The MPA "Parc naturel marin d'Iroise" (France, Brittany), a zone of high conservation value for kelp forest biodiversity

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Summary
The MPA « Parc naturel marin d'Iroise » (PNMI) aims to know and protect the marine environment and promote sustainable maritime activities. In this MPA, kelps form large underwater forests that dominate the low intertidal to high subtidal zone and two kelp species are currently harvested: *Laminaria digitata* and *Laminaria hyperborea*. Our aim was to explore the conservation value of the PNMI regarding kelp forest biodiversity by characterizing and comparing this zone to other regions of Brittany regarding environmental conditions, genetic diversity of the two harvested kelp species and species diversity of seaweed communities living beneath the kelp canopy. We showed that, together with the Morlaix Bay, the PNMI constitutes a cold resilient water pocket surrounded by warmer and less resilient ones. The use of genetic tools revealed that both *L. digitata* and *L. hyperborea* populations exhibit high levels of genetic diversity within the PNMI and the Morlaix Bay; moreover, our results suggested that *L. digitata* populations in these two regions display unique genetic diversity and may have an exporting role to adjacent regions. The PNMI and the Morlaix Bay also displayed highly diverse seaweed communities and might constitute a refuge area from climate change for some red seaweed species.

Introduction
The natural marine parks ("parcs naturels marins") constitute one of the 15 categories of marine protected areas that exist in France. They aim to fulfill three objectives: i) to know the marine environment, ii) to protect the marine environment and iii) to promote sustainable maritime activities. The « Parc naturel marin d'Iroise » (PNMI) has been the first French natural marine park to be created in 2007 in the Iroise Sea (western Brittany), a region presenting a high diversity of species and habitats that support tourism & fisheries activities. In particular, the PNMI harbours several habitat-forming kelp species emblematic of cold to temperate rocky shores that constitute a habitat for a myriad of other marine organisms, of which two are harvested in Brittany for their alginate contents: *Laminaria digitata* and *Laminaria hyperborea*. These two species and the biodiversity they shelter are therefore facing at least two kinds of pressures: climate change (that is of particular importance for these cold-water organisms) and harvesting. Moreover, our knowledge of the subtidal flora of Brittany is far from complete although the flora of Atlantic European waters is considered as one of the best documented flora throughout the world (see e.g. Dixon and Irvine 1977). Within this context, our objective was to explore the conservation value of the PNMI regarding kelp forest biodiversity by characterizing and comparing this zone to other regions of Brittany regarding environmental conditions, genetic diversity of the two harvested kelp species and species diversity of seaweed communities living beneath the kelp canopy.

Materials and methods
Our study area covers the ca 400 km coastline of Brittany that we divided in four regions: north-eastern Brittany, north-western Brittany, western Brittany (including the PNMI) and southern

Brittany. We compiled mean and amplitude of three abiotic parameters over the last twenty years: sea surface temperature, chlorophyll a concentration and concentration of suspended particulate inorganic matter. Across 20 sites located in St Malo Bay (north-eastern Brittany), Morlaix Bay (north-western Brittany), the PNMI and southern Brittany, we sampled *L. digitata* and *L. hyperborea* populations (ca 30 individuals by site and by kelp species) as well as their understorey seaweed communities (3 quadrats of 0.1 m^2 by site and by kelp species). Genetic diversity of kelp populations was characterised using microsatellite markers (Billot et al. 1998; Coelho et al. 2014) and data analyses methods are detailed in Couceiro et al. (2013) and Robuchon et al. (2014). Seaweed species were identified using a combination of morphological and molecular characters (detailed in Robuchon et al. in revision). Species distribution modelling was realised for 10 red seaweed species on the basis of the three aforementioned abiotic parameters (detailed in Gallon et al. in press).

Results and discussion

The analysis of sea surface temperature trends over the last twenty years revealed that western Brittany (including the PNMI) and north-western Brittany (including the Morlaix Bay) form a cold and resilient water pocket surrounded by warmer and less resilient ones: along the Brittany coastline, temperature conditions do not follow a classical South-North gradient but rather form a mosaic of contrasted temperature conditions (Gallon et al. in press). The use of genetic tools revealed that both *L. digitata* and *L. hyperborea* populations exhibit high levels of genetic diversity within the PNMI and the Morlaix Bay in comparison to southern Brittany and north-eastern Brittany (Robuchon et al. 2014). Moreover, our results suggested that *L. digitata* populations in these two regions display unique genetic diversity and may have an exporting role to adjacent regions (Couceiro et al. 2013). The PNMI and the Morlaix Bay also displayed highly diverse seaweed communities whereas seaweed diversity was minimal in St Malo Bay. In addition, results of species distribution niche modelling suggest that the particular temperature conditions in western Brittany (including the PNMI) and north-western Brittany (including the Morlaix Bay) might turn them into a refuge area from climate change for some red seaweed species (Gallon et al. in press).

All these findings indicate that both the PNMI and the Morlaix Bay are of high conservative value regarding kelp forests biodiversity because of their unique temperature conditions, their high diversity at both the intra (genetic diversity) and the inter specific (species diversity) organisation levels and the unique diversity and exporting role of their *L. digitata* populations.

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