Estuarine, Coastal and Shelf Science 155 (2015) 167–175

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Large brown seaweeds of the British Isles: Evidence of changes in abundance over four decades

Chris Yesson [a, b, *], Laura E. Bush [c], Andrew J. Davies [c], Christine A. Maggs [d], Juliet Brodie [a]

[a] Natural History Museum, Department of Life Sciences, Cromwell Road, London, SW7 5BD, United Kingdom
[b] Institute of Zoology, Zoological Society of London, Regent's Park, London, NW1 4RY, United Kingdom
[c] School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, LL59 5AB, United Kingdom
[d] School of Biological Sciences, Queen's University Belfast, Medical Biology Centre, 97 Lisburn Road, Belfast, BT9 7BL, United Kingdom

A R T I C L E I N F O

Article history:
Received 16 July 2014
Accepted 2 January 2015
Available online 29 January 2015

Keywords:
seaweeds
climate change
ecosystem engineers
kelp
fucoids

A B S T R A C T

The large brown seaweeds (macroalgae) are keystone species in intertidal and shallow subtidal marine ecosystems and are harvested for food and other products. Recently, there have been sporadic, often anecdotal, reports of local abundance declines around the British Isles, but regional surveys have rarely revisited sites to determine possible changes. An assessment was undertaken of changes in the abundance of large brown seaweeds around the British Isles using historical survey data, and determination of whether any changes were linked with climate change. Data were analysed from multiple surveys for 14 habitat-forming and commercially important species of Phaeophyceae, covering orders Laminariales, Fucales and Tilopteridales. Changes in abundance were assessed for sites over the period 1974–2010. Trends in distribution were compared to summer and winter sea surface temperatures (SST). Results revealed regional patterns of both increase and decrease in abundance for multiple species, with significant declines in the south for kelp species and increases in northern and central areas for some kelp and wracks. Abundance patterns of 10 of the 14 species showed a significant association with SSTs, but there was a mixture of positive and negative responses. This is the first British Isles-wide observation of declining abundance of large brown seaweeds. Historical surveys provide useful data to examine trends in abundance, but the ad hoc nature of these studies limit the conclusions that can be drawn. Although the British Isles remains a stronghold for large brown algae, it is imperative that systematic surveys are undertaken to monitor changes.

1. Introduction

Seaweed communities in different parts of the world have been profoundly impacted by humans, and in a time of rapid environmental change the large brown seaweeds have been the subject of an increasing number of reports documenting both their decline or loss coupled with an increase in populations of predominantly invasive species (Simkanin et al., 2005; Lima et al., 2007; Brodie et al., 2009, 2014; Koch et al., 2013). Large brown seaweeds are integral components of marine communities and are the main habitat formers in temperate reef ecosystems (Tuya et al., 2012), with kelp forests (Laminariales) dominating biomass in the subtidal and fucoids (wracks; Fucales) in the intertidal. Kelp forests are a major source of primary production and one of the most productive habitats on Earth (Reed et al., 2008). The highly productive fucoids also play a key role in carbon capture and transfer in coastal ecosystems (Golléty et al., 2008). These habitat-forming seaweeds facilitate a diverse community of understory algae, invertebrates and vertebrates (Jørgensen and Christie, 2003). Brown seaweeds are also an economically valuable resource: they were harvested for soda ash and iodine between the 17th and 19th centuries, and remain an important source of alginates (McHugh, 2003; Smale et al., 2013 and refs. therein). More recently, there has been interest in the biochemical properties of macroalgae for potential use in medicine (Wijesinghe and Jeon, 2012), in addition to the potential use of kelps in biofuel production (Roberts and Upham, 2012).

Causes of population level change in large brown seaweed abundance appear to be varied and complex, compounded by the life histories of these seaweeds, for example thermal tolerance

* Corresponding author. Institute of Zoology, Zoological Society of London, Regent's Park, London, NW1 4RY, United Kingdom.
E-mail address: chris.yesson@ioz.ac.uk (C. Yesson).

http://dx.doi.org/10.1016/j.ecss.2015.01.008
0272-7714/

Table 1
Summary of reported changes to key large brown seaweed species. Andersen et al., 2011; Davies et al., 2007; Eriksson et al., 2002; Fernández and Niell, 1982; Harries et al., 2007; Jueterbock et al., 2012; Morizur, 2001; Pearson et al., 2009; Pehlke and Bartsch, 2008; Roleda and Dethleff, 2011.

Species	Decline in distribution	Depleted genetic diversity	No apparent change	Range expansion	References
Alaria esculenta	+				Simkanin et al. (2005), Mieszkowska et al. (2006), Merzouk & Johnson (2011)
Ascophyllum nodosum	+				Simkanin et al. (2005)
Chorda filum	+				Erikkson et al. (2002)
Fucus serratus		+[2]	+[1]		1 Lima et al. (2007), 2 Pearson et al. (2009), 2 Jueterbock et al. (2012)
Fucus spiralis			+		Lima et al. (2007)
Fucus vesiculosus				+	Lima et al. (2007)
Himanthalia elongata	+[1]		+[2]		1 Fernández & Neill (1982), 1,2 Lima et al. (2007), 1 Davies et al. (2007), 2 Simkanin et al. (2005), 2 Merzouk & Johnson (2011)
Laminaria digitata	+				Cosson (1999), Morizur (2001)
Laminaria hyperborea	+[1]		+[2]		1 Simkanin et al. (2005), 1 Müller et al. (2009) 2 Lima et al. (2007)
*Laminaria ochroleuca**				+	Parke (1948)
Pelvetia canaliculata	+				Lima et al. (2007)
Saccharina latissima	+				Simkanin et al. (2005), Pehlke & Bartsch (2008), Brodie et al. (2009), Andersen et al. (2011), Roleda & Dethleff (2011), Moy & Christie (2012)
Saccorhiza polyschides	+				Fernández (2011)
Sargassum muticum				+	Harries et al. (2007)

changes over different life history phases (Koch et al., 2013). The geographic distributions of large kelp species (e.g. *Laminaria digitata, Laminaria hyperborea,* and *Saccharina latissima*) appear to be limited by summer and winter isotherms (Harley et al., 2012; Van den Hoek, 1982; Breeman, 1990) and some reviews have predicted declines in macroalgal abundance due to environmental change (Hiscock et al., 2004; Müller et al., 2009; Harley et al., 2012; Koch et al., 2013). Some species of macroalgae, such as *Alaria esculenta*, have been proposed as indicators of biotic response to climate change (Mieszkowska et al., 2006). Given that sea-surface temperatures in the northeast Atlantic have increased by approx. 0.3–0.8 °C per decade over the last *ca.* 25 years (Lima and Wethey, 2012), climate change is an important factor influencing coastal seaweed communities (Poloczanska et al., 2013).

In order to determine the extent of change in these seaweed communities, and to relate these changes to environmental influences, long term monitoring and/or reliable quantitative survey evidence from sites which can be resurveyed are required. However, frequently both types of evidence are lacking. Where losses of large brown seaweeds have been reported (Table 1), methods have included revisiting sites with historical surveys, undertaking a literature review, and making inferences from anecdotal evidence. Reported losses of *Alaria esculenta* in Ireland (Simkanin et al., 2005) and Britain (Mieszkowska et al., 2006) were determined by comparisons of sites with historical data. In the northwest Atlantic, retraction of this species at its southern edge was inferred from a literature review (Merzouk and Johnson, 2011). Losses of *Saccharina latissima* off the coast of Norway were determined by surveying 660 sites between 2004 and 2009 and making comparisons with a historical dataset (Moy and Christie, 2012). For reported losses of *S. latissima* and *Laminaria ochroleuca* from the north coast of Spain, sites were resurveyed between 2007 and 2010 to match previous surveys conducted between 1977 and 1978 (Fernández, 2011). In contrast, Tuya et al. (2012), who compared cold and warm water assemblages along the Portuguese coast, inferred that *Laminaria hyperborea* had retreated from its southern edge based largely on anecdotal and personal observations over recent decades.

The British Isles is an important biogeographic transition zone in the temperate region of the northeast Atlantic, and the littoral and shallow sublittoral regions support approx. 50% of the North Atlantic documented seaweed flora (Yesson et al., 2015). The northern and southern limits of the majority of commercially important large brown seaweed species occur outside the British Isles, except for *Laminaria ochroleuca*, which is at its northern limit in England, and *Alaria esculenta* whose southern limit is just into northern France (although the limits of *A. esculenta* and *Laminaria digitata* in France occur at the same isotherm as southern England). Seaweeds have been recorded for over 250 years and the first broad-scale survey of macroalgal populations to use a modern abundance scale classification was conducted over half a century ago by Crisp and Southward (1958) who pioneered a categorical classification of abundance defined by percentage cover thresholds based on a semi-logarithmic scale. This scale came to be known by the initials of the categories (ACFOR – Abundant, Common, Frequent, Occasional and Rare) (Crisp and Southward, 1958). Variants of this classification of abundance have been used regularly in surveys of the British and Irish coastlines. Although additional categories, such as dominant and superabundant, have been incorporated into the scale, and thresholds defining the categories have varied slightly, this system has remained in common use for coastal surveys (Hiscock, 1996; Mieszkowska et al., 2006; Wijesinghe and Jeon, 2012).

The ACFOR surveys of Crisp and Southward (1958) were repeated 45 years later to determine change in abundance of intertidal species around Ireland (Simkanin et al., 2005). Simkanin et al. (2005) found that three kelp species (*Alaria esculenta*, *Laminaria digitata* and *Saccharina latissima*) had declined significantly in abundance between 1958 and 2003. An equivalent systematic