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Influence of natural and anthropic perturbations on the distribution of salt marsh breeding birds in the Mont Saint-Michel bay

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Abstract: Anthropogenic pressures as sheep grazing and the spread of the grass *Elymus athericus* are two of the most significant changes affecting European salt marshes. The habitat value for breeding birds is likely to be modified by such factors. In this context, we investigated the bird community breeding in the salt marsh of the Mont Saint-Michel bay (France). Habitat characteristics and bird relative abundance were measured at each of 133 sampling points. Using a hierarchical cluster analysis of all habitat variables, five habitat types were defined from the middle to high marsh. Values of species richness, abundance and diversity index regularly increased from grazed stations to those dominated by *Elymus athericus*. Bird community observed in *Atriplex portulacoides* habitat showed intermediate values. The grazed habitat was the only one avoided by all bird species. This study underlined the contrasted influence of natural and anthropic perturbations on two bird species (Skylark, European Quail) with unfavorable conservation status in Europe.

Résumé : *Influence des perturbations naturelles et anthropiques sur la distribution des oiseaux se reproduisant dans les marais salés de la Baie du Mont Saint Michel.* Des perturbations anthropiques comme la pression de pâturage ou naturelles comme l'envahissement par une espèce herbacée (*Elymus athericus*) transforment les marais salés européens. Ces deux types de perturbations induisent des évolutions végétales et des modifications consécutives de l'habitat des oiseaux. L'objectif de cette étude a donc été d'analyser la communauté d'oiseaux se reproduisant dans les marais salés de la Baie du Mont Saint-Michel (France). Les paramètres d'habitat et l'abondance relative des oiseaux ont été mesurés à chacun des 133 points d'écoute. Une classification hiérarchique des variables environnementales a permis de distinguer cinq habitats différents. La richesse spécifique et l'abondance des oiseaux suivent un gradient croissant des zones pâturées, vers les zones à *Atriplex portulacoides* puis vers celles à *Elymus athericus*. Les zones surpâturées sont les seules à ne pas être sélectionnées par les oiseaux. Cette étude met en évidence l'influence contrastée des perturbations anthropiques et naturelles sur l'évolution des espèces d'oiseaux qui présentent un intérêt en biologie de la Conservation comme l'Alouette des champs (*Alauda arvensis*) et la Caille des blés (*Coturnix coturnix*).

Keywords: Salt marsh; Nesting birds; Habitat associations; Anthropic and natural perturbations.

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Introduction

Wetlands are considered as complex ecosystems that represent an interface between terrestrial and aquatic habitats. Coastal wetlands are made of different habitats including salt marshes defined as intertidal areas of fine sediments stabilized by vegetation, occurring extensively along the seaward edges of low-lying coastal areas (Boorman, 2003). In France, the Mont Saint-Michel bay presents one of the largest salt marsh of the French Atlantic coast with an area of 40 km^2 (Lefeuvre et al., 2003).

The net primary productivity of salt marshes is the highest of any of ecosystems (Lefeuvre, 2000). It initiates an invertebrate productivity that plays an important role in the food chains of the salt marshes by forming the food supply of juvenile fishes or waders and waterfowl (Lefeuvre et al., 2000; Eybert et al., 2003).

Waterbirds generally use low salt marshes temporarily during migration stopover or wintering as feeding or resting sites (Boorman, 2003). Conversely, passerine birds use salt marshes all year long and form the major part of the breeding avian community as observed in Mont Saint-Michel bay. Because the ecological functional of agricultural areas is degrading, salt marshes also provide habitat for typical farmland birds that are declining in Europe as Skylark *Alauda arvensis* (L., 1758) or European quail *Coturnix coturnix* (L., 1758) (Rocamora & Yeatman-Berthelot, 1999).

Salt marshes are among the most threatened ecosystems. In Europe, they have been dramatically changed since the 1960s and actually undergo an increasing threat with global warming, rising sea levels and anthropic pressures (Boorman, 2003). In the Mont Saint-Michel bay, the erosion of the salt marshes is not actually a threat since the salt marshes increase by about 10 ha.yr^{-1} (Bouchard et al., 2003) and the two main factors affecting the salt marshes are human activities (sheep grazing) and the spread of the invasive grass *Elymus athericus* (Link) Kerguelen 1983. Three quarters of the whole salt marshes support a free sheep grazing that varies from moderate to heavy intensity according to locations. Sheep graze the salt marshes all year around, but are less numerous during winter. In order to maintain this economic activity, farmers are obliged to increase the size of their herds. As a consequence of local intensifications, an increase of the total area of grazed salt marshes (71% to 77% in ten years) and an overgrazing of 25 to 30 % of these were observed (Bouchard et al., 2003). The rapid invasion by *Elymus athericus* has replaced middle marsh *Atriplex* community and has extended threefold its area within only 10 years at a rate of 4 ha.yr^{-1} (Lefeuvre et al., 2003, Valéry et al., 2004). These two main threats are likely to modify the habitat value of salt marshes, in term of biodiversity and ecological functioning of terrestrial birds. In salt marshes, passerine community is poorly documented and papers related to the breeding season did not only concern this specific habitat (Glue, 1971; Greenhalgh, 1971; Moller, 1975; Lewis & Casagrande, 1997). In this context, we assessed the value of main habitats that compose the Mont Saint-Michel salt marshes, in term of diversity, density and habitat selection by breeding birds. The aim of this study is also to discuss the consequences of the grazing and the spread of *Elymus athericus* on the bird community.

Materials and Methods

Study site

The Mont Saint-Michel bay is a 500 km^2 littoral zone, located in the Normanno-Breton Gulf (48°40'N, 1°35'W). Based on plant communities, natural salt marshes can be divided into four zones (Valéry et al., 2004): a pioneer area with *Spartina* spp. and *Salicornia* spp., a low marsh with *Puccinellia maritima* (Hudson, 1762), *Aster tripolium* (L., 1753) and *Sueda maritima* (auteur, année), a middle marsh dominated by *Atriplex portulacoides* (L., 1753) and a high marsh with *Elymus athericus* and *Festuca rubra* (L., 1753). Under grazing conditions and invasion of *Elymus athericus* to the middle and low marshes, the plant zonation tends to disappear to the detriment of *Atriplex portulacoides* (Bouchard et al., 2003; Valéry et al., 2004). Heavy grazing replaces original salt marsh vegetation by a short and much less productive monospecific plant communities dominated by *Puccinellia maritima* (Bouchard et al., 2003).

Bird sampling

Two observers assessed census of bird communities with the IPA point count method that gives an index of abundance for each species (IBCC, 1977). We established eight transects in four parts of the Mont Saint-Michel salt marshes that differed by presence and intensity of grazing (Fig. 1). Fixed census point (n = 133) were regularly distributed along theses transects and located by a GPS. The longer the transects the larger the salt marshes is. To avoid double counting of birds, we chose a distance of 250 m between point counts. We used 100 m radius point counts with a 20-minutes listening period to estimate avian relative abundances, species richness, and Shannon diversity index. To take into account the sedentary and migratory species and the maximal activity of breeding periods, all points were visited two times in 2003 (before and after 15 May to the end of June), between 06:00 to 10:00 (local time). Birds recorded only in flight were ignored. The higher of the two values, either from the first or the second count, is used as the IPA value.

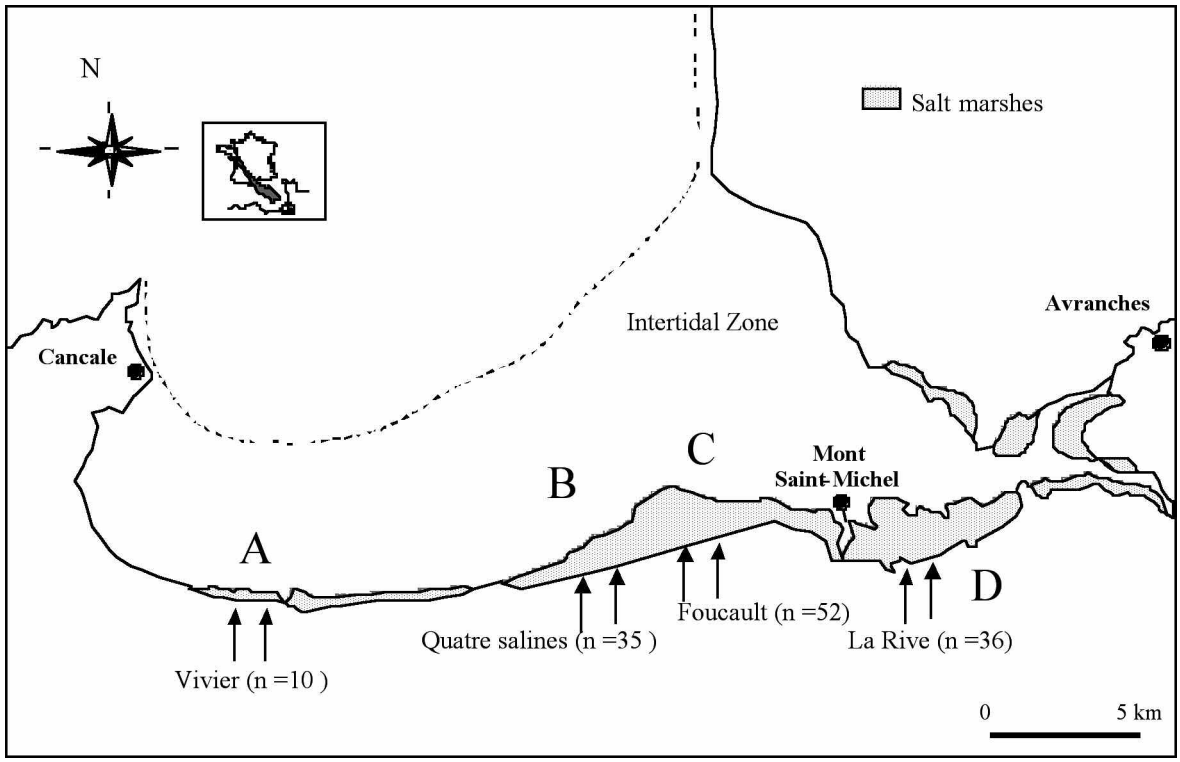

Figure 1. Location of eight transects in four parts of the Mont Saint-Michel salt marshes characterized by no (A), weak (B, C) and heavy (D) grazing. The number of point counts is indicated in brackets.

Figure 1. Localisation des huit transects répartis dans quatre secteurs des marais salés de la Baie du Mont Saint-Michel qui se caractérisent par une absence (A), une faible (B, C) et forte (D) pression de pâturage. Le nombre de points d'écoute est indiqué entre parenthèses.

Vegetation survey

Habitat was characterized within a 100 m radius around each census point, by cover of basal stratum, height of vegetation, number of plant species, dominant vegetal species (*Salicornia* spp., *Puccinellia maritima*, *Aster tripolium*, *Atriplex portulacoides*, *Elymus athericus)* and distance from the sea. Area covered by basal stratum (%) was estimated visually and recorded as low (0-50%), intermediate (50-75%) or high (75-100%). Height of basal stratum of vegetation was recorded as low (< 5cm), medium (5-30 cm) and high (> 30cm). Presence of plant species was assessed when it represented more than 10% of the sampled area. A plant species was considered as dominant when its percentage cover was more than 50% of the sampled area. The measurement of the distance from the sea was determined using the lowest limit of the vegetal pioneer area. The lowest parts of the salt marshes were not sampled because they were regularly flooded and could not support nests of passerine birds.

Statistical analysis

Data were analyzed with Systat for Windows, version 9.0 (SPSS, Chicago, IL) and statistical significance was set at $P < 0.05$. A hierarchical cluster analysis of all habitat variables was used to aggregate sampling points into different groups or habitat types that were similar in respect to structure and floristic composition. Relative values are presented as mean ± standard deviation. Within each habitat type, bird abundance (IPA value), species richness (S) and Shannon's Diversity Index (H'), that were normally distributed (Kolmogorov-Smirnov test, $P > 0.05$), were compared. A jackknife procedure (Zahl, 1977) was assessed to estimate the mean and standard deviation of H'. Bird abundance, species richness and Shannon's Diversity Index were compared among habitat types using one-way analysis of variance (ANOVA) followed by *post hoc* Tukey test.

Differences in habitat use were tested with G-test (one per species). In order to study habitat preferences, the proportion of bird records for each species from each habitat was compared with the total of sampling area using Jacobs' index (Jacobs, 1974):

$$D = (r - p) / (r + p - 2rp) \quad (1)$$

where r is the proportion of individuals of a species in a given habitat type, and p the proportion of this habitat type in the studied area. It ranges from –1 for maximum avoi-

dance to +1 for maximum preference. In order to determine D minimum and maximum values, the 95% confidence limits of r were calculated (Geslin et al., 2002).

Results

Habitat classification

From the hierarchical cluster analysis, a linkage distance of 0.28 was chosen to cut the dendrogram because it identified five homogeneous habitat types (Table 1): one of them was dominated by *Elymus athericus* (Habitat 1), three by *Atriplex portulacoides*, that differed according to vegetation cover (Habitat 2 *vs* Habitat 3 with a weaker percentage cover of vegetation) or distance from the sea (Habitat 4 distant from the sea), and one by *Puccinellia maritima* (Habitat 5). This last habitat, with a high degree of grazing, presented the lowest vegetation height. The number of plant species differed significantly among habitat types ($F_{4,128} = 16.30$; $P < 0.001$). The two poorest habitats were represented by grazed areas and habitat dominated by *Elymus athericus*. The distance from the sea also distinguished habitat types ($F_{4,128} = 24.99$; $P < 0.001$): the high marsh sampled represented preferentially grazed areas and the middle marsh sampled was dominated by *Atriplex portulacoides*.

Bird species, relative abundance and distribution

A total of nine breeding species was recorded on the whole sampling points: eight passerines and one galliform. Two species such as Skylark and Meadow Pipit *Anthus pratensis* (L., 1758) represented near than 70% of the avian community (35.1% and 34.5% respectively). Reed Bunting *Emberiza schoeniclus* (L., 1758) was about 10%, European Quail about 9%, Yellow Wagtail *Motacilla flava* (L., 1758) about 6% and Fan-tailed Warbler *Cisticola juncidis* (Raf, 1810) about 3%. The three other species (White Wagtail *Motacilla alba* (L., 1758), Bluethroat *Luscinia svecica* (L., 1758), Linnet *Carduelis cannabina* (L., 1758) represented each less than 2% of the breeding birds within the salt marshes.

Values of species richness, abundance and diversity index regularly increased from grazed stations to areas dominated by *Elymus athericus* (Table 2). Passerine community observed in areas dominated by *Atriplex portulacoides* showed intermediate values.

Habitat selection of breeding birds within the salt marshes

The six more abundant bird species showed significant variations of relative abundance between different habitats (Table 3). The other three species (White Wagtail, Bluethroat, Linnet), which were found at very low frequency, did not present a significant association with any habitat type. Figure 2 shows the degree to which the species selected or avoided each habitat. Among them, three species showed strong association with one habitat type. European Quail and Fan-tailed Warbler only selected positively habitat 1 dominated by *Elymus athericus* and Yellow Wagtail selected habitat 4 dominated by *Atriplex portulacoides*. Skylark was positively associated with three habitat types characteristic of the middle marsh (habitats 2, 3, 4) that were all dominated by *Atriplex portulacoides*. Meadow Pipit selected positively habitats 1 and 4 that were both distant from the sea. Reed Bunting was associated with habitats 1, 3 and 4 avoiding habitat 2 characterized by the highest density of the shrubby species *Atriplex portulacoides*. The grazed habitat 5 was the only one avoided by all bird species.

Discussion

Nine avian species bred on the Mont Saint-Michel salt marshes. This number was slightly higher than values observed in other salt marshes of Great Britain (e.g. 2 and 3 in Greenhalgh, 1971 and Moller, 1975 respectively) but equal to one found in newly enclosed salt marsh (Glue,

Table 1. Environmental parameters of the five habitat types based on hierarchical cluster analysis. n represents the number of census points.

Tableau 1. Caractéristiques environnementales des cinq habitats définis par une classification hiérarchique. n représente le nombre de points d'écoute.

	N	Basal Stratum Density (%)	Vegetation height (cm)	Mean number (± SD) of species	Distance (± SD) to the sea (m)	Dominant species
Habitat 1	31	75-100	> 30	1.52 ± 0.10	996.8 ± 75.5	*Elymus athericus*
Habitat 2	23	75-100	5-30	2.09 ± 0.8	500.0 ± 51.8	*Atriplex portulacoides*
Habitat 3	10	50-75	5-30	2.90 ± 0.23	310.0 ± 73.7	*Atriplex portulacoides*
Habitat 4	38	50-75	5-30	2.50 ± 0.14	1128.9 ± 80.4	*Atriplex portulacoides*
Habitat 5	31	50-75	< 5	1.42 ± 0.12	1390.3 ± 66.0	*Puccinellia maritima*

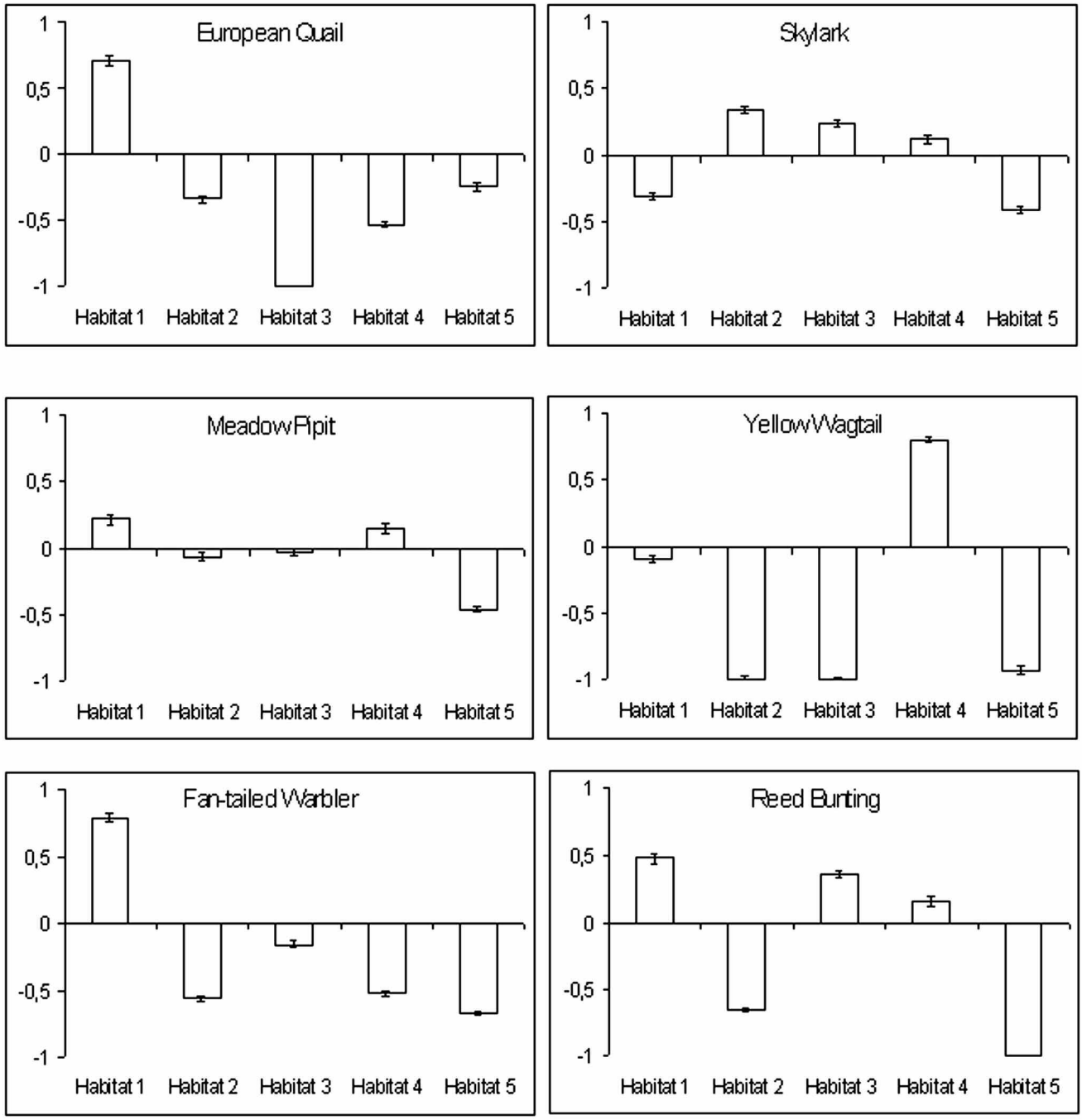

Figure 2. Jacob's preference index (with confidence limits at $P = 0.05$) for species recorded during breeding season within 5 studied habitats located in the salt marshes of the Mont Saint-Michel bay.

Figure 2. Sélection, par les oiseaux en période de reproduction, des cinq habitats définis dans les marais salés du Mont Saint-Michel (indice de Jacobs et intervalle de confiance à $P = 0,05$).

1971). According to the area of the sampling point, the number of breeding pairs (b.p.) per 10 ha might be estimated between 7.0 to 22.3 b.p. in relation to the different habitats of the Mont saint-Michel salt marshes. In open fields as in salt marshes, the transformation of relative into absolute values probably caused an over-estimation. In fact, birds could be often detected in a slightly greater radius than 100 m. However, the number of breeding pairs was higher than one observed in natural salt marsh (Greenhalgh, 1971), but close to those found in embanked or other natu-

Table 2. Characteristics (mean ± SD) of breeding bird community for each habitat type determined within the salt marshes of the Mont Saint-Michel bay. ***: $P < 0.001$. A dissimilar letter in exponent reports significant differences between values.

Tableau 2. Paramètres (moyenne ± écart-type) du peuplement reproducteur d'oiseaux dans chaque habitat des marais salés de la Baie du Mont Saint-Michel. Comparaisons significatives à $P < 0{,}001$: ***. Les lettres en exposant montrent les différences significatives.

	Habitat 1	Habitat 2	Habitat 3	Habitat 4	Habitat 5	ANOVA
Species richness	3.58 ± 0.04^{a}	2.35 ± 0.04^{b}	2.80 ± 0.13^{c}	3.34 ± 0.03^{d}	1.35 ± 0.04^{e}	$F_{4,133} = 10054.76$ ***
Abundance	7.00 ± 3.40^{a}	5.46 ± 1.90^{a}	6.05 ± 3.43^{a}	6.45 ± 2.45^{a}	2.21 ± 2.60^{b}	$F_{4,128} = 14.73$ ***
Shannon's Diversity index	2.47 ± 0.02^{a}	1.51 ± 0.05^{b}	1.73 ± 0.06^{c}	2.13 ± 0.02^{d}	1.86 ± 0.02^{e}	$F_{4,133} = 3878.51$ ***

Table 3. Abundance (mean IPA value) of birds breeding within each habitat type of the salt marshes located in the Mont Saint-Michel bay. The number of stations censused are given in brackets. G-Test: *ns*: not significant, *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

Tableau 3. Abondance relative (IPA moyen) des oiseaux reproducteurs dans chacun des habitats des marais salés de la Baie du Mont Saint-Michel. Le nombre de relevés est indiqué entre parenthèses. Test G : *ns* : non significatif, * : $P < 0{,}05$, ** : $P < 0$, 01, *** : $P < 0{,}001$.

	Habitat 1 (31)	Habitat 2 (23)	Habitat 3 (10)	Habitat 4 (38)	Habitat 5 (31)	G_{aj} test
Coturnix coturnix	1.32	0.26	0.00	0.18	0.32	28.89 ***
Alauda arvensis	1.11	3.22	2.90	2.21	0.90	27.91 ***
Anthus pratensis	2.55	1.65	1.75	2.28	0.79	18.43 **
Motacilla alba	0.06	0.15	0.05	0.04	0.15	1.54 *ns*
Motacilla flava	0.29	0.00	0.00	0.93	0.02	34.05 ***
Luscinia svecica	0.06	0.00	0.00	0.00	0.00	1.17 *ns*
Cisticola juncidis	0.42	0.04	0.30	0.05	0.03	9.54 *
Carduelis cannabina	0.11	0.00	0.00	0.09	0.00	4.72 *ns*
Emberiza schoeniclus	1.06	0.13	1.05	0.66	0.00	36.23 ***

ral salt marshes (Glue, 1971; Moller, 1975) and weaker than those observed in American salt marshes (Lewis & Casagrande, 1997) characterized by a higher habitat diversity. Species recorded might be regarded as habitat generalists. They are found in marsh habitat or associated with agricultural landscapes where the larger part of their population occurs.

Species richness and abundance were strongly influenced by vegetation parameters. The comparison of the five habitat types showed that vegetation height, cover and distance from the sea influenced avian community parameters. The richness, abundance and Shannon diversity index were influenced by natural and anthropogenic perturbations: they were maximal in habitat dominated by *Elymus athericus* and minimal in heavy sheep grazing areas. All breeding birds avoided this last habitat. Intensive grazing has a marked effect on the structure and composition of salt marsh vegetation by reducing the height of the vegetation and the diversity of plant and invertebrate species (Bouchard et al., 2003) and thus prevents the settlement of nesting birds. In contrast, the habitat dominated by the invasive plant was positively selected by four species because it provides a suitable habitat either to farming birds as European quail and Meadow Pipit or birds inhabiting reed beds as Fan-tailed Warbler or Reed Bunting. The middle marsh dominated by *Atriplex portulacoides* was strongly associated with Skylark (the whole habitat types), Yellow Wagtail and, in part, with Meadow Pipit and Reed Bunting.

Skylark has an unfavorable conservation status in Europe. From the mid-1970s to the mid-1980s, a 50 to 60% decrease in the numbers of nesting Skylark has been observed in most European countries, following changes in agricultural practices in particular the increase of autumn-sown cereals in arable areas (e.g. Eraud & Boutin, 2002). In the Mont Saint-Michel salt marshes, the mean density of Skylark was estimated (probably over estimated as previously explained) between 2.9 and 10.2 b.p. according to habitats of the salt marsh. These values, especially those in the habitats dominated by *Atriplex portulacoides*, tend to be higher than those in natural salt marshes (Glue, 1971; Greenhalgh, 1971) or arable land (Poulsen et al., 1998; Browne et al., 2000) and near or equal to those observed in set-aside and fallows (Poulsen et al., 1998; Toepfer & Stubb, 2001) or salted meadows (Williamson, 1967; Thiollay, 1968). The shrubby species *Atriplex portula-*

coides is one of the most productive plant species in European salt marshes (Boorman, 2003). It provides an optimum habitat for dense communities of marsh dwelling detritivorous crustaceans such as *Orchestia gammarella* (Pallas, 1766) and for diurnal wandering spiders as shown by recent studies (Laffaille et al., 2005; Pétillon et al., 2005). Skylark is originally a steppe bird species that selects during breeding season a 25-50 cm vegetation height (Wilson et al., 1997) and a 35-65% vegetation coverage (Toepfer & Stubb, 2001). This ground foraging species finds in *Atriplex* habitat, where the soil surface is partially bare, important food resources as indicated by regular observations of skylarks eating amphipods (Pétillon, pers. obs.). Moreover, skylarks, feeding their nestlings exclusively on insects and spiders during the first week of their life (Donald et al., 2001), find suitable conditions for chick rearing in *Atriplex* habitat. Selection of this habitat is thus related to both invertebrate abundance and availability of bare ground on which skylark forage.

European Quail is also a steppe-land bird that inhabits in grass vegetation. The European population was in serious decrease until the 1980s with the disappearance of the fallows and the use of the pesticides. European Quail is considered as "protected" in the Bern convention, and "in an unfavorable conservation status" in the Bonn convention. In Europe, this species is red-listed in six countries and its hunting is banned in eleven. In the Mont Saint-Michel salt marshes, European Quail appeared in 1981 (Lefeuvre, comm. pers.) in habitat dominated by *Elymus athericus*. This tall grass habitat is preferred by Quail for three main reasons (Aubrais et al., 1986): (1) its vertical structure like traditional wheat crops makes easier the moving by foot for this ground-dwelling species, (2) it provides important protection from avian predators and (3) it offers a shelter from the wind. Moreover an *Elymus athericus* community is also very productive (Boorman, 2003; Pétillon et al., 2005) and insect abundance is important for the diet of young quails (Combreau et al., 1990).

So, areas dominated by *Atriplex portulacoides* and *Elymus athericus* were respectively overridingly important for these two bird species with unfavorable European status. The role middle salt marshes in providing favorable habitats is particularly important in areas where intensive agriculture is increasing (Boorman, 2003). However *Elymus athericus* is invading the salt marshes to the detriment of habitats dominated by *Atriplex portulacoides* (Valéry et al., 2004). In the same way, moderate grazing increases plant diversity but over-grazing provokes partial destruction of plants (Lefeuvre et al., 2003). In the long term, the bird community is likely to be disturbed by decrease of habitat and trophic resources. The modification of bird community may perturb the whole food web and change particularly the highest levels represented by birds of prey and mammals. For both ecological and economical reasons, it is thus important to maintain a diversity of the practices of management (by natural evolution, pasture at various levels of intensity, mowing *Elymus athericus* to restraint its invasion) if one wishes to maximize bird diversity in term of biodiversity and particular threatened species.

REFERENCES

Aubrais O., Hémon Y.A. & Guyomarc'h J.-C. 1986. Habitat et occupation de l'espace chez la Caille des blés (*Coturnix coturnix coturnix*) au début de la période de reproduction. *Gibier Faune Sauvage*, **3**: 317-342.

Boorman L.A. 2003. Saltmarsh Review. An overview of coastal saltmarshes, their dynamic and sensitivity characteristics for conservation and management. JNCC Report, No. 334 Peterborough. 114 pp.

Bouchard V., Tessier M., Digaire F., Vivier J.-P., Valéry L., Gloaguen J.-C. & Lefeuvre J.-C. 2003. Sheep grazing as management tool in Western European saltmarshes. *Comptes Rendus Biologies,* **326**: 148-157.

Browne S.J., Vickery J. & Chamberlain D. 2000. Densities and population estimates of breeding Skylarks *Alauda arvensis* in Britain in 1997. *Bird Study*, **47**: 52-65.

Combreau O., Fouillet P. & Guyomarc'h J.-C. 1990. Contribution à l'étude du régime alimentaire et de la sélectivité des jeunes cailles des blés (*Coturnix coturnix coturnix*) dans la baie du Mont Saint-Michel. *Gibier Faune Sauvage*, **7**: 159-174.

Donald P.F., Muirhead L.B., Buckingham D.L., Evans A.D., Kirby W.B. & Gruar D.E. 2001. Body condition, growth rates and diet of skylark *Alauda arvensis* nestlings on lowland farmland. *Ibis*, **143**: 658-669.

Eybert M.-C., Geslin T., Questiau S. & Feunteun E. 2003. Shorebird community variations indicative of a general perturbation in the Mont Saint-Michel bay (France). *Comptes Rendus Biologies,* **326**: S140-S147.

Eraud C. & Boutin J.M. 2002. Density and productivity of breeding Skylarks *Alauda arvensis* in relation to crop type on agricultural lands in western France. *Bird Study*, **49**: 287-296.

Geslin T., Eybert M.-C., Lefeuvre J.C., Le Pajolec Y. & Questiau S. 2002. Salt exploitation and landscape structure in a breeding population of the threatened bluethroat (*Luscinia svecica*) in salt pans in western France. *Biological Conservation* **107**: 283-289.

Glue D. 1971. Saltmarsh reclamation stages and their associated bird life. *Bird Study,* **18**: 187-198.

Greenhalg M.E. 1971. The breeding bird communities of Lancashire saltmarsh. *Bird Study,* **18**: 199-212.

International Bird Census committee 1977. Censuing breeding birds by the IPA method. *Polish Ecological Studies*, **3**: 15-17

Jacobs J. 1974. Quantitative measurement of food selection, a modification of the forage ratio and Ivlev's electivity index. *Oecologia,* **14**: 413-417.

Laffaille P., Pétillon J., Parlier, E., Valéry L., Ysnel F., Radureau A., Feunteun E. & Lefeuvre J.-C. 2005. Does the

invasive plant *Elymus athericus* modify fish diet in tidal salt marshes ? *Estuarine, Coastal and Shelf Science*, **65**: 739-746.

Lefeuvre J.-C. 2000. La production végétale des zones humides. In: *Fonctions et valeurs des zones humides* (E. Fustec & J.-C. Lefeuvre eds), pp. 211-243. Dunod Press. Saint Just la Pendue.

Lefeuvre J.-C., Bouchard V., Feunteun E., Grare S., Laffaille P. & Radureau A. 2000. European salt marshes diversity and functioning: the case study of the Mont Saint-Michel bay, France. *Wetland Ecology and Management,* **8**: 147-161.

Lefeuvre J.-C., Laffaille P., Feunteun E., Bouchard V. & Radureau A. 2003. Biodiversity in salt marshes: from patrimonial value to ecosystem functioning. The case study of the Mont-Saint-Michel bay. *Comptes Rendus Biologies,* **326**: S125-131.

Lewis C. & Casagrande D.G. 1997. Using Avian Communities to Evaluate Salt Marsh Restoration. In : *Restoration of an urban salt marsh: an interdisciplinary approach*, vol. 100 (Casagrande D.G ed), pp : 204-236. Yale University New Haven, Connecticut

Moller H.K. 1975. Danish salt-marsh communities of breeding birds in relation to different types of management. *Ornis Scandinavica*, **6**: 125-133.

Pétillon J., Ysnel F., Canard A. & Lefeuvre J.-C. 2005. Impact of invasive plant (*Elymus athericus*) on the conservation value of tidal salt marshes in western France and implications for management: responses of spider populations. *Biological Conservation*, **126:** 103-117.

Poulsen J.G., Sotherton N.W. & Aebischer N.J. 1998. Comparative nesting and feeding ecology of skylarks *Alauda arvensis* on arable farmland in southern England with special reference to set-aside. *Journal of Applied Ecology*, **35:** 131-147.

Rocamora G. & Yeatman-Berthelot D. 1999. *Oiseaux menacés et à surveiller en France. Listes rouges et recherche de priorités. Populations. Tendances. Menaces. Conservation*. Société d'Etudes Ornithologiques de France / Ligue pour la Protection des Oiseaux. 560 pp.

Thiollay J.M. 1968. Densités estivales d'oiseaux dans quelques milieux herbacés de Vendée. *Terre et Vie*, **22:** 307-320.

Toepfer S. & Stubbe M. 2001. Territory density of the Skylark (*Alauda arvensis*) in relation to field vegetation in central Germany. *Journal für Ornithologie,* **142**: 184-194.

Valéry L., Bouchard V. & Lefeuvre J.-C. 2004. Impact of the invasive native species *Elymus athericus* on carbon pools in a salt marsh. *Wetlands*, **24**: 268-276.

Williamson P. 1967. A bird community of accreting sand dunes and salt marsh. *Bird study*, **60:** 147-157.

Wilson J.D., Evans J., Browne S.J. & King J.R. 1997. Territory distribution and breeding success of skylarks *Alauda arvensis* on organic and intensive farmland in southern England. *Journal of Applied Ecology* **34**: 1462-1478

Zahl S. 1977. Jack-knifing an index diversity. *Ecology,* **58**: 907-913.