Received: 10 August 2023 | Revised: 8 March 2024 | Accepted: 20 March 2024

DOI: 10.1002/ece3.11221

Ecology and Evolution Open Access WILEY

RESEARCH ARTICLE

Population distribution and drivers of habitat use for the Burrunan dolphins, Port Phillip Bay, Australia

Jemima Beddoe[1,2] | Jeff Shimeta[1] | Marcel Klaassen[3] | Kate Robb[2]

[1]School of Science, RMIT University, Melbourne, Victoria, Australia

[2]Australian Marine Mammal Conservation Foundation, Hampton East, Victoria, Australia

[3]School of Life and Environmental Sciences, Deakin University, Geelong, Victoria, Australia

Correspondence
Jemima Beddoe, School of Science, RMIT University, Melbourne; Australian Marine Mammal Conservation Foundation, Hampton East, Victoria, Australia.
Email: jemima@marinemammal.org.au

Funding information
Lord Mayor's Charitable Foundation; Australian Geographic Society; Department of Environment, Land, Water and Planning, State Government of Victoria

Abstract

Bottlenose dolphin (*Tursiops*) populations, also described as the Burrunan dolphins, consist of a resident population of approximately 150 individuals in Port Phillip Bay (PPB), Victoria. Previous reports indicate distribution across a small southern region of PPB; however, little is known about their full distribution patterns across the entire PPB region. Here, we investigate the spatiotemporal distribution of the Burrunan dolphins across four zones representative of PPB benthic habitats and bathymetry to gain a better understanding of the potential drivers of the population's habitat use. Port Phillip Bay, Victoria, Australia. One hundred and twenty-nine boat-based surveys were undertaken between March 2015 and August 2021, encompassing 181 sightings. Generalised linear models (GLMs) were used to investigate annual, seasonal and zonal variation. We found no variation in sighting frequencies between years. Austral summer and winter had a significantly higher sighting frequency than autumn. We found that Burrunan dolphins utilise the entire bay, further extending the species range, and show a significantly higher number of sightings in the southern zone than in any other zones. Overlaying dolphin sightings with known oceanographic characteristics within PPB, we found bathymetry and benthic habitats were potential drivers for the Burrunan dolphins distribution and habitat use within the bay, with the dolphins significantly favouring the 5–10 and 10–15 m contour depths. These results show a more widespread distribution across the bay than previously documented. We recommend expansion of the current marine protected areas in the north and south of the bay. This study has increased our understanding of the vital habitat for the Burrunan dolphin populations. By providing evidence-based conservation recommendations, we hope to improve and contribute to future research, conservation management plans and effective marine protected areas across PPB for the resident Burrunan dolphin population.

KEYWORDS
Burrunan dolphin, critically endangered, distribution, habitat use, marine protected area

TAXONOMY CLASSIFICATION
Population ecology

1 | INTRODUCTION

Marine mammals are a polyphyletic group comprised of approximately 129 species across three orders: Cetacea, Sirenia and Carnivora (Pompa-Mansilla et al., 2011). Cetaceans (whales, dolphins and porpoises) are amongst the most endangered taxa due to anthropogenic threats. Both coastal and marine habitats are threatened by a combination of anthropogenic impacts, such as the overexploitation of natural resources, habitat loss and degradation, chemical pollution and noise pollution (Marega-Imamura et al., 2020; Mirimin et al., 2011). Understanding species-environment relationships is crucial for identifying areas of biological importance and prioritising areas for conservation, marine protected area zoning design, resource management and impact assessment (Elith & Leathwick, 2009; Guisan & Thuiller, 2005; Zanardo et al., 2017). Place-based protection that is appropriately designated in a critical habitat for particular marine mammal populations can substantially reduce their likelihood of mortality (Hooker et al., 2011). Marine mammals appear to be one of the few groups that have benefitted most from a shift of management practices, away from resource exploitation towards wildlife conservation (Lotze & Milewski, 2004; Lotze & Worm, 2009; Magera et al., 2013).

Assessing spatial distribution, habitat use, site fidelity and the potential drivers for habitat usage allows for the prediction of how individuals might respond to changes in their environment, and provides effective and informed management strategies for endangered marine mammals (Balmer et al., 2013; Prado et al., 2016). Identifying the factors that may influence habitat selection at multiple spatial and temporal scales, such as food availability and predation risk (Heithaus & Dill, 2006), are essential for understanding the drivers of a population's distribution. Marine habitats are often highly variable and interactions between dolphins and their environmental parameters and habitat features are often dictated by the distribution and availability of their prey (Bilgmann et al., 2019). Geospatial analysis of visual sighting data can be helpful to gain insight into hotspots for core biological activities. Additionally, mitigating the impacts of anthropogenic activities requires knowledge about the geographic occurrence of threats (Avila et al., 2018; Cox et al., 2018) and marine mammals' interaction with those threats. Therefore, conservation approaches that use spatially explicit information on marine wildlife populations have the potential to facilitate recovery and contribute to national and international conservation target commitments (Harvey et al., 2017).

The Burrunan dolphins have been previously described as *Tursiops australis* (Charlton-Robb et al., 2011), an endemic species to south-eastern Australia, with a distribution from South Australia, eastern Tasmania and Victoria (Bilgmann et al., 2019; Charlton et al., 2006; Charlton-Robb et al., 2011, 2015; Pratt et al., 2018). The taxonomic status of the Burrunan dolphins, however, is in dispute (see Committee on Taxonomy, 2019; Jedensjö et al., 2017). In Victoria, there are only two known resident populations; one in Port Phillip Bay (PPB) with approximately 150 individuals and the other in Gippsland Lakes (GL) with approximately 60 individuals (Charlton-Robb et al., 2011). The effective population size (those contributing genes to the next generation) of PPB and GL is 81.5 and 65.5 individuals, respectively (Charlton-Robb et al., 2015). The Burrunan dolphins are considered vulnerable and at increased risk of decline and/or extinction due to their small population size, genetic distinctiveness, female natal philopatry, exposure to a large degree of associated human and maritime activity and restricted home range, which is in close proximity to a major urban city (Charlton-Robb et al., 2015; Warren-Smith & Dunn, 2006).

The Burrunan dolphins were regionally listed as 'Endangered' under the Victoria *Flora and Fauna Guarantee Act 1988* in 2013 (Department of Sustainability and Environment, 2013), and have been recently reassessed following the IUCN Red List criteria and the Australian *Environmental Protection and Biodiversity Act 1999* criteria, and is now listed as 'Critically Endangered' by the state of Victoria (State of Victoria, 2021). This classification was supported by the population's exposure to numerous anthropogenic threats, such as commercial and recreational fishing, anthropogenic contaminants, tourism, shipping, oil and gas mining, seismic exploration and environmental changes (Charlton-Robb et al., 2015; Duignan et al., 2020; Filby et al., 2014; Foord et al., 2024; Monk et al., 2014; Puszka et al., 2021). However, the Burrunan dolphins are not classified as threatened (endangered or critically endangered) at a national or global level. It has been documented that the Burrunan dolphins utilise southern PPB (Filby, Christiansen, et al., 2017; Howes et al., 2012; Scarpaci et al., 2003; Warren-Smith & Dunn, 2006); however, if and how the Burrunan dolphins utilise the whole of PPB (1930 km^2 in size), and the potential drivers for their distribution, are yet unknown, making the management of the population and mitigation of threats difficult. To this end, this study provides the first assessment of the Burrunan dolphins distribution throughout the whole of PPB, including annual and seasonal variation, and explores possible drivers for the distribution of individuals throughout this environment, providing baseline analysis for conservation recommendations. It further highlights key areas for the consideration of spatial conservation, a critical next step for the effective conservation and management of these regionally threatened populations.

2 | METHODS

2.1 | Study site

Port Phillip Bay (Figure 1) is the largest bay (1930 km^2) in the state of Victoria, Australia, with 333 km of coastline and an average depth of 13 m (Department of Environment, Land, Water and Planning, 2017), which is unusually shallow for its size (Harris et al., 1996). The catchment area of PPB is 9790 km^2, consisting of 21 natural drainage basins, eight of which deliver runoff directly into the bay. There is limited water exchange due to a narrow, 3-km wide opening to the

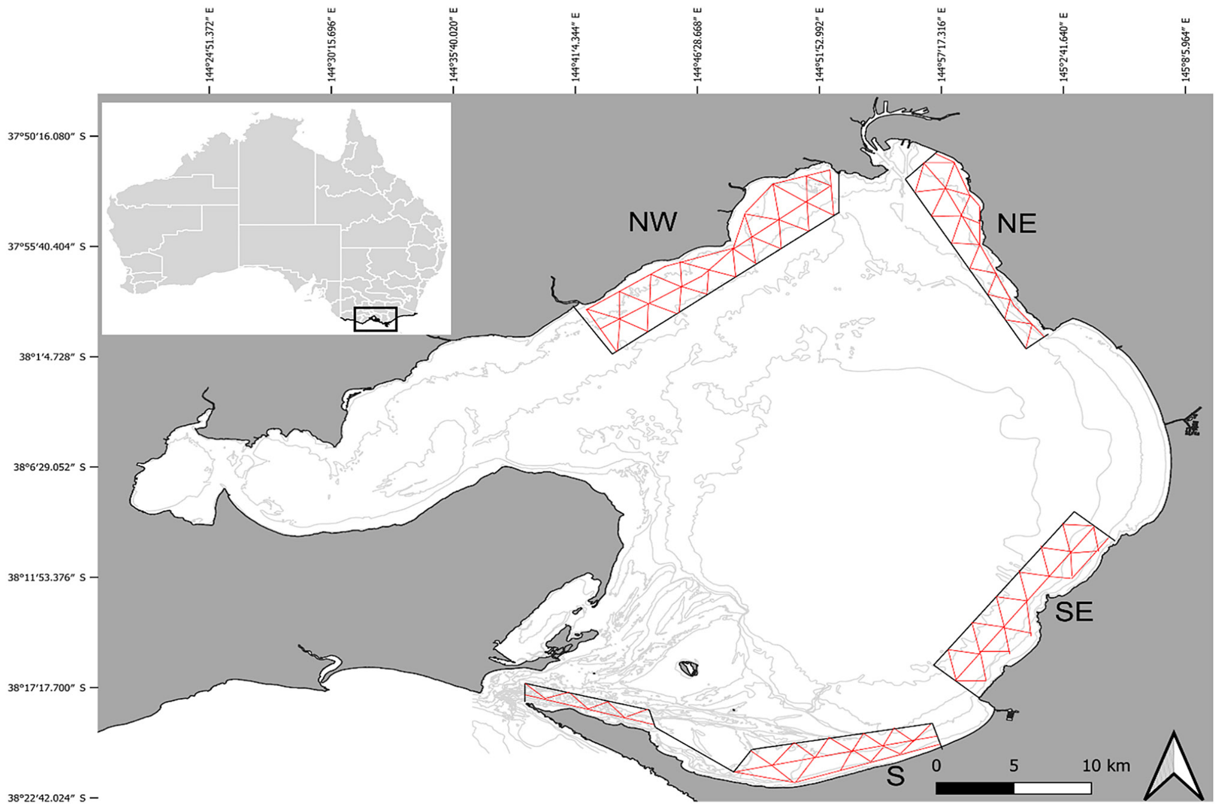

FIGURE 1 Port Phillip Bay (PPB), with insert showing location within Victoria, Australia. The four survey zones of PPB and the pre-determined transect line routes (red), NW – north-west, NE – north-east, SE – south-east and S – south.

Bass Strait (Fu et al., 2017), which results in a flushing time of approximately 12 months (Baker et al., 2016). There are 4.3 million people living within the catchment area of PPB and 1.3 million people living along the coastline (Department of Environment, Land, Water, and Planning, 2017).

2.2 | Data collection

Seasonal boat-based surveys were undertaken by the Australian Marine Mammal Conservation Foundation (Marine Mammal Foundation; MMF) from March 2015 to August 2021 across four regions/zones of PPB (Figure 1). Austral seasons were defined as summer (December–February), autumn (March–May), winter (June–August) and spring (September–November). The zones chosen are representative of the entire 1930 km^2 area of the PPB, covering the southern to the northern reaches (North-west (NW), North-east (NE), South-east (SE) and South (S), and incorporate various habitat types and depths). Some opportunistic sightings did occur outside of these zones. Surveys were conducted during daylight hours, following line transects across the four zones. A 2C research vessel, a 5.7-m Ensign 570 powered by a 90 hp Mercury engine, was used at survey speeds of 8–12 knots. Surveys were conducted on calm weather days in Beaufort Sea State with conditions of two or less (<15 knot winds), as poorer conditions significantly reduce the detectability of surfacing dolphins.

On each survey, GPS information of the vessel travel path along the transects was recorded using a Garmin eTrex20 handheld GPS, enabling survey effort recording. A crew of three or four researchers conducted constant visual scans across the horizon to sight the Burrunan dolphins. Once dolphins were sighted, the transect was paused, and the research vessel approached the dolphins in accordance with all required scientific research permits and animal ethics guidelines. Photographs of the dolphin's dorsal fins were collected, and behavioural focal points were undertaken during each sighting; however, the use of ID data was outside the scope of this geospatial assessment. Observers on the boat commencing audio recording, dictating the location, environmental conditions and dolphin observation data. Waypoints were recorded at the beginning and end of each dolphin sighting, with vessel movement thus equating to dolphin movement. Sighting observations were deemed complete when observers lost sight of the dolphins and/or the sighting was terminated (e.g., due to poor weather conditions), whereupon the line-transect was resumed at the point where the vessel left the transect route.

The vessel track of each survey and dolphin waypoints were exported via GPX data and imported into Q GIS 3.10 A Coruna (QGIS Development Team, 2021) to create survey effort maps and to isolate sighting data amongst the survey day tracks. Audio files were transcribed to gain information on each of the sightings for water depth and bathymetry at each 5-min interval throughout a survey

TABLE 1 The number of Burrunan dolphin sightings, number of survey days and the hours of survey effort across Port Phillip Bay, March 2015 to August 2021.

	Summer		Autumn		Winter		Spring		Total	
	Sightings	Effort (hours)	Sightings	Effort (hours)	Sightings	Effort (hours)	Sightings	Effort (hours)	Sightings	Effort (hours)
2015	0	0 (0)	7	9 (37)	34	17 (87)	0	0 (0)	41	26 (124)
2016	24	10 (44)	13	13 (67)	13	10 (55)	14	7 (41)	64	40 (207)
2018	8	3 (17)	0	4 (23)	5	6 (33)	10	7 (42)	23	20 (114)
2019	3	4 (19)	8	6 (34)	15	7 (41)	7	6 (35)	33	23 (129)
2020	5	4 (21)	2	3 (11)	4	3 (18)	3	4 (14)	14	14 (63)
2021	1	3 (6)	3	2 (11)	2	1 (5)	0	0 (0)	6	6 (23)
Total	41	24 (108)	33	37 (183)	73	44 (238)	34	24 (131)	181	129 (660)

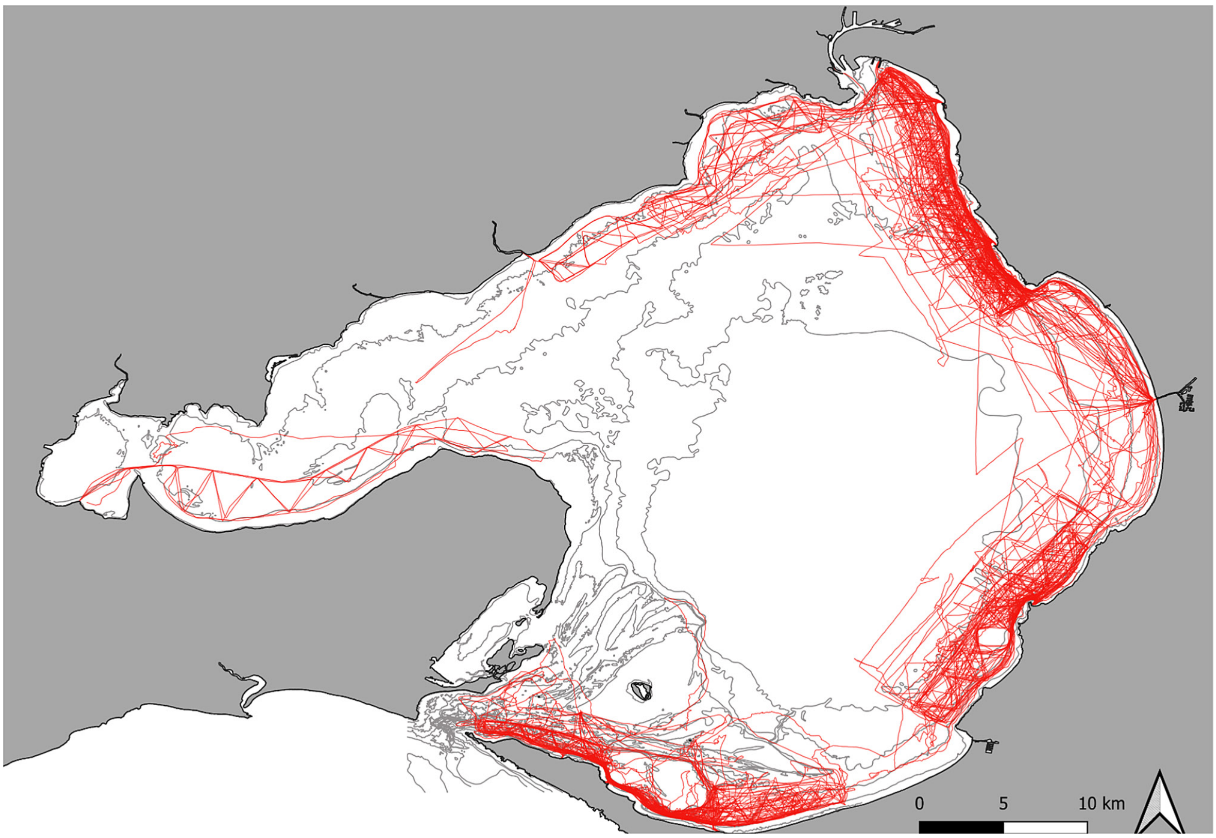

FIGURE 2 Port Phillip Bay, Victoria, Australia, with survey tracks (red) from March 2015 to August 2021.

and tallied into eight empirically selected depth contour categories (e.g., 0–5, 5–10 m, etc.) for each sighting.

2.3 | Data analysis

Dolphin sighting locations were extracted from GPX survey tracks using the position of the vessel at the time of the first sighting of a dolphin (typically within 20 m of the dolphin group). Heatmaps were created using Q GIS 3.10 A Coruna with plugin 'Heatmap' (QGIS Development Team, 2021) to display population distribution, zone usage and seasonal and annual variation of the Burrunan dolphins in PPB.

We used generalised linear models (family Poisson) to investigate spatiotemporal variation in the number of sightings during each survey using zone (NW, NE, SE and S) Austral season (summer, autumn, winter and spring) and year (2015–2016, 2018–2021) as factors and effort as a continuous explanatory variable. These statistical analyses were conducted using R Version 4.2.0, in RStudio 2022.02.0 Build 443. To investigate any significant factorial effects on the number of sightings in more detail, including post-hoc testing, we used package emmeans (Lenth, 2023). For annual comparison, a *p*-value adjustment using the Tukey method was used to compare a family of six estimates, for season and zone, a *p*-value adjustment using the Tukey method was used

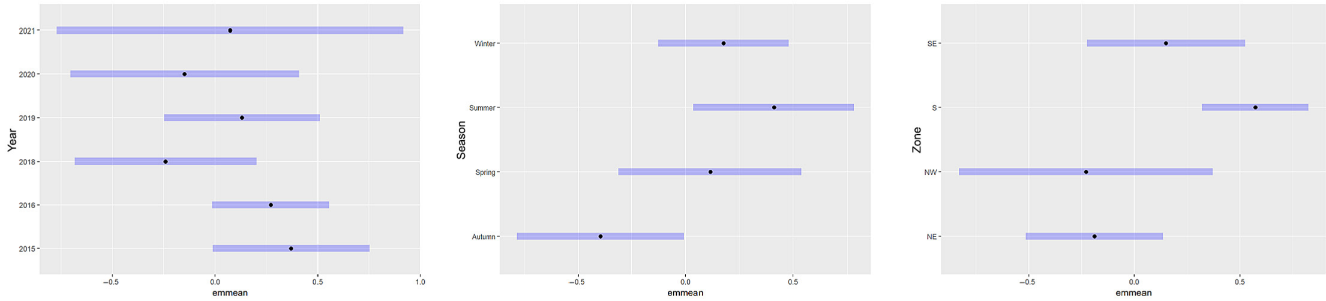

FIGURE 3 Investigating annual, seasonal and zonal influence of Burrunan dolphin distribution between March 2015 and August 2021 using emmeans. For annual comparison, a *p*-value adjustment using the Tukey method for comparing a family of six estimates, for season and zone, a *p*-value adjustment using the Tukey method for comparing a family of four estimates, significance level used $\alpha = .05$.

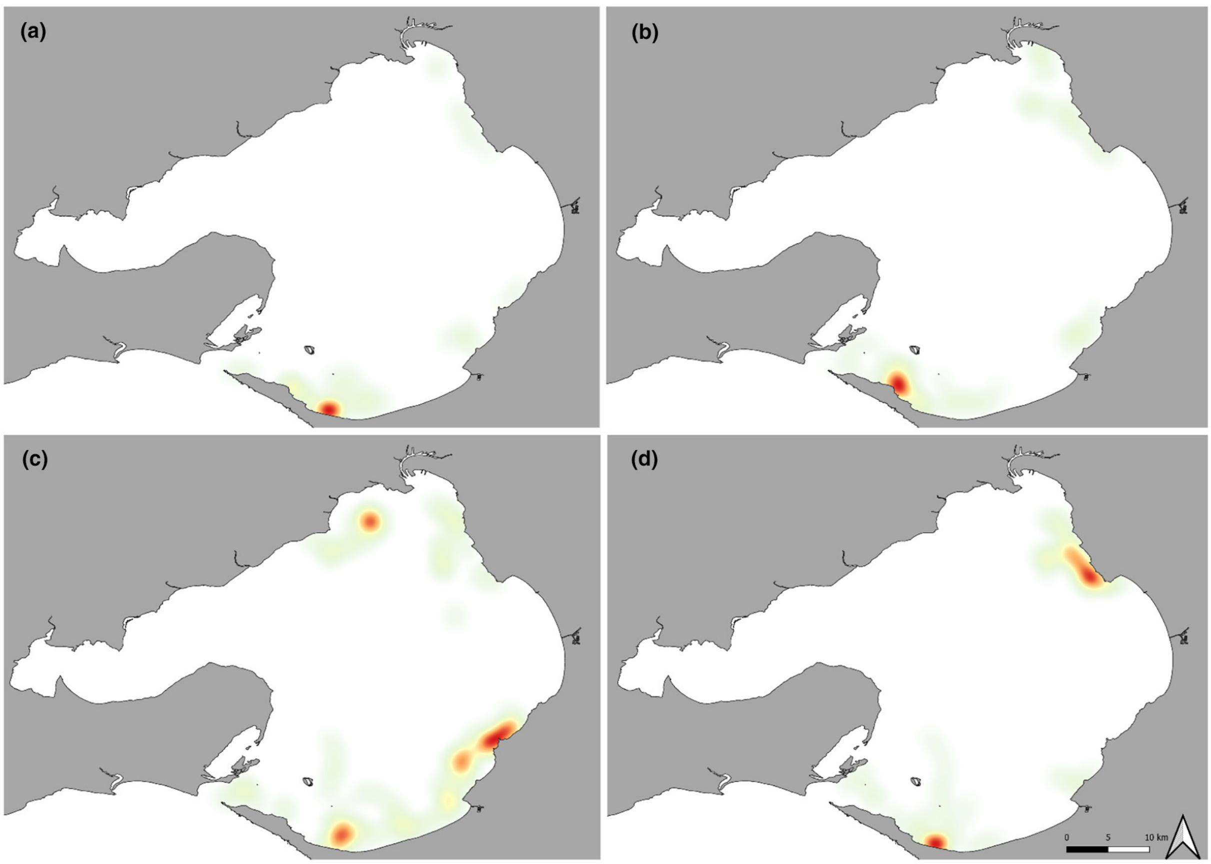

FIGURE 4 Seasonal heatmaps of Burrunan dolphin sightings from March 2015 to August 2021 in Port Phillip Bay, Victoria, with colours graduating from areas of high sightings (red) to areas of low sightings (green), (a) Summer, (b) Autumn, (c) Winter and (d) Spring.

to compare a family of four estimates; the significance level used $\alpha = .05$.

PPB presents a unique study site to explore whether small incremental bathymetry gradients (minimum 0 m – maximum 40 m) influence marine mammal distribution. Ivlev's selectivity or Jacob's index (Jacob, 1974) was used to evaluate the degree of preference for each depth category:

$$E_i = \frac{(U_i - A_i)}{(U_i + A_i)}$$

where U_i represents the proportion of use of a depth category *i* and A_i its proportional availability. The selectivity index E_i varies from −1 (indicating a use lower than the availability of the category *i*) to 1 (indicating overuse); a value of zero indicates a proportional use of a depth category in relation to its availability.

To visually explore habitat as a potential driver for the distribution of Burrunan dolphins, we used theme layers including Marine and Coastal Feature Atlas, Victorian Biotope Atlas and Planning and Administration from the online data repository CoastKit (Victorian Department of Environment, Land, Water and Planning).

These themes provided information about National Parks in PPB and Marine Protected Areas in PPB. The Combined Biotope Classification Scheme (CBiCS) Level 3 Class map (Figure 7) involving 19 different habitat complexes for the study area was developed and provided by the Victorian Department of Environment, Land, Water and Planning for exploration of physical benthic habitat types and communities (Mazor et al., 2021). CBiCS is an ecologically based hierarchical classification system unifying and standardising classifications across marine environments (Edmunds et al., 2021; Edmunds & Flynn, 2015, 2018). The term 'Biotope' describes a community of species in a defined abiotic habitat and is used throughout CBiCS; however, as this is not a common term in the literature, hereafter the term used will be 'benthic habitats'. Desired themes were downloaded as shapefiles and imported into Q GIS. These shapefiles were then overlain with distribution maps of the Burrunan dolphin sighting tracks to display associations of habitat use across PPB.

3 | RESULTS

During the study period from March 2015 to August 2021, a total of 181 sightings of Burrunan dolphins were recorded across 129 boat-based survey days in PPB, with 660 hours of survey conducted (Table 1), across all four survey zones, inclusive of vessel transit regions (Figure 2).

Assessment of pooled sightings throughout the 2015–2021 study period found that Burrunan dolphins were observed in all four survey zones in PPB. No annual variation was observed in sighting frequency during 2015–2021, with no differences observed between individual years. Emmeans graphs showed some seasonal variation in the sighting frequency of Burrunan dolphins. Autumn had a lower number of sightings than both summer and winter (p-value = .01 and .04, respectively), with spring being indistinguishable from other seasons (Figure 3). Zonal variation was also observed, with the S zone having a higher number of sightings than the NW and NE zones (p-value = .05 and <.01, respectively) (Figure 3).

Seasonal movement patterns were observed throughout the 2015–2021 survey period. Dolphin sightings were higher within the S zone of PPB in summer (December–February) and autumn (March–May), whilst a wider region of PPB was utilised during winter (June–August) and spring (September–November) (Figure 4).

Dolphin sighting tracks closely follow bathymetric contour lines (Figure 5) in both the north and south of PPB. The NE zone, SE zone and the southern region of PPB displayed high dolphin sightings; these regions also had complex bathymetrical contours (Figure 5).

The preference for Burrunan dolphins to use particular depth contours was explored using Ivlev's selectivity index (Figure 6). The Burrunan dolphins showed preference for the 5–10 and 10–15 m depth categories (I = 0.29 and 0.30, respectively). Furthermore, the Burrunan dolphins avoided areas of depth lower than 5 m and greater than 20 m (I = −0.06 and −0.87, respectively).

Using the CBiCS classification and seagrass layers to create exploratory maps, areas of high dolphin sighting tracks were seen around several benthic habitats, in particular sublittoral seagrass beds, sublittoral rhodolith beds and high and low energy infralittoral rock regions that transition into sublittoral mud and sand regions (Figure 7). These regions correspond with areas of bathymetry

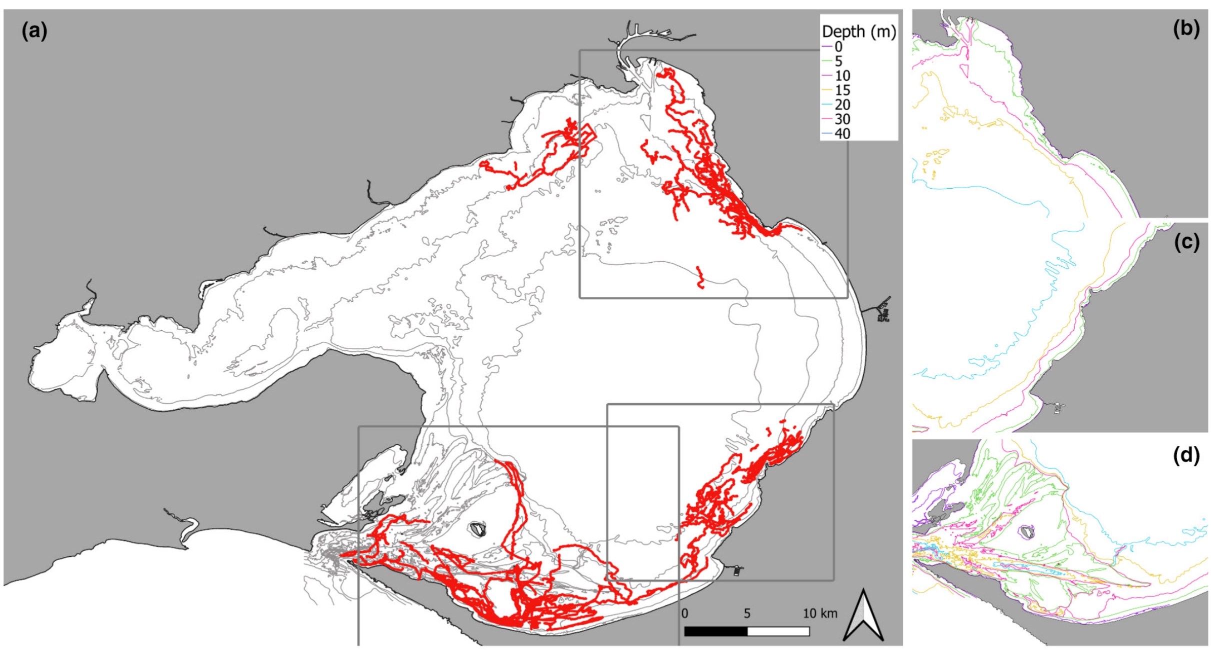

FIGURE 5 (a) Burrunan dolphin sighting tracks (red) from March 2015 to August 2021 with bathymetry contours of Port Phillip Bay (grey). Inserts showing greater details in high sightings areas with colour coded bathymetry depths, (b) NE zone, (c) SE zone and (d) S zone.

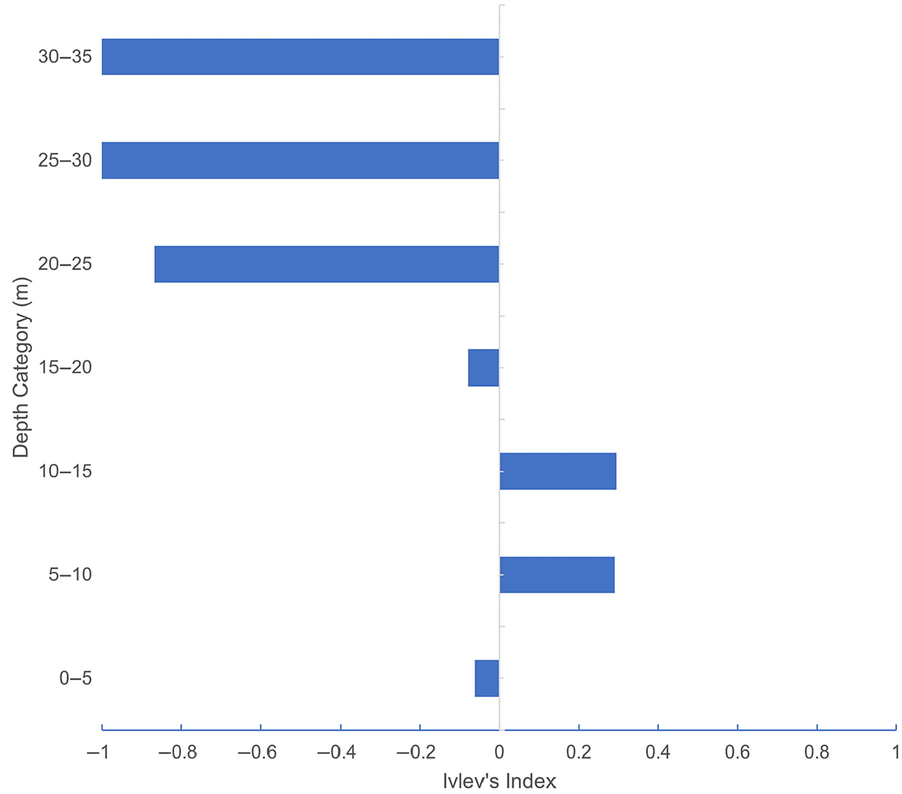

FIGURE 6 Burrunan dolphin depth contour preference between 0 and 35 m from March 2015 to August 2021 (Ivlev's selectivity index).

complexity (Figure 6). There was a high number of sightings around the transitional boundaries of benthic habitats.

Of the four marine parks and sanctuaries across PPB, the Burrunan dolphins frequented the Ricketts Point Marine Sanctuary in the NE zone (Figure 8). None of the sightings seen in the NW zone overlapped with the Point Cooke Marine Sanctuary. Few sightings were seen within the boundary of the protected areas within the Port Phillip Bay Heads Marine National Park, and three sightings were seen within the Ticonderoga Bay Sanctuary Zone.

4 | DISCUSSION

Baseline information on the distribution and movement patterns of a population is critical for effective conservation and management of wildlife. The analysis of population distribution patterns at a fine-scale provide the best resolution for examining local species-environment relationships, habitat usage and anthropogenic impacts (Brough et al., 2019; Harwood et al., 2014; Zanardo et al., 2016). Food availability, predation risk and anthropogenic activities are known to influence delphinid habitat use (Heithaus & Dill, 2006; Pirotta et al., 2019). Using sightings data collected during 2015–2021 from four survey zones representative of numerous benthic habitats and bathymetrically complex areas in PPB, we found that the Burrunan dolphins utilise the entirety of PPB, from the northern to the southern reaches, show seasonal distribution changes and have higher sightings in regions of complex bathymetry. Sublittoral seagrass beds, sublittoral rhodolith beds and high- and low-energy infralittoral rock regions that transition into sublittoral mud and sand regions were found to have a high number of sightings also.

4.1 | Seasonal variation in Burrunan dolphins distribution

Marine animal populations tend to shift their geographic ranges in response to varying environmental conditions, resulting in seasonal shifts in population distribution. In particular, dolphin associations with environmental parameters and habitat features are often dictated by the distribution and availability of prey (Bilgmann et al., 2019; Hastie et al., 2004; Heithaus & Dill, 2002; Rayment et al., 2010). Seasonal shifts in population distribution provide an additional challenge for the spatial protection of dolphin populations. We found consistent sightings across all seasons in the southern region, and a northwards trend in the Burrunan dolphins distribution was observed during the winter (SE zone, Figure 4) and spring (NE zone, Figure 4). We hypothesise that a subgroup of the population displays high site fidelity within the southern zone, remaining in the area year-round, whilst another subgroup of the population migrates north in winter and spring. Higher density of sightings across more zones during winter and spring indicates a broader region of PPB is being utilised throughout these seasons. Individual or small group movement patterns within a population can also vary greatly,

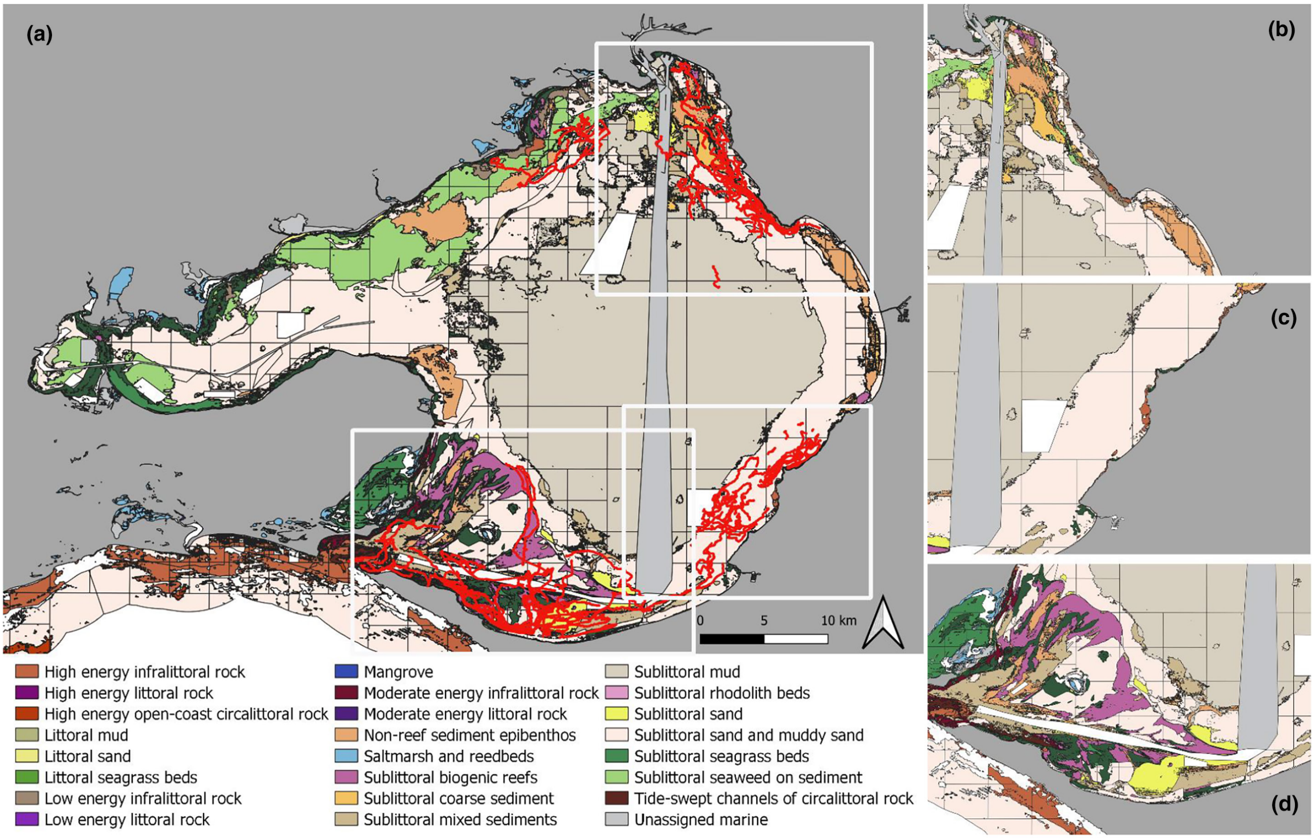

FIGURE 7 (a) Burrunan dolphin sighting tracks (red) from March 2015 to August 2021 overlain with Port Phillip Bay biotope regions. Inserts showing greater details in high sightings areas, (b) NE zone, (c) SE zone and (d) S zone.

as some members of a resident population may remain within a small home range (Gubbins, 2002; Zolman, 2002), whereas other members of the same population may display little preference for a particular area (Toth et al., 2011). Shane et al. (1986) suggested that ranging patterns of populations can vary from permanent local ranges to seasonal migration to short-term seasonal site fidelity. Confirmation of this high site fidelity perceived in certain subgroups is critical for effective conservation management, ensuring that the subgroup has a protected area to continue core biological activities and respite from anthropogenic activities such as high vessel traffic. Ongoing research is required to confirm this hypothesis, with continued boat-based surveys and photographic dorsal fin identification of individuals within the PPB population. This robust identification methodology would allow for individual and potential subgroup site fidelity and movement patterns to be further investigated.

Throughout all seasons, the southern region of PPB experienced a high dolphin presence (Figure 3). A decline in dolphin presence was previously hypothesised during the summer period due to increased recreational boat traffic and tour operator activity (Filby et al., 2014; Scarpaci et al., 2003); however, this was not evidenced during the current study. Four swim-with-dolphin tour vessels operate within the region, with each vessel running a maximum of two trips daily between October and May (Filby, Christiansen, et al., 2017). Filby et al. (2014) highlight the impacts of tour vessels and recreational boat interactions on dolphin behaviour, with these interactions often resulting in the expenditure of greater amounts of energy avoiding vessels in the dolphins impacted. Dolphins may remain in an area of high vessel disturbance while altering behaviour to minimise the disturbance (Lusseau, 2003; Williams et al., 2004). For example, they may temporarily move away during periods of high vessel activity but return once vessel traffic has reduced, or they may abandon a region that was once preferred due to vessel disturbances (Bejder et al., 2006). These impacts can indirectly affect the fecundity and survival of the population (Gill et al., 2001; Steckenreuter et al., 2011). Despite the biological cost linked to these human impacts, the Burrunan dolphins remained in the southern region during peak vessel activity (Figure 3). The Indo-Pacific bottlenose dolphin population found in Port Stephens, NSW (Steckenreuter et al., 2012; Wiszniewski et al., 2009, 2010) exhibited changes in their activity budgets in the presence of boats, with no resting, reduced feeding and socialising recorded and an increase in milling and travelling behaviours when boats were in the area. Similarly, the Burrunan dolphins spent less time foraging when swim-with-dolphin tourism vessels were present (Filby, Christiansen, et al., 2017). Unfortunately, the PPB population may not be able to avoid anthropogenic disturbance by moving away from the current habitat, as they have likely adapted to the environmental and ecological conditions of the area.

A potential driver for the observed seasonal shifts in the contraction and expansion of distribution ranges could be in response to breeding and/or birthing seasons (Clutton-Brock, 1997;

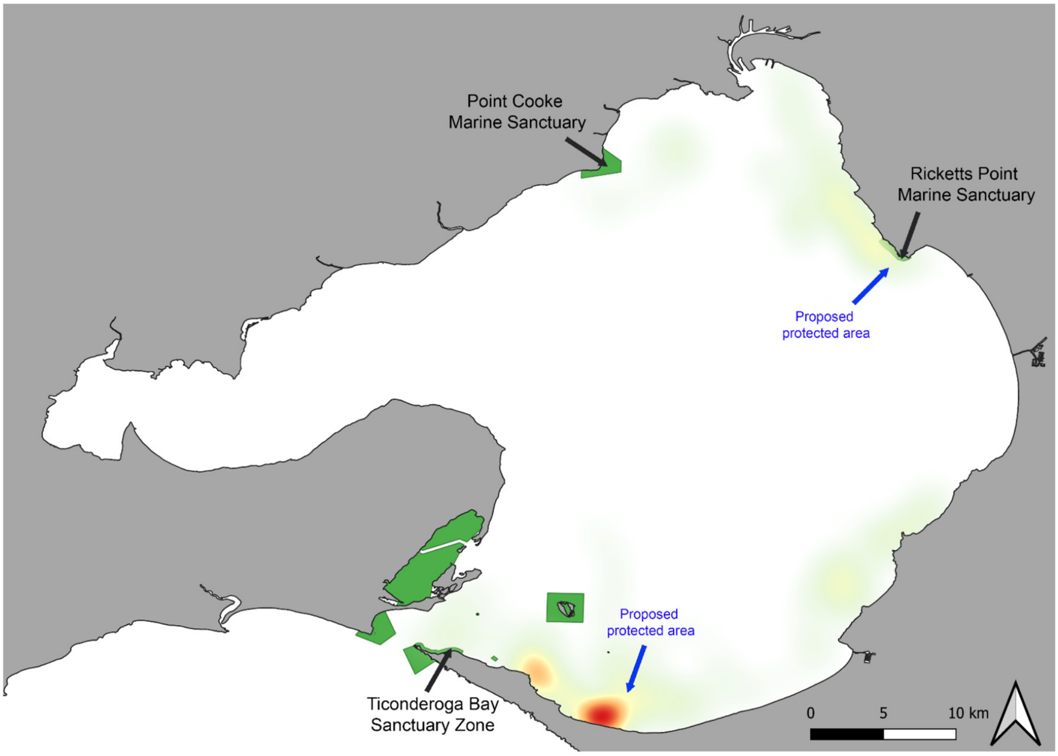

FIGURE 8 Burrunan dolphin pooled sighting from March 2015 to August 2021, represented as heatmaps with colours graduating from areas of high sightings 'hotspots' (red) to areas of low sightings (green), overlain with the Marine National Parks within Port Phillip Bay (green) and proposed protected areas (blue arrow).

Greenwood, 1980; Sprogis et al., 2016). Long-term studies of bottlenose dolphin populations have found that females tend to have a smaller home range and stronger site fidelity (Gubbins, 2002; Smith et al., 2013; Urian et al., 2015; Wells, 2003), while males tend to have lower site fidelity and larger home ranges, especially during nonbreeding seasons when they may adjust their home ranges to optimise prey intake (Sprogis et al., 2016, 2018). The age and sex of individuals included in this study are unknown; however, further investigation into the sex-specific distribution of the Burrunan dolphins would be beneficial for supporting the sub-group hypothesis previously mentioned.

Another potential driver for the observed seasonal shifts of distribution, and potential subgroup movement patterns, is prey availability. Information regarding the diet of the Burrunan dolphin is limited, although through observation and isotope analysis, the dolphins are thought to feed on garfish, calamari squid, snapper, sand flathead, yellowfin bream and barracouta (Filby, Stockin, & Scarpaci, 2017; Owen et al., 2011) (Appendix S1). Further to this, the examined contents of deceased PPB dolphins suggest that King George whiting and Australian salmon may also occur within their diet (Mason, 2007 as cited in Filby, Stockin, & Scarpaci, 2017). In comparing the high prevalence of sightings across all seasons in southern PPB with potential prey resources, we note peak spawning of southern calamari occurs in nearshore habitats typically between spring and early summer; however, this can occur all year round (Moltschaniwskyj & Steer, 2004; Smith et al., 2015). Spawning typically occurs in inshore coastal regions, with eggs laid in seagrass and algal reef habitats (Commissioner for Environmental Sustainability, 2021). Garfish have also been observed in deep seagrass regions in February and March within the south of PPB (Smith et al., 2012). We suggest that increased foraging occurs at the southern end of PPB due to bathymetry complexity, seagrass regions and prey availability, especially during the summer. However, it is also possible, given the close proximity of this region to Bass Strait, Burrunan dolphins may travel outside of PPB in search of resources. Stable isotope analysis conducted by Owen et al. (2011) found that the PPB population was 4.5% higher in δ^{15}N than the average signature of potential prey items within PPB. This suggests that the PPB population have additional unidentified prey resources that have a higher trophic level than that of the prey items sampled. This supports the hypothesis that a subgroup of Burrunan dolphins shows high site fidelity to the southern region of PPB all year round, and when resources inside the southern end of PPB are no longer sufficient, they may forage in Bass Strait and then utilise the inside of the bay in the southern region for other core biological activities (e.g., milling/resting and social activities).

Port Phillip Bay also experiences a major immigration of larger reproductive snapper during spring and summer, which have a limited summer spawning period (Hamer & Jenkins, 2004). High sightings of Burrunan dolphins in the NE zone (Figure 4) correspond with the peak recreational fish catch seen in late winter and spring, and this is driven by snapper movement into northern regions PPB in anticipation of spawning season (Hamer et al., 2011; Longmore, 2014; Ryan et al., 2019). The shallow reefs along the NE coastline have been identified as highly suitable for subadult snapper (Morris & Ball, 2006). In addition, spawning for King George whiting occurs near coastal reefs in autumn and early winter (Fowler et al., 2000; Jenkins & King, 2006), which spend their first 4 years maturing in the PPB seagrass nurseries (Commissioner for Environmental Sustainability, 2021). It is therefore likely that the numerous potential prey species aggregating in higher abundance in the northern reaches of the bay during this period, may enable greater foraging opportunities for the Burrunan dolphins. The seasonal distribution of these prey items supports the hypothesis of a subgroup migrating north to the SE zone during winter and moving further north to the NE zone during spring to follow prey resources. Further research investigating the foraging behaviour and prey choice of the Burrunan dolphins, both inside of PPB and possibly in the Bass Strait region, is encouraged to help identify other key regions of Burrunan dolphin distribution and confirm the population's specific diet preferences.

4.2 | Oceanographic drivers of distribution across Port Phillip Bay

Bathymetry is an important variable in explaining habitat distributions, as it acts as an indirect proxy of light availability (Ierodiaconou et al., 2018), which in turn may directly or indirectly affect zooplankton, fish phenology (Durant et al., 2019) and benthic communities (Douglas et al., 2022; Rovelli et al., 2019). Bathymetric variability and bottom structure can lead to increased biological productivity (Simard et al., 2015); surface complexity can also influence the availability of food, protection from predation, exposure to currents and wave action (Ierodiaconou et al., 2007). Studies have found that water depth and bathymetrical complexity are significant factors in determining the distribution of marine species (Gross et al., 2009; Hastie et al., 2004, 2005), with bathymetry strongly associated with patterns of marine mammal species richness and complementarity (Astudillo-Scalia & de Albuquerque, 2020). A high association between the Burrunan dolphins' movement patterns and the bathymetric contour lines was found (Figure 5), with sighting tracks often running parallel with bathymetry lines. These high sighting areas correlate to gradients in depth, with gradients from 5 to >15 m occurring close to shore (Figure 5), creating a complex bathymetry environment. Complex landscapes can facilitate prey capture by providing physical barriers to corral prey, slowing down the escape of prey and providing predator stalking cover (Bouchet et al., 2015; Chundawat, 1990; Sweanor et al., 2000). Orcas in the Pacific Northwest have been found to herd prey using bathymetric features, by driving fish towards physical barriers to concentrate the prey into denser groups (Bouchet et al., 2015; Heimlich-Boran, 1988). This is similar to the PPB Burrunan dolphin, which has shown a preference for complex bathymetrical regions, likely to aid with prey capture.

The PPB Burrunan dolphin population provides an insight into the effects of depth as a driver of distribution in a shallow coastal environment. We show evidence of the selection-avoidance of habitat types of differing depths, with the 20–25 m depth category being utilised in a significantly lower proportion relative to the percentage of this depth category within PPB (27%). Burrunan dolphins were found to prefer the 5–10 and 10–15 m depth contours. Our findings are similar to shallower water depth preference and/or occurrence of Australian humpback dolphin, Ningaloo Marine Park (Western Australia) 5–10 m (Hunt et al., 2020); the southern Australian bottlenose dolphin, Coffin Bay (South Australia), 2–4 and 7–10 m (Passadore et al., 2018); and the Indo-Pacific humpback dolphin Bay of Bengal (India) 5–15 m (Lin et al., 2021). In each of these studies, prey and predator avoidance have been the most commonly documented drivers for these depth preferences. Areas at these particular depths or gradients have been documented to improve accessibility to demersal fish, and the regional bathymetry profile could positively affect the handling efficacy of catching prey (Durden et al., 2019; Hastie et al., 2003, 2004; Wang et al., 2021; Wu et al., 2017). In this case, demersal fish, such as snapper and King George whiting, are documented prey items of Burrunan dolphins (Filby, Stockin, & Scarpaci, 2017; Owen et al., 2011). There is little peer-reviewed documentation on the preferred depths of the Burrunan dolphin's prey species in PPB. Trawls conducted by Parry et al. (1995) found the largest biomass of snapper at depths of 12 m, and anecdotal evidence describes King George whiting's preferred depth as 3–10 m. In an adjacent Victorian embayment, Western Port Bay, the highest proportion of snapper was found between 7 and 18 m, and the King George whiting was found within 2–10 m (Jenkins et al., 2020). Therefore, we loosely hypothesise, based on the limited data, that the Burrunan dolphin's preference for 5–10 and 10–15 m depth contours may be associated with prey availability and capture; however, more research is required to explore this theory.

Benthic habitat, or particular habitat regions (e.g., soft sediment, seagrass rock and reefs) play an important role as predictors of a species' spatial distribution. A wide range of benthic habitats have been thought to drive dolphin distribution around the world (Bennington et al., 2021; Bonneville et al., 2021; Gross et al., 2009; Sprogis et al., 2022; Zanardo et al., 2017). South Australian bottlenose dolphins were found to have a year-round preference for bare sand habitat; however, preference for seagrass regions was seen to increase during summer and autumn, which could be indicative of a seasonal variation in habitat preference (Cribb et al., 2013; Zanardo et al., 2017). Alternatively, Indo-Pacific bottlenose dolphins in the coastal areas of Noumea and Plum were found to favour muddy bottoms (Bonneville et al., 2021). Whereas, Indo-Pacific bottlenose dolphins in Bunbury southwestern Australia were found to have a preference for reef habitat, followed by a preference for sand and mud/silt (Sprogis et al., 2018). These regions likely constitute the habitat regions where the prey of the coastal dolphin are concentrated (Gross et al., 2009).

This study showed a higher number of sightings of Burrunan dolphins in sublittoral seagrass beds, sublittoral rhodolith beds and high- and low-energy infralittoral rock regions that transition into sublittoral mud and sand regions, indicating these regions provide suitable habitat for the dolphins and/or potential prey items. Seagrass beds and rhodolith beds have greater fish diversity and density than adjacent flattened areas (Costa et al., 2020; Heck et al., 1997; Horta et al., 2016). These zones also provide nursery grounds for many fish assemblages (Madi Moussa et al., 2020; Verweij et al., 2008), including some of the Burrunan dolphin prey species such as snapper (Owen et al., 2011), King George whiting and squid (Filby, Stockin, & Scarpaci, 2017). It is often assumed that dolphins feed primarily within seagrass beds, as these habitats are where fish are most abundant (Wilson et al., 2017). However, recent studies have suggested that these environments may hinder foraging, as seagrass attenuates echolocation and fish vocalisations by scattering sound energy (Wilson et al., 2013). Therefore, dolphins may prefer to forage in less dense seagrass patches (Mann et al., 2021) or on the edge of seagrass beds, in transitional zones (Allen et al., 2001; Nowacek, 2005), where acoustic detection of prey is more efficient. Infralittoral reefs are key habitats for many fish species because they can provide a source of food and shelter (Davis et al., 2020; Young et al., 2022). Anderson (2003) also found that sand-associated fish species such as sand flatheads were more common in close proximity to structured rather than completely unvegetated habitats, which further supports findings from Ferrell and Bell (1991) that non-seagrass fish species are more abundant in sand within 10m of seagrass (Smith et al., 2008). Juvenile snapper has also been found to be most abundant over soft sediments that are adjacent to rocky reef areas, preferring reef-sand boundaries (Langlois et al., 2005; Rees et al., 2021; Ross et al., 2007). As these are both prey species, this may explain why Burrunan dolphins are frequently sighted in these transitional zones (infralittoral rock to sublittoral mud and sand, and seagrass to sand regions). Overall, benthic habitats appear to play a key role in driving the distribution of Burrunan dolphins in PPB, in combination with other factors.

4.3 | Marine protected areas

Port Phillip Bay has four Marine National Parks and Sanctuaries; however, only one dolphin sanctuary zone is specified for the 'protection' of dolphins, located in southern PPB (Figure 8). Ticonderoga Bay Sanctuary Zone (TBSZ) was established in 1996, aiming to provide respite and refuge for resident Burrunan dolphins (Howes et al., 2012) through the introduction of stringent approach and speed regulations in place for vessels (Department of Environment, Land, Water, and Planning, 2019). However, as stated by Filby, Stockin, and Scarpaci (2017), the implementation of this sanctuary zone was not based on robust scientific observational data; rather, the proposal was based on anecdotal dolphin observations in the area, which did not reveal whether TBSZ was of critical importance to the population in terms of usefulness for core biological activities (Filby, Stockin, & Scarpaci, 2017) and was lacking scientific validation (Howes et al., 2012). As TBSZ is the only designated protected area for the Burrunan dolphins in PPB, we explored how the sightings observed in this study compared with the overall region. Of the 181 sightings that occurred during 2015–2021, only three sightings were observed in the TBSZ. This raises further questions about whether this one sanctuary zone is effective for the conservation management of the species. A much higher density of dolphin sightings was noted in the southern zone, further east of TBSZ (Figures 4 and 8). This higher sighting density area is of particular concern as anthropogenic activities intensify during the summer period in this location, with an increased number of recreational vessels, tour boat operations and swim-with-dolphin tourism. This peak in human activities is likely to overlap with Burrunan dolphin habitat use and potentially cause disturbances to the population.

Further, the Ricketts Point Marine Sanctuary, established in 2002 in the north-eastern PPB, appears to be a habitat 'hotspot' zone for the Burrunan dolphin population, showing a high sighting density (Figures 4d and 8). Ricketts Point Marine Sanctuary covers 115ha, within which fishing is prohibited. In the shallows of the marine park, there are seagrass beds that form nurseries and feeding grounds for many animals. Australian marine reserves were found to have a 28% greater abundance and 53% greater biomass of fished species compared to open fishing areas (Goetze et al., 2021). Additionally, many MPAs can produce 'habitat spillover' where species from inside the protected area move to surrounding unprotected areas (Forcada et al., 2009), and can be seen to benefit areas adjacent to implemented MPAs. The benefits of marine reserves were greater in highly protected (no-take reserves), like Ricketts Point Marine Sanctuary, and increased with size, age, connectivity and depth (Goetze et al., 2021). In this study, we see evidence of this, with a high number of dolphin sightings in and around the Ricketts Point Marine Sanctuary zone. As such, it is likely to be a worthy candidate for further protection. We recommend expanding the sanctuary borders to the 15-m depth contour line to increase the overall size and depth range incorporated in the sanctuary zone.

Overall, we found that the Burrunan dolphins used areas within and around existing protected areas. However, other core areas of high use still remain unprotected. As the Burrunan dolphins are regionally listed as a critically endangered species by the state of Victoria (State of Victoria, 2021), the successful implementation of MPAs (and marine mammal-specific MPAs) is critical for this population's survival. The Burrunan dolphins distribution and habitat use were found to have a low association with the TBSZ, with only three sightings within the zone throughout the 6years of survey. As such, we recommend that TBSZ remain a dedicated dolphin sanctuary zone until further research into the area is conducted. Two additional areas of PPB were identified as critical 'hotspot' zones and areas of importance for the Burrunan dolphins; the southern zone of PPB to the east of TBSZ and the NE zone of PPB, near the Ricketts Point Marine Sanctuary. Given the known anthropogenic threats impacting the species, and of particular note, Filby, Stockin, and Scarpaci (2017) and Puszka et al. (2021) observing behavioural impacts in the dolphins in response to vessel interactions, we recommend affording these two additional areas the same level of protection as TBSZ (no approach of vessels within 200m, no approach of jet skis within 300m, 5knots speed limit in the zone), allowing for greater protection of the Burrunan dolphins in both habitat 'hotspots'. This would see the creation of a new MPA in the southern zone, which we recommend to provide year-round protection for the Burrunan population since they are seen in the southern zone all throughout the year (Figures 4 and 8). In the NE zone, we recommend the expansion of Ricketts Point Marine Sanctuary. This expansion could be a seasonal protection that considers the influx of Burrunan dolphins into the NE zone during spring (Figure 4).

5 | CONCLUSION

For the first time, this study investigates the distribution and habitat use of the Burrunan dolphins throughout PPB, greatly increasing our understanding of species presence across PPB. The distribution of Burrunan dolphins was seen to vary seasonally, with prey resources presumably acting as a seasonal driver. The observed seasonality of sightings also inferred potential subpopulation site fidelity, with dolphin presence year-round in southern PPB, and more wide-spread distribution during winter and spring. Further, we found the dolphins favouring certain depth contours (5–10 and 10–15 m) and benthic habitat transitional zones (sublittoral seagrass beds, sublittoral rhodolith beds and high- and low-energy infralittoral rock regions that transition into sublittoral mud and sand regions). As the impacts of human activities may threaten the survival of this species, we recommend two additional dolphin sanctuary zones be established to serve as critical habitat hotspots for the population. This includes the addition of a new static sanctuary zone in the southern zone of PPB and the seasonal expansion of the current Ricketts Point Marine Sanctuary. We provide a baseline PPB-wide distribution study and recommend continued monitoring in the current zones and exploration into other undocumented areas across PPB based on these findings, as well as for the implementation of successful conservation management strategies for the protection of the Burrunan dolphins.

AUTHOR CONTRIBUTIONS

Jemima Beddoe: Conceptualization (equal); data curation (equal); methodology (equal); project administration (equal); visualization (equal); writing – original draft (lead); writing – review and editing (equal). **Jeff Shimeta:** Conceptualization (equal); methodology (equal); project administration (equal); supervision (equal); writing – review and editing (equal). **Marcel Klaassen:** Formal analysis (equal); methodology (supporting); writing – review and editing (equal). **Kate Robb:** Conceptualization (equal); funding acquisition (lead); methodology (equal); project administration (equal); resources (lead); supervision (equal); writing – review and editing (equal).

ACKNOWLEDGEMENTS

We pay our respects to the traditional custodians of the land and waters on which this study took place, the Yaluk-ut Weelam clan of the Boon Wurrung people of the Port Phillip region and the people of the Kulin Nation, and pay respects to elders past, present and emerging. We acknowledge the dedicated work of the past and present members of the Marine Mammal Foundation who assisted in data collection and processing, A. Howard for images of prey items in necropsy, and M. Carve Luzardo for her assistance with data processing. This work was financially supported by the Department of Environment, Land, Water and Planning (Victorian State Government), the Australian Geographic Society and Lord Mayor's Charitable Foundation. Open access publishing facilitated by RMIT University, as part of the Wiley - RMIT University agreement via the Council of Australian University Librarians.

CONFLICT OF INTEREST STATEMENT

We have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

ORCID

Jemima Beddoe https://orcid.org/0000-0002-6004-6751
Jeff Shimeta https://orcid.org/0000-0002-7003-7832
Marcel Klaassen https://orcid.org/0000-0003-3907-9599
Kate Robb https://orcid.org/0000-0002-7038-3612

REFERENCES

Allen, M., Read, A., Gaudet, J., & Sayigh, L. (2001). Fine-scale habitat selection of foraging bottlenose dolphins *Tursiops truncatus* near Clearwater, Florida. *Marine Ecology Progress Series*, *222*, 253–264. https://doi.org/10.3354/meps222253

Anderson, T. (2003). *The functional relationship between temperate fishes and the associated seagrass landscapes* [PhD Thesis, The University of Melbourne].

Astudillo-Scalia, Y., & de Albuquerque, F. S. (2020). The geography of high-priority conservation areas for marine mammals. *Global Ecology and Biogeography*, *29*(12), 2097–2106. https://doi.org/10.1111/geb.13175

Avila, I. C., Kaschner, K., & Dormann, C. F. (2018). Current global risks to marine mammals: Taking stock of the threats. *Biological Conservation*, *221*, 44–58. https://doi.org/10.1016/j.biocon.2018.02.021

Baker, J. K., Long, S. M., Hassell, K. L., Pettigrove, V. J., & Gagnon, M. M. (2016). Health status of sand Flathead (*Platycephalus bassensis*), inhabiting an industrialised and urbanised embayment, Port Phillip Bay, Victoria as measured by biomarkers of exposure and effects. *PLoS ONE*, *11*(10), e0164257. https://doi.org/10.1371/journal.pone.0164257

Balmer, B. C., Schwacke, L. H., Wells, R. S., Adams, J. D., George, R. C., Lane, S. M., McLellan, W. A., Rosel, P. E., Sparks, K., Speakman, T., Zolman, E. S., & Pabst, D. A. (2013). Comparison of abundance and habitat usage for common bottlenose dolphins between sites exposed to differential anthropogenic stressors within the estuaries of southern Georgia, U.S.A. *Marine Mammal Science*, *29*(2), E114–E135. https://doi.org/10.1111/j.1748-7692.2012.00598.x

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C., & Krützen, M. (2006). Decline in relative abundance of bottlenose dolphins exposed to Long-term disturbance. *Conservation Biology*, *20*(6), 1791–1798. https://doi.org/10.1111/j.1523-1739.2006.00540.x

Bennington, S., Rayment, W., Currey, R., Oldridge, L., Henderson, S., Guerra, M., Brough, T., Johnston, D., Corne, C., Johnson, D., Slooten, L., & Dawson, S. (2021). Long-term stability in core habitat of an endangered population of bottlenose dolphins (*Tursiops truncatus*): Implications for spatial management. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *31*(3), 665–676. https://doi.org/10.1002/aqc.3460

Bilgmann, K., Parra, G. J., Holmes, L., Peters, K. J., Jonsen, I. D., & Möller, L. M. (2019). Abundance estimates and habitat preferences of bottlenose dolphins reveal the importance of two gulfs in South Australia. *Scientific Reports*, *9*(1), 8044. https://doi.org/10.1038/s41598-019-44310-3

Bonneville, C. D., Derville, S., Luksenburg, J. A., Oremus, M., & Garrigue, C. (2021). Social structure, habitat use and injuries of indo-Pacific bottlenose dolphins (*Tursiops aduncus*) reveal isolated, coastal, and threatened communities in the South Pacific. *Frontiers in Marine Science*, *8*, 606975. https://doi.org/10.3389/fmars.2021.606975

Bouchet, P. J., Meeuwig, J. J., Kent, C. P. S., Letessier, T. B., & Jenner, C. K. (2015). Topographic determinants of mobile vertebrate predator hotspots: Current knowledge and future directions. *Biological Reviews*, *90*(3), 699–728. https://doi.org/10.1111/brv.12130

Brough, T., Rayment, W., Slooten, E., & Dawson, S. (2019). Fine scale distribution for a population of New Zealand's only endemic dolphin (*Cephalorhynchus hectori*) shows long-term stability of coastal hotspots. *Marine Mammal Science*, *35*(1), 140–163. https://doi.org/10.1111/mms.12528

Charlton, K., Taylor, A. C., & McKechnie, S. W. (2006). A note on divergent mtDNA lineages of 'bottlenose' dolphins from coastal waters of southern Australia. *Journal of Cetacean Research and Management*, *8*(2), 173–179.

Charlton-Robb, K., Gershwin, L., Thompson, R., Austin, J., Owen, K., & McKechnie, S. (2011). A new dolphin species, the Burrunan dolphin *Tursiops australis sp. Nov.*, endemic to southern Australian coastal waters. *PLoS ONE*, *6*(9), e24047. https://doi.org/10.1371/journal.pone.0024047

Charlton-Robb, K., Taylor, A., & McKechnie, S. (2015). Population genetic structure of the Burrunan dolphin (*Tursiops australis*) in coastal waters of south-eastern Australia: Conservation implications. *Conservation Genetics*, *16*, 195–207. https://doi.org/10.1007/s10592-014-0652-6

Chundawat, R. S. (1990). Habitat selection by a snow leopard in Hemis National Park, India. In L. Blomqvist (Ed.), *International Perdigree book of snow leopards* (pp. 85–92).

Clutton-Brock, T. H. (1997). Review lecture: Mammalian mating systems. *Proceedings of the Royal Society of London, Series B: Biological Sciences*, *236*(1285), 339–372. https://doi.org/10.1098/rspb.1989.0027

Commissioner for Environmental Sustainability. (2021). *State of the marine and coastal environment 2021 parts 1 and 2*. https://www.ces.vic.gov.au/publications-library/state-marine-and-coastal-environment-2021-report

Committee on Taxonomy. (2019). *List of marine mammal species and subspecies*. The Society for Marine Mammology.

Costa, A. C. P., Garcia, T. M., Paiva, B. P., Ximenes Neto, A. R., & Soares, M. O. (2020). Seagrass and rhodolith beds are important seascapes for the development of fish eggs and larvae in tropical coastal areas. *Marine Environmental Research*, *161*, 105064. https://doi.org/10.1016/j.marenvres.2020.105064

Cox, S. L., Embling, C. B., Hosegood, P. J., Votier, S. C., & Ingram, S. N. (2018). Oceanographic drivers of marine mammal and seabird habitat-use across shelf-seas: A guide to key features and recommendations for future research and conservation management. *Estuarine, Coastal and Shelf Science*, *212*, 294–310. https://doi.org/10.1016/j.ecss.2018.06.022

Cribb, N., Miller, C., & Seuront, L. (2013). Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) habitat preference in a heterogeneous, urban, coastal environment. *Aquatic Biosystems*, *9*(1), 3. https://doi.org/10.1186/2046-9063-9-3

Davis, T., Cadiou, G., Champion, C., & Coleman, M. (2020). Environmental drivers and indicators of change in habitat and fish assemblages within a climate change hotspot. *Regional Studies in Marine Science*, *36*, 101295. https://doi.org/10.1016/j.rsma.2020.101295

Department of Environment, Land, Water, and Planning. (2017). *Port Phillip Bay environmental management plan 2017–2027*. https://www.marineandcoasts.vic.gov.au/marine-and-coastal-knowledge/port-phillip-bay

Department of Environment, Land, Water, and Planning. (2019). *A guide to boating and swimming around whales, dolphins and seals*. Victorian State Government.

Department of Sustainability and Environment. (2013). *Advisory list of threatened vertebrate Fauna in Victoria*. Department of Sustainability and Environment.

Douglas, E. J., Bulmer, R. H., MacDonald, I. T., & Lohrer, A. M. (2022). Estuaries as coastal reactors: Importance of shallow seafloor habitats for primary productivity and nutrient transformation, and impacts of sea level rise. *New Zealand Journal of Marine and Freshwater Research*, *56*(3), 553–569. https://doi.org/10.1080/00288330.2022.2107027

Duignan, P. J., Stephens, N. S., & Robb, K. (2020). Fresh water skin disease in dolphins: A case definition based on pathology and environmental factors in Australia. *Scientific Reports*, *10*(1), 21979. https://doi.org/10.1038/s41598-020-78858-2

Durant, J. M., Molinero, J.-C., Ottersen, G., Reygondeau, G., Stige, L. C., & Langangen, Ø. (2019). Contrasting effects of rising temperatures on trophic interactions in marine ecosystems. *Scientific Reports*, *9*(1), 15213. https://doi.org/10.1038/s41598-019-51607-w

Durden, W. N., O'Corry-Crowe, G., Shippee, S., Jablonski, T., Rodgers, S., Mazzoil, M., Howells, E., Hartel, E., Potgieter, B., Londono, C., Moreland, L., Townsend, F., McCulloch, S., & Bossart, G. (2019). Small-scale movement patterns, activity budgets, and association patterns of radio-tagged Indian River lagoon bottlenose dolphins (*Tursiops truncatus*). *Aquatic Mammals*, *45*(1), 66–87. https://doi.org/10.1578/AM.45.1.2019.66

Edmunds, M., & Flynn, A. (2015). *A Victorian biotope classification scheme* (545; Australian Marine Ecology Report).

Edmunds, M., & Flynn, A. (2018). *CBiCS classification of Victorian biotopes*. Report to Department of Environment, Land, Water and Planning 560; Australian Marine Ecology Report, p. 179.

Edmunds, M., Flynn, A., & Ferns, L. (2021). *Combined biotope classification scheme (CBiCS). A new marine ecological classification scheme to meet new challenges*. The State of Victoria Department of Environment, Land, Water, and Planning 2021.

Elith, J., & Leathwick, J. R. (2009). Species distribution models: Ecological explanation and prediction across space and time. *Annual Review of Ecology, Evolution, and Systematics*, *40*(1), 677–697. https://doi.org/10.1146/annurev.ecolsys.110308.120159

Ferrell, D., & Bell, J. (1991). Differences among assemblages of fish associated with *Zostera capricorni* and bare sand over a large spatial scale. *Marine Ecology Progress Series*, *72*, 15–24. https://doi.org/10.3354/meps072015

Filby, N., Christiansen, F., Scarpaci, C., & Stockin, K. (2017). Effects of swim-with-dolphin tourism on the behaviour of a threatened species, the Burrunan dolphin *Tursiops australis*. *Endangered Species Research*, *32*, 479–490. https://doi.org/10.3354/esr00826

Filby, N. E., Stockin, K. A., & Scarpaci, C. (2014). Long-term responses of Burrunan dolphins (*Tursiops australis*) to swim-with dolphin tourism in Port Phillip Bay, Victoria, Australia: A population at risk. *Global Ecology and Conservation*, *2*, 62–71. https://doi.org/10.1016/j.gecco.2014.08.006

Filby, N. E., Stockin, K. A., & Scarpaci, C. (2017). Can marine protected areas be developed effectively without baseline data? A case study for Burrunan dolphins (*Tursiops australis*). *Marine Policy*, *77*, 152–163. https://doi.org/10.1016/j.marpol.2016.12.009

Foord, C. S., Szabo, D., Robb, K., Clarke, B. O., & Nugegoda, D. (2024). Hepatic concentrations of per- and polyfluoroalkyl substances (PFAS) in dolphins from south-east Australia: Highest reported globally. *Science of the Total Environment*, *908*, 168438. https://doi.org/10.1016/j.scitotenv.2023.168438

Forcada, A., Valle, C., Bonhomme, P., Criquet, G., Cadiou, G., Lenfant, P., & Sánchez-Lizaso, J. (2009). Effects of habitat on spillover from marine protected areas to artisanal fisheries. *Marine Ecology Progress Series*, *379*, 197–211. https://doi.org/10.3354/meps07892

Fowler, A. J., McLeay, L., & Short, D. A. (2000). Spatial variation in size and age structures and reproductive characteristics of the King George whiting (*Percoidei sillaginidae*) in south Australian waters. *Marine and Freshwater Research*, *51*(1), 11–22. https://doi.org/10.1071/mf99032

Fu, D., Bridle, A., Leef, M., Gagnon, M. M., Hassell, K. L., & Nowak, B. F. (2017). Using a multi-biomarker approach to assess the effects of pollution on sand flathead (*Platycephalus bassensis*) from Port Phillip Bay, Victoria, Australia. *Marine Pollution Bulletin*, *119*(1), 211–219. https://doi.org/10.1016/j.marpolbul.2017.03.067

Gill, J. A., Norris, K., & Sutherland, W. J. (2001). Why behavioural responses may not reflect the population consequences of human disturbance. *Biological Conservation*, *97*(2), 265–268. https://doi.org/10.1016/S0006-3207(00)00002-1

Goetze, J. S., Wilson, S., Radford, B., Fisher, R., Langlois, T. J., Monk, J., Knott, N. A., Malcolm, H., Currey-Randall, L. M., Ierodiaconou, D., Harasti, D., Barrett, N., Babcock, R. C., Bosch, N. E., Brock, D., Claudet, J., Clough, J., Fairclough, D. V., Heupel, M. R., … Harvey, E. S. (2021). Increased connectivity and depth improve the effectiveness of marine reserves. *Global Change Biology*, *27*(15), 3432–3447. https://doi.org/10.1111/gcb.15635

Greenwood, P. J. (1980). Mating systems, philopatry and dispersal in birds and mammals. *Animal Behaviour*, *28*(4), 1140–1162. https://doi.org/10.1016/S0003-3472(80)80103-5

Gross, A., Kiszka, J., Van Canneyt, O., Richard, P., & Ridoux, V. (2009). A preliminary study of habitat and resource partitioning among co-occurring tropical dolphins around Mayotte, southwest Indian Ocean. *Estuarine, Coastal and Shelf Science*, *84*(3), 367–374. https://doi.org/10.1016/j.ecss.2009.05.017

Gubbins, C. (2002). Use of home ranges by resident bottlenose dolphins (*Tursiops truncatus*) in a South Carolina estuary. *Journal of Mammalogy*, *83*(1), 178–187. https://doi.org/10.1139/juvs-2015-0021

Guisan, A., & Thuiller, W. (2005). Predicting species distribution: Offering more than simple habitat models. *Ecology Letters*, *8*(9), 993–1009. https://doi.org/10.1111/j.1461-0248.2005.00792.x

Hamer, P. A., Acevedo, S., Jenkins, G. P., & Newman, A. (2011). Connectivity of a large embayment and coastal fishery: Spawning aggregations in one bay source local and broad-scale fishery replenishment. *Journal of Fish Biology*, *78*(4), 1090–1109. https://doi.org/10.1111/j.1095-8649.2011.02921.x

Hamer, P. A., & Jenkins, G. P. (2004). High levels of spatial and temporal recruitment variability in the temperate sparid *Pagrus auratus*. *Marine and Freshwater Research*, *55*(7), 663. https://doi.org/10.1071/MF04024

Harris, G., Batley, G. E., Fox, D., Hall, D., Jernakoff, P., Molloy, R., Murray, A., Newell, B., Parslow, J., Skyring, G., & Walker, S. (1996). *Port Phillip Bay environmental study final report*. https://doi.org/10.4225/08/5856cf3221739

Harvey, G. K. A., Nelson, T. A., Fox, C. H., & Paquet, P. C. (2017). Quantifying marine mammal hotspots in British Columbia, Canada. *Ecosphere*, *8*(7), e01884. https://doi.org/10.1002/ecs2.1884

Harwood, L. A., Iacozza, J., Auld, J. C., Norton, P., & Loseto, L. (2014). Belugas in the Mackenzie River estuary, NT, Canada: Habitat use and hot spots in the Tarium Niryutait marine protected area. *Ocean and Coastal Management*, *100*, 128–138. https://doi.org/10.1016/j.ocecoaman.2014.08.004

Hastie, G. D., Swift, R. J., Slesser, G., Thompson, P. M., & Turrell, W. R. (2005). Environmental models for predicting oceanic dolphin habitat in the Northeast Atlantic. *ICES Journal of Marine Science*, *62*(4), 760–770. https://doi.org/10.1016/j.icesjms.2005.02.004

Hastie, G. D., Wilson, B., & Thompson, P. M. (2003). Fine-scale habitat selection by coastal bottlenose dolphins: Application of a new land-based video-montage technique. *Canadian Journal of Zoology*, *81*(3), 469–478. https://doi.org/10.1139/z03-028

Hastie, G. D., Wilson, B., Wilson, L. J., Parsons, K. M., & Thompson, P. M. (2004). Functional mechanisms underlying cetacean distribution patterns: Hotspots for bottlenose dolphins are linked to foraging. *Marine Biology*, *144*(2), 397–403. https://doi.org/10.1007/s00227-003-1195-4

Heck, K. L., Nadeau, D. A., & Thomas, R. (1997). The nursery role of seagrass beds. *Gulf of Mexico Science*, *15*(1), 50–54. https://doi.org/10.18785/goms.1501.08

Heimlich-Boran, J. R. (1988). Behavioral ecology of killer whales (*Orcinus orca*) in the Pacific northwest. *Canadian Journal of Zoology*, *66*(3), 565–578. https://doi.org/10.1139/z88-084

Heithaus, M. R., & Dill, L. M. (2002). Food availability and Tiger shark predation risk influence bottlenose dolphin habitat use. *Ecology*, *83*(2), 480–491. https://doi.org/10.1890/0012-9658(2002)083[0480:FAATSP]2.0.CO;2

Heithaus, M. R., & Dill, L. M. (2006). Does tiger shark predation risk influence foraging habitat use by bottlenose dolphins at multiple spatial scales? *Oikos*, *114*(2), 257–264. https://doi.org/10.1111/j.2006.0030-1299.14443.x

Hooker, S., Cañadas, A., Hyrenbach, K., Corrigan, C., Polovina, J., & Reeves, R. (2011). Making protected area networks effective for marine top predators. *Endangered Species Research*, *13*(3), 203–218. https://doi.org/10.3354/esr00322

Horta, P. A., Riul, P., Amado Filho, G. M., Gurgel, C. F. D., Berchez, F., Nunes, J. M. d. C., Scherner, F., Pereira, S., Lotufo, T., Peres, L., Sissini, M., Bastos, E. d. O., Rosa, J., Munoz, P., Martins, C., Gouvêa, L., Carvalho, V., Bergstrom, E., Schubert, N., … Figueiredo, M. (2016). Rhodoliths in Brazil: Current knowledge and potential impacts of climate change. *Brazilian Journal of Oceanography*, *64*, 117–136. https://doi.org/10.1590/S1679-875920160870064sp2

Howes, L., Scarpaci, C., & Parsons, E. C. M. (2012). Ineffectiveness of a marine sanctuary zone to protect Burrunan dolphins (*Tursiops australis* sp.nov.) from commercial tourism in Port Phillip Bay, Australia. *Journal of Ecotourism*, *11*(3), 188–201. https://doi.org/10.1080/14724049.2012.713362

Hunt, T. N., Allen, S. J., Bejder, L., & Parra, G. J. (2020). Identifying priority habitat for conservation and management of Australian humpback dolphins within a marine protected area. *Scientific Reports*, *10*(1), 14366. https://doi.org/10.1038/s41598-020-69863-6

Ierodiaconou, D., Laurenson, L., Burq, S., & Reston, M. (2007). Marine benthic habitat mapping using multibeam data, georeferenced video and image classification techniques in Victoria, Australia. *Journal of Spatial Science*, *52*(1), 93–104. https://doi.org/10.1080/14498596.2007.9635105

Ierodiaconou, D., Schimel, A. C. G., Kennedy, D., Monk, J., Gaylard, G., Young, M., Diesing, M., & Rattray, A. (2018). Combining pixel and object based image analysis of ultra-high resolution multibeam bathymetry and backscatter for habitat mapping in shallow marine waters. *Marine Geophysical Research*, *39*(1), 271–288. https://doi.org/10.1007/s11001-017-9338-z

Jacob, J. (1974). Quantitive measurement of food selection. A modification of the forage ratio and Ivlev's selectivity index. *Oceologia*, *14*, 413–417.

Jedensjö, M., Kemper, C. M., & Krützen, M. (2017). Cranial morphology and taxonomic resolution of some dolphin taxa (Delphinidae) in Australian waters, with a focus on the genus *Tursiops*. *Marine*

Mammal Science, *33*(1), 187–205. https://doi.org/10.1111/mms.12356

Jenkins, G. P., Ball, D., Coleman, R. A., & Conron, S. (2020). The application of recreational fishing survey data for ecological research, a case study from Western port, Australia. *Fisheries Management and Ecology*, *27*(4), 357–366. https://doi.org/10.1111/fme.12418

Jenkins, G. P., & King, D. (2006). Variation in larval growth can predict the recruitment of a temperate, seagrass-associated fish. *Oecologia*, *147*(4), 641–649. https://doi.org/10.1007/s00442-005-0336-5

Langlois, T. J., Anderson, M. J., & Babcock, R. C. (2005). Reef-associated predators influence adjacent soft-sediment communities. *Ecology*, *86*(6), 1508–1519. https://doi.org/10.1890/04-0234

Lenth, R. (2023). *Estimated Marginal Means, aka Least-Squares Means* (1.8.4-1) [Computer software]. https://github.com/rvlenth/emmeans

Lin, M., Liu, M., Lek, S., Dong, L., Zhang, P., Gozlan, R. E., & Li, S. (2021). Modelling habitat suitability of the indo-Pacific humpback dolphin using artificial neural network: The influence of shipping. *Ecological Informatics*, *62*, 101274. https://doi.org/10.1016/j.ecoinf.2021.101274

Longmore, A. (2014). *Spatial and temporal scales of key ecological processes in Victoria: Policy priorities for sustaining biodiversity* (4; Fisheries Victoria Science Report Series). Department of Environment and Primary Industries.

Lotze, H. K., & Milewski, I. (2004). Two centuries of multiple human impacts and successive changes in a North Atlantic food web. *Ecological Applications*, *14*(5), 1428–1447. https://doi.org/10.1890/03-5027

Lotze, H. K., & Worm, B. (2009). Historical baselines for large marine animals. *Trends in Ecology & Evolution*, *24*(5), 254–262. https://doi.org/10.1016/j.tree.2008.12.004

Lusseau, D. (2003). Male and female bottlenose dolphins *Tursiops spp*. have different strategies to avoid interactions with tour boats in doubtful sound, New Zealand. *Marine Ecology Progress Series*, *257*, 267–274. https://doi.org/10.3354/meps257267

Madi Moussa, R., Bertucci, F., Jorissen, H., Gache, C., Waqalevu, V. P., Parravicini, V., Lecchini, D., & Galzin, R. (2020). Importance of intertidal seagrass beds as nursery area for coral reef fish juveniles (Mayotte, Indian Ocean). *Regional Studies in Marine Science*, *33*, 100965. https://doi.org/10.1016/j.rsma.2019.100965

Magera, A. M., Mills Flemming, J. E., Kaschner, K., Christensen, L. B., & Lotze, H. K. (2013). Recovery trends in marine mammal populations. *PLoS ONE*, *8*(10), e77908. https://doi.org/10.1371/journal.pone.0077908

Mann, J., Foroughirad, V., McEntee, M. H. F., Miketa, M. L., Evans, T. C., Karniski, C., Krzyszczyk, E., Patterson, E. M., Strohman, J. C., & Wallen, M. M. (2021). Elevated calf mortality and Long-term responses of wild bottlenose dolphins to extreme climate events: Impacts of foraging specialization and provisioning. *Frontiers in Marine Science*, *8*, 617550. https://doi.org/10.3389/fmars.2021.617550

Marega-Imamura, M., Michalski, F., Silva, K., Schiavetti, A., Le Pendu, Y., & de Carvalho Oliveira, L. (2020). Scientific collaboration networks in research on human threats to cetaceans in Brazil. *Marine Policy*, *112*, 103738. https://doi.org/10.1016/j.marpol.2019.103738

Mason, S. (2007). *Correlates of bottlenose and common dolphin spatial distribution in southeastern Port Phillip Bay during winter 2007* [Honours thesis, Monash University].

Mazor, T., Edmunds, M., Flynn, A., & Ferns, L. (2021). *Port Phillip Bay habitat. Habitat complex modelling (CBiCS) level 3*. The State of Victoria Department of Environment, Land, Water and Planning.

Mirimin, L., Miller, R., Dillane, E., Berrow, S. D., Ingram, S., Cross, T. F., & Rogan, E. (2011). Fine-scale population genetic structuring of bottlenose dolphins in Irish coastal waters. *Animal Conservation*, *14*(4), 342–353. https://doi.org/10.1111/j.1469-1795.2010.00432.x

Moltschaniwskyj, N. A., & Steer, M. A. (2004). Spatial and seasonal variation in reproductive characteristics and spawning of southern calamary (*Sepioteuthis australis*): Spreading the mortality risk. *ICES Journal of Marine Science*, *61*(6), 921–927. https://doi.org/10.1016/j.icesjms.2004.06.007

Monk, A., Charlton-Robb, K., Buddhadasa, S., & Thompson, R. M. (2014). Comparison of mercury contamination in live and dead dolphins from a newly described species, *Tursiops australis*. *PLoS ONE*, *9*(8), e104887. https://doi.org/10.1371/journal.pone.0104887

Morris, L., & Ball, D. (2006). Habitat suitability modelling of economically important fish species with commercial fisheries data. *ICES Journal of Marine Science*, *63*(9), 1590–1603. https://doi.org/10.1016/j.icesjms.2006.06.008

Nowacek, D. P. (2005). Acoustic ecology of foraging bottlenose dolphins (*Tursiops truncatus*), habitat-specific use of three sound types. *Marine Mammal Science*, *21*(4), 587–602. https://doi.org/10.1111/j.1748-7692.2005.tb01253.x

Owen, K., Charlton-Robb, K., & Thompson, R. (2011). Resolving the trophic relations of cryptic species: An example using stable isotope analysis of dolphin teeth. *PLoS ONE*, *6*(2), e16457. https://doi.org/10.1371/journal.pone.0016457

Parry, G., Hobday, D., Currie, D., Officer, R., & Gason, A. (1995). *The distribution, abundance and diets of demersal fish in Port Phillip Bay*. https://doi.org/10.13140/2.1.1449.1521

Passadore, C., Möller, L. M., Diaz-Aguirre, F., & Parra, G. J. (2018). Modelling dolphin distribution to inform future spatial conservation decisions in a marine protected area. *Scientific Reports*, *8*(1), 15659. https://doi.org/10.1038/s41598-018-34095-2

Pirotta, V., Reynolds, W., Ross, G., Jonsen, I., Grech, A., Slip, D., & Harcourt, R. (2019). A citizen science approach to long-term monitoring of humpback whales (*Megaptera novaeangliae*) off Sydney, Australia. *Marine Mammal Science*, *36*, 472–485. https://doi.org/10.1111/mms.12651

Pompa-Mansilla, S., Ehrlich, P., & Ceballos, G. (2011). Global distribution and conservation of marine mammals. *Proceedings of the National Academy of Sciences of the United States of America*, *108*, 13600–13605. https://doi.org/10.1073/pnas.1101525108

Prado, J. H. F., Mattos, P. H., Silva, K. G., & Secchi, E. R. (2016). Long-term seasonal and interannual patterns of marine mammal Strandings in subtropical Western South Atlantic. *PLoS ONE*, *11*(1), e0146339. https://doi.org/10.1371/journal.pone.0146339

Pratt, E., Beheregaray, L., Bilgmann, K., Zanardo, N., Diaz-Aguirre, F., & Möller, L. (2018). Hierarchical metapopulation structure in a highly mobile marine predator: The southern Australian coastal bottlenose dolphin (*Tursiops cf. australis*). *Conservation Genetics*, *19*, 1–18. https://doi.org/10.1007/s10592-017-1043-6

Puszka, H., Shimeta, J., & Robb, K. (2021). Assessment on the effectiveness of vessel-approach regulations to protect cetaceans in Australia: A review on behavioral impacts with case study on the threatened Burrunan dolphin (*Tursiops australis*). *PLoS ONE*, *16*(1), e0243353. https://doi.org/10.1371/journal.pone.0243353

QGIS Development Team. (2021). *QGIS geographic information system [computer software]*. Open Source Geospatial Foundation. https://www.qgis.org

Rayment, W., Dawson, S., & Slooten, E. (2010). Seasonal changes in distribution of Hector's dolphin at banks peninsula, New Zealand: Implications for protected area design. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *20*(1), 106–116. https://doi.org/10.1002/aqc.1049

Rees, M. J., Knott, N. A., Hing, M. L., Hammond, M., Williams, J., Neilson, J., Swadling, D. S., & Jordan, A. (2021). Habitat and humans predict the distribution of juvenile and adult snapper (Sparidae: *Chrysophrys auratus*) along Australia's most populated coastline. *Estuarine, Coastal and Shelf Science*, *257*, 107397. https://doi.org/10.1016/j.ecss.2021.107397

Ross, P. M., Thrush, S. F., Montgomery, J. C., Walker, J. W., Parsons, D. M., Ross, P. M., Thrush, S. F., Montgomery, J. C., Walker, J. W., & Parsons, D. M. (2007). Habitat complexity and predation risk determine juvenile snapper (*Pagrus auratus*) and goatfish (*Upeneichthys lineatus*) behaviour and distribution. *Marine and Freshwater Research*, *58*(12), 1144–1151. https://doi.org/10.1071/MF07017

Rovelli, L., Attard, K. M., Cárdenas, C. A., & Glud, R. N. (2019). Benthic primary production and respiration of shallow rocky habitats: A case study from South Bay (Doumer Island, Western Antarctic peninsula). *Polar Biology*, *42*(8), 1459–1474. https://doi.org/10.1007/s00300-019-02533-0

Ryan, K. L., Meyer, D., Ryan, K. L., & Meyer, D. (2019). Predicting catch per unit effort from a multispecies commercial fishery in port Phillip Bay, Australia. *Marine and Freshwater Research*, *71*(4), 542–556. https://doi.org/10.1071/MF18286

Scarpaci, C., Nugegoda, D., & Corkeron, P. (2003). Compliance with regulations by 'swim-with-dolphins' operations in port Phillip Bay, Victoria, Australia. *Environmental Management*, *31*, 342–347. https://doi.org/10.1007/s00267-002-2799-z

Shane, S. H., Wells, R. S., & Würsig, B. (1986). Ecology, behavior and social Organization of the Bottlenose Dolphin: A review. *Marine Mammal Science*, *2*(1), 34–63. https://doi.org/10.1111/j.1748-7692.1986.tb00026.x

Simard, P., Wall, C., Allen, J., Wells, R., Gowans, S., & Forys, E. (2015). Dolphin distribution on the West Florida shelf using visual surveys and passive acoustic monitoring. *Aquatic Mammals*, *41*, 167–187. https://doi.org/10.1578/AM.41.2.2015.167

Smith, H. C., Pollock, K., Waples, K., Bradley, S., & Bejder, L. (2013). Use of the robust design to estimate seasonal abundance and demographic parameters of a coastal bottlenose dolphin (*Tursiops aduncus*) population. *PLoS ONE*, *8*(10), e76574. https://doi.org/10.1371/journal.pone.0076574

Smith, T., Sherman, C., & Green, C. (2015). Patterns of connectivity and population structure of the southern calamary *Sepioteuthis australis* in southern Australia. *Marine and Freshwater Research*, *66*, 942. https://doi.org/10.1071/MF14328

Smith, T. M., Hindell, J. S., Jenkins, G. P., & Connolly, R. M. (2008). Edge effects on fish associated with seagrass and sand patches. *Marine Ecology Progress Series*, *359*, 203–213. https://doi.org/10.3354/meps07348

Smith, T. M., Jenkins, G. P., & Hutchinson, N. (2012). Seagrass edge effects on fish assemblages in deep and shallow habitats. *Estuarine, Coastal and Shelf Science*, *115*, 291–299. https://doi.org/10.1016/j.ecss.2012.09.013

Sprogis, K., Christiansen, F., Raudino, H., Kobryn, H., Wells, R., & Bejder, L. (2018). Sex-specific differences in the seasonal habitat use of a coastal dolphin population. *Biodiversity and Conservation*, *27*, 3637–3656. https://doi.org/10.1007/s10531-018-1618-7

Sprogis, K. R., Parra, G. J., Sprogis, K. R., & Parra, G. J. (2022). Coastal dolphins and marine megafauna in Exmouth gulf, Western Australia: Informing conservation management actions in an area under increasing human pressure. *Wildlife Research*, *50*(6), 435–450. https://doi.org/10.1071/WR22023

Sprogis, K. R., Raudino, H. C., Rankin, R., MacLeod, C. D., & Bejder, L. (2016). Home range size of adult indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in a coastal and estuarine system is habitat and sex-specific. *Marine Mammal Science*, *32*(1), 287–308. https://doi.org/10.1111/mms.12260

State of Victoria. (2021). *Victoria Government Gazette: Flora and Fauna Guarantee Act 1988*.

Steckenreuter, A., Harcourt, R., & Möller, L. (2011). Distance does matter: Close approaches by boats impede feeding and resting behaviour of indo-Pacific bottlenose dolphins. *Wildlife Research*, *38*(6), 455–463. https://doi.org/10.1071/WR11048

Steckenreuter, A., Möller, L., & Harcourt, R. (2012). How does Australia's largest dolphin-watching industry affect the behaviour of a small and resident population of Indo-Pacific bottlenose dolphins? *Journal of Environmental Management*, *97*, 14–21. https://doi.org/10.1016/j.jenvman.2011.11.002

Sweanor, L. L., Logan, K. A., & Hornocker, M. G. (2000). Cougar dispersal patterns, metapopulation dynamics, and conservation. *Conservation Biology*, *14*(3), 798–808. https://doi.org/10.1046/j.1523-1739.2000.99079.x

Toth, J. L., Hohn, A. A., Able, K. W., & Gorgone, A. M. (2011). Patterns of seasonal occurrence, distribution, and site fidelity of coastal bottlenose dolphins (*Tursiops truncatus*) in southern New Jersey, U.S.A. *Marine Mammal Science*, *27*(1), 94–110. https://doi.org/10.1111/j.1748-7692.2010.00396.x

Urian, K., Gorgone, A., Read, A., Balmer, B., Wells, R. S., Berggren, P., Durban, J., Eguchi, T., Rayment, W., & Hammond, P. S. (2015). Recommendations for photo-identification methods used in capture-recapture models with cetaceans. *Marine Mammal Science*, *31*(1), 298–321. https://doi.org/10.1111/mms.12141

Verweij, M., Nagelkerken, I., Hans, I., Ruseler, S., & Mason, P. R. D. (2008). Seagrass nurseries contribute to coral reef fish populations. *Limnology and Oceanography*, *53*, 1540–1547. https://doi.org/10.2307/40058274

Wang, C.-C., Xu, Y., Li, N., Peng, C., Wu, H., & Huang, S.-L. (2021). Seasonal distribution of the Indo-Pacific humpback dolphins: Implications for coastal habitat management. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *31*(3), 696–707. https://doi.org/10.1002/aqc.3479

Warren-Smith, Á. B., & Dunn, W. L. (2006). Epimeletic behaviour toward a seriously injured juvenile bottlenose dolphin (*Tursiops sp.*) in port Phillip, Victoria, Australia. *Aquatic Mammals*, *32*(3), 357–362. https://doi.org/10.1578/AM.32.3.2006.357

Wells, R. S. (2003). Dolphin social complexity: Lessons from long-term study and life history. In F. B. M. de Waal & P. L. Tyack (Eds.), *Animal social complexity: Intelligence, culture, and individualized societies* (pp. 32–56). Harvard University Press. https://doi.org/10.4159/harvard.9780674419131.c4

Williams, T. M., Estes, J. A., Doak, D. F., & Springer, A. M. (2004). Killer appetites: Assessing the role of predators in ecological communities. *Ecology*, *85*(12), 3373–3384. https://doi.org/10.1890/03-0696

Wilson, C., Wilson, P., Greene, C., & Dunton, K. (2013). Seagrass meadows provide an acoustic refuge for estuarine fish. *Marine Ecology Progress Series*, *472*, 117–127. https://doi.org/10.3354/meps10045

Wilson, R. M., Tyson, R. B., Nelson, J. A., Balmer, B. C., Chanton, J. P., & Nowacek, D. P. (2017). Niche differentiation and prey selectivity among common bottlenose dolphins (*Tursiops truncatus*) sighted in St. George sound, Gulf of Mexico. *Frontiers in Marine Science*, *4*, 235. https://doi.org/10.3389/fmars.2017.00235

Wiszniewski, J., Allen, S. J., & Möller, L. M. (2009). Social cohesion in a hierarchically structured embayment population of Indo-Pacific bottlenose dolphins. *Animal Behaviour*, *77*(6), 1449–1457. https://doi.org/10.1016/j.anbehav.2009.02.025

Wiszniewski, J., Beheregaray, L. B., Allen, S. J., & Möller, L. M. (2010). Environmental and social influences on the genetic structure of bottlenose dolphins (*Tursiops aduncus*) in southeastern Australia. *Conservation Genetics*, *11*(4), 1405–1419. https://doi.org/10.1007/s10592-009-9968-z

Wu, H., Jefferson, T., Peng, C., Liao, Y., Huang, H., Lin, M., Cheng, Z., Liu, M., Zhang, J., Li, S., Wang, D., Xu, Y., & Huang, S.-L. (2017). Distribution and habitat characteristics of the Indo-Pacific humpback dolphin (*Sousa chinensis*) in the northern Beibu gulf, China. *Aquatic Mammals*, *43*(2), 219–228. https://doi.org/10.1578/AM.43.2.2017.219

Young, M. A., Porskamp, P., Critchell, K., Treml, E., Ierodiaconou, D., Pocklington, J., & Sams, M. (2022). *Statewide assessment of Victorian* *marine protected areas using existing data (parks Victoria technical series 118)*. Parks Victoria.

Zanardo, N., Parra, G., Passadore, C., & Möller, L. (2017). Ensemble modelling of southern Australian bottlenose dolphin *Tursiops sp*. distribution reveals important habitats and their potential ecological function. *Marine Ecology Progress Series*, *569*, 253–266. https://doi.org/10.3354/meps12091

Zanardo, N., Parra, G. J., & Möller, L. M. (2016). Site fidelity, residency, and abundance of bottlenose dolphins (*Tursiops sp*.) in Adelaide's coastal waters, South Australia. *Marine Mammal Science*, *32*(4), 1381–1401. https://doi.org/10.1111/mms.12335

Zolman, E. (2002). Residence patterns of bottlenose dolphins (*Tursiops truncatus*) in the Stono River estuary, Charleston County, South Carolina, U.S.A. *Marine Mammal Science*, *18*, 879–892. https://doi.org/10.1111/j.1748-7692.2002.tb01079.x

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Beddoe, J., Shimeta, J., Klaassen, M., & Robb, K. (2024). Population distribution and drivers of habitat use for the Burrunan dolphins, Port Phillip Bay, Australia. *Ecology and Evolution*, *14*, e11221. https://doi.org/10.1002/ece3.11221