Available online at www.sciencedirect.com
ScienceDirect
Deep-Sea Research II 54 (2007) 1129–1140
DEEP-SEA RESEARCH PART II
www.elsevier.com/locate/dsr2

Potential mechanisms of influence of the Leeuwin Current eddy system on teleost recruitment to the Western Australian continental shelf

Daniel J. Gaughan*

Research Division, Department of Fisheries, Government of Western Australia, P.O. Box 20, North Beach, WA 6920, Australia

Received 1 December 2005; received in revised form 27 May 2006; accepted 30 June 2006
Available online 19 June 2007

Abstract

The Leeuwin Current (LC), an oligotrophic, warm current that flows south (poleward) along the shelf-break off the west coast of Australia and then east along the south coast, is recognized as a key factor affecting fisheries production in the region, but the mechanisms for this influence have not been determined. Recruitment strength of the globally significant western rock lobster (*Panulirus cygnus*) stock is correlated to interannual variations in the strength of the LC. While this relationship has been based on a 2-decade time-series of *P. cygnus* recruitment data, the important teleost species of the region rarely have recruitment data for more than a few years; yet this group is nonetheless economically, socially and politically important. Furthermore, there is little knowledge of the egg- and larval-stage dynamics for the majority of these teleosts. Previous and new information on those aspects of the LC system that could theoretically impact on recruitment of shelf teleosts were identified to provide a basis for developing a conceptual model of how the LC could affect recruitment. The potential impacts of the LC system, which entrains shelf water, were examined with reference to retention/loss of teleost eggs and larvae and positive/negative influences on feeding conditions for larvae. Owing to the lack of early-life-history information for many teleosts in Western Australia, this was undertaken for generalized shelf species whose eggs are spawned on the shelf and whose larvae must settle on the shelf to access favourable nursery habitat. The results indicate that the LC system most likely contributes a net negative impact on success of teleost eggs and larvae. Larvae of shelf teleosts entrained and trapped in the warm-core (WC) eddies that form from the LC and then propagate offshore would contribute little to recruitment. Given that larval teleosts predominantly feed on copepods and that these were much less abundant in the WC eddy than is typical of shelf waters, the general larval feeding conditions in the WC eddy were inferior to those on the shelf. Any larvae that escaped from the eddy that were able to orientate towards the shelf and had sustained swimming capabilities would incur significant energetic penalties when attempting to return to the shelf. Furthermore, flow of the LC onto the shelf could dilute the concentrations of phytoplankton and zooplankton, negatively impacting feeding conditions for larvae that remain on the shelf. Clarification of the timing and geographical locations of interactions between the LC and shelf waters relative to spawning behaviour of shelf teleosts is required before the potential negative impacts on recruitment can be adequately quantified. However, because fisheries management issues cannot (always) await detailed understanding of biophysical effects on recruitment, the conceptual model of potential effects was developed here to provide immediate improvements for interpretation of stock assessment information, for which recruitment variability is

*Tel.: +61 8 9203 0214; fax: +61 8 9203 0199.
E-mail address: dgaughan@fish.wa.gov.au.

doi:10.1016/j.dsr2.2006.06.005

often a key uncertainty. Finally, an improved understanding of the effects of mesoscale oceanography on fish stocks will increase the ability for fisheries managers to discuss climate-change implications with stakeholders.

Keywords: Western Australia; Marine fish; Ichthyoplankton; Recruitment; Larvae; Coastal currents

1. Introduction

The relatively oligotrophic shelf waters of South-Western Australia (SWA) (e.g., Pearce et al., 2000; Hanson et al., 2005a, b; see Waite et al., 2007a) contrast with several other regions of the world that support globally important clupeoid fisheries, having neither significant upwellings, frontal zones nor rainfall regimes (expressed through terrestrial drainage) sufficient to generate large concentrations of nutrients, and hence plankton, in shelf waters or the euphotic zone of adjacent oceanic waters (Gaughan et al., 2001a). SWA, therefore, has small populations of small pelagic fish such as sardines, anchovies and mackerels. Because of these limited populations of small pelagic fish, which provide a crucial link between the nutrient-phytoplankton–zooplankton (NPZ) cycle and larger predators (Cole and McGlade, 1998), populations of piscivorous fish are also small in this region. Limited fisheries production (Lenanton et al., 1991) provides evidence that populations of pelagic, benthic and bentho-pelagic fish in SWA are very small by world standards, with stock sizes of individual species typically in the order of only 1000s of tonnes, whereas there are significant populations of benthic invertebrates, including the western rock lobster (*Panulirus cygnus*), which sustain annual harvest levels of around 10,000 tonnes (Lenanton et al., 1991).

The relative importance of benthic and pelagic productivity on population dynamics of teleost species in SWA is poorly understood; a possible explanation for the ability for the coastal waters of SWA to support a globally significant lobster population, but only small populations of teleosts, is that the latter are constrained by poor recruitment resulting from sub-optimal conditions for growth and survival of their pelagic larval stages. Gaughan et al. (2001a) suggested that the oligotrophic pelagic environment of SWA is responsible for low growth rates, and hence survival, of *Sardinops sagax* larvae, which in turn contributes to the small populations of this species; this also may apply to other teleost species, whose larval stages occur in SWA shelf waters and share similar prey resources. In contrast, *P. cygnus* also live on the shelf and have pelagic larvae, but are markedly more successful than teleost species in the same region.

The settlement stage (i.e. puerulus) of *P. cygnus* recruit to benthic shelf habitats at the conclusion of a 9–11-month pelagic phase that involves extensive movements of up to 1500 km offshore of the SWA shelf (Phillips et al., 1979; Phillips 1981). Griffin et al. (2001) modelled the movement of *P. cygnus* larvae from the SWA shelf using biological information derived from earlier plankton sampling and satellite-derived sea-surface height data with appropriate geostrophic forcing. This modelling indicated that *P. cygnus* larvae, which are spawned on the shelf, became widely distributed off the shelf, with eastward geostrophic forces eventually returning many to the shelf. Meuleners et al. (2007) also have described a potential transport mechanism for larval *P. cygnus* that relies on the dynamics of eddy dipoles associated with the LC, while the potential for persistent sub-surface anti-clockwise eddies at one location off the SWA coast may contribute to particularly high settlement rates of *P. cygnus* in that region (Meuleners et al., 2007). The sustainable exploitation of the *P. cygnus* stock for over five decades indicates that this early life history strategy is certainly successful. In contrast to the prolonged pelagic larval phase of *P. cygnus*, most teleosts have pelagic larval phases of around one to two months. Whereas reasonable proportions of *P. cygnus* larvae are returned to the shelf, the much shorter larval duration of finfish indicates that few would survive such an extensive offshore excursion, although larval behaviour and\or well-developed swimming abilities (e.g., Hindell et al., 2003) could potentially mitigate against initial offshore transport. Given the relatively short larval duration for many teleosts, the success of the planktonic egg and larval stages of shelf teleosts may be reliant on their remaining in shelf waters for their first month of life so as to access the best possible feeding opportunities and find suitable nursery habitat at the end of the larval phase.