Analysis of the spatial distribution of waders and benthic ressources to improve the definition and management of a marine protected area:

the example of the National nature reserve of the bay of Saint-Brieuc.

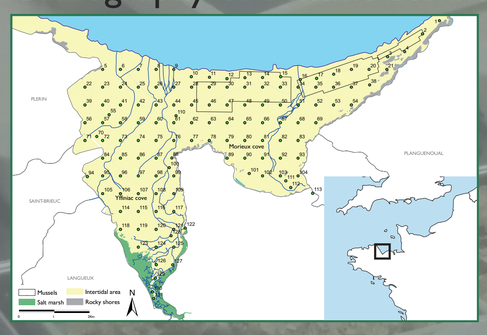
Ponsero A.[1], Sturbois, A.[1], Fournier J.[2], Desroy N.[3], Le Mao P.[3]

1 Réserve Naturelle Nationale de la Baie de Saint-Brieuc, site de l'étoile, 22120 Hillion, France, rn.saintbrieuc@espaces-naturels.fr
2 CNRS, UMR 7208 BOREA, Station Marine MNHN, 38 rue du Port Blanc, 35801Dinard cedex, France
3 IFREMER, laboratoire environnement ressource, 38 rue du Port Blanc, 35801Dinard cedex, France

The creation of a marine protected area, and its long-term management, needs an accurate knowledge of conservation issues. In a context of over-wintering waders, high tide roosting sites of intertidal areas are often better known that foraging sites, and are frequently used to spatially define protected areas for waders. On such ecosystems the birdlife in particularly waders are linked to bio-morpho-sedimentary characteristics. The distribution of shorebirds on the sand-flat depends on the type and the density of prey, their accessibility, the various types of sediment, and the events that may disturb birds or limit the accessibility of food resources. The delimitation of a protected area in order to protect and conserve overwintering waders should integrate all of these aspects. In the bay of Saint-Brieuc, a site of international importance for overwintering birds, benthic macrofauna and sedimentary facies has been identified and mapped. A study of the spatial distribution of the four main species of waders depending on their activities has as well been realized. The current analysis is based on bio-sedimentary and spatial distribution of birds data-matching, and on the comparison of potential foraging habitats with habitats that are currently exploited by birds. This kind of approach allows managers to identify important areas for conservation of birds, to assess the impact of disturbance and management on effective use of potential habitats, and to improve the understanding of the benthic resources/birds/human activities system.

Macrobenthos is an essential element for the functioning of estuarine or intertidal ecosystems. Many authors have highlighted the predominant function of this compartment in benthic and pelagic foodwebs, in particular its nutritional importance for birds. The spatial distribution of waders is strongly connected with the location of food and consequently depends on benthic assemblages characterized by important species composition and strong biomass. One of the difficulties in identifying such trophic relationships under natural conditions is to clearly know, concomitantly, the resource and modalities of exploitation by predators.
In this study, we aimed to combine, at large spatial scale, the use of intertidal space by waders in relation to physical (tidal fluctuations) and biological (distribution of trophic resource) data to define the contribution of each factor. This approach based on the combination of accurate spatial distribution of waders depending on their activity, bibliography of bird diet, macrobenthos data, type of sediment, and information about human activities is used to compare the potential foraging habitats with habitats that are currently exploited by birds. The study was conducted on an area of 2,900 ha (located in the bay of Saint-Brieuc) exposed to a megatidal regime, which one third is classified as a national nature reserve and gives a strong protection of all of the high tide roosting sites. Since some feeding areas are localized outside of the protected perimeter, determining their relative importance will help to define the necessity or not to preserve and manage a larger area to encompass the diverse requirement of bird species. Expected results for managers concerned the identification of functional areas with strong conservation issues for preservation of waders.

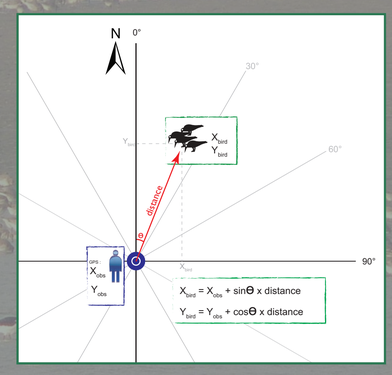
Cartography of benthic communities and sedimentary facies



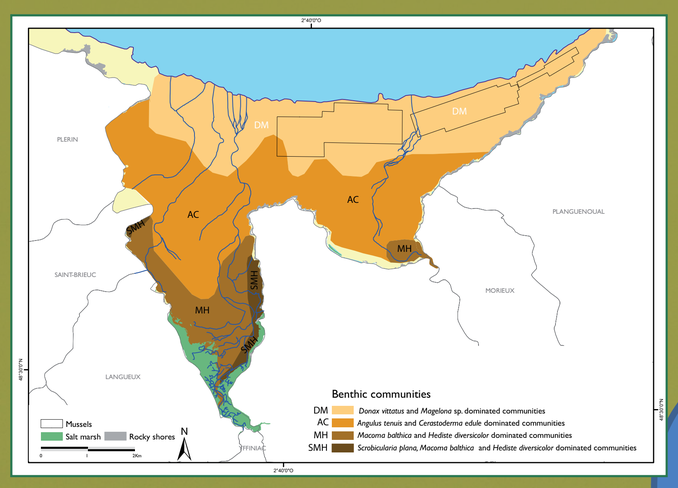
The distribution of macrofauna was established from a survey conducted in october 2010. We chose to sample at the beginning of the autumn to describe benthic communities and trophic potentialities preceding birds arrival. We used a regular sampling network of 131 stations 500m apart and covering the whole of the 2,900 ha intertidal area. On each station we realised, three samples of benthic macrofauna, two samples of sediment and a measure of the shearing strength of sediment. We also have an altimetry map of the tidal area.

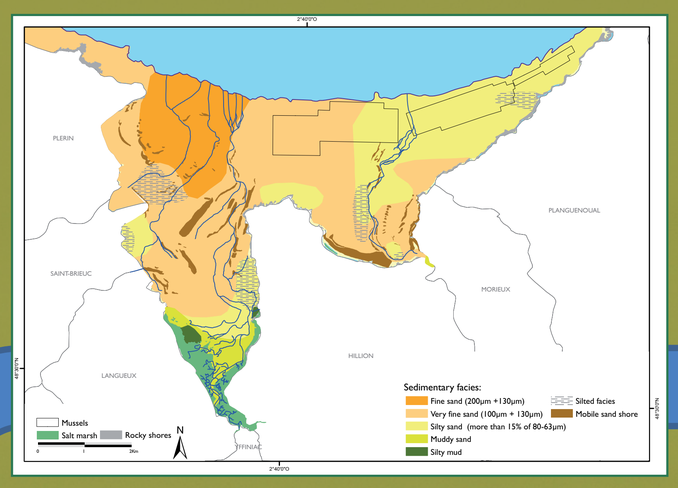
Identification of the foraging areas

Four of the most abundant wader species were studied during the winters of 2010/11 and 2011/12: Eurasian Oystercatcher (*Haematopus ostralegus*), Eurasian curlew (*Numenius arquata*), Bar-tailed godwit (*Limosa lapponica*), Redknot (*Calidris canutus*). Unpredictable movements of birds and viewing distance do not allow to follow fixed points of observation. So, it consists of following birds after movements.
For each group of birds, we noted the total number of individuals and the number of birds which were feeding in order to determine the proportion of feeding birds. Counting birds is realised with a telescope. The position of the groups is determined with a laser range-finder binocular which provides the distance and viewing angle from North. The position of the observer is obtain with a Global Positionning System, and the position of birds is calculated using trygonometry. The laser range-finder binocular takes effective measures up to 700 meters which limits disturbance of birds. Time is also noted to replace the observation in relation to tide conditions.

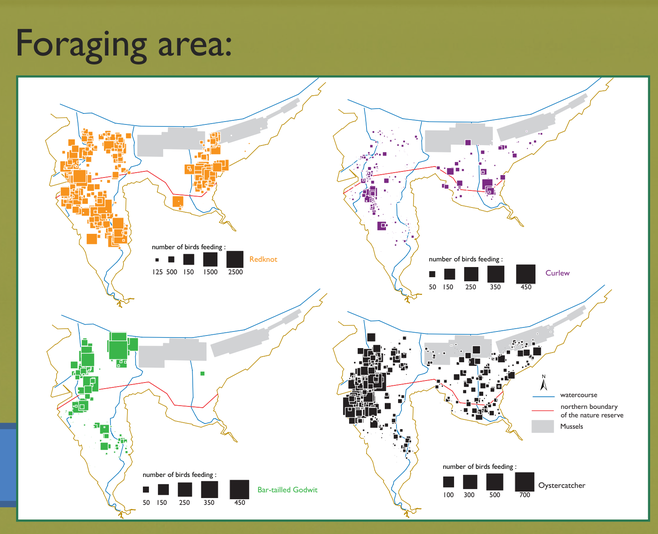


Benthic communities and sedimentary facies:



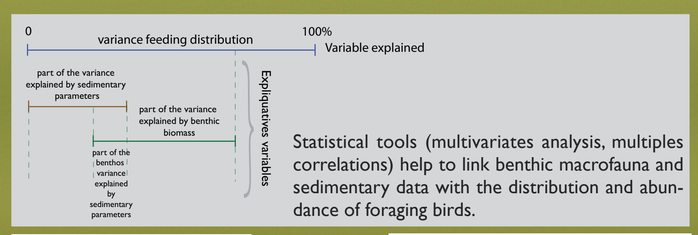


Foraging area:

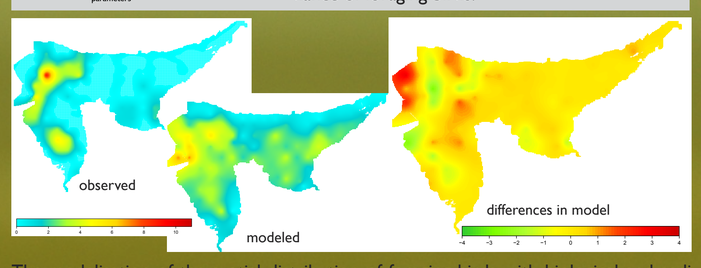


The study of the spatial distribution of waders highlights a different use depending on their activity. For the majority of birds, roosting sites are localized on high part of the intertidal area and used during high tide. The distribution of feeding birds is not homogeneous. Some foraging areas represent major importance for one or more species of birds. Other areas, such as mussels beds or compacted sediments, are poorly frequented.

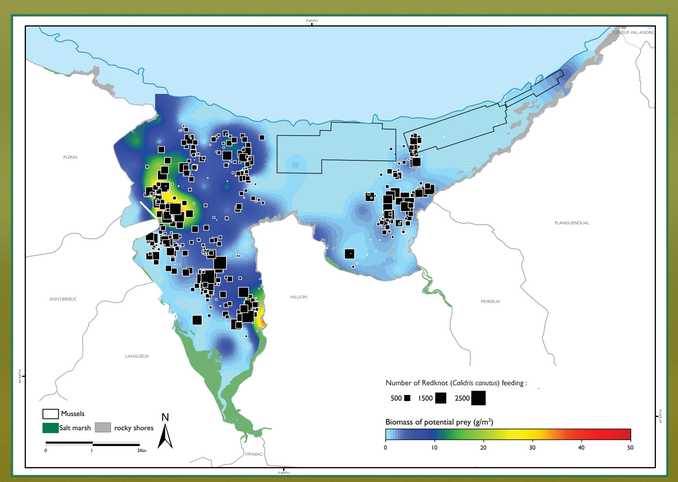
Exploring relationships habitat/prey/predator:



Statistical tools (multivariates analysis, multiples correlations) help to link benthic macrofauna and sedimentary data with the distribution and abundance of foraging birds.

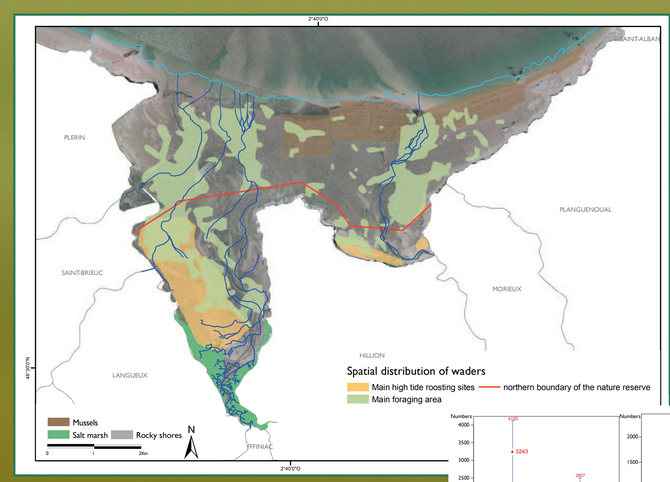


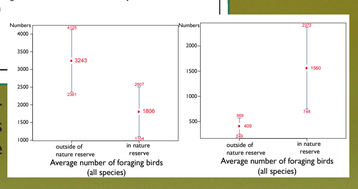
The modelisation of the spatial distribution of foraging birds with biological and sedimentary parameters help to produce a predictive map of the potential use of the intertidal area. These results are then compared with current birds observations. These modelisation tools facilitate a better understanding of which environmental parameters influence the presence and the abundance of birds on the sandflat.



The use of the intertidal area by birds depends on type and density of preys, their accessibility, the sediment characteristics, but also on events which cause local disturbance or limit the accessibility of feeding resources. The data set allows comparing potential habitats with currently foraging habitats to analyse the compatibility of a benthic resources/birds/human activities system.

Birds and marine protected area:



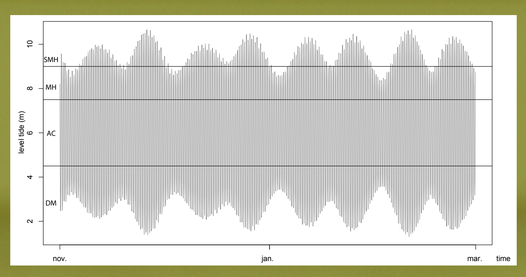


One third of the intertidal area is classified as a national nature reserve. If the reserve effectively protects high tide roosting sites, birds mainly forage outside the reserve.

Availability of foraging habitats:

The analyse helps to identify variation of the diet as new foraging habitats become available during ebb tide. The tide regime and bathymetry lead to important variations of foraging area really available and attractive for waders. To compare the use of different habitats by waders and the biomass that might be consumed, it requires weighting the number of birds with the surface truly available.

Benthic communities	height of land emergence (m)	duration of exposure will winter (h)	%	duration of exposure will average per day (h)
SMH	9	2442	84	20.2 ± 2.26
MH	7.5	1867	64	15.4 ± 0.89
AC	4.5	1039	36	8.5 ± 0.82
DM	< 4	247	8	3.5 ± 1.43



Cartographies of main foraging areas and distribution of benthic assemblages allow managers to identify functional areas with strong conservation issues. It also help to study potential feeding habitat compared with currently exploited habitat, and to analyze the compatibility of a complex benthic resources/birds/human activities system. This approach focused on the functioning of ecosystems can be easily adapted in other bays or estuarines to determine the perimeter of a project of marine protected area.

Acknowledgment
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