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First record of *Halidrys siliquosa* on the Portuguese coast: counter-intuitive range expansion?

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The occurrence of the pod weed, Halidrys siliquosa*, is recorded for the first time on the Portuguese coast. Several specimens of this brown algae were observed attached to the rocky surface in tide pools at 41°44′10″N 8°52′34″W, extending southward its previously known geographical distribution. The observed shift is inconsistent with general predictions of species migrations under warming climate conditions, which anticipate poleward shifts rather than southern expansions. Although more data will be required to undoubtedly uncover its cause, the recently observed range expansion raises important questions about the generalization of the previously stated biogeographic rules.*

Keywords: *Halidrys siliquosa*, biogeography, climate change, intertidal, Portugal, range limit

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INTRODUCTION

Halidrys siliquosa (Linnaeus) Lyngbye is the only species of this genus that can be found on the European coast. It is a perennial macroalga (Cabioc'h *et al.*, 1992; Buschbaum *et al.*, 2006) with a life span of at least three years (Moss & Lacey, 1963). Data from northern England showed that this species displays reproductive seasonality: in the first year only vegetative growth occurs; reproductive organs develop during the late summer and autumn and gamete discharge occurs from winter to early spring (Moss & Lacey, 1963).

Halydris siliquosa has a wide vertical range from pools at high water spring tides (HWST) to below the sublittoral fringe. On the most sheltered locations it can be found in the sublittoral and in rock pools below low water neap tides (LWNT), while on exposed locations it frequently occurs in deep pools in the eulittoral (Moss & Lacey, 1963). *Halydris siliquosa* is a common species in the intertidal zone from the north of the Scandinavian Peninsula (Luning, 1990) to Brittany, in north-west France (Crisp & Fischer-Piétte, 1959). Towards the south its density decreases progressively and this species is completely absent on the French Basque coast (Figure 1). Like many northern species, colonization of shores in this warmer region fails, even under a continuous supply of stranded fertile plants arriving from the north (Crisp & Fischer-Piétte, 1959). Throughout the northern Spanish coast, this species displays a scattered distribution (for a review, see Margalet & Navarro, 1990). Its historical southern range limit is located at the Galician province, in the Rías Baixas region. Several authors confirmed the existence of *H. siliquosa* in this area, although most of the references are of isolated or stranded specimens (for example Hamel, 1928; Miranda, 1934; Fischer-Piétte, 1955, 1963). However, at least in the northern Rías of Coruña, Muros, Arosa and Pontevedra, some subtidal populations have been recorded (e.g. Bárbara & Cremades, 1996) in locations sheltered by the sinuous coastline and under strong upwelling influence (see Otero-Schmitt & Pérez-Cirera, 2002). The southernmost individuals ever observed were found in the early 1930s inside the Ría of Pontevedra (Miranda, 1934).

The Portuguese intertidal communities have been extensively surveyed since the mid 1950s (Fischer-Piétte, 1958, 1963; Ardré, 1970; Santos, 1994, 2000; Boaventura *et al.*, 2002; Araújo *et al.*, 2005, 2006; Pereira *et al.*, 2006). Nonetheless, *Halidrys siliquosa* was never observed attached to rocky substrate. Some stranded specimens were found during the 1930s (Rodrigues, 1963; Ardré, 1970), but apparently populations never established successfully in northern Portugal.

MATERIALS AND METHODS

Sampling effort on the intertidal communities of northern Portugal has significantly increased in the last decade. Since the onset of a suite of monitoring studies started in the early 1990s (see Santos, 1994, 2000), extensive data on seaweed abundance and distribution has been obtained by the

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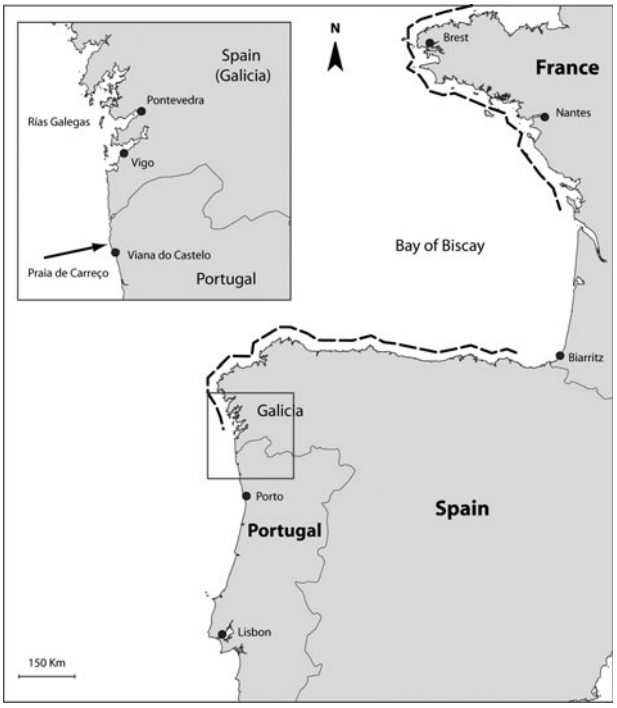

Fig. 1. Distribution range of *Halidrys siliquosa* in south-western Europe. Historical distribution is depicted by the dashed line. Inset figure represents a magnification of northern Portugal and southern Galicia. The new reported boundary is signalled with an arrow.

authors for this particular area. The majority of rocky shores, including Carreço, have been surveyed from two to four times per year, and in some years surveys were carried out monthly (1993–1996 and 2000–2002). Typical surveys included *ad libitum* transects and both fixed and haphazardly placed quadrats at several shore heights, covering the red and brown algal turfs, sabellarian reefs, pools, mussel and barnacle zones (see Stephenson & Stephenson, 1949). However, *Halidrys siliquosa* was never observed, neither stranded nor attached to the substrate. Subtidal surveys in 2003 and 2004 confirmed the absence of the species in this area.

While some of the newly observed specimens were collected and preserved in herbarium for reference, others were left *in situ* and the reproductive cycle was re-assessed throughout the autumn and winter. The collected specimens are deposited at the marine reference collection of CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, University of Porto, Portugal.

RESULTS AND DISCUSSION

In the summer of 2006 several individuals were observed for the first time in Portugal, at Praia de Carreço (41°44′10″N 8°52′34″W), near Viana do Castelo. Specimens were firmly attached to the rock surface, in several deep pools in the lower eulittoral (Figure 2).

Since Ardré (1957) observed fruiting *Halidrys siliquosa* in the north-western Spanish coast during February in the early 1950s, this newly established population was monitored until the end of the winter of 2007. Although individuals survived at least until March 2007, none showed signs of reproductive development. This observation does not necessarily mean

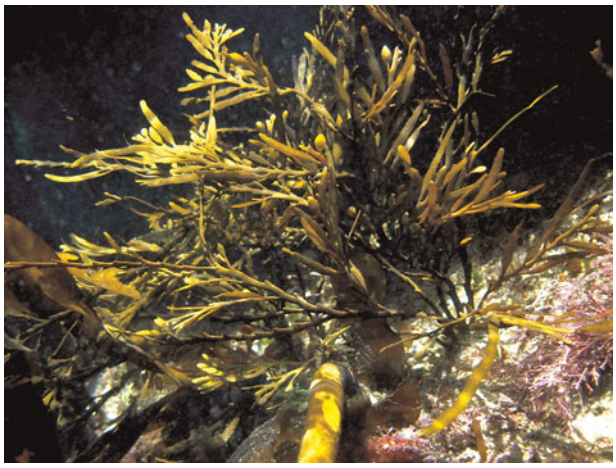

Fig. 2. *Halidrys siliquosa* in a tide pool in the Praia de Carreço, northern Portugal.

that the species is unable to reproduce at Praia do Carreço, since it is known that this algae only attains sexual maturity at the age of two years (Moss & Lacey, 1963).

Halidrys siliquosa produces large, rapidly sinking zygotes with restricted dispersal ability. Some may settle as far as 1 km from the parent algae, but probably most settle within a few metres (Norton, 1992). Although detached, floating adults may offer another potential route for dispersal, this mechanism is thought to be ineffective for most species of macroalgae (van den Hoek, 1987). The highly regionalized distribution of *Halidrys siliquosa* has been attributed to lack of long-range dispersal success (Wernberg *et al.*, 2001). The reduced dispersal ability may be slightly enhanced by a favourable hydrographic regime (Norton, 1992). Unexpectedly, the fertile period of this algae occurs during the winter months (Ardré, 1957; Moss & Lacey, 1963), coinciding with a predominance of northward currents off north-western Iberia (Pingree & Le Cann, 1989; Garcia-Soto, 2004), which do not favour the observed range expansion.

The observation of *Halidris siliquosa* at Praia do Carreço is a clear shift (roughly 80 km) of the previous southern distributional boundary at Ría de Pontevedra (Miranda, 1934). Given that during the last decades an increase in temperature has been documented for this area (Lemos & Pires, 2004; Lemos & Sansó, 2006; Lima *et al.*, 2006), the observed shift is inconsistent with general predictions of species migrations under warming climate conditions, which anticipate poleward shifts rather than southern expansions (Hughes, 2000; Walther *et al.*, 2002). Large brown macrophytes are sensitive indicators of climate change (see Helmuth *et al.*, 2006). Some of these species have their southern distributional limits in the northern Portuguese coast (Ardré, 1970), which have remained stable until present (Santos, 1994, 2000). However, a few species, such as *Himanthalia elongata* (Linnaeus) S.F. Gray and *Pelvetia canaliculata* (Linnaeus) Decaisne & Thuret, are known to be retreating northwards (Santos, 2000), thus in agreement with current knowledge of species responses to climate change. It is possible that stronger equatorial winds originated by the warming process lead to an intensified upwelling, as already reported for the north-east Pacific (Snyder *et al.*, 2003). That would cause a counter-intuitive expansion of cold-water low-shore and subtidal species. Nonetheless, this hypothesis lacks support since recent evidence suggests that upwelling

has been decreasing in the Portuguese coast (Lemos & Pires, 2004). Another hypothesis is that the current shift is part of the natural variability of this species' range dynamics. Still, this new record is of paramount importance for the study of climatic-driven biogeographic changes, for instance, whenever bioclimatic envelope models are to be developed. Only this level of spatial detail enables the partition of climate effects from natural small-scale spatial variability.

The present results emphasize the importance of taking into account the synchrony between climatic oscillations and species' population dynamics (Zacherl *et al.*, 2003) as well as accurate records of species distribution. Together with other species whose distributional limits are in a shifting process (see Lima *et al.*, 2006), *Halidrys siliquosa* is ideal for a continuous study, which will definitely help to build more accurate predictive models on how species ranges are likely to shift in response to global climate change.

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