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Seasonal variation and tidal influences on estuarine use by bottlenose dolphins (*Tursiops aduncus*)

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ABSTRACT

In order to show that dolphins use estuary habitats differently depending on the season and tidal state, possibly in response to prey distribution, temperature, risk of stranding and accessibility, Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) were observed year-round during a 3-year study in the Clarence River estuary (CR) and Richmond River estuary (RR) in northern New South Wales, Australia. Peak dolphin sightings occurred during the spring season and one or 2 h prior to high tide. The spatial distribution of the dolphins in each estuary was analysed using the distance in kilometres that the dolphins travelled upstream with seasons and tidal phase as determinants. A General Linear Model showed that in the CR the dolphin spatial distribution in the estuary was not determined by season ($F = 0.434$, df $= 3$, $P = 0.729$) but was by tidal phase ($F = 9.943$, df $= 3$, $P < 0.001$) and the interaction between season and tidal phase ($F = 3.398$, df $= 9$, $P < 0.002$). However, in the RR the spatial distribution of the dolphin use of the estuary was not determined by either season ($F = 1.647$, df $= 3$, $P = 0.194$) or tidal phase ($F = 0.302$, df $= 3$, $P = 0.824$). In the CR, the spatial distribution of the dolphins was largest on high and flood tides. This pattern of spatial distribution may occur because the CR is a relatively shallow estuary and this increased spatial distribution may reflect a lower stranding risk and an increase in accessibility of shallow areas during periods of higher tide. These areas could also provide access to their preferred prey items of sea mullet (*Mugil cephalus*) and sand whiting (*Sillago ciliata*).

1. Introduction

The habitat use of bottlenose dolphins (*Tursiops truncatus*) has been studied in several estuaries worldwide and some long-term studies have provided useful insights into their movement patterns, including studies in the Moray Firth, Scotland (Lewis and Evans, 1993; Wilson et al., 1997), the Shannon, Ireland (Berrow et al., 1996; Ingram and Rogan, 2002), and the Sado estuary, Portugal (dos Santos and Lacerda, 1987; Harzen, 1998; dos Santos et al., 2007). However there is limited information from studies on *Tursiops aduncus* habitat use patterns, particularly in Australian estuaries (Fury and Harrison, 2008).

Spatial use of habitats by bottlenose dolphins is known to be influenced by seasons and tidal phase, which is most likely in response to prey distribution (Irvine et al., 1981). However, responses by dolphins are diverse and depend on the site. For instance, in the Moray Firth in Scotland and the estuaries of Laguna's canal and Imarui-Santo Antonio's lagoon in Southern Brazil, bottlenose dolphins (*Tursiops. truncatus*) were seen all year round although the populations showed consistent seasonal fluctuations and their habitat use of different areas was dependant on the season (Wilson et al., 1997; Simoes Lopes and Fabian, 1999). Dolphins also show preference for particular tidal states, for example, in the Moray Firth sightings peaked before flood tide (Mendes et al., 2002), while in the Shannon estuary in Ireland, dolphin sightings peaked 3 h after high tide (Berrow et al., 1996). In areas that have a relatively constant supply of food resources, such as those provided by deep shipping channels, the effect of the different seasons on dolphin habitat use is thought to be minimal (Maze and Würsig, 1999). In more open areas, like Bahía San Jorge in the Gulf of California tidal changes did not appear to influence bottlenose dolphin sightings or behaviour (Mellink and Orozco-Meyer, 2006).

Given the range of responses by estuarine dolphins, site-specific data are needed to fully understand the importance of estuaries as a critical habitat for dolphins. Hence this study investigated the hypothesis that seasonal variation and tidal phases influence the spatial use patterns of Indo-Pacific bottlenose dolphins (*Tursiops. aduncus*) in two estuaries in northern New South Wales, Australia.

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2. Materials and methods

2.1. Study sites – Richmond and Clarence River estuaries

The Clarence River and the Richmond River estuaries are located on the subtropical north coast of New South Wales, Australia, and flow through adjacent river valleys, and the river mouths are separated by a minimum seaward distance of 65 km (Fig. 1). The Clarence River is a wave-dominated estuary located at (153°21'E 29°26'S) (Fig. 1), and has a catchment area of approximately 22,446 km^2, a waterway area of 89 km^2, volume of 204.7 $\times$ 10^6 m^3 and a mean depth of 2.3 m. The approximate length of the river tidal influence is about 60 km from the mouth. The mean spring tidal range at the entrance is 1.34 m (Eyre, 2000; Walsh et al., 2004). The Clarence River is the largest coastal river in northern New South Wales (NSW) (West, 2002). The Richmond River is a wave-dominated delta (Ryan et al., 2003) located at (153°35′E 28°53′S) (Fig. 1) and has a catchment area of approximately 6861 km^2, a waterway area of 19 km^2, volume of 67.7 $\times$ 10^6 m^3 and with a mean depth of 4.7 m (Eyre, 2000; Walsh et al., 2004). The estuary is well-mixed even in the dry season, with a maximum tidal influence of 60 km from the mouth, and semidiurnal tides with

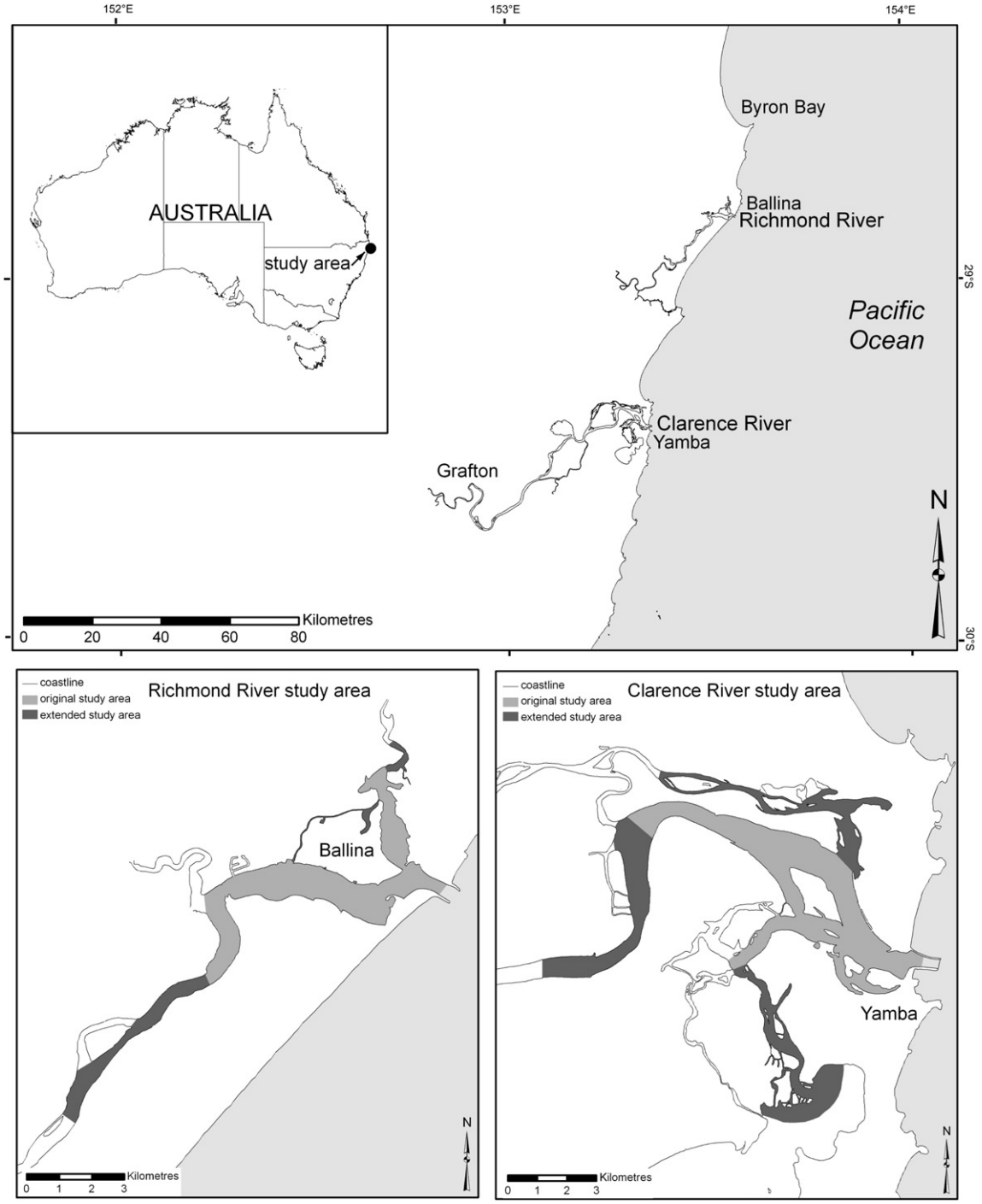

Fig. 1. Map of the study sites in northern New South Wales, Australia at the top, and a detailed map of the Clarence River and Richmond River estuaries indicating the survey areas.