Fine-scale understanding of Indo-Pacific bottlenose dolphin use of the Kwinana Shelf within Cockburn Sound and identification of key areas within the Shelf

Theme: Apex Predators and Iconic Species

WAMSI Westport Marine Science Program

WESTERN AUSTRALIAN MARINE SCIENCE INSTITUTION

WESTPORT

Better science **Better decisions**

WAMSI WESTPORT MARINE SCIENCE PROGRAM

ABOUT THE MARINE SCIENCE PROGRAM

The WAMSI Westport Marine Science Program (WWMSP) is a $13.5 million body of marine research funded by the WA Government. The aims of the WWMSP are to increase knowledge of Cockburn Sound in areas that will inform the environmental impact assessment of the proposed Westport development and help to manage this important and heavily used marine area into the future. Westport is the State Government's program to move container trade from Fremantle to Kwinana, and includes a new container port and associated freight, road and rail, and logistics. The WWMSP comprises more than 30 research projects in the biological, physical and social sciences that are focused on the Cockburn Sound area. They are being delivered by more than 100 scientists from the WAMSI partnership and other organisations.

FUNDING SOURCES
The $13.5 million WAMSI Westport Marine Science Program was funded by the Western Australian Government, Department of Transport. WAMSI partners provided significant in-kind funding to the program to increase the value to >$22 million.

DATA
Finalised datasets will be released as open data, and data and/or metadata will be discoverable through Data WA and the Shared Land Information Platform (SLIP).

YEAR OF PUBLICATION
October 2024

This report is part of the project: Spatio-temporal distribution of key habitat-uses and key prey species for Indo-Pacific bottlenose dolphins in Owen Anchorage and Cockburn Sound, including a fine-scale understanding of the use of the habitats in the Kwinana Shelf.

CITATION
Delphine, C. (2024). Fine-scale understanding of Indo-Pacific bottlenose dolphin use of the Kwinana Shelf within Cockburn Sound and identification of key areas within the Shelf. Prepared for the WAMSI Westport Marine Science Program. Western Australian Marine Science Institution, Perth, Western Australia. 50 pp.

FRONT COVER IMAGE
Theme: Apex Predators and Iconic Species
Front cover image: pod of dolphins in Cockburn Sound. Photo courtesy of: Delphine Chabanne (Murdoch University).

Contents

Figures

Tables

The WAMSI Westport Marine Science Program is a $13.5 million body of research that is designed to fill knowledge gaps relating to the Cockburn Sound region. It was developed with the objectives of improving the capacity to avoid, mitigate and offset environmental impacts of the proposed Westport container port development and increase the WA Government's ability to manage other pressures acting on Cockburn Sound into the future. Funding for the program has been provided by Westport (through the Department of Transport) and the science projects are being delivered by the Western Australian Marine Science Institution.

Fine-scale understanding of Indo-Pacific bottlenose dolphin use of the Kwinana Shelf within Cockburn Sound and identification of key areas within the Shelf.

Author

Delphine Chabanne, Harry Butler Institute, Murdoch University

Project

Spatio-temporal distribution of key habitat uses and key prey species for Indo-Pacific bottlenose dolphins in Owen Anchorage and Cockburn Sound, including a fine-scale understanding of the use of the habitats in the Kwinana Shelf

Executive Summary

Introduction:

This study aims to address gaps in our understanding of the distribution patterns of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) across the Kwinana Shelf within Cockburn Sound to improve the scientific basis for the environmental impact assessment (EIA) of the proposed Westport port development. This report presents the results from analysing data collected between 2022 and 2023, focusing on modelling dolphin occurrence and identifying key areas used by dolphins across the Kwinana Shelf. These findings provide valuable insights into dolphin habitat preferences.

Methods:

Between January 2022 and November 2023, 31 surveys were conducted across the Kwinana Shelf, following 21 pre-designed parallel survey routes. During these surveys, photo-identification, behaviour, group composition, and environmental variables such as water depth, sea surface temperature, and water visibility for dolphin sightings within the study area were recorded. Ensemble modelling using species distribution modelling methods was employed to model the distribution of dolphins across the Kwinana Shelf. Separate modelling was conducted for each season.

Findings:

The study reveals that dolphins are present year-round on the Kwinana Shelf (n = 150 individuals, including 32 calves), engaging in various behaviours such as foraging, resting, socializing, and travelling, with foraging being the most observed (45.5% of sightings). A significant number of adult dolphins were previously identified (57%), indicating long-term residency. Mother and calf pairs were prevalent (in 70% of the groups), highlighting the Kwinana Shelf's importance for nursing activities. The results of the models identified high dolphin occurrence areas, primarily being influenced by water depth, sea surface temperature, salinity, O_2 saturation, and fishing activity.

Variables included in the models demonstrated independent seasonal patterns, with some showing significant differences between seasons and being the most influential in the distribution of dolphins across multiple seasons. These findings suggest a complex, fine-scale spatial and temporal distribution of dolphins across the Kwinana Shelf. Dolphins are also likely to concentrate in areas where structural features indirectly provide important substrate types that influence the availability and distribution of their prey, as suggested by the correlation between dolphin occurrence and higher recreational fishing activities.

Key Areas:

The study identified key areas for dolphin occurrence at Woodman Point, Pinnacle Rock, D9 Wreck, and off James Point. Notably, the latter three areas are close to or overlap with the proposed port footprint. Although substrate type was not identified as a primary influencing variable in the overall model, all four key areas are predominantly characterised by reef, cobble, and seagrass substrates, along with a mixed substrate patch identified off James Point.

Challenges and Uncertainties:

Uncertainties arise regarding the potential impact of habitat loss due to some overlap with the port footprint and increased underwater noise on the dolphin community in Cockburn Sound, though noise was not explicitly included in this study (only approximated through occurrence of recreational vessels). These uncertainties highlight the need to understand how habitat changes, including reductions in prey availability, might affect the dolphin community, particularly in relation to calf nursing habitats. Questions remain about how dolphins might respond to habitat changes, and whether they would adapt or migrate in response to significant alterations, including changes in predation risks and climate conditions.

Conclusion and Recommendations:

The study sheds light on the complex relationship between dolphins and their environment on the Kwinana Shelf. By identifying key areas and highlighting conservation challenges, it provides a foundation for future research, management strategies and developmental activities. It is recommended that ongoing monitoring be conducted before, during, and after the development phase to assess changes in dolphin distribution and responses to port development activities as well as cumulative effects, such as climate change and metocean changes that can affect prey distribution and availability. Long-term surveys are essential for evaluating the effectiveness of mitigation measures aimed at minimizing habitat loss, noise, injuries, and other impacts associated with human activities.

1 Introduction

1.1 Background

Activities associated with the establishment and operation of a port in Cockburn Sound, have the potential to adversely affect the local marine fauna, including the Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), which are recognised as apex predators and iconic species in the region. The Indo-Pacific bottlenose dolphin is protected nationally under the *Environment Protection and Biodiversity Conservation Act 1999* and in Western Australia by the *Biodiversity Conservation Act 2016 (WA)*. Since 2019, the species has also been listed as 'near threatened' globally in the IUCN Red List of Threatened Species due to several factors: 1) the formation of small resident populations in restricted near-shore areas; 2) inhabiting habitats subject to increasing anthropogenic threats leading to habitat loss and degradation; 3) being highly vulnerable to entanglement in fishing gear; and 4) experiencing mortality rates that put populations at risk of decline (Braulik et al. 2019).

The ecological dynamics of dolphins in Perth metropolitan waters are characterised by fine-scale population structures, marked by long-term residency, strong site fidelity, and limited ranging patterns within Cockburn Sound, Owen Anchorage, and the Swan Canning Riverpark (Finn 2005, Chabanne et al. 2012, 2017a, 2017b). Within Cockburn Sound, resident dolphins (< 65 juvenile and adult individuals estimated from the 2011-2015 study) use the entire sound year-round. The core area for these resident dolphins overlaps with the Kwinana Shelf, the main area for a proposed port development, and is recognized as an important foraging habitat for dolphins, including as an area where large feeding aggregations of dolphins and seabirds occur (Finn 2005, Finn & Calver 2008, Chabanne et al. 2017a). While the broad-scale distribution patterns of the community of dolphins using Cockburn Sound remained consistent over decades and between seasons (see Report 8.3.1, Chabanne 2023), details regarding the use of the Kwinana Shelf are still limited. The proposed development activities across the Kwinana Shelf (i.e. the port and shipping channels) may have the potential to adversely affect dolphins if these activities result in a significant net decrease of key habitat and the availability of suitable prey on Kwinana Shelf and/or a significant increase in underwater noise (Chabanne et al. 2017a). Therefore, achieving a comprehensive understanding of the dolphins' ecology and distribution across the Kwinana Shelf at both individual and ecosystem levels requires detailed investigation.

As part of the WAMSI Westport Marine Science Program, developed to gain a comprehensive contemporary understanding of the marine environment with Cockburn Sound, a series of systematic photo-identification boat-based surveys were conducted across the Kwinana Shelf in 2022 and 2023 to identify important areas used by dolphins. The findings presented in this report will provide valuable information for informing environmental impact assessments pertaining to the proposed port development. These findings can guide the application of the Environmental Protection Authority's 'mitigation hierarchy' (avoid, mitigate, rehabilitate), which requires proponents to avoid adverse environmental impacts as a first preference and is commonly applied to ensure protection for areas with high environmental values. If impacts cannot be avoided, proponents are required to limit the degree or magnitude of the impact, e.g. by exploring mitigation measures to minimise potential effects on the resident dolphin communities.

1.2 Species distribution modelling and ensemble modelling

Information regarding the influence of various environmental and anthropogenic factors on the distribution of dolphins is fundamental for understanding their ecology and guiding spatial conservation efforts. Species distribution modelling (SDM), also known as habitat modelling or predictive habitat distribution modelling, has become increasingly valuable in identifying and predicting habitat associations (Tyne et al. 2015, Azzolin et al. 2020, Hunt et al. 2020). SDM employs computer algorithms to predict species distribution in a specific study area based on environmental factors (e.g. sea surface temperature and water depth) and/or anthropogenic parameters (e.g.

distance to human activities and boat density). However, selecting the most suitable modelling algorithm for a given dataset can be challenging due to significant disparities in performance and spatial predictions among different techniques (Thuiller et al. 2009, Grenouillet et al. 2011, Hunt et al. 2020). To address these challenges, an ensemble modelling (EM) approach emerged as a solution, providing more robust estimates of species distribution by combining multiple models and accounting for biases inherent in individual models (Araújo & New 2007, Franklin 2010, Grenouillet et al. 2011).

The ensemble model approach has been successfully employed in numerous studies focusing on coastal dolphins, providing insights for future spatial planning and conservation decisions. For example, it has been used for reviews of marine parks management plans (e.g. Passadore et al. 2018, Hunt et al. 2020) or to implement additional management strategies accordingly (e.g. Zanardo et al. 2017).

1.3 Aims and Objectives

By establishing links between habitat characteristics and the presence of dolphins, it becomes possible to identify important areas for population viability and assess the potential adverse effects of human disturbance on the dolphin population. This study aimed to achieve an understanding of areas with a high probability of dolphin occurrence across the Kwinana Shelf, Cockburn Sound, using data collected in 2022 and 2023.

The specific objectives of the study were to:

- Provide an overview of the dolphins' demography and primary behaviours, with a specific focus on the area known as Kwinana Shelf;
- Assess temporal variation among environmental and anthropogenic variables collected during dolphin sightings;
- Investigate environmental and/or anthropogenic variables affecting the distribution of dolphins across the Kwinana Shelf, employing an ensemble of species distribution modelling (SDMs);
- Generate a map depicting the predicted distribution of dolphins across the Kwinana Shelf using the ensemble of SDMs and identify preferred habitat areas (i.e. areas with a high probability of dolphin occurrence based on an ensemble model).

The identification of important areas and seasonal variation across the Kwinana Shelf can provide valuable information for conducting more detailed evaluations, facilitating ongoing environmental management of biodiversity resources and implementing appropriate mitigation strategies to minimise the potential effects of the proposed port development.

2 Materials and Methods

2.1 Data available

2.1.1 Scientific permits and animal ethics

Dolphin photo-identification surveys were conducted under Scientific Permits issued by the Department of Biodiversity, Conservation and Attractions (FO25000086-5, FO25000086-6, and FO25000086-7). Additionally, Animal Ethics approval was obtained from the Animal Ethics Committee of Murdoch University (R3365/21). Access approvals from Fremantle Ports and Alcoa were also obtained before approaching their respective marine infrastructure (jetties), including the exclusion zones around Kwinana Bulk Terminal and Alcoa's port facilities.

2.1.2 Study site and data collection

Boat-based photo-identification surveys were conducted between January 2022 and November 2023, covering all four seasons in the Australasian calendar: summer (January to February), autumn (April to May), winter (July to August), and spring (October to November). The surveys followed predetermined parallel transect lines with a consistent spacing of 500 m apart, using *Distance* 6.0 software (Thomas et al. 2009). This resulted in 21 transect lines orientated east/west and ranging from 0.99 to 3.40 km in length (**Figure 1**). Each transect line was surveyed once during a two consecutive days survey cycle and repeated four times per season, except for summer 2022, which was covered three times only.

Surveys were conducted at a constant speed of 8-10 knots under favourable conditions, namely wind speeds below 10 knots, Beaufort Sea State ≤ 3, and no rain. Each survey involved a crew of three to four observers on board. The observers scanned the area forward of the vessel's beam and within approximately 250 m on either side of the boat, searching for dolphins with the naked eye. Motorised vehicles (i.e. all-size recreational boats, jet skis, shipping barges, and tugs) were recorded during surveys and used as a proxy for underwater disturbance for modelling analyses. Additionally, stationary vessels engaged in fishing activity, including kayaks, were used as a proxy for prey distribution. Although the latter data were only collected in 2023, observations during surveys suggest similar patterns in 2022.

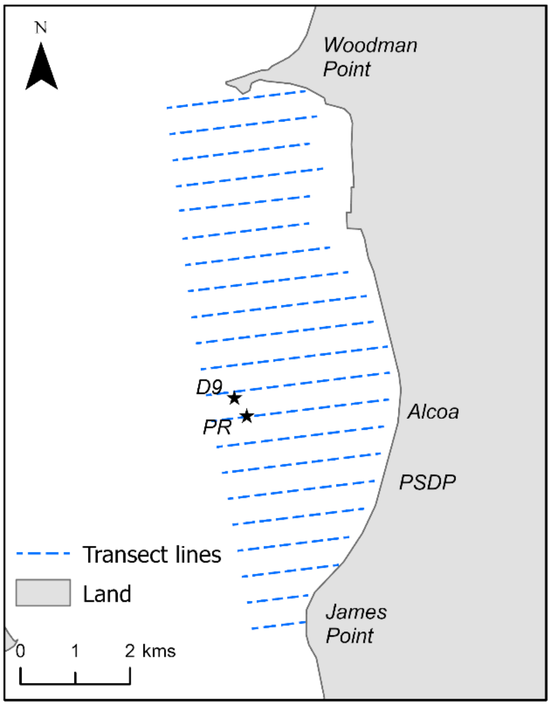

Figure 1. Map of the study area showing the Kwinana Shelf extended from Woodman Point to James Point. The map illustrates the 21 parallel transect lines conducted seasonally between January 2022 and November 2023. *Locations: Alcoa – Alcoa Kwinana Refinery; D9 – D9 Wreck; PR – Pinnacle Rock; PSDP – Water Corporation Perth Seawater Desalination Plant.*

When a dolphin group was encountered along a transect line, search efforts were paused, and the dolphins were approached within 5-30 m to conduct photo-identification and record their location (southing/easting using a handheld Garmin *GPS 72H* unit), initial behaviour observed within the first 5 minutes of approach, group size, and group age composition (categorised as calf or juvenile/adult following the definitions in Chabanne et al. 2017b). Calves were defined as individual's dependent on their mothers, as observed as being in close proximity (< 0.3 m) to them, and ranging in age from 0 to 3 years, inferred by size.

Dolphins were considered part of the same group if they were within 100 m of each other and engaged in the same behaviour (Wells et al. 1987, Quintana-Rizzo & Wells 2001). Behaviour was categorised into four main states: foraging, socialising, resting/milling and travelling (**Table 1**). After all dolphins in the group were photographed and data were collected, the search effort resumed from the point where the transect line had been temporarily left.

Table 1. Ethogram of dolphin behaviours

Behaviour	Description
Foraging	Dolphins are clearly involved in the pursuit of prey and feeding; behaviour events will vary depending on the techniques being used; deep dives, fast swims and porpoising may be observed.
Socialising	When two or more dolphins clearly interact with each other; making frequent physical contact and are surface active.
Resting/Milling	Dolphins frequently change travel direction, slowly swim and rest whilst remaining within a particular area.
Travelling	Dolphin moves consistently in a defined direction; often with consistent dive times

Environmental data including water depth (m), sea surface temperature (SST, °C), and water visibility, were collected *in situ* at each sighting and every hour during surveys. The research vessel's depth sounder was used to measure water depth and SST. Water visibility was measured using the Secchi disk approach and calculated as a proportion of the total depth measured in situ. Additional environmental data provided by the Department of Water and Environmental Regulation (DWER)/Marine and Freshwater Laboratory (MAFRL) and the Cockburn Sound Management Council (one measurement per month from 19 sites located across Cockburn Sound) were examined in relation to the sightings and included salinity (ppt), chlorophyll a (chla) concentration (mg/L), conductivity (µS/cm), oxygen saturation (%), and pH.

2.2 Data analysis

2.2.1 Modelling framework

The objective of this study was to identify dolphin distribution patterns and key areas across the Kwinana Shelf. The following steps were undertaken:

- Mapping the presence of dolphin sightings onto a 100 by 100 m grid resolution;
- Creating raster files of predictor variables at the same resolution;
- Assessing temporal variation and collinearity between predictor variables;
- Randomly selecting pseudo-absence cells and repeating the process ten times, resulting in ten datasets. This approach was necessary because, despite having equal coverage of the entire area, SDM was not successful when using one full dataset due to the high disparity between presence cells and absence cells;
- Selecting model algorithms based on single model algorithm assessments conducted ten times for each dataset. The models were tested using 80% of the data for training and 20% for validation;
- Predicting the distribution of the dolphins using an ensemble model prediction.

2.2.2 Explanatory variables

Explanatory variables used to model dolphin distribution across the Kwinana Shelf included abiotic, anthropogenic and biotic factors. Abiotic variables included SST, water visibility, water depth, seabed slope, distance to the coastline, salinity, chla concentration, O_2 saturation, pH, and conductivity. Anthropogenic variables included distance to recreational boat ramps and commercial jetties and the ratio of motorised vessels as a proxy for underwater noise (hereinafter referred to as 'noise'). One biotic variable was identified, although it could also be considered anthropogenic: the ratio of vessels engaged in fishing activity, used as a proxy for fish distribution (hereinafter referred to as 'fishing', see **Appendix 1**). This variable may represent the distribution of potential prey species targeted by dolphins, though to a limited temporal extent (see the WAMSI Westport Marine Science Program project report *Trophic ecology of Indo-Pacific bottlenose dolphins (Tursiops aduncus) in Owen Anchorage and Cockburn Sound inferred by stable isotopes*, Chabanne (2024)). Some of these variables are known to influence dolphin presence or prey distribution, while others serve as proxies for predation risk or anthropogenic disturbance.

Raster files for each explanatory variable were created in ArcGIS Pro using a 100 x 100 m grid resolution. The mapping projection was GDA2020 datum, and MGA2020 Zone 50 (Central Meridian 117˚East). Abiotic predictor variable layers were generated using *in situ* data and the *Ordinary Kriging Interpolation* tool, with a spherical semi-variogram model, a 100 m cell size, and a 12-point variable search radius. Water depth data across the study area were obtained from the Department of Transport (previously used in Chabanne et al. 2017a) and adjusted to a 100 x 100 m resolution using the ArcGIS Pro *Sample* tool. The slope was calculated using the *slope* tool, derived from water depth. Distance to the coastline was calculated using the ArcGIS Pro *Euclidean distance* tool, providing the shortest straight-line distance. Distance to recreational boat ramps or commercial jetties was calculated using the *Cost distance* tool. These tools were available in the Spatial Analyst extension for ArcGIS Pro.

Substrate type data for the entire area were obtained from the Westport ESRI geospatial platform in March 2023. Across the Kwinana Shelf, substrate types included seagrass (ephemeral and perennial), sand (soft substrate), hard substrate (reef and cobble), and a small patch of mixed substrate (hard/soft) (**Figure 2**).

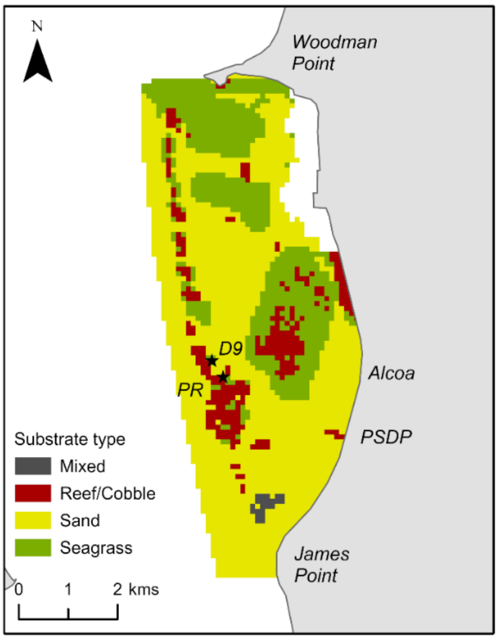

Figure 2. Benthic map showing the different substrate types available across the Kwinana Shelf (from Woodman Point to James Point). The map was modified from the original benthic map (Westport ESRI geospatial platform, available in March 2023) for modelling purposes (resolution of 100 x 100 m) and simplified to four substrate types: seagrass (ephemeral and perennial), soft substrate (sand), reef/cobble (hard substrate), and mixed (soft and hard substrates). *Locations: Alcoa – Alcoa Kwinana Refinery; D9 – D9 Wreck; PR – Pinnacle Rock; PSDP – Water Corporation Perth Seawater Desalination Plant.*

2.2.3 Presence-absence of dolphins

The study area was divided into 100 x 100 m grid cells, resulting in a total of 2,915 cells, all assumed to have been covered with equal efforts (see **Appendix 1**). Each grid cell was assigned a code of "1" to indicate the presence of dolphins if at least one sighting was recorded, and "0" to indicate absence otherwise. Sightings of dolphins observed while travelling initially were excluded from the analysis due to this behaviour being primarily associated with movement between suitable habitats.

Given the design of the transect lines, it was considered that all absence cells had similar effort (see **Appendix 1**), with all having the same probability of being false absence. False absences occur when dolphins are present but not detected and can arise from factors such as sampling design, although not the case in this study, observer effort, group size (smaller groups are more likely to go undetected), and species detection probability (Barbet-Massin et al. 2010). However, preliminary models using all available pseudo-absence cells failed (results not shown in this report). To address this issue, advice from experts, Barbet-Massin et al. (2012) and Colin MacLeod (*personal communication*) recommended using a random selection method, with equal weight given to models averaging several runs of selection. Specifically, the following steps were taken: 1) the number of pseudo-absence cells selected was three times the number of presence cells (Barbet-Massin et al. 2012), thus for each temporal scale (overall and seasonal); 2) pseudo-absence cells were selected from cells without dolphin presence and with a distance restriction of 200 m from presence cells to account for small uncertainty in the GPS location of a group when first sighted and the definition of group, where individuals are within 100 m of each other and engaged in the same behaviour (Wells et al. 1987, Quintana-Rizzo & Wells 2001); 3) ten repeats of the selection process were performed, resulting in ten datasets of pseudo-absence cells (Barbet-Massin et al. 2012).

The distribution of dolphins across the Kwinana Shelf was analysed for the entire study period (pooled data from 2022-2023) and by season (years pooled). SDMs were run using only dolphin sightings where travel was not the initial behaviour. Random selection and models were run in R version 4.1.3 (R Core Team 2023) using RStudio (RStudio Team 2021) and the package *Biomod2* (Thuiller et al. 2009).

2.2.4 Data exploration

Before running SDMs, the explanatory variables were explored for seasonal and yearly patterns using presence data only (i.e. sightings), as well as for variation based on the predominant behaviour (foraging *versus* socialising and resting) and the presence of at least one calf per group. Using the 'car' and 'dunn.test' packages, each variable was assessed for normality using the Shapiro-Wilk tests (Shapiro & Wilk 1965), and homoscedasticity was tested using Levene (1960) and Bartlett (1937) tests. The non-parametric Mann-Whitney *U* test (Mann & Whitney 1947) was used to compare one variable at a time between the years, and Kruskal-Wallis ANOVA (Kruskal & Wallis 1952) was used to compare one variable at a time between seasons or behaviour. Post hoc Dunn's test (1964) was then used to determine differences between pairs when prior tests were significant.

Stepwise procedures were then employed on selected variables using the *vifcor* and *vifstep* functions implemented in the *usdm* package (Naimi et al. 2014) to examine collinearity among the continuous numerical biotic, abiotic and anthropogenic variables. Variance inflation factors (VIFs) were calculated for each explanatory variable, along with the correlation coefficient (r) for all variable combinations. The *vifcor* procedure identified variable pairs with a maximum linear correlation greater than the threshold (r = 0.7), while the *vifstep* procedure excluded variables with the highest VIF exceeding the threshold (VIF = 3). These procedures were repeated iteratively until no variable had a correlation rate higher than 0.7 or a VIF rate greater than 3 (Naimi et al. 2014).

2.2.5 Ensemble modelling approach

To ensure accurate and unbiased modelling of dolphin presence-absence in relation to explanatory variables within the study area, an ensemble modelling (EM) approach was adopted, combining results from multiple single modelling algorithms. Using the *Biomod2* package (Thuiller et al. 2009), eight different modelling algorithms within three modelling methods were tested: regression methods (4) including generalised additive model (GAM), generalised boosted model (GBM), generalised linear model (GLM), and multivariate adaptive regression splines (MARS); classification methods (2) including classification tree analysis (CTA) and flexible discriminant analysis (FDA); and machine learning methods (2) including maximum entropy (MAXENT) and random forest (RF).

The parameters for each model algorithm were defined using the 'bigboss' settings of *Biomod2,* with a binomial error distribution and logit link function. Detailed information on the 'bigboss' settings for each algorithm can be found in the users' guide of the *Biomod2* package (Thuiller et al. 2024) as well as in **Appendix 2**.

For each SDM, a 10-fold cross-validation process was performed with a random split of the data, consisting of 80% used for model calibration and 20% for testing. SDMs were run for the entire study period and used a subset of presence datasets for each season (years pooled).

2.2.6 Model evaluation and statistical tests

To assess the predictive performance of the SDMs and mitigate false positives (i.e. predicting species occurrence where absent) and false negatives (i.e. failing to predict species occurrence where present), two evaluation metrics were employed: the area under curve (AUC) of the receiver operating characteristic (ROC) metric (Fielding & Bell 2002) and the true skill statistic (TSS, Allouche et al. 2006). The ROC evaluates the ratio between observed presence-absence values and model predictions, with values ranging from 0 to 1; scores above 0.5 indicate that the models perform better than expected by chance (Fielding & Bell 2002, Peterson et al. 2011). ROC values between 0.5 and 0.7 signify poor performance, 0.7 and 0.9 indicate reasonable predictions, and above 0.9 represent excellent model performance. Additionally, TSS, which is independent of prevalence data (Allouche et al. 2006) was used as an alternative to ROC for models with smaller sample sizes, such as seasonal SDMs. TSS values range from -1 to 1; values above 0 indicate that the models perform better than random. Values around 0.4 are considered good predictions, while values closer to 1 indicate excellent model performance (Allouche et al. 2006). The combination of ROC and TSS offers complementary performance statistics, with the former being threshold-independent and the latter unaffected by the size of the validation set (Allouche et al. 2006).

In addition to model evaluation, a randomisation procedure involving 10 permutation runs was implemented to assess the importance of the explanatory variables (Thuiller et al. 2009). This procedure calculates the Pearson correlation between standard predictions (i.e. fitted values) and predictions obtained by randomly permuting one variable. A high correlation indicates little difference in the predictions of variable importance, suggesting that the variable is not influential in the model. Conversely, a low correlation indicates that the variable plays a significant role. Each variable was then ranked on a scale of 0 (no influence) to 1 (most influential) based on the mean correlation coefficient (Thuiller et al. 2009). If a variable had a mean of means correlation coefficient < 0.05 using only well-performed single models (ROC > 0.7 and TSS > 0.4), single models for the SDMs were rerun without the variable until all variables exceeded 0.05 (note: a variable's rank could still be lower than 0.05 in the ensemble model).

3 Results

3.1 Survey effort and dolphin encounters.

A total of 31 boat-based systematic surveys were conducted across the Kwinana Shelf between January 2022 and November 2023 (n = 61 days), resulting in the sighting of 156 dolphin 'on effort' groups (**Figure 3**). No significant differences were found in the number of sightings per season once corrected by the number of days conducted (Pearson chi-squared χ^2= 0.22, p-value = 0.97). However, the average number of sightings per day in winter was 1.5 groups compared to autumn or spring, which averaged 3.1 and 3.3 groups, respectively.

An additional 78 sightings were recorded during biopsy sampling or while transiting across the study area (**Appendix 3**). However, these sightings were not included in the SDM analyses due to an effort bias across the study area. This bias was caused by transitions in the same areas and targeted locations when searching for dolphins for biopsy. No difference between seasons in the number of sightings (corrected by the number of survey days) was detected when accounting for the opportunistic sightings (Pearson chi-squared χ^2= 0.25, p-value = 0.97). Opportunistic sightings also included repeats of the same groups within the same day observed either a couple of hours later or at a different location.

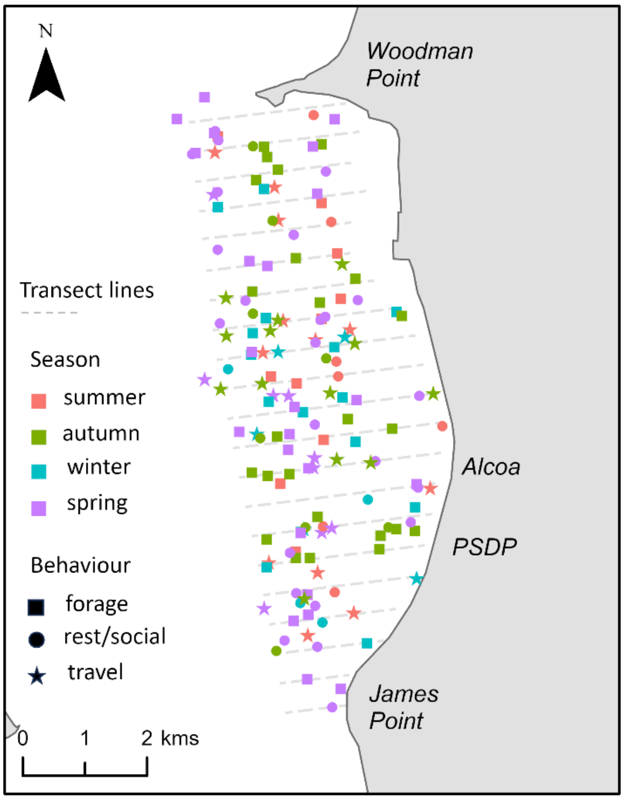

Figure 3. Distribution of Indo-Pacific bottlenose dolphin sightings (n = 153, excluding the three with no observation of behaviour) across the Kwinana Shelf, categorised by season and behaviour. Seasonal distinctions are depicted through colour variation, while behaviour is denoted by symbols. *Locations: Alcoa – Alcoa Kwinana Refinery; PSDP – Water Corporation Perth Seawater Desalination Plant.*

A total of 150 individual dolphins were identified in the Kwinana Shelf, comprising data from both systematic (n = 135 individuals) and opportunistic surveys (n = 127 individuals). Among them, 32 were still categorised as calves at the end of the data collection period (November 2023), and five had transitioned to juveniles. Out of 13 calves born during the study period, 11 were first observed in summer and autumn, while one was recorded in late winter and another in mid-spring. The number of times individuals were resighted in the area varied from one to 44 times. Among the identified juveniles and adults (n = 113), 65 (57%) were recognised from a previous study conducted between 2011 and 2015, including 38 known residents from Cockburn Sound, 18 from Owen Anchorage, and nine from the Swan Canning Riverpark. Of the 113 individuals observed, 36% were seen in fewer than four seasons. The majority of these individuals were residents from Owen Anchorage (n = 13) and the Swan Canning Riverpark (n = 7), while a smaller number were residents from Cockburn Sound (n = 4).

Among the 48 individuals not recognised from the previous study, several scenarios can be hypothesised: 1) they were unsuccessfully matched either because they were born between 2015 and 2020 (i.e. no baby position observed with an adult in 2022 and later), and therefore, no history was available to match them; 2) individuals were last observed with unmarked dorsal fins and were not recognisable seven years later; 3) at least 25% of them could have permanently migrated to Cockburn Sound from elsewhere during the seven years prior to 2022 if hypotheses 1 and 2 do not apply (i.e. based on sightings in at least seven out of the eight seasons surveyed in 2022 and 2023); and 4) 17% of them would be categorised as transient (i.e. seen in one season only) and therefore not commonly found in Cockburn Sound.

Based solely on the 'on effort' sightings (n = 156), all known states of behaviour were documented throughout the observations, although it was not possible to identify behaviour in three sightings

(**Figure 4**). Foraging emerged as the predominant behaviour in 45.5% of the documented groups. Travelling behaviour was initially recorded in 25% of the groups and was excluded from the SDM analyses due to its primary association with movement between suitable habitats. Although not considered in the SDM due to environmental variables reflecting the first 5 minutes of observations, hence capturing the initial behaviour, a shift in behaviour was observed in the majority (51.3%) of the groups (**Figure 4**).

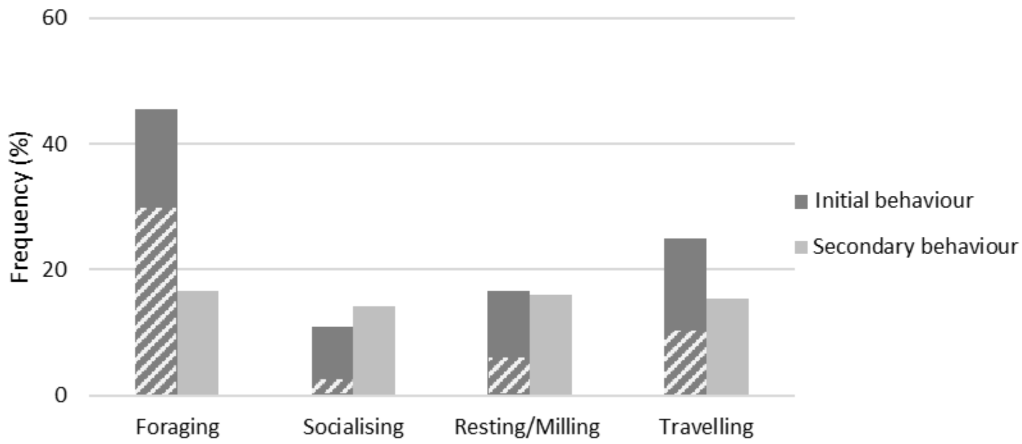

Figure 4. Initial behaviour states observed within the first 5 minutes of an encounter with a group of dolphins. Groups were recorded (n = 156, including three with unknown behaviours not represented here) during the 'on effort' surveys conducted across the Kwinana Shelf from January 2022 to November 2023. A shift in behaviour (i.e. secondary behaviour) occurred in 51.3% of the groups. The crossed section area within the initial behaviour represents the percentage of groups exhibiting exclusively the respective behaviour during the observations.

Group size ranged from one to 39 individuals, including calves, with an overall mean group size of eight individuals (SE = 0.67, median = 5). There was no significant difference in group size observed between seasons (Kruskal-Wallis test: χ^2 = 2.23, df = 3, p-value = 0.52) or years (Mann-Whitney U test: U =1835.5 , p-value = 0.08). However, a significant difference was found between initial behaviours (Kruskal-Wallis test χ^2 = 25.39, df = 2, p-value < 0.001, **Figure 5a**), with group size being significantly smaller when foraging (mean = 6, SE = 0.82, median = 3) compared to socialising (mean = 11, SE = 2.24, median = 8) or resting (mean = 14, SE = 1.86, median = 12). Groups with calves were also significantly larger than those without (Mann-Whitney U test: U = 460.5, p-value < 0.001, **Figure 5b**), with calves present in 70.5% of the groups.

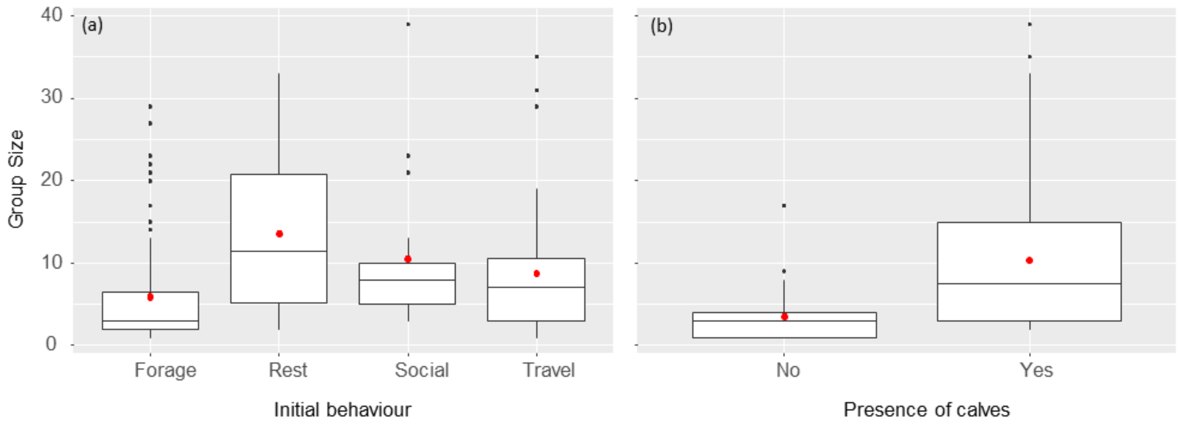

Figure 5. Group size variation for Indo-Pacific bottlenose dolphins sighted across the Kwinana Shelf depending on the initial behaviours (a) or the presence of calves (b) in a sighted group (n = 153, excluding three sightings with unknown behaviour). The mean is represented by the red dot.

During the study period, at least three calves were observed with fishing line entanglement (see **Appendix 4**).

3.2 Explanatory variables across group sightings

There were no significant differences observed among the sighted groups for water depth, distance to the coastline, slope, chla concentration, and substrate type between seasons, years or initial behaviour with or without calves (**Table 2**).

Across all variables, no significant differences were observed by year. However, pH was found to be significant among years (Mann-Whitney U test, $U = 2234$, p-value < 0.001), and the variables SST, water visibility, O_2 saturation, conductivity, salinity and pH were significantly different among seasons ($P < 0.004$, **Table 2** and **Figure 6**). The patterns of variation, however, varied among the variables, with conductivity varying among all seasons, while O_2 saturation was significantly different between summer and winter only. SST also significantly differed among most pairs of seasons, except between spring and autumn. Water visibility in spring significantly varied from autumn and winter, while pH in summer significantly varied between autumn and spring. Finally, significant variation in salinity was observed between autumn and winter or spring, as well as between summer and spring or winter.

Note that the variations found here may differ in other projects due to differences in how data were handled (i.e. variation in selection and method to create rasters covering the study area).

Table 2. Results of statistical tests assessing differences in each explanatory variable across season, years, or behaviour/presence of calves for Indo-Pacific bottlenose dolphins sighting across the Kwinana Shelf (based on 'on effort' surveys conducted in 2022-2023, n = 156 sightings).

Variables	Test	Test Statistic	p-value	
by season				
Water depth	Kruskal-Wallis	χ^2 = 3.37	0.338	
Distance to coastline	ANOVA	$F_{(3,110)}$ = 0.04	0.986	
Distance to ramps/jetties	ANOVA	$F_{(3,110)}$ = 0.72	0.541	
Slope	Kruskal-Wallis	χ^2 = 3.55	0.314	
Substrate type	Kruskal-Wallis	χ^2 = 7.575	0.271	
SST	Kruskal-Wallis	χ^2 = 74.13	<0.001	***
Water visibility	Kruskal-Wallis	χ^2 = 20.94	<0.001	***
chla	Kruskal-Wallis	χ^2 = 0.54	0.910	
O_2 saturation	Kruskal-Wallis	χ^2 = 96.94	<0.001	***
Conductivity	Kruskal-Wallis	χ^2 = 102.24	<0.001	***
Salinity	Kruskal-Wallis	χ^2 = 89.09	<0.001	***
pH	Kruskal-Wallis	χ^2 = 3.372	0.004	**
by year				
Water depth	Mann-Whitney	U = 1519.50	0.782	
Distance to coastline	t-test	$t_{(109.75)}$ = -0.95	0.345	
Distance to ramps/jetties	t-test	$t_{(111.74)}$ = -0.68	0.497	
Slope	Mann-Whitney	U = 1565.00	0.738	
Substrate type	Kruskal-Wallis	χ^2 = 7.58	0.275	
SST	Mann-Whitney	U = 1678.00	0.522	
Water visibility	Mann-Whitney	U = 1308.00	0.938	
chla	Mann-Whitney	U = 1913.00	0.103	
O_2 saturation	Mann-Whitney	U = 1610.00	0.937	
Conductivity	Mann-Whitney	U = 1648.00	0.896	
Salinity	Mann-Whitney	U = 1593.00	0.861	
pH	Mann-Whitney	U = 2234.00	<0.001	***
by behaviour/presence of calves				
Water depth	Kruskal-Wallis	χ^2 = 0.29	0.963	
Distance to coastline	ANOVA	$F_{(3,107)}$ = 0.25	0.859	
Distance to ramps/jetties(1)	ANOVA	$F_{(3,107)}$ = 2.76	0.046	*
Slope	Kruskal-Wallis	χ^2 = 1.724	0.632	
Substrate type	Kruskal-Wallis	χ^2 = *9.425*	0.310	
SST	ANOVA	$F_{(3,105)}$ = 0.81	0.494	
Water visibility	Kruskal-Wallis	χ^2 = 6.95	0.074	
chla	Kruskal-Wallis	χ^2 = 3.68	0.298	
O_2 saturation	Kruskal-Wallis	χ^2 = 7.03	0.071	
Conductivity	Kruskal-Wallis	χ^2 = 1.43	0.698	
Salinity	Kruskal-Wallis	χ^2 = 2.85	0.416	
pH	Kruskal-Wallis	χ^2 = 1.95	0.583	

(1) While significant, a post hoc analysis (Tukey's Honestly Significant Difference test) did not detect significant results between all possible pairs of means.

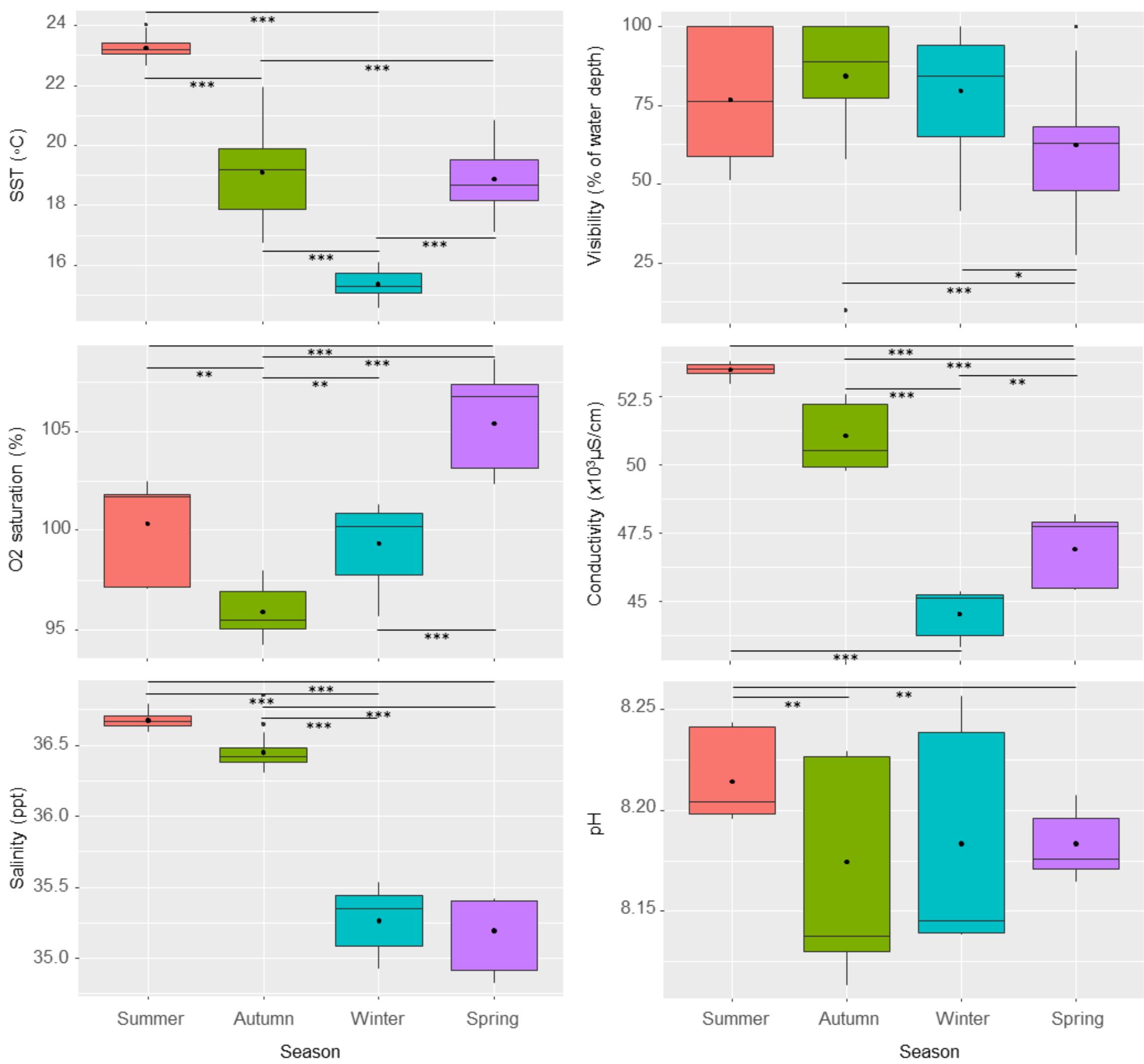

Figure 6. Boxplots showing the distribution of explanatory variables across seasons associated with groups of Indo-Pacific bottlenose dolphins sighted during the 'on effort' surveys conducted in 2022-2023 (n = 156 sightings). Significant variables include SST, water visibility, O_2 saturation, conductivity, salinity and pH. Horizontal bars indicate significant pairwise differences (***p-value < 0.001; **p-value <0.01; *p-value <0.05).

3.3 Distribution modelling

3.3.1 Overall

Preliminary collinearity tests between water depth, distance to the coastline, distance to recreational boat ramps and commercial jetties, slope, substrate type and chla variables revealed no correlations, except between the distances (r = 0.80). Similar SDM results were found regardless of the variable being excluded; therefore, only SDM results when the variable distance to recreational boat ramps and commercial jetties was excluded for further analyses are provided in this report. Additionally, no variable had a mean of the means rank (i.e. correlation coefficient) less than 5% after the first round of single modelling and were, therefore, all retained for the ensemble modelling.

The evaluation of single SDM algorithms using ROC and TSS indicated that most models in the calibration step performed better than random (ROC range = 0.57-1, mean = 0.80, median = 0.77; TSS range = 0.15-0.98, mean = 0.51, median = 0.42, **Figure 7**). However, the performance of the same models during the validation step yielded mixed results (ROC range = 0.45-0.82, mean = 0.65, median = 0.66; TSS range = -0.14-0.58, mean = 0.21, median = 0.21, **Figure 7**).

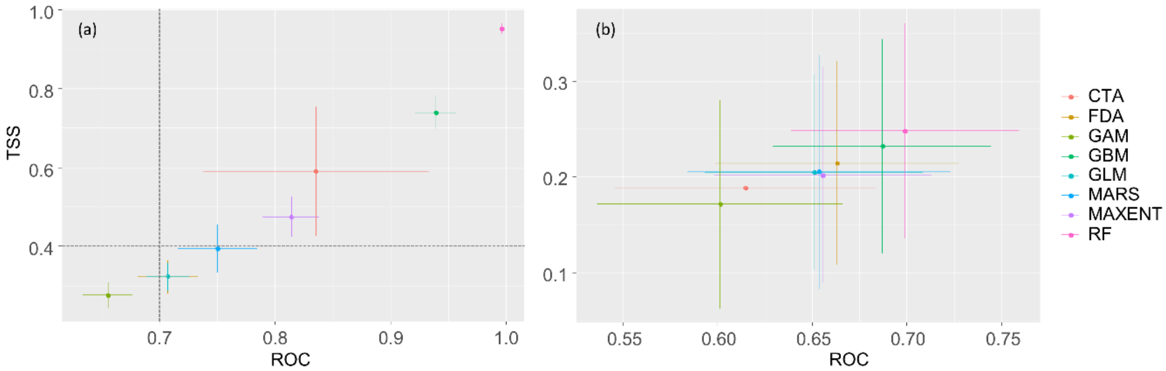

Figure 7. Model performance comparison of the single models run per algorithm for Indo-Pacific bottlenose dolphins across Kwinana Shelf (2022-2023 pooled data) using the area under the receiver operating characteristic curve (ROC) and the true skill statistic (TSS) for both the calibration step (a) and the validation step (b). The centre points represent the mean estimates for each algorithm, and the lines the standard deviations. CTA: classification tree analysis; FDA = flexible discriminant analysis; GAM = generalized additive model; GBM = gradient boosting machine; GLM = generalized linear model; MARS = multivariate adaptive regression splines; MAXENT = maximum entropy model; RF = random forest. X and Y-axes scales vary for each season. Grey dash lines show the threshold values used for model's selection (ROC = 0.7; TSS = 0.4).

After excluding poorly performing single runs in both calibration and validation steps, only 21 out of 800 single models were retained for ensemble modelling. These models contributed to a higher performance, with a mean ROC value of 0.91 (median = 0.88) and TSS of 0.68 (median = 0.60), indicating a good ensemble model performance.

Using the ranking method, the ensemble model revealed that the most influential variable driving the distribution of dolphin groups across the Kwinana Shelf was water depth (**Figure 8** and **Appendix 5** for details). Specifically, the response curves generated by the ensemble model indicated that the probability of dolphin occurrence was higher in areas where water depth ranged from 4 to 9 m (see **Figure 9**).

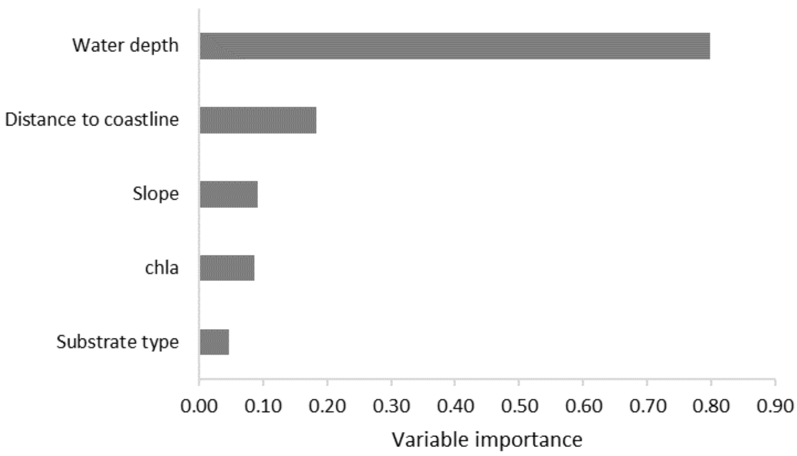

Figure 8. Importance of the explanatory variables used in the ensemble SDM of Indo-Pacific bottlenose dolphins across Kwinana Shelf for the overall study period (2022-2023 data pooled).

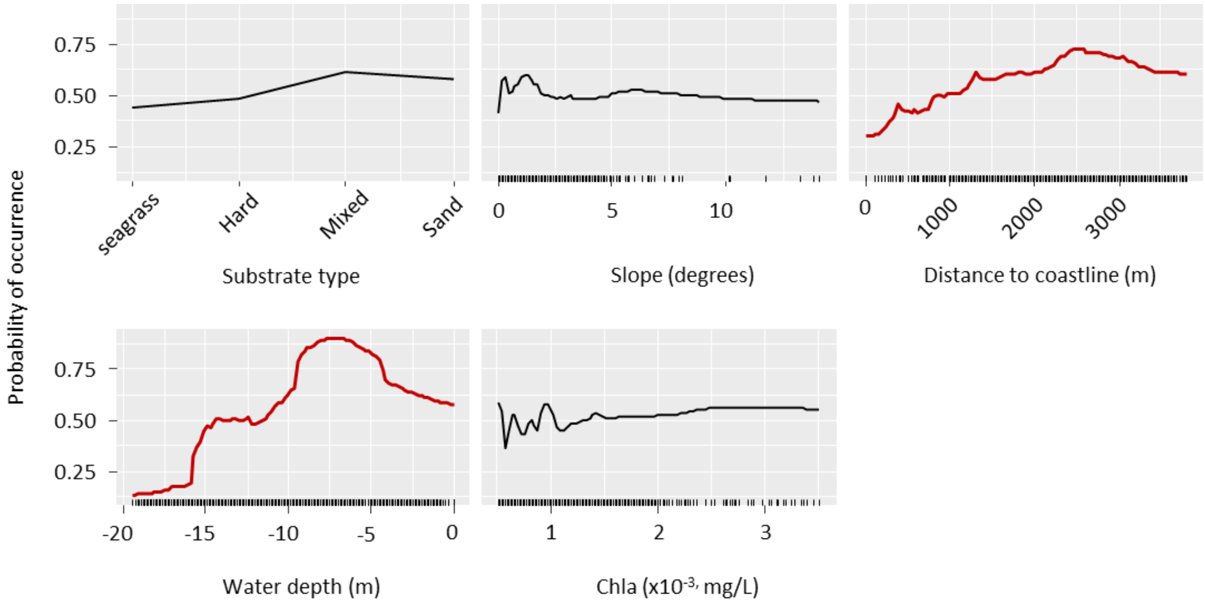

Figure 9. Response curves of the probability of occurrence of dolphins in relation to the explanatory variables obtained for the ensemble SDM run for distribution mapping of Indo-Pacific bottlenose dolphins across the Kwinana Shelf over the entire study period (2022-2023 data pooled). Curves highlighted in red identify the most influential variables.

The ensemble model revealed that dolphins had high probabilities of occurrence (> 0.60) across the majority of the shelf, with the highest occurrence (> 0.80) identified on the west side of the shelf and surrounding Pinnacle Rock, as well as toward James Point. Conversely, Medina and Calista Channels and their close surrounding habitats were identified with the lowest probability of occurrence (**Figure 10**).

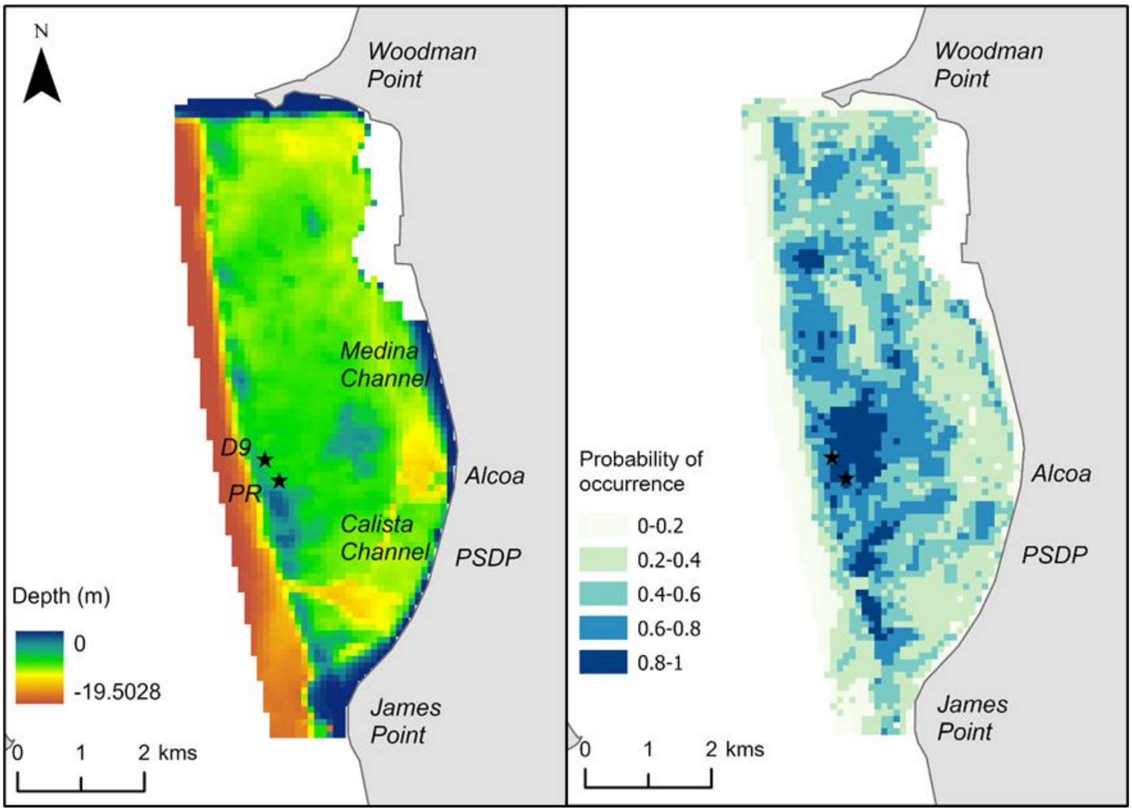

Figure 10. Water depth (m) and overall ensemble models of Indo-Pacific bottlenose dolphin probability of occurrence across Kwinana Shelf (2022-2023 data pooled and excluded travelling behaviour). Colours as shown in the legend indicate the probability of occurrence of dolphins: very low (0-0.2); low (0.2-0.4); moderate (0.4-0.6); high (0.6-0.8); very high (0.8-1). *Locations: Alcoa – Alcoa Kwinana Refinery; D9 – D9 Wreck; PR – Pinnacle Rock; PSDP – Water Corporation Perth Seawater Desalination Plant.*

3.3.2 Seasonal

Water depth or distance to the coastline was identified as the most or second most influential variable when included in the seasonal SDMs, potentially overshadowing responses from other variables. To explore these further, additional models excluding water depth and distance to the coastline were run. There was little variation in areas identified with high probabilities of dolphin occurrence between the two sets of SDMs for each season. Therefore, only the results excluding depth and distance to the coastline are presented here with further details in **Appendix 6** (but see **Appendix 7** for seasonal SDMs including water depth and distance to the coastline).

The steps for the selection of explanatory variables for the seasonal ensemble modelling varied among seasons. For summer, preliminary correlation tests indicated a high correlation between O_2 saturation and salinity (r = -0.75). Consequently, O_2 saturation was removed for the subsequent models. Additionally, the mean of the means rank was less than 5% after the first round of single modelling for SST and conductivity, leading to their removal. Therefore, the ensemble modelling for summer was built with five explanatory variables: water visibility, salinity, pH, noise and fishing.

For autumn, preliminary correlation tests indicated a high correlation between conductivity and salinity (r = 0.75). Consequently, conductivity was removed for the subsequent models with the autumn dataset. There was no variable with a mean of the means rank less than 5% after the first round of single models. Consequently, the ensemble modelling for autumn was built with seven explanatory variables: SST, water visibility, salinity, pH, O_2 saturation, noise and fishing.

For winter, preliminary correlation tests indicated a high correlation between conductivity and salinity (r = 0.74). Consequently, conductivity was removed for the subsequent models with the autumn dataset. There was no variable with a mean of the means rank less than 5% after the first round of single models. The ensemble modelling for winter was therefore built with seven explanatory variables: SST, water visibility, salinity, pH, O_2 saturation, noise and fishing.

Finally, for spring, there was no correlation between the variables. However, salinity was excluded from the ensemble model due to the low ranking (<5%) in the preliminary single model runs. The ensemble modelling for spring was therefore built with seven explanatory variables: SST, water visibility, conductivity, pH, O_2 saturation, noise and fishing.

The evaluation of single seasonal SDM algorithms using ROC and TSS indicated that during the calibration step, most single models performed better than random with ROC means higher than 0.79 and TSS means higher than 0.52 (**Table 3**). However, the performances of the same models during validation were mixed for all seasons. Performances were generally poor during the validation step with ROC means ranging from 0.50 and 0.62 and TSS means ranging from -0.03 to 0.18 (**Table 3**).

Table 3. Statistic summary of the predictive performance for seasonal SDMs run for Indo-Pacific bottlenose dolphins across the Kwinana Shelf. The two metrics used for evaluation were the area under curve of the receiver operating characteristic (ROC) metric (a) and the true skill statistic (TSS) (b). Selection of the pseudo-absence cells was repeated 10 times (i.e. total of 800 single models using 10 datasets tested with eight algorithms and 10 repeats each).

(a)	ROC (Calibration step)			ROC (Validation step)			ROC (Ensemble)	
	Range	Mean	Median	Range	Mean	Median	Mean	Median
Summer	0.51-1	0.83	0.83	0.07-1	0.62	0.63	0.90	0.87
Autumn	0.57-1	0.81	0.81	0.14-1	0.54	0.54	0.90	0.87
Winter	0.51-1	0.83	0.84	0.09-0.96	0.50	0.50	0.92	0.91
Spring	0.53-1	0.79	0.77	0.13-0.85	0.52	0.52	0.87	0.84

(b)	TSS (Calibration step)			TSS (Validation step)			TSS (Ensemble)	
	Range	Mean	Median	Range	Mean	Median	Mean	Median
Summer	0.23-0.98	0.60	0.59	-0.60-1	0.18	0.20	0.67	0.62
Autumn	0.16-1	0.58	0.54	-0.50-0.65	0.06	0.04	0.68	0.60
Winter	0.13-1	0.62	0.62	-0.73-0.91	-0.03	-0.02	0.76	0.72
Spring	0.08-0.96	0.52	0.46	-0.67-0.68	0.06	0.06	0.57	0.53

After excluding the poorly performing single model runs considering both calibration and validation, the ensemble models for each season outperformed all respective single SDMs, with ROC means ranging from 0.87 for spring to 0.92 for winter, and TSS means ranging from 0.57 for spring to 0.76 for winter. These results indicated good model performances for all seasonal ensemble models (**Table 3**).

The ensemble models for each season revealed the significance of certain variables in influencing dolphin distribution across the Kwinana Shelf, generally consistent with the well-performed single models (refer to **Appendix 6** for details of the variable responses in the single models). In autumn and spring, SST and O_2 saturation emerged as the two most influential variables (**Figure 11**). In summer and winter, salinity was identified as the most influential variable, followed by fishing (**Figure 11**).

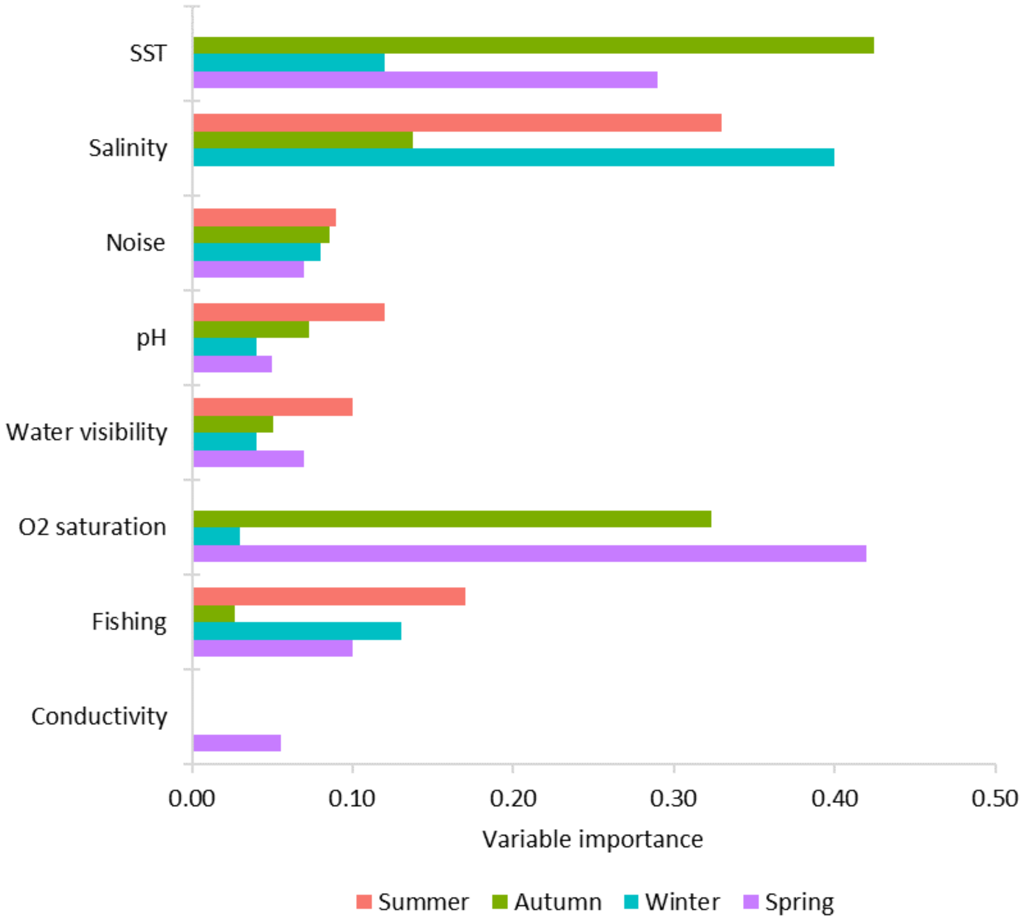

Figure 11. Importance of the explanatory variables used in the ensemble SDMs of Indo-Pacific bottlenose dolphins sighted across the Kwinana Shelf for summer, autumn, winter and spring (years pooled by season and excluded travelling behaviour).

The response curves generated by the ensemble models (**Figure 12**) provided valuable insights into the probability of dolphin occurrence across the Kwinana Shelf for each season. In autumn and spring, the response curve for SST revealed a bimodal distribution, indicating that the likelihood of dolphin presence was higher at both the coldest (~18°C) and warmest (> 19.5-20°C) temperatures recorded for each season. Additionally, dolphins showed a preference for areas with the highest O_2 saturation recorded in spring and autumn, with levels higher than 95% in autumn and above 103.5% in spring. During both summer and winter, higher salinity correlated with a greater probability of dolphin occurrence. In summer, the threshold was salinity levels higher than 36.30 ppt, while in winter, it was any condition exceeding 35.262 ppt, with a maximum recorded value between 35.272 and 35.300 ppt. Additionally, in summer, dolphins were more likely to be found in areas with higher fishing activities, whereas in winter, their occurrence was higher in areas with lesser fishing activities (**Figure 12**).

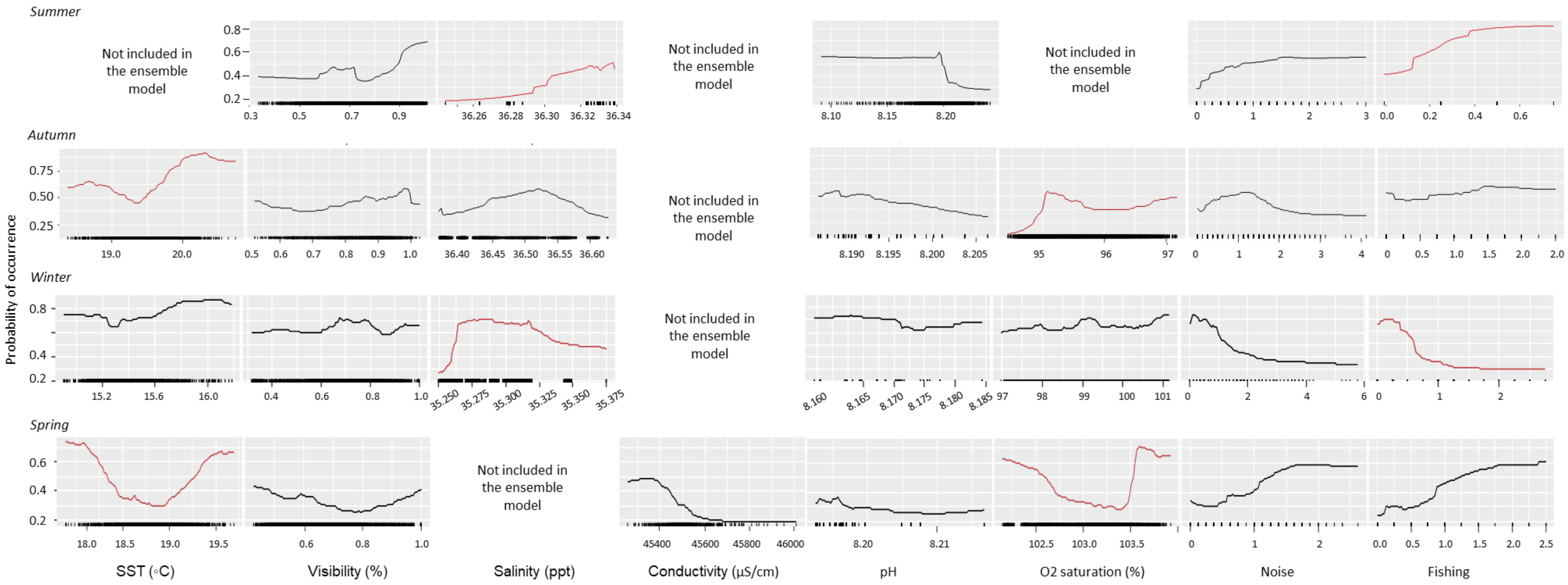

Figure 12. Response curves of the seasonal ensemble models of Indo-Pacific bottlenose dolphin probability of occurrence across the Kwinana Shelf (years 2022-2023 pooled by season and excluded travelling behaviour). Curves highlighted in red identified the biggest influential variable for each season.

The combined ensemble models revealed minimal seasonal shifts in the distribution probabilities of dolphin occurrence across the Kwinana Shelf. Across seasons, the models exhibited a high probability of dolphin occurrence near Woodman Point (the north section of the Kwinana Shelf), Pinnacle Rock and its surrounding areas, as well as James Point. This pattern dissipated in winter, with a high probability of occurrence covering most of the bottom half of the shelf, showing homogeneity in distribution between the Alcoa Kwinana Refinery and James Point, including the area surrounding the Water Corporation Perth Seawater Desalination Plant (PSDP) outfall. Areas surrounding James Point were also identified as hotspots in spring with probabilities of dolphin occurrence exceeding 80%. (**Figure 13**).

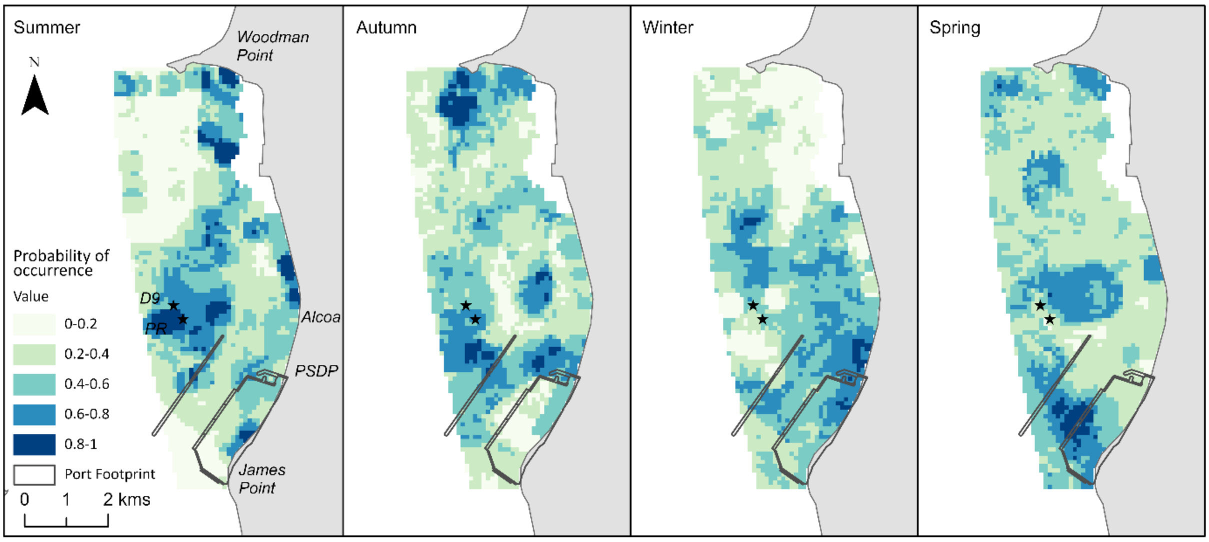

Figure 13. Seasonal ensemble models of Indo-Pacific bottlenose dolphin probability of occurrence across the Kwinana Shelf (years pooled by season and excluded travelling behaviour). Colours as shown in the legend indicate the probability of occurrence of dolphins: very low (0-0.2); low (0.2-0.4); moderate (0.4-0.6); high (0.6-0.8); very high (0.8-1). (Stage 3 port footprint – credit WSP). *Locations: Alcoa – Alcoa Kwinana Refinery; D9 – D9 Wreck; PR – Pinnacle Rock; PSDP – Water Corporation Perth Seawater Desalination Plant.*

4 Discussion

The study provides valuable insights into the spatiotemporal distribution patterns of dolphins across the Kwinana Shelf, within which the proposed Westport development is planned. Indo-Pacific bottlenose dolphins were observed year-round in this region, engaging in various activities such as foraging, resting, and socialising. A significant proportion of the adult dolphins were identified from previous studies, supporting their long-term residency pattern and use of the area. Furthermore, the predominant presence of mother and calf pairs emphasises the area's importance for nursing activities. The use of an ensemble model enabled the identification of high dolphin occurrence areas within the Kwinana Shelf by assessing various environmental and anthropogenic variables. Among these factors, water depth emerged as the primary influencer of dolphin distribution, with key habitats typically found at depths less than 10 m. Additionally, environmental variables such as sea surface temperature, salinity, and oxygen saturation, along with anthropogenic variables like fishing activity, were found to influence dolphin distribution, albeit with varied effects across seasons. These findings underscore the complexity of fine-scale spatial and temporal distribution of Indo-Pacific bottlenose dolphins across the Kwinana Shelf.

4.1 Individual characteristics pertinent to the use of the Kwinana Shelf

Indo-Pacific bottlenose dolphins were sighted across the Kwinana Shelf, totalling 150 individuals, including at least 32 calves in two years of data collection. Among the juveniles and adults, the majority (57%) were identified from previous studies conducted in Cockburn Sound in 2011-2015 (with a few known from 1993-97 and 2000-03 studies; Finn 2005, Chabanne et al. 2017b). Additionally, 64% (n = 75 juveniles and adults) were observed in more than 75% of the seasons, confirming the year-round and long-term use of the Kwinana Shelf by the Cockburn Sound dolphin community (Finn 2005, Finn & Calver 2008, Chabanne et al. 2017a). Interestingly, several resident individuals from Owen Anchorage and the Swan Canning Riverpark were observed in the Kwinana Shelf area on more than one occasion suggesting that the connections between these communities are more significant than previously described, or there has been a change in dynamics over the last decade (Chabanne et al. 2017a). In this context, the Kwinana Shelf may serve as a suitable habitat where interactions, including mating between neighbouring dolphin communities, could take place (Chabanne et al. 2021, Chabanne et al. 2022).

With more than 70% of the recorded dolphin groups including at least one calf (dependent dolphin), the data highlights the importance of the shelf as a nursery area, including learning and teaching of foraging skills (Finn 2005). Peak births occur during the warmer months of summer and autumn, as described in other populations of dolphins located at a similar latitude (Smith et al. 2016, Nicholson 2021). In Bunbury, those months coincide with the highest density of females in the inner waters, while their distribution is more dispersed in the coolest months of winter and spring (Smith et al. 2016). While a density analysis was not undertaken in this study, the high number of seasonal resights observed among individual females across the Kwinana Shelf supports a pattern where females stay in the same area regardless of the season. Although additional dedicated surveys would be needed to better inform on the females and calves' movement between the Kwinana Shelf and their extended home range (Chabanne et al. 2017a), the Kwinana Shelf represents a significant proportion of the most suitable habitat available for the resident dolphins of Cockburn Sound, regardless of the season, annual variation or behaviour (see the WAMSI Westport Marine Science Program project report: *Broad-scale distribution and habitat modelling of Indo-Pacific bottlenose dolphins (Tursiops aduncus) in Owen Anchorage and Cockburn Sound using boat-based survey data from 2011-2015*, Chabanne 2023).

4.2 Identified key conditions and thereby areas across the Kwinana Shelf

4.2.1 Environmental conditions

Across the Kwinana Shelf, the ensemble model highlighted water depth as the primary variable influencing dolphin distribution, emphasizing important areas with depths less than 10 m. This finding aligns with the broader distribution patterns outlined in the WAMSI Westport Marine Science Program project report *Broad-scale distribution and habitat modelling of Indo-Pacific bottlenose dolphins (Tursiops aduncus) in Owen Anchorage and Cockburn Sound using boat-based survey data from 2011-2015* (Chabanne 2023) and other studies on coastal dolphins (e.g. Hunt et al. 2020, Jackson-Ricketts et al. 2020, Haughey et al. 2021). Despite the flat topography of the Kwinana Shelf, areas overlapping the Medina and Calista Channels, characterised by deeper waters, exhibited lower probabilities of dolphin occurrence. This trend persisted across most seasons when considering the water depth variable in the models. In addition to the previously discussed risks outlined in Chabanne (2023) regarding increased underwater noise from dredging machinery and long-term shipping noise, any necessity to deepen areas coinciding with the potential port development's footprint and shipping channels (deeper than 10 meters) could lead to a loss of suitable dolphin habitat due to the overlap with high-probability dolphin occurrence areas.

The interaction between water depth and various environmental and anthropogenic variables revealed a complex relationship, with seasonal variations demonstrating asynchronous patterns.

Seasonal distribution models pinpointed sea surface temperature (SST), salinity and O_2 saturation, as well as fishing activity, as influential variables. These environmental predictors, often serving as proxies for prey distribution, play a crucial role in shaping dolphin distribution, although their occurrence often reflects a balance between prey availability and predation pressure (Heithaus and Dill, 2002, 2006; Wirsing et al., 2008). In temperate regions, dolphins exhibit seasonal distribution patterns in response to changes in prey abundance, which are driven by fluctuations in water conditions (McCluskey et al. 2016, Sprogis et al. 2016). Despite seasonal variability in environmental conditions across the Kwinana Shelf, dolphins maintain a year-round presence (this study but see Chabanne et al. 2017b for movement at the community level). During winter, a higher probability of dolphin occurrence is observed across the lower part of the Kwinana Shelf, which corresponds with areas where salinity levels were higher compared to the upper shelf. The upper part of the Shelf may be exposed to freshwater influxes from the Swan Canning estuary during storms, reducing surface salinity, particularly from mid-winter to spring (D'Adamo, 2002; CSMC, 2018). Conversely, the PSDP outfall located in the lower part of the shelf may counteract this effect, though it is considered negligible (Water Corporation 2019; 0.025ppt difference in this study), potentially enhancing conditions for prey abundance in this area. However, the extent of this influence remains uncertain.

Fluctuations in salinity regimes have the potential to influence the dissolved oxygen concentration, as observed in summer here with the significant negative correlation (-0.75) between salinity and O_2 saturation. Data available to inform O_2 saturation in the study area showed a reduction in autumn, a pattern that is known to occur in Cockburn Sound during this season, although generally reported at the bottom rather than the surface and when winds are the lightest and temperatures are still high (Rose et al. 2012, Xiao et al. 2022). As saturation in dissolved O_2 may be regarded as a proxy for photosynthetic activity (Taylor et al. 1992), this result suggests that locally enhanced primary production may affect the availability of prey for dolphins, thus influencing habitat selection for dolphins. Typically, dolphins would avoid areas with lower O_2 saturation since it can lead to reduced prey abundance and increased stress. Conversely, areas with higher O_2 saturation are more likely to support diverse marine life (Craig et al. 2001).

Sea surface temperature (SST) also exhibits seasonal variability, ranging from 14.59°C in winter to 25.50°C in summer, and largely influenced by the poleward flowing Leeuwin Current (Feng et al., 2003; Waite et al., 2007). While warmer waters can lead to shifts in prey distribution, cooler temperatures may favour certain species, thereby attracting dolphins. This may explain the higher probability of dolphin occurrence at both cooler and warmer SST peaks in autumn and spring, when SST varies significantly between the beginning and end of the season. For example, a recent study indicated that the abundance of Australian butterfish (*Pentapodus vitta*), a species contributing to the dolphin diet in winter (see the WAMSI Westport Marine Science Program project report: *Trophic Ecology of Indo-Pacific Bottlenose Dolphins (Tursiops aduncus) in Owen Anchorage and Cockburn Sound Inferred by Stable Isotopes,* Chabanne (2024)), was more abundant in autumn than in summer (Bowe 2023) and found in every habitat type.

4.2.2 Overlap with human users

Given that the highest occurrences of dolphins were found around Woodman Point (the north section of the Kwinana Shelf), Pinnacle Rock and D9 Wreck, and their surrounding areas, as well as James Point, across multiple seasons and varying conditions (i.e. lowest or highest ranges of SST; highest O_2 saturation or salinity within a particular season yet significantly different between seasons), the identification of these key areas is unlikely to directly reflect any of the environmental variables, regardless of water depth (Davis et al. 2002). Instead, dolphins may tend to concentrate in these areas where structural features indirectly affect the availability and distribution of their prey. This is suggested by the higher occurrence of dolphins in areas with significant recreational fishing activities, as identified during summer. In this study, fishing activities were recorded from observations of fishing gear being used on recreational vessels, including kayaks and jet skis, while on transect surveys.

Pinnacle Rock and D9 Wreck were identified as the most used recreational fishing spots (also see Westport Stage 2 - recreational fishing spots in ArcGIS Westport portal for overlap and other spots). The overlap between dolphins and recreational fishing spots highlights a trade-off between the highly productive areas and the risk of injuries and depredation behaviour associated with risks of fishing gear entanglement and begging behaviour (Donaldson et al. 2010, Donaldson et al. 2012). This is no exception for dolphins in Cockburn Sound with at least three calves reported to be entangled in fishing gear during the two-year study, an issue also well highlighted in neighbouring communities (Nicholson 2023).

Dolphins also face trade-offs between finding preferred habitats for activities and avoiding recreational boating, which generates underwater noise. Although boat traffic was identified as having minimal or no influence on the distribution of dolphins in this study, it is unclear whether behavioural changes occur. The Woodman Point boat ramp is one of the busiest recreational boat ramps in Perth metropolitan area (Department of Transport 2023), with boats generally crossing the northern section of the Kwinana Shelf east to/from west. While other studies demonstrate that dolphins actively avoid or are displaced from preferred habitats heavily used by boats (Nowacek et al. 2001, Bejder et al. 2006, Steckenreuter et al. 2011), a mix of environmental conditions and hydrological features could support a density of prey high enough for dolphins to be accustomed to high levels of noise from boat traffic (e.g. Marley et al. 2016). As previously indicated in Chabanne (2023), the persistent spatial association with the Kwinana Shelf, including the high occurrence of mother-calf pairs across decades, combined with the already occupied neighbouring suitable habitats by other resident communities (such as the Swan Canning Riverpark, Owen Anchorage, and Shoalwater Bay: Chabanne et al. 2017a, Nicholson et al. 2021), suggests that shifts in their core may not be feasible without further risk inducing demographic declines in either the Cockburn Sound community or neighbouring communities, as they share limited resources. However, variation in dolphin behaviour in response to boat traffic may still occur, as the complexity of their tolerance level can vary over time and across individuals (Pirotta et al. 2014). Responses can include but are not limited to: 1) reduction in time spent socialising and foraging; 2) increase in swimming speeds and reorientation rates, potentially resulting in an imbalance between energy consumption and expenditure; 3) long-term elevations in stress hormones and whistle frequency due to increased ambient noise levels; and 4) exposure to direct and significant injuries (e.g. Fair & Becker 2000, Jensen et al. 2009, Donaldson et al. 2012, Piwetz 2019). Although the 2022-2023 data were not collected to assess behavioural activities, future research should investigate any variation in behaviour between areas of high and low traffic to understand whether such a decision for dolphins comes at an extra cost, potentially compromising their fitness and reproductive success (e.g. Manlik et al. 2016, Nicholson et al. 2023).

4.2.3 Importance of substrate type

In Cockburn Sound, fish assemblages comprised markedly fewer species (31%) in low abundance when caught in flat sandy areas, while reef/cobble and seagrass habitats had richer fish assemblages with more than 60% of the species found (Wakefield et al. 2013). Therefore, dolphins likely attribute high importance to reef/cobble and seagrass environments due to the diverse prey types supported by these ecosystems. Additionally, seagrass meadows in Cockburn Sound serve as crucial breeding and nursery areas for various fish species (Wakefield et al. 2013). While SDMs did not identify substrate type variable as an important variable influencing the distribution of dolphins, areas characterised by reef, cobble and seagrass overlapped with high probabilities of occurrence of dolphins as well as habitat requirements for their main prey that are benthic detritivores or omnivores and invertebrates' cephalopods (see the WAMSI Westport Marine Science Program project report: *Trophic Ecology of Indo-Pacific Bottlenose Dolphins (Tursiops aduncus) in Owen Anchorage and Cockburn Sound Inferred by Stable Isotopes*, Chabanne (2024)). A permanent loss of these substrates could therefore result in decreased prey availability in these areas.

4.3 Limitations

4.3.1 Explanatory variables

The SDMs in this study were developed using a set of explanatory variables that did not encompass all potential factors influencing the spatial distribution of dolphins. The resolution at which some of the variables, such as conductivity, salinity, O_2 saturation, pH, and chla, was limited to one measurement per month at 19 sites spread across the entire Cockburn Sound. While data with higher temporal resolution were available (WWMSP *Theme 5*), they were limited to only one site, thus strongly constraining the spatial information. Although dolphin distribution is unlikely to be influenced directly by any of the variables considered in this study, the interpretation of the spatial and temporal fine-scale variation of the available environmental conditions may lack accuracy. Future studies should consider collecting a larger number of environmental variables *in situ* during surveys to achieve fine-scale resolution.

4.3.2 Overall update on the status of the community of resident dolphins in Cockburn Sound

This study specifically examined the distribution of dolphins using the Kwinana Shelf through systematic surveys conducted solely within this area. Since the Kwinana Shelf represents only a portion of the community's extended home range (Chabanne et al. 2017a), the findings are limited to this specific location. Consequently, the data collected in this study cannot be used to understand the demographic trends of the resident community in Cockburn Sound over decades (i.e. abundance estimates, survival rates, emigration rates, e.g. Chabanne et al. 2017b). This limitation arises due to variations in coverage between this study area and the broader Cockburn Sound, as well as, but not limited to, potential environmental factors not considered here that may influence the community at a large spatial scale.

5 Conclusions/Recommendations

The Kwinana Shelf has been described as an important area for the resident community of dolphins in Cockburn Sound for more than four decades. The observations of dolphins visiting from the Swan Canning Riverpark, Owen Anchorage or previously observed in Shoalwater Bay also suggest the importance of the Kwinana Shelf for neighbouring communities to interact (i.e. genetically connected; Chabanne et al. 2021).

While this study highlights the promise of habitat modelling in predicting dolphin occurrence based on hydrological and physiographical data, it faces challenges, particularly at fine spatial scale. The relatively uniform topography of the Kwinana Shelf, coupled with variations in hydrological parameters, leads to changes in predictors of dolphin occurrence from one season to another. This complexity underscores the influence of hydrological variables in shaping key habitat use by dolphins, likely influencing seasonal shifts in prey distribution across the Kwinana Shelf. With the absence of discernible seasonal or yearly patterns at the broader scale (Chabanne 2023), shifts in dolphin distribution would likely still remain confined to the Kwinana Shelf, emphasising the area's overall importance.

The SDMs also identified several key areas being frequently used by dolphins throughout the year, some of which coincide with recreational fishing spots. Among these areas are Woodman Point (located in the northern section of the Kwinana Shelf), as well as closer to the proposed Westport footprint, including Pinnacle Rock, D9 Wreck, and James Point. Conserving these identified areas should be a priority to prevent disruption to the resident and neighbouring dolphin communities.

In a scenario where there is a loss of habitat or an increase of underwater noise beyond the dolphins' tolerance level on the Kwinana Shelf (which is currently unknown), it highlights the uncertainty regarding the viability of the resident community in Cockburn Sound. This uncertainty is associated with the questions about their potential responses:

1) Whether the loss of a portion of their current key areas would have a negligible impact, prompting the dolphins to remain in the area, or if it would induce a shift elsewhere for some or all individuals.
2) How nursing females would respond to a reduction in habitat quality (due to habitat loss and/or noise disturbance) and the potential for flow-on effects on demographics and/or population viability.
3) If a shift to another location does occur, whether the new core habitat would be appropriately managed to sustain the dolphin community, especially in conjunction with other developments expected to occur in Cockburn Sound over the next decades.

It is important to note that this interpretation does not fully account for potential changes in predation risk, especially if shifted to less protected locations. Additionally, it does not consider the impact of more frequent and intense climatic events (Cai et al. 2015). This is particularly relevant given previous observations of declines in survival and reproduction success for dolphins in Shark Bay following the 2011 marine heatwave, which led to catastrophic losses of seagrass meadows, as well as mass mortalities of invertebrates and fish communities(Wild et al. 2019).

Continued monitoring of dolphin density, behaviour and health before, during, and after potential disturbances is essential for assessing species distribution and responses to port development operations. Ongoing, long-term surveys for dolphins will help evaluate the effectiveness of mitigation measures aimed at minimising habitat loss, noise, injuries, and other impacts associated with human activities as well as ongoing changes such as climate change and metocean changes that can affect prey distribution and availability.

6 References

Allouche O, Tsoar A, Kadmon R (2006) Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). J Appl Ecol 43:1223-1232.

Araújo MB, New M (2007) Ensemble forecasting of species distributions. Trends Ecol Evol 22:42-47.

Azzolin M, Arcangeli A, Cipriano G, Crosti R, Maglietta R, Pietroluongo G, Saintingan S, Zampollo A, Fanizza C, Carlucci R (2020) Spatial distribution modelling of striped dolphin (*Stenella coeruleoalba*) at different geographical scales within the EU Adriatic and Ionian Sea Region, central-eastern Mediterranean Sea. Aquat Conserv 30:1194-1207.

Barbet-Massin M, Jiguet F, Albert CH, Thuiller W (2012) Selecting pseudo-absences for species distribution models: how, where and how many? Methods Ecol Evol 3:327-338.

Barbet-Massin M, Thuiller W, Jiguet F (2010) How much do we overestimate future local extinction rates when restricting the range of occurrence data in climate suitability models? Ecography 33:878-886.

Bartlett MS (1937) Properties of sufficiency and statistical tests. Proc R Soc Lond 160:268-282.

Bejder L, Samuels A, Whitehead H, Gales N (2006) Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. Anim Behav 72:1149-1158.

Bowe BE (2023) Biology of Western Butterfish (*Pentapodus vitta*) in Cockburn Sound, Western Australia. Honours thesis, Murdoch University, Perth, Western Australia.

Braulik G, Natoli A, Kiszka J, Parra G, Plön S, Smith BD (2019) *Tursiops aduncus*, Indo-Pacific Bottlenose Dolphin. The IUCN Red List of Threatened Species:e.T41714A50381127.

Cai W, Wang G, Santoso A, McPhaden MJ, Wu L, Jin F-F, Timmermann A, Collins M, Vecchi G, Lengaigne M, England MH, Dommenget D, Takahashi K, Guilyardi E (2015) Increased frequency of extreme La Niña events under greenhouse warming. Nat Clim Chang 5:132-137.

Chabanne D, Finn H, Salgado-Kent C, Bejder L (2012) Identification of a resident community of bottlenose dolphins (*Tursiops aduncus*) in the Swan Canning Riverpark, Western Australia, using behavioural information. Pac Conserv Biol 18:247-262.

Chabanne DBH (2023) Broad-scale distribution and habitat modelling of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Owen Anchorage and Cockburn Sound using boat-based survey data from 2011-2015. Prepared for the WAMSI Westport Marine Science Program. Western Australian Marine Science Institution, Perth, Western Australia.

Chabanne DBH (2024) Trophic ecology of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Owen Anchorage and Cockburn Sound inferred by stable isotopes. Prepared for the WAMSI Westport Marine Science Program. Western Australian Marine Science Institution, Perth, Western Australia.

Chabanne DBH, Allen SJ, Sherwin WB, Finn H, Krützen M (2021) Inconsistency between socio-spatial and genetic structure in a coastal dolphin population. Front Mar Sci 7:1217.

Chabanne DBH, Finn H, Bejder L (2017a) Identifying the relevant local population for environmental impact assessments of mobile marine fauna. Front Mar Sci 4:148.

Chabanne DBH, Krützen M, Finn H, Allen SJ (2022) Evidence of male alliance formation in a small dolphin community. Mammal Biol 102:1285–1298.

Chabanne DBH, Pollock KH, Finn H, Bejder L (2017b) Applying the multistate capture-recapture robust design to characterize metapopulation structure. Methods Ecol Evol 8:1547-1557.

Craig JK, Crowder LB, Gray CD, McDaniel CJ, Kenwood TA, Hanifen JG (2001) Ecological Effects of Hypoxia on Fish, Sea Turtles, and Marine Mammals in the Northwestern Gulf of Mexico. In: Rabalais NN, Turner RE (eds) Coastal Hypoxia: Consequences for Living Resources and Ecosystems

Davis RW, Ortega-Ortiz JG, Ribic CA, Evans WE, Biggs DC, Ressler PH, Cady RB, Leben RR, Mullin KD, Würsig B (2002) Cetacean habitat in the northern oceanic Gulf of Mexico. Deep Sea Res 49:121-142.

Department of Transport (2023) Woodman Point recreational boating precinct. Accessed 24 May 2024. https://www.transport.wa.gov.au/imarine/ml-woodman-point.asp#:~:text=The%20Woodman%20Point%20Recreational%20Boating%20Precinct%20is%20one,and%20420%20car%20and%20boat%20trailer%20parking%20bays.

Donaldson R, Finn H, Bejder L, Lusseau D, Calver M (2012) The social side of human-wildlife interaction: wildlife can learn harmful behaviours from each other. Anim Conserv 15:427-435.

Donaldson R, Finn H, Calver M (2010) Illegal feeding increases risk of boat-strike and entanglement in bottlenose dolphins in Perth, Western Australia. Pac Conserv Biol 16:157-161.

Dunn OJ (1964) Multiple comparisons using rank sums. Technometrics 6:241-252.

Fair PA, Becker PR (2000) Review of stress in marine mammals. J Aquat Ecosyst Stress Recovery 7:335-354.

Fielding AH, Bell JF (2002) A review of methods for the assessment of prediction errors in conservation presence/absence models. Environ Conserv 24:38-49.

Finn H (2005) Conservation biology of bottlenose dolphins (*Tursiops* sp.) in Perth metropolitan waters. PhD thesis, Murdoch University, Perth.

Finn H, Calver MC (2008) Feeding aggregations of bottlenose dolphins and seabirds in Cockburn Sound, Western Australia. W Austral 26:157-172.

Franklin J (2010) Mapping species distributions: spatial inference and prediction. Cambridge University Press, Cambridge.

Grenouillet G, Buisson L, Casajus N, Lek S (2011) Ensemble modelling of species distribution: the effects of geographical and environmental ranges. Ecography 34:9-17.

Haughey R, Hunt TN, Hanf D, Passadore C, Baring R, Parra GJ (2021) Distribution and Habitat Preferences of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus)* Inhabiting Coastal Waters With Mixed Levels of Protection. Front Mar Sci 8:617518.

Hunt TN, Allen SJ, Bejder L, Parra GJ (2020) Identifying priority habitat for conservation and management of Australian humpback dolphins within a marine protected area. Sci Rep 10:14366.

Jackson-Ricketts J, Junchompoo C, Hines EM, Hazen EL, Ponnampalam LS, Ilangakoon A, Monanunsap S (2020) Habitat modeling of Irrawaddy dolphins (*Orcaella brevirostris*) in the Eastern Gulf of Thailand. Ecol Evol 10:2778-2792.

Jensen F, Bejder L, Wahlberg M, Aguilar de Soto N, Johnson M, Madsen P (2009) Vessel noise effects on delphinid communication. Mar Ecol Prog Ser 395:161-175.

Kruskal WH, Wallis WA (1952) Use of ranks in one-criterion variance analysis. J Am Stat Assoc 47:583-621.

Levene H (1960) Robust tests for equality of variances. In: I. Olkin, S. G. Ghurye, W. Hoeffding, W. G. Madow, Mann HB (eds) Contributions to probability and statistics: Essays in Honor of Harold Hotelling. Stanford University Press

Manlik O, McDonald JA, Mann J, Raudino HC, Bejder L, Krutzen M, Connor RC, Heithaus MR, Lacy RC, Sherwin WB (2016) The relative importance of reproduction and survival for the conservation of two dolphin populations. Ecol Evol 6:3496-3512.

Mann HB, Whitney DR (1947) On a test of whether one of two random variables is stochastically larger than the other. Ann Math Statist 18:50-60.

Marley SA, Salgado Kent CP, Erbe C (2016) Occupancy of bottlenose dolphins (*Tursiops aduncus*) in relation to vessel traffic, dredging, and environmental variables within a highly urbanised estuary. Hydrobiologia 792:243-263.

McCluskey SM, Bejder L, Loneragan NR (2016) Dolphin prey availability and calorific value in an estuarine and coastal environment. Front Mar Sci 3:30.

Naimi B, Hamm NAS, Groen TA, Skidmore AK, Toxopeus AG (2014) Where is positional uncertainty a problem for species distribution modelling? Ecography 37:191-203.

Nicholson K (2021) Dolphins as part of the ecological character of Ramsar-listed wetlands: a case study of Indo-Pacific bottlenose dolphins in the Peel-Harvey Estuary, Western Australia. PhD thesis, Murdoch University, Perth, Western Australia.

Nicholson K (2023) Entanglement in recreational fishing gear poses a threat to estuarine and coastal dolphins: Animal welfare and population level impacts should guide intervention decision making. Mar Pollut Bull 192:115094.

Nicholson K, Loneragan N, Finn H, Bejder L (2021) Social, spatial and isotopic niche partitioning identify an estuarine community of bottlenose dolphins as a discrete management unit. Aquat Conserv

31:3526-3542.
Nicholson K, van Aswegen M, Loneragan N, Bejder L (2023) Demographics and viability of an estuarine community of Indo-Pacific bottlenose dolphins. Mar Mamm Sci 39:59-76.
Nowacek SM, Wells RS, Solow AR (2001) Short-term effects of boat traffic on bottlenose dolphins, Tursiops truncatus, in Sarasota Bay, Florida. Mar Mamm Sci 17:673-688.
Passadore C, Möller LM, Diaz-Aguirre F, Parra GJ (2018) Modelling dolphin distribution to inform future spatial conservation decisions in a marine protected area. Sci Rep 8:15659.
Peterson AT, Soberón J, Pearson RG, Anderson RP, Martínez-Meyer E, Nakamura M, Araújo MB (2011) Ecological niches and geographic distributions. Princeton University Press, Oxfordshire.
Pirotta E, Thompson PM, Cheney B, Donovan CR, Lusseau D (2014) Estimating spatial, temporal and individual variability in dolphin cumulative exposure to boat traffic using spatially explicit capture–recapture methods. Anim Conserv 18:20-31.
Piwetz S (2019) Common bottlenose dolphin (*Tursiops truncatus*) behavior in an active narrow seaport. PLoS One 14:e0211971.
Quintana-Rizzo E, Wells RS (2001) Resighting and association patterns of bottlenose dolphins (*Tursiops truncatus*) in the Cedar Keys, Florida: insights into social organization. Can J Zool 79:447-456.
Rose TH, Smale DA, Botting G (2012) The 2011 marine heat wave in Cockburn Sound, southwest Australia. Ocean Sci 8:545-550.
Shapiro SS, Wilk MB (1965) An analysis of variance test for normality (complete samples). Biometrika 52:591-611.
Smith H, Frère C, Kobryn H, Bejder L (2016) Dolphin sociality, distribution and calving as important behavioural patterns informing management. Anim Conserv 19:462-471.
Sprogis KR-A, Pollock KH, Raudino HC, Allen SJ, Kopps AM, Manlik O, Tyne JA, Bejder L (2016) Sex-specific patterns in abundance, temporary emigration and survival of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in coastal and estuarine waters. Front Mar Sci 3:12.
Steckenreuter A, Harcourt R, Möller L (2011) Distance does matter: close approaches by boats impede feeding and resting behaviour of Indo-Pacific bottlenose dolphins. Wild Res 38
Taylor AH, Watson AJ, Robertson JE (1992) The influence of the spring phytoplankton bloom on carbon dioxide and oxygen concentrations in the surface waters of the northeast Atlantic during 1989. Deep Sea Res 39:137-152.
Team R (2021) RStudio: Integrated Development Environment for R. RStudio, PBC, Boston, MA.
Team RC (2023) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
Thomas L, Laake JL, Rexstad E, Strindberg S, Marques FFC, Buckland ST, Borchers DL, Anderson DR, Burnham KP, Burt ML, Hedley SL, Pollard JH, Bishop JRB, Marques TA (2009) Distance 6.0. release 1. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK.
Thuiller W, Georges D, Gueguen M, Engler R, Breiner F, Lafourcade B, Patin R, Blancheteau H (2024) biomod2: Ensemble Platform for Species Distribution Modeling. R package version 4.2-5. https://biomodhub.github.io/biomod2/.
Thuiller W, Lafourcade B, Engler R, Araújo MB (2009) BIOMOD - a platform for ensemble forecasting of species distributions. Ecography 32:369-373.
Tyne JA, Johnston DW, Rankin R, Loneragan NR, Bejder L (2015) The importance of spinner dolphin (*Stenella longirostris*) resting habitat: implications for management. J Appl Ecol 52:621-630.
Wakefield CB, Lewis PD, Coutts TB, Fairclough DV, Langlois TJ (2013) Fish assemblages associated with natural and anthropogenically-modified habitats in a marine embayment: comparison of baited videos and opera-house traps. PLoS One 8:e59959.
Water Corporation (2019) Perth Seawater Desalination Plant 2 - Referal. Environmental Review Document. Perth, Australia.
Wells RS, Scott MD, Irvine AB, Genoways H (1987) The social structure of free-ranging bottlenose dolphins. In: Genoways HH (ed) Current Mammalogy. Springer, Boston, MA.
Wild S, Krutzen M, Rankin RW, Hoppitt WJE, Gerber L, Allen SJ (2019) Long-term decline in survival and reproduction of dolphins following a marine heatwave. Curr Biol 29:R239-R240.

Xiao R, Gao G, Feng M, Greenwood J, Keesing J, Yin B, Yang D, Feng X, Xu L, Liu Z, Lv X (2022) Three-dimensional numerical simulation of circulation and vertical temperature structure during summer in Cockburn Sound. Reg Stud Mar Sci 51

Zanardo N, Parra GJ, Passadore C, Möller LM (2017) Ensemble modelling of southern Australian bottlenose dolphin *Tursiops* sp. distribution reveals important habitats and their potential ecological function. Mar Ecol Prog Ser 569:253-266.

7 Acknowledgements

I would like to express my sincere gratitude to several colleagues who provided invaluable feedback and support throughout this study. I am particularly thankful to many volunteers and intern students without whom the fieldwork data collection would have been impossible.

I would also like to extend my thanks to members of the Science Program Leadership Team and other experts who reviewed the draft report.

8 Appendices

8.1 **Appendix 1.** Spatial distribution of survey effort and fishing activities recorded across the Kwinana Shelf.

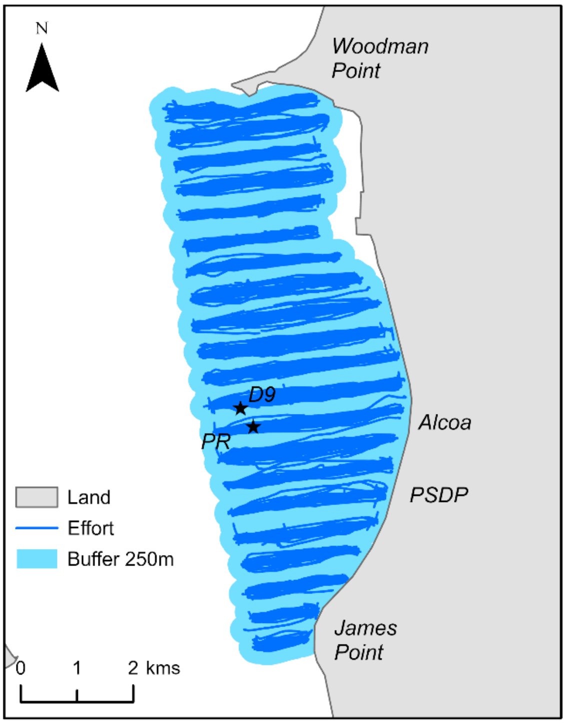

Figure 14. Map of the survey efforts carried out across Kwinana Shelf in 2022 and 2023. The blue lines show the vessel tracks with the light blue representing the 250m buffer on each side of the tracks. *Locations: Alcoa – Alcoa Kwinana Refinery; PSDP – Water Corporation Perth Seawater Desalination Plant.*

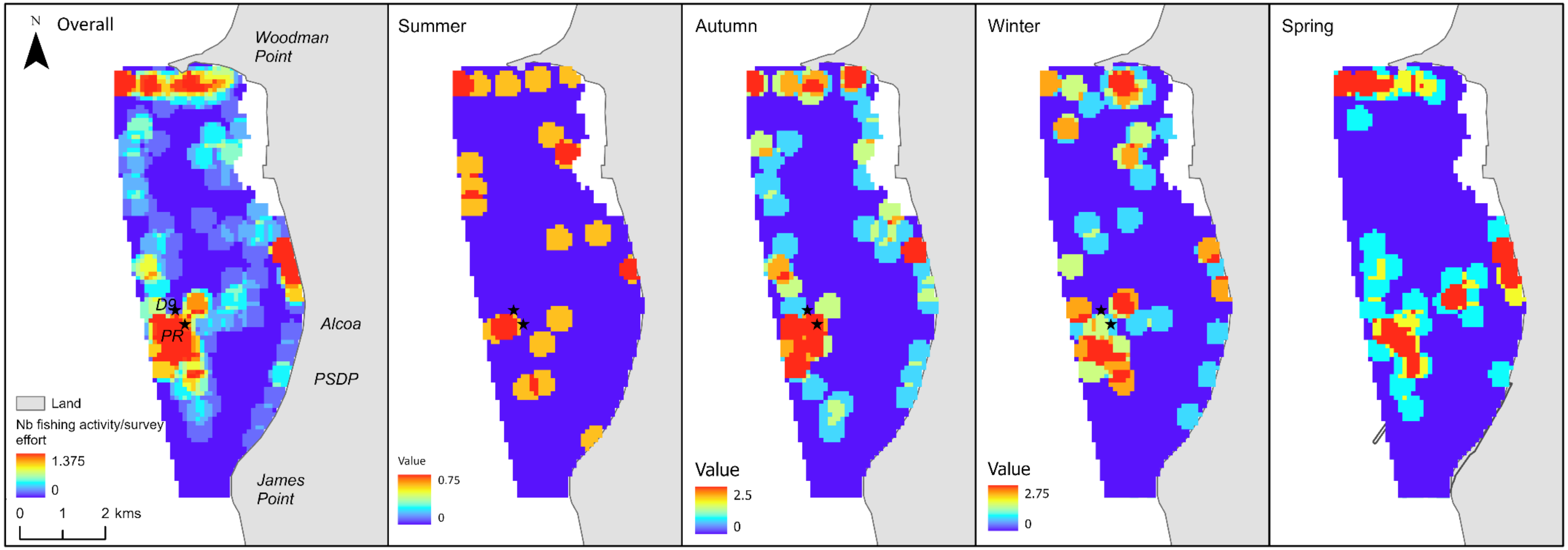

Figure 15. Fishing activity (ratio) recorded during survey efforts out across Kwinana Shelf in 2022 and 2023. The ratio of fishing activity was calculated as the number of vessels in fishing activity corrected by number of surveys. A 250 m buffer from the recorded geographic coordinates was used. The map has a resolution of 100 x 100 m. *Locations: Alcoa – Alcoa Kwinana Refinery; PSDP – Water Corporation Perth Seawater Desalination Plant*

8.2 **Appendix 2.** 'Bigboss' settings for species distribution modelling (only showing parameters with specific settings).

CTA options (datatype: binary, package: rpart , function: rpart) :

- na.action = na.rpart
- method = "class"
- model = FALSE
- x = FALSE
- y = TRUE
- control = $xval 5 $minbucket 5 $minsplit 5 $cp 0.001 $maxdepth 25 (default:)

FDA options (datatype: binary, package: mda , function: fda) :

- formula = formula(data)
- data = sys.frame(sys.parent())
- eps = .Machine$double.eps
- method = "mars" (default: polyreg)

GAM options (datatype: binary, package: mgcv , function: gam) :

- family = Family: binomial Link function: logit
- data = list()
- weights = NULL
- subset = NULL
- offset = NULL
- method = "GCV.Cp"
- optimizer = c("outer", "newton")
- control = $epsilon 1e-06 $trace FALSE $maxit 100 (default: $nthreads 1 $ncv.threads 1 $irls.reg 0 $epsilon 1e-07 $maxit 200 $trace FALSE $mgcv.tol 1e-07 $mgcv.half 15 $rank.tol 1.490116e-08 $nlm nlmndigit 7 nlmgradtol 1e-06 nlmstepmax 2 nlmsteptol 1e-04 nlmiterlim 200 nlmcheck.analyticals FALSE $optim $optim$factr 1e+07 $newton $newton$conv.tol 1e-06 $newton$maxNstep 5 $newton$maxSstep 2 $newton$maxHalf 30 $newton$use.svd FALSE $idLinksBases TRUE $scalePenalty TRUE $efs.lspmax 15 $efs.tol 0.1 $keepData FALSE $scale.est "fletcher" $edge.correct FALSE)
- scale = 0
- select = FALSE
- knots = NULL
- sp = NULL
- min.sp = NULL
- H = NULL
- gamma = 1
- fit = TRUE
- paraPen = NULL
- G = NULL
- in.out = NULL
- drop.unused.levels = TRUE
- drop.intercept = NULL
- nei = NULL
- discrete = FALSE

GBM options (datatype: binary, package: gbm , function: gbm) :

- formula = formula(data)
- distribution = "bernoulli"
- data = list()
- var.monotone = NULL
- n.trees = 2500 (default: 100)
- interaction.depth = 7 (default: 1)

- n.minobsinnode = 5 (default: 10)
- shrinkage = 0.001 (default: 0.1)
- bag.fraction = 0.5
- train.fraction = 1
- cv.folds = 3 (default: 0)
- keep.data = FALSE (default: TRUE)
- verbose = FALSE
- class.stratify.cv = NULL
- n.cores = 1 (default: NULL)

GLM options (datatype: binary, package: stats, function: glm) :

- family = Family: binomial Link function: logit
- start = NULL
- mustart = 0.5 (default:)
- control = $epsilon 1e-08 $maxit 50 $trace FALSE (default: list())
- model = TRUE
- method = "glm.fit"
- x = FALSE
- y = TRUE
- singular.ok = TRUE
- contrasts = NULL

MARS options (datatype: binary, package: earth, function: earth) :

- glm = $family Family: binomial Link function: logit (default: NULL)
- ncross = 0 (default: NULL)
- penalty = 2 (default: NULL)
- thresh = 0.001 (default: NULL)
- pmethod = "backward" (default: NULL)

MAXENT options (datatype: binary, package: MAXENT, function: MAXENT):

- path_to_maxent.jar = "."
- memory_allocated = 512
- initial_heap_size = NULL
- max_heap_size = NULL
- background_data_dir = "default"
- visible = FALSE
- linear = TRUE
- quadratic = TRUE
- product = TRUE
- threshold = TRUE
- hinge = TRUE
- lq2lqptthreshold = 80
- l2lqthreshold = 10
- hingethreshold = 15
- beta_threshold = -1
- beta_categorical = -1
- beta_lqp = -1
- beta_hinge = -1
- betamultiplier = 1
- defaultprevalence = 0.5

RF options (datatype: binary, package: randomForest, function: randomForest) :

- type = "classification"
- ntree = 500 (default: NULL)
- strata = 0 1 Levels: 0 1 (default: NULL)
- nodesize = 5 (default: NULL)

8.3 **Appendix 3.** Opportunistic sightings of Indo-Pacific bottlenose dolphins across the Kwinana Shelf.

Opportunistic sightings were recorded during days dedicated to biopsy sampling (see the WAMSI Westport Marine Science Program project report: *Trophic Ecology of Indo-Pacific Bottlenose Dolphins (Tursiops aduncus) in Owen Anchorage and Cockburn Sound Inferred by Stable Isotopes,* Chabanne (2024)) and during transit, totalling an additional 78 groups across the Kwinana Shelf (**Figure 16**).

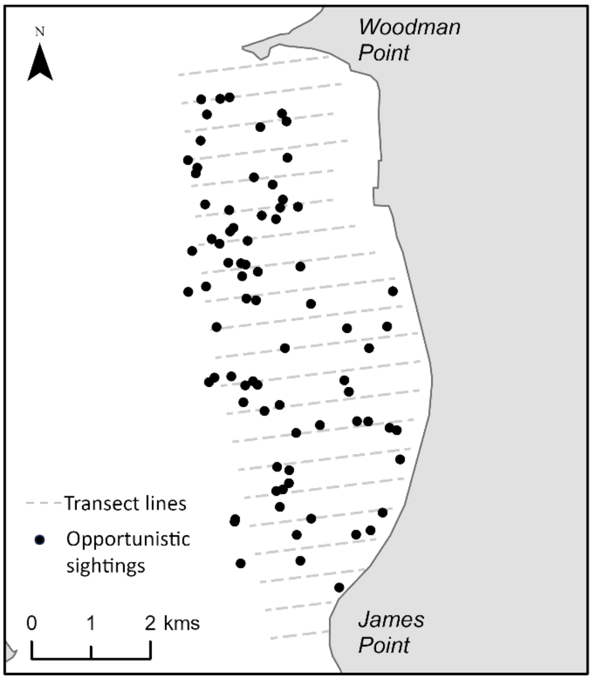

Figure 16. Opportunistic group sightings (n = 78) of Indo-Pacific bottlenose dolphins across the Kwinana Shelf recorded between January 2022 and November 2023. *Locations: Alcoa – Alcoa Kwinana Refinery; PSDP – Water Corporation Perth Seawater Desalination Plant.*

8.4 **Appendix 4.** Fishing line entanglements.

During the study period, at least three calves were observed with fishing line entanglement (**Figure 17**). Two of these calves were observed during the surveys and one was reported directly by members of the public to the Department of Biodiversity, Conservation and Attractions (DBCA) and confirmed to be a different, though not identified, calf from those previously reported. One of the calves was initially observed with a line around its body in February 2022, the second was reported in November 2022 (as depicted in **Figure 17**, which illustrates the entanglement on the calves). In July 2023, DBCA responded to a distressed mother with her calf, the latter entangled in fishing gear. However, the calf could not be identified, and no follow-up could be made.

Figure 17. Photos of two six-month-old calves with fishing gear entanglement. Calf reported in February 2022: A) February 2022; B) April 2022 (line underneath the skin); C) and D) August 2022 (post entanglement around the body but still present at the pectoral). Calf reported in November 2022: E) November 2022; F and G) July 2023 (post entanglement).

8.5 **Appendix 5.** Statistical summary of SDMs of dolphins across the Kwinana Shelf over the entire study period.

Among all the single algorithms, 21 passed the performance evaluation criteria (ROC ≥ 0.7 and TSS ≥ 0.4), with three algorithms (Flexible discriminant analysis (FDA), generalised additive model (GAM) and generalised linear model (GLM)) being excluded from the selection. Water depth was identified as one of the most influential variables by all algorithms (**Table 4**). While distance to coastline was second best with a MAXENT approach, slope and chla were considered important in other algorithms. In all, but MAXENT, substrate type was the least influential variables (**Table 4**).

Table 4. Importance of the predictor variables used in the SDMs of Indo-Pacific bottlenose dolphins across Kwinana Shelf for the overall study period (years pooled and excluded travelling behaviour). Retained SDMs algorithms after performance selection were classification tree analysis (CTA); generalised boosted model (GBM); multivariate adaptive regression splines (MARS); maximum entropy (MAXENT) and random forest (RF). Variable importance is presented as the mean value over the well performed runs conducted for each algorithm (i.e. runs meeting the ROC ≥0.7 and TSS ≥0.4 thresholds). The number of runs of each algorithm that was included in the ensemble is indicated in subscript. Variables of greatest influence are highlighted in bold.

Algorithms	Explanatory variables				
	Water depth	Distance to coastline	Slope	Substrate type	chla
CTA_5	**0.70**	0.24	0.32	0.16	**0.50**
GBM_4	**0.70**	0.11	**0.17**	0.06	**0.18**
$MARS_2$	**0.63**	0.17	0.23	0.05	**0.35**
$MAXENT_2$	**0.78**	**0.39**	0.16	0.24	0.29
RF_8	**0.45**	0.18	**0.22**	0.14	**0.21**
Ensemble	**0.80**	**0.18**	0.09	0.05	0.09

8.6 **Appendix 6.** Statistical summary of the seasonal SDMs of Indo-Pacific bottlenose dolphins across the Kwinana Shelf using on-effort sightings (excluding groups initially observed travelling)

Summer

Among all the single algorithms run with the summer dataset (presence cells = 17), 151 passed the performance evaluation criteria (ROC ≥ 0.7 and TSS ≥ 0.4), with all eight algorithms being retained. Water visibility, salinity, pH, and fishing were identified as one of the most influential variables in at least four algorithms. Noise, in comparison, was the least influential variable (**Table 5**).

Autumn

Among all the single algorithms run with the autumn dataset (presence cells = 19), 21 passed the performance evaluation criteria (ROC ≥ 0.7 and TSS ≥ 0.4), with two algorithms (generalised boosted model (GBM) and generalised linear model (GLM)) being excluded from the selection. SST and O_2 saturation were identified as the most important variables by the majority of the algorithms and were highlighted in the ensemble model (**Table 5**).

Winter

Among all the single algorithms run with the winter dataset (presence cells = 34), 18 passed the performance evaluation criteria (ROC ≥ 0.7 and TSS ≥ 0.4), with three algorithms (Flexible discriminant analysis (FDA) and generalised additive model (GAM) and multivariate adaptive regression splines (MARS)) being excluded from the selection. All algorithms with well-performed models identified salinity as the most influential variable. However, inconsistency between algorithms for the second most influential variable occurred (**Table 5**).

Spring

Among all the single algorithms run with spring dataset (presence cells = 42), 15 passed the performance evaluation criteria (ROC ≥ 0.7 and TSS ≥ 0.4), with two algorithms (Flexible discriminant analysis (FDA) and generalised additive model (GAM)) being excluded from the selection. Most of the algorithms detected O_2 saturation and SST as important variables, although conductivity and fishing were also identified by GLM and MAXENT models, respectively (**Table 5**).

Table 5. Importance of the predictor variables used in the seasonal SDMs of Indo-Pacific bottlenose dolphins across Kwinana Shelf (2022-2023 years pooled by season and excluded travelling behaviour) and based on the well performed single models (i.e. runs meeting the ROC ≥0.7 and TSS ≥0.4 thresholds). SDMs algorithms were classification tree analysis (CTA); flexible discriminant analysis (FDA); generalised additive model (GAM); generalised boosted model (GBM); generalised linear model (GLM), multivariate adaptive regression splines (MARS); maximum entropy (MAXENT) and random forest (RF). Variable importance is presented as the mean value over the well-performed runs for each algorithm (among 10 runs per algorithms and for 10 datasets of randomly selected pseudo-absence cells). The number of runs of each algorithm included in the ensemble model is indicated in subscript. Variables of greatest influence are highlighted in bold.

Season	Algorithms	Explanatory variables							
		SST	Visibility	Salinity	pH	Conductivity	O2 saturation	Noise	Fishing
Summer	CTA_{18}		**0.55**	0.22	**0.23**			0.06	0.19
	FDA_{7}		**0.46**	0.09	0.00			0.00	**0.60**
	GAM_{14}		0.10	**0.45**	0.08			0.12	**0.22**
	GBM_{25}		**0.21**	0.19	**0.23**			0.16	0.02
	GLM_{22}		0.11	**0.46**	**0.25**			0.19	0.16
	$MARS_{11}$		0.25	**0.33**	0.12			0.13	**0.27**
	$MAXENT_{16}$		0.12	**0.43**	0.01			0.14	**0.31**
	RF_{38}		**0.22**	0.11	**0.22**			0.11	**0.15**
	Ensemble		0.10	**0.33**	0.12			0.09	**0.17**
Autumn	CTA_{1}	0.00	**0.47**	0.00	0.00		**0.86**	0.00	0.00
	FDA_{2}	**0.52**	0.00	0.08	0.00		**0.64**	0.00	0.00
	GLM_{9}	0.38	0.05	**0.45**	0.14		**0.42**	0.19	0.05
	$MARS_{2}$	**0.34**	0.06	0.14	0.00		**0.62**	0.11	0.00
	$MAXENT_{2}$	**0.46**	**0.55**	0.26	0.09		0.22	0.14	0.16
	RF_{5}	**0.19**	0.05	0.06	0.06		**0.10**	**0.10**	0.07
	Ensemble	**0.42**	0.05	0.14	0.07		**0.32**	0.09	0.03

Table 5. *Ongoing*

Season	Algorithms	Explanatory variables							
		SST	Visibility	Salinity	pH	Conductivity	O2 saturation	Noise	Fishing
Winter	CTA[2]	0.23	0.12	**0.33**	0.00		**0.33**	**0.30**	0.09
	GBM[4]	0.10	**0.18**	**0.30**	0.01		0.16	0.10	0.03
	GLM[3]	0.23	0.05	**0.69**	0.18		0.15	0.15	**0.25**
	MAXENT[6]	**0.46**	**0.39**	**0.39**	0.27		0.33	0.32	0.21
	RF[3]	**0.11**	0.04	**0.11**	0.08		0.06	0.05	0.07
	Ensemble	0.12	0.04	**0.40**	0.04		0.03	0.08	**0.13**
Spring	CTA[1]	**0.50**	0.00		0.00	0.00	**0.47**	0.22	0.00
	GBM[2]	**0.22**	0.14		0.06	0.05	**0.31**	0.04	0.03
	GLM[3]	**0.31**	0.12		0.18	**0.32**	**0.32**	0.03	0.17
	MARS[3]	**0.25**	0.13		0.00	0.03	**0.49**	0.05	0.21
	MAXENT[1]	0.28	0.14		0.10	0.06	**0.58**	0.30	**0.49**
	RF[5]	**0.18**	0.06		0.05	0.07	**0.16**	0.08	0.10
	Ensemble	**0.29**	0.07		0.05	0.06	**0.42**	0.07	0.10

8.7 **Appendix 7**. Seasonal SDMs of Indo-Pacific bottlenose dolphins across the Kwinana Shelf with water depth and distance to the coastline included as potential explanatory variables

8.7.1 Statistical summary of the models

The selection of variables in seasonal ensemble modelling varied among seasons. For summer, preliminary correlation tests indicated a high correlation between O_2 saturation and salinity (r = -0.75). Consequently, O_2 saturation was excluded from the subsequent models. No variable had a mean rank of less than 5% after the first round of single models. Therefore, the ensemble model for summer included nine explanatory variables: water depth, distance to the coastline, SST, water visibility, salinity, conductivity, pH, noise, and fishing.

In autumn, a high correlation between conductivity and salinity (r = 0.75) was found. Additionally, the variable O_2 saturation had a VIF > 3. Consequently, conductivity and O_2 saturation were excluded from the subsequent models. There was no variable with a mean of the means rank less than 5% after the first round of single models. As a consequence, the ensemble modelling for autumn comprised eight explanatory variables: water depth, distance to the coastline, SST, water visibility, salinity, pH, noise, and fishing.

In winter, correlation tests indicated a high correlation between conductivity and salinity (r = 0.74) and prompted the removal of conductivity. There was no variable with a mean of the means rank less than 5% after the first round of single models. Hence, the ensemble model for winter included nine explanatory variables: water depth, distance to the coastline, SST, water visibility, salinity, pH, O_2 saturation, noise, and fishing.

Lastly, in spring, there was no correlation between variables, and no variable had a mean of the means ranking less than 5% after the first round of single models. Thus, the ensemble model for spring featured all available explanatory variables: water depth, distance to the coastline, SST, water visibility, salinity, conductivity, pH, O_2 saturation, noise, and fishing.

The evaluation of single seasonal SDM algorithms using ROC and TSS indicated that during the calibration, most single models performed better than random, with ROC means higher than 0.81 and TSS means higher than 0.57 (**Table 6**). However, the performances of the same models during validation were mixed. Performances were generally poor during the validation step, with ROC means ranging from 0.51 and 0.58 and TSS means ranging from 0.04 to 0.13 (**Table 6**).

After excluding the poorly performing single model runs considering both calibration and validation, the ensemble models for each season outperformed all respective single SDMs, with ROC means ranging from 0.91 for spring to 0.95 for summer, and TSS means ranging from 0.70 for spring to 0.87 for summer, indicating good model performances for all seasonal ensemble models (**Table 6**).

Table 6. Statistic summary of the predictive performance for seasonal SDMs run for Indo-Pacific bottlenose dolphins across the Kwinana Shelf, incorporating water depth and distance to coastline as potential explanatory variables. The evaluation metrics included the area under curve of the receiver operating characteristic (ROC) (a) and the true skill statistic (TSS) (b). The selection of pseudo-absence cells was repeated 10 times, using 10 datasets tested with eight algorithms, each repeated 10 times, resulting in a total of 800 single models).

(a)	ROC (Calibration step)			ROC (Validation step)			ROC (Ensemble)	
	Range	Mean	Median	Range	Mean	Median	Mean	Median
Summer	0.54-1	0.88	0.90	0.07-1	0.57	0.57	0.95	0.93
Autumn	0.55-1	0.81	0.79	0.12-0.86	0.51	0.51	0.93	0.91
Winter	0.54-1	0.88	0.89	0.05-1	0.58	0.59	0.93	0.92
Spring	0.54-1	0.82	0.81	0.22-0.93	0.55	0.55	0.91	0.90

(b)	TSS (Calibration step)			TSS (Validation step)			TSS (Ensemble)	
	Range	Mean	Median	Range	Mean	Median	Mean	Median
Summer	0.25-1	0.71	0.71	-0.80-1	0.11	0.13	0.87	0.84
Autumn	0.13-1	0.57	0.52	-0.71-0.66	0.04	0.02	0.75	0.80
Winter	0.20-1	0.72	0.73	-0.66-0.82	0.13	0.14	0.77	0.77
Spring	0.10-1	0.59	0.54	-0.44-0.92	0.09	0.09	0.70	0.69

8.7.2 Variable importance and response curves

All seasonal SDMs identified water depth as one of the most important variables influencing dolphin distribution across the Kwinana Shelf (**Figure 18** and **Table 7**). In summer, salinity emerged as the most influencing variable, as identified by the majority of the single model algorithms. Similarly, in winter, salinity was identified as the second most influential variable, as indicated by three algorithms across 38 single models. For spring, SST was recognised as the most influential variable, supported by nine single models (out of 17) across three algorithms (**Table 7**). In autumn, SST was also identified as the second most influential variable by the ensemble model; however, the well-performed single models exhibited inconsistency, with each algorithm highlighting a different variable: distance to the coastline for MAXENT; SST for CTA; water visibility or salinity for GBM and pH for RF (**Table 7**).

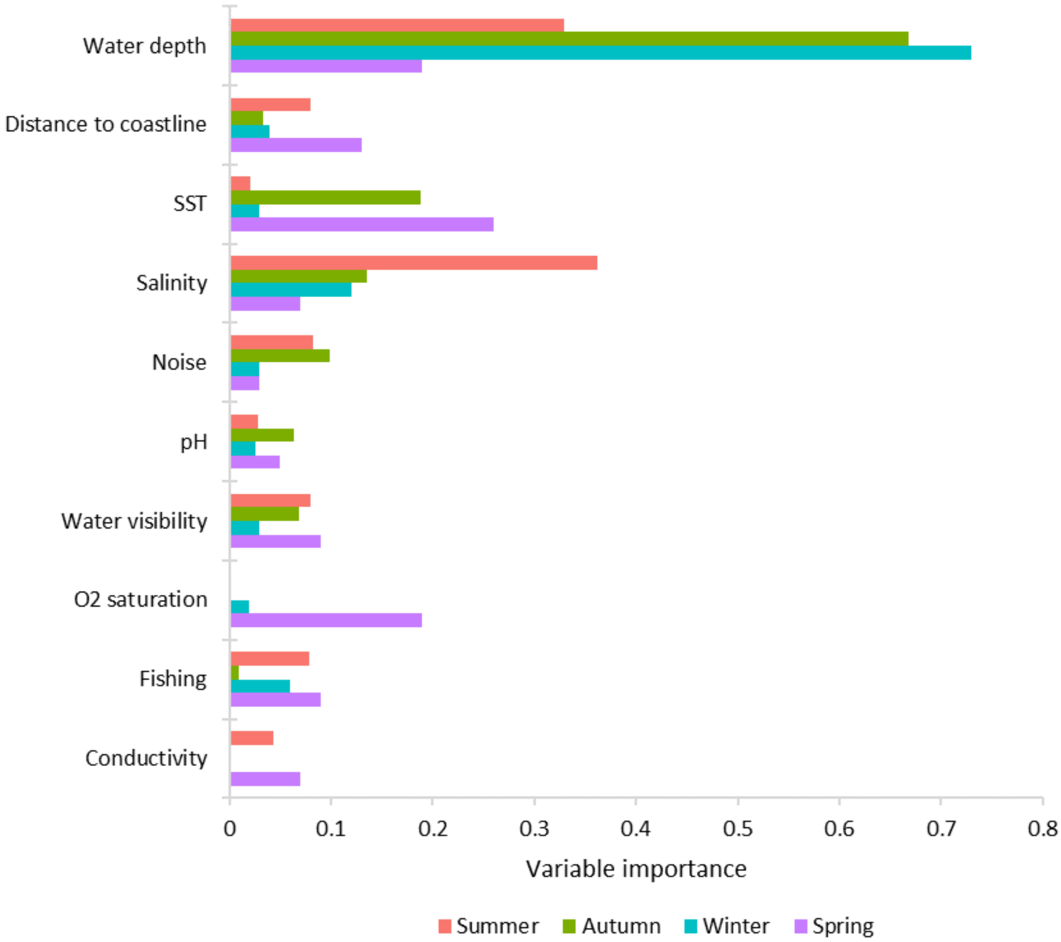

Figure 18. Importance of the explanatory variables used in the ensemble SDMs of Indo-Pacific bottlenose dolphins sighted across the Kwinana Shelf for summer, autumn, winter, and spring (years pooled by season and excluded travelling behaviour) and including water depth and distance to the coastline as potential explanatory variables of the distribution of dolphins.

Table 7. Importance of the predictor variables used in the seasonal SDMs of Indo-Pacific bottlenose dolphins across Kwinana Shelf (2022-2023 years pooled by season and excluded travelling behaviour) and based on the well-performed single models (i.e. runs meeting the ROC ≥0.7 and TSS ≥0.4 thresholds). SDMs algorithms were classification tree analysis (CTA); flexible discriminant analysis (FDA); generalised additive model (GAM); generalised boosted model (GBM); generalised linear model (GLM), multivariate adaptive regression splines (MARS); maximum entropy (MAXENT) and random forest (RF). Variable importance is presented as the mean value over the well-performed runs for each algorithm (among 10 runs per algorithm and for 10 datasets of randomly selected pseudo-absence cells). The number of runs of each algorithm included in the ensemble model is indicated in subscript. Variables of greatest influence are highlighted in bold.

Seasons	Algorithms	Explanatory variables									
		Water depth	Distance to coastline	SST	Water visibility	Salinity	Conductivity	pH	O_2 saturation	Noise	Fishing
Summer	CTA^{6}	**0.26**	**0.29**	0.02	0.20	0.22	0.13	0.16		0.00	0.00
	FDA^{9}	0.34	0.05	0.00	**0.36**	0.04	0.04	0.02		0.00	**0.39**
	GAM^{12}	**0.21**	0.18	0.04	0.09	**0.55**	0.16	0.06		0.10	0.16
	GBM^{14}	**0.32**	0.13	0.05	0.08	0.13	0.06	**0.16**		0.04	0.00
	GLM^{21}	**0.45**	0.27	0.23	0.35	**0.55**	0.26	0.10		0.20	0.16
	MARS^{14}	**0.48**	0.20	0.07	0.27	**0.41**	0.18	0.00		0.15	0.04
	MAXENT^{9}	**0.46**	0.05	0.02	0.02	**0.33**	0.01	0.02		0.18	0.14
	RF^{15}	**0.07**	0.05	0.03	**0.07**	0.05	0.04	0.06		0.04	0.05
	Ensemble	**0.33**	0.08	0.02	0.08	**0.36**	0.04	0.03		0.08	0.08
Autumn	CTA^{4}	**0.53**	0.16	**0.32**	0.28	0.27		0.14		0.07	0.00
	GBM^{1}	0.12	0.03	0.19	**0.38**	**0.45**		0.00		0.00	0.00
	MAXENT^{3}	**0.43**	**0.40**	0.39	0.23	0.29		0.19		0.30	0.16
	RF^{1}	**0.09**	0.05	0.12	0.02	0.04		**0.08**		0.04	0.04
	Ensemble	**0.67**	0.03	**0.19**	0.07	0.14		0.06		0.10	0.01

Table 7. *Ongoing*

Seasons	Algorithms	Explanatory variables									
		Water depth	Distance to coastline	SST	Water visibility	Salinity	Conductivity	pH	Saturation in O_2	Noise	Fishing
Winter	CTA[12]	**0.81**	0.05	0.03	0.17	**0.24**		0.00	0.02	0.00	0.00
	FDA[10]	**0.76**	0.00	**0.12**	0.00	0.10		0.00	0.04	0.00	0.02
	GAM[12]	**0.57**	**0.21**	0.11	0.21	0.05		0.12	0.14	0.11	0.17
	GBM[13]	**0.64**	0.03	0.02	0.07	**0.13**		0.05	0.04	0.04	0.01
	GLM[10]	**0.48**	**0.37**	0.35	0.22	0.50		0.28	0.27	0.19	0.28
	MARS[8]	**0.75**	0.00	0.08	0.00	0.08		0.00	0.10	0.08	**0.16**
	MAXENT[14]	**0.46**	0.29	0.37	0.11	0.42		0.27	**0.39**	0.31	0.25
	RF[13]	**0.17**	0.04	0.05	0.03	**0.06**		0.03	0.03	0.04	0.03
	Ensemble	**0.73**	0.04	0.03	0.03	**0.12**		0.03	0.02	0.03	0.06
Spring	GBM[4]	**0.21**	0.13	0.13	0.08	0.11	0.01	0.00	**0.14**	0.03	0.02
	GLM[4]	0.28	**0.42**	0.23	0.27	0.15	0.27	**0.32**	0.17	0.05	0.20
	MARS[1]	0.00	**0.46**	**0.42**	0.00	0.00	0.00	0.00	0.00	0.00	0.22
	MAXENT[3]	0.32	0.27	**0.43**	0.19	0.22	0.08	0.23	**0.46**	0.23	0.30
	RF[5]	0.06	0.03	**0.08**	0.02	0.03	0.03	0.02	**0.07**	0.03	0.04
	Ensemble	**0.19**	0.13	**0.26**	0.09	0.07	0.07	0.05	**0.19**	0.03	0.09

The response curves generated by the ensemble models, with water depth and distance to the coastline added as explanatory variables (**Figure 19**), revealed that dolphin occurrence was consistently greater in water depths less than 10 m across all seasons. The second most influential variable explaining their distribution was equivalent to SDMs excluding water depth and distance to the coastline, with higher SST values in autumn (> 20°C) or following a bimodal distribution in spring, where dolphins were more prevalent at SST around 18°C or greater than 19.5°C. In spring, higher probabilities of dolphin occurrence were identified in the highest O_2 saturation condition (> 103.5%) available. In summer and winter, areas with the highest salinity values (> 36.30 ppt and > 35.260 ppt, respectively) correlated with a higher probability of dolphin occurrence (**Figure 19**).

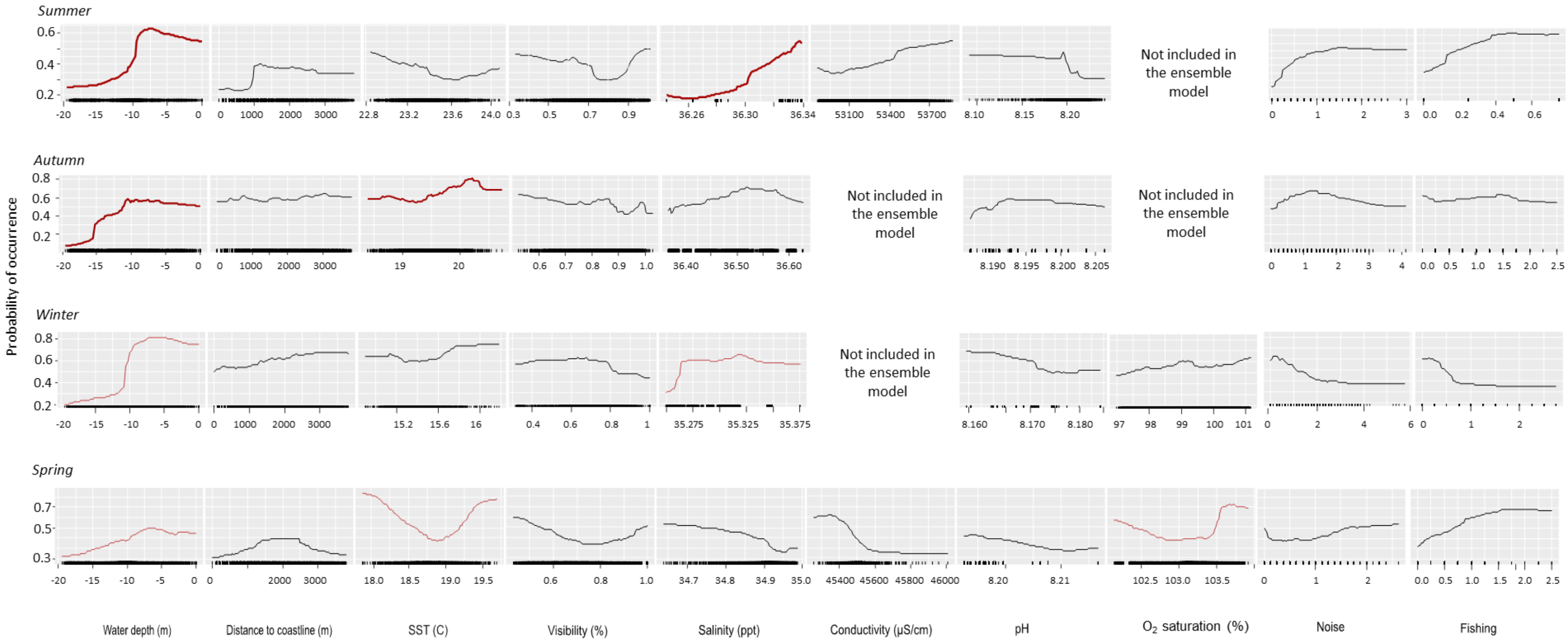

Figure 19. Response curves of the presence of dolphins in relation to the explanatory variables obtained for the ensemble SDMs run for each seasonal distribution mapping of Indo-Pacific bottlenose dolphins across the Kwinana Shelf, with the inclusion of water depth and distance to coastline as potential explanatory variables of the distribution of dolphins.

8.7.3 Distribution and maps

Across seasons, the ensemble models exhibited a high probability of dolphin occurrence near Pinnacle Rock and its surrounding areas, as well as close to James Point during spring. In winter, the distribution of probabilities of occurrence reflected the inclusion of water depth as an explanatory variable, with areas previously identified with high occurrence along the channels now showing the lowest probabilities. However, high probabilities were still identified near the coast between Alcoa Kwinana Refinery and James Point, including around the desalination brine. While areas of very high probabilities of occurrence were not as obvious in autumn when adding water depth as an explanatory variable, the overall distribution of high probabilities of occurrence was similar to that predicted by the model without water depth, notably a higher occurrence in the northern section of the shelf and scattered locations surrounding Pinnacle Rock and area of the desalination brine.

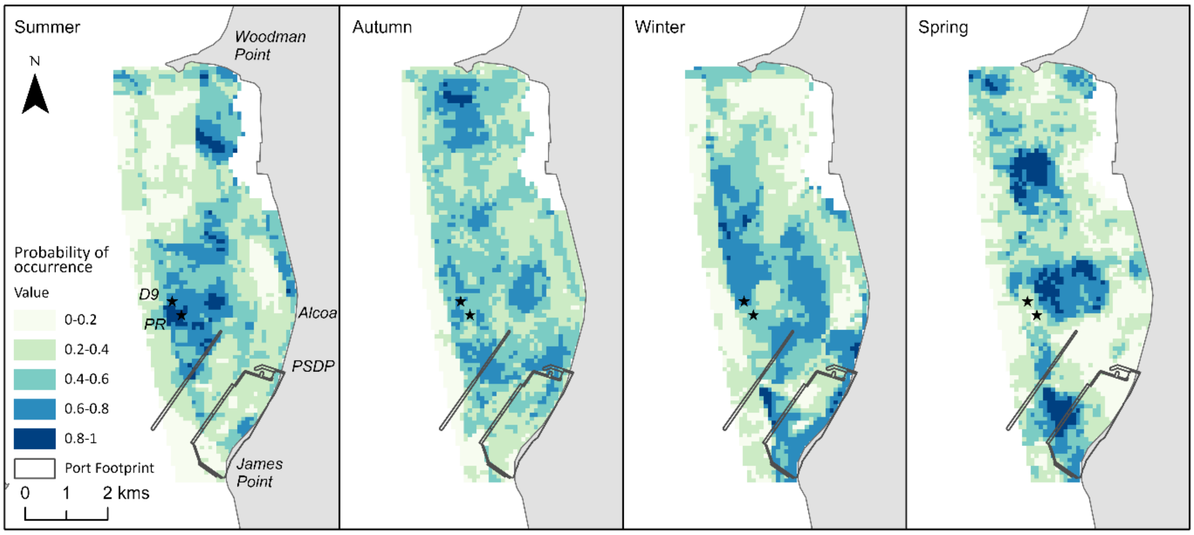

Figure 20. Seasonal ensemble models of Indo-Pacific bottlenose dolphin probability of occurrence across the Kwinana Shelf (years pooled by season and excluded travelling behaviour). Colours as shown in the legend indicate the probability of occurrence of dolphins: very low (0-0.2); low (0.2-0.4); moderate (0.4-0.6); high (0.6-0.8); very high (0.8-1). SDMs were run with the inclusion of water depth and distance to the coastline among the explanatory variables. *Locations: Alcoa – Alcoa Kwinana Refinery; D9 – D9 Wreck; PR – Pinnacle Rock; PSDP – Water Corporation Perth Seawater Desalination Plant.*

Submitted as draft	27/5/2024
Review completed	26/7/2024
Submitted as revised draft	24/8/2024
Approved by Science Program Leadership Team	10/10/2024
Approved by WAMSI CEO	25/10/2024
Final report	29/10/2024

WESTERN AUSTRALIAN
MARINE SCIENCE
INSTITUTION