Journal of Experimental Marine Biology and Ecology 400 (2011) 17–32

Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

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

Climate change cascades: Shifts in oceanography, species' ranges and subtidal marine community dynamics in eastern Tasmania

Craig R. Johnson [a,*], Sam C. Banks [b], Neville S. Barrett [c], Fabienne Cazassus [d], Piers K. Dunstan [d], Graham J. Edgar [c], Stewart D. Frusher [c], Caleb Gardner [c], Malcolm Haddon [e], Fay Helidoniotis [a,e], Katy L. Hill [e], Neil J. Holbrook [f], Graham W. Hosie [g], Peter R. Last [e], Scott D. Ling [a], Jessica Melbourne-Thomas [a], Karen Miller [a], Gretta T. Pecl [c], Anthony J. Richardson [h], Ken R. Ridgway [e], Stephen R. Rintoul [e], David A. Ritz [d], D. Jeff Ross [c], J. Craig Sanderson [a], Scoresby A. Shepherd [i], Anita Slotwinski [c], Kerrie M. Swadling [c], Nyan Taw [d]

[a] Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 129, Hobart, TAS 7001, Australia
[b] The Fenner School of Environment and Society, The Australian National University, Canberra, ACT 0200, Australia
[c] Institute for Marine and Antarctic Studies, Marine Research Laboratories, University of Tasmania, Private Bag 49, Hobart, TAS 7001, Australia
[d] School of Zoology, University of Tasmania, Private Bag 5, Hobart, TAS 7001, Australia
[e] CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, TAS 7001, Australia
[f] School of Geography and Environmental Studies, University of Tasmania, Private Bag 78, Hobart, TAS 7001, Australia
[g] Australian Antarctic Division, Channel Highway, Kingston, TAS 7050, Australia
[h] CSIRO Marine and Atmospheric Research, PO Box 120, Cleveland, QLD 4163, Australia
[i] SARDI Aquatic Sciences, 2 Hamra Avenue, West Beach, SA 5024, Australia

A R T I C L E I N F O

Keywords:
Cascading effects
Climate change
Eastern Tasmania
Marine ecosystems
Range expansion
Sea urchin

A B S T R A C T

Several lines of evidence show that ocean warming off the east coast of Tasmania is the result of intensification of the East Australian Current (EAC). Increases in the strength, duration and frequency of southward incursions of warm, nutrient poor EAC water transports heat and biota to eastern Tasmania. This shift in large-scale oceanography is reflected by changes in the structure of nearshore zooplankton communities and other elements of the pelagic system; by a regional decline in the extent of dense beds of giant kelp (*Macrocystis pyrifera*); by marked changes in the distribution of nearshore fishes; and by range expansions of other northern warmer-water species to colonize Tasmanian coastal waters. Population-level changes in commercially important invertebrate species may also be associated with the warming trend.

Over-grazing of seaweed beds by one recently established species, the sea urchin *Centrostephanus rodgersii*, is causing a fundamental shift in the structure and dynamics of Tasmanian rocky reef systems by the formation of sea urchin 'barrens' habitat. Formation of barrens represents an interaction between effects of climate change and a reduction in large predatory rock lobsters due to fishing. Barrens realize a loss of biodiversity and production from rocky reefs, and threaten valuable abalone and rock lobster fisheries and the local economies and social communities they support. This range-extending sea urchin species represents the single largest biologically mediated threat to the integrity of important shallow water rocky reef communities in eastern Tasmania.

In synthesizing change in the physical ocean climate in eastern Tasmania and parallel shifts in species' distributions and ecological processes, there is evidence that the direct effects of changing physical conditions have precipitated cascading effects of ecological change in benthic (rocky reef) and pelagic systems. However, some patterns correlated with temperature have plausible alternative explanations unrelated to thermal gradients in time or space. We identify important knowledge gaps that need to be addressed to adequately understand, anticipate and adapt to future climate-driven changes in marine systems in the region.

Contents

* Corresponding author. Tel.: +61 3 6226 2582.
E-mail address: Craig.Johnson@utas.edu.au (C.R. Johnson).

0022-0981/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.jembe.2011.02.032

1. Introduction

An important predicted consequence of global warming is change in large scale patterns of ocean circulation (Meehl et al., 2007). These changes are likely to have flow-on effects to ecological communities through alteration of transport of planktonic stages and species (Harley et al., 2006; Brierley and Kingsford, 2009) and changes in biogeochemical cycling (Sarmiento et al., 2004; Schmittner et al., 2008) reflecting shifts in nutrients, temperature and community structure. In the eastern Pacific and the North East Atlantic, including the North Sea and English Channel, pronounced shifts in oceanic conditions linked to climate over the past century have been associated with large shifts in marine ecosystem structure and dynamics (e.g. Southward et al., 1995, 2005; McGowan et al., 1998; Benson and Trites, 2002; Hawkins et al., 2003; Alheit and Niquen, 2004; Beaugrand, 2004; Edwards and Richardson, 2004).

The rate of ocean warming off south eastern Australia over recent decades is ~3–4 times the global average (Holbrook and Bindoff, 1997; Ridgway, 2007b), making this one of the fastest warming regions in the southern hemisphere — a global 'hotspot'. Recent studies have shown that the decadal to multi-decadal warming in this region is consistent with a 'spin up' of the South Pacific gyre (Cai et al., 2005; Cai, 2006; Ridgway, 2007a,b; Roemmich et al., 2007), the western margin of which is the warm East Australian Current (EAC; Fig. 1). The EAC is the major boundary current off the east coast of Australia, with a substantial eastwards separation from the coast at ~32.5° S to form the Tasman Front which extends to New Zealand (Godfrey et al., 1980). Extension of the EAC south of this separation area now realizes longer and stronger incursions into waters off eastern Tasmania, which has the effect of transporting both heat (Cai, 2006; Ridgway, 2007a,b) and larvae of northern species (Johnson et al., 2005; Ling et al., 2009b; Banks et al., 2010) southward to Tasmania.

Increased incursions of the EAC in eastern Tasmania not only influence temperature and transport of larvae, but have also probably affected nutrient loading in the region. This is because the EAC is nutrient-poor (e.g. often ≤1 μM nitrate, particularly in summer) relative to the sub-Antarctic water masses that, until recently, dominated the oceanographic signature on the east coast of Tasmania (Harris et al., 1987; Ridgway, 2007a). EAC-driven ocean warming off eastern Tasmania is therefore likely to be strongly confounded with a decrease in nutrient availability, although it is worth noting that there is no evidence yet of a long term trend in nitrate levels at the single monitoring site in eastern Tasmania where nutrients have been sampled routinely (Thompson et al., 2009).

While there is unequivocal evidence of fundamental changes to ocean circulation and the physical parameters of waters off south eastern Australia, links to changes in species' distributions, with concomitant downstream effects on community structure and dynamics, and on local economies, are unclear (Poloczanska et al., 2007). These questions are important given the concentration of biodiversity, very high levels of endemism (Anon, 2008), and the high economic value of recreational and commercial fisheries in south east Australia in general and Tasmania in particular. In addition, in south eastern Australia the human population is strongly concentrated in coastal urban areas (Australian Bureau of Statistics, www.abs.gov.au). Fisheries in the region are among the most productive in the country, with New South Wales, Victorian and Tasmanian state waters together yielding ~33% (by value) of the total production of Australian state-based fisheries in 2008–09 (ABARE, 2010). Of individual states, Tasmania had the largest gross value of fisheries production (AUD

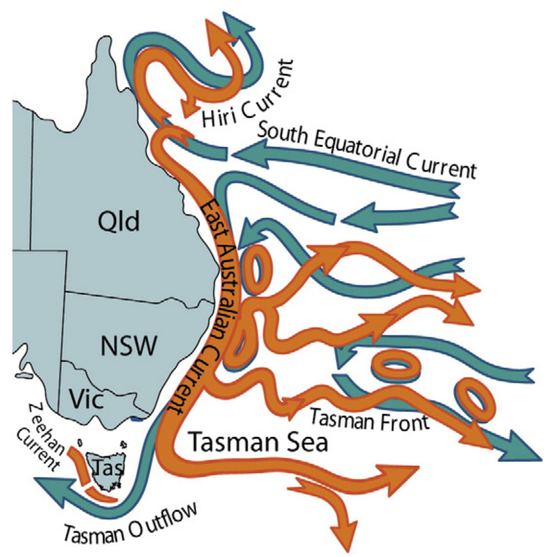

Fig. 1. Schematic representation of major current patterns off eastern Australia, including the East Australia Current (EAC) and the Tasman Front (TF). Surface currents are shown in orange and subsurface currents are in blue. Qld = Queensland, NSW = New South Wales, Vic = Victoria, Tas = Tasmania.