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Spiders as indicators of microhabitat changes after a grass invasion in salt-marshes: synthetic results from a case study in the Mont-Saint-Michel Bay

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Abstract: Salt marshes are simple ecosystems characterized by extreme conditions; two abiotic factors appear to structure habitats: regular submergence and the resulting soil salinity. These ecosystems support highly specialized species that have a high conservation value. In the last ten years, invasion by *Elymus athericus* (Poaceae) has led to a major change in vegetation cover (including changes in micro-habitats architecture) in salt marshes of the Mont-Saint-Michel Bay (France). In this study, we tried to determine whether ecological structure and high conservation value of invaded salt marshes had been preserved using spiders as indicators. The functional groups, abundances and flood resistance abilities of spider communities were compared between initial and invaded stations during 2002 and 2003. Invasion by *E. athericus* had both positive and negative consequences for spider communities, in particular for the dominant halophilic species. *Pardosa purbeckensis* populations clearly declined in habitats invaded by *E. athericus*, whereas *Arctosa fulvolineata* seemed to benefit greatly from the invasion. Functional groups were strongly affected by the plant invasion. Relation between the habitat change (vegetal invasion) and changes in the spider communities (both in terms of functional groups and halophilic species) confirms the high value of this taxon as bioindicators. Lastly, we suggest using abundances of *P. purbeckensis* as a parameter likely to help monitoring further salt marsh evolutions (such as management).

Résumé. *Les araignées comme indicateurs de l'évolution des microhabitats après l'invasion de marais salés par le chiendent : synthèse des résultats obtenus en Baie du Mont Saint Michel.* Les marais salés sont des écosystèmes structurellement simples, dont les habitats sont soumis à deux contraintes originales : une immersion régulière et la salinité du sol qui en résulte. Ces écosystèmes abritent une biodiversité hautement spécialisée, qui contribue largement à leur valeur patrimoniale. Suite à l'invasion du chiendent *Elymus athericus* (Poaceae) depuis une dizaine d'années, les marais salés de la Baie du Mont-Saint-Michel (France) ont vu fortement évoluer leur couvert végétal, y compris l'architecture de leur micro-habitat. Lors de cette étude, l'hypothèse d'une modification de la structure écologique et de la valeur conservatoire des marais salés est testée. Les groupes fonctionnels, basés sur le mode de prédation des araignées, les abondances et les capacités de résistances à l'immersion des communautés d'araignées ont été comparés en 2002 et 2003 entre des habitats naturels et des habitats envahis. L'invasion par le chiendent a entraîné à la fois des modifications positives et négatives pour les peuplements d'araignées, en particulier pour les espèces halophiles dominantes. Ainsi les populations de *Pardosa purbeckensis* sont fortement réduites dans les habitats envahis, tandis que *Arctosa fulvolineata* semble tirer profit de cette invasion. Il a de plus

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été montré la forte réponse des groupes fonctionnels d'araignées à la progression du chiendent. La relation entre le changement d'habitat étudié (une invasion végétale) et les changements de peuplements d'araignées (tant au niveau des groupes fonctionnels que des espèces halophiles) confirme la forte valeur bio-indicatrice de ce groupe. Enfin, nous proposons de suivre les abondances de *P. purbeckensis* comme paramètre indicateur de futures évolutions de marais salés (notamment la gestion).

Keywords: Araneae; Bio-indicators; Invasive species; Salt marsh; Halophilic species.

Introduction

A bioindicator is defined as a qualitative or quantitative biological trait (from individual to community level) likely to indicate particular conditions of natural or artificial state and its change in the future (Blandin, 1986). The use of such biotic traits, instead of the usual abiotic parameters, is mainly justified by the sensitivity of their responses, but also by some ethical aspects such as conservation of biodiversity (Lévêque, 1994). Among the indicator traits, the so-called "indicator groups" are taxa or functional guilds used to compare environmental or micro-environmental conditions between ecosystems (Noss, 1990; New, 1995). Several specific ecological features emphasized the potential bioindicative value of spiders (see the review of Marc et al., 1999); they can be summarized as follows: (i) spiders constitute an abundant and diversified taxonomic group, (ii) specialized (stenotopic) species exist and can be considered as "indicator species", (iii) because spider families target preys differently, communities are divided into several functional groups according to their hunting habits: nocturnal or diurnal wanderers, ambush hunters, frame-web, sheet-web and orb web spiders. The variation of functional groups can be detected at the microhabitat level and for all vegetation strata in most European ecosystems (Canard, 1990; Ysnel et al., 1996; Ysnel & Canard, 2000), (iv) most individuals can be identified to species level and are of reasonable size, and the group can easily be sampled. It can thus be supposed that spiders are good candidates for general studies on habitat alterations. As a part of a project on ecosystem structure and functioning, we tested the reaction of spiders to habitat changes in salt marshes. These ecosystems are subjected to periodical tides and two original factors structure habitats: regular submergence and resulting soil salinity. These ecosystems therefore support highly specialized species, contributing to their high conservation value (e.g. Desender & Maelfait, 1999). Unfortunately, probably due to an increase of soil nitrogen coming from surrounding agricultural lands, Mont-St-Michel Bay was recently recovered by a native grass species, *Elymus athericus* (Link) Kerguélen (1983) (Poaceae). This nitrophilous grass, normally confined to the upper marsh, has invaded the lower parts of the marsh since 1990 and has replaced the initial vegetation (Valéry et al., 2004).

Such an extension (characteristic of an invasive species: Bockelmann & Neuhauss, 1999) raises the issue of possible biodiversity changes, which we want to evaluate using spiders as bioindicators, because they represent one of the major components of the salt marsh arthropod fauna (e.g. Meijer, 1977; Talley & Levin, 1999). We present here a set of synthetic results in order to answer the question: How do spider communities react to such a habitat change? In this study, we will focus on two bioindicative parameters: (i) spider functional groups (based on their predation habits) and (ii) the stenotopic (restricted to salt marshes) species. In this study, the dominant species (i.e. the most easy to sample species) are two lycosid species, *Pardosa purbeckensis* F.O. Pickard-Cambridge, 1895 and *Arctosa fulvolineata* (Lucas, 1846) (Fouillet 1986; Pétillon et al., 2004). Habitat use of these species has been studied by comparing relative (abundances: number of individuals by catch unit) and absolute (densities: number of individuals by surface) measurements in invaded and natural stations. Aerial and underground (roots) structures of vegetation are known to influence flood resistance and flood avoidance by terrestrial invertebrates (e.g. Foster & Treherne, 1976; Kneib, 1984). Therefore, we hypothesise that spiders can be influenced by the new habitat structure, potentially modifying their salt marsh resident status, here defined as a combination of salinity tolerance and flood resistance (Pétillon et al., 2004). The impact of *E. athericus* on the flood-resistance ability for the whole community, as well as for stenotopic species will then be studied. Finally, we discuss the potential role of spiders as suitable indicators to monitor future "natural" or artificial (i.e. management) changes in salt marsh ecosystems.

Material and methods

Study sites, sampling design and habitat characteristics

Mont Saint-Michel Bay (France) is a wide littoral zone located along the French coast of the English Channel (Latitude 48°40' N, Longitude 1°40' W) extending over 500 km^2. This area is a macrotidal system characterized by a high tidal range (mean tidal range = 10-11 m, maximum = 16 m). The intertidal area includes 40 km^2 of salt marshes that are only submerged during spring tides; the salt-marshes are delimited in their upper part by dikes that are not submerged during high tides.

In order to assess *Elymus* consequences on spider communities, “natural” stations (dominated by *Atriplex portulacoides*, Chenopodiaceae) and invaded stations (dominated by *Elymus athericus*, Poaceae) were compared at three different marsh levels at the ‘Ferme Foucault’ (the upper levels 1 and 2) and ‘La Rive’ (the lower level 3) sites. Natural (Nx) and invaded (Ix) stations were positioned at the same distance from the dike, because of an increasing soil salinity across the salt marsh westward (Pétillon et al., 2004). Stations were sampled from April to November 2002 and during June and July 2003 (see below for details). In order to determine if *Elymus* vegetal cover modifies species’ ability to resist flooding, three natural and three invaded vegetal communities were studied at each distance from the dike (i.e. level) at the ‘Vivier-sur-mer’ site. Samples were gathered before and after a spring tide (tidal range: 13.35 metres) in April 2004. In each station investigated, the vegetation was described four times within a radius of 1 m: litter depth (to the nearest mm), vegetation height (to the nearest cm), total vegetation cover and the percentage cover of each plant species (%).

Sampling techniques

Impact of *Elymus athericus* on spider communities. Cursorial (i.e. ground-living) spiders were sampled with pitfall traps, consisting of polypropylene cups (10 cm diameter, 17 cm deep) set into the ground such that the lips were placed at the soil surface. Ethylene-glycol was used as preservative, because it is not attractive for spiders (Topping & Luff, 1995). Traps were covered with a raised wooden roof to keep out rain and were visited weekly when tides permitted. Catches in pitfall traps were related to trapping duration and pitfall perimeter (Luff, 1975; Curtis, 1980), yielding an activity-abundance measurement (measurement of mobile individuals). Four pitfall traps were placed in each station (total of 24 traps).

In order to catch web-spiders, that are only caught in pitfall traps during periodical migrations, monthly standardized hand collections were conducted during May, June and July 2002. Each station was visited for one hour in the afternoon by three people. Mean and total richness were compared between habitats, both for species (number of species identified) and taxonomic (number of species identified plus number of immature taxa) richness. Relative abundances of functional groups (i.e. number of species per group) were compared between invaded and natural stations.

Total spider densities were estimated by the quadrat-flotation technique and compared between invaded and natural stations (I_2 and N_2). Homogeneous 0.25 m^2 areas were isolated by metallic quadrats (0.5 m width and 1 m height) set into the ground to a depth of 0.20 m. All vegetation was removed and stored in sealed bags to be sorted in the laboratory. Remaining spiders within the quadrat were then hand collected on the bare soil until none were visible. A pitfall trap was placed in the middle of the quadrat and was active until all remaining moving individuals were caught. During pitfall trap activity, each quadrat was covered by resistant plastic in order to avoid aerial contaminations (due to spider aerial dispersion by “ballooning”). At the time of pitfall trap collection, one last hand collection was carried out. The spider density was then obtained by the addition of individuals from the initial and final hand collections to the catches by both pitfall trap and vegetation samplings. Four replicates were used in each station, and this technique was repeated four times during June 2002.

Because measurements by pitfall traps can be influenced by microhabitat structure (e.g. Spence & Niemelä, 1994), we wanted to confirm comparison of abundances between invaded and natural habitats by absolute sampling. In order to compare the absolute densities (measurement of all individuals present on a surface) of the two dominant halophilic species – *A. fulvolineata* and *P. purbeckensis*, 1 m^2 areas were isolated by iron quadrats (1 m width and 1 m height). The methodology was the same as described above, but the vegetation was not removed. These larger quadrats gave more detailed results for densities of the two species. Eight spatial replicates were sampled in each vegetation type (i.e. invasive and natural), and this technique was used four times in June and July 2003 (i.e. 32 replicates per vegetation type).

Impact of *Elymus athericus* on flood resistance. In order to compare flood resistance abilities of spiders between natural and invaded habitats, four pitfall traps were placed in each station (total of 24 traps) and activated during the same duration (3 days), four days before and two days after the high tide (i.e. the time necessary to completely drain seawater). Catches were completed by hand collecting (1.5 hour per station before and after the high tide) during activation and collection of pitfall traps.

Data analyses

Mean environmental and community variables were compared using ANOVA tests if data had a normal distribution (according to Kolmogorov-Smirnov tests) or using Mann-Whitney tests if not. Compositions of communities in functional groups were compared using Chi square tests. All statistics were calculated using MINITAB version 12.1.

Results

Microhabitat changes in invaded habitats

Invasive habitat structure was very different from the natural one. In particular, invaded stations (*E. athericus*) differed from natural stations (*Atriplex portulacoides*) by their deeper litter and by their taller plant cover (respectively : 2.9 ± 0.4 cm vs 0.03 ± 0.03 cm, U-test, U = 329.0, d.f. = 29, p < 0.001 and 58 ± 6 cm vs 26 ± 1cm, U-test, U = 323.0, d.f. = 29, P < 0.001).

Impact of Elymus athericus *on spider communities*

Impact on the whole community. When comparing communities between invaded and natural plots, it can be noticed that total species and taxonomic (including immature taxa) richness were higher in invaded stations than in natural ones (respectively 33 vs. 27 for species richness and 42 vs. 30 for taxonomic richness: Table 1; taxonomic list: Table 3). Species and taxonomic richness were also higher in invaded stations than in natural ones. By each method, richness was significantly higher in invaded stations than in natural ones. Lastly, mean densities were significantly higher in invaded stations than in natural ones.

Spider communities differed significantly between invaded and natural vegetation in the relative abundance of functional groups (χ^2 = 172.01, d.f. = 5, p < 0.001). Sheet weavers and ambush hunters, and less markedly diurnal and nocturnal wanderers, decreased in invaded areas compared to natural areas, whereas the relative abundance of orb and frame weavers was proportionally higher in invaded stations (Fig. 1). The comparison of natural stations between 1984 and 2002 showed some temporal changes in functional groups with the same trends as after *Elymus* invasion (Fig. 1), namely a decrease of sheet weavers and nocturnal wanderers and an increase of diurnal wanderers, orb weavers and frame weavers.

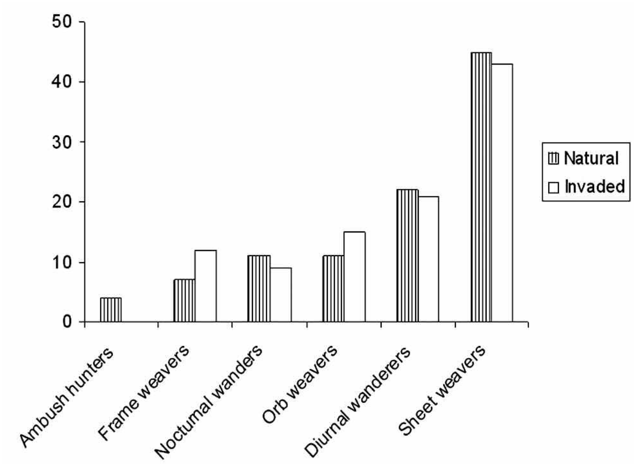

Figure 1. Relative abundance of functional groups (%) based on their number of species in natural and invaded stations (3 stations per vegetation, respectively 3176 and 3330 individuals).

Figure 1. Abondance relative des groupes fonctionnels (%) sur la base de leur nombre d'espèces dans les stations naturelles et envahies (3 stations par végétation, respectivement 3176 et 3330 individus).

Impact on the halophilic species. Catches by pitfall traps revealed that *Pardosa purbeckensis* abundances were significantly higher in natural plots than in invaded ones (Table 1). In accordance with this trend, *Pardosa purbeckensis* had a significantly higher density in natural plots. However, *Arctosa fulvolineata* had much higher densities in invaded plots than in natural ones, whereas its abundance did not significantly differ between the two vegetation covers (Table 1).

Impact of Elymus athericus *on flood resistance*

Impact on the whole community. Invaded stations presented a higher percentage of flood-resistant species than natural stations (respectively 94% vs 71%). This is explained by the disappearance of five species after the tide in natural stations whereas only one species did not resist flooding in invaded stations. After the tide, species richness was therefore higher in invaded stations than in natural ones (Table 2). Before the tide, we note once more the higher percentage of web-building species (orb and sheet weavers) in invaded areas than in natural ones (respectively 7% and 26% in invaded stations against 2% and 9% in natural stations: Figs. 2 & 3). On the contrary, diurnal wanderers appeared to be better represented in natural stations than in invaded ones (respectively 73% vs. 50%). Functional groups reacted differently to the tide in natural and invaded stations. After the tide, the functional groups of spider communities were almost the same as before in natural stations (χ^2 = 6.24, d.f. = 4, p = 0.182), whereas they differed significantly from pre-flood groups in invaded stations (χ^2 = 17.29, d.f. = 4, p = 0.002). In particular, the percentage of orb and frame weavers increased after tide in invaded stations whereas these groups remained constant or decreased in natural stations (Figs. 2 and 3).

Impact on the halophilic species. *Arctosa fulvolineata* presented comparable abundances before and after the high tide in invaded stations (Table 2), whereas its mean abundance significantly decreased in natural stations after the high tide. *Pardosa purbeckensis* showed significantly decreasing abundances after the high tide in invaded stations and constant abundances in natural stations (Table 2).

Table 1. Comparison of total densities (N = 4), richness (N = 12 for pitfall traps and N = 3 for hand collection), species abundances by pitfall trapping (10.number of individuals.day^{-1}.metre^{-1}, N = 12) and densities by quadrat flotation technique (number of individuals.m^{-2}, N = 12) between invaded and natural vegetation and significance by ANOVA (n.s.: not significant, *: p < 0.05, **: p < 0.01).

Tableau 1. Comparaison des densités totales (N = 4), de la richesse (N = 12 pour les pièges d'interception et N = 3 pour les chasses à vue), des abondances (10.nombre d'individus.jour^{-1}.mètre^{-1}, N = 12) et des densités par espèce entre végétation naturelle et invasive et significativité par ANOVA (n.s. : non significatif, * : p < 0,05 ; ** : p < 0,01).

	Natural plots			Invaded plots			F-ratio	P
	N_1	N_2	N_3	I_1	I_2	I_3		
Species richness	22	15	15	25	19	22		
Taxonomic richness	25	17	16	32	22	27		
Total species Richness		27			33			
Total taxonomic richness		30			42			
Mean Richness (pitfall traps)		8.8 ± 0.6			11.9 ± 0.9		9.19	**
Mean Richness (hand collection)		6.0 ± 0.6			8.7 ± 0.3		16	*
Mean densities (N ind/m^2)		31.8 ± 10.1			82.6 ± 17.2		6.46	*
Abundance of *P. purbeckensis*		93.9 ± 16.9			43.3 ± 5.6		8.04	**
Abundance of *A. fulvolineata*		11.2 ± 2.5			12.2 ± 2.4		0.08	n.s.
Density of *P. purbeckensis*		3.9 ± 1.2			1.4 ± 0.3		4.09	*
Density of *A. fulvolineata*		0.03 ± 0.03			0.4 ± 0.1		9.71	**

Table 2. Comparison of number of individuals, species richness (3 stations per vegetation type) and species abundances (number of individuals.day^{-1}.metre^{-1}, N = 12) before (B.t) and after (A.t.) the high tide in natural and invaded stations and significance by ANOVA (n.s.: not significant, *: p < 0.05, **: p < 0.01).

Tableau 2. Comparaison du nombre d'individus, de la richesse spécifique (3 stations par type de végétation) et de l'abondance par espèce (nombre d'individus.jour^{-1}.mètre^{-1}, N = 12) avant (B.t) et après (A.t.) la marée dans des stations naturelles et envahies et significativité par ANOVA (n.s. : non significatif, * : p < 0,05, ** : p < 0,01).

	Natural stations		F-ratio	P	Invaded stations		F-ratio	P
	B. t.	A. t.			B. t.	A. t.		
Total number of individuals	491	358			558	385		
Species richness	17	12			16	15		
Abundance of *P. purbeckensis*	3.4 ± 1.1	2.1 ± 0.5	1.00	n.s.	4.7 ± 1.1	2.0 ± 0.5	5.04	*
Abundance of *A. fulvolineata*	1.8 ± 0.5	0.4 ± 0.2	6.14	*	1.0 ± 0.3	0.8 ± 0.3	0.21	n.s.

Discussion

Consequences of Elymus athericus *invasion*

As a first conclusion, by modifying the ground surface micro-environment, the invasive *Elymus athericus* can be considered as an "ecological engineer" in the invaded plots. On the one hand, the increased density and diversity of spiders within the entire salt marsh may represent a gain of prey for arthropods consumers such as the numerous birds foraging in the salt marsh (see Eybert et al., this volume). But on the other hand, despite an increase of potential preys, such an invasion could reduce the fish nursery functions of the salt marsh at high tide (e.g. Laffaille et al., 1998) by strongly reducing the accessibility of resources due to the higher complexity of the invaded micro-habitat. Depending on the degree of change associated with the newly created vegetation structure, it is assumed that the impact of an invasive plant species on arthropod assemblages may vary from a minimal impact (no significant change) to a general alteration of the native invertebrate diversity (Toft et al., 2001; Standish, 2004). Invasion by *Elymus* caused changes in functional groups, but also in residual natural areas compared to the initial composition of functional groups (i.e. before invasion: Fouillet, 1986). These changes in the natural station community towards

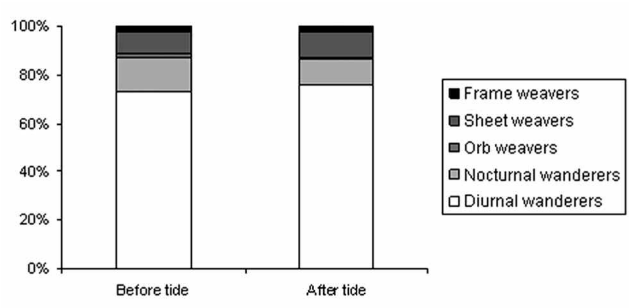

Figure 2. Relative abundance of functional groups before and after tide in natural stations (3 stations; 943 individuals).

Figure 2. Abondance relative des groupes fonctionnels avant et après la marée dans les stations naturelles (3 stations ; 943 individus).

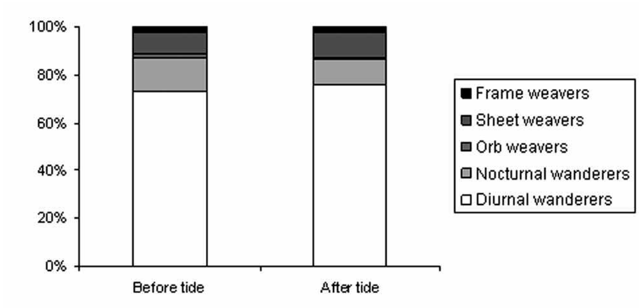

Figure 3. Relative abundance of functional groups before and after tide in invaded stations (3 stations; 849 individuals).

Figure 3. Abondance relative des groupes fonctionnels avant et après la marée dans les stations envahies (3 stations ; 849 individus).

Table 3. Taxonomic list by functional groups of spiders caught during the study (data collection from April 2002 to April 2004; Mont St Michel Bay, France) (names in bold are the halophytic species according to the literature).

Tableau 3. Liste taxinomique par groupes fonctionnels des araignées capturées lors de l'étude (données récoltées d'avril 2002 à avril 2004 ; Baie du Mont Saint-Michel, France) (les espèces en gras sont les espèces halophiles d'après la littérature).

Ambush hunters	Orb weavers
Thomisidae *Ozyptila simplex* (O.P. Cambridge, 1862)	Araneidae *Araneus diadematus* Clerck, 1757
Diurnal wanderers	Araneidae *Argiope bruennichi* (Scopoli, 1772)
Lycosidae *Alopecosa pulverulenta* (Clerck, 1757)	Araneidae *Larinioides cornutus* (Clerck, 1757)
Lycosidae *Pardosa prativaga* (L. Koch, 1870)	Araneidae *Neoscona adianta* (Walckenaer, 1802)
Lycosidae *Pardosa pullata* (Clerck, 1757)	Tetragnathidae *Tetragnatha extensa* (Linnaeus, 1758)
Lycosidae ***Pardosa purbeckensis*** F.O.P.- Cambridge, 1895	Sheet weavers
Lycosidae *Pirata piraticus* (Clerck, 1757)	Linyphiidae *Bathyphantes gracilis* (Blackwall, 1841)
Lycosidae *Trochosa ruricola* (Degeer, 1778)	Linyphiidae *Erigone atra* (Blackwall, 1841)
Frame weavers	Linyphiidae *Erigone dentipalpis* (Wider, 1834)
Dictynidae ***Argenna patula*** (Simon, 1874)	Linyphiidae ***Erigone longipalpis*** (Sundevall, 1830)
Theridiidae *Crustulina sticta* (O.P.-Cambridge,1861)	Linyphiidae *Oedothorax fuscus* (Blackwall, 1834)
Theridiidae ***Enoplognatha mordax*** (Thorell, 1875)	Linyphiidae *Oedothorax retusus* (Westring, 1851)
Theridiidae *Anelosimus vittatus* (Koch C.L., 1836)	Tetragnathidae *Pachygnatha clercki* Sundevall, 1823
Nocturnal wanderers	Tetragnathidae *Pachygnatha degeeri* Sundevall, 1830
Liocranidae *Agroeca lusatica* (L. Koch, 1875)	Linyphiidae ***Silometopus ambiguus*** (O.P.-Cambridge, 1905)
Lycosidae ***Arctosa fulvolineata*** (Lucas, 1846)	Linyphiidae *Stemonyphantes lineatus* (Linnaeus, 1758)
Clubionidae *Clubiona stagnatilis* Kulczynski, 1897	Linyphiidae *Tenuiphantes tenuis* (Blackwall, 1852)
Gnaphosidae *Zelotes latreillei* (Simon, 1878)	Linyphiidae *Tiso vagans* (Blackwall, 1834)

that of the invaded stations can be explained by individuals emigrating from invaded areas, especially if natural stations are surrounded by dense *Elymus* cover (Pétillon et al., 2005a). Differences in responses of functional groups after high tide require more investigation to better understand the impact of *Elymus* invasion on flood resistance abilities in the newly created micro-habitats. More than ten years after the grass invasion, the two dominant halophilic spider species are still present in invaded salt marshes but they strongly differ in their responses to the invasion. Clearly the nocturnal lycosid *Arctosa fulvolineata* benefits from invaded habitats whereas the diurnal species *Pardosa purbeckensis* is affected by the invasive species through a reduced frequentation and a worst flood resistance in invaded habitats. Competition for space and food between native and non-coastal species or microhabitat change led to a serious population decline for the dominant native species such as *Pardosa purbeckensis* (Pétillon et al., 2005b; this study) and could, in the near future, potentially result in local extinctions. Such extinctions would be damageable in a perspective of biodiversity conservation because the Mont Saint-Michel constitutes of the rare sites for these stenotopic species at a regional scale (Canard et al., 1990). A long-term survey of population dynamics of these species is then necessary in order to better assess the consequences of *Elymus* invasion. Because *E. athericus* is invading more and more salt marshes in Western Europe (Bockelmann & Neuhaus, 1999), it may be advisable to assess management techniques such as mowing in the Mont St-Michel bay (Pétillon et al., 2005a) to reduce negative effects of such invasions on the biodiversity of typical salt marshes of high conservation significance.

Bioindicative value of spiders in salt marshes

The two halophilic species studied in this study reacted differently to the invasion, both in terms of abundances or absolute densities. Although absolute spider densities were measured in June and compared to the annual relative abundance of spiders, there was a close correspondence between the significantly higher abundance of *Pardosa purbeckensis* and its higher density. For *P. purbeckensis*, the estimation of its activity abundance can be an effective warning of significant native community change, likely to be used in the future. For the other dominant species *Arctosa fulvolineata*, density was found to be a good indicator parameter of the invasion, unlike its abundance which remained equal in natural and invaded communities. However, it must be stressed that the capture rate (activity level) of a pitfall trap has to be carefully considered when comparing two communities. It is well known that the activity-level is a function of population density and trappability which is also influenced by microhabitat structure and movement behaviour (Topping & Sunderland, 1992). Therefore, we do not suggest using this species as a potential indicator because of its contrasted responses and because of difficulty of measuring its densities. At the community level the allocation of species to "functional groups" and the comparison of the variation in relative abundance of each functional group showed marked responses to environmental changes due to the plant invasion in the salt marshes. A relatively stable composition of the dominant functional group was observed before the invasion (Fouillet, 1986) and in the non-invaded natural plots (Pétillon et al., 2005a). Although it has been demonstrated that, within a functional group, the specific dominance of species could change from year to year (Canard, 1990; Ysnel et al., 1996), this constancy in the presence of functional groups for a given vegetation structure clearly emphasises that this indicator could provide key information about the stability in a given biotope. Functional groups of spiders can thus be considered as good indicators of habitat change in salt marshes (Pétillon et al., 2005a; this study) and could be used to monitor the effects of management on the restoration of initial macrohabitat environment in invaded areas.

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