SEASONAL VARIABILITY IN UPWELLING AND BLUE WHALE OCCURRENCE IN A COASTAL FEEDING GROUND OFF SOUTH-EAST AUSTRALIA 2002-2007

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Introduction & aims

Blue whales *Balaenoptera musculus* gather each austral summer to feed on krill *Nyctiphanes australis* in a regional upwelling system along the continental shelf of south-east Australia (Gill, 2002). Forced by SE winds, upwelling extends west from the Bonney Upwelling surface plume to about 136°E in the Great Australian Bight (GAB; see Figure 1; Middleton & Bye, 2007). Despite being the most biologically rich marine region in Australian waters, this system has been little studied until recently and its eastern extent was undescribed. This work investigates relationships between blue whale relative abundance (n=318 sightings) from 47 aerial surveys over six seasons, and aspects of upwelling. These include upwelling extent (using temperature loggers), and descriptors of upwelling seasons such as length of season, upwelling intensity, duration of upwelling events, and duration of intervening 'relaxation periods'. This work forms part of an ongoing analysis describing blue whale feeding habitat on a regional scale.

Methods & results

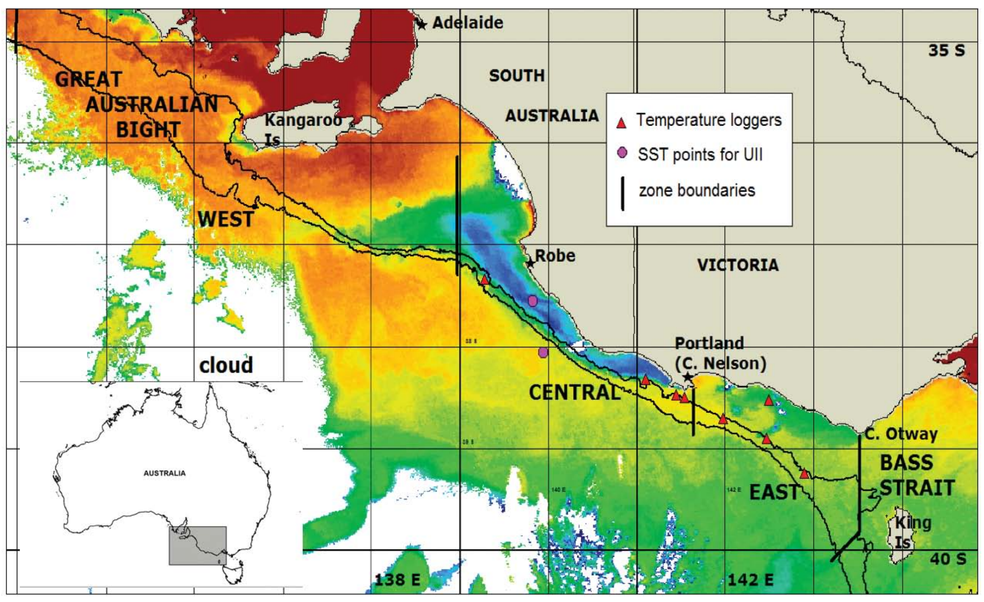
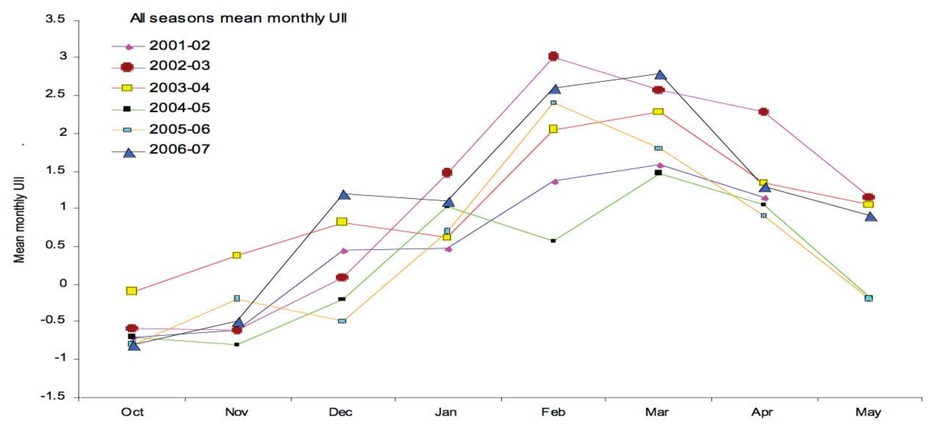


FIGURE 1. The Bonney Upwelling surface plume is shown between Portland and west of Robe (AVHRR SST image, 12 Feb 2007, courtesy CSIRO). Upwelling is subsurface west into the GAB, with some surface expression off SW Kangaroo Is and further NW. Upwelling between Portland and Cape Otway is typically sub-surface, with some surface expression during stronger events. On the basis of shelf width & upwelling type, the study region was divided into West, Central & East Zones.

FIGURE 2. Monthly upwelling intensity index (UII), derived from AVHRR SST difference between 'cold' & 'warm' pink circles in Figure 1.



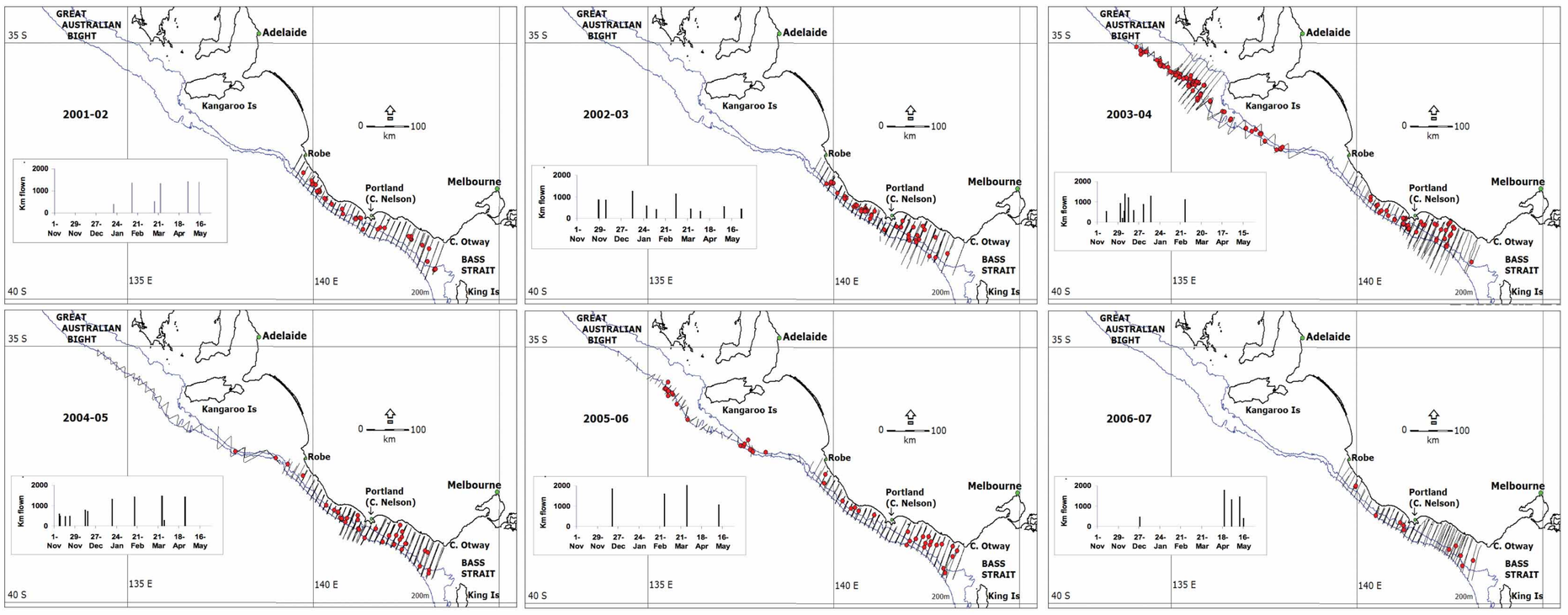


FIGURE 3. Results of aerial surveys; timing and length (km) shown in inset box. Mean group size 1.3 ± 0.61, only seven calf sightings (2%). Earliest sighting 8 Nov 2004 , latest 16 May 2007. See Fig. 4 for encounter rates (ERs).

WESTERN ZONE: High ER in Dec of 2/3 years, very low at other times. Peak ER in 2003-04 season. 90% sightings <10km N/S of shelf break. Mean sighting depth 331 ± 280m.

CENTRAL ZONE: Whales present in all seasons. Highest ER in 2003-04. Sightings often in narrow band along seaward edge of BU surface plume. Mean sighting depth 97 ± 42m.

EASTERN ZONE: Whales present in all seasons. Highest ER in 2003-04. Sightings spread well across shelf. Mean sightings depth 89 ± 42m.

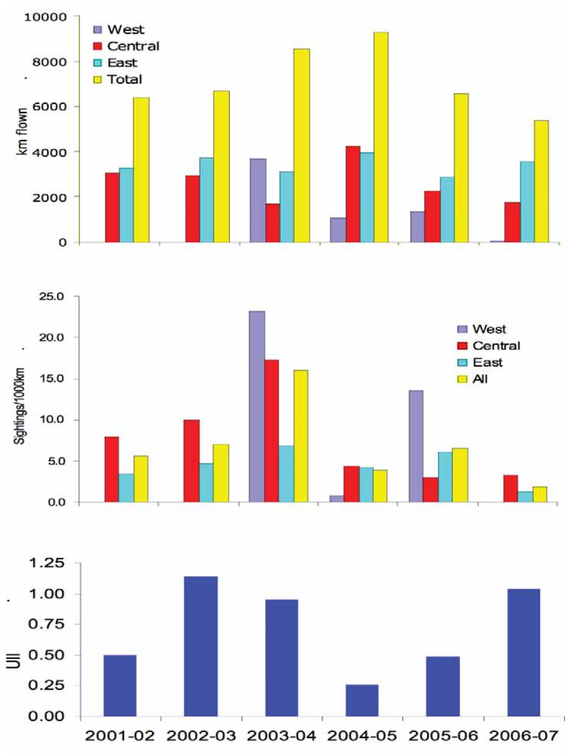


FIGURE 4.

TOP:
Survey effort, all zones. Western Zone first covered in 2003-04 prior to seismic survey in previously unsurveyed area.

MIDDLE:
Blue whale encounter rate (ER; sightings/1000km) peaked in all Zones during 2003-04 season.

BOTTOM:
Mean UII for each season. Most intense upwelling seasons 2002-03 and 2006-07, weakest season 2004-05.

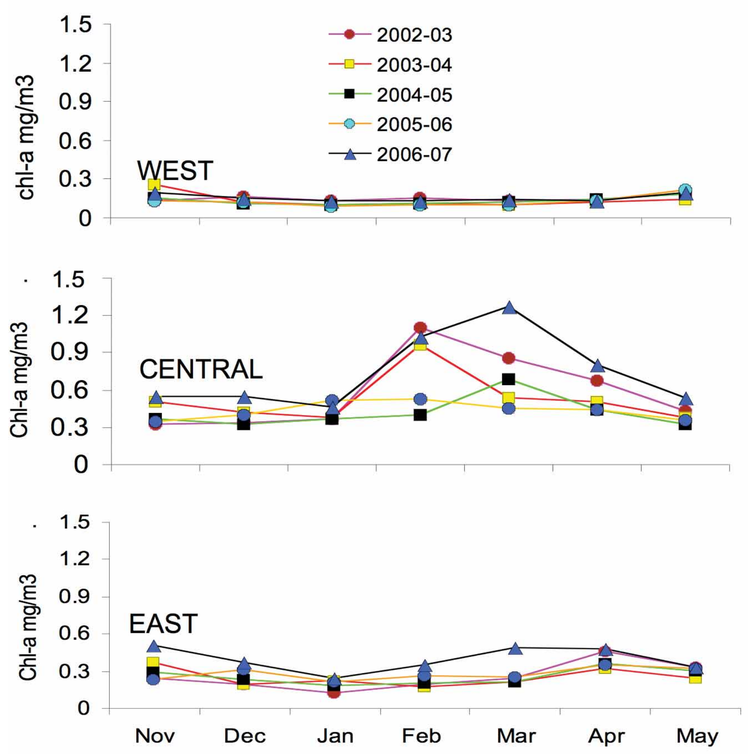


FIGURE 5.

Surface chlorophyll-*a* concentrations, NOAA Giovanni 9km sensor (mid-2002 on). Monthly mean data, 30x50km box in centre each zone.

WESTERN ZONE:
Little variability. Nov 2003 showed slightly elevated levels that corresponded with high blue whale ER in early Dec 2003.

CENTRAL ZONE:
Chl-*a* peaks evident in Feb-Mar of most seasons, ~3mo after upwelling onset. Moderate chl-*a* levels in 2003-04 season, with highest blue whale ERs. Highest chl-*a* levels in 2006-07, with low blue whale ERs.

EASTERN ZONE:
Chl-*a* levels comparable to central zone during Nov-Jan, but no clear seasonal peak. Levels slightly higher and more variable than western zone.

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Summary and significance:

We have established that blue whales feed in upwelling habitat along ~950km (~40,000km2) of shelf, including the Eastern Zone where upwelling was previously unproven. The relationship between upwelling intensity and blue whale relative abundance is not straightforward. The two most intense upwelling seasons (2002-03, 2006-07) showed low-moderate encounter rates, comparable to the weaker upwelling seasons. This supports the hypothesis that primary productivity is optimal when forcing winds are not too strong or too weak (Huntsman and Barber, 1977). The 2002-03 and 2006-07 seasons featured a high UII after a relatively weak start, long ('02-03) and short ('06-07) mean upwelling events, and short mean relaxation periods. The 'best' whale season (2003-04) featured a long upwelling season with a very strong start, relatively high UII, moderate mean length of upwelling events, and the longest mean inter-upwelling 'relaxation' periods, which potentially optimised primary and secondary productivity.

As off California (Croll *et al.*, 2005), chl-*a* peaks in the Central Zone lagged 3 months behind upwelling onset. However, surface chl-*a* levels may be limited as indicators of whale abundance, particularly in sub-surface upwelling Zones. Even in the Central Zone, higher chl-*a* values were not associated with higher blue whale ERs. This supports the likelihood that complex sub-surface processes are a major factor in prey aggregation at a range of scales. Morrice *et al*. (see poster, this conference) are investigating fine-scale 3-dimensional relationships between whales, prey and habitat.

The next step in this work is to model a range of habitat variables including upwelling indices, to provide a predictive framework for blue whale feeding habitat in this region.