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The biological oceanography of the East Australian Current and surrounding waters in relation to tuna and billfish catches off eastern Australia

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ABSTRACT

The surface and sub-surface biological oceanography of tuna fishing grounds within the East Australian Current (EAC) was compared in 2004 with two other fishing areas further offshore. Our aim was to determine whether the biological oceanography of the region could explain the distribution and intensity of pelagic fishery catches inside and outside the EAC at that time. The EAC fishing area was noticeably warmer, less saline and lower in nutrients than waters in the other fishing areas. The EAC waters were dominated by large diatoms, the biomass of which was significantly higher than in the seamount and offshore areas, apparently the result of a cold core eddy beneath the EAC surface filament. Over the seamount and offshore more typical Tasman Sea waters prevailed, although the presence of a relatively deeper oxygen minimum layer over the seamount suggested topographically induced mixing in the area. Notably, sub-surface zooplankton and micronekton biomass was significantly higher around the seamount than in the two other areas. The offshore region was characterised by frontal activity associated with the Tasman front. Micronekton net biomass was generally highest in surface waters in this region. Examination of tuna catch records at that time showed yellowfin tuna (*Thunnus albacares*) dominated the catches of the EAC, whereas swordfish (*Xiphias gladius*) and bigeye tuna (*Thunnus obesus*) were the main species caught offshore. We suggest the yellowfin tuna concentrate in waters that are not only warmer but where prey species are concentrated near the surface. Offshore, deeper living species such as swordfish and bigeye tuna (*T. obesus*) can take advantage of prey species that are distributed deeper in the water column and along the flanks of the many seamounts in the region, or that are concentrated at fronts associated with the Tasman Front. Although only a snapshot of the region, relatively consistent catch data over time suggests the underlying biological oceanography may persist over longer time periods, particularly during the Austral spring.

1. Introduction

The Eastern Tuna and Billfish Fishery (ETBF) is a wide-ranging fishery that at different times operates along the length of eastern Australia and seaward beyond the limits of the Exclusive Economic Zone (EEZ; Figs. 1 and 10). However, a significant proportion (~38%) of the present catch is taken between 25°S and 30°S. Inshore, fishers target waters of the East Australia Current, whereas offshore they target a range of environments including seamounts, and waters of the Tasman and Coral Seas. Inshore, the catch is dominated by yellowfin tuna, whereas offshore swordfish and other tunas are more prevalent (Campbell, 2008). Much of the understanding of these differences in distribution has been derived from spatial analyses of catch effort but with less attention to oceanographic influences. More recently, efforts have been made using satellite data to relate fish catches to the surface oceanography, although the explanatory power of the resulting relationships has been relatively low (Young et al., 2000; Campbell and Hobday, 2003; Hobday et al., 2011). As most fish top predators are considered opportunistic feeders it is more likely that the oceanographic and topography features to which they were linked were also the sites of increased prey biomass (e.g. Holland et al., 1999; Polovina et al., 2001; Young et al., 2001; Lebourges-Dhaussy et al., 2009). However, without a greater understanding of the intermediate links, in particular potential prey (and predator) concentrations, in the relationship between surface circulation and top predators, explanations for the observed catch distributions and fluctuations are likely to be limited.

The importance of the sub-surface environment, particularly in relation to the processes leading to concentrations of the larger predators, has not been adequately addressed in this region. There is a significant body of literature on the vertical physical structure of the offshore waters of the Coral and Tasman Sea (e.g. Cresswell and Legeckis, 1986; Ridgway and Dunn, 2003). However, there have been relatively few biological studies in the EAC, all of which were carried out south of the study area (e.g. Brandt, 1981; Tranter et al., 1986; Young et al., 2001; Baird et al., 2008).

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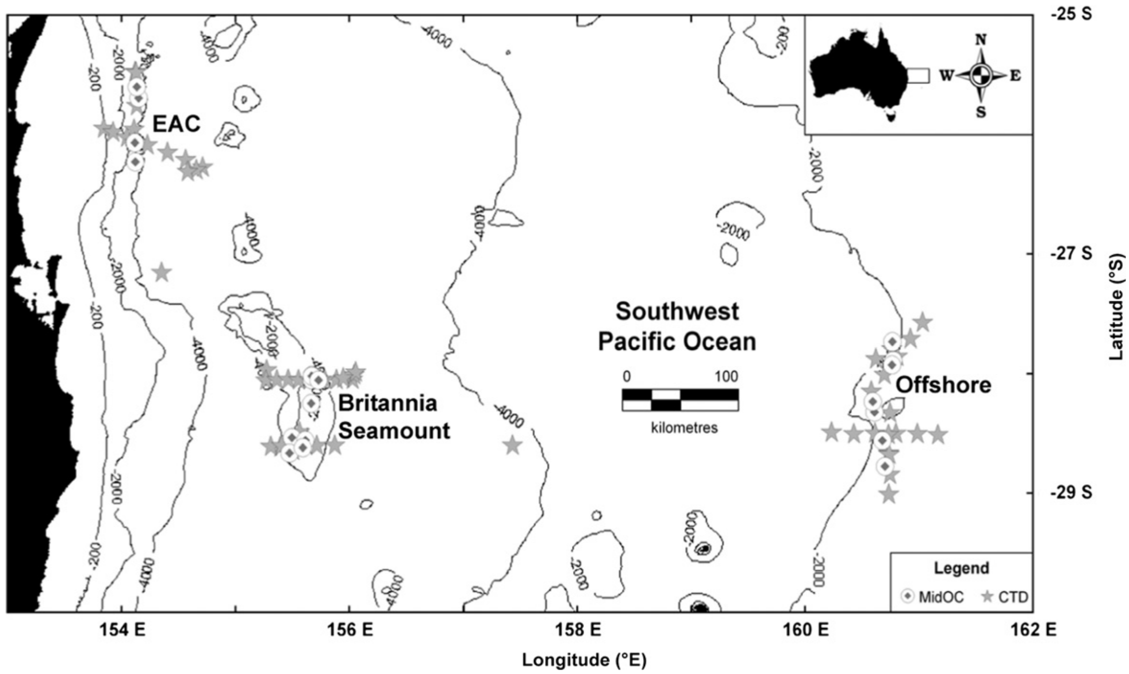

Fig. 1. Study area showing sampling positions occupied during a research voyage to the main fishing area of the Eastern Tuna and Billfish Fishery off eastern Australia (1–16 September 2004). Symbols indicate the sampling methods.

The patterns of pelagic fish distribution, visualised as captures by the tuna fishery, suggest these fishes are responding to their environment in potentially predictable ways. In the northern hemisphere, studies of large pelagic fish distributions identified associations with a number of physical variables, particularly seabed topography, fronts and sea surface temperature (e.g. Fiedler and Barnard, 1987; Podesta et al., 1993; Bigelow et al., 1999; Sedberry and Loefer, 2001). We found similar associations off eastern Australia and were able to also identify physical factors associated with captures of swordfish and tropical tuna (Young et al., 2000, 2001). However, with the exception of yellowfin tuna, which is thermally less tolerant than other tunas, these physical correlates are likely to be proxies for concentrations of suitable prey, rather than directly affecting predator distributions (Lebourges-Dhaussy et al., 2009). There have been relatively few studies linking sub-surface structure with the distribution of tuna and billfish off eastern Australia (although see Evans et al., 2005). The development of satellite altimetry (e.g. Polovina et al., 2001) and high resolution ocean models (e.g. Oke et al., 2008) is helping to distinguish sub-surface structure, but how these patterns relate to the distribution of prey fields will be greatly aided by *in situ* studies.

Our objective here was to characterise the physical ocean habitat and biological community of the waters of the EAC fishery in relation to two other fishing areas in the region (Young et al., 2009). We were interested in determining whether primary productivity, and/or concentrations of potential prey as determined by net collections of macrozooplankton and micronekton and acoustics could be linked to variability in catch distributions of tuna and billfish inside and outside the EAC.

2. Methods

2.1. Physical oceanography

In September 2004 we compared the biological and physical oceanography of three areas frequented by longliners within the Australia EEZ using the Marine National Facility RV Southern Surveyor. We focused on three areas: one inside the EAC, one over Britannia Seamount as an example of the many seamounts in the region, and one further offshore (Fig. 1). The vertical structure of the regional oceanography was described from a series of hydrographic transects to 500 m in each area (Fig. 1). On each transect, casts of CTDs (General Oceanics Mark IIIC CTD with a General Oceanics 12 bottle rosette and SeaTech fluorometer mounted on the frame) were made at ~10 nmi intervals to record temperature, salinity and fluorescence to a depth of 500 m.

2.2. Phytoplankton

The composition and concentration of phytoplankton was determined from 10-L Niskin bottles taken during each CTD cast. In the laboratory, phytoplankton species composition was determined from samples that were concentrated to a 1 mL aliquot following Hötzel and Croome (1998), examined microscopically with a phase contrast facility, and imaging software. Counts were made to genus or species level in the microplankton (i.e. above 20 μm diameter) and to class level in the nanoplankton (2–20 μm). Additionally, totals of diatoms, dinoflagellates, small flagellates and microzooplankton grazers were enumerated. The biomass (volumes) of counted cells was estimated from standard geometries detailed in Hillebrand et al. (1999). An estimate of total counts and biomass of taxa > 10 μm, and between 2 and 10 μm was also made. Chlorophyll biomass (C_{chl}) was determined by trapezoidal integration (Waite et al., 2007). To determine primary productivity and carbon uptake, samples were incubated at sea following the methods of Waite et al. (2007) and Harris et al. (1987).

2.3. Net sampling

The macrozooplankton (size range 2–20 mm) was sampled during the day with bongo nets (mesh size 500 μm) fished obliquely to 200 m depth, complemented by simultaneous surface tows. Flowmeters were used to determine water volume through