Approaches for surveying bottlenose dolphin (*Tursiops truncatus*) behaviour in Cardigan Bay

Abigail Louise Parker

Figure 1: A bottlenose dolphin (*Tursiops truncatus*) group surfacing off the coast of New Quay, Wales.

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Field supervisor: Katrin Lohrengel

PRIFYSGOL BANGOR UNIVERSITY

sea watch FOUNDATION

Declaration

This work has not previously been accepted in substance for any degree and is not being currently submitted for any degree.

This dissertation is being submitted in partial fulfilment of the requirement for the degree of Master of Science in Marine Biology.

The dissertation is the result of my own independent work and investigation, except where otherwise stated.

Other sources are acknowledged by footnotes giving explicit references and a bibliography is appended.

I hereby give consent for my dissertation, if accepted, to be made available for photocopying and for inter-library loan, and the title and summary to be made available to outside organisations.

Signed:

Date: 21/09/17

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All photographs used in this study are credited to the appropriate contributor. Photographs taken during the course of this study on board vessels are marked as/Sea Watch Foundation, and /Sea Watch Foundation[ID] for those taken under the Natural Resources Wales photo-identification licence following appropriate protocols.

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Abstract

Approaches for surveying bottlenose dolphin (*Tursiops truncatus*) behaviour in Cardigan Bay

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The bottlenose dolphin (*Tursiops truncatus*) is a profoundly social and intelligent cetacean species present around UK waters, and displays a wide range of complex behaviours to travel, feed and interact with conspecifics. Special Areas of Conservation (SACs) have been implemented for their protection, and in order to monitor the use and thus continued effectiveness of these SACs, a range of surveying methodologies have been utilised, including land-based and boat-based surveys, both with advantages and disadvantages to their approaches. The purpose of this study was to observe, record and photograph differences in behaviour, pod dynamics and social structure across the surveying methods, in addition to reviewing potential new surveying techniques, such as the use of drone technology. A total of 177.93 hours of surveys (N=105) were undertaken during the study period from 7th June – 15th August, which included 99.26 hours of land-based data and 78.67 hours of boat-based data. A wide diversity of behaviours were photographed and recorded, including courtship, mother and calf associations and interactions with barrel jellyfish (*Rhizostoma pulmo*). Suspected Feeding was the most prevalent behaviour, and had a significantly higher frequency of occurrence on land-based surveys ($p < 0.05$), suggesting New Quay is a prime feeding hotspot for bottlenose dolphins, confirming the importance of the SAC. Pod sizes ranged from one to seven, with a 'fission-fusion' society occurring amongst groups. A significant negative correlation was found between sea state and average number of dolphins from boat-based surveys. Both land-based and boat-based surveys have their merits, be it minimal disturbance and longer observation time from land, but interesting behaviours such as bow-riding, and greater opportunity for photography from vessels. Due to logistical constraints, drone surveys were not undertaken, however photography from a clifftop perspective offered an insight into the potential use of drones for surveying cetaceans, for further study.

Contents

Declaration……………………………………………………………………………….. ii

Acknowledgements………………………………………………………………………. iii

Abstract………………………………………………………………......................... iv

List of figures……………………………………………………………………………viii

List of tables…………………………………………………………………………...xiv

List of abbreviations……………………………………………………………………...xv

1. Introduction……………………………………………………………………….. 1

1.1 The bottlenose dolphin (*Tursiops truncatus*)……………………………………………….1

1.1.1 Bottlenose dolphin biology & distribution…………………………………………....1

1.1.2 Bottlenose dolphin cognitive ability & behavioural capabilities……………………3

1.1.3 Main behaviours: socialising & feeding………………………………………..3

1.1.4 Main behaviours: defensive & anti-predatory responses………………...…5

1.2 The need for conservation and Marine Protected Areas (MPAs)…………………........5

1.3 Current methodologies for surveying dolphin behaviour………………………………7

1.3.1 Land-based surveying……………………………………………………………...8

1.3.2 Boat-based surveying………………………………………………………...9

1.3.3 Photography……………………………………………………………..10

1.3.4 The introduction of unmanned aerial vehicles…………………….………11

1.3.5 The Sea Watch Foundation & Cardigan Bay bottlenose population……12

1.4 Study aims & hypotheses……………………………………………………………..14

2. Methodology………………………………………………………………………………15

2.1 The primary study site – New Quay, Ceredigion……………………………………...15

2.1.1 Geology & species richness……………………………………………………….16

2.1.2 Vessel activity & tourism…………………………………………………………17

2.2 Survey approaches………………………………………………………………………18

2.2.1 Land watches – New Quay Pier……………………………………………………..20

2.2.2 Cliff watches – New Quay Head…………………………………….............21

2.2.3 Cliff watches – Aberystwyth…………………………………….............21

2.2.4 Casual sightings……………………………………………………..........22

2.2.5 Boat surveys – Ermol VI……………………………………….........23

2.2.6 Dedicated surveys – Dunbar Castle II & Machipe…………………24
2.3 Effort & sightings data……………………………………...……………………28
2.3.1 Land watches……………………………………..…………………………..29
2.3.2 Boat surveys – Ermol VI, Dunbar & Machipe…………………………………...30
2.4 Behavioural data, sightings & sets………………………………………..................31
2.5 Photographing bottlenose dolphins……………………………………….................37
2.5.1 Technical details for cetacean photography………………………………………..37
2.6 Constraints and logistical issues to be overcome……………………………………...38
2.6.1 Trialling the survey methodologies……………………………………............38
2.6.2 Effort data & boat encounters……………………………………….................38
2.6.3 Weather & abandoned surveys………………………………………........39
2.6.4 Drone surveys……………………………………..............................39
2.7 Data analysis & visualisation………………………………………..........................39
2.7.1 Software for analysis…………………………………….................................39
2.7.2 Temporal trends & Sighting Per Unit Effort (SPUE) …………………………...40
2.7.3 Outliers, poor weather & abandoned land watch data……………………40
2.7.4 Environmental data……………………………………….................40
2.7.5 Behavioural data……………………………………….................41
2.7.6 Dive times…...………………………...………………………41
2.7.7 Average total number of individuals per sighting…………….42
3. Results……………………………......……………………………………..................43
3.1 Survey intensity & bottlenose dolphin presence……………………………………......43
3.1.1 Bottlenose dolphin sightings, temporal change & Sighting Per Unit Effort (SPUE).49
3.1.2 Bottlenose dolphin usage of the Cardigan Bay SAC……………………………50
3.2 Environmental factors (effort data) & probability of detection……………………..52
3.3 Bottlenose dolphin behaviour…………………………………......……………………53
3.3.1 Behaviour types & surveying methods………………………………...................53
3.3.2 Temporal changes in behaviour - land & cliff watches…………………………54
3.3.3 Temporal changes in behaviour – Ermol VI, Dunbar & Machipe…………...56
3.3.4 Comparison of behaviour between methodologies………………………..58

3.3.5 Interactions with other species & unique behaviours…………………….59
3.3.6 Specific responses to vessels………………………………………...62
3.3.7 Dive time across the survey methodologies……………………..65
3.4 Social structure & pod dynamics…………………......……………………………..66
3.4.1 Who's in a pod?…………………......……………………......……………..66
3.5 Photo-ID & inter-individual associations…………………......……………………….69
3.5.1 Standing out: A focus on 'Ghost' & 'Riptide'…………………......………………..69
3.6 An aerial view & the power of photography…………………......……………………72
4. Discussion…………………......……………………......…………………….....76
4.1 Bottlenose behaviour & social structure…………………......………………………..76
4.1.1 Bottlenose behaviours in Cardigan Bay – a focus on feeding………………........76
4.1.2 Other behaviours and pod associations…………………......…………………...79
4.2 Surveying methodologies: a comparison…………………......………………………..80
4.3 Study limitations & future recommendations…………………......…………….....81
4.4 Conclusion…………………......…………………..………………......……………...82
5. References…………………......……………………......……………………...83

Appendix I: The Beaufort wind scale, used to classify sea state in this study. Taken & adapted from Met Office, 2016.…………………......………………………………………89

Appendix II: Examples of *Tursiops truncatus* behaviours photographed from land and boat-based surveys.…………………......……………………......………………………..90

Appendix III: The bottlenose dolphin diet: fish species observed being consumed by the bottlenose dolphin in Welsh waters (Evans, Pers. comms., 2017). Each species is given with their common and Latin name; for fish not specified to species level, the family name is given. * This species is pelagic in the first 2-3 months. …………………......………………93

Appendix VI: Behavioural data forms utilised in this study for land-based surveys and boat-based surveys. …………………......……………………......………………………..94

Appendix V: The following is a list of condensed codes utilised for statistical analysis with the R Software. …………………......……………………......………………………97

List of figures

Figure 1: A bottlenose dolphin (*Tursiops truncatus*) group surfacing off the coast of New Quay, Wales…………………………………………………………………....Cover

Figure 2: The distribution of the bottlenose dolphin around the UK, in relation to effort (hours) and depth; sightings are associated with the continental shelf edge. Red circles indicate the two primary populations of bottlenose dolphins in the UK, East Scotland & Cardigan Bay. Taken & adapted from Reid *et al*., 2003..…………………......……….2

Figure 3: A bottlenose dolphin showing percussive behaviours in pursuit of an Atlantic salmon (*Salmo salar*) in New Quay, Ceredigion..……………......…………………......……...5

Figure 4: The location of the Pen Llŷn a'r Sarnau SAC and Cardigan Bay SAC in Wales, both implemented in 2004, with the latter designated primarily for protection of bottlenose dolphins. Taken and adapted from: Pesante *et al*., 2008. As one of the largest bays in the UK, Cardigan Bay is ~100km in length from the Llyn Peninsula down to St David's (Countryside Council for Wales, 2009).……………......…………………......……….7

Figure 5: Bottlenose dolphin fins show a great degree of variation, with several features, such as tooth rake marks & notches, caused by interactions with other dolphins, and discolouration, all of which can be used for photo-ID of an individual. Cropped photograph taken on board *Ermol VI* on 19th June. ……………......…………………...9

Figure 6: Comparison of bottlenose dolphin photographs with the dorsal fins visible, taken from **a)** land on the seafront, **b)** land from a clifftop vantage point, **c)** a wildlife-watching vessel, the *Ermol VI*, and **d)** a dedicated line transect survey for bottlenose dolphins on the *Dunbar Castle II*. All photographs are uncropped for comparison and all are slightly marked individuals to demonstrate a fair comparison of photography quality and resolution. Note how similar quality dorsal fin photographs can be obtained from casual wildlife-watching vessels in addition to dedicated surveys. Land surveys offer a good platform for cetacean surveying, however the images may not be of sufficient quality unless the individual is in very close proximity to land…………….10

Figure 7: The seasonal movements of bottlenose dolphins between the two Welsh SACs and around Anglesey, North Wales. Each coloured dot represents a specific individual. Taken from Norrman *et al*., 2015.……………......…………………......……………11

Figure 8: Bottlenose dolphin counts per 10km around Wales, UK, for 1990-2009. Notice the large 'hotspot' around within Cardigan Bay. Taken from Baines & Evans, 2012…….13

Figure 9: Temporal changes in the abundance estimates of bottlenose dolphins in the Cardigan Bay SAC. Total refers to total number of individuals. Dashed lines are 95% confidence intervals. Taken from ICES Advice, 2016..……………......……………….….......…13

Figure 10: New Quay main town & Harbour beach at low tide, photographed from the Quay West Caravan Park on a grey evening in May.……………......………………………15

Figure 11: New Quay main pier photographed from Traethgwyn beach during a clear sunset in June. ……………......…………………......…………………......………………...16

Figure 12: The diversity of marine species seen around Cardigan Bay, in addition to *Tursiops truncatus*. **a)** An Atlantic grey seal surfacing at Cardigan Island (52.129603, -4.684917); **b)** a harbour porpoise feeding amongst Manx shearwaters during a line transect survey in thick fog (52.125239, -4.806281); **c)** the breeding seabird colony seen from the *Ermol VI* (52.217356, -4.373061), arrows indicate the three bird species nesting here, including kittiwakes (*Rissa tridactyla*), razorbills (*Alca torda*) and guillemots (*Uria aalge*), some with chicks, such as the guillemot chick indicated by the blue arrow……………......…………………......…………………......……………..17

Figure 13: Surveying locations in **a)** New Quay and **b)** Aberystwyth, Ceredigion, for land & boat-based surveys, along with key landmarks.……………......……………………..19

Figure 14: New Quay main pier on a quiet evening, from which myself and Sea Watch interns would sit to survey for bottlenose dolphins.……………......…………………………20

Figure 15: The sea view from the surveying location at the top of New Quay Head in favourable weather conditions with >10km visibility. In these conditions Aberystwyth can be seen, as indicated by the white arrow……………......…………………......….21

Figure 16: Aberystwyth town, seafront & pier seen from the surveying location on the coastal path to Constitution Hill at the end of June, with sea state 5 observed on this day…....22

Figure 17: Left: Myself & Stephanie Byford sitting on the roof of the *Ermol VI* of *Dolphin Spotting Boat Trips,* on its return to New Quay, to acquire boat-based data on marine mammals in Cardigan Bay; right: leaving the harbour to record data from the roof of the wheelhouse on a clear, sunny surveying day……………......…………………….....23

Figure 18: A Google Earth satellite map of typical *Ermol VI* boat tracks, including a day of shorter bay trips when sea state was poor (22/06/2017; total 17.2km covered), a day of full hour trips, but not all the way to Cwm Tydu due to time restraints after spending time encountering bottlenose dolphins (20/06/2017; total 28.4km covered), and full hour trips all the way to Cwm Tydu, a small cove indicated by the red placemark (26/06/2017; total 28.3km covered). Key towns including New Quay, the departing location for the trips, are shown as red marker dots. Tracks were obtained using the GPS 'log' function on a Canon 7D Mark II camera model, technical details are given in 2.7 Data analysis & visualisation……………......…………………......…………..24

Figure 19: The *Dunbar Castle II* vessel seen from the *Ermol VI*, used to undertake LT and NLT surveys, operating out of New Quay. Arrows show the seating locations for the two independent observers at the back of the boat, and two primary observers on the bench above the wheelhouse……………......…………………......…………………25

Figure 20: **a)** A Google Earth satellite map of the two dedicated *Dunbar* LT and NLT surveys undertaken in June. Total length of the survey was 71.1km for the LT survey on 14/06/2017, and 25km for the NLT survey on 18/06/2017. **b)** The two dedicated *Dunbar* LT surveys undertaken in July. Total length of the survey was 103km for the LT survey on 05/07/2017, and 96.5km for the LT survey on 25/07/2017. Key towns including New Quay, the departing location for the surveys, are shown as red marker dots, and Cwm Tydu, the turning location for the *Ermol VI*, is indicated by the red placemark. Satellite image: © Google Earth, 2017……………......…………………….26

Figure 21: The transect lines undertaken with the Cardigan Bay SAC and Pen Llŷn a'r Sarnau SAC/offshore area on dedicated surveys by the Sea Watch Foundation. Taken from Lohrengel & Evans, 2017……………......……………………......……………………......27

Figure 22: Sitting at the stern of the *Machipe*, during a line transect survey in the Pen Llŷn a'r Sarnau SAC, while travelling to the next transect start point. Slightly different to the *Dunbar*, independent observers would sit at either side of the bow, or at the stern if there was too much spray, and primary observers above the wheelhouse…………….27

Figure 23: A Google Earth satellite map of the dedicated *Machipe* LT survey undertaken in July. Key towns including Aberystwyth, the departing location for the survey, are shown as red marker dots, and Harlech, the furthest point reached on the survey, is indicated by the red placemark. Satellite image: © Google Earth, 2017………………28

Figure 24: The photo-ID flag raised during bottlenose dolphin encounters to inform other boat users of our behaviour. The flag was *only* raised during photo-ID encounters outside the New Quay harbour, never within the confines of the harbour……………………..28

Figure 25: Aberarth and Aberaeron visible from the pier, indicating a visibility radius of at least 6-10km. The northerly Cardinal Mark is also outlined, which warns boat users of the Llanina Reef, used as a benchmark for making distance measurements…………..30

Figure 26: Photographic examples of different bottlenose dolphin life stages taken during the study period. **a)** A calf with prominent foetal folds, indicated by the white arrow, which are from when the calf was curled up inside the mother, indicating that this is a newborn calf; **b)** a potential juvenile surfacing, indicated by the absence of foetal folds, darker colouration, small body size and generally smooth, unmarked dorsal fin; **c)** a mother and calf pair, with the calf indicated by the white arrow. Adults are large in size and can have a range of dorsal fin markings and discolouration, in comparison to the smaller, unmarked calf. The calf in this photograph has lost its foetal folds, and hence is not classed as a newborn..……………......……………………......…………………..36

Figure 27: A visualisation of the different types of surveys undertaken, with the overall time spent recording data for that particular survey type in minutes/hours along with total number (N) of surveys.……………......……………………......…… ……………........44

Figure 28: An example of a casual sighting observed from the Quay West Caravan Park on 27th May at 21:54. The individual appears to be a lone dolphin engaging in Suspected Feeding amongst moored vessels. The time of day and large distance between the photographer and focal dolphin reduces the image quality; nevertheless, photographs provide an important documentation of dolphin activity within the bay. ……………..48

Figure 29: The surveying effort per month (hours), for each type of survey: land watches, cliff watches, *Ermol VI* boat surveys and dedicated LT/NLT boat surveys on the *Dunbar/Machipe*.……………......……………………......……………………......……..48

Figure 30: The Sighting Per Unit of Effort (SPUE) of focal bottlenose dolphin pods followed during land-based surveys and boat-based surveys, over the study period. Dates are shown every three days over the whole study period from 7th June to 15th August. Land data encompasses land watches (N=44) & cliff watches (N=8); boat data encompasses

Ermol VI surveys (N=43) & *Dunbar/Machipe* surveys (N=5). * Denotes a significant linear regression output, at $p < 0.05$. ……………......…………………......………….50

Figure 31: a) Locations of bottlenose dolphin sightings around Ceredigion seen from the Ermol VI and Dunbar. Colours denote the composition of each sighting, including all adults, a mixture of adults and juveniles, all juveniles, unknown life stage and groups with calves or newborns. **b)** A closer view of New Quay, where the greatest proportion of sightings were recorded. N=75 sightings recorded from boat-based surveys………51

Figure 32: The average total number of dolphins per sighting from land & boats, in relation to average sea state (rounded to nearest 0.5) of each survey. N=52 land-based surveys, N=48 for boat-based surveys. * Denotes a significant ANOVA output at $p < 0.05$…...52

Figure 33: A pie chart showing the proportion of each behaviour seen from a) land watches & cliff watches combined, N=845 behavioural observations, and b) *Ermol VI* & *Dunbar* surveys combined, N=249 behavioural observations. Socialising encompasses all social behaviour, along with Bow-Riding; active behaviours encompass Aerial Behaviour & Percussive Behaviour. Feeding behaviour is composed of Suspected Feeding as no Definite Feeding was observed during the favourable weather surveys………………53

Figure 34: a) The average frequency of Slow Swimming, Normal Swimming & Fast Swimming; **b)** Suspected Feeding, Resting/Milling & Socialising; **c)** Bow-Riding, Aerial Behaviour & Percussive Behaviour for each land-based survey undertaken. Average frequencies derived from 1025 five-minute intervals over the study period. * Denotes a significant linear regression output, at $p < 0.05$, along with trend lines for the behaviours which returned significant change over time. ……………......…………...56

Figure 35: a) The average frequency of Slow Swimming, Normal swimming & Fast Swimming; **b)** Suspected Feeding, Resting/Milling & Socialising; c) Bow-Riding, Aerial Behaviour & Percussive Behaviour for each boat-based survey undertaken. Average frequencies derived from 531 five-minute intervals over the study period. * Denotes a significant linear regression output, at $p < 0.05$, along with trend lines for the behaviours which returned significant change over time..……………......…………58

Figure 36: A photograph panel, in order from **a)** to **h)**, showing a series of direct play interactions between an inquisitive bottlenose dolphin and a barrel jellyfish, observed from New Quay Head on 18th June during a survey from approximately 13:19-13:56..60

Figure 37: A form of 'spy hopping' behaviour observed on board the *Ermol VI* on 10th July, which could potentially be a form of social behaviour..……………......……………..61

Figure 38: A rather large family group of five surfacing in the swell, seen from the *Ermol VI* on 10th July. Dolphins were frequently observed waiting in the swell for a wave to approach, which they could then swim with……………......…………………......…..61

Figure 39: Possible courtship behaviour between two individuals observed on 18th June from New Quay Head. One individual would repeated expose their white underside before surfacing in close proximity to the other dolphin. ……………......…………………...62

Figure 40: The total number of behavioural responses to vessels separated by surveying method; N=94 behavioural observations on the *Ermol VI*, N=72 on *Dunbar*…………63

Figure 41: Bottlenose dolphins in Cardigan Bay appear largely unfazed by the presence of vessels and high volume of boat traffic. Individual photographed on board the *Ermol VI* on 19th June. ……………......……………………......……………………......………..63

Figure 42: A photograph panel in order from **a)** to **h)**, showing bow-riding behaviour by an inquisitive individual who swam over to join the *Ermol VI* on 20th June, at 12:32. The red structure visible in a) is the bow of the *Ermol VI*..……………......………………64

Figure 43: The average dive time for mothers with calves and focal individuals, for each surveying method. For mothers & calves, N=10 dive times for land watches, N=5 for *Ermol VI* surveys & N=7 for *Dunbar* surveys. For focal individuals, N=45 dive times for land watches, N=10 for *Ermol VI* surveys & N=13 for *Dunbar* surveys. ±SE bars are shown for each bar. No significant differences were found between survey methods ($p > 0.05$) ……………......……………………......……………………......………………65

Figure 44: A sighting of a larger bottlenose dolphin pod composed of seven individuals surfacing in synchrony in a tight formation, seen from the *Ermol VI*. Arrows indicate the location of each individual; a barrel jellyfish (*Rhizostoma pulmo*) was also in association with the pod, as indicated by the white arrow……………......…………...66

Figure 45: The average total number of individuals per sighting, over the survey period. Each diamond represents one sighting. N=77 sightings from land-based surveys; N=75 from boat-based surveys……………......……………………......……………………......……..67

Figure 46: The total proportion (%) of sightings with adults, juveniles, calves, newborns and individuals for which life stage could not be determined, unknown, within the pod. Data is separated by survey type. N=77 sightings from land-based surveys; N=75 from boat-based surveys……………......……………………......……………………......…………..67

Figure 47: Examples of mother and calf pairs seen on board **a)** *Dunbar* on 18th June, and **b)** *Dunbar* also on 18th June. Mothers with calves often swim in tight association, sometimes with the calf slightly further back from the mother, known as echelon swimming (Noren *et al*., 2007) ……………......……………………......………………68

Figure 48: Temporal change in the total number of sets per survey, separated by land and boat-based surveys. N=135 sets recorded during land-based surveys; N=95 sets recorded during boat-based surveys……………......……………………......…………………....69

Figure 49: Photo-ID images of 'Ghost', showing her **a)** left side, with discolouration on the dorsal fin, and **b)** right side, with two distinctive white patches at the base of the dorsal fin. Taken on 19th June on board the *Ermol VI*……………......…………………........70

Figure 50: A comparison of dorsal fin photographs of 'Ghost'; **a)** & **b)** are from the 2011 photo-ID catalogue, and **c)** & **d)** were taken during the course of this study (2017). The remarkable differences between **b)** and **d)** of the right side of the fin show how marks can change greatly over time. **a)** & **b)** Taken from Feingold & Evans, 2012; **c)** & **d)** are © Abigail Parker/Sea Watch Foundation, taken on board the *Ermol VI* on 19th June…71

Figure 51: Photo-ID image of 'Riptide', showing his left side, with distinctive white colouration at the top of the dorsal fin. Taken on 19th June on board the *Ermol VI*……71

Figure 52: A comparison of dorsal fin photographs of 'Riptide'; **a)** is from the 2011 photo-ID catalogue, and **b)** was taken during the course of this study. As with 'Ghost', these photographs illustrate how markings can change slightly over time. **a)** Taken from Feingold & Evans, 2012; **b)** is © Abigail Parker/Sea Watch Foundation, taken on board the *Ermol VI* on 19th June……………......……………………......……………………..72

Figure 53: 'Riptide' seen from the pier, indicated by the white arrow, demonstrating that photo-ID can be undertaken from land for individuals which can be identified by eye. Taken on 4th June……………......……………………......……………………......………72

Figure 54: A single bottlenose dolphin broke off from the pair to approach the wildlife-watching vessel, *Anna Lloyd,* during the clifftop survey on 18th June………………...74

Figure 55: A photograph panel from **a)** to **d)** showing an interaction between a bottlenose dolphin and a barrel jellyfish. It appears as though the individual may have attempted to 'kick' the jellyfish, possibly as a form of play, but was unsuccessful. Photographed during the clifftop survey from New Quay Head on 18th June………………………74

Figure 56: A bottlenose dolphin performing a breach, a form of Percussive Behaviour, in close proximity to another dolphin. Observed from New Quay Head on 18th June…………75

Figure 57: A bottlenose dolphin pair, engaging in what was originally thought to be exclusively social/sexual behaviour, but upon confirmation with photography, one individual was actually in pursuit of a fish at one point during the sighting. The fish was not seen in the sequential photograph, so successful capture of the prey was assumed. Photograph taken from a cliff watch on 18th June at New Quay Head………75

Figure 58: A still image taken from the *Phantom 2 Vision+* drone footage, utilised for a short trial survey at Bull Bay, on 10th May, 2017. Footage credit to: David Roberts, the licensed drone operator & Ocean Sciences Technician, Bangor University…………76

Figure 59: The diverse prey species consumed by the bottlenose dolphin in Welsh waters. a) European eel; b) garfish; c) sea bass; d) sand eel; e) Atlantic salmon; f) smooth-hound shark……………......……………………......……………………......……………………...78

List of tables

Table 1: The ten different behaviours classified in the study, with a short description of their classification features, along with an Unknown category for those that could not be attributed to any of the behavioural categories……………....…………………........32

Table 2: The five categories used to classify group form in the study, along with a description of their key characteristics……………......…………………......…………………....34

Table 3: Details of casual sightings noted during the study period, including location of sighting, date & time, best estimate of the maximum number of individuals and any details of behaviour. Locations for which coordinates were obtained are included in brackets beneath the survey location. * Denotes a sighting which was originally supposed to be a survey, but turned into a casual sighting as the survey could only be done for 30 minutes instead of the original hour due to time constraints. ^ Denotes a sighting for which location, date and time could not be identified when compiling the dataset……………......…………………......…………………......…………………45

Table 4: Details of the abandoned land watches (N=4), including date, time spent recording before being abandoned, and reasoning behind cancelling the land watch……………49

List of abbreviations

SAC: Special Area of Conservation

MPA: Marine Protected Area

PCB: Polychlorinated Biphenyl

Behaviours

SS: Slow Swimming

NS: Normal Swimming

FS: Fast Swimming

FF: Definite Feeding

SF: Suspected Feeding

R: Resting

S: Socialising

B: Bow-Riding

AB: Aerial Behaviour

PB: Percussive Behaviour

Surveying methodologies

Dunbar**:** *Dunbar Castle II* surveying vessel

NLT: Non-Line Transect survey

LT: Line Transect survey

GPS: Global Positioning System

Photo-ID: Photo-Identification

UAV: Unmanned Aerial Vehicle

Statistics

SPUE: Sighting Per Unit Effort

ANOVA: one-way Analysis of Variance

1. Introduction

1.1 The bottlenose dolphin (*Tursiops truncatus*)

1.1.1 Bottlenose dolphin biology & distribution

As a highly charismatic species, which has been immortalised worldwide as a friendly, sociable and endearing marine mammal, the bottlenose dolphin (*Tursiops truncatus*) (**Figure 1**), also known as the common bottlenose dolphin, is of high scientific interest due to its perceived intelligence (Reiss *et al*., 1997), complex social structure & behaviour (Connor *et al*., 2001), and developed vocal communication, in the form of signature whistles (Janik & Slater, 1998). The bottlenose is one of 34 cetacean species belonging to the *Delphinidae* family, within the suborder *Odontoceti* (International Whaling Commission, 2001). Generally, the bottlenose has a fairly wide global distribution, with two main sub-populations present within the UK – the east coast of Scotland & Cardigan Bay, West Wales (**Figure 2**). The Scottish sub-population is comprised of ~200 individuals (Quick *et al*., 2014), and a population of ~222 individuals is thought to be utilising the Cardigan Bay area, as of 2015 (ICES Advice, 2016). An estimated ~600,000 individuals are thought to be present worldwide (Wells & Scott, 2009), with ~16,485 present in European Atlantic continental shelf waters (Hammond *et al*., 2013). Their distribution is predominantly associated with this coastal shelf edge, which has been identified as an area of high primary productivity due to the abundance of chlorophyll *a* (Holligan, 1981), supporting phytoplankton production, particularly in the summer months (Bot & Colijn, 1996). This primary production contributes to a wide diversity of prey species within the ecosystem food web, and hence, these productive areas are a valuable foraging ground for the bottlenose. Opportunities for feeding have been shown to greatly influence bottlenose dolphin distribution (Hastie *et al*., 2004). Generally, the primary component of the bottlenose dolphin diet is fish, followed by crustaceans and cephalopods; stranding data from the Bay of Biscay revealed a high proportion of fish species (91% of total mass) in 25 dolphin stomachs, particularly demersal fish species (Spitz *et al*., 2006). This rich, highly calorific and generalist diet composition is required to support the high energy expenditure as a consequence of actively diving in pursuit of prey, a commonly shared trait in carnivorous marine mammals (Williams *et al*., 2001), with the annual food intake estimated to be 1900kg for captive bottlenose dolphins over five years of age (Kastelein *et al*., 2003). A highly nutritious diet is also thought to allow for the development of a large and complex brain structure, which has been perceived as an indicator of 'social intelligence' (Connor, 2007). In regards to physical morphology, the bottlenose can reach in the region of up to 3.20m for females, and 3.42m for males at adulthood (SAC Veterinary Services, In: Evans, 1990), and weigh ~365kg (Evans, 1990). In regards to life history and reproductive strategies, the bottlenose generally exhibits high longevity, reaching up to 40-50 years in the wild, with females usually outliving males (Countryside Council for Wales, 2009). However, this extended life span means maturation and reproduction is time consuming and energetically costly; females can only produce one calf approximately every 2-6 years, and the gestation period prior to calving extends to ~1 year (Countryside Council for Wales, 2009). As a consequence of this prolonged gestation period, lactating females require a very high energetic input to sustain the costs of calving and milk production, with increases in energy intake of up to 204% documented in captive bottlenose dolphins (Reddy *et al*., 1991).

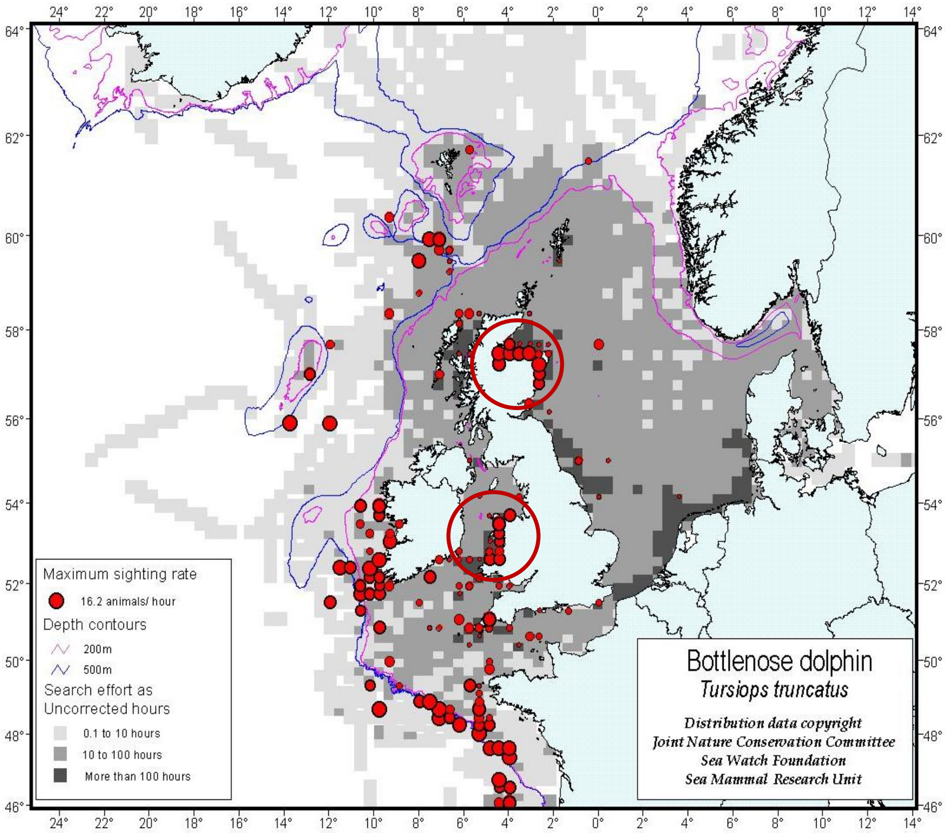


Figure 2: The distribution of the bottlenose dolphin around the UK, in relation to effort (hours) and depth; sightings are associated with the continental shelf edge. Red circles indicate the two primary populations of bottlenose dolphins in the UK, East Scotland & Cardigan Bay. Taken & adapted from Reid *et al*., 2003.

1.1.2 Bottlenose dolphin cognitive ability & behavioural capabilities

Cetaceans have been identified as highly intelligent, analogous in some respects to humans, capable of demonstrating a variety of behaviours and a form of communication. The reasoning behind this lies within the brain structure; cetacean species within the *Delphinidae* family in particular, show a high degree of encephalisation of the brain (Marino, 1998). Some species, including bottlenose dolphins, have an Encephalisation Quotient (EQ) level, a "relative measure of brain size", which impressively exceeds that of any anthropoid primates, with the exception of ourselves, *Homo sapiens* (Marino, 1998). This heightened EQ level/larger brain size is thought to be linked to a high level of 'social intelligence', that is required to produce the diversity of complex behaviours and social structures formed by many Delphinid species. Intelligence may be defined in several ways, but has frequently been characterised by the ability to demonstrate behavioural traits, including the capacity to self-recognise and show a degree of self-awareness; classic Mirror Self-Recognition (MSR) experiments involving placement of reflective surfaces in aquariums, have shown bottlenose dolphins to respond inquisitively when temporary markings are planted on the body, using the mirrors to investigate the locations of the marks (Reiss & Marino, 2001). In regards to 'social intelligence', the evolution of a large brain size has facilitated the ability to form complex social alliances, with a key example being the Indo-Pacific bottlenose population (*Tursiops aduncus*) which resides in Shark Bay, Australia, in which males form 'super-alliances' to cooperatively gain opportunities for mating with females (Connor *et al*., 2001). Finally, communication and language form an important component of cooperating effectively within a group, to transfer information relating to prey availability, conspecifics or induce anti-predatory responses. Within dolphin pods, variations in whistle characteristics are thought to be an important form of communication (Janik & Sayigh, 2013). Individuals have been found to possess a unique 'signature whistle' that is predominantly used when the whistling dolphin is separated from the group, as a mechanism to maintain group cohesion (Janik & Slater, 1998; Janik & Sayigh, 2013). These whistles have also been shown to maintain close contact within mother-calf pairs, in which the mother predominantly uses her signature whistle to reunite with her calf (King *et al*., 2016), and offer parental protection.

1.1.3 Main behaviours: socialising & feeding

The social structure within bottlenose dolphin populations is complex, and individuals engage in various forms of social behaviours, including exchange between pods, termed a ‘fission-fusion society’ (Connor *et al*., 2000). A well-studied, classic example of this elaborate social structure is the bottlenose population in Shark Bay, Australia. Individuals within this population show extensive group coordination in the form of ‘alliances’, in which groups of males cooperate to ‘herd’ females, in order to gain mating opportunities (Connor *et al*., 1992). Group composition within these ‘alliances’ is fluid, and can change over time, demonstrating a ‘fission-fusion’ relationship between pods and an open social structure (Connor, 2007; Randić *et al*., 2012). In regards to other social behaviours, play forms a large part of dolphin behaviour, taking many forms, including aerial & percussive behaviours, and interacting with other marine species. Dolphins are naturally inquisitive, and wild bottlenose dolphins have been documented interacting, or ‘playing’ with multiple objects, including kelp (*Macrocystis* sp.; Würsig & Würsig, 1979) and barrel jellyfish (*Rhizostoma pulmo*; Bel’kovich *et al*., 1991).

Another primary behaviour displayed by bottlenose is feeding, which has been shown to predominantly determine their distribution (Hastie *et al*., 2004). Catching highly mobile prey is no easy task, and dolphins have developed unique behavioural traits thought to facilitate prey capture. Notable examples include using forms of percussive behaviour (*see* **2.4 Behavioural data, sightings & sets**; **Figure 3**). Shane, 1990 described a multitude of distinctive behaviours attributed to feeding, such as ‘fish kicks’, involving a dolphin kicking a fish vertically into the air with the tail fluke, possibly to prepare the fish for easier digestion, and ‘surface tail slaps’, involving the dolphin bringing its fluke above the water surface and down again to create suction (Shane, 1990), possibly aiding fish capture. From a social perspective, bottlenose dolphins have been known to engage in cooperative behaviours to corral shoals of fish, including allocation of roles amongst the pod (Gazda *et al*., 2005).

Figure 3: A bottlenose dolphin showing percussive behaviours in pursuit of an Atlantic salmon (*Salmo salar*) in New Quay, Ceredigion.

1.1.4 Main behaviours: defensive & anti-predatory responses

Anti-predatory responses form another important component of dolphin behaviour, essential for ensuring survivability of the whole pod, particularly young calves. This can range from an individual-level, such as the close-knit synchronisation of behaviours between a mother and her calf, to afford maternal protection over the calf (Mann & Smuts, 1999), up to a group level in which whole bottlenose pods can synchronise behaviours, such as breathing rate, in response to anthropogenic threats, including disturbance in the form of vessel presence (Hastie *et al*., 2003). In regards to the threat of predation, natural predators of the bottlenose worldwide include tiger sharks (*Galeocerdo cuvier*) & orca (*Orcinus orca*), however predation on bottlenose dolphins in the UK is infrequent (Evans, 1990). Ultimately, it is anthropogenic disturbance that is one of the primary threats to the bottlenose (Evans, Pers. comms., 2017). The sensitivity of cetaceans to disturbance has prompted the implementation of regulations, such as the Marine Code of Conduct, and designation of protected areas to manage levels of anthropogenic disturbance and protect critical habitats for the bottlenose dolphin.

1.2 The need for conservation & Marine Protected Areas (MPAs)

As previously mentioned, a prominent threat to the bottlenose in the UK includes anthropogenic disturbance, predominantly by the arrival/presence of vessels. In the Moray Firth, arrival of vessels has been shown to induce ‘anti-predatory’ responses, causing negative alterations to the surfacing patterns of the bottlenose dolphin, *i.e.* they dive for much longer to avoid interactions with the vessel, as observed in the Moray Firth (Janik & Thompson, 1996), and for mothers with calves in Cardigan Bay (Hudson, 2014). In addition to disturbance, dolphins face a multitude of marine pollutants present in our oceans, primarily Polychlorinated Biphenyls (PCBs), a form of industrial solvent. Necropsies of stranded dolphins around Cardigan Bay have found high levels of PCBs accumulated within the tissues, including that of a ten-month old calf, suggesting substantial maternal transfer of pollutants during weaning (Law, Allchin & Morris, 1995).

In order to ensure appropriate mitigation is taken against the aforementioned threats, among others, the bottlenose has been protected under multiple directives & conventions, including: Annex II of the EU Habitats Directive 92/43/EEC (1992); Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS; 1992); Annex II of the Convention on the Conservation of Migratory Species of Wild Animals/Bonn Convention (1983, applies to North & Baltic Sea populations); Appendix II of The Convention on the Conservation of European Wildlife and Natural Habitats/Bern Convention (1983) & The Convention for the Protection of the Marine Environment of the North-East Atlantic/OSPAR Convention (1998) (Evans, 1990; EU Habitats Directive (92/43/EEC), 2013). In the UK, several Marine Protected Areas (MPAs), in the form of Special Areas of Conservation (SACs), exist to protect key species and their associated habitats. For the bottlenose dolphin, two primary sites have been designated as SACs, exclusively for the protection of the species, the Cardigan Bay SAC (Lohrengel & Evans, 2017) and Moray Firth SAC (JNCC, 2017a) (**Figure 4**). A third additional SAC is in place, the Pen Llŷn a'r Sarnau SAC, although this was designated to conserve unique habitat features, such as the Morfa Gwyllt lagoon (JNCC, 2017b), and the bottlenose dolphin is a secondary qualifying feature present in the area (Lohrengel & Evans, 2017).

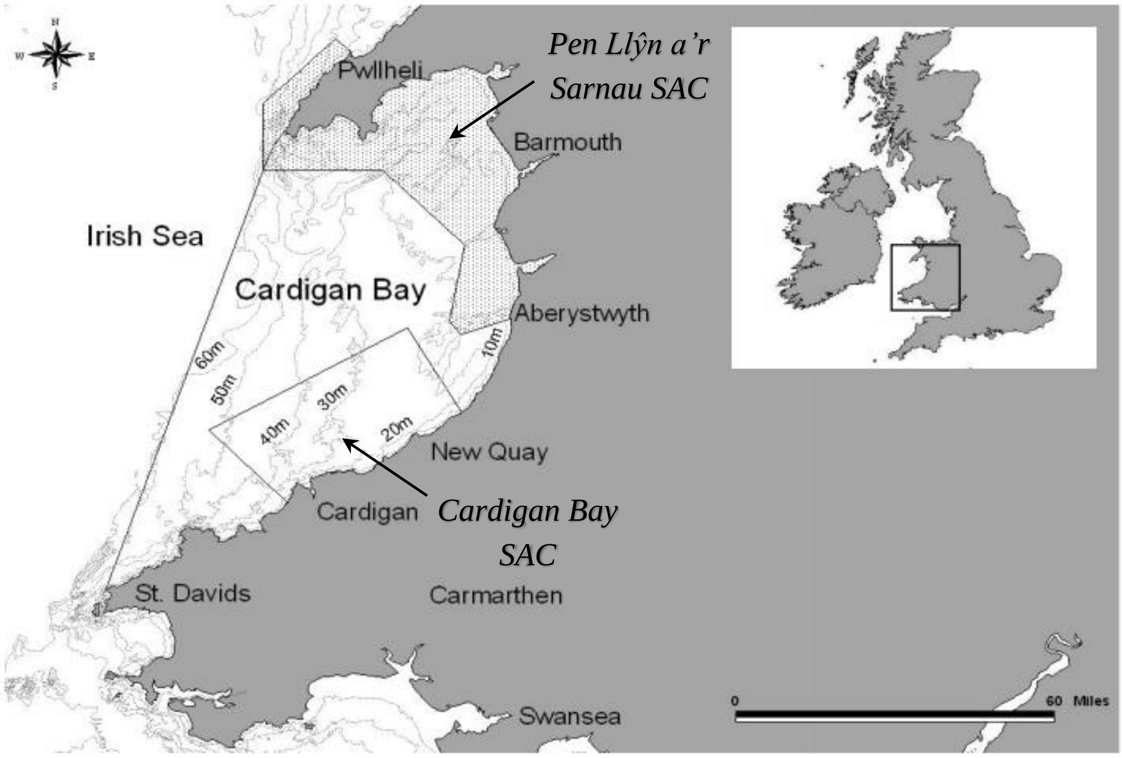


Figure 4: The location of the Pen Llŷn a'r Sarnau SAC and Cardigan Bay SAC in Wales, both implemented in 2004, with the latter designated primarily for protection of bottlenose dolphins. Taken and adapted from: Pesante *et al.*, 2008. As one of the largest bays in the UK, Cardigan Bay is ~100km in length from the Llyn Peninsula down to St David's (Countryside Council for Wales, 2009).

1.3 Current methodologies for surveying dolphin behaviour

In order to monitor dolphins in protected areas such as SACs, routine surveying must be undertaken to observe their use of protected areas over time, and ensure appropriate enforcement of the Marine Code of Conduct. This, in turn, informs management decisions and legislation, as the SAC can be revaluated if it is no longer deemed to offer adequate protection to bottlenose dolphins due to a change in their distribution. For example, the Archipelago of Azores contains an MPA between the islands of Faial and Pico, which hosts a population of ~600 bottlenose dolphins (Silva *et al*., 2012). Boat surveys of the area revealed a primary part of the core feeding area was outside the boundaries of the SAC, so a new extended boundary to the Southern part of the SAC was proposed, and was consequently accepted in 2008 (Silva *et al*., 2012). Standard methodologies for monitoring cetacean distribution and behaviour involve observation of dolphins from vantage points on land, and from casual or dedicated surveys by boat. Both methodologies have differing merits in terms of the amount of information obtained/observation time, quality of photographs, and cost-effectiveness.

1.3.1 Land-based surveying

Land-based surveying is a widely utilised surveying methodology, that can be conducted virtually anywhere with a fixed vantage point for observing cetaceans. A primary advantage to surveying from land is that surveys generally require fewer resources, and are more cost-effective in comparison to boat surveys (Evans & Hammond, 2004; Giacoma *et al*., 2013), meaning they can be undertaken more frequently (Evans & Hammond, 2004), and hence a larger data set can be pooled together. Furthermore, land surveys are non-invasive and hence incur no disturbance to the cetaceans (Evans & Hammond, 2004; Giacoma *et al*., 2013), thus a longer time can be spent observing and documenting dolphin activity. On the contrary, surveying from a fixed point ashore means the total survey area covered is very limited, although repeated temporal surveys in the same area can give a detailed insight into cetacean use of that particular area (Evans & Hammond, 2004). However, weather has been shown to significantly affect the sightings rate for land-based surveys, with a significant reduction in sightings in sea states higher than zero, although this is likely to be platform-dependent (Giacoma *et al*., 2013). Surveys for cetaceans should only be carried out in sea state ≤ 3, as surveying in conditions more adverse than this greatly reduces detection ability by the observer (Norrman *et al*., 2015). The increased distance to the individuals, as land surveys are often conducted from high vantage points such as clifftops, incurs fewer opportunities for undertaking photo-identification (photo-ID; **Figure 5**) (Giacoma *et al*., 2013), and data collection that requires a closer proximity to the animals cannot be undertaken (Evans & Hammond, 2004), such as sex, approximate age and physical condition (Giacoma *et al*., 2013). Therefore, if the objective of the survey is to identify individual dolphins and associated parameters, then the use of a vessel for surveying is more appropriate and accurate.

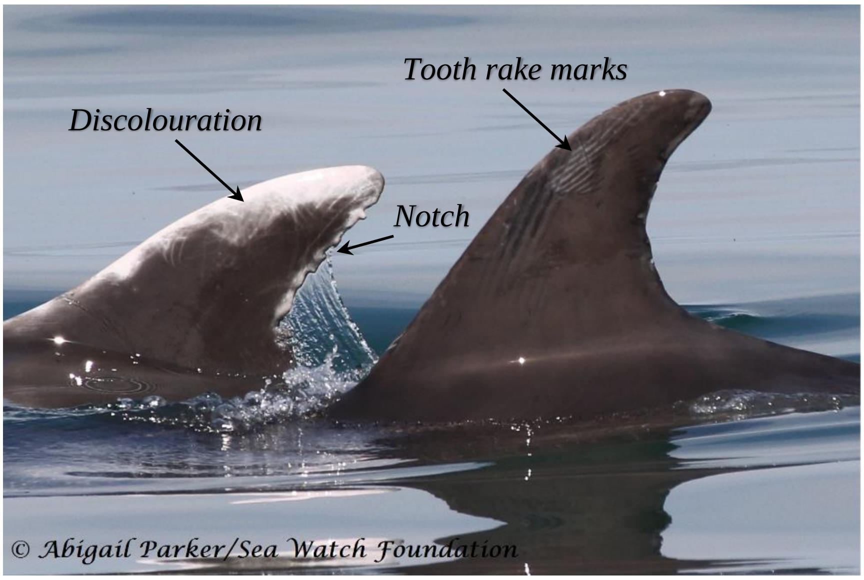


Figure 5: Bottlenose dolphin fins show a great degree of variation, with several features, such as tooth rake marks & notches, caused by interactions with other dolphins, and discolouration, all of which can be used for photo-ID of an individual. Cropped photograph taken on board *Ermol VI* on 19th June.

1.3.2 Boat-based surveying

An alternative methodology involves the use of vessels to undertake surveys at sea. These can either be casual surveys, such as those involved with wildlife-watching operators and on board ferries, or dedicated line transect surveys, that usually span over a long period to assess dolphin presence in a given survey area. Vessels have multiple merits in that they can generally cover a much larger area than land-based surveys from a fixed point, and the closer proximity to cetaceans facilitates collection of a greater array of data, including photo-ID images, details on body condition & health, sex, age and social interactions within pods (Giacoma *et al*., 2013). On the other hand, the presence of vessels can incur unwarranted disturbance to cetaceans (Giacoma *et al*., 2013), although this can be species-specific (Würsig *et al*., 1998). Furthermore, dedicated surveys can be expensive, and require multiple personnel to participate in surveys, and be allocated to different roles, including primary observers, independent observers, effort recorder and dedicated personnel for photo-ID (Evans & Hammond, 2004). Considering the merits of both methodologies, a combination of both may be suitable, with frequent land watches accompanied by occasional vessel surveys (Giacoma *et al*., 2013). However, this ultimately depends on the information of interest to the observer, weather conditions, budget and availability of personnel to assist with the survey.

1.3.3 Photography

Photography is a critical part of cetacean surveying, primarily utilised for individual identification, termed 'photo-ID' (**Figure 6**). Currently, the Cardigan Bay photo-ID catalogue contains 382 identified individuals (Norrman *et al*., 2015). Photo-ID allows observers to follow movements of specific individuals in 'capture mark-recapture' studies, in which an individual can be photographed in one location, and then re-identified elsewhere to assess temporal changes in abundance and distribution (Pesante *et al*., 2008); this is particularly useful for assessing individual movement patterns in relation to the use of SACs. Photo-ID studies from 2007-2013 of the bottlenose in Welsh waters have found that 66% of individuals who utilise Cardigan Bay also make use of areas around Anglesey, North Wales (Feingold & Evans, 2014; **Figure 7**); this seasonal movement of individuals to areas outside the SACs may be attributed to opportunities for foraging. In addition to monitoring the movements of specific individuals, photography can also be highly useful for objectively confirming sightings (Evans & Hammond, 2004), be it species or counts of individuals. Overall, the development of photography for use in cetacean surveying has been extremely beneficial in aiding our understanding of population abundance, distribution and migration patterns.

Figure 6: Comparison of bottlenose dolphin photographs with the dorsal fins visible, taken from **a)** land on the seafront, **b)** land from a clifftop vantage point, **c)** a wildlife-watching vessel, the *Ermol VI*, and **d)** a dedicated line transect survey for bottlenose dolphins on the *Dunbar*

Castle II. All photographs are uncropped for comparison and all are slightly marked individuals to demonstrate a fair comparison of photography quality and resolution. Note how similar quality dorsal fin photographs can be obtained from casual wildlife-watching vessels in addition to dedicated surveys. Land surveys offer a good platform for cetacean surveying, however the images may not be of sufficient quality unless the individual is in very close proximity to land.

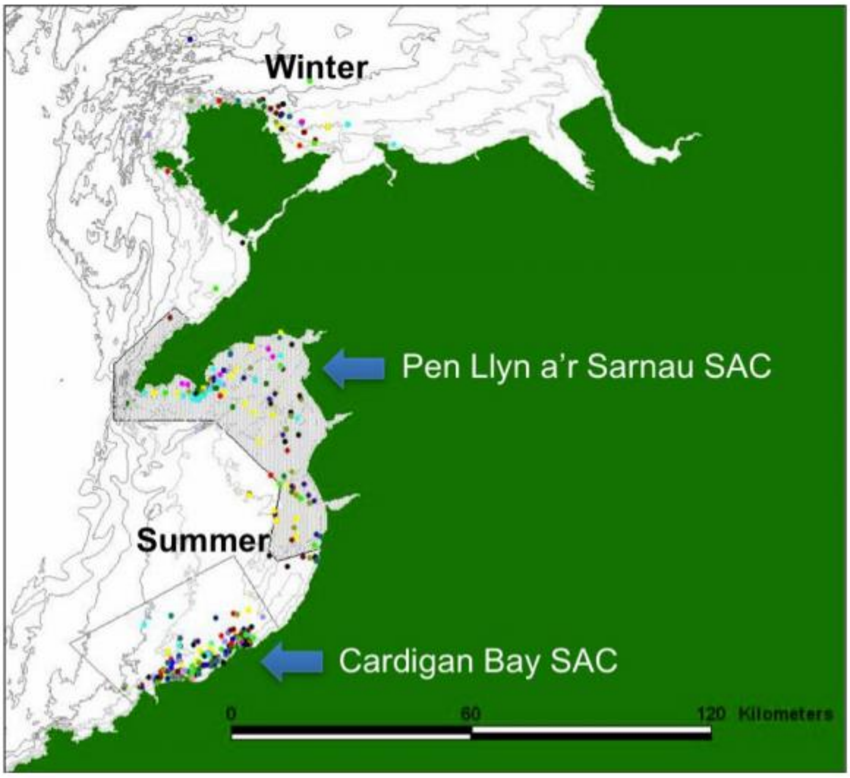


Figure 7: The seasonal movements of bottlenose dolphins between the two Welsh SACs and around Anglesey, North Wales. Each coloured dot represents a specific individual. Taken from Norrman *et al*., 2015.

1.3.4 The introduction of unmanned aerial vehicles

Whilst boat and land-based surveys both have their merits, a novel surveying approach which offers an alternative perspective is gradually being trialled: the use of Unmanned Aerial Vehicles (UAVs), or drones. This technology focuses on obtaining photographs and video footage from above, greatly reducing the level of disturbance which may otherwise occur from a survey vessel, whilst obtaining a greater diversity of data than those gathered from land surveys. Current published work includes a focus on photogrammetry, determining body measurements from photographs of pods of large cetaceans, such as orcas (*Orcinus orca*) (Durban *et al*., 2015). For smaller species, research has shown promise, and dolphins have been identified down to species level using UAVs (Hodgson *et al*., 2013). Of course, it is of upmost importance that ethical guidelines are maintained to ensure minimal disturbance to wildlife.

UAVs currently show advantages in comparison to vessel surveys in that a low frequency level of noise generated from a drone is principally below the hearing threshold of some toothed whale species, including the bottlenose dolphin, however, this is dependent on the drone model (Christiansen *et al*., 2016). The next step for aerial technology would be in the direction of monitoring behaviours, social interactions and parameters associated with body lengths, such as overall condition, health & growth rates.

1.3.5 The Sea Watch Foundation & Cardigan Bay bottlenose population

Wales has an excellent diversity of cetacean species; eighteen in total have been recorded since 1990 (Baines & Evans, 2012), including the bottlenose dolphin. Cardigan Bay in Ceredigion, West Wales, is one of two main areas for sighting the charismatic bottlenose dolphin in the UK (Carwardine, 2016; **Figure 8**), particularly in the summer, and supports a large coastal population of ~222 dolphins at the last 2015 estimate, with ~159 utilising the Cardigan Bay SAC (ICES Advice, 2016). The apparent decline in recent years may be due to an increase in the number of individuals utilising habitats outside the SAC (ICES Advice, 2016; **Figure 9**). The introduction of the UK Cetacean Group, which has been gathering data opportunistically since 1973, and became the Sea Watch Foundation, a research charity, founded by Dr. Peter Evans in 1991, has facilitated regular surveying to better monitor cetacean populations around the British Isles & the threats they face, and has now grown into one of the leading charities for cetacean conservation. The involvement of interns and volunteers enable a large amount of land-based and boat-based data to be gathered on dolphin activity every year, to better understand dolphin abundance, distribution and utilisation of the Cardigan Bay, and to use these data to make suitable management decisions and inform policy.

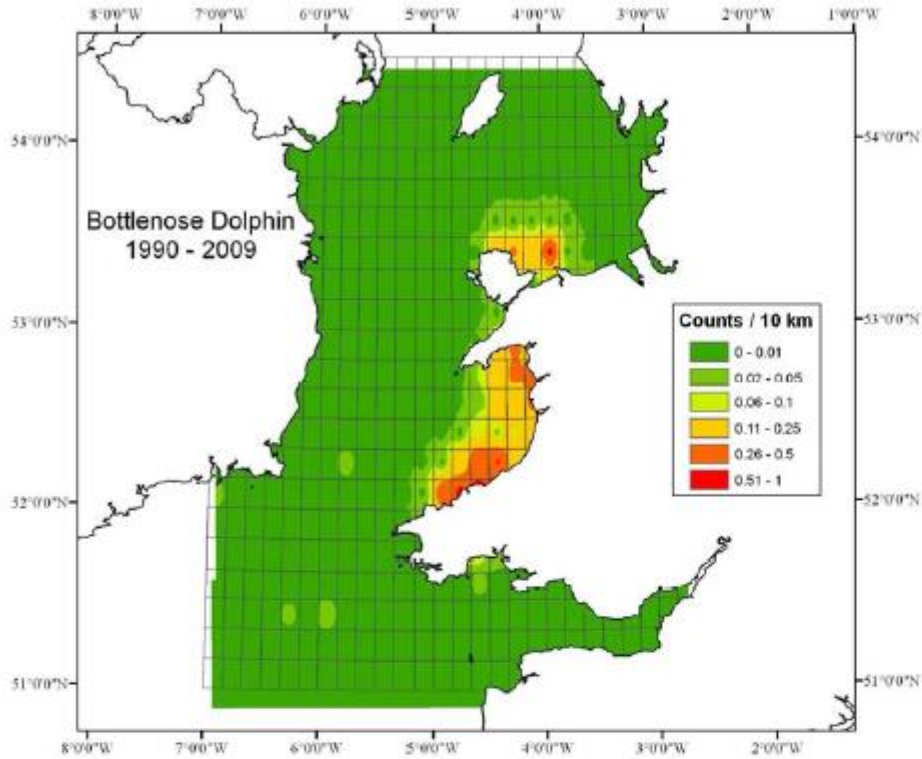


Figure 8: Bottlenose dolphin counts per 10km around Wales, UK, for 1990-2009. Notice the large 'hotspot' around within Cardigan Bay. Taken from Baines & Evans, 2012.

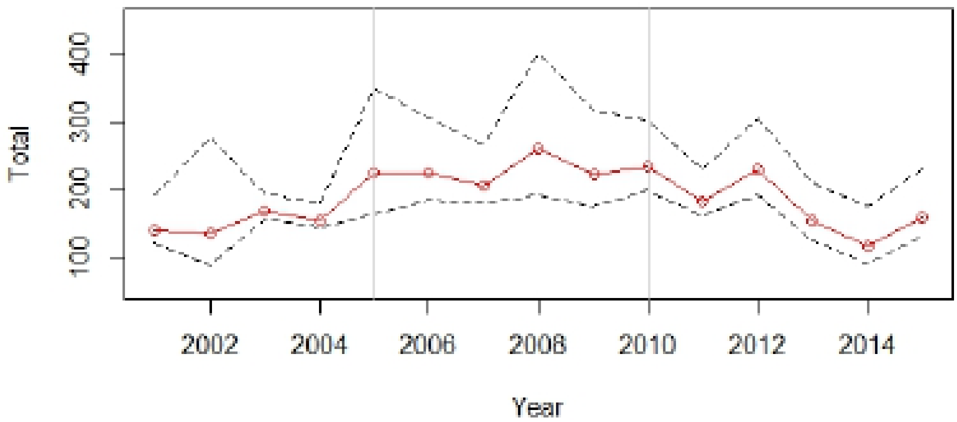


Figure 9: Temporal changes in the abundance estimates of bottlenose dolphins in the Cardigan Bay SAC. Total refers to total number of individuals. Dashed lines are 95% confidence intervals. Taken from ICES Advice, 2016.

1.4 Study aims & hypotheses

1) To record and digitally photograph the full range of bottlenose dolphin behaviour in Cardigan Bay, and to assess changes in behaviour over the study period.

2) To compare the methodologies (land, boat and drone surveys) in regard to the range of behaviours seen during each type of survey; is a greater diversity of behaviours recorded from land due to the absence of disturbance otherwise caused by a vessel; do drones capture more seldom-seen behaviours?

3) To compare the methodologies in regard to the group size & structure of bottlenose dolphins; are more sightings recorded from land due to fewer surveying constraints?

4) To compare the methodologies in regard to disturbance; do vessels induce avoidance behaviours, such as longer dive time in comparison to land-based surveying methodologies?

5) To investigate bottlenose dolphin sightings in relation to environmental variables; do average counts of dolphins decline with increasing sea state due to reduced likelihood of detection in rougher seas?

6) To investigate the extent to which suitable quality photographs can be obtained from the surveying methodologies; is photo-ID of individuals exclusively constrained to boat-based surveys?

2. Methodology

2.1 The primary study site – New Quay, Ceredigion

Fieldwork for this study was undertaken at various sites around the coast of Ceredigion, which encircles part of Cardigan Bay, although primarily surveys were based out of New Quay (52.22°N, 4.36°W; **Figure 10**). New Quay is a small seaside town which offers several prime locations for surveying the resident bottlenose dolphin population, and hence becomes a popular tourist destination during the summer season due to the charismatic nature of this species and the regularity of sighting them in the bay. Boat operators and recreational activities operate out of the main harbour, which can be accessed from the pier (**Figure 11**); at high tide the sea submerges the intertidal zone all the way up to the pier, offering a suspected shallow feeding habitat for a variety of species, including the bottlenose dolphins. In addition, the fish factory which processes common whelks (*Buccinum undatum*) & brown crab (*Cancer pagurus*), discharges waste shells into the sea, providing an alternative food source for fish, consequently regularly attracting dolphins to the area to feed on the increased abundance of prey fish species (Denton, 2012). New Quay Head overlooks the town, and offers some shelter and protection from adverse weather; the whole headland can be hiked by following the scenic coastal path, which runs all the way down to Cwm Tydu & Ynys Lochtyn, and offers a high vantage point for undertaking land-based cetacean surveys.

Figure 10: New Quay main town & Harbour beach at low tide, photographed from the Quay West Caravan Park on a grey evening in May.

Figure 11: New Quay main pier photographed from Traethgwyn beach during a clear sunset in June.

2.1.1 Geology & species richness

New Quay is unique in many respects in its geology and bathymetry, being of interest due to the fine-grain turbidite sequences, a series of sedimentary layers deposited in the ocean by turbidity currents, and the elaborate seabed structure (Anketell & Lovell, 1976). Generally the bay is relatively shallow, reaching ~50m in depth in the outermost parts of the bay, although closer to the coastline is fairly shallow (Countryside Council for Wales, 2009). Swell is generally low, with waves reaching greater than 1m in height ~25% of the time during the summer, with this increasing to ~50% in the winter, however New Quay has some shelter from adverse weather conditions (Countryside Council for Wales, 2009). Salinity is affected by an input of fresh water into the ocean, through run-off after rainfall, and from estuaries flowing into the bay, with an average of $113m^3s^{-1}$ of fresh water entering the bay through riverine systems (Countryside Council for Wales, 2009). The high productivity of the area provides an excellent source of food availability for a diversity of species, including Atlantic grey seals (*Halichoerus grypus*), harbour porpoise (*Phocoena phocoena*) and seabird colonies (**Figure 12**). In addition, occasional sightings have also been reported of common dolphins (*Delphinus delphis*) that are common in South-West Wales (Baines & Evans, 2012), although none were encountered during this study.

Figure 12: The diversity of marine species seen around Cardigan Bay, in addition to *Tursiops truncatus*. **a)** An Atlantic grey seal surfacing at Cardigan Island (52.129603, -4.684917); **b)** a harbour porpoise feeding amongst Manx shearwaters during a line transect survey in thick fog (52.125239, -4.806281); **c)** the breeding seabird colony seen from the *Ermol VI* (52.217356, -4.373061), arrows indicate the three bird species nesting here, including kittiwakes (*Rissa tridactyla*), razorbills (*Alca torda*) and guillemots (*Uria aalge*), some with chicks, such as the guillemot chick indicated by the blue arrow.

2.1.2 Vessel activity & tourism

The popularity and regularity of the bottlenose dolphins around New Quay has facilitated several businesses offering dolphin-spotting trips around the bay. These include *Dolphin Spotting Boat Trips (Ermol V & VI)*, *SeaMor Wildlife Tours* & *Dolphin Survey Boat Trips (Anna Lloyd)*, and *Dolphin Survey Boat Trips* (*Sulaire*), along with other recreational excursions such as *Epic Fishing Trips*, making the waters of New Quay busy in the peak summer season. *Dolphin Survey Boat Trips* also runs the Cardigan Bay Marine Wildlife Centre (CBMWC) undertaking boat-based surveys for cetaceans, whereas *Dolphin Spotting Boat Trips* works in conjunction with the charity by allowing interns, students and staff to come on board and survey for cetaceans, whilst complying with the Marine Code of Conduct.

Furthermore, in calmer conditions, other recreational activities such as paddleboarding, kayaking & sailing frequently operate around the bay, and multiple sailing regattas take place during the year. Vessels are subject to the Marine Code of Conduct to partake in activities within the Cardigan Bay SAC; an SAC patrol vessel undertakes inspections to assess vessel adherence to these guidelines for operating around cetaceans.

2.2 Survey approaches

Data were gathered primarily by undertaking land watches and boat surveys from multiple locations around Ceredigion (**Figure 13**). No set minimum number was chosen for surveys, but as many as possible were completed to maximise data collection. Time periods and days for surveying were chosen to work in harmony with fluctuating weather conditions, time constraints and personal commitments, such as part-time work, desktop duties and Sea Watch public awareness shifts. Data collection took place from 7th June to 15th August 2017, in varying intensities. The first week of June, 30th May - 4th June, served as a training week with the Sea Watch Foundation, during which training was given on land watch and boat survey protocols. The following week was very poor weather-wise, so this was used as a trial week for practicing the methodologies, photography and fine-tuning the data sheets. A vast amount of data was gathered in June, in hindsight much more than anticipated, since the behavioural data were obtained every five minutes, coupled with a high volume of photographs taken on the majority of surveys, and therefore intensity of data collection fluctuated over time to facilitate time for data handling. Surveys were undertaken into August to allow for observation and recording of dolphin behavioural patterns over time and in anticipation of drone work. Weather varied greatly over the summer period, and hence surveys were highly weather dependent. Therefore in optimal weather conditions, survey effort was intensified to gather more data as conditions allowed. During poor weather, data were collected where possible. However, these were analysed separately. Further clarification of ‘poor weather data’ is detailed in **2.7 Data analysis & visualisation**.

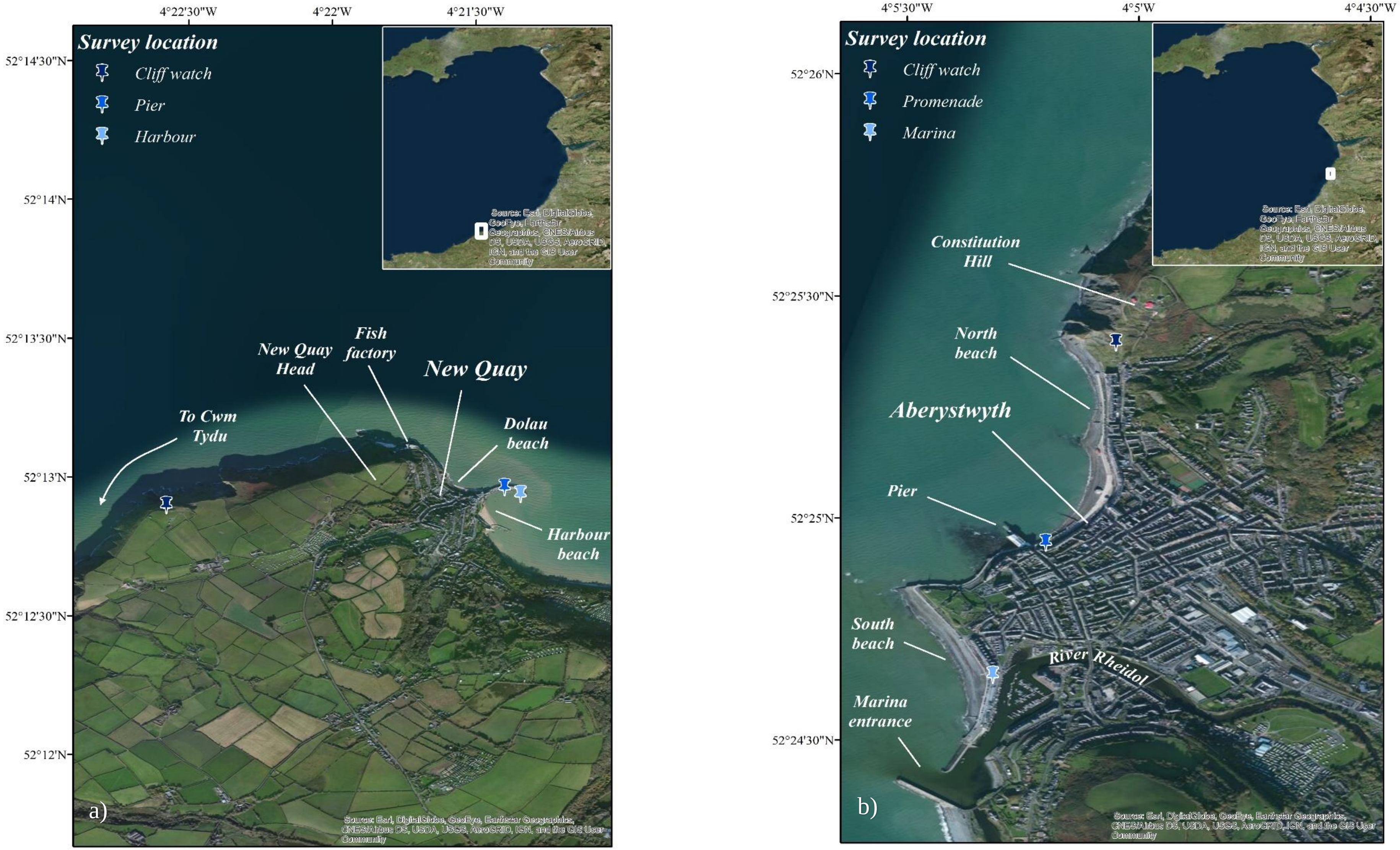


Figure 13: Surveying locations in **a)** New Quay and **b)** Aberystwyth, Ceredigion, for land & boat-based surveys, along with key landmarks.

2.2.1 Land watches – New Quay Pier

Land watches formed a key component of the field work, since generally they could be undertaken in more unfavourable conditions (within reason), by comparison with boat-based surveys, which are heavily constrained by sea state, swell & weather. The pier served as a primary location for completing land watches (**Figure 14**), which involved observing the sea and noting details of cetacean sightings and effort data for two hours, conditions permitting. The Sea Watch Foundation run land watches from 7am-9pm, which are completed by interns and local volunteers in two hour blocks; rotating shifts every two hours minimises fatigue and reduces the likelihood of cetaceans being missed completely or mis-counted, which may occur after several hours of continuous surveying by the same person. I participated on land watches alongside interns, who collected effort and sightings data, whilst I collected behavioural data, dive times and photographs. I was also scheduled into the intern rota at least once a week to undertake a land watch, in which case I completed all three datasets (effort, sightings and behaviour) single-handedly. Any sightings data were entered into the Sea Watch Sightings Database upon completion of the land watch. In the event that precipitation became heavy and persistent, visibility was seriously reduced (<1km), or sea state became too high, land watches were abandoned after an initial attempt, but the data retained for separate analysis. In some cases, weather permitted the land watch to go ahead but the sea state changed, increasing above 3 during the course of the survey; in this case the data were also retained and collated with the abandoned survey data.

Figure 14: New Quay main pier on a quiet evening, from which myself and Sea Watch interns would sit to survey for bottlenose dolphins.

2.2.2 Cliff watches – New Quay Head

New Quay is overlooked by a large headland (New Quay Head) which is accessed via a steep coastal path. The surveying location on the headland (52.21498, -4.3763), is approximately 98m high, and therefore offers a very high vantage point from which to survey cetaceans (**Figure 15**). The first data from New Quay Head were collected on the 18th June, during a Sea Watch training weekend for the general public interested in learning identification and surveying techniques. Two juvenile bottlenose dolphin individuals were observed from 13:19-13:56, and the photographs obtained are similar in many respects to what can be obtained from surveying using a drone, in terms of minimal disturbance and an aerial perspective. Therefore, surveying from New Quay Head was scheduled in when possible, for at least an hour, along with cliff watches from Aberystwyth (*see 2.2.3 Cliff watches - Aberystwyth*) to obtain aerial land-based data and photographs, to be analogous to drone footage.

Figure 15: The sea view from the surveying location at the top of New Quay Head in favourable weather conditions with >10km visibility. In these conditions Aberystwyth can be seen, as indicated by the white arrow.

2.2.3 Cliff watches – Aberystwyth

In addition to completing regular land watches at New Quay Pier, surveying was also expanded to include Aberystwyth from the 29th June. The reasoning behind this was through acquisition of some local knowledge from a visitor to New Quay, who communicated to myself that dolphins had been seen at the end corner of the seafront, next to the railway recently (25th June). This also coincided with the expansion of line transect surveying to include the Pen Llŷn a'r Sarnau SAC, from which the *Machipe* was utilised, which operates out of Aberystwyth and covers the surrounding areas (*see 2.2.6 Dedicated surveys*). The surveys in Aberystwyth were done from a picnic spot located on the coastal path on Constitution Hill (52.423264, -4.084161), which is also serviced by the Cliff Railway. The exception to this was during heavy rainfall on the 29th July, and therefore the survey was relocated to a sheltered area on the seafront (52.415753, -4.086695); an hour survey was also done from the seafront on the 8th August, as the sea state was very calm (sea state 2). The location on the cliff offered a high vantage point for surveying (approximately 62.3m), especially in high sea states, and overlooks Aberystwyth town (**Figure 16**). The longer travelling distance to Aberystwyth meant that surveys were undertaken for at least an hour, even in poorer weather conditions, such as heavy rain or high sea state when land watches would normally be abandoned.

Figure 16: Aberystwyth town, seafront & pier seen from the surveying location on the coastal path to Constitution Hill at the end of June, with sea state 5 observed on this day.

2.2.4 Casual sightings

In order to record as many dolphin sightings as possible, casual sightings were also noted for interest. These involved noting down any sightings seen when not on a dedicated survey, such as those observed from the office window, and when walking from living accommodation into New Quay town from which the main road offers a view over the harbour; a full list of casual sighting locations is given in **3. Results**. For casual sightings, as much information as possible was recorded, within a minimum five-minute observation window. This included time of sighting, best estimate of total number, approximate location, behaviour, vessel presence, and environmental conditions such as sea state, swell & visibility. Casual sightings were often observed *en route* or from a distance, and hence less detail could be given for these sightings, by comparison to dedicated surveys or watches from land and vessels.

2.2.5 Boat surveys – Ermol VI

Another key component of surveying was the use of the *Ermol VI* of Dolphin Spotting Boat Trips for undertaking boat-based surveys (**Figure 17**). These boat trips lasted for one hour, and departed from New Quay pier, travelling down to Cwm Tydu, weather and time permitting (**Figure 18**). In some cases the sea state was too rough to pass around the corner where the fish factory is located, and therefore the trip was confined to the calmer waters of the harbour area, and sometimes reduced to a 30-minute trip due to travel restrictions. In good sea states, data were collected by sitting on the roof, which offers an unrestricted view from a higher vantage point, ideal for assessing and photographing cetacean behaviour. When sea state was rough and it was deemed unsafe to sit on the roof, dolphins were observed from the bottom deck, where passengers would be seated. Effort and sightings data were collected either by interns or myself, although primarily by myself as the interns would utilise the *Ermol V*; two-hour boat trips. However, the shorter *Ermol VI* trips were better for fitting in the remainder of my schedule, and could run in more unfavourable conditions. All behavioural data were collected by myself.

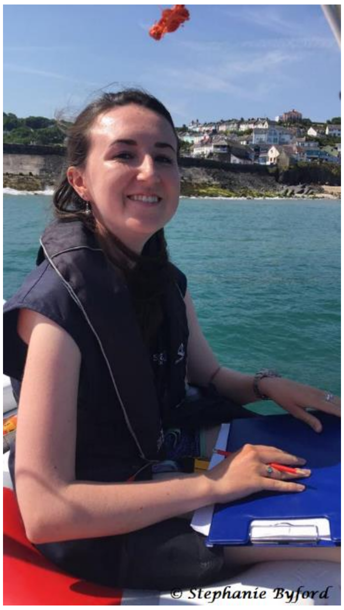


Figure 17: Left: Myself & Stephanie Byford sitting on the roof of the *Ermol VI* of *Dolphin Spotting Boat Trips,* on its return to New Quay, to acquire boat-based data on marine mammals in Cardigan Bay; right: leaving the harbour to record data from the roof of the wheelhouse on a clear, sunny surveying day.

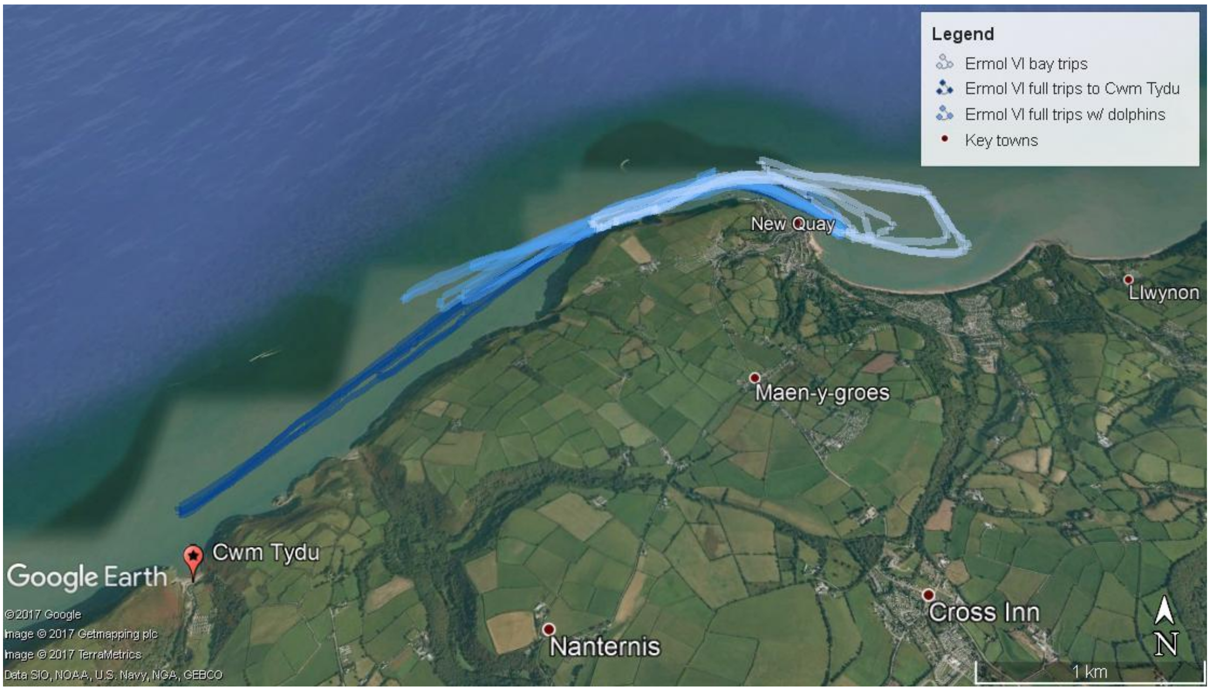


Figure 18: A Google Earth satellite map of typical *Ermol VI* boat tracks, including a day of shorter bay trips when sea state was poor (22/06/2017; total 17.2km covered), a day of full hour trips, but not all the way to Cwm Tydu due to time restraints after spending time encountering bottlenose dolphins (20/06/2017; total 28.4km covered), and full hour trips all the way to Cwm Tydu, a small cove indicated by the red placemark (26/06/2017; total 28.3km covered). Key towns including New Quay, the departing location for the trips, are shown as red marker dots. Tracks were obtained using the GPS 'log' function on a Canon 7D Mark II camera model, technical details are given in **2.7 Data analysis & visualisation**.

2.2.6 Dedicated surveys – Dunbar Castle II & Machipe

In addition to embarking on regular *Ermol VI* surveys, dedicated photo-ID surveys were completed on occasions, although not as frequently, as the extended survey duration meant that conditions had to be near optimal to be given the go-ahead, ideally with a low wind speed and a flat sea state. Departing from New Quay, the *Dunbar Castle II* (**Figure 19**) was utilised for three line transect (LT) surveys, one in June (**Figure 20a**) and two in July (**Figure 20b**), and one non-line transect (NLT) survey in June (**Figure 20a**). The LT surveys were long days (up to 9.68 hours) and covered a vast area, ranging from Aberaeron to Cardigan Island, following different transect lines (**Figure 21**) within the Cardigan Bay SAC on each survey. A shorter NLT survey was undertaken on 18th June (3.03 hours), as part of the Sea Watch Foundation Cetacean training course for the general public. In addition to undertaking surveys from New Quay on the *Dunbar Castle II*, a vessel operating out of Aberystwyth, the *Machipe* (**Figure 22**), was also used to complete a series of transects in the Pen Llŷn a'r Sarnau SAC on 8th July. No dolphins were encountered on this survey, but a large area, approximately 177km, was covered over 9.68 hours (**Figure 23**), due to the *Machipe* being able to travel much more expeditiously between transect locations, and was able to survey all the way up to Harlech. The purpose of these dedicated surveys was for the Sea Watch Foundation to acquire high quality effort & sightings data and dorsal fin photographs for photo-ID. In order to gather these data, the Sea Watch Foundation possesses a photo-ID licence granted under Natural Resources Wales (licence no: 75535a:OTH:SA:2017), which allows the boat operators to carefully approach dolphins in order to obtain useable dorsal fin photographs. To inform other boat operators of possession of this licence, a flag is raised during photo-ID (**Figure 24**). On each LT survey, roles were allocated to each student/volunteer, such as primary observer, which were rotated every hour, or every fifteen minutes on the shorter NLT survey. An intern was always included as a 'back-up', who could take over from myself, Katrin Lohrengel, or Laura Bartlett for a particular role during dolphin encounters, so photo-ID could be performed, and the behavioural data sheets and photography for this study could be completed (**Appendix IV**).

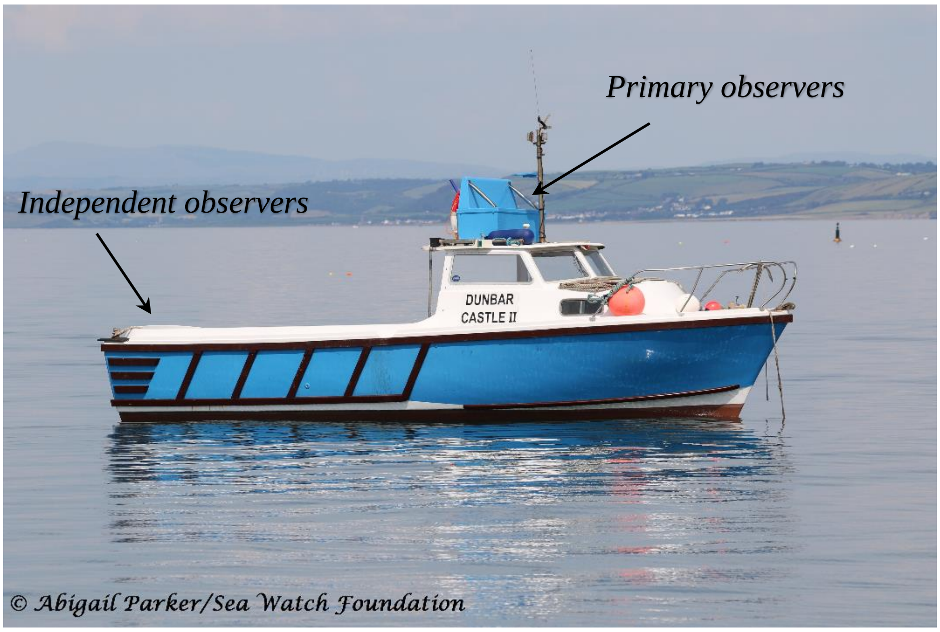


Figure 19: The *Dunbar Castle II* vessel seen from the *Ermol VI*, used to undertake LT and NLT surveys, operating out of New Quay. Arrows show the seating locations for the two independent observers at the back of the boat, and two primary observers on the bench above the wheelhouse.

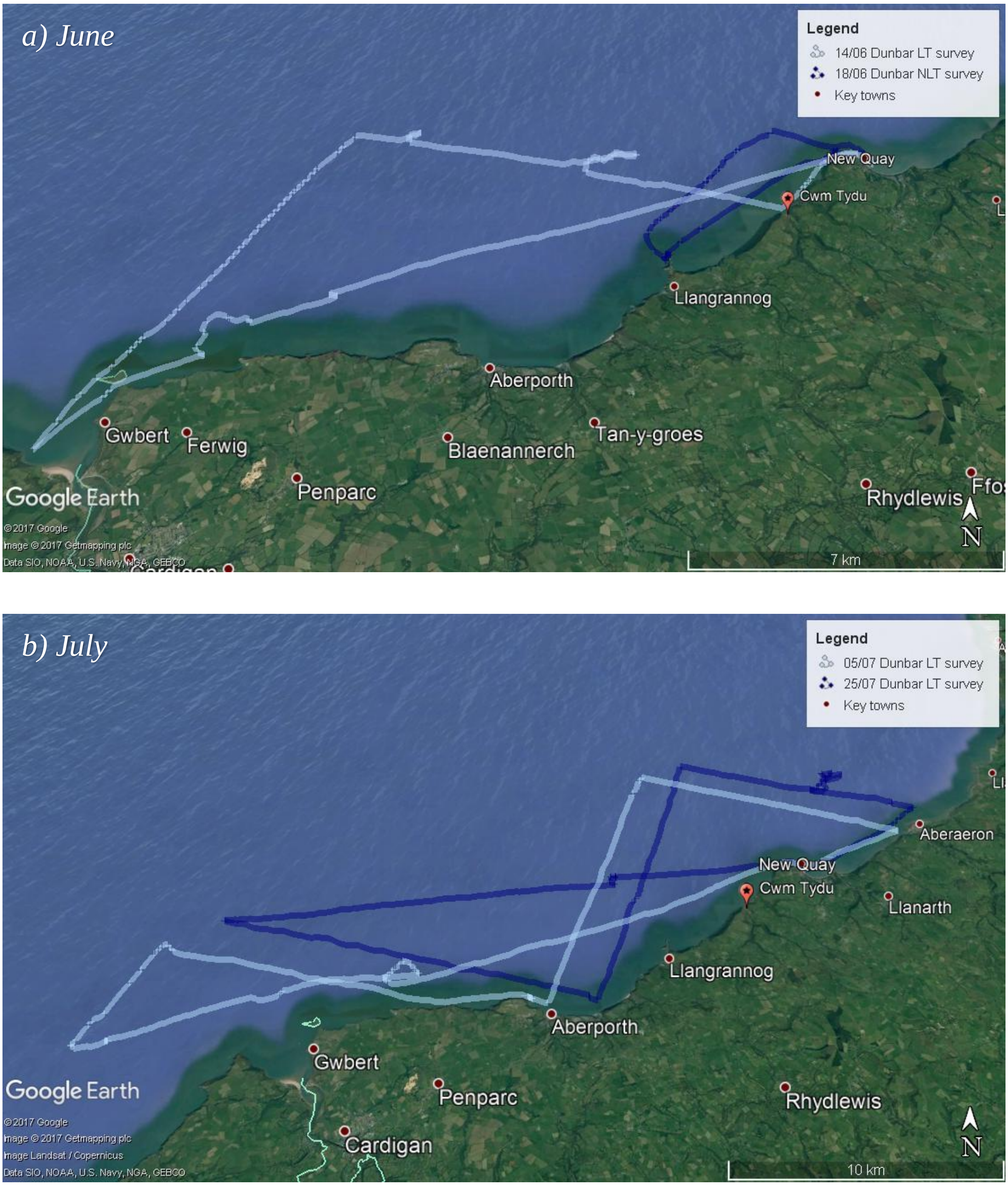


Figure 20: a) A Google Earth satellite map of the two dedicated *Dunbar* LT and NLT surveys undertaken in June. Total length of the survey was 71.1km for the LT survey on 14/06/2017, and 25km for the NLT survey on 18/06/2017. **b)** The two dedicated *Dunbar* LT surveys undertaken in July. Total length of the survey was 103km for the LT survey on 05/07/2017, and 96.5km for the LT survey on 25/07/2017. Key towns including New Quay, the departing location for the surveys, are shown as red marker dots, and Cwm Tydu, the turning location for the *Ermol VI*, is indicated by the red placemark. Satellite image: © Google Earth, 2017.

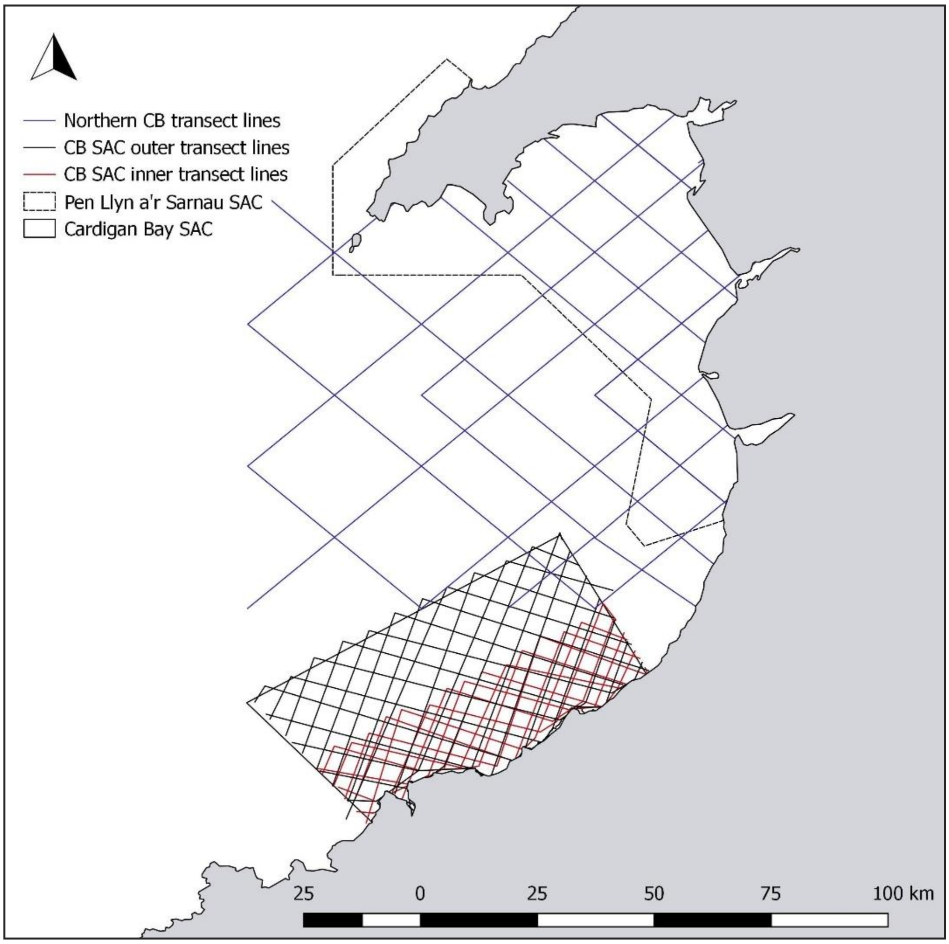


Figure 21: The transect lines undertaken with the Cardigan Bay SAC and Pen Llŷn a’r Sarnau SAC/offshore area on dedicated surveys by the Sea Watch Foundation. Taken from Lohrengel & Evans, 2017.

Figure 22: Sitting at the stern of the *Machipe*, during a line transect survey in the Pen Llŷn a'r Sarnau SAC, while travelling to the next transect start point. Slightly different to the *Dunbar*, independent observers would sit at either side of the bow, or at the stern if there was too much spray, and primary observers above the wheelhouse.

Figure 23: A Google Earth satellite map of the dedicated *Machipe* LT survey undertaken in July. Key towns including Aberystwyth, the departing location for the survey, are shown as red marker dots, and Harlech, the furthest point reached on the survey, is indicated by the red placemark. Satellite image: © Google Earth, 2017.

Figure 24: The photo-ID flag raised during bottlenose dolphin encounters to inform other boat users of our behaviour. The flag was *only* raised during photo-ID encounters outside the New Quay harbour, never within the confines of the harbour.

2.3 Effort & sightings data

Effort and sightings data forms were all standardised and were provided by the Sea Watch Foundation. The components of each form differed slightly for land and boat-based surveys, along with descriptions of codes used. For both land watches and boat-based surveys, effort data were recorded to provide environmental information every fifteen minutes; these data were either collected by myself along with the behavioural data, or by a fellow Sea Watch intern/volunteer whilst I was gathering behavioural data. Full acknowledgement to all individuals who gathered the effort data as part of their volunteering/internship at Sea Watch is given in the **Acknowledgements**.

2.3.1 Land watches

For land watches, environmental effort data consisted of a start and end time for each fifteen minute block, and within each block, the sea state (Beaufort scale, *see* **Appendix I**), wind direction and visibility (km) were noted. Visibility was deduced based on which seaside towns were visible from the pier; <1km if the Cardinal Mark was not visible, 1-5km if only Aberaeron was visible, 6-10km if Aberaeron and Aberarth were visible (**Figure 25**), and >10km if Aberaeron, Aberarth and Aberystwyth could be seen. In addition, within every block it was noted whether a bottlenose dolphin sighting occurred, and, if so, the time of sighting, number of individuals, approximate location and whether there was a boat encounter. The first boat encounter within each block was recorded, and was defined as any boat encountering dolphins within a 300m radius. Details noted for boat encounters included vessel type (and name, if known); number of vessels in the 300m radius, vessel distance to cetaceans; vessel behaviour; cetacean behaviour and cetacean response to vessel presence. The northerly Cardinal Mark (**Figure 25**) provided a useful reference for approximating distance measurements, as it is located exactly 1km from the pier. A tally was also kept of the boat activity throughout the duration of the survey; any boat which crossed the end of the pier to enter or leave the harbour was simply tallied according to vessel type.

Figure 25: Aberarth and Aberaeron visible from the pier, indicating a visibility radius of at least 6-10km. The northerly Cardinal Mark is also outlined, which warns boat users of the Llanina Reef, used as a benchmark for making distance measurements.

2.3.2 Boat surveys – Ermol VI, Dunbar & Machipe

Effort data for *Ermol VI* surveys, *Dunbar* & *Machipe* were also noted in fifteen minute blocks, and within each block the GPS location (latitude, longitude), sea state and swell height, boat speed (knots), boat course (degrees), effort type, precipitation and visibility. The presence of any other vessels was also noted by recording the vessel types seen during the block (only recording one type once). The dedicated surveys (*Dunbar* & *Machipe*) had additional variables, including sun glare (degrees), transect number and leg number that were also noted every fifteen minutes, and during a sighting the frequency of recording effort data was increased to every three minutes. For sightings during the dedicated transect surveys, the sighting number, time, GPS location (latitude, longitude), effort type, angle of animal (degrees), boat course (degrees), distance to animal (in metres), species, total number & life stage, cue to animal, behaviour & direction, and reaction to the boat were recorded by the primary observers, and by independent observers if seen by them also. Sightings data for the *Ermol VI* were similar. However, due to difficulties with the logistics of filling in multiple forms in addition to taking photographs & dive times, in some cases effort data were not obtained or were incomplete. Behavioural data forms were always completed so details of the animals were still obtained (*see* **2.4 Behavioural data, sightings & sets**).

2.4 Behavioural data, sightings & sets

The data sheet used to collect behavioural data (**Appendix IV**) was adapted slightly from the Sea Watch Foundation template, and followed the behavioural data collection protocol used to record behavioural data every three minutes during dedicated LT or NLT surveys. If multiple dolphin groups were present at a time, the first group to be sighted was ‘followed’ for the duration of their presence; once a group left the study area or could no longer be seen, the next group to arrive was then recorded as a new sighting. In this study, a *sighting* was defined as a group of dolphins “observed in apparent association, moving in the same direction and often, but not always, engaged in the same activity” (Shane, 1990), with all individuals “usually remaining within approximately 100m of each other” (Bearzi *et al*., 1999). The behaviour of the focal group was observed and documented in five minute intervals; if new individuals joined the group or existing individuals left, then this was recorded as a new *set*, within the sighting. If no dolphins were present during a time interval, this was simply recorded as ‘none sighted’ to acquire absence data. Each main behaviour was designated a code defined by the Sea Watch behavioural data collection protocol, which are described in **Table 1**. A behavioural photographic catalogue, showing key examples of some types of behaviour, is available in **Appendix II**.

Table 1: The ten different behaviours classified in the study, with a short description of their classification features, along with an Unknown category for those that could not be attributed to any of the behavioural categories.

Behaviour (code)	*Description*
Slow Swimming/travelling (SS)	A regular pattern of swimming/diving and surfacing to travel through an area at a speed of less than 3 knots; note, this was recorded as a *travelling* behaviour
Normal Swimming/travelling (NS)	A regular pattern of swimming/diving and surfacing to travel through an area at a speed of 3-6 knots; note, this was recorded as a *travelling* behaviour
Fast Swimming/travelling (FS)	A regular pattern of swimming/diving and surfacing to travel through an area at a speed of more than 6 knots; note, this was recorded as a *travelling* behaviour
Definite Feeding (FF)	Feeding confirmed as definite by sighting the dolphins consuming or pursuing fish
Suspected Feeding (SF)	Most likely feeding behaviour but cannot confirm as definite as no fish are seen; a characteristic behaviour of SF/FF is the observation of a tail fluke as an individual undertakes a deep foraging dive (‘flukes-up’, defined by Shane, 1990) or observation of the peduncle, but not tail fluke, as the animal dives (‘tail-stock’, defined by Shane, 1990)
Bow-Riding (B)	Dolphins observed moving towards the boat to swim alongside the bow in the pressure wave created by the boat movement, “between the surface and a meter or less underwater” (Weaver, 1987; Bearzi *et al*., 1999)
Resting/Milling (R)	No significant movement patterns and no apparent direction, with a large proportion of time spent at the surface; includes behaviours such as floating, “stationary position at interface, exposing foresection of animal” (Weaver, 1987; Bearzi *et al*., 1999)
Socialising (S)	Multiple individuals in tight association with one another, with lots of inter-individual interaction, displaying percussive & aerial behaviours, interacting with jellyfish or mating behaviours, usually accompanied with lots of spray and splashing as dolphins break the surface
Percussive Behaviour (PB)	Includes behaviours during which ***part***, but not all, of the body comes out of the water. Key examples include tail slapping, the “flat and noisy contact of caudal section on water surface” (Weaver, 1987; Bearzi *et al*., 1999) and breaching, in which an individual “elevates of portion of foresection above surface, and drops flatly and noisily on lateral side” (Weaver, 1987; Bearzi *et al*., 1999)

Aerial Behaviour (AB)	Includes behaviours during which the ***whole*** body comes out of the water, including leaps, the "airborne forward progress of at least one body length, while in dorsal position" (Weaver, 1987; Bearzi *et al*., 1999)
Unknown (U)	Behaviour could not be attributed to any of the categories described above

In addition to recording the types of behaviour present, a number of other behavioural variables were noted in each five-minute interval, including group form (**Table 2**), surf mode & direction to give a greater understanding of the movement patterns and associations within a group. Surf mode was defined as Quiet (Q), where surfacing is low impact with no foam or spray; Peppy (P), where surfacing is associated with faster movements and has lots of spray/splashes, or Uncertainty (U), where surfacing is variable or does not fit appropriately into the other categories. Direction was categorised as None (No), with no specific travelling direction and behaviour is maintained in one area; Poor (Po), with direction variable, including zig-zagging, but gradual directional movement occurs; Straight (St), with individuals moving significantly in a given direction; or Unknown (U), where direction could not be attributed to any of the aforementioned categories.

Table 2: The five categories used to classify group form in the study, along with a description of their key characteristics.

Group form (code)	*Description*
Alone (A)	A single individual travelling alone
Tight (T)	Individuals within a pod are less than 1 dolphin body length from one other (Shane, 1990; Bearzi *et al*., 1999), commonly seen with mothers and calves
Loose (L)	"At least one individual is within 1-5 dolphin body lengths from the others" (Shane, 1990; Bearzi *et al*., 1999)
Dispersed (D)	"At least one individual is more than 5 dolphin body lengths from the others" (Shane, 1990; Bearzi *et al*., 1999)
Patchy (P)	Group form is unknown, changes quickly, or does not fit appropriately into the other categories

Aside from behavioural variables, detail of the overall composition of the group was recorded as the number of Adults (A), Juveniles (J), Calves (C), Newborns (N), or Unknown (U) (**Figure 26**), along with total group size. All timekeeping and dive times were monitored using a Casio wristwatch, with the start of the dive commencing as soon as the animal began to go under the surface, and end of the dive immediately upon resurfacing. Dive times (seconds) were recorded for a focal individual within the group, ideally one of which would be chosen at random, as many times as possible. However, individuals with unique markings or mother and calf pairs often caught the eye, and were easier to confirm upon resurfacing, so the choice of individual to follow for a dive time may not necessarily be completely random. Finally, the cetacean response to the vessel was noted during boat-based surveys (Away (A), Towards (T), Neutral (N) or Unknown (U)), and the equivalent for land-based surveys, observation of any vessel presence within each five minute interval. The presence of birds circling above dolphins, often associated with feeding behaviour (Evans, 1982), was recorded also; this includes species such as herring gulls (*Larus argentatus*), gannets (*Morus bassanus*) and great black-backed gulls (*Larus marinus*).

a) *Newborn calf*

Presence of foetal folds, meaning calf is less than 12 months old and is classified as newborn; calves over this age lose foetal folds as they grow

Small body size

Pale skin pigmentation

b) *Juvenile*

Foetal folds lost; individual is over 12 months old

Moderate body size, often unmarked, smooth dorsal fins in comparison to adults

Darker skin pigmentation

c) *Adult w/ calf*

Adults have a large body size and frequently have well-marked dorsal fins

Dark skin pigmentation, scratches and discoloration often present

Can be seen in association with calves, note the larger body & dorsal fin size of the adult

Figure 26: Photographic examples of different bottlenose dolphin life stages taken during the study period. **a)** A calf with prominent foetal folds, indicated by the white arrow, which are from when the calf was curled up inside the mother, indicating that this is a newborn calf; **b)** a potential juvenile surfacing, indicated by the absence of foetal folds, darker colouration, small body size and generally smooth, unmarked dorsal fin; **c)** a mother and calf pair, with the calf indicated by the white arrow. Adults are large in size and can have a range of dorsal fin markings and discolouration, in comparison to the smaller, unmarked calf. The calf in this photograph has lost its foetal folds, and hence is not classed as a newborn.

2.5 Photographing bottlenose dolphins

In addition to recording effort and behavioural data, photographs of the dolphins were taken whenever possible, to be used for capturing different behaviours, brief image analysis and potential photo-identification (photo-ID). All photographs of dolphins obtained during this study were taken by myself using a Canon 7D Mark II Digital Single-Lens Reflex (DSLR) camera, with a 70-300mm lens with image stabiliser. The exception to this was five dolphin photographs taken on the 27th May, which were photographed by family members as a casual sighting. In addition, in order to photograph high sea states or adverse/wet weather, an Olympus Tough digital camera was used in place of the main Canon camera, as this was waterproof and avoided any damage to the camera body & lens. The Canon DSLR also had a Global Positioning System (GPS) function built into the camera, meaning that photographs could be geotagged and coordinates obtained for each photograph when the GPS was enabled, in addition to the time/date stamp, altitude, focal length (mm), exposure time (shutter speed), International Standards Organisation (ISO) speed and a bearing when the digital compass was calibrated. Furthermore, a GPS logging function could also be enabled to produce a real-time track of boat surveys, which could be downloaded and visualised on the Canon Map Utility software, as shown in section **2.2 Surveying approaches**. Enabling the GPS quickly expended the battery, so therefore the GPS was set to update every 15 seconds during tracking instead of every second on order to conserve battery life whilst gathering accurate survey tracks.

2.5.1 Technical details for cetacean photography

In regards to specific settings for photographing bottlenose dolphins, in this study the following settings were primarily used with the Canon DSLR: 1/2000 shutter speed, 400-800 ISO, although this range was increased depending on availability of natural light, and continuous shooting in Shutter Priority (TV) mode. The Shutter Priority mode allowed for control of shutter speed and aperture was adjusted automatically. A continuous shooting mode allowed for a large volume of images to be taken in a short time frame, increasing the chance of obtaining a suitable high quality photograph. To maintain organisation of photographs and mark separate sightings, a ‘spacer’ photograph was taken when possible between sightings to avoid mix-up of encounters and information from data sheets could be appropriately cross-compared with photographs. Spacer photographs included the pier, herring gulls and objects on board vessels; photographs of the sea were avoided as these could be confused as a potential sighting.

2.6 Constraints and logistical issues to be overcome

2.6.1 Trialling the survey methodologies

As with the majority of field work, in some cases obstacles occur or certain aspects may be constrained by logistical/weather-related problems. The first week of surveying following the training week suffered from a bout of bad weather, which halted boat activities and surveying was constrained to land when possible. However, this provided a useful opportunity to trial the proposed surveying methodologies, practice photography when conditions allowed, and identify any logistical issues. The initial issue to be recognised during this week was the originally proposed three-minute observation intervals for recording behaviours. This was found to be incredibly difficult, as the three-minute intervals did not allow sufficient time to complete the data sheets and attempt photography before the next interval, hence it was altered to five-minute intervals to ensure the data set obtained was of high quality. Another issue addressed during this first week was the possibility of following multiple pods for behaviour recordings. Originally, all pods encountered in the survey area were proposed to be observed and their behaviours recorded; again, this was extremely difficult and led to confusion on the datasheets, so the decision was made to record only one pod at a time; this would be the first pod seen and they would be observed until they left the study area. Upon leaving, the next pod to arrive/already in the area would be observed as a new sighting.

2.6.2 Effort data & boat encounters

Effort data was aimed to be collected on all surveys, however, as previously mentioned, completing effort, sightings & behaviour data sheets along with undertaking photography on board the *Ermol VI* was notoriously difficult. Therefore, many of the effort measurements for this methodology are incomplete. In addition, surveying from cliff locations away from New Quay meant that assessing specific environmental parameters was difficult due to absence of landmarks, and hence for some locations this effort data is also incomplete. However, sea state was recorded by myself for every five-minute interval from land, cliff and on board the *Ermol VI*, and every fifteen minutes on the longer *Dunbar/Machipe* surveys. This was to undertake a specific focus on sea state for my environmental variables hypothesis, to correlate with average number of individuals recorded and compare between survey methodologies. In regards to boat encounters recorded during land surveys, the first boat encounter seen within each fifteen-minute interval for any pod was recorded on the effort form. This may not necessarily have been the pod I was following at the time, and therefore boat encounters could not be assessed for my data set. Reaction to the vessel was recorded for boat surveys, so this was used as an alternative for identifying bottlenose dolphin reactions and avoidance behaviours in response to vessels.

2.6.3 Weather & abandoned surveys

As previously stated, cetacean surveying is highly weather dependent. Ideally, conditions should be sea state ≤ 3, a visibility radius of at least 1.5km, and no precipitation (Norrman *et al*., 2015). Weather can vary greatly over the course of a survey, and this led to abandoned surveys from land (N=4), which were cancelled after a turn in weather during the survey. To account for differences in likelihood of detecting cetaceans in poor weather conditions, abandoned surveys were collated separately along with data in which the sea state was > 3 (*see* **2.7 Data analysis & visualisation**).

2.6.4 Drone surveys

Unfortunately, due to weather conditions, boat availability, time and logistical constraints, no drone surveys were carried out during the course of the study. However, the cliff watches undertaken offered an alternative aerial perspective, with photography taken where possible to investigate the potential images that might be generated from drone footage. This was also compared with test footage acquired from a drone trial at Bull Bay, Anglesey on 10th May 2017.

2.7 Data analysis & visualisation

2.7.1 Software for analysis

All data was collated and visualised using Microsoft Excel (2013) & statistical analysis was performed using R Statistical Software, version 3.1.2, with the following packages installed: "*car*" for Levene's Test of Homogeneity of Variances & "*Kendall*" for Kendall's Rank Correlation. R code for analysis is given in **Appendix V**. Maps of surveying and sighting locations were produced using ArcMap version 10.4.1, with shapefiles made in ArcCatalog 10.4.1, using Comma Separated Values (CSV) files of data inputted into Excel spreadsheets. In regards to mapping vessel survey tracks, GPS log tracks were downloaded from the camera, and opened in Canon Utilities Map Utility, version 1.8.1.2, converted to a Keyhole Markup Language (KMZ) file which is compatible with Google Earth. KMZ files were opened in Google Earth Pro, version 7.3.0.3832, and aesthetically altered for inclusion in this thesis. Total length of each survey (km) could be obtained from this software also. All Google satellite images utilised are © Google Earth, 2017; data contributors to satellite imagery are embedded in the bottom corner of the maps.

2.7.2 Temporal trends & Sighting Per Unit Effort (SPUE)

To investigate trend over time in the number of pods followed for behavioural analysis, the Sighting Per Unit Effort (SPUE) was calculated as the number of pods observed per survey, divided by the total surveying time (minutes), separated by land and boat surveys. SPUE was visualised as scatter plots, and a regression line fitted to determine temporal trends. Prior to statistical analysis, surveying dates were converted to decimal days, which can be read by R. Decimal days are simply attributing a number to where that day falls in the year, e.g. January 1st = 1, January 2nd = 2, and so forth. After land-based data met the assumption of homogeneity for a linear model (Levene's Test for Homogeneity of Variances, $p = 0.75$), a linear regression was performed; this was repeated for boat-based data which also met the homogeneity assumption ($p = 0.19$).

2.7.3 Outliers, poor weather & abandoned land watch data

After some initial statistical analysis, a single outlier was found, the land watch from the 7th June at 11:00-13:00 (SPUE=0.07); this was the first land watch of the study undertaken, so is likely to be due to attempting to record multiple dolphin pods at once, hence the behaviour of every pod encountered was attempted to be observed, but this was found to be logistically difficult and data quality was poorer. The decision was made to remove this outlier from all statistical analysis to avoid overestimation of sightings, pod counts and behaviours. In addition, six surveys were completed in unfavourable weather conditions, however, to maintain appropriate cetacean surveying protocol and avoid underestimations of pod counts, behavioural observations and sightings, they were considered separately to the favourable weather dataset, along with abandoned land watches. The exception to this was for environmental data & SPUE, in which poor weather data was included to assess the effect of sea state on total number of dolphins recorded, and to investigate temporal patterns in the total number of sightings recorded over the study period.

2.7.4 Environmental data

In regards to environmental variables influencing likelihood of cetacean detection, the average total number of individuals per sighting was determined along with average sea state for the survey. Average sea state was rounded to the nearest 0.5, and visualised as a scatter plot. A linear model (one-way ANOVA) was performed for land and boat data separately, after both met the homogeneity assumptions of a linear model (Levene's Test for Homogeneity of Variances, $p = 0.93$ & 0.96, respectively). Rounded sea state data was also used for the ANOVA to correlate with average total number of individuals.

2.7.5 Behavioural data

The behavioural data set was particularly large due to recording behaviour in five-minute intervals, for both land and boat-based surveys, so for visualisation purposes, the land watch data were split into cliff watches & pier data for each month, and boat data split into *Ermol VI* trips and dedicated surveys, also for each month. Surveys varied in their duration, due to factors such as time constraints. When data were initially collected during the first week, more data were obtained as multiple groups of dolphins were attempted to be observed and recorded during the survey. Therefore, to account for variation in the number of intervals spent watching and recording the dolphins on any given survey, an average was taken of the frequency of occurrence of every behaviour recorded for every land watch and boat survey, and visualised as a scatter graph to show temporal change. Temporal change for each behaviour was tested statistically by undertaking a Levene's Test for Homogeneity for each behaviour, of which all were homogeneous ($p > 0.05$). Land and boat data were analysed separately by a linear regression of survey day (decimal day) against average frequency of occurrence of each behaviour. The one exception was Suspected Feeding for the boat-based data, which violated the assumptions of the Levene's Test ($p = 0.05$), and could not be log-transformed due to the presence of zeros in the data set, hence a non-parametric alternative, Kendall's Rank Correlation was performed. Normally a Spearman's Rank would be sufficient, however Kendall's Rank is specifically suited to data sets with ties, or values which are the same, by computing a more exact *p*-value. In this case, multiple surveys were done on the same day, and therefore several ties in the data set (same day), deemed Kendall's Rank to be more appropriate. In regards to comparing surveying methodologies, a one-way ANOVA was performed for each behaviour, including type of survey as the independent variable. This was post a Levene's Test for Homogeneity of which all behaviours met the assumptions ($p > 0.05$).

2.7.6 Dive times

With regards to dive times, both the data for focal individuals and mothers with calves showed a non-parametric distribution when the data was visually inspected, and hence a Kruskal-Wallis Rank Sum Test was performed to compare dive times between methodologies for both focal individuals and mothers with calves. The data was visualised as a bar chart with calculated Standard Error (SE) bars for each month, separated into land watches, *Ermol VI* surveys and *Dunbar* surveys.

2.7.7 Average total number of individuals per sighting

To determine any differences in the average total number of individuals between land and boat-based surveys, firstly the total number of individuals was averaged for every sighting for both surveying methods. An average needed to be undertaken because pod sizes were recorded in five-minute intervals; simply summing these would not be representative. A Levene's Test returned non-significance for both data sets combined ($p = 0.97$), and therefore a one-way ANOVA was performed to test for significance in average total number of individuals per sighting between the survey types. In addition, temporal trends over time were investigated for each surveying method. Date of each survey was converted to decimal day for analysis, both land and boat data returned non-significance following a Levene's Test ($p = 0.88$ and $p = 0.50$, respectively). Therefore a linear regression could be undertaken for both surveying types.

3. Results

3.1 Survey intensity & bottlenose dolphin presence

A total of 177.93 hours/10,676 minutes of surveying was undertaken during the study period (N=105 surveys), from 7th June until 15th August, which included 99.26 hours of land-based data and 78.67 hours of boat-based data (**Figure 27**). A total of 24 casual sightings were observed during the study (**Table 3**). June was the primary surveying month, with 49.34% (N=87.80 hours) of surveys (including abandoned surveys; **Table 4**), followed by July 42.83% (N=76.20 hours) and August 7.83% (N=13.93 hours) (**Figure 29**). Bottlenose dolphins were very active during the study period, with dolphins sighted on 69.52% of surveys (N=73), yielding a large volume of data and a wide diversity of behaviours recorded and photographed.

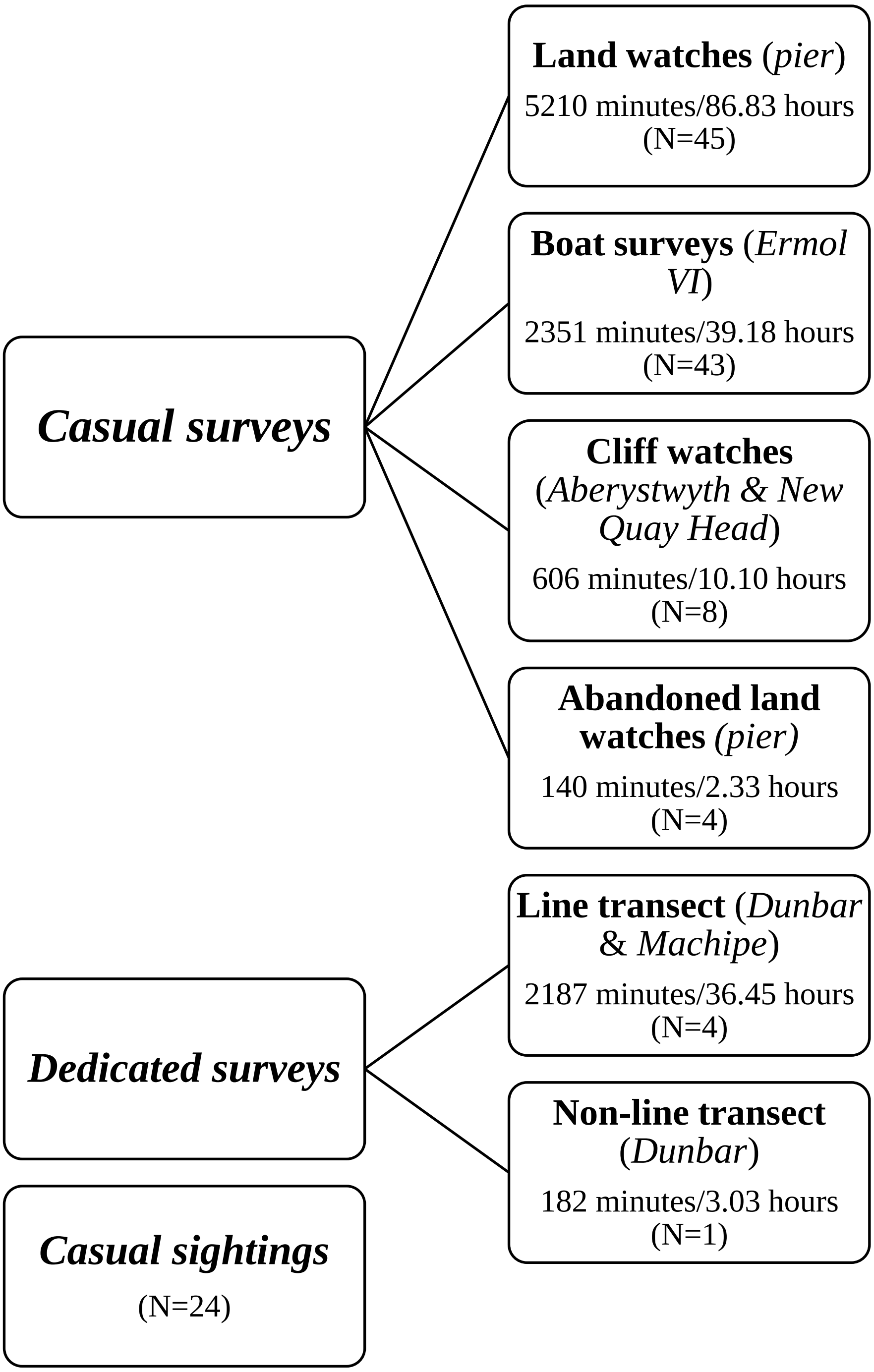


Figure 27: A visualisation of the different types of surveys undertaken, with the overall time spent recording data for that particular survey type in minutes/hours along with total number (N) of surveys.

Table 3: Details of casual sightings noted during the study period, including location of sighting, date & time, best estimate of the maximum number of individuals and any details of behaviour. Locations for which coordinates were obtained are included in brackets beneath the survey location. * Denotes a sighting which was originally supposed to be a survey, but turned into a casual sighting as the survey could only be done for 30 minutes instead of the original hour due to time constraints. ^ Denotes a sighting for which location, date and time could not be identified when compiling the dataset.

#	*Location when sighted*	*Date & time*	*Best estimate of total number of individuals*	*Details (behaviour)*
1	Quay West Caravan Park (**Figure 28**)	27/05/2017; 21:54	1	Individual sighted amongst harbour boats (SF)
2	From Sea Watch office window	11/06/2017; 17:00	2	Individuals travelling close to shore, with a paddle boarder present, sighting location approximately 52.216368, -4.359344 (deduced from Google Earth) (NS; SF; PB)
3	New Road	14/06/2017; 06:15	2	Individuals feeding by Cardinal Mark in a loose aggregation and peppy surfacing mode (SF)
4	Outside Sea Watch office	14/06/2016; 06:33	1	Individual feeding by fish factory in a peppy surfacing mode (SF)
5	New Road	18/06/2017; 07:00	3	Two individuals tight together in VPB wake by Cardinal Mark, one individual by fish factory, quiet surfacing mode, no direction (NS; SF)
6	Cardigan Island (52.129561, -4.684931)	19/06/2017; 17:29	3	Individuals surfacing tight together, most likely two adults and a calf, showing a quiet surfacing mode, straight swimming direction

7	Coastal path from New Quay Head	02/07/2017; 19:16	1	Individual surfacing by Cardinal Mark (NS)
8	New Road	03/07/2017; 15:15	1	Individual swimming close to pier (NS)
9	From outside Sea Watch office	05/07/2017; 06:47	1	Individual seen swimming close to shore adjacent to car park (SF)
10	From Sea Watch office window	14/07/2017; 16:34	2	Individuals tight together, showing peppy surfacing and undertaking deep dives, in a poor direction (SF)
11	New Quay Head* (52.215036, -4.375950)	17/07/2017; 18:00	5	Five individuals, including four adults and a calf/newborn, showing peppy surfacing, poor direction, and alternating between tight and distant in group form. This group were observed from 18:00-18:30, no boats present until *Epic Fishing Trips* at 18:15 and *SeaMor* at 18:20 (S; AB; PB; SF)
12	New Quay Head	17/07/2017; 18:38	1	Lone individual showing a peppy surfacing mode and no direction (SF)
13	From Sea Watch office window	22/07/2017; 15:02	3	Three individuals tight together showing lots of aerial displays and a peppy surfacing mode, no direction (SF; AB)
14	From Sea Watch office window	22/07/2017; 16:35	1	Individual surfacing quietly in the presence of a boat (NS)
15	From Sea Watch office window	26/07/2017; 18:41	4	Group possibly including ‘Ghost’, individuals showing tail slaps with the *Anna Lloyd* present (PB; NS)

16	From Sea Watch office window	26/07/2017; 18:41	1	Lone individual swimming (NS)
17	From Sea Watch office window	27/07/2017; 12:47	2	Individuals splashing in a tight aggregation and peppy surfacing mode, with no direction, boat present (PB)
18	From outside Sea Watch office	27/07/2017; 10:13	1	Individual surfacing by the pier, showing a quiet surfacing mode and no direction (NS)
19	From Sea Watch office window	28/07/2017; 15:30	1	Individual surfacing quietly by the pier, displaying poor direction (NS)
20	From Sea Watch office window	28/07/2017; 17:08	2	Individuals surfacing tight together, at the end of Dolau beach, with a quiet surfacing mode and straight direction; kayak was present (NS)
21	From Sea Watch office window	30/07/2017; 15:00	2	Individuals surfing the waves in a loose formation at the point, showing aerial behaviours and peppy surfacing mode, with no direction (AB)
22	From Sea Watch office window	31/07/2017; 16:22	2	Individuals surfacing in a loose formation near a boat, showing a peppy surfacing mode and variable swimming direction (NS)
23	From Sea Watch office window	02/08/2017; 19:33	1	Possible juvenile surfacing off Dolau beach, with a quiet surfacing mode (NS)
24	?^	?	4	Individuals in tight aggregation and peppy surfacing mode (SF; AB; PB)

Figure 28: An example of a casual sighting observed from the Quay West Caravan Park on 27th May at 21:54. The individual appears to be a lone dolphin engaging in Suspected Feeding amongst moored vessels. The time of day and large distance between the photographer and focal dolphin reduces the image quality; nevertheless, photographs provide an important documentation of dolphin activity within the bay.

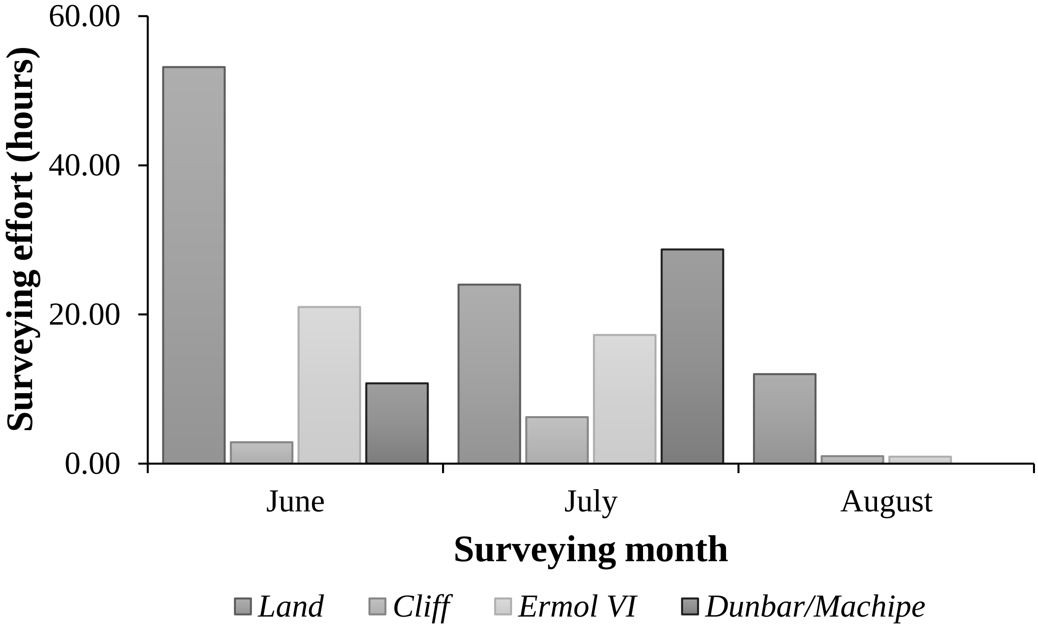


Figure 29: The surveying effort per month (hours), for each type of survey: land watches, cliff watches, *Ermol VI* boat surveys and dedicated LT/NLT boat surveys on the *Dunbar/Machipe*.

Table 4: Details of the abandoned land watches (N=4), including date, time spent recording before being abandoned, and reasoning behind cancelling the land watch.

Date (dd/mm/yyyy)	*Time spent recording (minutes)*	*Reason for abandonment*
07/06/2017	0.35	Heavy rain
08/06/2017	0.30	Heavy rain; poor visibility
11/06/2017	0.60	High swell & sea state
22/06/2017	0.15	Heavy rain, poor visibility

3.1.1 Bottlenose dolphin sightings, temporal change & Sighting Per Unit Effort (SPUE)

Bottlenose dolphins were a regular visitor on surveys throughout the study period, being sighted on 84.44% of land watches (N=38), 80.00% of dedicated LT/NLT surveys (N=4), 62.79% of *Ermol VI* boat surveys (N=27) and 25.00% of cliff watches (N=2). Sightings occurred on 50.00% (N=2) of abandoned land watches. For land-based data (pier and cliff watches), the Sighting Per Unit Effort (SPUE) shows a significant decrease over time (linear regression, df = 1,50, f = 10.76, p = 0.002; **Figure 30**). The decrease in SPUE for followed focal pods indicates a higher 'turnover' of pods at the start of June, more pods are entering and leaving the harbour area in the same time frame (effort period) than those later in the summer, hence the higher number of pods followed. Throughout the summer, the same pods could sometimes be observed for the entire land watch duration, for example, the 09:00-11:00 land watch on 19th June, where the same pod was observed for the whole two hours, comprising of five sets, indicating that dolphins are staying in the area for a prolonged period of time; this appeared to increase over the course of the summer and hence the 'turnover' rate, or SPUE, is lower because the same pod(s) are followed. In contrast, for boat-based data (*Ermol VI*, *Dunbar* & *Machipe*), the SPUE shows a non-significant increase over time (linear regression, df = 1,46, f = 2.78, p = 0.10; **Figure 30**). Again, this may be attributed to a number of pods remaining in the harbour area for a longer duration at the end of summer, and so boats are more likely to encounter the same pod twice upon departure and return to New Quay as separate sightings.

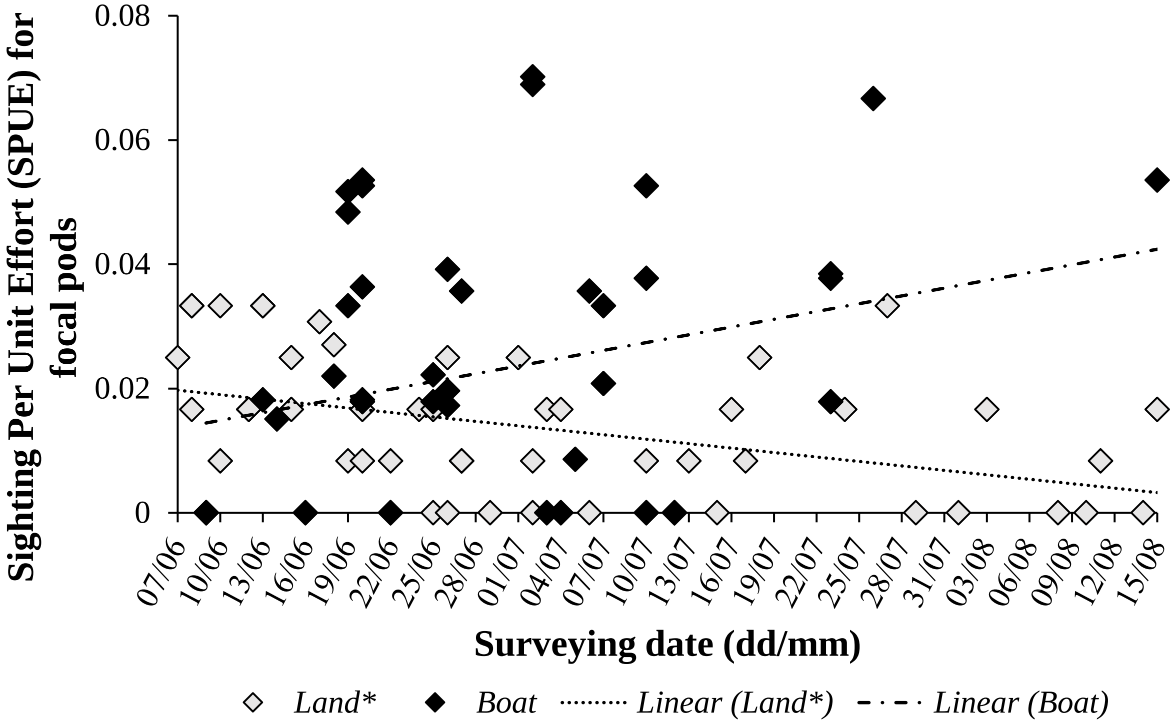


Figure 30: The Sighting Per Unit of Effort (SPUE) of focal bottlenose dolphin pods followed during land-based surveys and boat-based surveys, over the study period. Dates are shown every three days over the whole study period from 7th June to 15th August. Land data encompasses land watches (N=44) & cliff watches (N=8); boat data encompasses *Ermol VI* surveys (N=43) & *Dunbar/Machipe* surveys (N=5). * Denotes a significant linear regression output, at $p < 0.05$.

3.1.2 Bottlenose dolphin usage of the Cardigan Bay SAC

With regards to location of bottlenose dolphin sightings, the majority were predominantly observed around New Quay (**Figure 31**), confirming the importance of the Cardigan Bay SAC. Unfortunately, no bottlenose dolphins were observed from Aberystwyth or in the Pen Llŷn a'r Sarnau SAC, so it is most likely that this area is used as a migration pathway, rather than for Suspected Feeding or other activities.

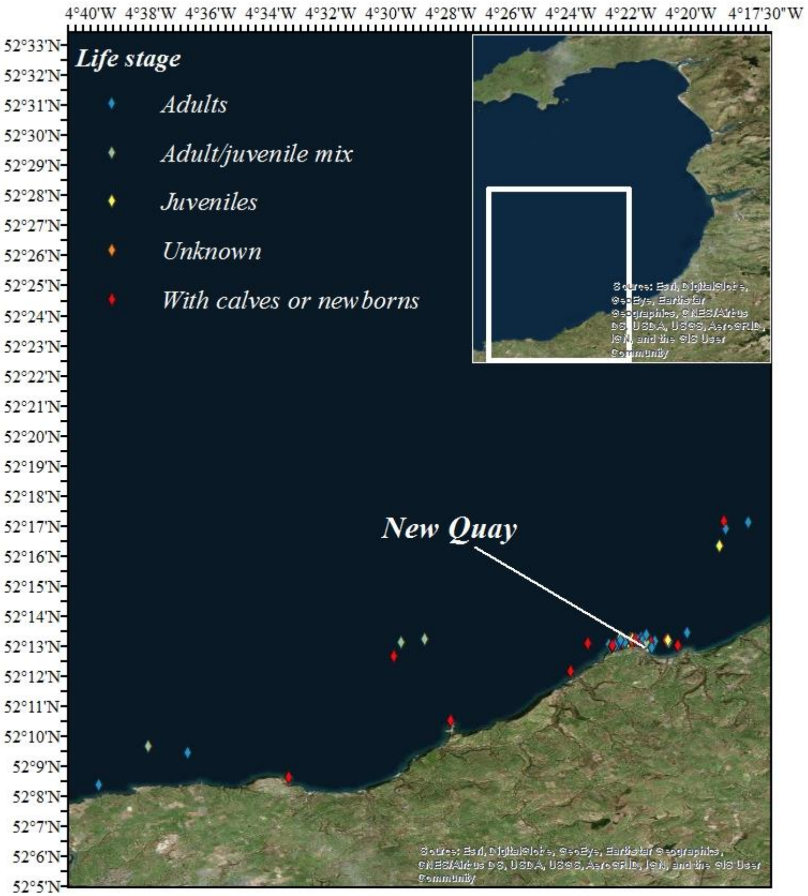


Figure 31: a) Locations of bottlenose dolphin sightings around Ceredigion seen from the *Ermol VI* and *Dunbar*. Colours denote the composition of each sighting, including all adults, a mixture of adults and juveniles, all juveniles, unknown life stage and groups with calves or newborns. **b)** A closer view of New Quay, where the greatest proportion of sightings were recorded. N=75 sightings recorded from boat-based surveys.

3.2 Environmental factors (effort data) & probability of detection

Sea state was found to fluctuate over the course of the study, varying from zero to five on the Beaufort scale during surveys (**Appendix I**). Sea state six was observed on 29th June from New Quay, however no surveying was carried out in New Quay on this day due to the unfavourable conditions. The maximum average sea state observed during land-based surveys was 5.00, and lower for boat-based surveys at 3.50; the activity of vessels was greatly altered by weather, so in high sea states boat surveys could not be undertaken or were confined to the calmer region around the harbour, hence the average maximum sea state is much lower than for land-based surveys. There was no significant correlation between average sea state and average total number of dolphins for land-based surveys, although it appears to show a slight negative correlation (one-way ANOVA, $df = 1,50$, $f = 0.82$, $p = 0.37$). However, a significant negative correlation was found for boat-based surveys (one-way ANOVA, $df = 1,46$, $f = 16.91$, $p < 0.001$; **Figure 32**). Therefore, sea state likely influences observer accuracy by increasing the likelihood of mis-counting/underestimating the total number of individuals in higher swell, particularly for boat-based surveys.

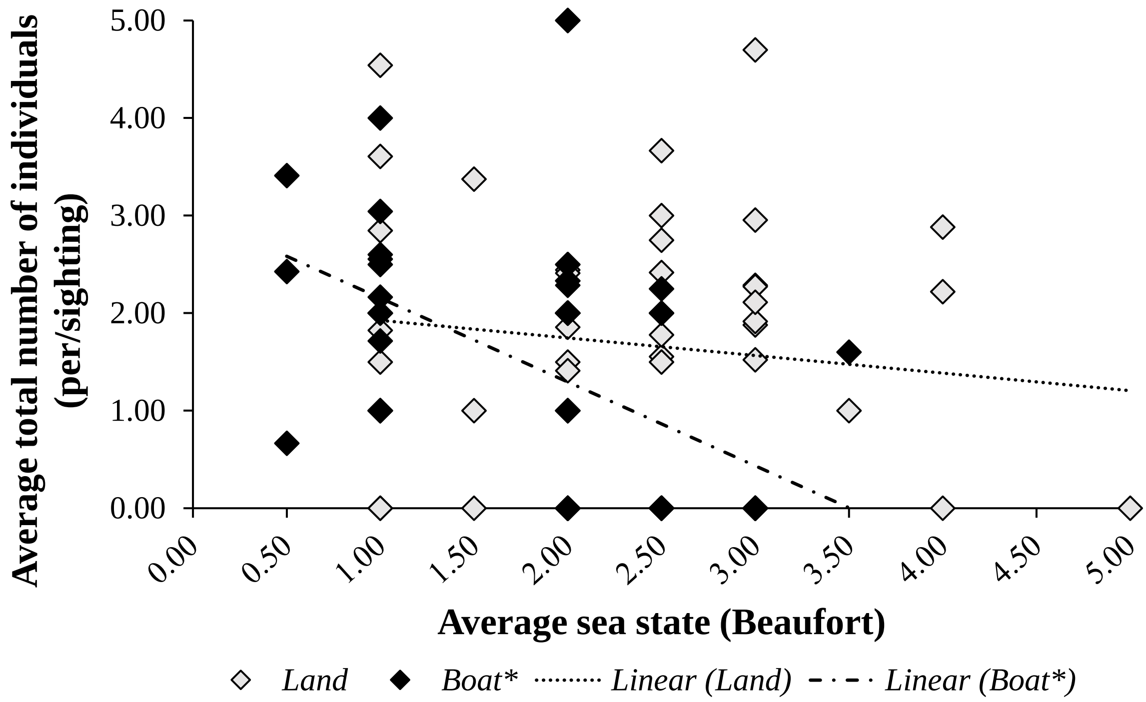


Figure 32: The average total number of dolphins per sighting from land & boats, in relation to average sea state (rounded to nearest 0.5) of each survey. N=52 land-based surveys, N=48 for boat-based surveys. * Denotes a significant ANOVA output at $p < 0.05$.

3.3 Bottlenose dolphin behaviour

3.3.1 Behaviour types & surveying methods

Overall, ten different types of behaviour were recorded across the study period, including eight 'Main behaviours' and two 'Other behaviours'. A full behavioural photograph catalogue is available in **Appendix II**. In some cases, behaviour was difficult to determine, in which case they would be categorised as 'Unknown'. A total of 1133 behavioural observations were made from 1573 five minute intervals for land watches, cliff watches and all boat surveys combined. The most frequently recorded behaviour overall for all surveys combined was Suspected Feeding (SF), being recorded in 37.86% of behavioural observations (N=429 observations) across the study period, followed by Normal Swimming (NS) (31.24%; N=354) and Percussive Behaviour (PB) (12%; N=136) (excluding abandoned/poor weather data). Unknown (U) behaviours accounted for just 0.26% (N=3) of behavioural observations. Definite Feeding (FF) was not recorded at all during the good weather surveys. In regards to survey methodologies, Suspected Feeding behaviours were the primary behaviour recorded for land-based surveys (41.89%), whereas swimming/travelling was the predominant behaviour recorded during boat-based surveys (46.18%) (**Figure 33)**. On the whole, all behaviours were recorded more frequently from land, with the exception of Bow-riding which was observed more from boats, as to be expected (0.36% & 4.42% respectively). It is likely that effort-related variables are attributed to these differences; land-based surveys were conducted for longer, and dolphin pods could be observed for much longer due to having no restrictions from the Marine Code of Conduct, unlike boat surveys.

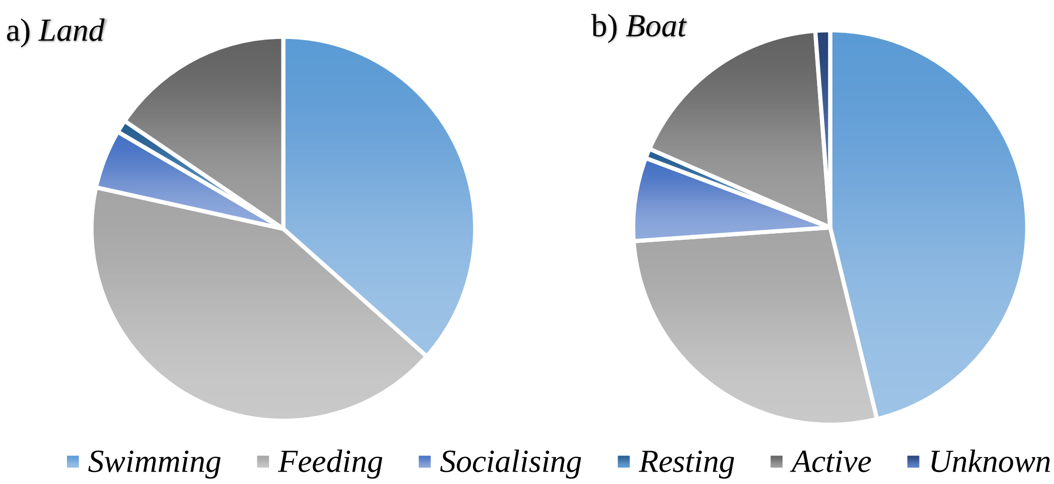


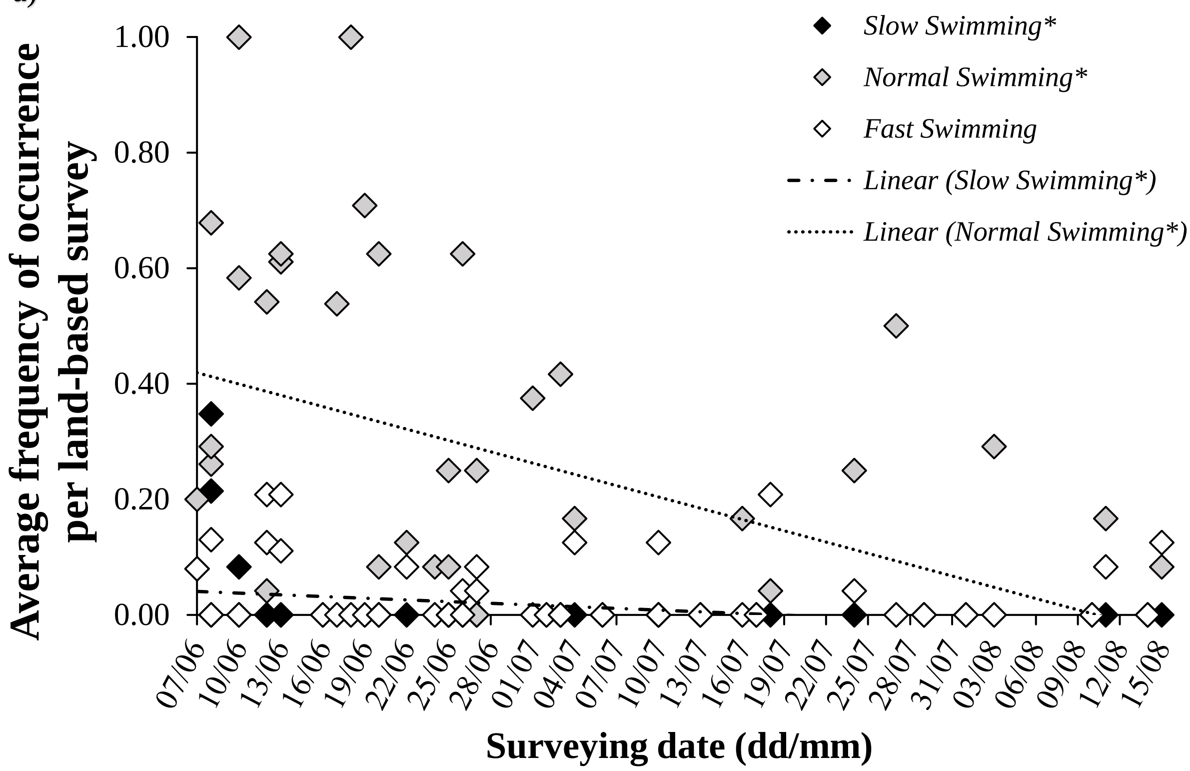
Figure 33: A pie chart showing the proportion of each behaviour seen from **a)** land watches & cliff watches combined, N=845 behavioural observations, and b) *Ermol VI* & *Dunbar* surveys

combined, N=249 behavioural observations. Socialising encompasses all social behaviour, along with Bow-Riding; active behaviours encompass Aerial Behaviour & Percussive Behaviour. Feeding behaviour is composed of Suspected Feeding as no Definite Feeding was observed during the favourable weather surveys.

3.3.2 Temporal changes in behaviour - land & cliff watches

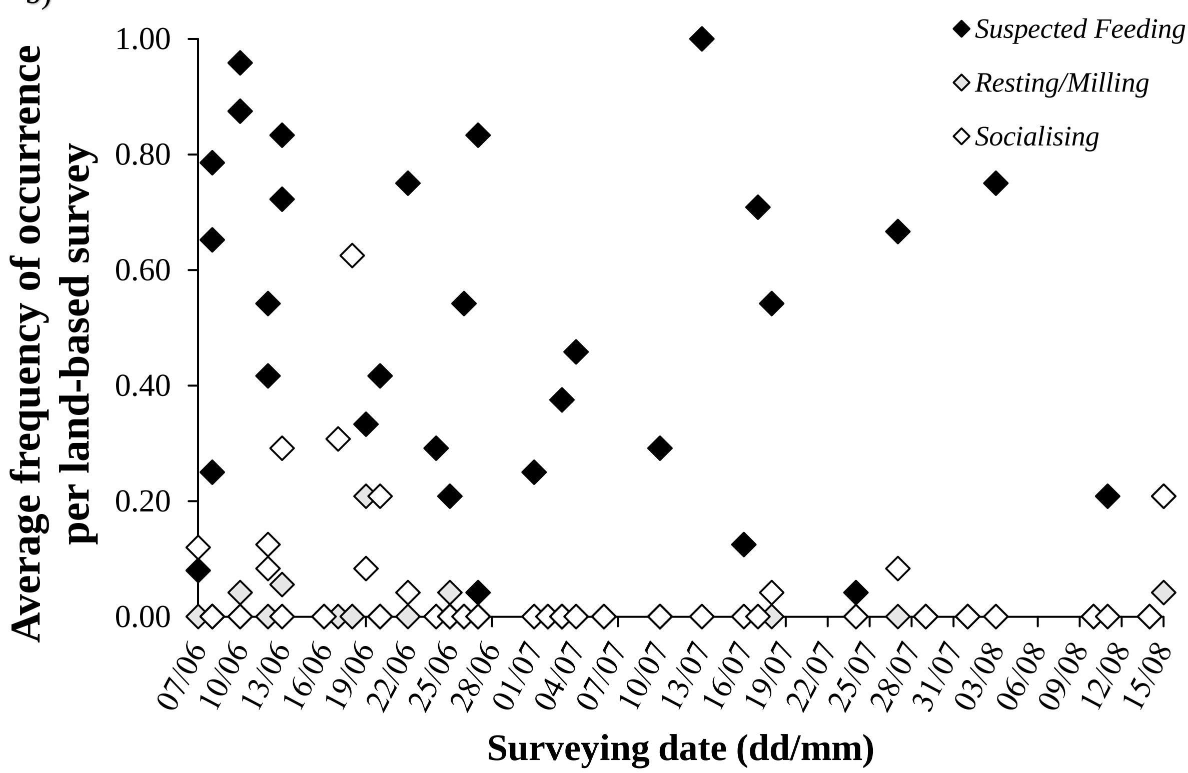
For land-based surveys in good weather, there were significant changes over time in four of the nine behaviours seen (**Figure 34**). Slow Swimming showed a strong significant decrease over time (linear regression, $df = 1,44$, $f = 4.88$, $p = 0.03$), as did Normal Swimming (linear regression, $df = 1,44$, $f = 11.43$, $p < 0.01$). Fast Swimming did not significantly change over time (linear regression, $df = 1,44$, $f = 0.46$, $p = 0.50$). Suspected Feeding was frequently recorded across the study period, however did not change significantly in frequency of occurrence over time (linear regression, $df = 1,44$, $f = 2.66$, $p = 0.11$), nor did Resting/Milling (linear regression, $df = 1,44$, $f = 0.54$, $p = 0.46$). Socialising also showed no significant change in frequency over time (linear regression, $df = 1,44$, $f = 1.45$, $p = 0.24$), and Bow-Riding was only rarely seen from land, nor did it show any significant temporal change (linear regression, $df = 1,44$, $f = 1.03$, $p = 0.32$) Percussive Behaviour did show a significant decrease over time (linear regression, $df = 1,44$, $f = 4.84$, $p = 0.03$), as did Aerial Behaviour, which was strongly significant (linear regression, $df = 1,44$, $f = 4.42$, $p = 0.04$).

a)



Slow Swimming*
Normal Swimming*
Fast Swimming
Linear (Slow Swimming*)
Linear (Normal Swimming*)
Average frequency of occurrence per land-based survey
1.00
0.80
0.60
0.40
0.20
0.00
07/06
10/06
13/06
16/06
19/06
22/06
25/06
28/06
01/07
04/07
07/07
10/07
13/07
16/07
19/07
22/07
25/07
28/07
31/07
03/08
06/08
09/08
12/08
15/08
Surveying date (dd/mm)

b)



Suspected Feeding
Resting/Milling
Socialising
Average frequency of occurrence per land-based survey
1.00
0.80
0.60
0.40
0.20
0.00
07/06
10/06
13/06
16/06
19/06
22/06
25/06
28/06
01/07
04/07
07/07
10/07
13/07
16/07
19/07
22/07
25/07
28/07
31/07
03/08
06/08
09/08
12/08
15/08
Surveying date (dd/mm)

c)

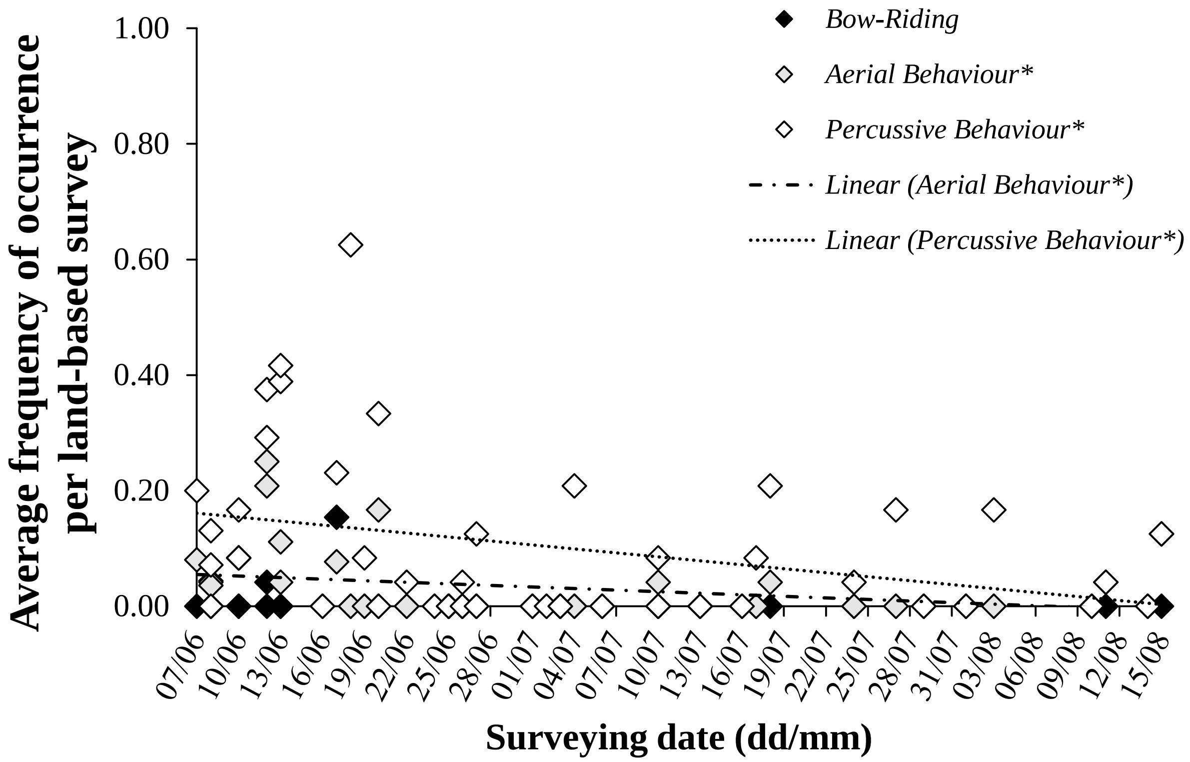
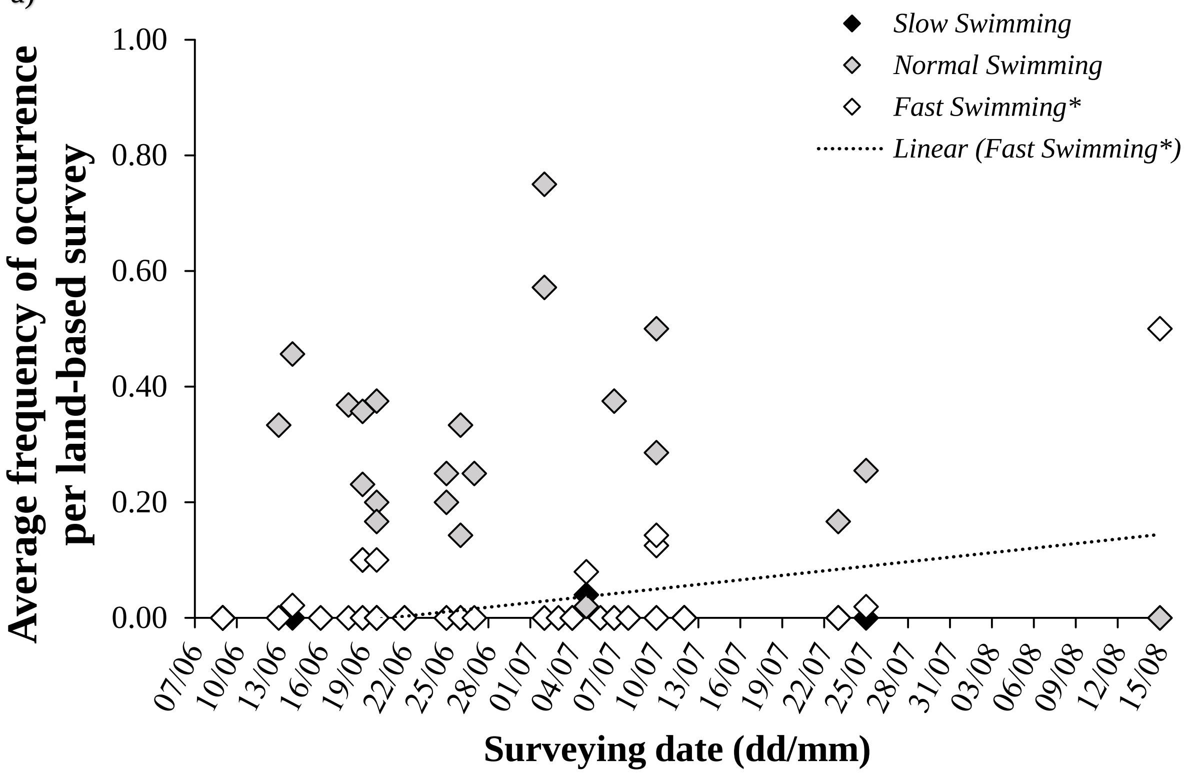


Figure 34: a) The average frequency of Slow Swimming, Normal Swimming & Fast Swimming; **b)** Suspected Feeding, Resting/Milling & Socialising; **c)** Bow-Riding, Aerial Behaviour & Percussive Behaviour for each land-based survey undertaken. Average frequencies derived from 1025 five-minute intervals over the study period. * Denotes a significant linear regression output, at $p < 0.05$, along with trend lines for the behaviours which returned significant change over time.

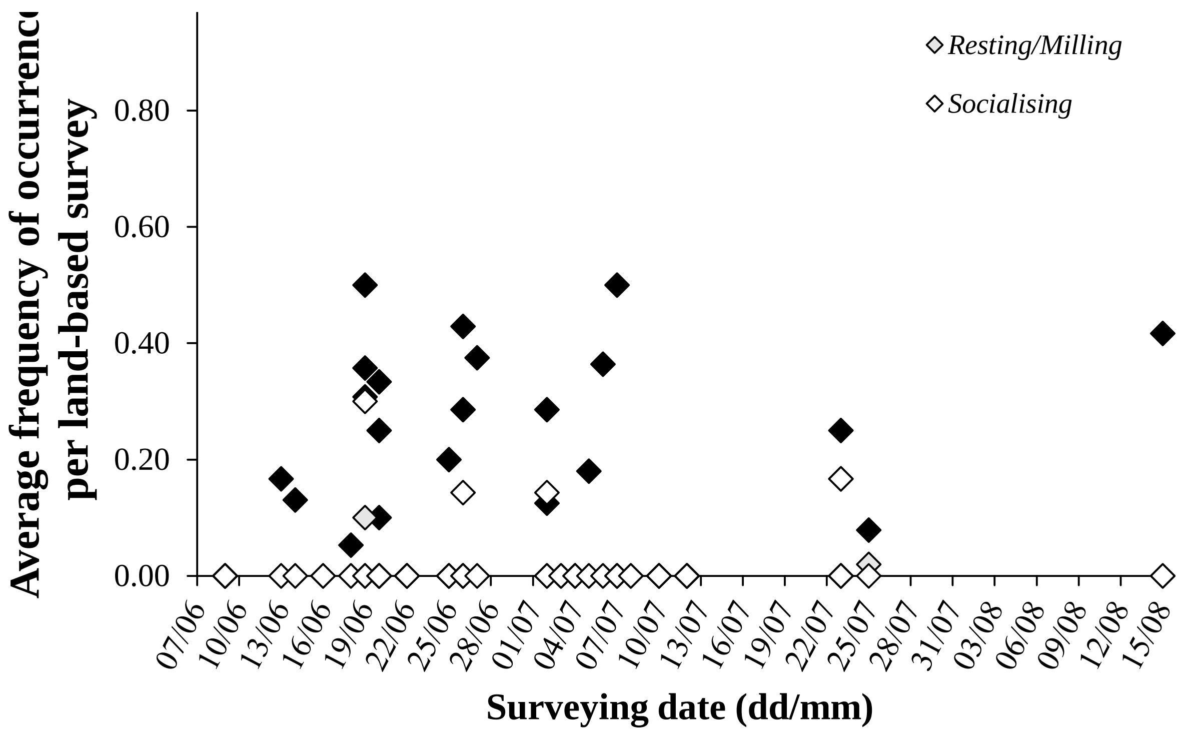
3.3.3 Temporal changes in behaviour – Ermol VI, Dunbar & Machipe

For boat-based surveys in good weather, there were no significant changes over time in any of the behaviours seen, with the exception of Fast Swimming (**Figure 35**). The average frequency of Slow Swimming behaviour did not change significantly over time (linear regression, *df* = 1,45, *f* = 0.32 , *p* = 0.60), nor did Normal Swimming (linear regression, *df* = 1,45, *f* = 0.49 , *p* = 0.49). Fast Swimming behaviour showed a significant positive correlation (linear regression, *df* = 1,45, *f* = 12.88 , *p* < 0.01). Suspected Feeding showed a non-significant slight decrease in frequency over time (Kendall's Rank Correlation, *tau* = -0.01, *2-sided p* = 0.91). Resting/Milling behaviour also showed a non-significant relationship (linear regression, *df* = 1,45, *f* = 0.16 , *p* = 0.69), as did Socialising (linear regression, *df* = 1,45, *f* < 0.01 , *p* = 0.95) and Bow-Riding (linear regression, *df* = 1,45, *f* = 0.36 , *p* = 0.55). For the other behaviours, Percussive Behaviour showed no significant change (linear regression, $df = 1,45$, $f < 0.001$, $p = 0.95$), nor did Aerial Behaviour (linear regression, $df = 1,45$, $f < 0.01$, $p = 0.95$).

a)



b)



c)

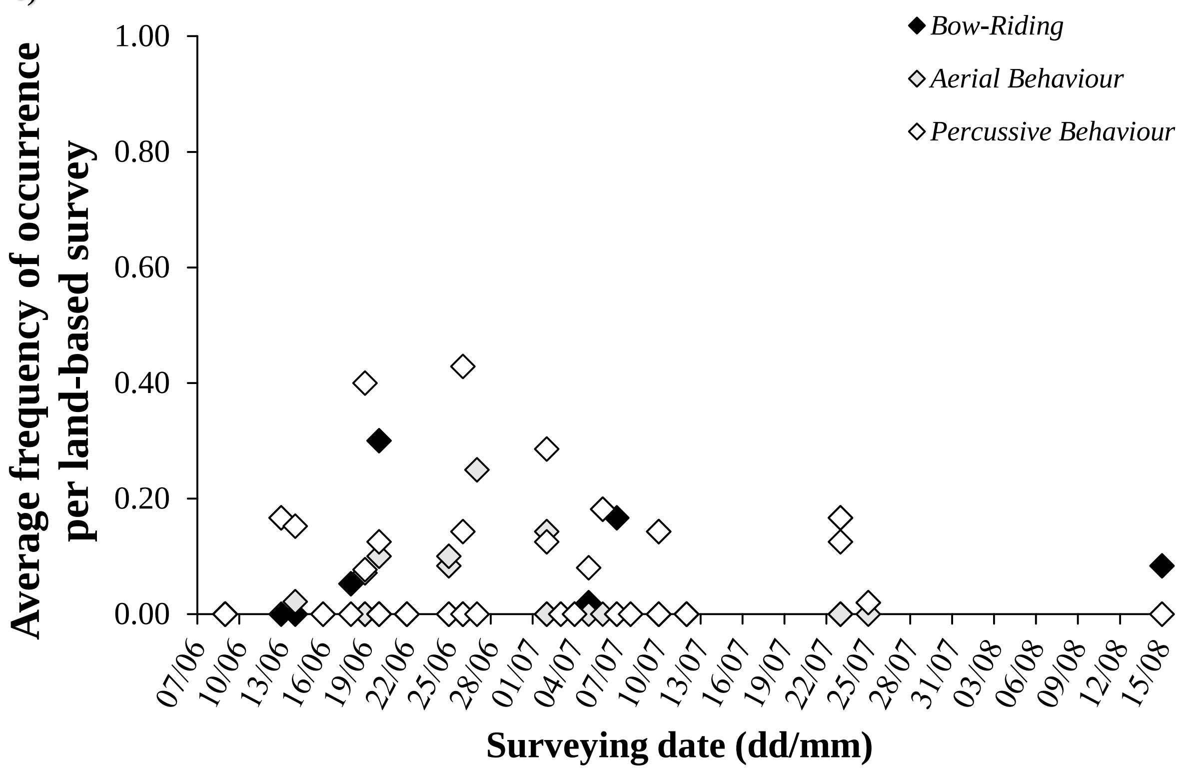


Figure 35: a) The average frequency of Slow Swimming, Normal swimming & Fast Swimming; **b)** Suspected Feeding, Resting/Milling & Socialising; **c)** Bow-Riding, Aerial Behaviour & Percussive Behaviour for each boat-based survey undertaken. Average frequencies derived from 531 five-minute intervals over the study period. * Denotes a significant linear regression output, at $p < 0.05$, along with trend lines for the behaviours which returned significant change over time.

3.3.4 Comparison of behaviour between methodologies

Comparing the surveying methodologies, only Suspected Feeding and Normal Swimming showed significant differences between land and boat-based surveying. The average frequency of occurrence of both Suspected Feeding and Normal Swimming was significantly higher for land-based surveys (one-way ANOVA, $df = 1,91$, $f = 4.41$, $p = 0.04$; one-way ANOVA, $df = 1,91$, $f = 12.72$, $p < 0.001$, respectively). However, these differences in frequency of behaviours is most likely attributed to differences in surveying effort.

3.3.5 Interactions with other species & unique behaviours

Bottlenose dolphins were also observed to have inter-specific associations with other marine species. Dolphins were documented and photographed four times interacting with barrel jellyfish during the course of the study. One association included a pair of juvenile dolphins engaging in social/sexual behaviour. However, one individual proceeded to break away from this behaviour to interact with a barrel jellyfish, possibly biting the jellyfish before showing percussive behaviour and proceeding to swim away (**Figure 36**). In addition, multiple other interesting behaviours were photographed during the course of the study, including a form of ‘spy hopping’ (**Figure 37**), ‘surfing’, in which individuals were observed floating on the surface, until a wave came along, which they would then swim with (**Figure 38**), and possible courtship behaviour (**Figure 39**). Overall, the bottlenose dolphins in Cardigan Bay display a wide diversity of behaviours and social interactions.

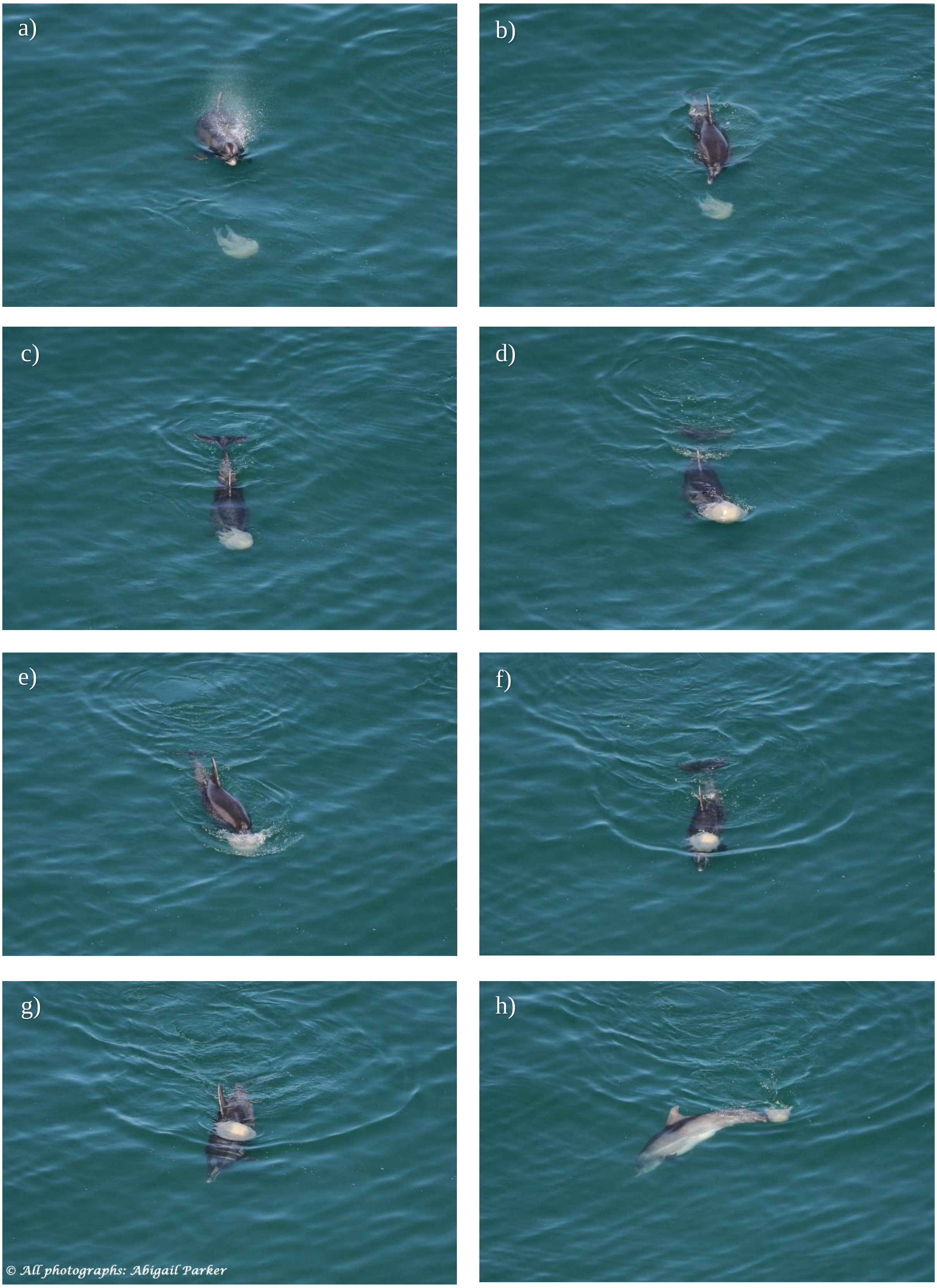


Figure 36: A photograph panel, in order from **a)** to **h)**, showing a series of direct play interactions between an inquisitive bottlenose dolphin and a barrel jellyfish, observed from New Quay Head on 18th June during a survey from approximately 13:19-13:56.

Figure 37: A form of 'spy hopping' behaviour observed on board the *Ermol VI* on 10th July, which could potentially be a form of social behaviour.

Figure 38: A rather large family group of five surfacing in the swell, seen from the *Ermol VI* on 10th July. Dolphins were frequently observed waiting in the swell for a wave to approach, which they could then swim with.

Figure 39: Possible courtship behaviour between two individuals observed on 18th June from New Quay Head. One individual would repeated expose their white underside before surfacing in close proximity to the other dolphin.

3.3.6 Specific responses to vessels

With regards to group responses to either *Ermol VI* or *Dunbar* presence during boat surveys, a Neutral response was found to be the predominant response out of all the sightings (58.43%; N=97), followed by Toward (19.88%, N=33), Unknown (14.46%; N=24) & Away (7.23%, N=12); **Figure 40**); this shows there is likely habituation to the presence of vessels of at least some bottlenose dolphins in Cardigan Bay, presumably as a result of the large volume of boat traffic observed during the summer. In regards types of behaviour in response to vessels, many pods/individuals appeared to be unfazed by boat presence (**Figure 41**), and would move towards the boat to bow-ride in the pressure wave (**Figure 42**).

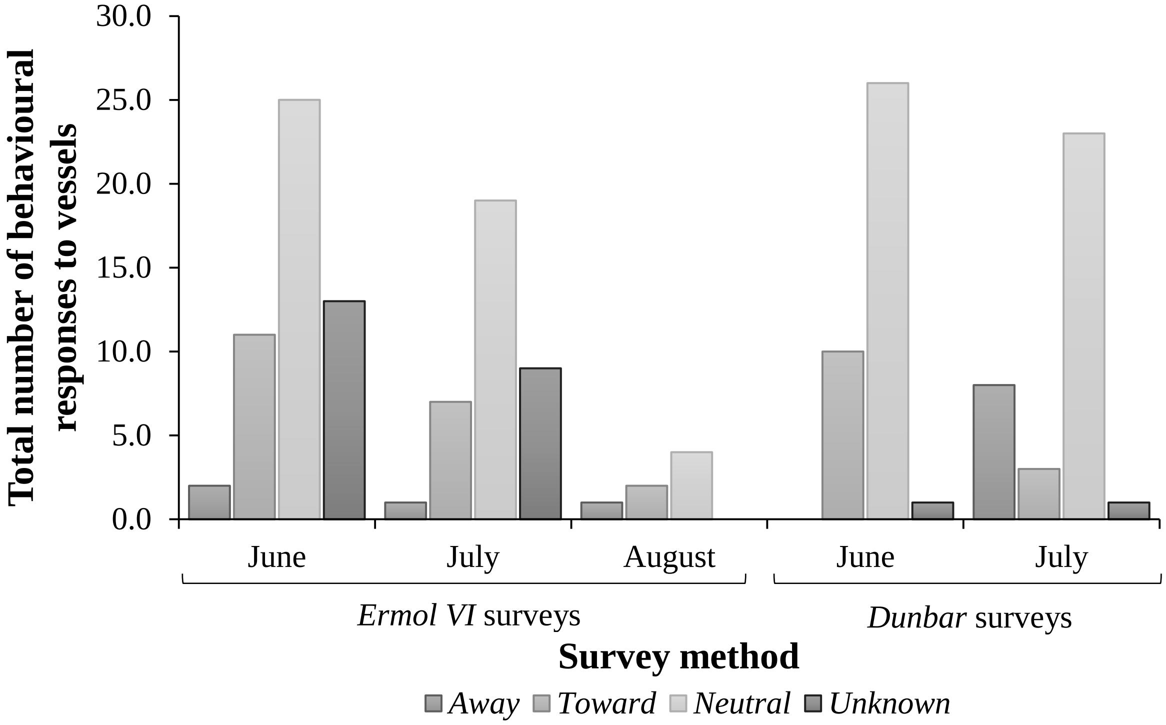


Figure 40: The total number of behavioural responses to vessels separated by surveying method; N=94 behavioural observations on the *Ermol VI*, N=72 on *Dunbar*.

Figure 41: Bottlenose dolphins in Cardigan Bay appear largely unfazed by the presence of vessels and high volume of boat traffic. Individual photographed on board the *Ermol VI* on 19th June.

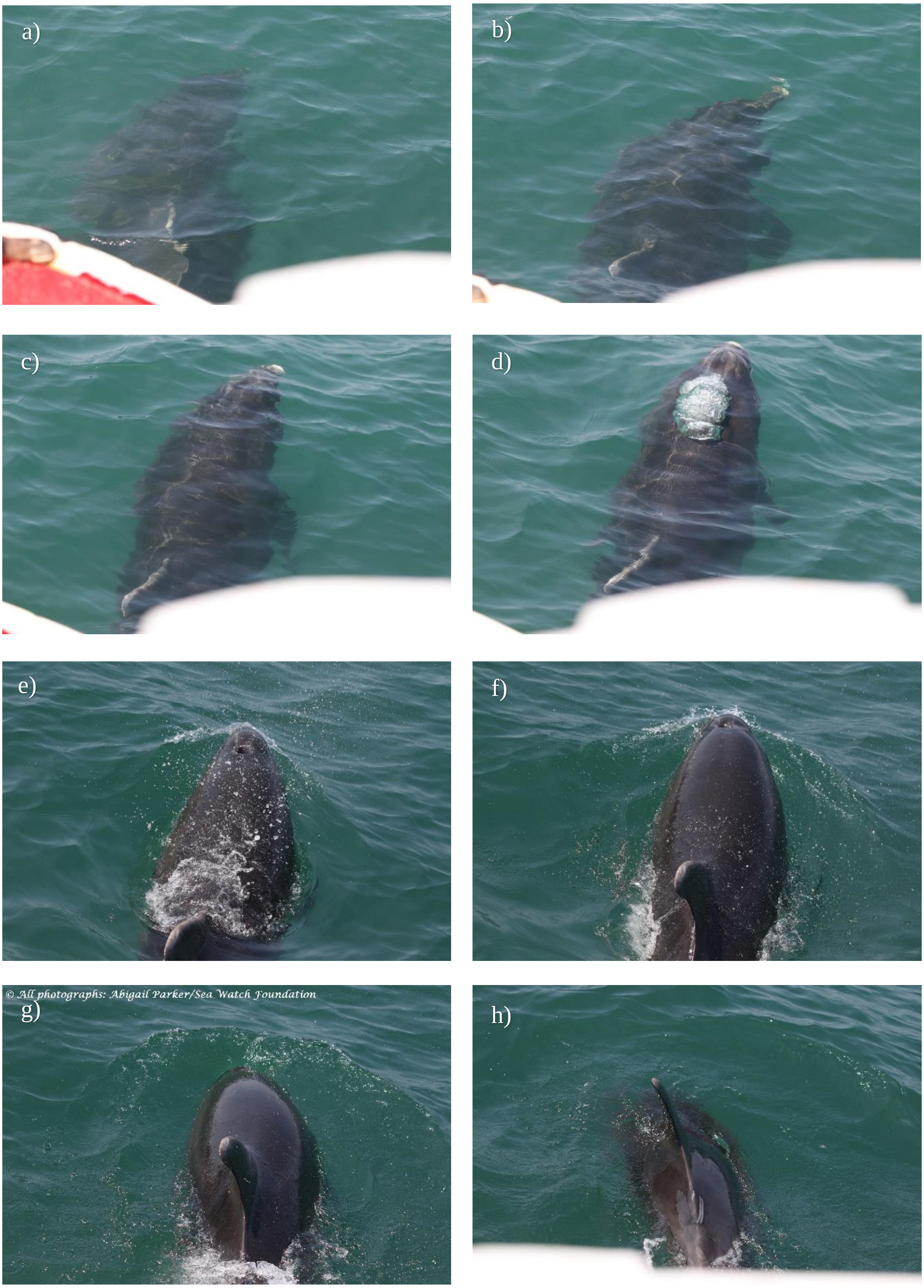


Figure 42: A photograph panel in order from **a)** to **h)**, showing bow-riding behaviour by an inquisitive individual who swam over to join the *Ermol VI* on 20th June, at 12:32. The red structure visible in a) is the bow of the *Ermol VI*.

3.3.7 Dive time across the survey methodologies

Dive time was not found to vary significantly between the surveying methods either for mothers with calves (Kruskal-Wallis Rank Sum Test, $df = 33$, $f = 33$, $p = 0.47$), or for focal individuals (Kruskal-Wallis Rank Sum Test, $df = 17$, $f = 17$, $p = 0.45$). This suggests that boat-based surveying does not elicit disturbance in the form of increased dive times to avoid vessels. However, the small sample size and variability in the number of dive times recorded per life stage category may affect the results; for example, mothers with calves are recorded less frequently, so more recordings are likely to be made of focal individuals. It is worth noting, however, that the greatest average dive time for mothers with calves occurred during June surveys on the *Dunbar*, which is allowed to approach dolphins under licence, for photo-ID purposes (**Figure 43**).

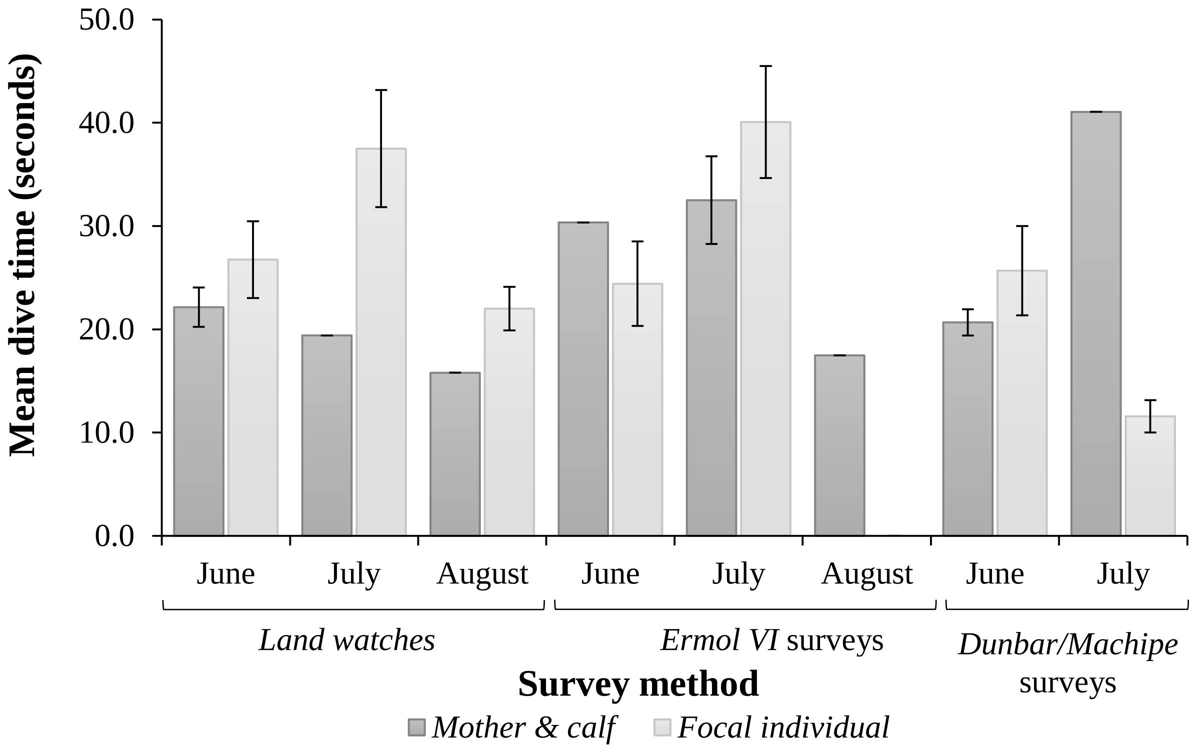


Figure 43: The average dive time for mothers with calves and focal individuals, for each surveying method. For mothers & calves, N=10 dive times for land watches, N=5 for *Ermol VI* surveys & N=7 for *Dunbar* surveys. For focal individuals, N=45 dive times for land watches, N=10 for *Ermol VI* surveys & N=13 for *Dunbar* surveys. ±SE bars are shown for each bar. No significant differences were found between survey methods ($p > 0.05$).

3.4 Social structure & pod dynamics

3.4.1 Who's in a pod?

A total of 152 sightings were observed in favourable weather conditions over the study period, including 75 during land watches from the pier; two from cliff watches at New Quay Head; 53 from boat surveys on the *Ermol VI* and 22 from dedicated *Dunbar* surveys. Overall total pod sizes within these sightings varied from one to seven individuals overall (**Figure 44**). For land-based surveys total pod size recorded in the five-minute intervals ranged from one to six, and one to seven for boat-based surveys. There was no significant difference in average total number of individuals recorded per sighting between boat-based and land-based surveys (one-way ANOVA, df = 1,150, f = 0.03, p = 0.85; **Figure 45)**. In addition, there was no significant change over time in the average total number of individuals per sighting for land-based surveys (linear regression, df = 1,75, f = 2.02, p = 0.16) or for boat-based surveys (linear regression, df = 1,73, f = 0.14, p = 0.71). In regards to group composition, adults predominantly made up the pod structure, present in 94.81% of sightings from land and 82.67% of sightings from vessels (**Figure 46**). This was followed by calves, which were present in 33.77% of sightings from land and 36.00% of sightings from vessels. Calves and newborns combined were present on 51.95% of land surveys and 40.00% of boat surveys, suggesting Cardigan Bay is utilised as a nursery area for mothers with calves (**Figure 47**).

Figure 44: A sighting of a larger bottlenose dolphin pod composed of seven individuals surfacing in synchrony in a tight formation, seen from the *Ermol VI*. Arrows indicate the location of each individual; a barrel jellyfish (*Rhizostoma pulmo*) was also in association with the pod, as indicated by the white arrow.

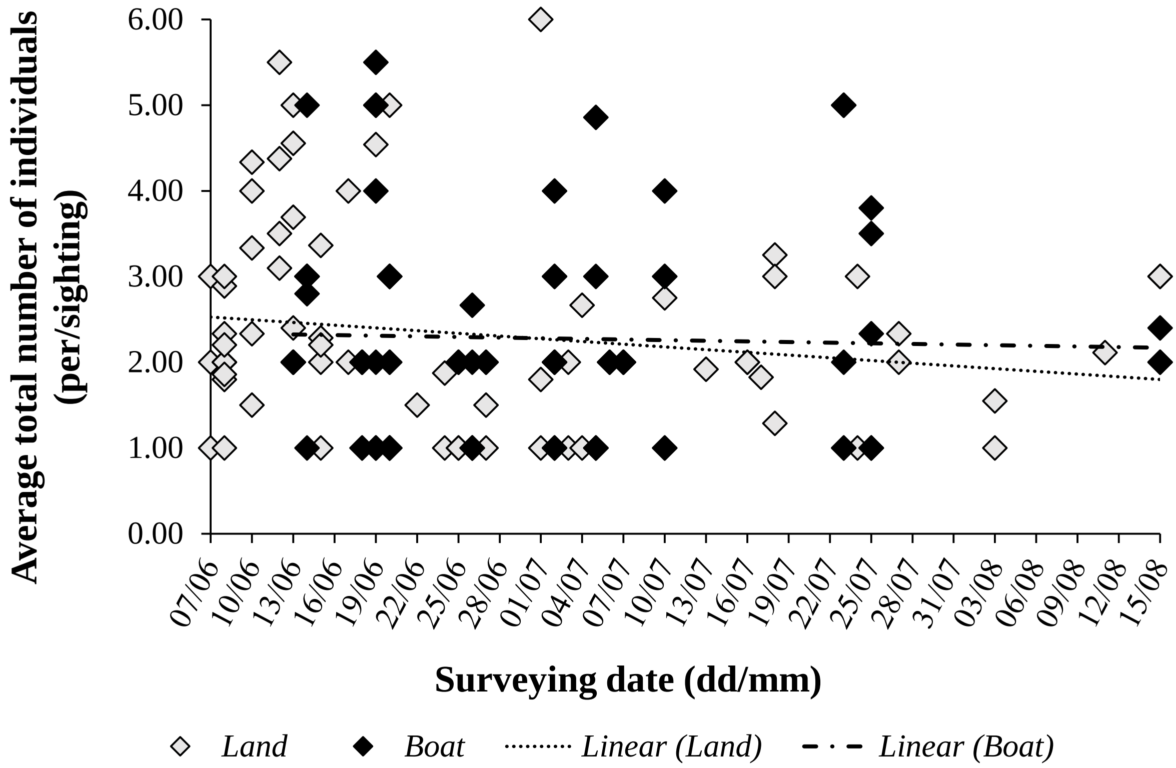


Figure 45: The average total number of individuals per sighting, over the survey period. Each diamond represents one sighting. N=77 sightings from land-based surveys; N=75 from boat-based surveys.

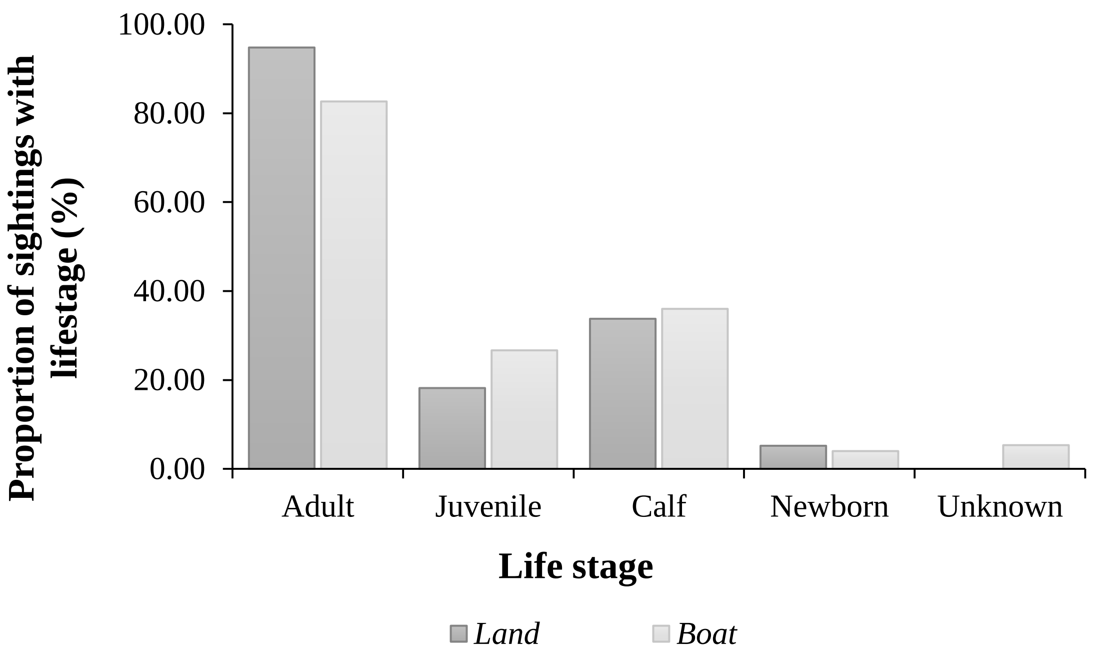


Figure 46: The total proportion (%) of sightings with adults, juveniles, calves, newborns and individuals for which life stage could not be determined, unknown, within the pod. Data is separated by survey type. N=77 sightings from land-based surveys; N=75 from boat-based surveys.

Figure 47: Examples of mother and calf pairs seen on board **a)** *Dunbar* on 18th June, and **b)** *Dunbar* also on 18th June. Mothers with calves often swim in tight association, sometimes with the calf slightly further back from the mother, known as echelon swimming (Noren *et al*., 2007).

The total number of sets per survey ranged from one to eleven for land-based surveys, and one to eleven for boat-based surveys, with a total of 135 sets recorded from land surveys and 95 from vessels. This verifies the previous research that pods are interchangeable and engage in a 'fission-fusion' community. The total number of sets per survey mirrored the SPUE, as to be expected, with the number of sets decreasing over time for land-based surveys but increasing over time for boat-based surveys (**Figure 48**). Unfortunately due to time constraints, the interchangeability of pods could not be investigated down to an individual level utilising photo-

ID, nor could group form or pod direction. However, these findings demonstrate the fluidity of bottlenose dolphin pods, with each pod varying with regards to size and composition.

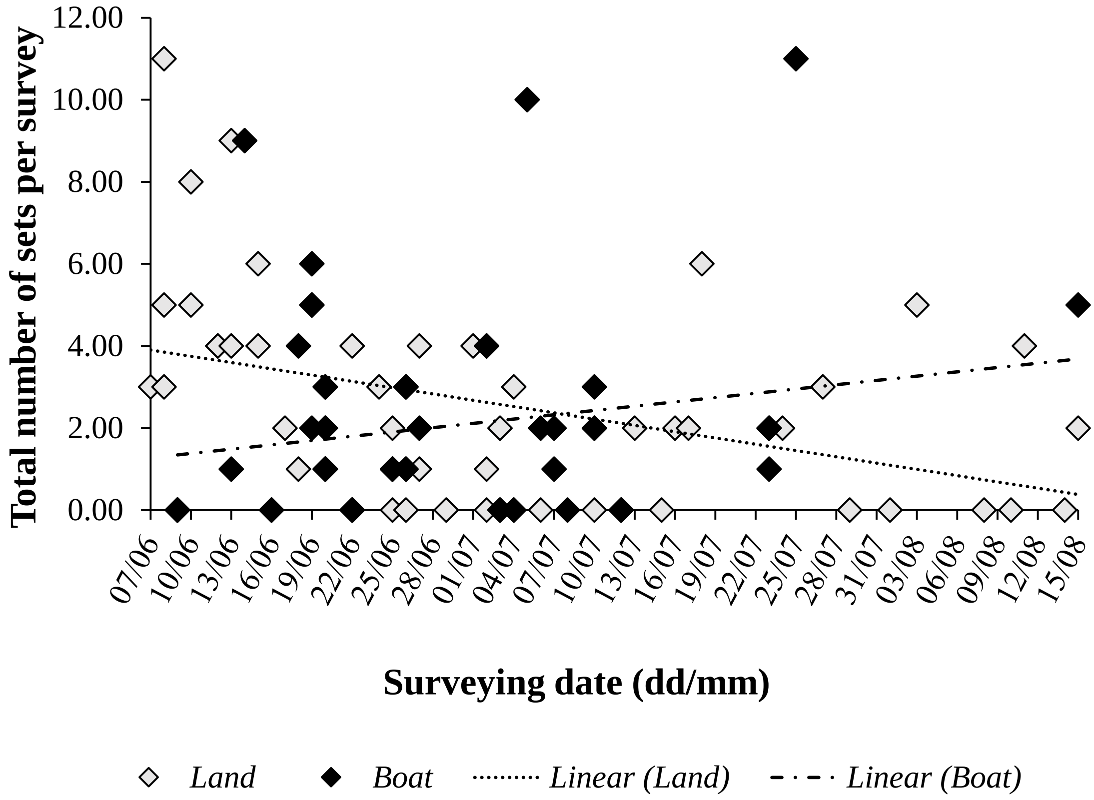


Figure 48: Temporal change in the total number of sets per survey, separated by land and boat-based surveys. N=135 sets recorded during land-based surveys; N=95 sets recorded during boat-based surveys.

3.5 Photo-ID & inter-individual associations

3.5.1 Standing out: A focus on 'Ghost' & 'Riptide'

Of the identifiable dolphins photographed during this study, an adult female nicknamed 'Ghost', and possibly an adult male (Feingold & Evans, 2012), 'Riptide', were particularly unique in their markings and hence were easy to identify by eye alone, and therefore they could be photographically documented from both land and sea, even at great distance. 'Ghost' is aptly named due to the characteristic white patch on the left side of the dorsal fin (**Figure 49a**), and two white dots at the base of the right side of the fin (**Figure 49b**). Previous photo-ID images show a remarkable change in the colouration of the dorsal fin on her right side in particular (**Figure 50a-d**). With regards to behaviours, 'Ghost' was photographed Suspected Feeding, Normal Swimming, and in association with other dolphins. 'Riptide' is also conspicuous due to the presence of white discolouration running along the top of the dorsal fin (**Figure 51**). Although ‘Riptide’ was only photographed from the left side during this study, once again, a comparison to the previous 2011 photo-ID catalogue shows a change in colouration of the dorsal fin (**Figure 52a-b**). ‘Riptide’ was a very social dolphin, photographed in pods with other dolphins (*see* cover photograph), although he was also seen logging solitarily. Due to the uniqueness of the dorsal fins of these particular individuals, both ‘Ghost’ and ‘Riptide’ were photographed and identified during land watches from the pier (**Figure 53**). This shows the potential for undertaking photo-ID from land, although as with these individuals, identification must be fairly obvious to confirm a match from further afield. Nonetheless, photographs obtained from boat surveys are still preferentially superior to those taken from land, with regards to image quality and suitability for photo-ID.

Figure 49: Photo-ID images of ‘Ghost’, showing her **a)** left side, with discolouration on the dorsal fin, and **b)** right side, with two distinctive white patches at the base of the dorsal fin. Taken on 19th June on board the *Ermol VI*.

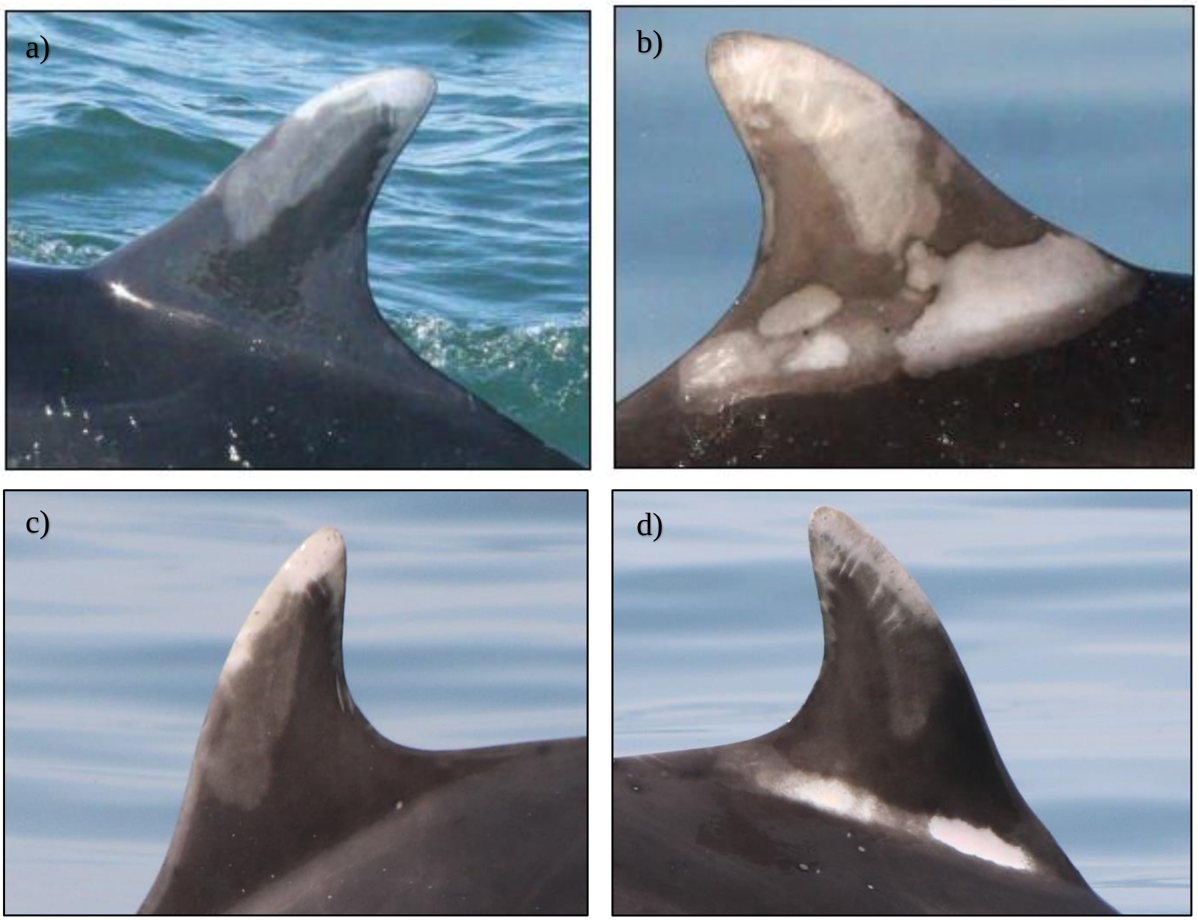


Figure 50: A comparison of dorsal fin photographs of 'Ghost'; **a)** & **b)** are from the 2011 photo-ID catalogue, and **c)** & **d)** were taken during the course of this study (2017). The remarkable differences between **b)** and **d)** of the right side of the fin show how marks can change greatly over time. **a)** & **b)** Taken from Feingold & Evans, 2012; **c)** & **d)** are © Abigail Parker/Sea Watch Foundation, taken on board the *Ermol VI* on 19th June.

Figure 51: Photo-ID image of 'Riptide', showing his left side, with distinctive white colouration at the top of the dorsal fin. Taken on 19th June on board the *Ermol VI*.

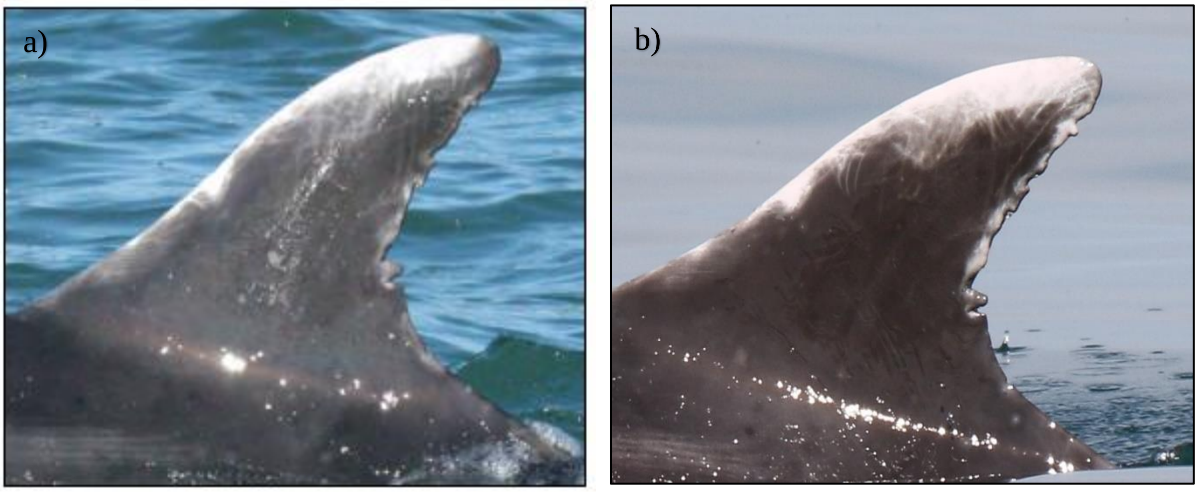


Figure 52: A comparison of dorsal fin photographs of 'Riptide'; **a)** is from the 2011 photo-ID catalogue, and **b)** was taken during the course of this study. As with 'Ghost', these photographs illustrate how markings can change slightly over time. **a)** Taken from Feingold & Evans, 2012; **b)** is © Abigail Parker/Sea Watch Foundation, taken on board the *Ermol VI* on 19th June.

Figure 53: 'Riptide' seen from the pier, indicated by the white arrow, demonstrating that photo-ID can be undertaken from land for individuals which can be identified by eye. Taken on 4th June.

3.6 An aerial view & the power of photography

Undertaking cliff watches from New Quay Head during the summer offered a unique perspective into dolphin behaviour, despite dolphins not being seen as regularly as from New Quay pier. A survey undertaken on the 18th June provided a rare opportunity to photograph and document an interesting behaviour in wild dolphins, courtship/sexual behaviour. At 13:19, two potentially juvenile bottlenose dolphins were observed swimming in a sheltered cove close to the seabird colony at Bird’s Rock, also often used as a haul-out site for Atlantic grey seals at low tide. The pair were in close proximity for the duration of the survey, occasionally breaking off to approach wildlife-watching vessels, such as the *Anna Lloyd* (**Figure 54**), or to interact with other fauna, such as barrel jellyfish (*Rhizostoma pulmo*) (**Figure 55**). Multiple courtship behaviours were photographed for the duration of the survey (*see* **Figure 39**), including inverted turns to show their white underside, along with percussive interactions, such as breaching (**Figure 56**), whilst maintaining close contact and surfacing in synchrony. Whilst this was considered to be the primary behaviour, another interesting observation was made upon cropping and zooming in on the photographs in August: one individual in pursuit of a fish (Definite Feeding behaviour) (**Figure 57**). The original dataset was not altered to reflect this, as all of the behavioural observations were done by eye, and at the time this behaviour was not seen. It was assumed to be part of the social/courtship behaviour, so therefore the decision was made to keep this observation separate, and behavioural data was exclusively decided upon by eye. However, it stresses the importance of photography to give a greater insight into behaviours which can be easily missed by observers, especially from land, or from this case, clifftop, where proximity to dolphins is usually greater. Therefore, Definite Feeding was seen twice in this study, once by eye in poor weather, and the other confirmed by photograph. However, it was still the least recorded behaviour type in the study. After this survey, dolphins were infrequently seen when surveying from New Quay Head, however, the data gathered from this initial survey offered a truly remarkable insight into dolphin behaviour, from a novel, aerial perspective, with minimal disturbance to the individuals being observed, and mimics still images that could be obtained from a survey using a drone (**Figure 58**).

Figure 54: A single bottlenose dolphin broke off from the pair to approach the wildlife-watching vessel, *Anna Lloyd*, during the clifftop survey on 18th June.

Figure 55: A photograph panel from **a)** to **d)** showing an interaction between a bottlenose dolphin and a barrel jellyfish. It appears as though the individual may have attempted to 'kick' the jellyfish, possibly as a form of play, but was unsuccessful. Photographed during the clifftop survey from New Quay Head on 18th June.

Figure 56: A bottlenose dolphin performing a breach, a form of Percussive Behaviour, in close proximity to another dolphin. Observed from New Quay Head on 18th June.

Figure 57: A bottlenose dolphin pair, engaging in what was originally thought to be exclusively social/sexual behaviour, but upon confirmation with photography, one individual was actually in pursuit of a fish at one point during the sighting. The fish was not seen in the sequential photograph, so successful capture of the prey was assumed. Photograph taken from a cliff watch on 18th June at New Quay Head.

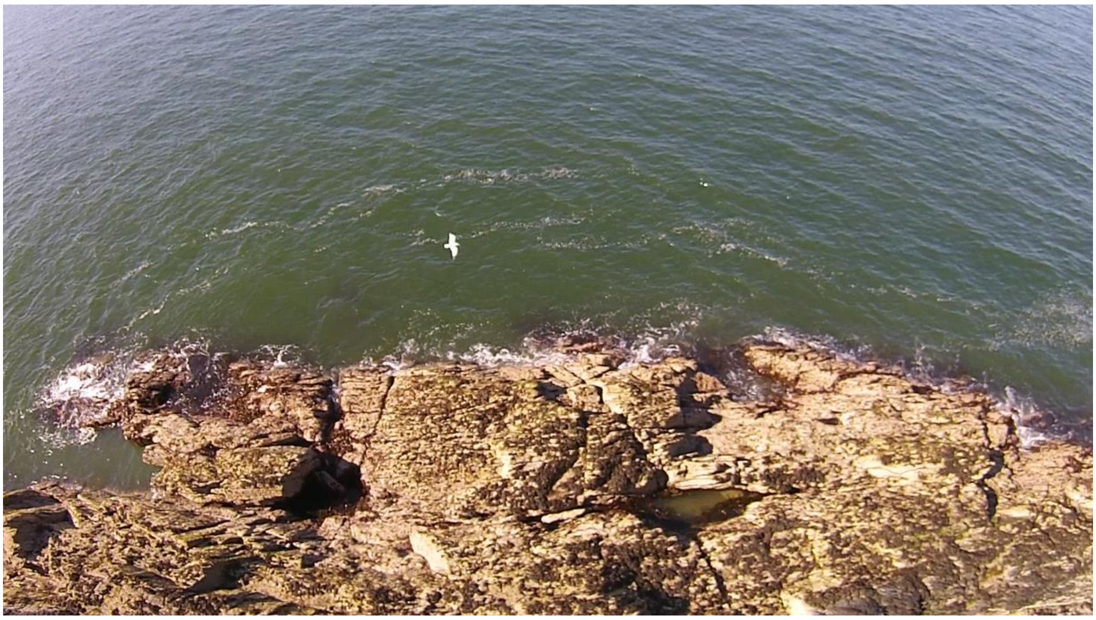


Figure 58: A still image taken from the *Phantom 2 Vision+* drone footage, utilised for a short trial survey at Bull Bay, on 10th May, 2017. Footage credit to: David Roberts, the licensed drone operator & Ocean Sciences Technician, Bangor University.

4. Discussion

4.1 Bottlenose behaviour & social structure

4.1.1 Bottlenose behaviours in Cardigan Bay – a focus on feeding

The behavioural dataset presented in this study confirms the importance of the Cardigan Bay habitat, particularly around New Quay, as a regularly visited foraging ground for the bottlenose dolphin, with Suspected Feeding present during 37.86% of behavioural observations (five-minute intervals). This mirrors previous research on the study area, which also concluded feeding/foraging to be the most predominant behaviour in Cardigan Bay. Observations from land-based surveys at several sites around Ceredigion found repeated diving in the same area, consistent with foraging for demersal species, to be the most prominent behaviour overall (55%), and at four out of six study sites (Pierpoint *et al*., 2009); in 2002, 2012 & 2013, foraging/feeding was the predominant behaviour recorded during line-transect & *ad-libitum* surveys in Cardigan Bay (Norrman *et al*., 2015). In Welsh waters, the bottlenose dolphin has been observed to feed on a diverse variety of marine species, including the European eel (*Anguilla anguilla*); Atlantic salmon (*Salmo salar*); sea bass (*Dicentrarchus labrax*); smooth-hound shark (*Mustelus mustelus*); sand eel (family *Ammodytidae*), and garfish (*Belone belone*);

(Evans, Pers. comms., 2017; **Figure 59)**. A full list of prey species in Welsh waters is available in **Appendix III**. However, the fish species taken by a bottlenose dolphin in this study was unable to be identified to species level, and was most likely an opportunistic feeding. Previous 'snacking' styles of feeding have been documented in bottlenose dolphin populations, which is characterised by a behaviour of swimming belly-side up to drive fish to the surface (Mann & Smuts, 1999; Sargeant *et al*., 2006), including in newborn dolphins, who sometimes mimic 'snacking' by engaging in 'play snacking' (Mann & Smuts, 1999). New Quay and the surrounding areas appear to be a prime Suspected Feeding 'hotspot' for cetaceans, hosting a rich diversity of prey species that attracts the bottlenose dolphin during the summer months. A variety of potential Suspected Feeding behaviours were documented over the course of the study, many of which have been previously described. One of the most frequently observed behaviours was 'tail slapping' or 'surface tail slapping', which most likely draws prey downwards using suction created by the tail (Shane,1990; Hastie *et al*., 2004). A rather unusual way of feeding also seen during the study was simply 'lying at surface', which involves a dolphin lying "stationary with part of body exposed at surface for 5 or more seconds" (Shane, 1990), which is most likely opportunistic feeding. It is rather apparent that the bottlenose utilises Cardigan Bay as a primary feeding ground, in which they utilise a variety of behaviours to maximise prey capture; which behaviour is used is most likely determined by the prey species or composition of the bottlenose dolphin pod at the time of feeding.

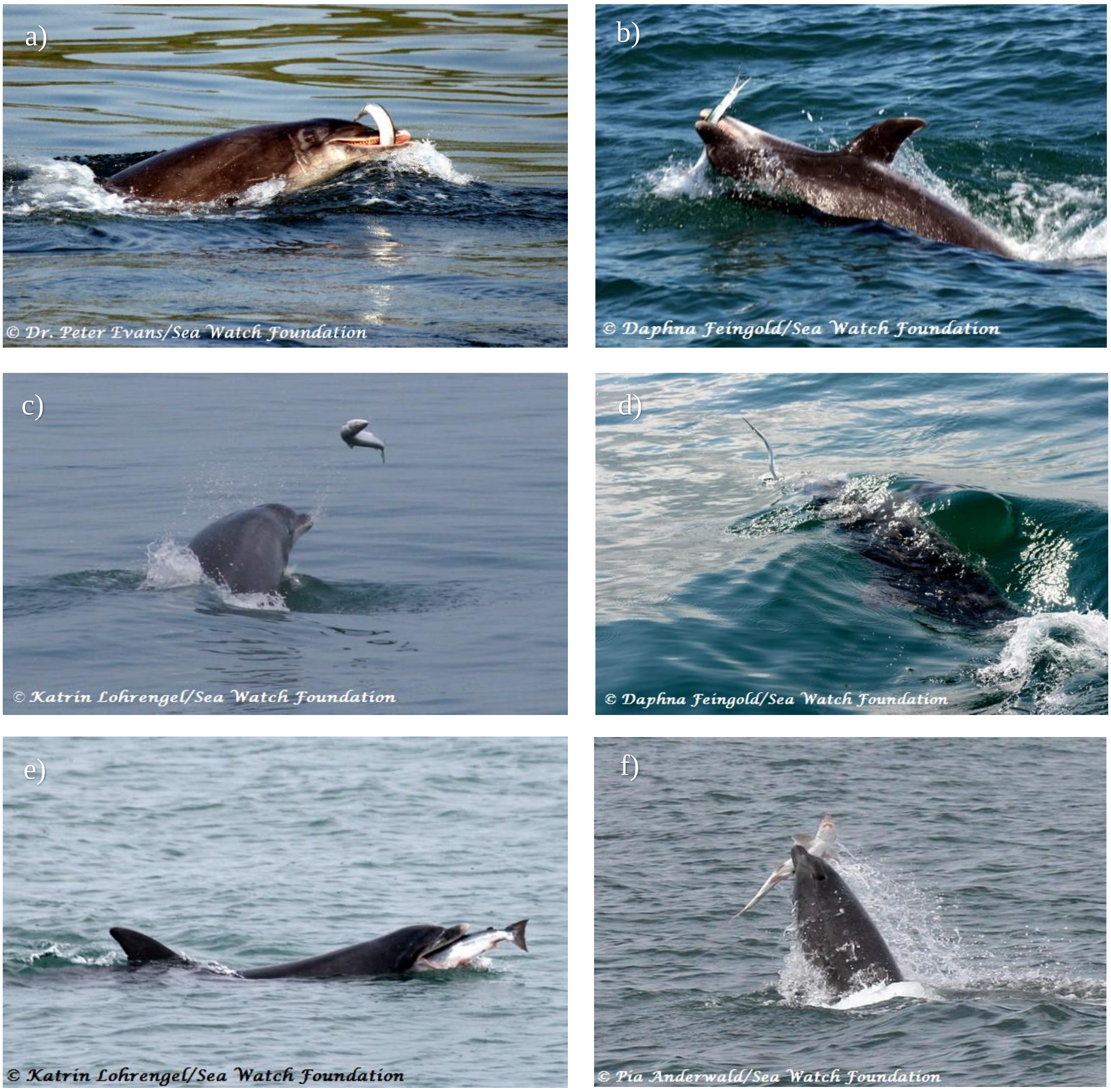


Figure 59: The diverse prey species consumed by the bottlenose dolphin in Welsh waters. **a)** European eel; **b)** garfish; **c)** sea bass; **d)** sand eel; **e)** Atlantic salmon; **f)** smooth-hound shark.

On the contrary, during some previous years travelling has been found to be the predominant behaviour, followed closely by feeding behaviour (Bristow *et al*., 2001; Evans & Lohrengel, 2015; Norrman *et al*., 2015). However, ultimately it is opportunities for feeding that have been shown to be the primary factor in determining bottlenose dolphin distribution (Hastie *et al*., 2004). In the context of Cardigan Bay, changes in prey availability may reflect the behavioural changes and movement patterns within the bay. In 2014, sightings declined following June, suggesting seasonal movement out of the SAC (Norrman *et al*., 2015); this is consistent with movement outside of the SAC boundary during the winter months, which is undertaken by some individuals to travel North to Anglesey & the surrounding areas (Feingold & Evans, 2014). With regards to temporal trends in feeding, little can be deduced from this study due to the limited timescale, however both boat and land-based surveys showed a very slight decline in Suspected Feeding behaviours over time, suggesting dolphins are foraging for less time later in the summer, although this may be attributed to survey effort. Previous analyses have found a reduction in Definite Feeding but increase in Suspected Feeding over the course of a season, implying that although dolphins may be actively foraging for longer, their success at obtaining prey items may be poor (Norrman *et al*., 2015), which may be why individuals show seasonal movement away from the SAC in winter (Feingold & Evans, 2014), possibly to gain new opportunities for feeding.

4.1.2 Other behaviours and pod associations

In addition to Suspected Feeding, multiple other behaviours were recorded during the course of this study, with play and social behaviour also forming a key component of bottlenose dolphin activities. Dolphin play has been documented on multiple occasions for both wild and captive dolphins. Previous examples of play in wild dolphins include interacting with other species, such as barrel jellyfish (Bel'kovich *et al*., 1991), as documented in this study. Another form of play observed during this study was surfing on the swell, also previously documented in the literature for bottlenose dolphins (Würsig & Würsig, 1979; Hanson & Defran, 1993). As for why dolphins engage in play behaviours remains uncertain, however, it has been suggested that play may be a significant part of calf development. Bottlenose calves have shown to display more complex play behaviours as they become older, indicating that play behaviour may be performed to aid problem solving, as the calf reaches maturity (Kuczaj *et al*., 2006). In addition, dolphins will imitate the behaviours of others, suggesting social learning may be a route of transmission for play behaviours (Kuczaj *et al*., 2006). A form of 'spy hopping' behaviour was also photographed during this study; this has previously been termed 'head out', with the "entire head exposed at the surface, and rostrum pointed at an angle", as a form of social behaviour (Shane, 1990). Other cetaceans engage in 'spy hopping', although usually larger whales such as orcas, which investigate prey above the surface, *e.g.* seals hauled out (Pitman & Ensor, 2003). Bottlenose dolphins typically dive and investigate below the water surface for their prey, so it would seem that this behaviour is likely a part of socialising.

Bottlenose dolphins observed during the summer period were profoundly social, and engaged in a 'fission-fusion' society (Connor *et al*., 2000), where individuals would frequently exchange between pods and associate with others. In addition, a range of life stages made up the pod composition. On a substantial proportion of sightings (40.00-51.95%), a calf or newborn was sighted amongst the pod, usually in close association with an adult, indicating that the Cardigan Bay SAC is a primary nursery area for mothers and their calves (Norrman *et al*., 2015), and therefore stresses the importance of its continued protection.

4.2 Surveying methodologies: a comparison

With regards to survey methodologies, few differences were found between land and boat-based surveys, however, both Normal Swimming and Suspected Feeding were seen more frequently from land. Potentially, the presence of a vessel could decrease the proportion of time dolphins spent suspected surface feeding (Bas *et al*., 2017), however, the differences in the hours of effort for each survey type (99.26 hours from land & 78.67 hours from vessels) likely accounts for any differences. However, observations over the summer concluded that there were some notable advantages and disadvantages with each surveying method. Surveying from boats allowed for the observation of certain behaviours not typically seen as frequently from land, including Bow-Riding. Contrary to expectation, dolphins in Cardigan Bay appear to be largely unfazed by boat activities, in terms of physical avoidance behaviours and dive time, and in some cases individuals approached vessels to bow-ride on the boat pressure wave. This mirrors previous research on the bottlenose dolphins; Würsig & Würsig, 1979, found no avoidance behaviours by bottlenose dolphins in their study, and 77% of the total reactions including Bow-Riding. However, this should be taken with caution, as the effect of boat presence is most likely affected by the group composition, *i.e.* if there are any newborns or calves in the group. Previous research on vessel avoidance behaviours in Cardigan Bay found mothers with calves dove for significantly longer than lone individuals in the presence of a vessel (Hudson, 2014).

With regards to photography, the increased proximity to the dolphins on boat surveys allowed for better quality photographs to be taken, particularly for photo-ID images, as demonstrated with ‘Ghost’ and ‘Riptide’. However, dolphins can be photographically identified if markings are conspicuous enough to be recognised by eye, although previous photographs from the 2011 photo-ID catalogue show how markings can change significantly over time, and hence photo-ID catalogues must be updated regularly in order to reflect this. In contrast, land-based surveys offered a much greater time window for surveying cetaceans, as on multiple occasions, pods could be followed for the entire land watch duration, having no limitations from the Marine

Code of Conduct. Despite this, there were no differences in average counts of dolphins between the surveying methods; it is likely that surveying conditions affect observer ability in the field. Weather conditions in terms of sea state was found to affect group counts from boats and from land, mirroring previous research that counts of cetaceans are lower in higher sea states (Evans & Hammond, 2004). In addition, the effect of sea state was significant for boat-based surveys but not for land, confirming previous knowledge that the effect of sea state is platform specific (Evans & Hammond, 2004). The use of aerial photography from a clifftop in this study effectively mimicked what could be obtained from a drone, gathering an exciting insight into bottlenose dolphin social and play behaviour. The use of drones to produce high quality, aerial images with minimal disturbance to the animals could revolutionise cetacean surveying by combining the merits of both surveying techniques performed in this study.

4.3 Study limitations & future recommendations

This study offered an insight into cetacean behaviour through the use of photography and comparing surveying methodologies. However, it isn't without limitations. The very limited timeframe of this study makes it difficult to draw conclusions on changes in abundance, distribution or behaviour over a meaningful timescale. Therefore, in order to assess behavioural changes in response to environmental conditions, such as food availability, conducting surveys over multiple years, or at least for a whole surveying season would be greatly beneficial. In addition, multiple environmental variables that were not assessed during this study due to time constraints may aid our understanding of bottlenose dolphin behaviour. For example, bathymetry has been shown to determine prey 'hotspots' for the bottlenose (Hastie *et al*., 2004). Narrow channel structures, coupled with oceanographic fronts may concentrate prey species, making them an ideal location for the bottlenose dolphin to forage, and in addition, steep gradients are generally preferred (Bailey & Thompson, 2010). Furthermore, another constraint of this study was the inability to 'follow' multiple focal pods at the same time, due to impracticalities. Having multiple personnel, potentially as a form of citizen science, could facilitate data collection of multiple pods at once. The high volume of data gathered on land watches could promote land surveys as an alternative to wildlife-watching tourism from a vessel to engage the public (Giacoma *et al*., 2013). However, then there is an issue of subjectivity; engaging the public is an excellent way of increasing the volume of data gathered, however this must incur some quality control to ensure standardisation and account for variation in the experience of observers (Evans & Hammond, 2004). This could be minimised with adequate training and provision of species-identification guides (Evans & Hammond, 2004), as well as standardised data sheets and the use of behavioural catalogues to inform participants.

4.4 Conclusion

Cardigan Bay, particularly New Quay, is a key habitat for the bottlenose dolphin, primarily for feeding and likely as a nursery area for mothers and calves, hereby stressing the importance of the SAC and the need for protection. Boat traffic is high in New Quay during the summer, and although dolphins may have become habituated, previous work and behavioural observations during this study suggests some vessels may induce a negative response. Dolphins in New Quay appear to engage in a 'fission-fusion' society, changing pods frequently, and engaging in a range of social behaviours. In regards to surveying methodologies, surveying from land offers the opportunity for much longer observations of dolphin sightings, due to no limitations such as the Marine Code of Conduct, and can be undertaken in poorer weather conditions which may not necessarily be suitable for vessels. In contrast, with boat-based surveys, a limited amount of time can be spent with dolphins to minimise the effect of disturbance, however higher quality photographs can be obtained, and behaviours such as Bow-Riding can be seen, which may not necessarily be able to be seen from land. Both land and boat-based surveying provided a large dataset of behavioural observations, which when coupled with photography, particularly from an aerial perspective, gave exciting insights into dolphin behaviour, such as feeding and courtship. In the future, the use of drone technology to survey cetaceans could combine the merits of both surveying methodologies, obtaining aerial photographs with minimal disturbance, to obtain a novel outlook on dolphin social structure and behaviour. With the development of technology and advancements in photography, the future holds exciting prospects for marine mammal surveying, enabling us to understand delve deeper into the intriguing world of the bottlenose dolphin.

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Appendix I

The Beaufort wind scale, used to classify sea state in this study. Taken & adapted from Met Office, 2016.

Beaufort wind scale	*Wind descriptive terms*	*Probable wave height (m)*	*Probable maximum wave height (m)*	*Sea state*	*Sea descriptive terms*
0	Calm	-	-	0	Calm (glassy)
1	Light air	0.1	0.1	1	Calm (rippled)
2	Light breeze	0.2	0.3	2	Smooth (wavelets)
3	Gentle breeze	0.6	1.0	3	Slight
4	Moderate breeze	1.0	1.5	3-4	Slight - Moderate
5	Fresh breeze	2.0	2.5	4	Moderate
6	Strong breeze	3.0	4.0	5	Rough
7	Near gale	4.0	5.5	5-6	Rough-Very rough
8	Gale	5.5	7.5	6-7	Very rough - High
9	Strong gale	7.0	10.0	7	High
10	Storm	9.0	12.5	8	Very High
11	Violent storm	11.5	16.0	8	Very High
12	Hurricane	14+	-	9	Phenomenal

Appendix II

Examples of *Tursiops truncatus* behaviours photographed from land and boat-based surveys.

Regular surfacing – part of Slow, Normal or Fast Swimming behaviour

Possible deep foraging dive, showing the tail fluke

Suspected Feeding behaviours

Aerial & Percussive behaviours

Appendix III

The bottlenose dolphin diet: fish species observed being consumed by the bottlenose dolphin in Welsh waters (Evans, Pers. comms., 2017). Each species is given with their common and Latin name; for fish not specified to species level, the family name is given. * This species is pelagic in the first 2-3 months.

Habitat	*Species common name*	*Latin or family name*
Riverine	Atlantic salmon	*Salmo salar*
	Trout	Family *Salmonidae*
	European eel	*Anguilla anguilla*
Benthic	Sole	Family *Soleidae*
	Brill	*Scophthalmus rhombus*
Bentho-pelagic	Sand eel	Family *Ammodytidae*
Demersal	Whiting*	*Merlangius merlangus*
Shallow pelagic	European sea bass	*Dicentrarchus labrax*
	Garfish	*Belone belone*
	Common smooth-hound	*Mustelus mustelus*

Appendix IV

Behavioural data forms utilised in this study for land-based surveys and boat-based surveys.

Behaviour – Land

Date:

Location:

Set	Time (BST)	Lat N	Long E	Sea state	Group form						Surf mode			Direction			Main behaviours										Other		Group composition					Boats present?	Birds	Dive Time	
					A	T	L	D	S	P	Q	P	U	No	Po	St	SS	NS	FS	FF	SF	B	R	S	O	U	AB	PB	A	J	C	N	Total			M & C/N	F

Behaviour – Boat

Date:

Location:

Set	*Time (BST)*	*Lat N*	*Long E*	*Sea state*	*Group form*						*Surf mode*			*Direction*			*Main behaviours*										*Other*		*Group composition*					*Cetacean response*				*Birds*	*Dive Time*	
					A	T	L	D	S	P	Q	P	U	No	Po	St	SS	NS	FS	FF	SF	B	R	S	O	U	AB	PB	A	J	C	N	Total	A	T	N	U		M & C/N	F

Appendix V

The following is a list of condensed codes utilised for statistical analysis with the R Software.

Temporal trends in SPUE

1) leveneTest(Day,SPUE); to test for homogeneity assumptions of a linear model, homogenetity is defined as $p < 0.05$

2) model<-lm(Day~SPUE); after meeting the assumptions, a model is created to run a linear regression to test for significant temporal trends in SPUE, which was performed separately for land and boat data

3) summary(model); displays the degrees of freedom (*df*), f-statistic (*f*) and p-value (*p*) for the regression

Average total number of individuals & average sea state (rounded to nearest 0.5)

1) leveneTest(Rounded,Average_total); to test for homogeneity assumptions of a linear model

2) model<-aov(Rounded~Average_total); after meeting the assumptions, proceed by running a one-way ANOVA to test for significant differences between average sea state and average total number of dolphins, which was performed separately for land and boat data

3) summary(model); summary displays the *p*-value to determine significance

Temporal trends in average frequency of occurrence of behaviours

1) leveneTest(Day,Slow_Swimming); to test for homogeneity assumptions of a linear model, which was repeated for each behaviour. Suspected Feeding for boat-based data did not return homogeneity, so a non-parametric alternative to a linear regression was used (see below)

2) model<-lm(Day~Slow_Swimming); after meeting the assumptions, a model is created to run a linear regression to test for significant temporal trends in average frequency of occurrence of the behaviour, which was performed separately for land and boat data, and repeated for each behaviour

3) summary(model); displays the degrees of freedom (*df*), f-statistic (*f*) and p-value (*p*) for the regression

Kendall's Rank Correlation for Suspected Feeding

1) leveneTest(Day,Suspected_Feeding); Suspected Feeding returned a significant result for the Levene's Test for boat-based data, and hence a Kendall's Rank Correlation was used

2) Kendall(Day,Suspected_Feeding); Kendall's rank correlation is a non-parametric alternative to linear regression, and is more suited to the dataset as it contains ties; results are returned as a *tau* value (whether the regression is +/-, and how strong the relationship is), and a two-sided *p*-value

Comparison of average frequency of occurrence of behaviours between surveying methodologies

1) leveneTest(Type,Slow_Swimming); to test for homogeneity assumptions of a linear model, which was repeated for each behaviour

2) model<-aov(Type~Slow_Swimming); after meeting the assumptions, proceed by running a one-way ANOVA to test for significant differences between type of survey and average frequency of occurrence of each behaviour, repeated for each behaviour

3) summary(model); summary displays the *p*-value to determine significance

Dive times

1) kruskal.test(Type,Focal); a non-parametric alternative to ANOVA, to compare average dive time for focal individuals between the surveying methodologies

2) kruskal.test(Type,Mother_calf); repeated for mother & calf dive times; results are returned as a *chi-square* value, *df* and *p*-value

Average total number of individuals per sighting between surveying methodologies

1) leveneTest(Type,Average); to test for homogeneity assumptions of a linear model

2) model<-aov(Type~Average); after meeting the assumptions, proceed by running a one-way ANOVA to test for significant differences in average total number of individuals between the type of survey

3) summary(model); summary displays the *p*-value to determine significance

Temporal change in average total number of individuals per sighting

1) leveneTest(Day,Average); to test for homogeneity assumptions of a linear model

2) model<-lm(Day~Average); after meeting the assumptions, proceed by running a linear regression to test for temporal changes in the average total number of individuals per sighting, which was performed separately for land and boat data

3) summary(model); displays the degrees of freedom (*df*), f-statistic (*f*) and p-value (*p*) for the regression