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WETLAND HABITAT CHARACTERISTICS FOR WATERFOWL WINTERING IN CAMARGUE, SOUTHERN FRANCE : IMPLICATIONS FOR CONSERVATION

Olivier DEHORTER and Alain TAMISIER*

INTRODUCTION

Wetlands as natural resources yield scientific, economic, and esthetic benefits that are increasingly important in research programs and in biological conservation. Waterfowl species like ducks (*Anatidae*) and coots (*Fulica atra*) rely on wetlands all the year round ; recruitment and mortality depend on the quality, the distribution and the availability of wetland habitats. Recent studies revealed conclusively that breeding success of many migrating waterfowl species is controlled by the amount of nutrients stored by females on their wintering grounds, usually several thousand kilometers further south (Ankney *et al.*, 1991). Wetland habitat quality in winter has a great influence on the capability of ducks to meet the energy demand required for better fitness in breeding success (Heitmeyer & Fredrickson, 1981). More recently it has been hypothesized, using a model of wintering strategy that body condition of ducks at the beginning of the winter season controls body condition at the end of the season, thus controlling recruitment (Tamisier *et al.*, 1995). So an increasing interest is focused on the function of wetlands for waterfowl in winter (Weller, 1988). Characteristics of wetlands considered to be important waterfowl habitat in winter must be analysed precisely, including recent man-influenced variables which modify the original biological conditions of wetlands and/or control their availability for birds. These characteristics guide habitat selection of waterfowl species and can determine the ability of birds to fulfil their energy requirements during this period of the annual cycle. Hence they must be defined for a better understanding of the possible role of winter habitat in waterfowl recruitment.

Wetlands are being reclaimed for agriculture, industry, urban development or recreation, resulting in drastic reduction of wetland area on all continents. In the Mediterranean area, the loss is probably worse and involves every coastal country (Finlayson *et al.*, 1992). Detailed analysis has not been conducted for the entire region but the decrease of wetland area is believed to be partly responsible for the large decline (54 %) of most regional winter waterfowl populations during the last 15-20 years (Van Vessem *et al.*, 1992). The Camargue is one of the most important winter areas in the Mediterranean region for western palearctic waterfowl species

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(Monval & Pirot, 1989) ; here as well, in spite of some of the more comprehensive conservation policies, loss and degradation of wetlands are significant (Tamisier, 1990). Monitoring of wintering populations for the last 30 years shows no clear trend over this period (Tamisier & Grillas, 1994). However, most wetlands are hunted. Both the direct reduction in numbers from hunting, and even more significantly the disturbance it causes (Bell & Owen, 1990 ; Dahlgren & Korschgen, 1992 ; Van Vessem *et al.*, 1992), are considered major threats for waterfowl wintering in the Camargue.

The objectives of this paper are : 1) to present the main characteristics of Camargue wetlands according to their physical and man-influenced variables, 2) to illustrate major changes that have occurred on these wetlands during the last quarter of century, and 3) to make some proposals for their protection and conservation. These results confirm the qualitative data presented in a previous paper (Tamisier & Grillas, 1994), providing them a quantitative support.

MATERIALS AND METHODS

Camargue is a wide delta (145,000 ha, Fig. 1) at the mouth of the Rhône River on the Mediterranean coast with 60,000 ha of wetlands and 25,000 ha of salt marshes ; the remaining surface is mostly farmland (Tamisier, 1990). The only agricultural areas used by waterfowl are ricefields after the autumn harvest when they become nocturnal feeding areas for some species (Pirot *et al.*, 1984). All wetlands are shallow (mean depth c. 0.5 m to 0.8 m, maximum 2.0 m). Important changes have occurred during the last century after the construction of dikes on the riversides and the seaside, and more recently during the last 50 years because of rapid development of human activities including agriculture, hunting and tourism. Today, artificiality is more and more apparent in marshes pumped with fresh water for hunting purposes as well as in salt marshes flooded with seawater for salt production. Only 22 % of wetlands are protected and much less water controlled. Therefore wetlands, already inventoried according to physical and biological (mostly plants) variables (Britton & Podlejski, 1981) should also be characterised by human influence.

We sampled all large wetlands (n = 74) of the Camargue that comprise > 90 % of the total wetland area. They were selected for monthly waterfowl census, carried out from September to March from 1967-68 to 1990-91 (24 years). They support the entire wintering populations of ducks and coots in the area (Tamisier & Pradel, 1992). Each site was characterised according to seven variables (Table I), five dealing with the physical nature of wetlands (Temporality, Surface, Salinity, Parcelling and Water management), two dealing with its human use (Status and Disturbance). Several (2 to 5) categories were distinguished for each variable. Sites were given an annual value for each variable. Temporary marshes dry up annually for more than two to three months while semi-permanent marshes dry up irregularly and for shorter periods. Drying is considered a key point in the functioning of Mediterranean wetlands (Grillas & Duncan, 1986). Surface area was measured at 100 % water-level. Three categories of salinity characterise the submerged macrophyte community which is dominated by *Myriophyllum spicatum* (< 5 g/l), *Potamogeton pectinatus* (5 to 20 g/l) or *Ruppia cirrhosa* (> 20 g/l) (Dervieux & Tamisier, 1987 ; Allouche *et al.*, 1989 ; Grillas, 1990 ; Tamisier & Pradel, 1992). Parcelling concerns some large marshes, mostly

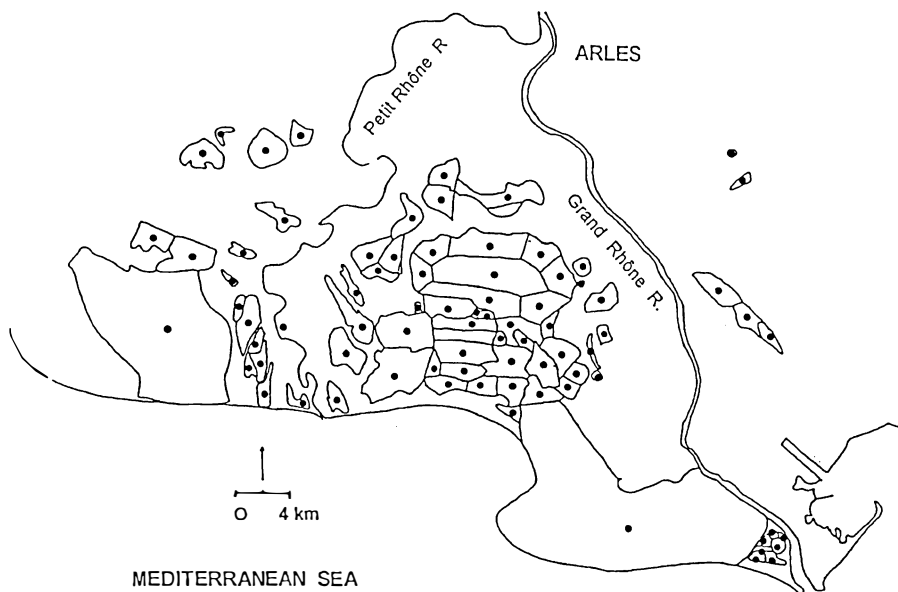


Figure 1. — Map of the Camargue. Dots represent the 74 selected wetlands.

hunted, where beds of *Phragmites australis* isolate several ponds and prevent birds from visual contact from both sides of the beds. Water management is considered as « strong » when an artificial flooding occurs in summer, mainly for hunting purpose. Status categories are : protected vs. hunted sites. Disturbance results mostly from waterfowl hunting. The length of the hunting season ranged from 6.5 to 8.5 months according to the year (the shortest duration occurring most recently) and to administrative locations (departement). Null disturbance (rank 0) refers usually to non-hunted areas, medium disturbance (rank 1) refers to rare hunting places where shooting occurs less than 2 days a week, and strong disturbance (rank 2) refers to most other hunting places.

We used Multiple Correspondence Analysis (MCA) rather than the usual Correspondence Analysis (CA) because the later implies a linear relationship between the categories of each variable (Dervin, 1988) which our data violated. MCA provides factorial planes where all important categories of variables are distributed according to relative similarities. The coordinates of each category on the factorial plane are its centre of gravity. Proximity between or among categories on the factorial plane means that they are associated in the field. Typically, the further the categories are from the origin, the more informative they are. The only variables dealing with the physical aspects of wetlands were used to construct the axes. The amount of information carried by an axis is given by its relative inertia (Table II). As compared to a CA, maximum inertia for each axis differs from 100 % so that inertia are given as a percentage of this maximum (relative inertia, Table II). Axes are ordered (Axis 1, Axis 2, Axis 3 etc.) by decreasing importance of relative inertia.

TABLE I

Description of the categories distinguished for each variable.

Variables	Categories				
	1	2	3	4	5
Temporality (water)	Temporary	Semi-permanent	Permanent		
Surface (ha)	10-50	50-100	100-250	250-500	>500
Salinity (g/l)	< 5 (fresh)	5-20 (brackish)	> 20 (salty)		
Parcelling	Yes	No			
Water Management	Weak	Strong			
Status	Reserve	Hunted			
Disturbance	Null to weak	Medium	Strong		

TABLE II

Eigen-values and relative inertia for the first three axis of the Multiple Correspondence Analysis. 78 % (total explained variance) of the information contained in the data is included on these axes.

	Axis 1	Axis 2	Axis 3
Eigen-values	0.39	0.20	0.20
Relative inertia (%)	38	20	20

The importance of each variable in the construction of the axis is given by its relative contribution (cf. Table III). The variables which concern the human use of wetlands (Status and Disturbance) were considered as *supplementary variables*. They were not used in constructing the axes, yet their location on the factorial plane can be interpreted as for the other variables : proximity of a category of Status and Disturbance with categories of any variable on the factorial plane means association with it in the field. We dealt with 1,776 statistical units (24 years x 74 sites).

TABLE III

Relative contributions of variables for the first three axis. The most important values (in bold) indicate the variables which construct the axis.

	Temporality	Surface	Salinity	Parcelling	Water Mgmt.
Axis 1	11.7	9.3	26.3	28.6	24.1
Axis 2	35.4	36.0	16.1	0.0	12.5
Axis 3	21.6	56.3	3.8	18.3	0.0

Evaluating trends in wetland characteristics during the study period relied on analysing changes in the frequency of categories of the four variables most susceptible to change : Salinity, Water Management, Status and Disturbance. We also compared the distribution of sites according to Status and Salinity at the first year and the last year of the study period (1967-68 and 1990-91). We used the test of Williams (G_w , Sokal & Rohlf, 1981) to evaluate the homogeneity of the data.

RESULTS

The complete data set provides a general description of the main characteristics of Camargue wetlands for the period 1967-1991 (Fig. 2). The first two axes carry 58 % of the total information contained in the data base, and the first three axes carry 78 % (Table II). Five variables have important contributions in the construction of the axes (Table III) ; Parcelling, Salinity and Water Management explain Axis 1. Surface and Temporality are important on both Axis 2 and 3. Two groups of wetlands are clearly isolated along Axis 1 (Fig. 2) : fresh water and parcelled wetlands with strong water management on the right of the diagram, saline waters without parcelling or water management on the left. Hunted and highly disturbed areas are associated with the first group of wetlands, protected areas with the second group. Axis 2 represents a surface gradient with small sites on the upper part of the diagram and large sites on the lower part.

Changes which occurred during the study period concerned four variables (Salinity, Status, Water Management and Disturbance) on several sites (Fig. 3).

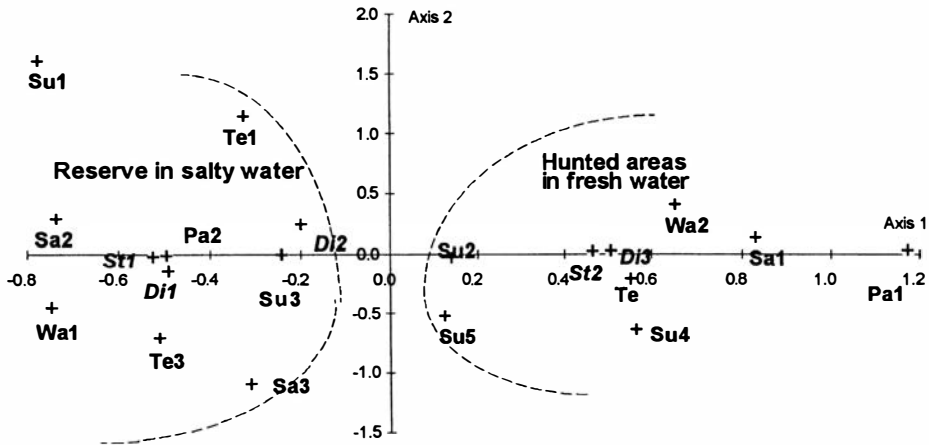


Figure 2. — Factorial plane (Axis 1-Axis 2, Multiple Correspondence Analysis) illustrates the bimodal pattern of wetland characteristics for the whole period (1967-68 to 1990-91). Five variables were used to construct the axes : Temporality (Te), Surface (Su), Salinity (Sa), Parcelling (Pa) and Water Management (Wa). Status (St) and Disturbance (Di), as supplementary variables, are located on the factorial plane according to similarities with other variables. Numbers following codes indicate categories (see Table I). Two groups of wetlands are isolated : freshwater wetlands on the right, associated with hunted sites, saline wetlands on the left, associated with protected sites.

Changes in Status and Disturbance were correlated and concerned 15 sites which changed from hunted status to protected status, mostly between 1977 and 1979 (1 site in the National Reserve, 7 acquired by the Conservatoire du Littoral) and in 1980-81 (4 large sites in the National Reserve). Changes in Salinity illustrate an accidental intrusion of seawater in many wetlands of the National Reserve altering them from brackish water to salt water. More and more sites are under Water Management : today all hunted sites are managed, as well as a few protected sites.

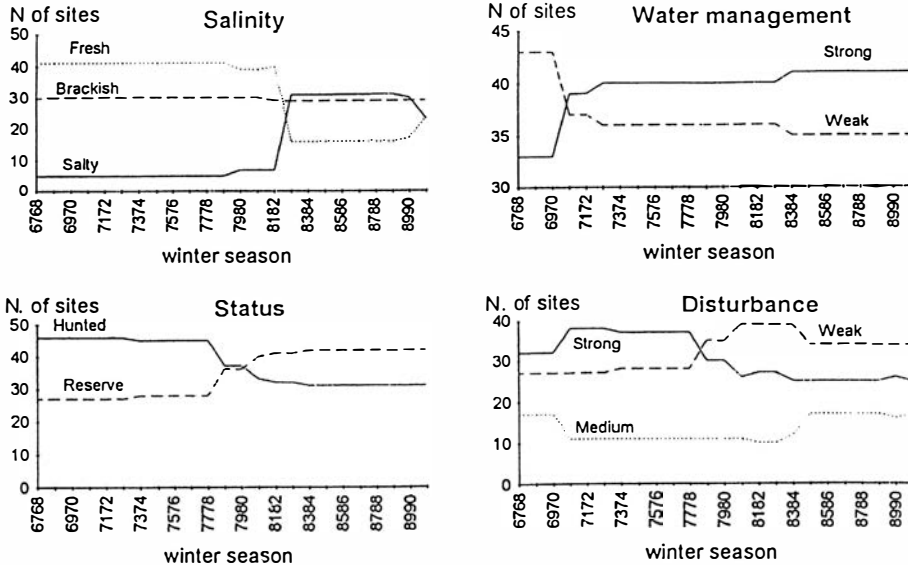


Figure 3. — Changes in site numbers for categories of four variables from 1967-68 to 1990-91. Because of large variations in the mean size of sites, these numerical changes in categories do not reflect their actual importance (area) for the whole of Camargue. For instance, protected sites are more numerous than hunted sites, but hunting occurs on 78 % of the area.

Between the first (1967-68) and the last (1990-91) year, a clear discrepancy can be observed in the distribution of sites (Table IV). The increase in protected sites involves mostly saline wetlands. By the end of the period (1991), most hunted sites are fresh water. The homogeneity test is less significant in 1967-68 ($G_w = 11,2249$, $p < 0.05$) than in 1990-91 ($G_w = 26,0536$, $p < 0.01$), meaning that the difference between groups is higher at the end of the period than at the beginning.

DISCUSSION

The main characteristics of wetlands in Camargue are distributed in a bimodal pattern which distinguishes hunted freshwater sites from protected saline sites (Fig. 2). This radical discrimination illustrates the present use of wetlands, either

TABLE IV

Distribution of sites in 1967-68 and 1990-91 according to their categories of Status (1, 2) and Salinity (1, 2, 3). Distribution is statistically more homogeneous during the first year than the last one when two groups opposite : freshwater hunted sites and salty protected ones (see Table I for the categories of the variables, and in the text for more details).

1967-68		Salinity			Total
		1	2	3	
Status	1	6	21	0	27
	2	26	18	3	47
	Total	32	39	3	74

1990-91		Salinity			Total
		1	2	3	
Status	1	7	18	17	42
	2	24	4	4	32
	Total	31	22	21	74

for hunting or protection. In the former case, water management consists of pumping freshwater into the marshes to reduce the original constraints (salt level and evaporation in the summer). The result is a strong increase of the productivity of aquatic plants (Van Wijk, 1988 ; Tamisier & Grillas, 1994) which are the main food of waterbirds in winter. Hence, managers hope to attract more birds which can be harvested in higher numbers (150,000 ducks per year). In the latter case, water management is occasionally undertaken for recreational or scientific purposes, concerning only small parts of wetlands ; it does not affect the mean salinity of most protected sites. As a consequence, protected sites reflect at best the original physical and biological conditions of Camargue wetlands. This is particularly true for the National Reserve where most wetlands are not affected by any direct water management plan and can be considered most similar to Camargue wetlands before.

This bimodal pattern was less obvious before 1980 than at present (Table IV). It appears as a new general characteristic of the Camargue wetlands and results from two main changes. First, most hunted sites which became protected sites were brackish wetlands, and secondly hunted sites are more and more subject to freshwater management because of the increase of hunting which brings economic inputs. As a matter of fact, hunted sites, whilst less numerous than before (Fig. 3), still cover 67,000 ha, that is 78 % of the total wetland area in the Camargue region, and hunting intensity, measured in number of hunters/hunting area, is c. 60 %

higher now than 20 years ago (Tamisier, 1992); this higher hunting pressure, evaluated over the whole Camargue, could not be taken into consideration at the site level for the present analysis because of practical considerations.

This wetland typology is contrary to the suggestion of Britton & Podlejski (1981) that « wetlands of the Camargue form a continuum with no obvious subdivisions » (p. 223). It also differs from the general conception that the Camargue is made up of a mosaic of biotopes whose spatial and temporal diversity is responsible for the richness and the originality of the region (Blondel & Isenmann, 1981 ; Boulot, 1991). These differences have two explanations. First, Britton & Podlejski (1981) refer to data collected in 1976-1977 and we have witnessed rapid changes in the situation. Secondly, most authors had a global perception of wetlands whereas our objective was to define wetlands in the context of habitat selection by wintering waterfowl. Consequently, these authors referred to physical and biological criteria, while we had to add several anthropic criteria which are supposed to influence habitat selection of waterfowl species. Nevertheless, we can consider that the original high diversity of Camargue wetlands has been progressively replaced during recent decades by a simplified two-wetland system for waterfowl. This bimodal pattern is particularly obvious in waterfowl habitats where diurnal resting places on protected sites oppose to nocturnal feeding areas on hunted freshwater sites (Allouche *et al.*, 1989).

The consequence of the loss of wetland diversity on waterfowl populations which winter in the area is not clear since the observed trend for the 1967-68/1990-91 period reveals a non significant decrease for the whole duck populations, with distinct species specific responses : a negative trend for Teals *Anas crecca* ($p < 0.01$), a significant decrease for Mallards *Anas platyrhynchos* ($p < 0.05$) or a non significant increase for Gadwalls *A. strepera*, and no significant trend for Shovelers *A. clypeata* and Wigeons *A. penelope*. The decrease for coots (*Fulica atra*) is not significant (Fig. 4). This relative independence of the present size of the wintering waterfowl population towards environmental variables will be analysed on a separate paper. Our hypothesis is that changes in waterfowl number result from opposite effects of the described parameters. Positive effects rely on three points : 1) the increased productivity of most hunted wetlands due to water management makes these wetlands more attractive to birds, mostly as nocturnal feeding areas ; they actually gather 90 % of ducks at night ; 2) the higher number of protected sites (15 new ones covering c. 2,300 ha) which extend over 19,000 ha in 1991 (all protected sites) allows more birds to exploit resting places during the day ; and 3) some protected areas also are managed like hunted wetlands and attract more birds. Negative effects rely on the observed increasing hunting pressure which limits the numbers of ducks since it reduces the availability of most feeding grounds because of hunting. Thus positive and negative environmental effects counterbalance each other, possibly explaining the lack of comprehensive changes in waterfowl numbers.

On the opposite, the duck density on protected sites (3.56 ducks per ha) is almost four times higher than the duck density on hunted sites (0.97 duck per ha, test *t* of Student, $p < 0.001$), whilst the latter are much more productive. Ducks not only select protected areas for security, they also avoid the richest wetlands and loose feeding advantages because of disturbance. There is no significant effect of the increase in number of protected sites on these duck densities from 1977 ; this is explained by the fact that in terms of surface, the increase is 14 % only. This absence of effect can also indicate that duck numbers on the reserves are limited

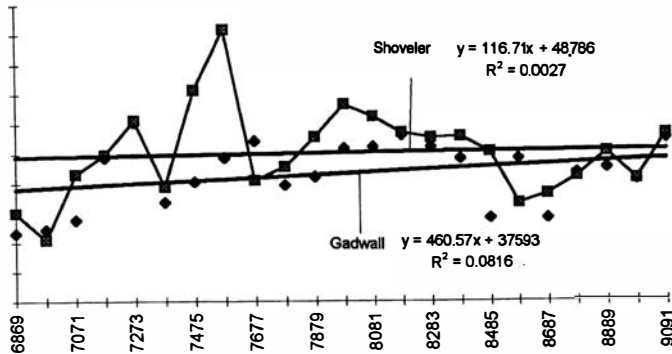
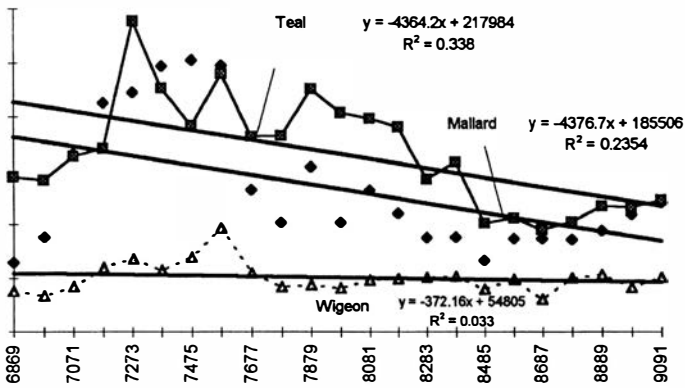
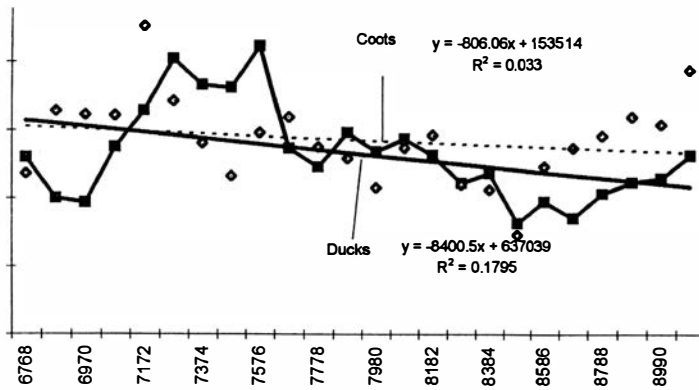


Figure 4. — Demographic trends of waterfowl populations for the 1967-68/90-91 period. The general pattern is a non significant decrease of these populations wintering in the Camargue.

by the present low availability of feeding (hunted) sites in the Camargue. This point confirms the hypothesis that duck populations wintering in the Camargue are limited by hunting (Tamisier & Grillas, 1994).

These results emphasize the difficulty in evaluating the effect of a qualitative loss of diversity of habitats on populations levels of vertebrates, even though these animals rely on them for more than half a year. It also supports Morrison's (1986) claim about the limited value of bird populations as indicators of environmental parameters when these parameters are counterbalanced.

In terms of conservation, we are facing a contradictory situation because of these water management practices on wetlands in the Camargue. Since the described type of water management increases plant productivity of marshes by reducing salt and dessication constraints, it can be considered as positive for ducks and coots which rely on these marshes for food. For that reason, several environmental agencies also use them to attract birds. However one of the consequence is that more and more wetlands (all hunted areas and some protected ones) loose their mediterranean specificity and look like continental permanent marshes, the final consequence being the observed loss of biological diversity in the Camargue (Tamisier & Grillas, 1994). This point has to be taken into consideration when long term conservation politics are concerned.

Finally, our results can be compared with the North American situation where practices in wetland habitat management can lead to « providing refuge areas or attracting birds for hunting » (Pederson *et al.*, 1988). Since waterfowl populations in the Mediterranean region are mostly threatened by loss of habitat and disturbance (mostly hunting, Van Vessem *et al.*, 1992), and since they are probably limited in the Camargue by hunting, the most urgent practical implications of our results are the need to enhance protection on some of the wetlands which are presently hunted. Managers of these newly protected sites will have to face two possibilities of management according to whether they like to directly advantage waterfowl (through more food resources) rather than wetland diversity. In the first case, strong water management of wetlands could be maintained, favoring higher productivity and attractiveness for waterfowl. The carrying capacity of wetlands would be much higher than today because of the absence of hunting, potentially leading to an increase in the size of the waterfowl populations wintering there. In the second regime, wetlands would not be subjected to any standardized water management which is responsible for the loss of wetland diversity. They would be restored through Mediterranean-type water management including a higher variability and unpredictability in water levels and salinities. Both regimes could have distinct advantages, either for population size of wintering waterfowl or for wetland diversity. We suggest that both be used in the Camargue according to sites, water management regime being applied on the most artificialized sites, the second regime being as often as possible applied on more natural wetlands.

SUMMARY

In the Camargue, southern France, 74 wetlands representing more than 90 % of the total wetland surface, support the entire wintering waterfowl populations in the region. We characterized the habitat of these wetlands during the period 1967-68 to 1990-91. We measured five physical variables of the wetlands proper

and two variables describing human use. Multiple Correspondence Analysis clearly discriminated freshwater wetlands which are hunted, more productive and highly disturbed, from the protected saline wetlands. A trend was observed during the last 24 years in which a mosaic-type distribution of wetlands has been progressively replaced by a bimodal pattern as a consequence of human interference (water management and disturbance) linked to protection policies and economic (hunting) development. A loss of biological diversity has resulted, requiring new models of conservation. The population size of wintering waterfowl (ducks and coots) did not present corresponding changes, since it seems to result from apparent opposite effects of the described parameters. We recommend better protection of winter habitats for waterfowl populations with less hunting. Wetlands should be managed according to a Mediterranean-type water control including more variability and unpredictability in water levels and salinities.

RÉSUMÉ

Les 74 étangs et marais de Camargue qui représentent plus de 90 % de la surface totale des zones humides locales, accueillent la totalité de la population d'oiseaux d'eau hivernant dans la région. Pendant la période 1967-68 à 1990-91, ces plans d'eau ont été caractérisés par 5 variables portant sur leur nature physique et par 2 variables portant sur leur exploitation humaine. Une Analyse Factorielle des Correspondances Multiples discrimine clairement les milieux doux qui sont chassés et fortement perturbés, et les milieux salés qui sont protégés. On observe une tendance au cours de ces 24 années ; la distribution en mosaïque des milieux, caractéristique camarguaise, laisse progressivement la place à une distribution bi-modale, par suite des interventions humaines : d'une part une politique de protection en faveur des sites salés (nouvelles créations de réserves) et d'autre part des aménagements hydrauliques et un fort dérangement qui sont liés à la chasse, nouveau facteur de développement économique. Il en résulte une perte de diversité biologique et la nécessité de recourir à de nouveaux modèles de conservation. La taille du peuplement d'oiseaux d'eau ne reflète pas cette perte car elle semble résulter d'effets contradictoires des paramètres mesurés. La protection des habitats nécessaires aux populations d'oiseaux d'eau hivernants doit être repensée ; il serait notamment judicieux que 1) des marais doux actuellement chassés soient mis en réserve et 2) que leur gestion réponde autant que possible aux caractéristiques méditerranéennes de variabilité et d'imprévisibilité du niveau d'eau et de salinité.

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