas platyrhynchos* L., teal *Anas crecca* L., pintail *Anas acuta* L., shoveler *Anas clypeata* L., wigeon *Anas penelope* L. and gadwall *Anas strepera* L.

Methods

THE CHOICE OF MEASURES OF HABITAT QUALITY CHANGE FOR WINTERING DUCKS

The decline in the area of wetland habitats, natural and semi-natural, due to human activities has had important consequences for many bird species (Bildstein *et al.* 1991). In an analysis of the factors influencing declines of 10 duck species in Canada, Bethke & Nudds (1995) first controlled for trends due to climatic conditions and found that the residual variation in numbers was correlated with the loss of wetland habitat to agriculture. Similar results were obtained from a study of mallard (Johnson & Shaffer 1987). Many areas of North America hold fewer ducks than is predicted simply by precipitation-driven changes in wetland abundance, and these studies show that conversion of prime duck habitat to intensive agriculture is an important factor explaining recent declines in several species. In western France semi-natural grasslands are known to be of great importance as a feeding habitat for wintering dabbling ducks

(Schricke 1983), so it is likely that conversion to farmland would have negative effects here too.

Although the effects of water management on ducks in the western marshes of France have not been studied, information from other wetlands cited above indicates that the winter distribution of mallard and teal is strongly related to seasonal changes in water conditions (Gilburn & Kirby 1992; Reinecke, Brown & Nassar 1992; see also Kadlec & Smith 1989; Smith, Pedersen & Kaminski 1989). The shoveler may be particularly sensitive to changes in water management, such as drainage or land reclamation, because of its dependence on shallow waters for feeding (Kirby & Mitchell 1993). The area of semi-natural wet grasslands and water levels are therefore likely to be good measures of the quality of duck habitat.

Wildfowling is known to have had a powerful effect on the numbers and distribution of waterbirds in northern Europe through its effects on habitat use as well as on survival (Ebbinge 1991; Madsen 1995). The number of kills is obviously important, and under certain conditions disturbance of feeding birds associated with hunting activity has as strong an effect on their use of a site (Frederick, Clark & Klaas 1987; Madsen 1995; Fox & Madsen 1997). Hunting therefore has a powerful effect on the quality of duck habitat.

Habitat loss or degradation and hunting are believed to be the two most important threats affecting the abundance of duck populations of the western Palaearctic, including France (Dehorter & Tamisier 1996), and these factors have been proposed as an explanation for the decline in the duck population of the Baie de l'Aiguillon (Trollet 1996). Indeed, a combination of excessive hunting and loss of wetland habitat, converted to agriculture or drained for urban development, brought about the recent extinction of the Mariana mallard *Anas platyrhynchos oustaleti* in the 1960s (Reichel & Lemke 1994). There is therefore evidence from other areas that duck populations are affected by reductions in the area of wetland habitat, by the amount of flooding and by increased shooting pressure. We use indices of long-term trends in these measures of habitat to seek possible causes of the declines in the duck populations wintering in the Marais Poitevin.

THE STUDY AREA

The study covered the period 1966–95 in the Baie de l'Aiguillon and the surrounding Marais Poitevin on the west coast of France (46°33'N, 1°48'W). This area includes parts of three départements: Charente-Maritime and Deux-Sèvres in the south and east, and the Vendée in the north (Fig. 1). There are 4500 ha of intertidal mudflats and saltmarshes, and 65 000 ha of wet grasslands and arable farmlands up to 20 km from the Baie; we did not cover the wetlands further inland because the feeding range of ducks around their day

roosts is generally <20 km (Tamisier 1985; Lovvorn & Baldwin 1996). The Marais Poitevin, which was a bay during the Flandrian transgression, has become a freshwater wetland since Roman times by natural sedimentation combined with dyking (Ducloux & Nijs 1972; see Verger 1968 for a description of the geomorphology of the Baie). In 1973 the northern part of the Baie was made a reserve (2100 ha where shooting is prohibited) by the Fédération départementale des chasseurs de la Vendée. The habitat is intertidal mudflats with approximately 500 ha of emergent vegetation dominated by halophytes and grasses, and this is where most of the ducks roost in the daytime. The reserve can serve as a feeding area for some thousands of ducks, principally the grazing species (authors' unpublished data).

GRASSLAND FEEDING HABITAT

Grasslands in the Marais Poitevin included some 6000 ha of communal grazing in the 1960s, and the size of these areas (up to 300 ha) and their tranquillity made them particularly important for waterbirds. The vegetation is semi-natural and has been described by Bouzillé, Foucault & Lahondere (1984). We used four different sources of information to describe changes in grassland availability: photointerpretation, satellite imagery, land-use surveys and a field survey. The area of grasslands was determined for 1973 by the Institut Géographique National (Anonymous 1974) by interpretation of panchromatic photographs, and it was mapped at 1 : 100 000. For 1990 a map at 1 : 50 000 was prepared by interpretation of satellite imagery (SPOT; Anonymous 1990). The two maps were digitized at 1 : 100 000 using the GIS Idrisi (Eastman 1992). Spatial analyses were carried out on a raster layer with a resolution of 50 × 50-m pixels in four concentric bands 5 km wide centred on the Baie de l'Aiguillon. The detection of grasslands on aerial photographs and satellite images is not perfect, but differences between the two methods are not great so the results should be comparable. For 1970, 1979 and 1988 we used data on land use from the Recensement Général Agricole conducted by the Ministry of Agriculture: the use (grassland, arable, other) of each field was determined by questionnaire surveys. This agricultural census is used as a basis for tax evaluation and is believed to be very accurate. The results are summed by 'commune', with each farm allocated to the 'commune' (approximately the size of a parish in England, UK) where its buildings are located, which certainly introduced some error. For 1986 the same method was used by the Association Interdépartementale pour la promotion agricole et rurale du Marais Poitevin; and for 1995 the 1990 interpretation of the SPOT image was updated by field observations by staff of the Parc (Fichet, Rosoux & Tournebize 1996). We calculated the area of grassland as a proportion of all land-use types.

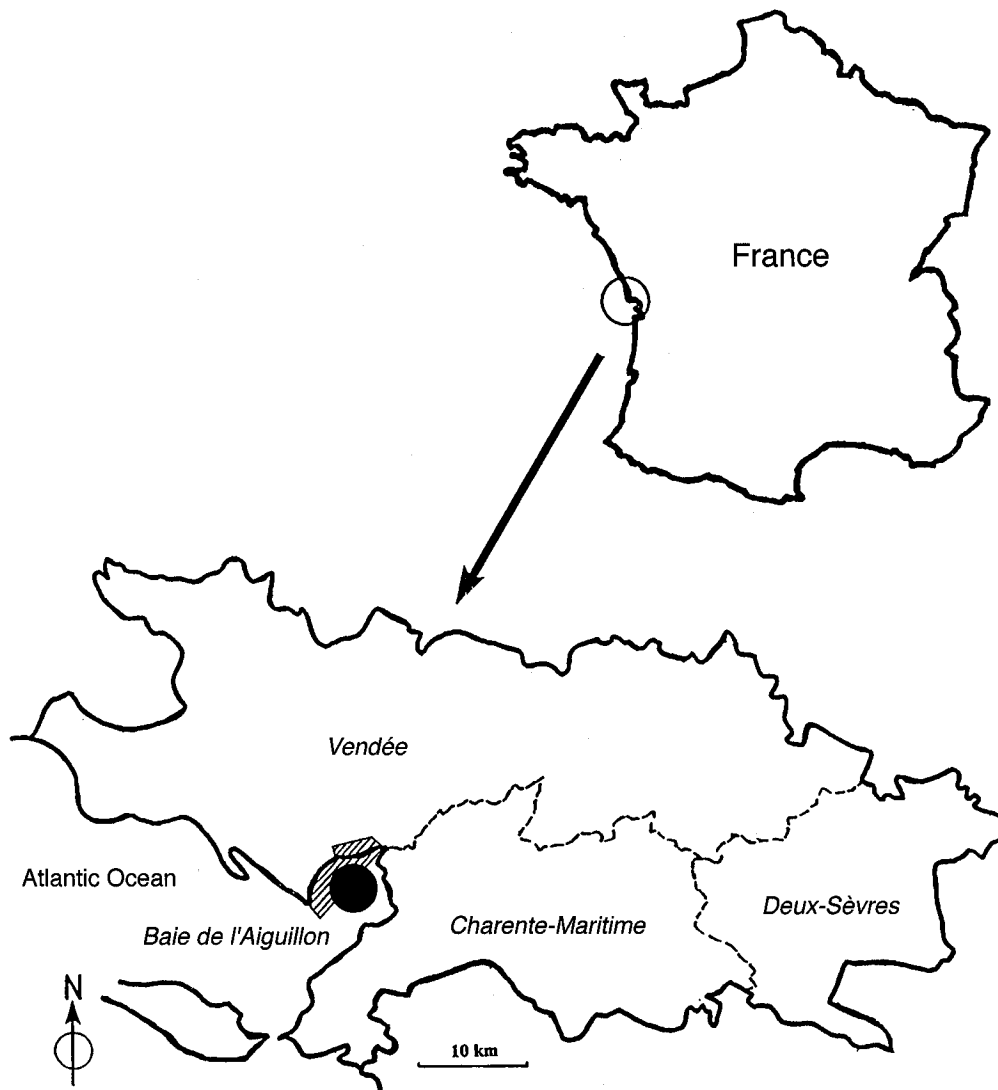


Fig. 1. The Marais Poitevin in central western France. The main day roost of the ducks is shown by the black dot; the hatched area is a reserve where shooting has been prohibited since 1973.

WATER LEVELS

The climate is oceanic with seasonal rainfall, which peaks in winter (the mean monthly value is 85–90 mm between October and January, and 42 mm in July). The 30-year mean annual precipitation at Sainte-Gemme-la-Plaine on the northern edge of the Marais is 810 mm (data from Météo-France) and average annual evapotranspiration is 760 mm. Mean daily temperatures (from 1 October to 15 January) increased by 1.28°C over the study period, and rainfall tended to increase although this was not statistically significant.

The hydrological cycle in the Marais is determined by rainfall and runoff from the surrounding calcareous plateau. There are seven rivers, the main one being the Sèvre Niortaise; the catchment area of the whole Marais is large, 5300 km². The Marais is intersected by canals and their water levels are managed with two objectives: to reduce the risk of flooding in

winter; and to provide fresh water in the summer for livestock and irrigation. Over the study period there have been two major changes in water management: there has been a great increase in the area of irrigated maize; and improvements have been made to the infrastructures, in particular the sluice gates have been widened. It could be expected that these changes have led to lower water levels in summer–autumn, when the requirements for irrigation are the greatest, and to less flooding in winter.

There are no data on the areas flooded, so we studied variations in the up- and downstream water levels of one of the principal reaches, Bazoin, which receives water from three rivers including the Sèvre Niortaise, for the period 1966–95 (data from the Direction Départementale de l'Équipement). The correlation between reaches of the up- and downstream levels was high ($r = 0.98$, $n = 10,592$), and the upstream water levels were more variable than the downstream, so we present the upstream data only.

Flooding events were recorded by the keeper of the Bazoin sluice gate when the level was > 2 m (c. 8% of the measures), which occurred almost every year. We tested for long-term trends in the frequency and duration. In view of the apparently arbitrary nature of the 2-m criterion, we took the maximum upstream water level observed in the winter of the driest year, 1.89 m, as the flooding threshold and calculated for each year the cumulated sum of average daily water levels above this threshold (i.e. the units of this index of flooding are 'day-cm'), working on the basis of 'hydrological years' (October to September); flooding events represented 18% of the daily records over the 30 years. The same analysis was conducted for thresholds of 2 m and 2.23 m (5% of records); since the trends were similar we present the results for the 1.89 m threshold only.

WILDFOWLING

Three methods are used to shoot ducks in this area: (i) when walking on foot in the marshes, usually with a dog; (ii) during evening and morning flights from butts of two types, light ones made of reeds, heather, etc., for flying or swimming birds, and concrete underground butts called 'tonnes' for shooting swimming birds; and (iii) at night from tonnes, which is illegal but tolerated in half of the French coastal Départements including Charente-Maritime, but not the Vendée or Deux-Sèvres. Since the beginning of this century artificial ponds of 1–4 ha have been built to attract ducks to tonnes; living and/or model decoys are commonly used.

Accurate data on wildfowling are not available for the Marais Poitevin, but we obtained indices of trends in hunting pressure. Artificial ponds are easily counted on the ground and on aerial photographs, and they have been censused periodically by the Office National de la Chasse and by nature protection organizations. Counts of the ponds were made in the study area in 1979, 1981, 1984, 1990 and 1995 (reviewed in Fichet, Rosoux & Tournebize 1996); we assumed that the number of gun-nights per pond had not changed over the period and used the number of ponds as an index of gun-nights in butts in the Marais Poitevin.

It was more difficult to evaluate trends in shooting on foot and during the evening and morning flights. However, a special permit is necessary for wildfowling in the months of July and August (timbre gibier d'eau), which is bought by keen wildfowlers. We used the numbers of permits bought in the Vendée, Charente-Maritime and Deux-Sèvres as an index of trends for the years where data are available. The number of shooting licences (all species of game) and the members of the local wildfowling association, the Groupement des Chasseurs de Migrateurs de la Vendée, 1980–95, provided other indices of long-term trends in the numbers of hunters.

Estimates of duck bags were available for the whole

of the Département de la Vendée for the seasons 1983–84, 1992–93, 1993–94, 1994–95 and 1995–96, using the same questionnaire method for each year. Returns were obtained from about a third of the hunters to whom the questionnaire was sent. Confidence limits for the bag were available for the 1990s, calculated as described in Landry, Lavergne & Havet (1986); estimations of the variance were obtained from the frequency distribution of the number of birds killed per hunter.

TRENDS IN THE DUCK POPULATIONS

Dabbling ducks wintering in north and west France have been monitored for the mid-January International Waterfowl Counts at 768 sites since 1967. In the Baie de l'Aiguillon counts have been made every year except 1990, organized by staff of the Office National de la Chasse. Since 1978 the procedure has involved simultaneous counting by experienced observers from at least seven observation points. Underhill & Prys-Jones (1994) have proposed new methods for the analysis of trends in waterfowl populations. Using this technique trends in duck abundance have been analysed for a set of 67 sites and the Baie de l'Aiguillon; values for missing data were calculated using a simple multiplicative model:

$$X_{ij} = S_i Y_j$$

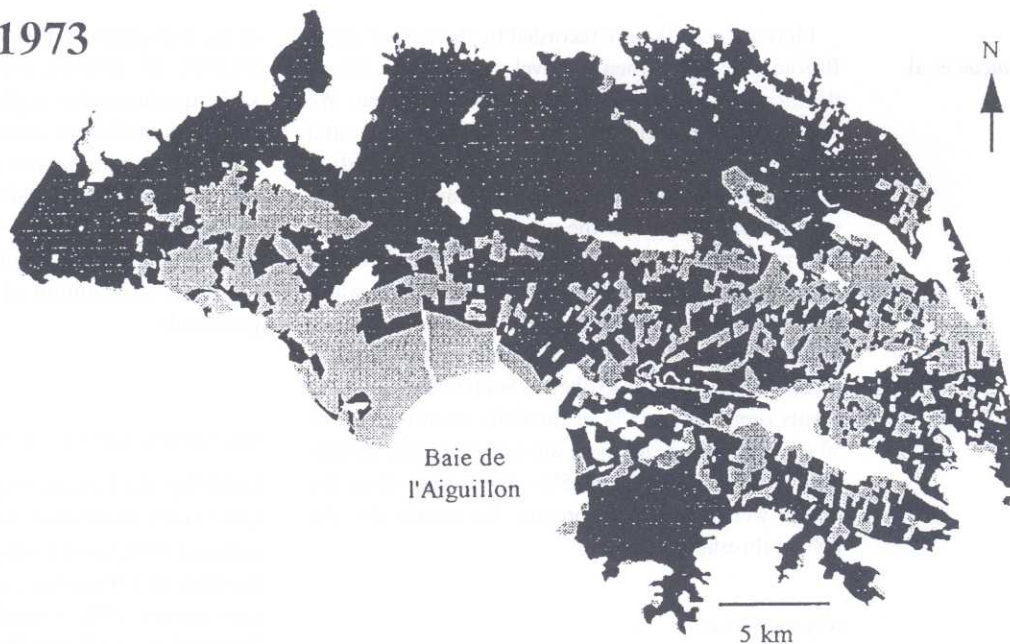
where X_{ij} represents a count of birds of one species at site i in year j , S_i is a site factor and Y_j a year factor. A base year was selected where this factor was set to 1. The year factor is the annual population index number for that site and is simply the ratio between the total count for a given year and the total count in the base year. Missing counts were input from the above model using an iterative algorithm, inserting the mean value of all counts as the seed and running a certain number of iterations until convergence was achieved.

Results

CONVERSION OF GRASSLAND FEEDING HABITAT

In 1973 grasslands covered 68% of the area, but by 1990 they had declined by half to 34% of the study area (Fig. 2). The rate of decline was fastest in the 1980s (Fig. 3); it appears to have slowed between 1990 and 1995, and it was stronger close to the Baie (Table 1) where the latest polders are. The soils here are better and conversion to croplands is more profitable than in the rest of the wetland where there are hedges to remove as well as drains to install. In the communal grazing areas the pattern was similar to the general trend, with a decline of 64%, to 2100 ha in 1995.

1973



1990

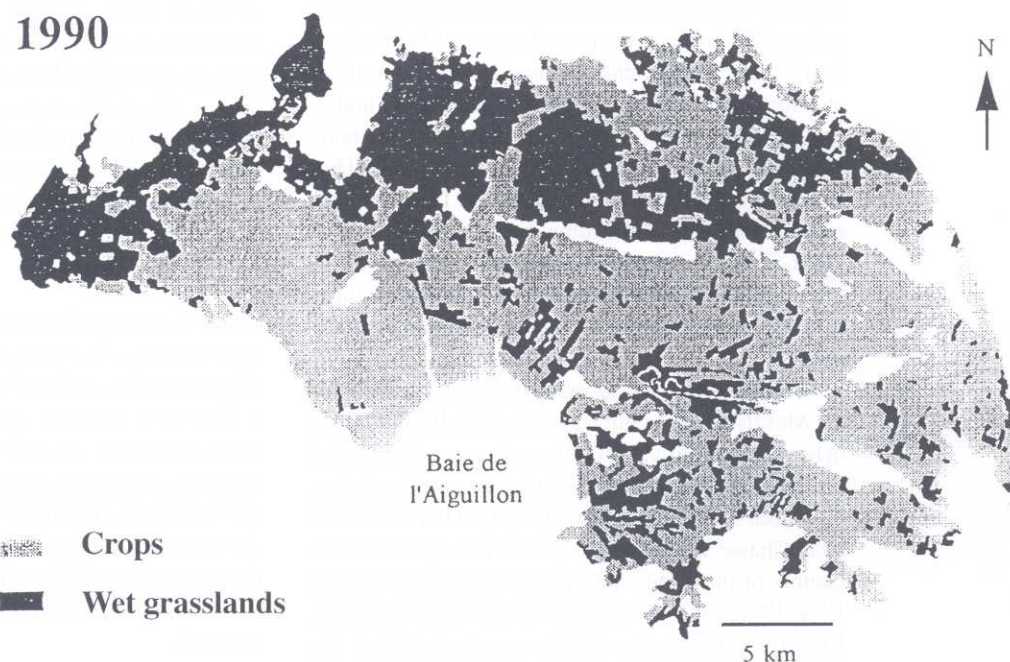


Fig. 2. Grasslands (black) and crops (grey) in the Marais Poitevin in 1973 and 1990.

WATER LEVELS

The average monthly mean upstream water level over the 30 years varied between 1.67 and 2.07 m and there was a clear seasonal pattern, with the highest water levels in January/February and the lowest in September (Fig. 4a). In spite of management, the water regime of the Marais Poitevin therefore retained a natural pattern throughout the period, with low levels in summer and extensive flooding in wet winters, as in 1994 when the level went as high as 3.5 m. About

half of the study area was then under water. Rainfall over the large catchment area was the main force driving the hydrology during the 30 years. Although the annual flooding index tended to decline over the period, it was not significant (Fig. 4b). This trend was observed in all months except January but was significant in the months May–November only. The slopes of the regressions of mean monthly water levels on year were strongest at the end of the summer (August–October; Table 2), the season when the requirements for irrigated maize are greatest.

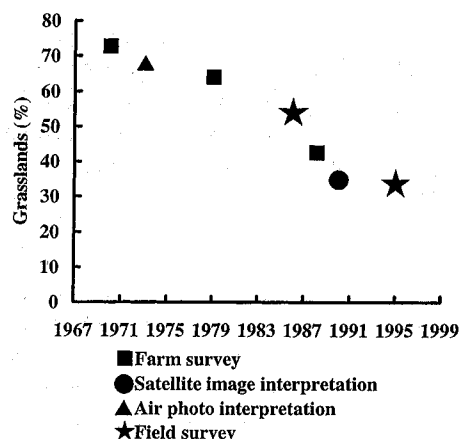


Fig. 3. Variations in the area of grasslands in the Marais Poitevin, as a percentage of the 65,000-ha study area, across the study period.

Table 1. Variations in the percentage of grasslands (P%) converted into arable crops in the study area between 1973 and 90, as a function of distance from the Baie de l'Aiguillon (D)

D	P%
0–5 km	58.23
5–10 km	58.77
10–15 km	45.86
15–20 km	45.05
Whole area	50.50

WILDFOWLING

The number of wildfowling permits was stable in the Deux-Sèvres; in the Charente-Maritime the number declined by 19%, from 4300 in 1985 to 3500 in 1995; in the Vendée the number declined by 16% from 1980 to 1989 (Fig. 5a). The membership of the local wildfowling association (Groupement des Chasseurs de Migrateurs de la Vendée) and the total number of shooting licences (for all game species) in the Vendée declined as well (Fig. 5b). The numbers of wildfowling in this area therefore appear to have declined since about 1980, as have the numbers of hunters (for all species) in the Vendée, and in France as a whole (data provided by the Office National de la Chasse).

The first artificial pond for wildfowling in the Marais Poitevin was constructed in 1953, and the number increased in a near exponential manner, reaching a total of 219 in 1995 (Fig. 5c). Wildfowling at these ponds has therefore increased over the study period, particularly since 1985, at a time when the numbers of wildfowling declined. There were therefore opposing trends in these two measures of wildfowling activity.

The total waterfowl bag in the Vendée varied between 67 000 and 117 000 in the period 1992–96, and was much higher in all years than the estimate for

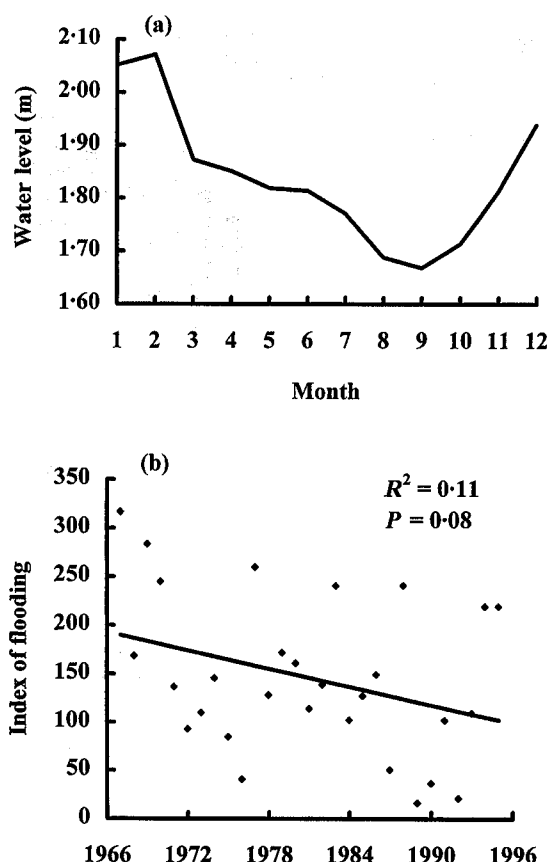


Fig. 4. Water levels in the Marais Poitevin. (a) Monthly mean upstream water levels in the Bazoin reach of the Sèvre Niortaise. (b) Variations in the flooding index (see the Methods) across the study period.

Table 2. Trends over the 30 years in the mean monthly water levels. *** $P < 0.001$; ** $P < 0.01$

Month	r^2	Slope	P
1	0.01	0.0023	
2	0.00	−0.0022	
3	0.07	−0.0028	
4	0.04	−0.0024	
5	0.45	−0.0037	***
6	0.39	−0.0035	***
7	0.20	−0.0052	0.013
8	0.23	−0.0111	**
9	0.25	−0.0125	**
10	0.27	−0.0106	**
11	0.20	−0.0062	0.013
12	0.03	−0.0052	

1983–84 of 46 000 ducks (Table 3). Confidence limits for the estimate for 1983–84 were not available so it was not possible to test the significance of the differences formally. However, for mallard, the confidence limits in the 1990s were all close to 11% of the estimate. The kill therefore did not decline with the number of hunters, and may have doubled between 1983–84 and the 1990s. For the other species the pattern

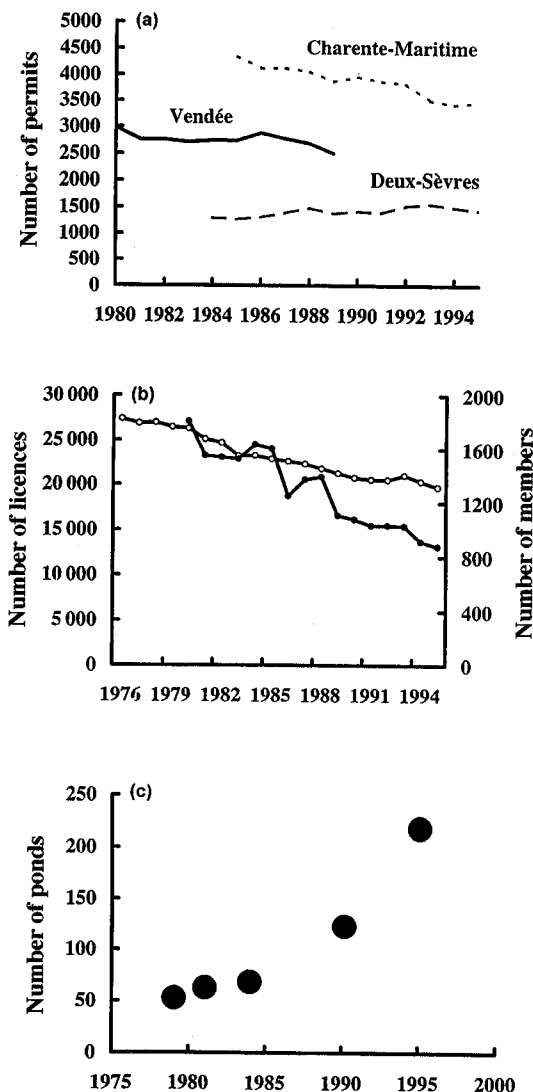


Fig. 5. Hunting in the Marais Poitevin. (a) The numbers of wildfowling permits in the Charente-Maritime, Deux-Sèvres and the Vendée 1980–95. (b) The numbers of hunting licences sold in the Vendée (open circles) and the number of members of the local wildfowling association (Groupement des Chasseurs de Migrateurs de la Vendée; closed circles). (c) The numbers of artificial wildfowling ponds in the Marais Poitevin 1975–95.

was similar, except for the teal bag which was very variable. It should be noted that no comparable data are available for the Charente-Maritime and the Deux-Sèvres, but there is no reason to think that duck bags declined there.

TRENDS IN THE DABBING DUCK COMMUNITY

The data on duck numbers in the Baie and the totals for the other 67 sites are given in Fig. 6, and summary statistics of trends in the numbers of six duck species in the Baie and in a set of sites in north and west France are presented in Table 4. Pintail declined in the Baie over the 30 years while remaining stable (or perhaps increasing) in the other 67 sites.

The other species showed a complex pattern, with a period of high numbers between 1979 and 1983, which makes the detection of long-term trends difficult. The increase in the 1970s was a regional phenomenon as the same pattern was observed in the set of other sites (cf. Figure 6; mallard and teal). The creation of the reserve in 1973 therefore seems not to have had a marked effect on use of the Baie by ducks.

Over the whole period, teal, shoveler and gadwall increased in the other sites while declining or remaining stable in the Baie (Fig. 6). The pattern of change in mallard numbers was more complex, with an increase between 1967 and 1978 and a decline of 50% between 1984 and 1996 (Fig. 6 and Table 4). Wigeon numbers were highly variable and showed no significant trends in the Baie or the other sites. However, in the cold winter of 1996 they did not use the Baie in large numbers, in spite of cold weather movements into north and west France that would normally encourage them into the area (authors' unpublished data). For five of the six species (and possibly wigeon too) trends in the Baie reflected trends in the other sites in the region until the early 1980s, but thereafter numbers using the Baie contrasted with patterns in the other sites, declining or failing to increase. It should be noted that the trends in these 67 sites are likely to

Table 3. Duck bags in the Département de la Vendée in five shooting seasons with 95% confidence intervals; *n* = number of questionnaires analysed

	1983–84	1992–93	1993–94	1994–95	1995–96	1992–96 mean
Mallard	29 000	72 000 ± 9500	46 000 ± 5200	60 000 ± 5900	66 000 ± 7100	61 000
Teal	11 000	25 000 ± 4000	12 000 ± 1800	14 000 ± 1900	21 000 ± 2900	18 000
Wigeon		5100 ± 1400	3400 ± 860	7900 ± 1200	8900 ± 1500	6325
Pintail		3500 ± 1100	600 ± 340	3600 ± 800	4700 ± 1000	3100
Shoveler		8500 ± 1900	3700 ± 890	9000 ± 1400	14 400 ± 2100	8900
Wigeon, pintail, shoveler + other	6000	19 400	9000	21 800	30 300	20 000
Total	46 000	116 400	67 000	95 800	117 300	99 100
<i>n</i>	246	287	459	538	437	

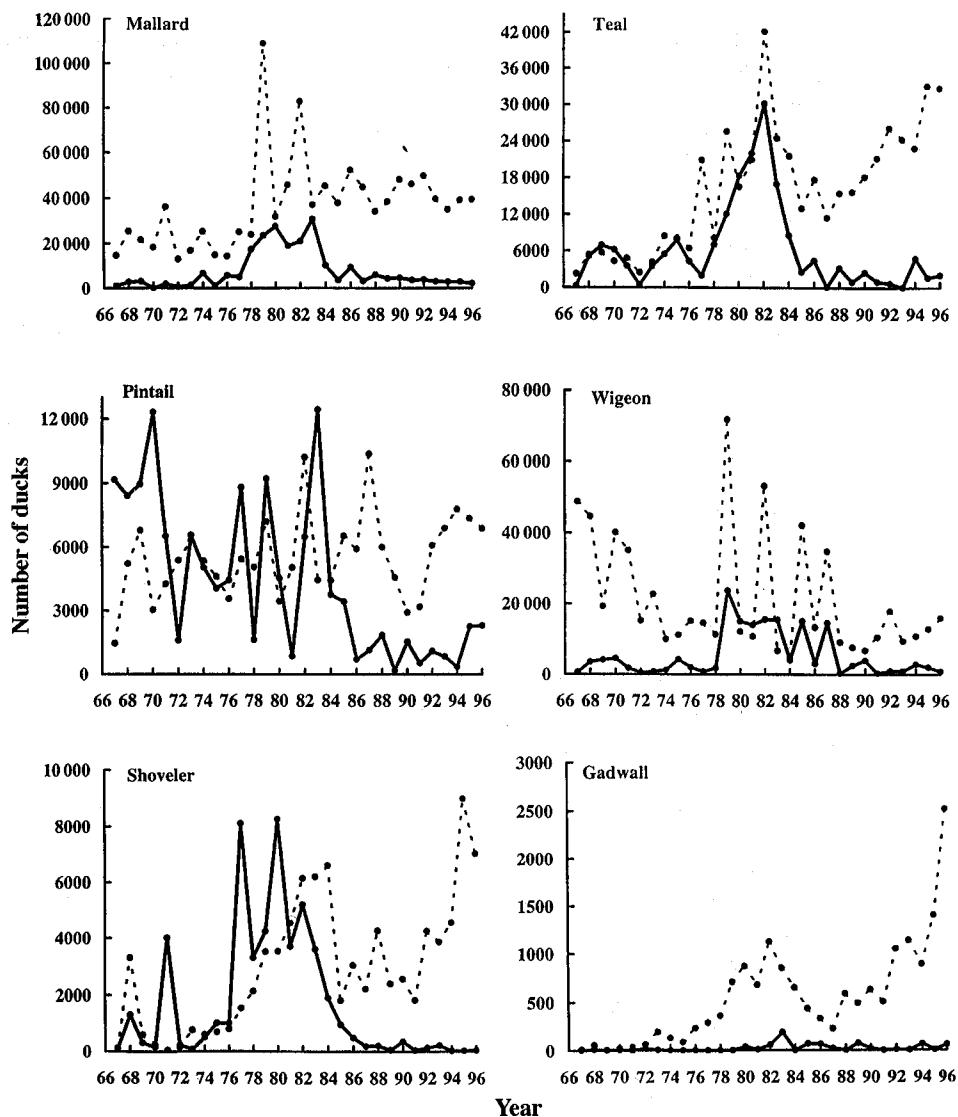


Fig. 6. The numbers of six species of ducks observed on the winter counts in the Baie de l'Aiguillon (solid lines), and the total counted in the set of 67 other sites in north and west France (dotted lines) across the study period.

Table 4. Trends in duck numbers in 67 sites in north and west France and in the Baie de l'Aiguillon (rs—Spearman correlation coefficients). Values in bold type are statistically significant after the sequential Bonferroni correction

		1967–96 (n = 30)		1984–96 (n = 13)	
		rs	P-value	rs	P-value
<i>A. crecca</i> (teal)	North and west France	+0.78	0.0001	+0.82	0.0006
	Baie de l'Aiguillon	−0.31	0.09	−0.35	0.25
<i>A. clypeata</i> (shoveler)	North and west France	+0.70	0.0001	+0.75	0.003
	Baie de l'Aiguillon	−0.47	0.02	−0.82	0.0005
<i>A. strepera</i> (gadwall)	North and west France	+0.83	0.0001	+0.78	0.002
	Baie de l'Aiguillon	+0.37	0.04	−0.12	0.69
<i>A. platyrhynchos</i> (mallard)	North and west France	+0.67	0.0001	−0.44	0.133
	Baie de l'Aiguillon	+0.23	0.22	−0.80	0.001
<i>A. acuta</i> (pintail)	North and west France	+0.34	0.07	+0.42	0.156
	Baie de l'Aiguillon	−0.70	0.0001	−0.22	0.47
<i>A. penelope</i> (wigeon)	North and west France	−0.36	0.04	+0.15	0.616
	Baie de l'Aiguillon	−0.06	0.76	−0.61	0.03

reflect regional trends since 1979, when near complete coverage of the main wintering sites of dabbling ducks was achieved by the IWRB network (R. Mahéo, personal communication). They do not necessarily reflect regional trends before that time.

Discussion

THE INDICES OF LONG-TERM CHANGES IN DUCK HABITAT

Tracking changes in the area of grasslands over nearly 30 years necessitated the use of different methods. This will have introduced some error into the estimations but it is not likely that the error is substantial, and the results are consistent across methods (Fig. 3). The area of the principal feeding habitat for the ducks therefore declined by about a half. Losses of semi-natural grasslands have occurred in most European wetlands, although not often with such speed, for instance in the fenlands of East Anglia drainage has led to a loss of 71% of wetlands over 200 years (Thomas, Allen & Grose 1981).

In the Marais Poitevin these changes occurred principally in the 1980s. Subsidies for drainage were stopped in 1992 (CIEPP 1994) and conservation measures to encourage farmers to maintain this habitat were initiated and managed by the Parc, including designation as an Environmentally Sensitive Area (ESA) under the Structural Funds of the European Union (Article 19, now 20/21), with subsidies of up to 1000 FF ha⁻¹ of grasslands. Part of the Marais has also been designated a Special Protected Area under the 'Wild Birds Directive'. The results presented here suggest that these conservation measures may have slowed down the rate of grassland conversion.

Some wind erosion of the soil is likely to have occurred, lowering the surface of the land. No data are available, but the fall in water levels observed in late summer and autumn was so great (> 30 cm over the 30 years) that there has undoubtedly been a decline in the area flooded in autumn. There was therefore a long-term tendency for less surface water in the Marais Poitevin in summer and autumn, but rainfall maintained high water levels, and therefore flooding, in winter. Our measure of this trend, the water level, underestimates the extent of the decline in the flooded area and therefore the consequences for the birds.

Less flooding in the summer is likely to reduce the production of wetland plants, and less flooding in autumn would reduce the feeding habitat for all species, except perhaps wigeon at the time when most of the wintering birds arrive (October–November, H. Fritz, personal observations). Winter flooding, although it tended to decline over the 30 years, is still determined principally by rainfall and has not been halted by the improvements to the infrastructures that have been made since the 1960s.

The data on changes in wildfowling in the region

suggest that the numbers of wildfowling around the Baie has declined, along with a decline in shooting in France as a whole. However, the number of artificial ponds for wildfowling in the Marais Poitevin increased strongly up to 1995. The data on waterbirds killed in the Vendée show that the decline in the numbers of wildfowling has not been accompanied by a reduction in the bag, which may even have doubled. This is likely to be a consequence of the increase in artificial ponds where birds can be shot more easily.

This study shows that profound changes occurred in the landscape, hydrology and wildfowling of this wetland during the study period. As far as duck feeding habitat is concerned the principal changes have been the loss of grasslands and a decline in water levels (May–November), leading to less flooding in summer and autumn; both are consequences of agricultural intensification. In 1987 only approximately 2000 ha of the remaining grasslands were flooded (Tesson 1996).

Wildfowling practices have also changed: there are fewer wildfowling, fewer ducks and less semi-natural habitat for the sport. Among those who still shoot, many construct artificial wetlands to replace the natural wetlands. This increase in tonnes has occurred throughout the region and is not limited to the Marais Poitevin; it leads to intensification of wildfowling, especially in Charente-Maritime where night-shooting is tolerated. In conclusion, the quality of the feeding habitat of the ducks has declined over the study period by all three measures: the area of grasslands decreased, there was less water and an increase in shooting from tonnes.

TRENDS IN THE DUCK POPULATIONS

Pintail declined in the Baie while remaining stable in the set of other sites; mallard, teal, shoveler and gadwall declined or showed no significant changes in the Baie, while increasing strongly in the set of other sites; and wigeon no longer use the Baie in large numbers. For all the dabbling duck species, except perhaps for the highly variable wigeon, trends in the Baie have therefore become uncoupled from trends in other regional sites.

Pintail showed a long-term decline from tens of thousands in the late 1960s to thousands in the 1990s. This is much greater than the decline in grasslands in the Marais Poitevin. During winter this species concentrates on large patches of flooded grasslands (Blanchon 1989) and we suggest that the reduction in grasslands, combined with the reduction in autumn flooding, has caused its decline.

The continuous decline in shoveler numbers over the last 15 years was stronger than in any other species and led to the near disappearance of the species from the Baie. The loss of half of the grasslands, which occurred mainly in the 1980s, is inadequate to account for this. Feeding habitat loss must therefore have combined with one or more other factors: wildfowling is

likely to have had an effect as shoveler are attracted to artificial ponds, whose seasonal drawdown encourages zooplankton. Large numbers of shoveler are killed in the Vendée (Table 3), the 'département' to the north of the Baie (Fig. 1).

Mallard numbers have declined sharply (50%) and continuously over the period 1984–96. This decline was much stronger than trends in grassland area and water levels. Wildfowling may have had an effect on this species too, since the off-take was high, particularly recently (see above; Table 3). Several studies have shown that wildfowling can account for a high proportion of mortality in ducks (Halse *et al.* 1993). The striking differences between those regions of France where night hunting occurs and those where it does not, in terms of the total hunting bag and the number of ducks overwintering in a particular region, suggest that this form of shooting can have particularly strong effects. In those areas where night shooting is tolerated, wildfowl numbers are 7–10 times lower than elsewhere and the total number of ducks shot is almost double (Tamisier & Saint-Gérard 1981). Night hunting is tolerated in Charente-Maritime, and the number of ponds where this is practised has increased greatly in recent years. This change could therefore be partly responsible for the decline in shoveler and mallard numbers in the Baie de l'Aiguillon, with more disturbance and kills causing ducks to avoid this area and contributing to the population crashes observed.

Teal declined by a factor of two between the periods 1967–78 and 1984–96, but have remained stable more recently (Table 4). This pattern is consistent with the pattern of loss of grasslands, and the abundance of this species at wintering sites in the UK is known to be closely linked to the area of habitat available (Gilburn & Kirby 1992).

Wigeon showed a highly variable pattern of use of the Baie, and responded to cold weather in northern Europe by arriving in large numbers during the cold spells of the 1970s and early 1980s. However, in spite of cold weather in 1996 few wigeon came to the Baie. For this species, too, it is not necessary to invoke factors other than habitat loss to explain the decline in the use of the Baie.

The numbers of gadwall were small and variable. It is not clear why they have failed to increase in the Baie as they have done elsewhere in western France.

In view of the covariance between the three measures of habitat quality at this site, it was not possible to separate their effects statistically. This analysis does, however, lead to the hypothesis that the loss of grassland habitat is the main factor responsible for the decline in wintering ducks of the Marais Poitevin, and that for three species, drainage and wildfowling have also played a rôle. This could be tested by (i) a comparative analysis of trends in duck populations in relation to habitat quality at the regional level (north and west France, or western Europe); and (ii) exper-

imental management of water levels and hunting in the night feeding areas around the Baie.

CONSERVATION MEASURES, PAST AND FUTURE

The need to integrate conservation and development, and to involve local people in this process, was realized in France as long ago as the 1960s when the concept of Parcs naturels régionaux (PNR) was developed; since then 32 such Parcs have been created, including the Marais Poitevin, which was a PNR from 1979 to 1991 when it lost its PNR label due to a vote in favour of a motorway in the Marais by the Board of the Parc. During this period the fastest rate of loss of the semi-natural grasslands occurred (Fig. 3), the reduction of summer and autumn water levels continued, and there was a sharp decline in numbers of wintering ducks. This study therefore provides no evidence that the Parc had an effect on the processes leading to loss of semi-natural habitats and their wildlife, which appear to have been driven largely by the agricultural support policies.

The slower rate of wetland loss since 1992 coincides with the emergence of new agro-environmental policies in Europe and with the start of a new phase of the Common Agricultural Policy (CAP). Financial incentives to increase the area under intensive cereal production have been reduced. Extensive areas of wetlands in Europe have recently been declared Special Protected Areas by the member states, with commitments to prevent the powerful Structural Funds of the CAP from destroying internationally important wildlife resources. In France these changes have led to a halt in subsidies for drainage of wetlands and to the initiation of ESA subsidies for the conservation of semi-natural habitats (in the Marais Poitevin the ESA programme was initiated and is managed by the Parc). It is likely that these mechanisms are the cause of the slower rates of grassland loss in the Marais Poitevin in recent years (Fig. 3).

The government, recognizing the international importance of this wetland, extended the 2100-ha reserve covering the northern half of the Baie to a 2300-ha national Réserve naturelle in 1997. Negotiations are under way to double the size of the Réserve naturelle, which would then cover the whole Baie. The management plan of the Réserve naturelle is being prepared and it is likely that a prime objective will be to build up the wintering duck populations. The results of this study suggest that for this to succeed it will be necessary not only to maintain low levels of disturbance in the traditional roosting sites within the Réserve, but also to restore significant areas of wet grassland feeding habitat. Given that there are only approximately 500 ha inside the reserve, this will need to be done through contractual arrangements with neighbouring farmers leading to:

- maintenance and restoration of wet grasslands;

- management of water levels to maintain autumn and winter flooding;
- management of wildfowling using modern principles in order to reduce disturbance on the feeding areas.

This will be difficult to achieve because of the scale involved. Previous observations in the Marais Poitevin suggest that patches of undisturbed feeding habitat of the order of 300 ha would be necessary (Blanchon 1989), and the design of such refuge areas is of critical importance. However, a framework is available (Hill *et al.* 1997) and the fact that the Reserve now has national status could provide the impetus necessary to carry out a major programme of restoration in this internationally important wetland.

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