

# Coastal upwelling areas as safe havens during climate warming

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#### 1 COMMENTARY

### 2 Coastal upwelling areas as safe havens during climate warming

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Seaweeds have long been recognized as "ecosystem engineers" and carbon sinks in 8 9 coastal marine ecosystems. However, recent ocean warming has had drastic eco-physiological impacts on seaweed assemblages and hence coastal community 10 structure (Wernberg et al., 2011, 2013). Seaweeds, particularly species that prefer 11 12 lower water temperatures, are facing imminent threat and will experience strong population-size reductions at low-latitude range limits (Wernberg *et al.*, 2011, 2013). If 13 they fail to acclimatize/adapt eco-physiologically to these new stressful conditions or 14 15 fail to track more suitable habitats moving poleward, they will eventually become extinct (Wernberg et al., 2011, 2013). Understanding how climate change affects 16 seaweed distribution shifts may allow for the identification of potential refugia where 17 these species and their associated biota can retreat to and persist; this, in turn, will 18 offer pivotal conservation insights for sustaining biodiversity. 19 20 So, is there any chance for coastal temperate species to persist in global warming 21 scenarios, even at their low-latitude range limits? Fortunately, the answer seems to be "yes". In a recent issue of the Journal of Biogeography, Lourenço et al. (2016) found 22

that the brown alga Fucus guiryi Zardi, Nicastro, Serrão & Pearson persists in several 23 upwelling areas along the coasts of south-western Iberia and north-western Africa 24 25 where sea surface temperatures (SST) have undergone significant warming during the last decades. These southern refugia have retained distinctive genetic pools, 26 27 highlighting the fundamental potential of coastal upwelling systems to maintain regional or global marine biodiversity threatened by climate change. Interestingly, a 28 study involving both phylogeography and ecological niche modeling have indicated 29 30 that the southern upwelling centres of the Canary Current were stable refugia for 31 another temperate brown alga (Saccorhiza polyschides (Lightfoot) Batters) during the warmer Mid-Holocene (Assis et al., 2016). 32 Coastal upwelling regimes are located along continental margins where equatorial 33 34 winds push surface waters offshore and replace them with deeper, cold, nutrient-rich waters, enabling higher primary production and colder SST than surrounding areas 35 (Wang et al., 2015). These current systems play a crucial role in structuring the 36 37 abundance and richness of pelagic plankton, and hence coastal marine ecosystems and 38 fisheries. It has been proposed that global climate change might intensify upwelling regimes (Wang et al., 2015), allowing for the persistence of localized extensions of cold 39 water embedded in warmer coastal waters for the years ahead and leading to more 40 drastic gradients of oceanic conditions in these regions. However, these trends are not 41 spatially homogeneous; if upwelling is expected to effectively strengthen along the 42 poleward portions of these currents, it could diminish along equatorial coasts (e.g. 43 along north-western Africa for the Canary Current; Wang et al., 2015). So, while some 44

evidence suggests that these systems could be resilient to anthropogenic climate 45 change, their fate remains uncertain due to the large number of physical and 46 47 biogeochemical factors that influence ecosystem processes (Byrnes et al., 2011; Wang et al., 2015). 48 49 In spite of the clear importance of coastal upwelling systems as potential refugia for marine biota facing ocean warming, little attention has been paid to the diversity and 50 dynamics of seaweeds in these areas. However, Ormond & Banaimoon (1994) 51 52 reported that along the coast of southern Yemen, the maximum growth of intertidal 53 macroalgal assemblages followed the onset of elevated nutrient levels driven by intense southern Arabian coastal upwelling. On the other hand, Leliaert et al. (2000) 54 described a drastic change in seaweed community composition around the Cape 55 56 Peninsula of South Africa in relation to oceanic conditions (i.e. the Atlantic side is dominated by the Benguela upwelling system while no upwelling occurs within False 57 Bay). Such evidence indicates that coastal upwelling systems greatly influence the 58 59 diversity and biogeographic patterns of coastal marine macroalgae. 60 The newly published work by Lourenço et al. (2016) has extended our understanding of how upwelling systems have acted as climatic refugia and how these systems have 61 influenced the evolution and biodiversity of seaweeds. Comparing historical and 62 recently collected data of algal presence and coverage along the North Atlantic, the 63 authors were able to confirm that the range of F. guiryi is shrinking and that, south of 64 65 37°N, the species has disappeared except near upwelling centres that act as cold-water refugia. Moreover, information from nine microsatellite loci shows clear genetic 66

uniqueness of the remaining southern populations, suggesting that these 67 southernmost populations should potentially be targeted in future conservation and 68 69 management plans. One could also wonder about the possible importance of the southernmost populations for the evolutionary potential of the species. Indeed, 70 71 populations of genetic variants specifically encountered in the warmer areas of F. guiryi's range could potentially be undergoing adaptive evolution to ocean warming 72 conditions. However, even if upwelling centres show certain resilience to ocean 73 74 warming (Wang et al., 2015; Assis et al., 2016; Lourenço et al., 2016), one might ask 75 how long they will act as refugia. Are these southern refugia sufficiently stable to allow remnant populations to adapt to new climatic conditions or even only to survive until 76 77 conditions become favourable again - if ever? Lourenço et al. (2016) reported that 78 relict populations of F. guiryi are small and sparse, and processes linked to the Allee effect (i.e. negative effects of decreasing population density on fitness) or genetic drift 79 could greatly increase this species' vulnerability to extinction. Future studies of 80 81 recruitment patterns in relict populations of F. guiryi would be interesting considering that Fucus is a perennial genus and some areas where it is found could be suitable for 82 adult survival but not for successful reproduction; these areas could be mistaken for 83 refugia. Moreover, some non-climatic factors have also been demonstrated to impose 84 severe eco-physiological effects on the growth, reproduction, and distribution of 85 canopying-forming Fucus species (e.g. Vadas et al., 1992). Knowledge of the effect of 86 87 these non-climatic factors is highly relevant when developing effective management and conservation plans since they may further exacerbate the effect of oceanic 88

89 warming on seaweed populations.

It is yet unknown whether the patterns of rapid population shrinkage and isolation 90 91 at range limits reported by Lourenço et al. (2016) for F. guiryi can be generalized to other marine organisms facing the imminent threat of global warming. Sequential field 92 surveys and genetic studies in other major coastal upwelling systems worldwide (i.e. 93 the California Current System, the Benguela Current, and the Peru–Humboldt Current) 94 can undoubtedly provide more insights into the role of upwelling systems in shaping 95 96 seaweed populations and communities. Assessing the environmental requirements for 97 life cycle completion in populations along entire species' ranges is a prerequisite to predicting possible shift in seaweed distributions. This is also critical for characterizing 98 the underlying linear and/or non-linear relationships between seaweed performance 99 100 and key oceanic parameters (e.g. temperature, salinity or pH) that are expected to change steadily during the 21st century (Harley et al., 2012). Lastly, it is essential to 101 gather historical and current distribution records for a large number of sympatric 102 species in order to empirically identify coastal community changes under global 103 warming scenarios. 104

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