Swansea University
Prifysgol Abertawe

STANDARDISED METHODS FOR COLLABORATIVE LONG-TERM MONITORING AND MANAGEMENT OF HARBOUR PORPOISE (*PHOCOENA PHOCOENA*) IN WALES

Rhian Louise Forrest BSc, MSc.

Submitted to Swansea University in fulfilment of the requirements for the Degree of MRes Biosciences.

Swansea University

2020

Abstract

Monitoring long terms trends of species abundance is a fundamental requirement for effective conservation. Surveying wildlife creates a baseline to measure changes in the population and to detect and manage specific abiotic and biotic threats. However, long term monitoring is not always effective or achievable because of insufficient finances, resources, planning or limited project focus. Establishing a collaborative network of scientists to bring together similar research may provide the solution as seen with networks on seagrass, aquatic macrophytes and avian populations. Frequently there are many organisations working in isolation using multiple approaches on similar species. This case study specifically investigates the social barriers leading to a lack of collaborative efforts in cetacean monitoring in Wales where there are four organisations independently undertaking systematic long-term monitoring. Here, I produce, trial and analyse a simple low-cost standardised methodology that could be used for long-term monitoring by multiple organisations and review the potential of a collaborative acoustics project to enable simple comparisons of encounter rates for cetaceans Wales-wide. An online questionnaire to stakeholders revealed that primary barriers to collaborative research were personality differences and funding competition; participants indicated that the re-establishment of a marine mammal working group by Natural Resources Wales would enable development of personal relationships and fair access to resources. Similar working groups have been established in terrestrial and aquatic ecology which have attempted to overcome the challenges in effective long-term monitoring. It is anticipated that this research could be duplicated to other species to assess any barriers and solutions to collaborative working and establish more cohesive long-term monitoring strategies in ecology.

Keywords: Cetacean, Collaboration, Conservation Network, Vantage Point Survey, Land- Based Survey, SAM, Acoustic Monitoring, C-POD.

Declarations

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

Signed: [redacted]

Date: 15th February 2020

This thesis is the results of my own investigations, except where otherwise stated and that other sources are acknowledged by footnotes giving explicit references and that a bibliography is appended.

Signed: [redacted]

Date: 15th February 2020

I hereby give consent for the thesis, if accepted to be made available online in the University's Open Access Repository and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed: [redacted]

Date: 15th February 2020

Statement of Expenditure

Student Name: Rhian Louise Forrest
Student Number: [redacted]
Project title: Standardised Methods for Collaborative Long-Term Monitoring and Management of Cetaceans in Wales

Category	Item	Description	Cost*
Conference	ECS Italy	Registration	£78.38
Conference	ECS Italy	Flight	£199.72
Conference	ECS Italy	Parking	£29.50
Conference	ECS Italy	Accommodation	£144
Conference	ECS Italy	Membership	£27.77
Subtotal			£479.37

Bardsey Fieldwork: expenses below shared between two projects and covered by SEACAMS.			
Accommodation	Bardsey Fieldwork	Caravan	£450
Travel	Bardsey Fieldwork	Fuel	£71
Travel	Bardsey Fieldwork	Hire Car	£121.70
Subsistence	Bardsey Fieldwork	Food	£123.65
Travel	Bardsey	Travel	£78.31
Subsistence	Bardsey	Meal	£9.11
Subtotal			£853.77

Total:	**£1333.14**

*including VAT and delivery where applicable

I hereby certify that the above information is true and correct to the best of my knowledge.

[redacted]

Signature (Supervisor)

[redacted]

Signature (Student)

Statement of Contributions

Contributor role	Persons involved
Conceptualization	HKN, **RLF**
Data Curation	**RLF**, HKN
Formal Analysis	**RLF**, HKN
Funding Acquisition	HKN
Investigation	**RLF**, APJ
Methodology	**RLF**, HNK
Project Administration	HKN, **RLF**
Resources	HKN, **RLF**
Software	**RLF**, HKN
Supervision	HKN
Validation	NA
Visualization	**RLF**
Writing – Original Draft Preparation	**RLF**
Writing – Review & Editing	HKN

Ethics Approval

Ethics:COS Animal vertebrate review form

cosethics@swansea.ac.uk
Sent: 23 February 2018 06:41
To: [redacted]

Your application: Ethics:COS Animal vertebrate review form has been reviewed by COS Ethics Committee/AWERB Group and it's status indicates as Approved Proposal.

Comments:
The CoS Ethics Committee has no ethical concerns and approves this application

R1 - no concerns
R2 - no concerns
R3 - no concerns
R4 - no concerns

Click the link:
https://science.swansea.ac.uk/intranet/safety/forms/ethics/committeedecisionforms/231/edit?session=1718 to view the details.

Project Ethics Assessment Confirmation

cosethics@swansea.ac.uk
Sent: 23 February 2018 06:41
To: FORREST R.[redacted]
Cc: Nuuttila [redacted]

This is an automated confirmation email for the following project. The Ethics Assessment status of this project is: APPROVED

Applicant Name: Rhian Forrest
Project Title: Acoustic monitoring of cetaceans for long-term monitoring and management in Wales.
Project Start Date: January 2018
Project Duration: 9 months
Approval No: SU-Ethics-Student-230218/472

Data Supply Agreement

Date: 31st August 2018

From (Data Supplier):
Wildlife Trust of South and West Wales
Cardigan Bay Marine Wildlife Centre, Patent Slip Building, Glanmor Terrace, New Quay, SA45 9PS
Contact: Sarah Perry
Tel: [redacted]
Email: [redacted]

To: Rhian Forrest
Organisation: Swansea University
Contact: [redacted]
Tel: [redacted]
Email: [redacted]

Data requested:
New Quay Bay C-POD data collected from two sites (New Quay Reef and New Quay Fish Factory) in New Quay Bay from April 2016 until September 2017.

Data supplied:
The data supplied is as multiple CP1 files as well as a file containing deployment information (Deployment_data.xls).

Purpose and permitted specific use:
Permitted use: Data has been supplied to the student, Rhian Forrest for use in her MRes project "STANDARDISED METHODS FOR COLLABORATIVE LONG-TERM MONITROING AND MANAGEMENT OF CETACEANS IN WALES".

Copies of the final report in electronic and hard copy must be supplied to the organisation within 6 months of the date of this agreement 31st August 2018, unless agreed otherwise.

Restrictions:
This is original data which has been supplied and is not for reproduction other than for use in the project specified above. The data is not for resale or redistribution without written permission from Dr Sarah Perry or an alternative agreed representative of the Wildlife Trust of South and West Wales Living Seas staff team at the Cardigan Bay Marine Wildlife Centre.

All original data remains the intellectual property of the organisation and full credit, acknowledgement and co-authorship must be given in any publications, including the inclusion of the organisation logo in any documentation produced (including dissertation thesis) as a result of the use of this data in any format or derivatives of the original data. Logo can be supplied upon request.

Individual/Organisation to be credited: Dr Sarah L Perry, Cardigan Bay Marine Wildlife Centre part of the Wildlife Trust of South & West Wales, Patent Slip Building, Glanmor Terrace, New Quay, SA45 9PS.

Cardigan Bay Marine Wildlife Centre
Canolfan Bywyd Gwyllt Morol Bae Ceredigion

Cardigan Bay Marine Wildlife Centre
Patent Slip Building
Glanmor Terrace
New Quay
Ceredigion
SA45 9PS

Phone: 01545 560224
E-mail: info@cbmwc.org
www.cbmwc.org
www.facebook.com/CBMWC
www.twitter.com/CBMWC

The Cardigan Bay Marine Wildlife Centre is part of the of the Wildlife Trust of South and West Wales

The Wildlife Trust of South and West Wales
The Nature Centre
Fountain Road
Tondu
Bridgend
South Wales
CF32 0EH

www.welshwildlife.org
info@welshwildlife.org

Reg Charity No. 1091562

YMDDIRIEDOLAETH natur WILDLIFE TRUST
South and West Wales
De a Gorllewin Cymru

Protecting Wildlife for the Future

Gwarchod Natur ar gyfer y Dyfodol

Additional credit and acknowledgement must be provided to Steve Hartley, Dolphin Survey Boat Trips.

Any further notes:

I can confirm that I RHIAN FORREST have read and understood the general conditions of data supply and use and confirm that I agree to the conditions detailed in the Data Supply Agreement documentation.

Signed by [redacted]

Signed by:

Date: 02-09-2018

Date:

On behalf of Organisation:

Swansea University

On behalf of Individual/Organisation:

Helping to conserve Cardigan Bay's **marine wildlife** through education and research.

Helpu i warchod **bywyd gwyllt morol** Bae Ceredigion drwy addysg ac ymchwil.

Risk Assessments

Risk Assessment for Teaching, Administration and Research Activities

Swansea University; College of Science

Name: Rhian Forrest .... Signature: [redacted]... date: 01-02-2018

Supervisor*: Hanna Nuuttila..... Signature [redacted] date: 01-02-2018

Activity title: Land Surveys...Base location (room no.) ....

(* the supervisor for all HEFCW funded academic and non-academic staff is the HOC)

University Activity Serial # (enter Employee No. or STUREC No: [redacted] ....

Start date of activity (cannot predate signature dates): 01/03/2017 ....

End date of activity (or 'on going'): on going ....

Level of worker (delete as applicable): PG ....

PG,

Approval obtained for Gene Manipulation Safety Assessment by SU ? not applicable

Licence(s) obtained under "Animals (Scientific Procedures) Act (1986)" ? not applicable

Approval obtained for use of radioisotopes by COS ? not applicable

Record of specialist training undertaken

Course	date

Summary of protocols used; protocol sheets to be appended plus COSHH details for chemicals of category A or B with high or medium exposure

Protocol Details						Protocol Details					
#	Assessment					#	Assessment				
	1st date	Frequency of re-assessment	Hazard category	Secondary containment level	Exposure potential		1st date	Frequency of re- assessment	Hazard category	Secondary containment level	Exposure potential
1						11					
2						12					
3						13					
4						14					
5						15					
6						16					
7						17					
8						18					
9						19					
10						20					

See notes in handbook for help in filling in form (Continue on another sheet if necessary)

Bioscience and Geography Protocol Risk Assessment Form

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol #	**Title:**
Associated Protocols #.........................	**Description:**

Location:

circle which Bioscience and Geography Local Rules apply –

Boat **Field** Genetic-Manipulation Laboratory Office/Facility Radioisotope

Identify here risks and control measures for work in this environment, additional to Local Rules

See additional forms

Chemicals	Quantity	Hazards	Category (A,B,C,D)*	Exp. Score

Hazard Category (known or potential)
- **A** (e.g. carcinogen/teratogen/mutagen)
- **B** (e.g. v.toxic/toxic/explosive/pyrophoric)
- **C** (e.g. harmful/irritant/corrosive/high flammable/oxidising)
- **D** (e.g. non classified)

Exposure Potential Circle the **highest Exposure Score** above. Use this to calculate the exposure potential for the entire protocol (see handbook). Indicate this value below.

Low **Medium** **High**

Primary containment (of product) sealed flask/bottle/glass/plastic/other (state) :-

Storage conditions and maximum duration :-

Secondary containment (of protocol) open bench/fume hood/special (state) :-

Disposal e.g. autoclaving of biohazard, SU chemical disposal

Identify other control measures (circle or delete) - latex/nitrile/heavy gloves; screens; full face mask; dust mask; protective shoes; spillage tray; ear-defenders; other (state)

Justification and controls for any work outside normal hours

Emergency procedures (e.g. spillage clearance; communication methods)

Supervision/training for worker (circle)

None required Already trained Training required Supervised always

Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures.

Name & signature of worker [redacted]......................................

Name & counter-signature of supervisor...[redacted]........ *Date* 1-2-18.

Date of first reassessment Frequency of reassessments

x

Risk Assessment: Cetacean Survey, Strumble Head, Pembrokeshire.	
What's it about?	The purpose of this generic risk assessment is to identify the common significant risks which applies during visual sightings of cetaceans and to identify the appropriate control measures.
When does it apply?	19th February – 1st August 2018
Where does it apply?	Strumble Head, Pembrokeshire
Completed by?	Rhian Forrest 01/02/2018

It is possible to identify the level of risk by carrying out a simple calculation: (L) Likelihood/ Frequency of Exposure X (C) Severity/Consequence

L		Likelihood. Frequency of Occurrence
1	Rare	Can't believe this will ever happen
2	Unlikely	Do not expect it to happen but it is possible
3	Possible	May recur occasionally
4	Likely	Will probably recur but is not a persistent issue
5	Almost Certain	Likely to occur on many occasions

C		Consequence/ Severity of outcome
1	None	No injury of adverse outcome
2	Minor	Short term harm or damage (injury will be resolved in 1 month)
3	Moderate	Semi-permanent injury (injury taking up to 1 year to resolve)
4	Major	Permanent harm (loss of body part(s), RIDDOR reportable injury)
5	Catastrophic	Death

Once the level of risk has been identified, Action should be taken as soon as is reasonably practicable. However, the following may provide guidelines for determining the level of risk and the timescale y which action should be taken.

Likelihood	Consequence				
	1 - None	2 - Minor	3 - Moderate	4- Major	5-Catastropic
1 – Rare	1	2	3	4	5
2 – Unlikely	2	4	6	8	10
3 – Possible	3	6	9	12	15
4 – Likely	4	8	12	16	20
5 – Almost certain	5	10	15	20	25

Total	Level of risk	Timescale
12 – 25	High	Immediate
6 – 10	Medium	12 Months
1 - 5	Low	No priority

Task Element	Hazard and harmful effect	Likelihood Information				Control measures	Controlled Risk level			
		L	C	R						
Working in remote environme nt	Being remote	4	2	8	Moderate	Inform at least one person your intended time in the field and anticipated return, including your location.	3	2	6	Moderate
	Lack of phone signal	4	2	8	Moderate	Due to the patchy mobile phone network there may be lack of signal in the field. Agree watch times and sites in advance. Avoid watches	2	1	2	Low
Working in the Field.	Slips, trips and falls	3	2	6	Moderate	Staff should ensure they wear appropriate clothing and footwear with a thick tread to avoid slips and trips. Carry a first aid kit. Be mindful that the terrain is rocky and along a cliff. Stay away from cliff edges and be always stick to footpath	2	2	4	Low
	Exposure to wet/ cold/ sun/ hypothermia/ illness	3	2	6	Moderate	Researcher should be dressed appropriately for wet, windy and cold and hot weather such as waterproof and windproof clothing, hats and sunlotions. Ensure that if researcher get wet, then they should dry off as quickly as possible. Researcher should maintain hydration and eat regularly before, during and after fieldwork activities. Researcher should carry a mobile phone, walkie talkie and other telephone numbers in case of an emergency.	2	2	4	Low
	General injuries Back/ Muscular	2	1	2	Low	Staff should carry a first aid kit at all times. Staff should be careful on uneven or slippery surfaces, avoiding unnecessary bending or stretching in awkward positions. Carrying of heavy equipment should be distributed amongst staff and be strapped to the back in the first instance making sure that the straps are adjusted to the individuals.	2	1	2	Low
	Injury from wild horses	1	4	4	Low	Actively avoid the horses. Do not walk near them or encourage them.	3	1	6	Low

	Injury from vehicles	1	5	5	Low	Once out of the vehicle proceed to the path and do not remain near the road or car park.	1	1	1	Low
	Driving on coast road next to cliff edge	1	5	5	Low	Drive slowly to the car park staying on the road near to the field. Alternatively, park in the laybys before coming to the coast and walk to the site.	1	5	5	Low

Rhian Forrest 01-02-2018 [redacted]	Anghharad James 01/02/2018 [redacted]

Risk Assessment: Cetacean Survey, Pwllheli, North Wales	
What's it about?	The purpose of this generic risk assessment is to identify the common significant risks which applies during visual sightings of cetaceans and to identify the appropriate control measures.
When does it apply?	June – July 2018
Where does it apply?	New Quay, Ceredigion
Completed by?	Rhian Forrest 01/02/2018

It is possible to identify the level of risk by carrying out a simple calculation: (L) Likelihood/ Frequency of Exposure X (C) Severity/Consequence

L		Likelihood. Frequency of Occurrence
1	Rare	Can't believe this will ever happen
2	Unlikely	Do not expect it to happen but it is possible
3	Possible	May recur occasionally
4	Likely	Will probably recur but is not a persistent issue
5	Almost Certain	Likely to occur on many occasions

C		Consequence/ Severity of outcome
1	None	No injury of adverse outcome
2	Minor	Short term harm or damage (injury will be resolved in 1 month)
3	Moderate	Semi-permanent injury (injury taking up to 1 year to resolve)
4	Major	Permanent harm (loss of body part(s), RIDDOR reportable injury)
5	Catastrophic	Death

Once the level of risk has been identified, Action should be taken as soon as is reasonably practicable. However, the following may provide guidelines for determining the level of risk and the timescale y which action should be taken.

Likelihood	Consequence				
	1 - None	2 - Minor	3 - Moderate	4- Major	5-Catastropic
1 – Rare	1	2	3	4	5
2 – Unlikely	2	4	6	8	10
3 – Possible	3	6	9	12	15
4 – Likely	4	8	12	16	20
5 – Almost certain	5	10	15	20	25

Total	Level of risk	Timescale
12 – 25	High	Immediate
6 – 10	Medium	12 Months
1 - 5	Low	No priority

Task Element	Hazard and harmful effect	Likelihood Information				Control measures	Controlled Risk level			
		L	C	R						
Working in remote environme nt	Lack of phone signal	4	2	8	Moderate	Due to the patchy mobile phone network there may be lack of signal in the field. Agree watch times and sites in advance.	2	1	2	Low
Working in the Field.	Slips, trips and falls	3	2	6	Moderate	Staff should ensure they wear appropriate clothing and footwear with a thick tread to avoid slips and trips. Carry a first aid kit. Be mindful that the terrain is rocky and along a cliff. Stay away from cliff edges and be always stick to footpath	2	2	4	Low
	Exposure to wet/ cold/ sun/ hypothermia/ illness	3	2	6	Moderate	Researcher should be dressed appropriately for wet, windy and cold and hot weather such as waterproof and windproof clothing, hats and sun lotions. Ensure that if researcher get wet, then they should dry off as quickly as possible. Researcher should maintain hydration and eat regularly before, during and after fieldwork activities. Researcher should carry a mobile phone, walkie talkie and other telephone numbers in case of an emergency.	2	2	4	Low
	General injuries Back/ Muscular	2	1	2	Low	Staff should carry a first aid kit at all times. Staff should be careful on uneven or slippery surfaces, avoiding unnecessary bending or stretching in awkward positions. Carrying of heavy equipment should be distributed amongst staff and be strapped to the back in the first instance making sure that the straps are adjusted to the individuals.	2	1	2	Low
	Fall from the harbour wall	1	3	3	Low	Do not walk or stand near the edge of the wall. Remain to the path and seating areas.	1	1	1	Low

Rhian Forrest R. Forrest 07/06/18 [redacted]	Angharad James AJAMES 07/06/18 [redacted]

Risk Assessment for Teaching, Administration and Research Activities

Swansea University; College of Science

Name: Rhian Forrest .... Signature: .[redacted] **date:** 4/7/18

Supervisor*: Hanna Nuuttila..... Signature:[redacted]**. date** 4/7/18

Activity title: Land Survey. **Base location (room no.)** Bardsey, North Wales

(* the supervisor for all HEFCW funded academic and non-academic staff is the HOC)

University Activity Serial # (enter Employee No. or STUREC No: [redacted] ....
Start date of activity (cannot predate signature dates): 14/07/18 ....
End date of activity (or 'on going'): 21/07/18 ....

Level of worker (delete as applicable): PG ....

PG,

Approval obtained for Gene Manipulation Safety Assessment by SU ?	not applicable
Licence(s) obtained under "Animals (Scientific Procedures) Act (1986)" ?	not applicable
Approval obtained for use of radioisotopes by COS ?	not applicable

Record of specialist training undertaken

Course	date

Summary of protocols used; protocol sheets to be appended plus COSHH details for chemicals of category A or B with high or medium exposure

Protocol Details						Protocol Details					
#	Assessment					#	Assessment				
	1st date	Frequency of re-assessment	Hazard category	Secondary containment level	Exposure potential		1st date	Frequency of re- assessment	Hazard category	Secondary containment level	Exposure potential
1						11					
2						12					
3						13					
4						14					
5						15					
6						16					
7						17					
8						18					
9						19					
10						20					

See notes in handbook for help in filling in form **(Continue on another sheet if necessary)**

Bioscience and Geography Protocol Risk Assessment Form

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol #	**Title:**
Associated Protocols #........................	**Description:**

Location:

circle which Bioscience and Geography Local Rules apply –

Boat **Field** Genetic-Manipulation Laboratory Office/Facility Radioisotope

Identify here risks and control measures for work in this environment, additional to Local Rules

See additional forms

Chemicals	Quantity	Hazards	Category (A,B,C,D)*	Exp. Score

Hazard Category (known or potential) **A** (e.g. carcinogen/teratogen/mutagen) **B** (e.g. v.toxic/toxic/explosive/pyrophoric) **C** (e.g. harmful/irritant/corrosive/high flammable/oxidising) **D** (e.g. non classified)	**Exposure Potential** Circle the **highest Exposure Score** above. Use this to calculate the exposure potential for the entire protocol (see handbook). Indicate this value below. **Low** **Medium** **High**

Primary containment (of product) sealed flask/bottle/glass/plastic/other (state) :-

Storage conditions and maximum duration :-

Secondary containment (of protocol) open bench/fume hood/special (state) :-

Disposal e.g. autoclaving of biohazard, SU chemical disposal

Identify other control measures (circle or delete) - latex/nitrile/heavy gloves; screens; full face mask; dust mask; protective shoes; spillage tray; ear-defenders; other (state)

Justification and controls for any work outside normal hours

Emergency procedures (e.g. spillage clearance; communication methods)

Supervision/training for worker (circle)

None required Already trained Training required Supervised always

Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures.

Name & signature of worker .[redacted]..

Name & counter-signature of supervis[redacted]......................... *Date*...9/7/18...

Date of first reassessment Frequency of reassessments

Risk Assessment: Cetacean Survey, Strumble Head, Pembrokeshire.	
What's it about?	The purpose of this generic risk assessment is to identify the common significant risks which applies during visual sightings of cetaceans and to identify the appropriate control measures.
When does it apply?	14/07/2018 – 21/07/2018
Where does it apply?	Uwchmynydd, Pwllheli, North Wales.
Completed by?	Rhian Forrest 02/07/2018

It is possible to identify the level of risk by carrying out a simple calculation: (L) Likelihood/ Frequency of Exposure X (C) Severity/Consequence

L		Likelihood. Frequency of Occurrence
1	Rare	Can't believe this will ever happen
2	Unlikely	Do not expect it to happen but it is possible
3	Possible	May recur occasionally
4	Likely	Will probably recur but is not a persistent issue
5	Almost Certain	Likely to occur on many occasions

C		Consequence/ Severity of outcome
1	None	No injury of adverse outcome
2	Minor	Short term harm or damage (injury will be resolved in 1 month)
3	Moderate	Semi-permanent injury (injury taking up to 1 year to resolve)
4	Major	Permanent harm (loss of body part(s), RIDDOR reportable injury)
5	Catastrophic	Death

Once the level of risk has been identified, Action should be taken as soon as is reasonably practicable. However, the following may provide guidelines for determining the level of risk and the timescale y which action should be taken.

Likelihood	Consequence				
	1 - None	2 - Minor	3 - Moderate	4- Major	5-Catastropic
1 – Rare	1	2	3	4	5
2 – Unlikely	2	4	6	8	10
3 – Possible	3	6	9	12	15
4 – Likely	4	8	12	16	20
5 – Almost certain	5	10	15	20	25

Total	Level of risk	Timescale
12 – 25	High	Immediate
6 – 10	Medium	12 Months
1 - 5	Low	No priority

Task Element	Hazard and harmful effect	Likelihood Information				Control measures	Controlled Risk level			
		L	C	R						
Working in remote environment	Being remote	4	2	8	Moderate	Inform at least one person your intended time in the field and anticipated return, including your location.	3	2	6	Moderate
	Lack of phone signal	4	2	8	Moderate	Due to the patchy mobile phone network there may be lack of signal in the field. Agree watch times and sites in advance.	2	1	2	Low
Working in the Field.	Slips, trips and falls	3	2	6	Moderate	Staff should ensure they wear appropriate clothing and footwear with a thick tread to avoid slips and trips. Carry a first aid kit. Be mindful that the terrain is rocky and along a cliff. Stay away from cliff edges and be always stick to footpath	2	2	4	Low
	Exposure to wet/ cold/ sun/ hypothermia/ illness	3	2	6	Moderate	Researcher should be dressed appropriately for wet, windy and cold and hot weather such as waterproof and windproof clothing, hats and sun lotions. Ensure that if researcher get wet, then they should dry off as quickly as possible. Researcher should maintain hydration and eat regularly before, during and after fieldwork activities. Researcher should carry a mobile phone, walkie talkie and other telephone numbers in case of an emergency.	2	2	4	Low
	General injuries Back/ Muscular	2	1	2	Low	Staff should carry a first aid kit at all times. Staff should be careful on uneven or slippery surfaces, avoiding unnecessary bending or stretching in awkward positions. Carrying of heavy equipment should be distributed amongst staff and be strapped to the back in the first instance making sure that the straps are adjusted to the individuals.	2	1	2	Low

Rhian Forrest [redacted] 15-07-18

Angharad [redacted] 15/7/18

Sarah Dickson [redacted] 15/7/18

Jure Zeleznik [redacted] 15/7/18

Table of Contents

Acknowledgements

I would like to thank and acknowledge the following people who have encouraged and supported me throughout this project.

Firstly, I would like to express my upmost gratitude to Dr Hanna Nuuttila: for agreeing to supervise me; and for the expertise, amazing opportunities and encouragement along the way. Thank you.

I would also like to thank all the staff and volunteers at Sea Trust CIC who have assisted in this project, namely: Cliff Benson, Anna Elliot, Sarah Dickson, Holly Dunn, Adam Goodall, Marged Jones and Lloyd Nelmes,

Thank you to Sarah Perry from Cardigan Bay Marine Wildlife Centre for still finding the time to respond to my emails while on maternity leave. Thank you, Sarah and Steve Hartley, for access to the New Quay C-POD data for which I am very grateful.

I also thank Anouska Medzil, Chiara Bertelli and Jure Zelesnik for assisting with the fieldwork, even if it meant driving to Pembrokeshire and finding a blanket of fog. A special thank you to my close friend Angharad James, for her help in data collection and as a sounding board when I needed to talk things through.

And finally, I would like to thank Paul McAvoy for his continued help in cetacean monitoring and my family for their on-going support, without you this project would not be possible.

List of Tables

List of Illustrations

List of Abbreviations

CCW	Countryside Council for Wales
CBMWC	Cardigan Bay Marine Wildlife Centre
DPM	Detection Positive Minutes
GAM	Generalized Additive Model
GLM	Generalized Linear Model
IGBC	Interagency Grizzly Bear Committee
MPA	Marine Protected Area
NBHF	Narrow Band High Frequency
NGO	Non- Governmental Organisation
NRW	Natural Resources Wales
NWWT	North Wales Wildlife Trust
WTSWW	Wildlife Trust of South and West Wales
SAC	Special Area of Conservation
SAM	Static Acoustic Monitoring
SMRU	Sea Mammal Research Unit
STCIC	Sea Trust CIC
SWF	Sea Watch Foundation
WDC	Whale and Dolphin Conservation Society

Introduction

Monitoring long term trends is fundamental for species conservation (Kuemmerlen, Stoll, Sundermann, & Haase, 2016; Riley et al., 2017). It enables assessment of the abiotic and biotic factors that impact a community while providing an early warning system for change to support effective establishment of management practices (Beever, 2006; Schmeller et al., 2017). However, long term monitoring is not always achievable, and many limiting factors contribute to this, including limitations on finances and resources, insufficient planning and limited focus (Lindenmayer & Likens, 2009; McDonald-Madden et al., 2010). When monitoring by a single organisation may be unattainable, collaborative efforts may provide the solutions (Baird et al., 2017). Research collaborations range from providing informal advice and knowledge sharing to labour-intensive participation (Katz & Martin, 1995). Collaborative projects have successfully brought stakeholders together through global initiatives and joint databases on animal movements (Hoenner et al., 2017; Kranstauber et al., 2011), nucleotide genetic sequences (Benson et al., 2013), habitat restoration (Duffy et al., 2019; Miloslavich et al., 2018) and regional capture-mark-recapture sampling projects (Barker & Williamson, 2010; Holmberg, Norman, & Arzoumanian, 2009). Standardisation and unification of monitoring and management efforts by non-governmental organisations (NGOs) could save limited resources; expand species and habitat ecological knowledge; lead to conservation area efficiency and thus yield a higher return of investment (Belaire, Dribin, Johnston, Lynch, & Minor, 2011; Guerrero, Mcallister, & Wilson, 2015; Hooper, Mcdonald, & Mitchell, 1999; Kark et al., 2015; Miloslavich et al., 2018). If organisations held longer term views and considered systems as a whole, rather than isolated studies, resource and environmental management outcomes would improve (Hooper et al., 1999).

Current Land-Based Cetacean Recording Schemes

Land-based vantage point surveys are primarily used for surveying species temporal occurrence, diversity, distribution and habitat use within a defined area using abundance indices to produce site specific encounter rates (Buckland & York, 2009). They are not designed to estimate absolute or even relative population size (Buckland et al., 2001; Evans & Hammond, 2004). Two potential approaches to vantage point surveys have been described within the literature: timed watches and scan sampling (Evans et al., 2015). Timed watches are census-based surveys, whereby the start and end times, environmental conditions and sighting information are recorded (Evans et al., 2015). Timed watches are described as suitable for recording cetaceans in low densities when it is possible for an observer to monitor individual animals and school size (Evans & Hammond, 2004). As the number of animals within a survey area increase it becomes increasingly difficult for an observer to keep track of animals already detected, therefore scan sampling becomes more appropriate to eliminate repeat sightings (Evans et al., 2015).

Scan sampling is a scan of the survey area for a pre-determined duration and the number of animals of each species are recorded, often with environmental conditions recorded at the beginning of the scan (Evans et al., 2015). This method was designed specifically for harbour porpoise (*Phocoena phocoena*) to detect short-term temporal changes in site occurrence and is ideal when recording high numbers of cetaceans (De Boer, Simmonds, Reijnders, & Aarts, 2014; Pierpoint, 1993).

"Surface counting" methods have also been used by observers to count the number of times cetaceans surface to breathe within a set time period to record the presence and absence of the species. The method was introduced as a simple means of collecting data by inexperienced observers (C Benson 2018, pers.comm., 23 March). Multiple observers are collectively counting aloud surfacing events without consideration for duplicate counting, animal behaviour, life stage or location. This method records surfacing frequency per unit time which requires the knowledge of the surfacing rate (surfacings per animal per unit time) to estimate species abundance (number of animals in the sample) (Buckland & York, 2009). It is not possible without additional auxiliary information to disentangle whether there is one individual spending a lot of time foraging, whether there are multiple animals travelling throughout the site or if the same animal is being counted aloud by more than one observer.

Surfacing rate can be counted by monitoring a representative sample of animals (Buckland, Rexstad, Marques, & Oedekoven, 2015), however, this monitoring can be problematic as surfacing behaviour is erratic and unpredictable thus it is challenging to estimate number of animals being observed even for the most experienced observer (Evans & Hammond, 2004). In addition, animals may alter behaviours in response to the presence of an observer and there may be a tendency to sample animals that are more active and thus inflate surfacing rates resulting in biased estimates (Buckland et al., 2001). Previous studies outside the UK provide surfacing rates for harbour porpoise but highlight that ventilation patterns differ depending on whether the animas are foraging or travelling, the age of the animal and external stressors causing behavioural disruptions such as shipping noise (Dyndo, Wiśniewska, Rojano-Doñate, & Madsen, 2015; Eskesen et al., 2009; Watson & Gaskin, 1983; Westgate, Head, Berggren, Koopman, & Gaskin, 1995). Therefore, without recording which behaviours are being observed, life stage of the animal or whether there are external factors such as boat presence it would lead to skewed estimates. For an accurate surfacing rate, studies of different sized and aged animals displaying various behaviours would be required. Cue counting is a valid method often used for counting whales from their blows, birds from their song or organisms from specific cues (Buckland, Marsden, & Green, 2008; Simon & Heide-Jorgensen, 2007; Thompson, Schwager, & Payne, 2010; Thompson, Schwager, Payne, & Turkalo, 2010), but without auxiliary information on vocal behaviour, ventilation rate or surfacing rate of the target species it is not possible to convert this to a comparable abundance estimate (Borchers, Pike, Gunnlaugsson, & Víkingsson, 2009; Buckland & York, 2009).

Therefore, the surface counting methodology will not be considered further for a standardised survey protocol. A comparison of the scan and timed methods used by cetacean organisations will be used as a baseline to produce recommendations for a standard visual cetacean protocol that is realistic, affordable and logistically simple to do by organisations within Wales (Hughes & Peck, 2008).

Challenges in Recording Sightings

In order to recommend a practical and user-friendly survey methodology it is worth recapping the various challenges encountered when recording and analysing sighting data. Weather, environmental conditions, height of the observation platform and habitat selection, observer ability and experience, and animal detectability are significant variables influencing the detection of a species and need to be accounted for in any survey and subsequent statistical analysis (Bart, 2005; Buckland et al., 2001; Dénes, Tella, & Beissinger, 2017; Evans & Hammond, 2004; Evans et al., 2015).

Cetacean vantage point surveys are not normally conducted over sea state 3 (preferably 0-1), or visibility less than 10 km, as smaller cetaceans such as harbour porpoise are less likely to be detected due to their small size, surfacing behaviour and blow (Evans et al., 2015; Evans & Hammond, 2004; Nuuttila, Courtene-Jones, Baulch, Simon, & Evans, 2017). Minimum environmental conditions recorded should include sea state, swell, wind direction, visibility, precipitation and the sun's glare as these will directly impact the ability of the observer to detect cetaceans (Evans & Hammond, 2004). Often cloud cover and general weather conditions, such as whether it is fair, dry or sunny are collected, this provides good reference information for a later date. When there is a failure in a method to record the minimum environmental conditions, it is challenging to compare studies using different methods. For example, if statistical analysis required excluding swell above 2 meters and visibility less than 6 kilometres because they impact the detectability of a specific species, methods that failed to record those variables would have to be excluded from analysis. This may necessitate a need to collect additional data at a considerable cost.

The probability of detecting an animal can be categorised into four constituents: the chance that the home range overlaps the observation site, that the animals are present during the survey, whether they make themselves available to be surveyed (availability) such as birds being concealed in vegetation at different angles and times of day, and whether the observer can detect them (perceptibility) (Buckland et al., 2008; Dénes et al., 2017; Mackenzie et al., 2013; Nichols, Thomas, & Conn, 2009). Also, animals are typically not assumed to be distributed equally over the study area and their age, sex and behaviour may affect their detectability (Evans, 1976; Kéry & Schmid, 2004; Mackenzie et al., 2013; Nuuttila, 2015; Oedekoven, Mackenzie, Scott-Hayward, & Rexstad, 2014). For example, Zamora-marín et al. (2019) found bird detectability increased during the breeding season when vocalisations between the sexes tend to increase. The findings also highlighted a variability between different bird groups with some species significantly more vocal. In the case of cetaceans, they can be missed by observers or unavailable for detection because they are highly mobile, spend the majority of time underwater and can swim fast in and out of the survey area without being detected, which can vary by species (Akamatsu et al., 2007). Thus, estimating the number of individuals is challenging when animal detectability can vary spatially and temporally.

A further challenge that should be considered is that cetaceans are rarely observed at the surface simultaneously, therefore interpreting surfacing synchrony, known spatial location and the observation of distinctive animals such as calves or injured fins is used to estimate group size (Paxton, Mackenzie, Rexstad, & Thomas, 2016). Furthermore, observer sighting efficiency and perceptibility declines with increasing distances from the observation point and will contribute to missed detections of animals (false absences) leading to an underestimation of the population size (Buckland et al., 2001; Denes, Silveira, & Beissinger, 2015; Evans & Hammond, 2004; Mackenzie et al., 2013; Richman et al., 2014). It has been suggested that calibration of observers should be conducted before surveys to minimise observer variance (Williams, Leaper, Zerbini, & Hammond, 2007), yet if researchers conducting continuous surveys throughout daylight hours switch observers every hour or undertake single observer surveys this could be difficult to achieve.

Understanding species spatial location is important to assess habitat selection, life histories and social relationships (Hoekendijk et al., 2015). Recording animal locations are important in distance sampling surveys, as accurate locations are required to calculate the probability of detection, relative abundance and allows for exclusion of duplicate sightings during analysis (Borchers, Marques, Gunnlaugsson, & Jupp, 2010; Buckland & York, 2009; Williams et al., 2007). A primary assumption in distance sampling statistical analysis is that recorded distances are exact (Alldredge, Simons, & Pollock, 2007; Buckland et al., 2001; Chen, 1998; Chen & Cowling, 2001; Williams et al., 2007). Without the recorded distance to the animals and distribution patterns within the survey area it is not possible to correct for imperfect detection or to conclude that if few animals are detected far from the observer if this is due to observation bias or low abundance of animals at that distance (Buckland et al., 2015; Mackenzie et al., 2013; Oedekoven et al., 2014). Previous studies have shown that observers are generally poor at judging distances to fixed and transient targets, resulting in an overestimation in abundance (Marques, 2004; Williams et al., 2007). Analytical correction factors have been developed to minimise bias from inaccurate estimates, however these are not straightforward and maybe overly simplistic when not all survey covariates are considered, leading to less robust estimates than if errors were minimised in the sampling stage by an appropriate protocol (Marques, 2004; Williams et al., 2007).

Distance is recorded in a number of ways including naked eye estimations; laser range finders; reticule binoculars; range finder sticks and theodolites; all with varying degrees of accuracy (Lerczak, Hobbs, & Evans, 1998; Williams et al., 2007). Theodolites are the most accurate method for collecting cetacean distances in the field, however they are still expensive and exclusive and thus not practical or accessible for use by all researchers (Bailey et al., 2010). Reticule binoculars are standard equipment for line-transect surveys for measuring distances to animals, however this results in grouped distance bins. Grouping data does not impact the precision but information for assessing detection function model fit is lost (Buckland et al., 2015).

Using the same trigonometric principles as reticule binoculars photogrammetric methods are becoming more widely used for tracking objects and producing spatial information (Muheim, Henshaw, Sjöberg, & Deutschlander, 2014; Parekh, Thakore, & Jaliya, 2014; Williams et al., 2007). A video camera and binocular are attached to a tripod at an observation point and used to scan the survey area. For analysis the horizon needs to be in view, focal length known and a calibration object with a known size is required (Nuuttila & Mendzil, 2014; Williams et al., 2007). The requirement for keeping the horizon in view at all times leads to challenges when surveying from a platform where the horizon and sightings cannot be viewed simultaneously but there is promise in these modern techniques to minimise survey bias (Nuuttila & Mendzil, 2014).

Development of a standardised survey methodology that considered and took into account all these biases and challenges and became widely adopted by organisations studying the same geographical populations would be advantageous for cetacean conservation as it would enable currently collected data to be pooled for robust statistical analyses (Evans & Hammond, 2004) benefitting conservation and management goals more effectively.

Challenges in Monitoring Species Abundance

For effective environmental management it is essential to monitor population status through reliable absolute or relative abundance estimates to determine if a species is continuing as a sustainable member of its habitat on a long term basis (Dawson, Wade, Slooten, & Barlow, 2008). In addition to the specific challenges for recording accurate animal numbers and measuring distance to each sighting, (as mentioned above), density estimates also require the area surveyed to be calculated, as well as the imperfect detection probability to be accounted for. When the angle of the observable survey area and platform is known it is possible to calculate both the distance to the horizon and to the maximum sighting at that location ($\frac{1}{2} r^2 \emptyset$) (Veness, 2019). The survey area will vary depending on both the platform height and the field of view which may affect sightings rate (Evans & Hammond, 2004; Nuuttila, 2015).

When inter-site comparisons are required area surveyed can be restricted during observation or post processing of the data. These are specifically discussed with relation to Distance sampling techniques, which allow for the density of animals to be defined within an area and assess the related detection probability (Buckland et al., 2001). From the sighting distances a model can be built for the probability of detection (detection function) to a specified truncation distance from the observer which can be used to infer the number of missed sightings (Buckland et al., 2001; Miller, Rexstad, Thomas, Marshall, & Laake, 2014). It is assumed an observer would see everything at zero distance and as the distance increases the number of sightings are assumed to fall (in a line transect). A curve is fitted that displays the relationship between the detection probability and distance, data above the curve are assumed to be sightings that have been missed (Buckland et al., 2001). DISTANCE software is the most popular aid in the design and analysis of line and point transect surveys by fitting the detection functions to produce density estimates for a given area (Miller et al., 2014).

Vantage point methodologies can be regarded as a point sampling survey where the observers are on a stationary platform recording sightings within a predefined area around the observer (Oedekoven et al., 2014). Some of the assumptions of distance sampling fail for vantage point surveys, particularly that all animals would be uniformly distributed around the observer (Mackenzie et al., 2013; Oedekoven et al., 2014). It is understood that an animal density gradient maybe present in land-based vantage point surveys, with marine mammal sightings decreasing towards the observation platform which may vary by species, geological features and location due to non-randomised design (Cox, Borchers, & Kelly, 2013; Mackenzie et al., 2013; Oedekoven et al., 2014). This is similar to studies collecting species abundance estimates along linear features. For example, Irish hares (*Lepus timidus hibernicus*) are often surveyed from roads for observer ease but their distribution is impeded along the road and field edges (Marques, Buckland, Borchers, Tosh, & McDonald, 2010; Tiago A Marques, Buckland, Bispo, & Howland, 2013) Therefore, if few animals are seen far from the observer an analyst using Distance sampling methods cannot be certain that the low numbers are due to an observer failing to detect the animals or if there are fewer animals to be detected there (Oedekoven et al., 2014).

It is rarely possible to separate the imperfect detection process and the uneven distribution of animals in the survey area from the dataset for vantage point surveys and often no correction for these biases are made in statistical analysis resulting in abundance estimates that are too small and leaves the user modelling relative abundance over time (Mackenzie et al., 2013; Marques et al., 2010; Oedekoven et al., 2014). Statistical packages exist to attempt to overcome the violation of statistical assumptions (Buckland et al., 2015; Oedekoven et al., 2014). Nupoint is one such package that provides the estimation of density allowing for the detection function and animal density gradient (Cox et al., 2013). The method requires bearing of the sighting to the observer as well as the estimated distance. However, this software package is currently not being actively maintained by the developer and is not operational in R versions newer than 3.0.0. Buckland et al. (2015) states that these are advanced methods requiring bespoke code because of the problems related to implementation and model sensitivity, and that non-random sampling methods should only be used as a last resort. Furthermore, if no attempt to estimate density gradient is made then consideration for the bias compromising the study objective should be understood (Buckland et al., 2015).

Vantage point surveys and volunteer networks are a low cost means of collecting data on cetaceans, therefore relative abundance over time and species encounter rates (number of individuals sighted/ total survey time) have been used in place of absolute abundance and densities (Danbolt et al., 2010; Di Tullio, Gandra, Zerbini, & Secchi, 2016; Kiszka, Macleod, Van Canneyt, Walker, & Ridoux, 2007). Although this is a perfectly feasible alternative for single site monitoring, it offers little help when data is pooled from different sites. Failure to collect the same environmental conditions, differences in recording details (such as counting surfaces vs group sizes), inability to confirm resighting of individuals and unequal temporal cover of the survey area between scan and timed watches make comparison of methodologies challenging. Survey standardisation is important for cross-study quantitative comparisons of populations temporally and spatially, it results in data which can be interpreted with more confidence than data collected from a myriad of different methods (Legault et al., 2013; McGrew, Marchant, & Phillips, 2009; Nadon & Stirling, 2006; Rödel & Ernst, 2004).

Acoustic Surveys

Vantage point surveys are often conducted in areas where animals are regularly sighted with few occurring outside of these sites (Evans & Hammond, 2004). Where visual surveys lack in temporal coverage, acoustic dataloggers are a low-cost and low-effort means to collect large datasets from ambient noise (Merchant et al., 2016; Southall & Novacek, 2009). An acoustic sensor is an arrangement of hydrophones to detect or record sound and are often designed specifically for ecological monitoring (Sousa-Lima, Norris, Oswald, & Fernandes, 2013). Acoustic techniques can be classified as either passive or active.

Passive acoustic monitoring is when a hydrophone passively records the sounds within the environment (Sousa-Lima et al., 2013). Conversely, active acoustic methods are when a sound is produced from the device and the returning echo from an animal is analysed (Mellinger, Stafford, Moore, Dziak, & Matsumoto, 2007). The hydrophones are either towed behind a ship in an aquatic environment or static, moored on the seabed (Sousa-Lima et al., 2013). Passive acoustic monitoring is widely used and is subdivided into static or mobile techniques (Mellinger et al., 2007), as well as animal-attached data loggers, such as sound and orientation recording tags (Akamatsu et al., 2005; Johnson, Madsen, Zimmer, de Soto, & Tyack, 2006; Zimmer, Johnson, Madsen, & Tyack, 2005). There are various autonomous event recorders available including C-PODS, Atags and AquaTec 100, (Boström, Krog, Kindt-Larsen, Lunneryd, & Wahlberg, 2013; Gallus et al., 2012; Kyhn et al., 2008, 2012; Li et al., 2010; Sousa-Lima et al., 2013), and acoustic sound loggers including SoundTrap, Soundscape and Sonar Products (Deecke, Ford, & Slater, 2005; Sarnocinska, Tougaard, Johnson, Madsen, & Wahlberg, 2016; Wahlberg, 2002). The choice of device and survey design depends on the target species, deployment location, need to avoid unnecessary costs, consideration of battery life and data storage capacity (Sousa-Lima et al., 2013).

Passive static acoustic monitoring (SAM) has become widely used in cetacean research due to its relatively low cost and ease of use and the ability of devices to continuously monitor throughout the diel cycle, year round and in all weather conditions (Simon et al., 2010). SAM devices have been used to assess animal presence; measure seasonal patterns; detect fine scale temporal patterns undetected by visual surveys, study activity patterns and reactions to anthropogenic impacts and to calculate relative density estimates (Nuuttila, Courtene-Jones, et al., 2017; Pirotta et al., 2014; Simon et al., 2010; Verfuß et al., 2007). C-PODs and affiliated software (CPOD.exe, Chelonia Ltd. 2014) are leading static event loggers used to autonomously detect and categorise trains of echolocation clicks of porpoises, dolphins and other toothed whales (excluding sperm whales) through vocalisations in prey detection, orientation and social interactions (Nuuttila, Bertelli, Mendzil, & Dearle, 2017; Pirotta et al., 2014; Tregenza, 1999). Therefore, enabling individuals with limited expertise and skill in marine acoustics to access and interpret acoustic data (Dähne, Verfuß, Brandecker, Siebert, & Benke, 2013; Robbins et al., 2015). C-PODs were originally developed to detect harbour porpoise movement around gill nets, when a large decline in their density had been reported (Chelonia Limited, 2018). As harbour porpoises are the most frequently encountered species in UK waters C-PODs would be an ideal device for a proposed collaborative acoustic monitoring project (Baines & Evans, 2012; Reid, Evans, & Northridge, 2003).

Despite developments in SAM technology, C-PODs do have limitations that need to be understood. Individual C-PODS have limited spatial coverage; can only detect vocalising animals within 150 - 400 m for harbour porpoise and 1000 - 2000 m for dolphins; and are dependent on the directionality of the vocalisation such that animals would need to vocalise towards the device (Nuuttila, Bertelli, et al., 2017; Nuuttila et al., 2018). Regardless, the ability of SAM devices to record continuously makes it a valuable data collection technique to complement vantage point surveys. Where possible an acoustic monitoring study spanning multiple years complementing the vantage point sampling would enable inter-annual comparison and further emphasises the need for collaborative working between marine mammal research groups (Nuuttila, Courtene-Jones, et al., 2017).

Collating Cetacean Data

Current, accessible and high-quality data is necessary for ecological monitoring and management. At present, land-based monitoring data from UK cetacean researchers are not collated into a single centralised database for ease of access by government organisations, industry, academics, researchers or students. Within Wales Natural Resources Wales (NRW) have a contract in place with the Sea Watch Foundation (SWF) to manage a National Cetacean Sightings Database, yet there is limited data integration from other sources (T Stringell 2018, pers.comm., 29 January; K James 2018, pers.comm., 12 March). SWF have been collecting data since the 70s and have the longest record for regular vantage point surveys in the UK (Evans, 1976). In 2013 SWF established a citizen science project, called the Welsh Sea Watchers Group, whereby members of the public are encouraged to organise timed land watches as well as report incidental sightings. Data from Irish Whale and Dolphin Group, Manx Whale and Dolphin Group, Welsh Sea Watchers Group and Whale and Dolphin Conservation Society (WDC) have a data sharing agreement but transfer is not systematic or consistent (B Manley 2018, pers.comm., 2 October). Cardigan Bay Marine Wildlife Centre (CBMWC) have their own established database to enter vantage point records, which is not currently shared or publicly available (L Evans, pers.comm., 12 March). Data from Sea Trust Community Interest Group (STCIC) is provided to the West Wales Biodiversity Information Centre (C Benson 2018, pers.comm., 23 March). Therefore, at present no other organisation apart from SWF is consistently contributing to the sightings database contracted by NRW. Furthermore, there are no systematic acoustic data collection or storage despite several organisations having trialled C-POD monitoring (CBMWC, NRW, SWF) at various times and locations (S Perry 2018, pers.comm., 3 January; K James 2018, pers.comm., 13 March).

Sharing vantage point and acoustic monitoring data would enable population trends to be detected more easily by filling gaps in data collection and has the potential to cover a larger area through collaborative research efforts. Different cetacean species require slightly different observation and data collection standards (Evans & Hammond, 2004), therefore, developing a tailored protocol for all cetacean species was beyond the scope of this project and thus a focal species was required. Harbour porpoise is an ideal focal species both for a standardised visual survey and a collaborative acoustic monitoring project due to their coastal habit; widespread year round distribution in UK waters (Baines & Evans, 2012; Reid et al., 2003); and their highly stereotypical vocalisation (Akamatsu et al., 2007; Nuuttila, Bertelli, et al., 2017).

Wales is indicative of many localities around the world where cetacean conservation efforts are fragmented and would benefit from collaborative long-term monitoring to combine understanding of species populations for these highly migratory animals. Therefore, this study will use Wales as a case study to explore the potential of a collaborative vantage point sampling and acoustic monitoring programme.

Aims and Objectives

This paper aims to:

(i) explore the perceived barriers and potential solutions for collaboratively monitoring and managing cetaceans in Wales;

(ii) describe the current survey methods used for cetacean monitoring in Wales, produce recommendations for a standard visual cetacean protocol and present a case study highlighting how data could be analysed to show temporal trends;

(iii) make recommendations for a systematic regional acoustic monitoring project, discuss the necessity of a joint database and present a case study highlighting how acoustic data could be analysed to show spatial and temporal trends.

Materials and Methods

Case Study Location

Efforts to survey cetaceans around Wales, UK, have been made since the 1970s (Evans, 1976). Despite the UK being under obligation by the EU Habitat Directive Annex II to manage, protect and designate prime areas of cetacean habitat specifically for their ecological needs (European Commission, 1992), there is an apparent lack of leadership from the UK environment agency to conduct required monitoring in a systematic way and very limited collaboration and partnership with stakeholders, or independent non-profit conservation organisations. This results in non-comparable datasets, often on the same species using different methodological approaches, such as non-systematic boat and land-based surveys, line-transect sampling; mark- recapture, click or cue counts, land-based scan-sampling and acoustic monitoring (Anderwald et al., 2013; Evans et al., 2015). Within Wales there is a sense of collective responsibility: no single individual or organisation are acknowledging liability for monitoring or managing cetacean populations. Natural Resources Wales (NRW; previously Countryside Council for Wales, CCW) and local councils have contracted their monitoring obligations to local NGO's to conduct independent research (A Rogers 2017, pers.comm., 25 January; T Stringell 2018, pers.comm., 29 January).

Currently, four organisations each with a dedicated network of mainly volunteer individuals record incidental sightings, conduct vessel and vantage point surveys and have established mark- recapture projects on cetaceans in Wales: (i) CBMWC; (division of The Wildlife Trust of South and West Wales, WTSWW) collect data in West Wales;

(ii) SWF collect data in North and West Wales; (iii) STCIC in South West Wales and (iv) WDC collect survey data around Bardsey island during August and September.

Barriers to Collaboration

A total of 26 individuals with expert knowledge on cetacean monitoring within conservation organisations and academic research institutions were consulted through an online questionnaire on SurveyMonkey to gain an understanding of vantage point and acoustic survey use, previous collaborations and past and present reasons for the lack of collaboration on cetacean research in Wales (Appendix 1). Individuals with relevant experience with cetacean monitoring and in-depth experience working as or with welsh researchers were considered experts in this topic (Krueger, Page, Hubacek, Smith, & Hiscock, 2012). Based on this, the number of researchers was small and it was important that individuals remain anonymous to ensure accurate and open responses to the survey, therefore it was decided not to ask for sector or other information that could lead to identification.

The survey consisted of 10 questions with an estimated completion time of 10 minutes. Previous studies were consulted and terminology noted to attempt to avoid asking questions that could produce unintended bias in answers (Authier et al., 2017; Nuno, Bunnefled, & Milner-Gulland, 2014; Robins, Bates, & Pattison, 2011). It was determined that no terminology needed defining, since the questionnaire was sent to an expert focus group. Formulation of the survey questions aimed to use simple, precise syntax and familiar words without ambiguous or suggestive meanings (Brace, 2008; Krosnick & Presser, 2010; White, Jennings, Renwick, & Barker, 2005). Consideration was taken that answers were mutually exclusive, precise and meaningful, without contradictions and aimed to avoid loaded questions to influence or bias the participant. Furthermore, the response framework was thought-out by 2 researchers to consider all conceivable responses to prevent leading responses and ordered randomly to prevent selection bias, minimise fatigue and aid in memory retrieval (Brace, 2008; Foddy, 1994; Krosnick & Presser, 2010). Respondents also had the option to select 'other' in the multiple-choice questions and further elaborate to increase respondent optimizing (thoroughly choosing an unbiased answer) and reduce automatic compliance (completing the questionnaire without intrinsic motivation) or satisficing (choosing a response that is mildly suitable) (Krosnick & Presser, 2010). Questions comprised of multiple response answers, categorical data and open responses; and descriptive statistics were used for relative frequencies in RStudio 3.5.0 (Aguilar-Støen & Dhillion, 2003; Baghli & Verhagen, 2003; Bouton & Frederick, 2003; Jacobson, Sieving, Jones, & Van Doorn, 2003; Peters, Schreiber, Guay, & Baedell, 2015; RStudio Team, 2016).

Determining a Standard Vantage Point Protocol

A study was conducted on the 23rd April 2018 and 3rd May 2018 from Strumble Head, Pembrokeshire, to trial and assess vantage point survey methodologies currently used within Wales. Strumble Head was chosen for the vantage point surveys due to the pre-existing record of high harbour porpoise abundance (Evans et al., 2015).

Strumble Head is a headland in Northern Pembrokeshire, Wales, near Southern Cardigan Bay. There are deep channels between the headland and Strumble Bank (approximately 3 km from Strumble Head) shaped by strong tidal currents with flow speeds of 42 knots at high water depositing sand and sediment (Natural Resources Wales, 2015b). Strumble Head is a shallower sandy gravel bar (<30 m) with high wave stress (Natural Resources Wales, 2015b). Cetacean land-based observations have occurred from Strumble Head by STCIC since its establishment following the sea empress disaster in 1996 (C Benson 2018, pers.comm., 23 March).

Requests were made to CBMWC, SWF, STCIC, NWWT, Gwent Wildlife Trust, NRW; and WDC for use of their marine mammal survey methodologies. Vantage point survey methods were received from CBMWC (timed sampling), SWF citizen science recording form and primary researcher recording form (timed sampling), North Wales Wildlife Trust (NWWT; scan sampling) and WDC (scan sampling). CBMWC and SWF use the same methodologies for their primary studies on bottlenose dolphins in Wales, thus four methods were compared in this study. All methods were anonymised and with the assistance of 10 volunteers each method was trialled simultaneously to assess the capability of the practiced observer to record the number of porpoises within the survey area. Each method had the required number of observers as instructed in the protocol and were run simultaneously from the same platform but ensuring observers were not influenced by sightings made by other observers. The survey methods were qualitatively evaluated, individually scored from poor to excellent (1 - 5) against pre-determined criteria on their capability to minimise repeated sightings and species or group size uncertainty, their ability to record individual sightings locations; the ease of recording for the observer, and the capability to minimise observer fatigue and the prevention of observer distraction during a 2-hour period (Table 1). These scores were then used to rank each survey method 1-4. As the scan intervals ranged between 5 - 15 minutes the sightings data was combined into 30-minute intervals for ease of comparison. Some surveys alternated observers every scan therefore it was not included as a covariate in the combined dataset. A one-way ANOVA was done to compare the number of individual harbour porpoise detected by the different methods.

Table 1. Scoring rubric for comparison of vantage point survey methodologies. Methods are scored from 1 (poor) to 5 (excellent) to represent the pre-set criteria.

Criteria	Notes	Scoring
Minimise recording repeated sightings	Repeated sightings could occur from scanning the same area more than once, losing track of individuals or combining two observers simultaneously during a scan.	1 = Multiple observers simultaneously scanning and recording. 2 = Scanning repeatedly without consideration for repeated sightings. 3 = Keeping track of recorded individuals while continuing scan. 4 = Scanning once to ensure each individual recorded only once. 5 = Two independent surveys conducted simultaneously.
Record sightings locations accurately between observers	Between observer inaccuracies in measurement distances can occur with estimation, plotting sightings on a reference map, height difference of observers using reticules.	1 = Not accounting for sightings locations. 2 = Training observers to do it by eye. 3 = Using distances to known landmarks or buoys. 4 = Using a scale within standard equipment (e.g. reticules). 5 = Using equipment specifically for accurate distances (e.g. theodolites, range finders).
Remove scan bias	Prevention of an observer favouring areas known to be a cetacean hotspot during the scanning process.	1 = The observer focused solely at known hotspots. 2 = The observer showed definite bias for observing in hotspots. 3 = Scanned the area back and forth. 4 = Scan left to right over the survey area evenly. 5 = Scan front to back left to right evenly.
Minimise time lost during the scan	Time lost can occur because the observer has to write down observations, removal of binoculars to estimate range, stopping the scan to track other sightings.	1 = Observer stopped scan and could not continue. 2 = Observer stopped scan to track previous sightings. 3 = Observers paused scan to write environmental and sightings data. 4 = Observer paused scan to estimate distances. 5 = Observers could do the scan uninterrupted.
Ease of form completion for observer	Is the form simple to use by both inexperienced and experienced observers?	1 = Inability of observer to complete the form. 2 = Observer missed recording an entire covariate. 3 = Observer missed more than 25% of the recording form. 4 = Observer missed less than 25% of the recording form 5 = Observer completed all of the recording form.
Minimise observer fatigue	Is there rotation of observers to minimise fatigue?	1 = No rotation of observers 2 = Rotation but no breaks for an observer. 3 = Rotation and breaks for an observer. 4 = Rotation with short surveying periods (< 2 hour). 5 = Rotation with scan breaks and short surveying period (< 2 hour) per observer.
Minimise user distraction	Similarly, to minimising time lost. Distractions occur because the observer has to write down observations, removal of binoculars to estimate range, stopping the scan to track other sightings.	1 = Observer stopped scan and could not continue. 2 = Observer stopped scan to track previous sightings. 3 = Observers paused scan to write environmental and sightings data. 4 = Observer paused scan to estimate distances. 5 = Observers could do the scan uninterrupted.
Equipment cost	Does the methodology require equipment outside of standard materials (ie binoculars and clipboard)?	1 = Yes, costly* and difficult to obtain. 2 = Yes, costly* but easy to obtain. 3 = Yes, affordable* but difficult to obtain. 4 = Yes, affordable* and easy to obtain. 5 = No *Compared to a standard pair of marine binoculars (approx. £200)

Estimating Area Observed

Following the comparison of vantage point methodologies, the method that ranked the best against the pre-selected criteria was determined and trialled at Strumble Head, and in locations where long-term monitoring by Welsh NGOs currently occur: New Quay and Bardsey Sound.

In order to allow for comparison of observed encounter rates in the form of relative density of animals at each site, the area observed for each observation site was calculated, based on the height of the observation platform and available field of view. From this a recommendation was made how one could potentially achieve more comparable density estimates by either restricting scans to a certain distance and field of view around the observer, or alternatively, limiting data-analysis within a certain pre-determined area, based on information from observed distances and bearings to animals.

The height of each observation site above sea level was 5, 28, 33 m for New Quay, Strumble Head and Bardsey respectively. Assuming no atmospheric refraction, and a spherical Earth with a radius of 6371 km, with the height of the observer forming a right angle, it is possible to calculate the approximate distances to horizon using Pythagorean theorem.

The total field of view scanned at each of the sites is known: 170, 130 and 100 degrees. From these two known values it is possible to calculate a total sea area available for each site. However, even with 7 x 50 binoculars it is not possible to pick up animals at these maximum distances, so instead of using distance to horizon the maximum distance where animals were sighted at each of these sites was used as an indicator of a potential observable distances.

This was done by converting the reticule measurements from the binoculars into sighting distance.

$$h \times 1000/m \quad \text{(Eqn.1)}$$

where h was the eye height above sea level and m is the number of mils in each reticule of the binoculars.

The observable area was then calculated as the area of a sector of a circle, where the observer would be based at the centre of a circle. The equation used was

$$\frac{1}{2} r^2 \varnothing \qquad \text{(Eqn.2)}$$

where r was the radius of the circle (the maximum sighting distance during our experiment), and the $\emptyset$ was the angle of the field of view in radians subtended by the arc at the centre of the circle (Fig 1).

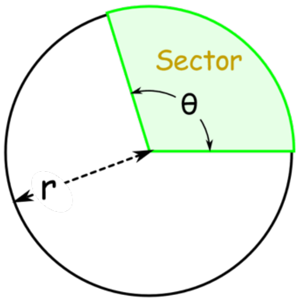

Fig 1. Area of a sector of a circle.

As the maximum distances are most likely affected by both perception bias and availability bias (Mackenzie et al., 2013; Oedekoven et al., 2014), the distribution of observed distances was examined by plotting the sighting distances for both sites/species in histograms to assess whether a rough estimation of detection probability would be possible (Buckland et al. 2001), and to assess whether a cut off for scanning distance could be recommended.

Detecting Accurate Distances

The importance of accurately reporting cetacean distances have been discussed in this study. A field study was undertaken to assess the ability of observers to accurately estimate distances with the naked eye.

Observers estimated various static distances with the naked eye while the recorder measured the distance with a laser rangefinder (Nikon Forestry Pro). Bland Altman analysis and Wilcoxon signed rank test was done to measure the agreement between the rangefinder and the observer. To assess the bias of the measurement error, line and point transect survey data were simulated with the under and overestimate measurement error. Using RStudio (RStudio Team, 2016) and DISTANCE package 0.9.7 (Miller, 2017) models were constructed with the inbuilt Minke and Montrave bird data sets with half normal (line transect) and uniform cosine (point transect) detection functions (Miller et al., 2014). Model selection was based on lowest AIC values. It was assumed that all assumptions of distance sampling methods had been met, including that animals were distributed uniformly within the survey area.

Case Study 1: Trialling the Standard Vantage Point Protocol

The chosen method was trialled at Strumble Head, New Quay and Bardsey Sound with tidal race sea state on the Beaufort scale and wind direction added to the recording form. The chosen protocol required one observer to scan left to right once with a set duration specific to the requirements of that area (10 minutes). The survey necessitated a minimum of two trained observers and a sea state below Beaufort scale 4, no precipitation and the ability to detect the horizon. One observer scanned the survey area from left to right, forward to backwards slowly through reticule binoculars and recited sightings to the recorder, the observer switched every scan. The environmental conditions were noted at the beginning of the scan period and when conditions changed.

Due to unfavourable weather conditions impeding successful surveys during the fieldwork period 231 10-minute scans were completed in Strumble Head between May-July; 12 at New Quay and 39 at Bardsey Sound. No cetaceans were sighted at Bardsey Sound and 2 hours at New Quay were insufficient for statistical analysis, therefore analysis was limited to Strumble Head dataset only. The detailed methodology of the chosen protocol with the addition of tidal race sea state and wind direction is available in appendix 2 and 3.

Statistical Analysis

Best estimates of the number of individuals and number of sightings were summarised for each 10-minute interval and additional variables including: hour difference from high water, and hour difference from sunrise and sunset were added to enable analysis of diel and tidal patterns. Sunrise and sunset times were obtained from the U.S. Naval Observatory (http://aa.usno.navy.mil/index.php) and tide times from WillyWeather (https://www.willyweather.co.uk).

The dataset was tested for homogeneity of variance, over dispersion, collinearity and independence in RStudio 3.5.0 prior to statistical modelling (RStudio Team, 2016). After testing collinearity with VIF in the *car* package 3.0.0 (Fox & Weisberg, 2011) variables were excluded based on reducing the VIF value below 2 (Zuur, Ieno, & Elphick, 2010). Remaining variables selected to model included: high water difference to assess tidal variations on harbour porpoise presence at either flood or ebb within the tidal cycle, swell, sea state on the Beaufort scale, tidal race sea state on the Beaufort scale as they will impact the ability of the observer to detect harbour porpoise, sunset difference for diurnal variations resulting from internal body clock, prey diurnal rhythms or external cues; and boat presence as a binary variable to assess if harbour porpoise react to vessel noise (Dyndo et al., 2015; Gregory & Rowden, 2001; Johnston, Westgate, & Read, 2005;

Nuuttila, Bertelli, et al., 2017; Nuuttila, Courtene-Jones, et al., 2017; Pierpoint, 2008). All variables excluding boat presence (factor variables) were treated as smooth variables. To model the relationship between the response variable (counts of individual animals) and explanatory variables (environmental and observer) Generalized Additive Models (GAM) in *mgcv* package 1.8-26 was used (Mackenzie et al., 2013; Oedekoven et al., 2014). GAMs provide a means of modelling relationships between animal counts, observer and environmental covariates (Dähne, Gilles, et al., 2013; de Boer, Eisfeld, & Simmonds, 2012; Mackenzie et al., 2013; Nuuttila, Courtene-Jones, et al., 2017; Oedekoven et al., 2014). For the vantage point survey it was important to determine which covariates impacted the counts of harbour porpoise to ensure this covariate was included in future vantage point survey protocols. GAMS enable continuous covariates that have curved relationships (nonlinear) with the response data to be modelled and therefore using generalised linear models would have been a poor choice (Evans & Hammond, 2004; Mackenzie et al., 2013).

The model used a negative binomial error distribution (negbin), log link and autocorrelation structure using the *bam* function due to overdispersion and autocorrelation within the data (Wood, 2011). Model selection was based on the Akaike's Information Criterion (AIC) with consideration of the r^2 adjusted values and deviance explained (Barlow, Gerrodette, & Forcada, 2001; Forney et al., 2011; Guisan, Edwards, & Hastie, 2002). Thin plate regression splines were used in the model and knot selection was based on Generalized Cross Validation (GCV).

Case Study 2: Wales Wide Acoustic Monitoring

Three C-PODs were deployed in Strumble Head and one in Bardsey Sound during 2018 and combined with existing datasets from New Quay (2016 – 2017, supplied by CBMWC); Oxwich (2015 & 2018, supplied by SEACAMS 2); and Skomer (2017 – 2018, supplied by SEACAMS 2). Deployment dates and locations are presented in figure 2 and appendix 4. The combined dataset facilitated analysis of harbour porpoise trends in hotspots indicated by Baines & Evans (2012).

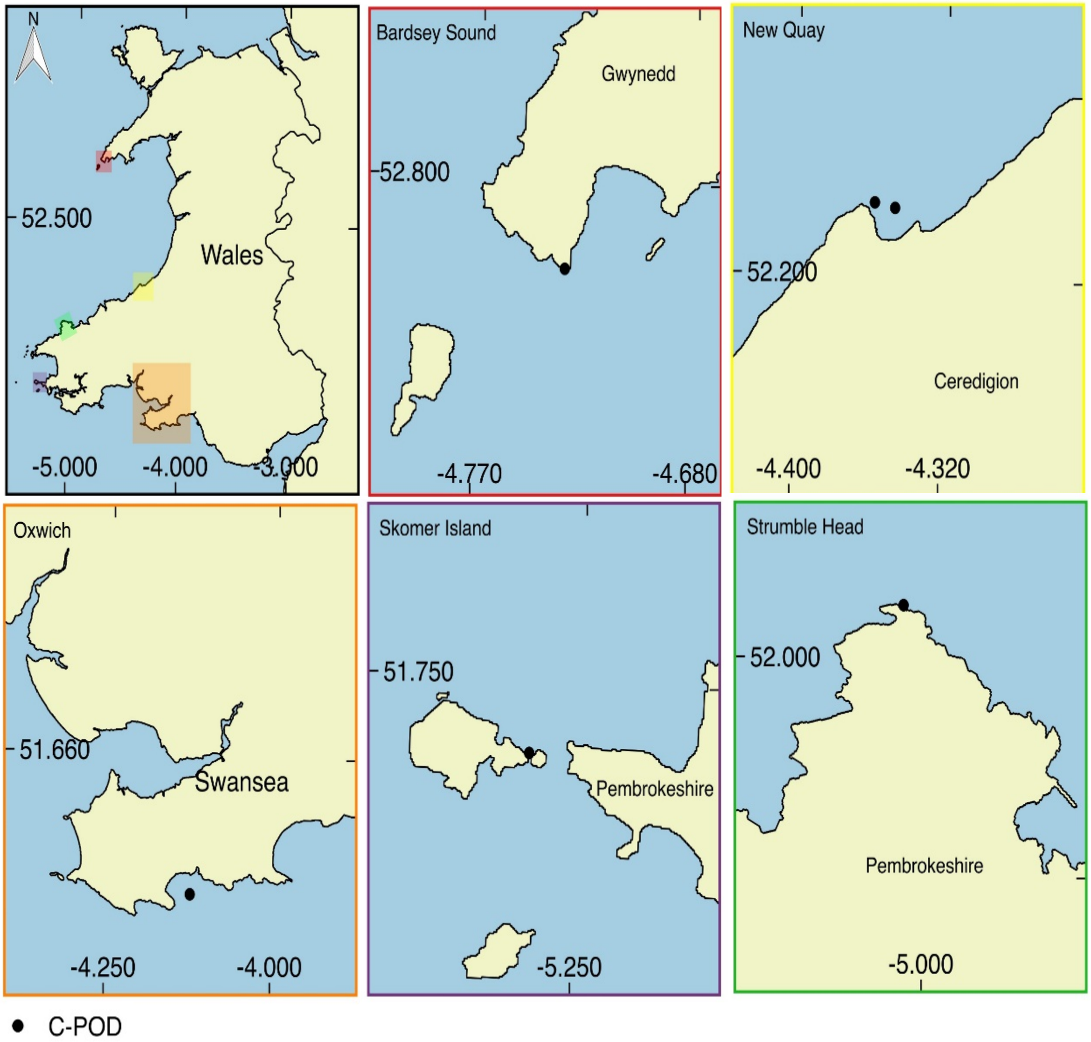

Fig 2. Location of five C-POD deployment sites around Wales (black points).

CPOD.exe will categorise click trains defined by detection thresholds on its likely origin (porpoise, dolphin, boat sonar, unclassed) and its quality class based on the chance the click train arose from a non-cetacean source (Hi, Mod, Low, Doubtful) with an inbuilt algorithmic classifier (Chelonia Limited., 2014). Harbour porpoise detections were exported from C-POD.exe as Narrow Band High Frequency (NBHF) with the quality classes Hi, Mod and Lo. Quality classes are categorised by different sensitivity thresholds based on the risk of false positives (detection of an animal when one is not present) and misclassification of detections. According to the manufacturer, at Hi and Mod the approximate false positives are below 15% and is recommended for statistical analysis (Chelonia Limited., 2014). If a false positive below 15% is required, the manufacturer advises the user to manually validate the detections. Failing to consider false positives may lead to a bias in survey conclusions (Clement, Rodhouse, Ormsbee, Szewczak, & Nichols, 2014).Therefore, High and Mod quality classes were used in the analysis as per the recommendation. Intervals that recorded less than 60 minutes or had more than 5% time lost were removed. The C-POD will turn off when at 90 degrees off vertical and excluding those intervals without a full 60 minutes ensures transfer and deployment times and other disturbances that would put the C-POD upside down affecting its ability to detect cetaceans are removed (Chelonia Limited., 2016). Background clicks (noise) can fill the device memory and surpass a maximum threshold causing the logger to stop recording and miss potential cetacean detections (Chelonia Limited., 2014). More than 5% time lost was determined suitable for removal by comparing correlations of number of clicks and time lost for various percentages (Nuuttila, Bertelli, et al., 2017).

Statistical Analysis

Additional variables were added to the dataset including: high water difference, sunrise difference, sunset difference; tidal range and dolphin presence. Tidal times, sunset and sunrise times were downloaded from WillyWeather (https://www.willyweather.co.uk), U.S Naval Observatory (http://aa.usno.navy.mil/index.php) and Mobile Geo Graphics (http://tides.mobilegeographics.com).

Similarly to case study 1, the dataset was tested for homogeneity of variance, over dispersion, collinearity and independence prior to statistical modelling with Generalized Additive Model in *mgcv 1.8-26* (Mackenzie et al., 2013; Oedekoven et al., 2014; Wood, 2011). C-POD data is count data that is not independent, non-linear, mostly composed of zeros and often over dispersed therefore GAM was determined the most suitable analytical method (Evans & Hammond, 2004; Mackenzie et al., 2013). Tidal range was removed from the analysis due to collinearity and the final model was analysed with a negative binomial error distribution (negbin), log link and autocorrelation structure. The *bam* function in *mgcv* was used because of the large number of data points. Model selection was also based on the Akaike's Information Criterion (AIC) with consideration of the r^2 adjusted values and deviance explained (Barlow et al., 2001; Forney et al., 2011; Guisan et al., 2002). Cyclic penalized cubic regression splines were used for month, hour after highwater, sunrise and sunset differences and generalized cross-validation was used for knot selection.

The response variable was the number of detection positive minutes per hour (DPM) and the explanatory variables for the final model were: month, hour of the day (UTC), hour from high water, hour from sunrise, hour from sunset, sea temperature recorded from the C-POD, deployment locations, and dolphin presence. All variables except for dolphin presence (factor variable) were modelled as smooth variables. Locations were modelled individually and collectively; the detailed methodology for individually modelled locations are available in Appendix 4.

Results

Barriers to Collaboration

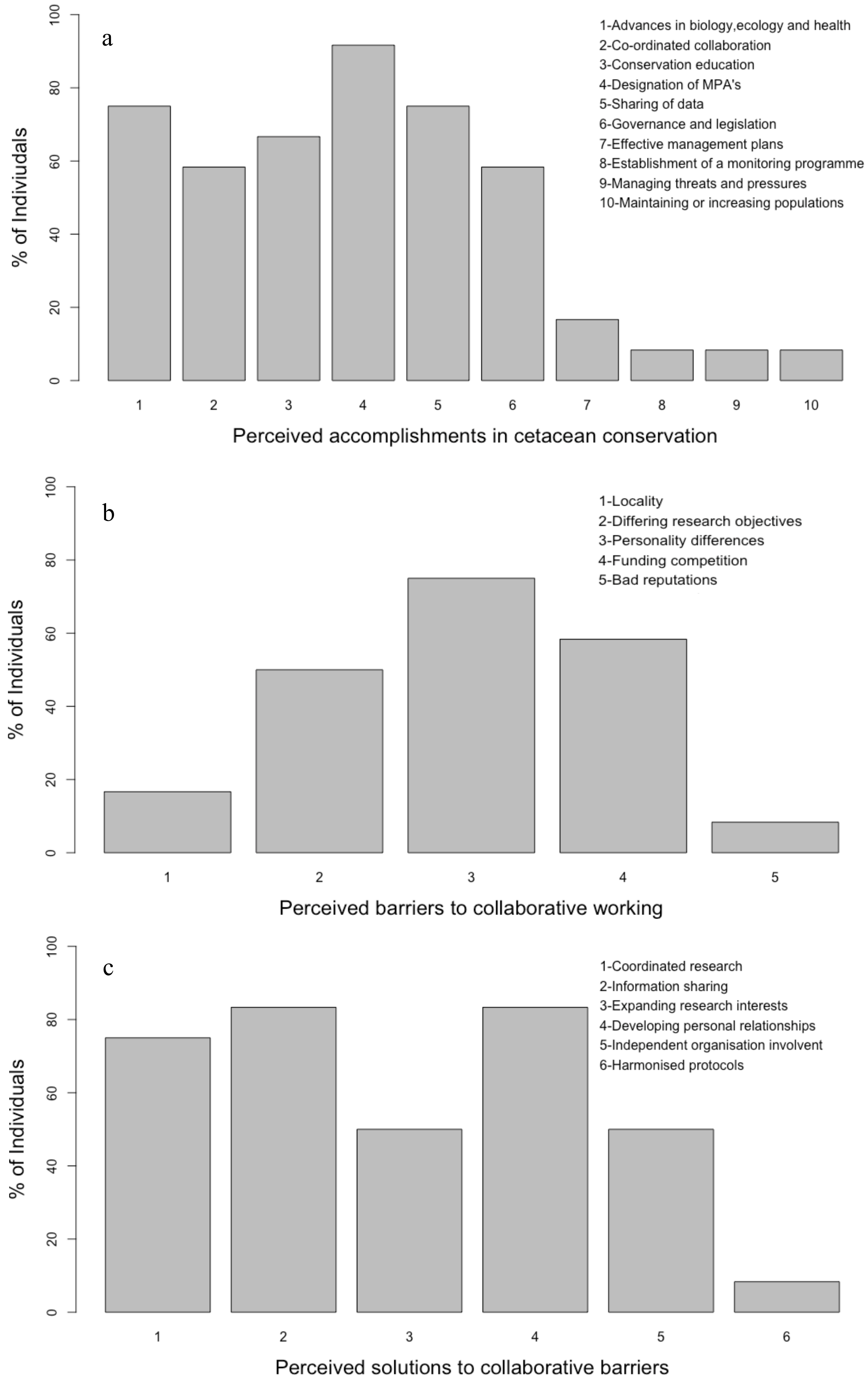

Fig 3. Participant responses to: (a) perceived accomplishments in cetacean conservation; (b) barriers to collaborative working; and (c) potential solutions from the questionnaire.

Of the questionnaire participants, 12 subjects completed the online questionnaire (46% of 26); with half of participants undertaking vantage point surveys within their organisation for an existing long-term monitoring project. The perception of achievements in cetacean conservation varied between participants: the consensus was that designation of Marine Protected Areas (MPA) (n=11, 92%); advances in species biology, ecology, health and disease (n=9, 75%) and sharing data (n=9, 75%) were the main accomplishments (Fig 3a). One responder expressed the opinion that a meaningful monitoring program established by NRW would be a greater accomplishment for conservation because it would facilitate the alliance between organisations in Wales.

Half of the participants (n=6, 50%) had previously collected acoustic data from SAM devices in Wales, including: Lleyn Peninsula, Swansea Bay, Oxwich, Skomer Island, Bardsey Island, and New Quay Ceredigion. The majority of participants intend to implement acoustic monitoring in the near future (n=5, 42%); 33% (n=4) of participants intended to but have barriers preventing them, such as access to equipment, ability to deploy or funding restrictions.

Cetacean data is not being shared or unified within Wales. A third of participants (n=4, 33%) noted that their data is contributed to a national or regional database, while the rest (n=7, 58%) stated that their data is not currently supplied to a database but is available on request. Two individuals (17%) reported that their data is not available in a database nor easily available. However, the majority of those with the intention to collect acoustic data in the future reported that they would be willing to share the data into a centralised database (n=7, 88%). Interestingly, participants stated two caveats to sharing data: one was the opinion that to retrieve any data from a joint database the organisation or individual should first submit their own data; and the second was that data needed to be held by a neutral external organisation.

Of the 12 participants, three quarters (n=9) reported that collaborative working had functioned well previously, and they would consider it again in the future. Of those, a third (n=3) indicated issues, including: other organisations were less willing to share data or had to be contacted repeatedly to do so within a timely manner and that relationships had become very strained at times. The majority of participants reported that personality differences were the primary collaborative barrier (n=9, 75%), as well as direct funding competition (n=7, 58%) (Fig 3b). Additional comments provided by participants stated that funding policies directly cause competition and set organisations against each other; and that organisations and individuals needed to relinquish egos and desire for total control and to focus on current conservation objectives. Over half of those surveyed indicated the solutions to the aforementioned barriers include developing personal relationships and information sharing (n=10,83%). Three quarters of survey participants (n=9) agreed that it would be viable to coordinate research within Wales, and half of the participants (n=6) reiterated a need to create a Wales-wide collaborative group and the introduction of harmonised protocols (Fig 3c). When asked to highlight any additional comments in the open question, participants stated that a central database and a standardised protocol was vital to success. It was stressed that there is currently a lack of leadership to bring the organisations together and guidance is needed from NRW and a financial commitment from Welsh Government.

Determining Standard Vantage Point Protocol

There was not a significant statistical difference between group means for the number of harbour porpoise detected between the four methods ($F(3,12) = 1.094$, $P = 0.389$). These results suggest that statistically, scan methodologies do not differ from timed methodologies in the number of porpoises detected. However, it does not provide an indication on the logistics of the protocols in the field (Table 2). After scoring each method from 1 – 5 (poor – excellent) the methods were ranked to indicate the best method against each criterion, reported in table 3. Method four ranked first followed by method three and then method one. Method four consistently ranked either first or tied first in all criteria. The qualitative comparison highlights that method four ranks best for survey logistics and user experience.

Methodology one required the sightings to be marked on a map and necessitated monitoring each individual for the survey period to prevent duplicate recordings. This method was difficult during large numbers of small highly mobile individuals (n= >50). Many observation sites around the coast have very limited markers of identifiable characteristics to enable an observer to correctly mark locations of animals at sea. Trialling this showed that observers openly questioned their own accuracy in plotting sightings. Hence, this method was not considered practical for a standardised protocol, even if it may well work at a particular site.

Methodology two had the highest count rates per hour (count rate = number of individuals/ survey duration; 58.5 individuals/h) but had the lowest sightings per hour (of individuals or groups; 8 sightings/h), suggesting more animals were counted in fewer groups. The form required a sighting start and end time which was problematic during peak sightings in the trial. Volunteers had significant difficulty completing the recording form resulting in large gaps in sightings end time (42%) and distance estimates (85%), which may have been used to indicate repeated sightings in analysis.

Table 2. Vantage point survey protocol and recording variables for the four methods trialled concurrently. Y=data collected, N= data not collected.

Method ID	1	2	3	4
Method Type	Timed	Timed	Scan	Scan
General weather	Y	N	Y	N
Wind direction	Y	Y	Y	Y
Wind speed	N	N	N	N
Visibility	N	N	Y	Y
Cloud Cover	N	N	N	Y
Precipitation	N	N	N	Y
Glare	N	N	N	Y
Swell	N	Y	Y	Y
Race	N	N	Y	N
Sea state	Y	Y	Y	Y
Distance	Dot on map	Estimate	Estimate	Reticule
Bearing	Dot on map	Estimate	Binocular compass	Binocular compass
Scan method	N	N	Left to right once	Left to right once
Minimum observer	One	One	Two	Two
Observer rotation	N	N	10 minutes	10 minutes
Scan duration	15 minutes	15 minutes	10 minutes	10 minutes

Table 3. Rank of the four vantage point methods from the comparison survey at Strumble Head. Ranks range from 1 (best) to 5 (worst). If there was a tie in the assessment results were sub-ranked.

Method ID	1	2	3	4
Minimise recording repeated sightings	4	3	1.1	1.1
Record sightings locations accurately between observers	4	2.2	2.1	1
Remove scan bias	3	4	1.1	1.1
Minimise time lost during the scan	3	4	2	1
Ease of form completion for observer	3	4	1.1	1.1
Minimise observer fatigue	3	4	1.1	1.1
Minimise user distraction	3.1	3.2	2	1
Equipment cost	1.1.	1.1	1.1	1.1

The third method required the observer to estimate the sighting distance by eye, which required removing the binoculars to estimate. This however creates two problems, firstly, the distances are always subjective estimations and not standardised between observers and secondly, the observer could have missed a sighting while estimating with the naked eye. The fourth method had a similar protocol but enabled the observer to provide distance measurements via the reticules inside the binoculars which minimised the disruption to the scan.

Estimating Area Observed

The height of the observation platform for each site was 5, 28, 33 m and the distance to horizon was calculated as 7, 19 and 21 km for New Quay, Strumble Head and Bardsey sound respectively. The binocular reticules were converted into distances as shown in table 4.

Table 4. Calculated distances for the reticule measurements for each survey site.

Reticules	Distance (m)		
	New Quay	Strumble Head	Bardsey Sound
1	1000	5600	6600
2	500	2800	3300
3	333	1867	2200
4	250	1400	1650
5	200	1120	1320
6	167	933	1100
7	142	800	943
8	125	700	825

Maximum sighting distance for harbour porpoises at Strumble was 5.6 km. There were no porpoises sighted at New Quay, but the maximum bottlenose dolphin sighting was 2 km. As Bardsey sound yielded no observations, no further calculations were made for this site. The observable area based on maximum distances calculated for Strumble head was 35402 km^2 and for New Quay 5449 km^2, although it is crucial to note that these were based on sightings distance for different species. Using this calculated area an estimate density as 0.002 harbour porpoise per hour and km^2 and 0.004 bottlenose dolphins per hour and km^2 were calculated.

The histograms of sighting distances are depicted in figure 4, and the probable detection probability estimated as 0.193 (se 0.032) and 0.339 (se 0.109) for Strumble Head and New Quay. This is not a true detection probability as we cannot assume that animals were distributed evenly, as would be the assumption in line and point transect sampling. Based on observations, we know that animal sightings are low nearer to the observer (the coast/cliff edge) and increase further offshore, especially at Strumble Head where porpoises tended to be mostly observed associated with the tidal flow.

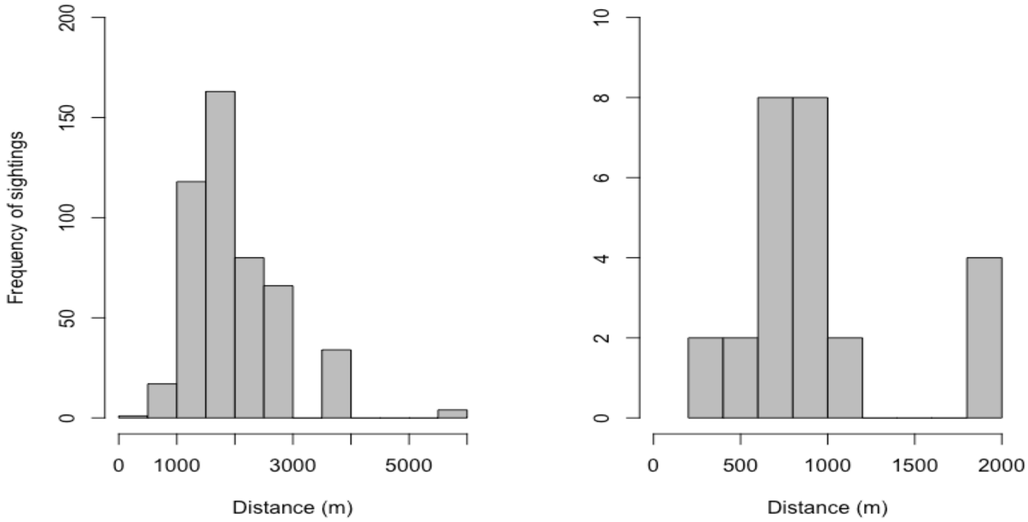

Fig 4. Number of sightings with calculated distances from binocular reticules for (a) harbour porpoise at Strumble Head and (b) bottlenose dolphins at New Quay.

Detecting Accurate Distances

A Wilcoxon signed rank test in RStudio indicated that the naked eye estimation and laser range finder distances were correlated (P-value = 0.02534). The mean difference between the naked eye observation and the laser range finder was 8.93 m (SD 36.75). Figure 5 illustrates that when the average range is between 100 and 175 m the largest differences occurs therein, with observers overestimating sighting distances. Within this distance 40% of data points lie outside of the 95% limits of agreement.

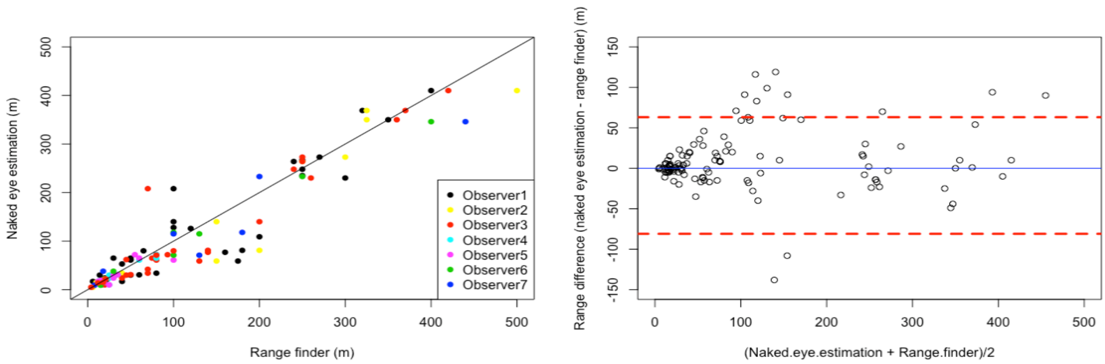

Fig 5. Range estimations: difference (naked eye estimations – range finder) versus average estimations by the observers with the naked eye and range finder with 95% limits of agreement.

When applying the mean difference of naked eye estimates and range finder to the simulated data the density estimates differed by -0.05 animals/ km^2 and + 0.07 animals/ km^2 for point transect whereby the observers underestimate and overestimate by 8.93m respectively (Fig 6; Table 5). For line transect samples the density estimates varied by -0.0004 animals/ km^2 and + 0.0004 animals/ km^2 for 8.93 m underestimate and overestimate.

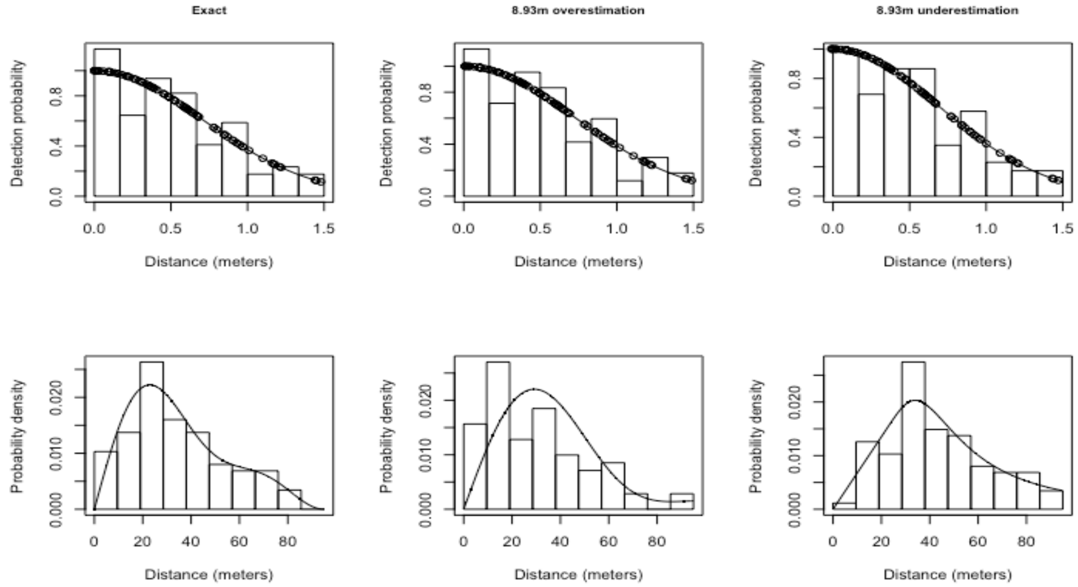

Fig 6. Detection probabilities for line transect data (top row) and probability density for point transect data (bottom row) with the exact distances (left), 8.93 m overestimation (middle) and 8.93m underestimation (right) of the Minke and Montrave distance data.

Table 5. Summary for the detection function models fitted to the Minke and Montrave data with exact distances, 8.93 m overestimation and underestimation for line and point transect.

Analysis		N	se(N)	CV(N)	N/A	se(N/A)	CV(N/A)
Line	Exact	17191.90	5135.5862	0.2987212	0.024034	0.00717	0.298721
Line	Underestimate	17467.692	5213.5878	0.2984703	0.024419	0.007288	0.298470
Line	Overestimate	16917.764	5058.0295	0.2989774	0.023650	0.007071	0.298977
Point	Exact	6.610352	1.236488	0.1870532	0.199107	0.0372436	0.187053
Point	Underestimate	4.436479	0.6184194	0.1393942	0.1336289	0.1393942	0.139394
Point	Overestimate	1.700524	0.4358017	0.2562749	0.05122061	0.0131266	0.256275

Case Study 1: Trialling the Standard Vantage Point Protocol

From the methods trialled in the initial study, method number four was found to be the protocol best suited for use at different geographical sites and for ease of use in citizen science and long-term monitoring projects. An adapted version of the method was developed for this case study. Due to weather limitations 231 10-minute intervals were conducted over 20 days from 3rd May 2018 to the 11th July 2018, of these there were 329 sightings of porpoises (n=601 individuals). The majority of surveys had sightings of porpoises (n=164, 71%), but no other cetacean species were sighted.

The finalised GAM model included all variables: high water difference, sunset difference, swell, sea state, tidal race sea state, except boat presence; which did not explain the variance in the dataset (P-value >0.05, Appendix 4). The most significant variable in the model was tidal race sea state, based on the change in AIC value and deviance explained, followed by swell and sea state. The final model summary is depicted in table 6.

Harbour porpoise count rates within this study are not consistent throughout the tidal cycle or time of day and are impeded by sea conditions. Hour of the day and sunrise difference were removed prior to modelling due to collinearity, therefore diel variation was quantified by sunset difference. Harbour porpoise counts started to decline 9 hours after sunset (M 6.00 counts/ 10 min, SD 5.20) before increasing at 16 hours after sunset (M 5.06, SD 4.82).

There was an increase by 2 DPM/hour 2 hours after high water until 8 hours after high water (Fig 7). The highest mean count rate occurred 3 hours after high water (M 7.70 counts/10 min SD 5.03). The lowest count rate was 1 hour after high water (1.61 counts/10 min SD 3.18). As the tidal race sea state exceeds 1 and general sea state exceeds 2, the harbour porpoise detections decrease sharply by 4 DPM/hour and 16.5 DPM/hour respectively. Surprisingly, the reverse happens for the swell: the harbour porpoise count rate increased by 22 DPM/ hr when the swell increased.

Table 6. Final model summary of count rates from the vantage point survey for harbour porpoise at Strumble Head.

Smooth terms	Edf	Df	F-Value	P-Value	Parametric coefficients	Estimate	Std error	T-value	P-Value
High water difference	2.003	10.000	0.623	0.02098	Intercept	1.3363	0.4753	2.811	0.00538
Sunset difference	2.423	9.000	0.721	0.03042					
Swell	1.863	1.974	2.775	0.04919					
Sea state	2.733	2.936	2.524	0.05681					
Race	2.876	3.405	5.395	0.00231					

R-sq.(adj) = 0.161 Deviance explained = 19% fREML = 359.93 Scale est. = 0.8993 n = 231

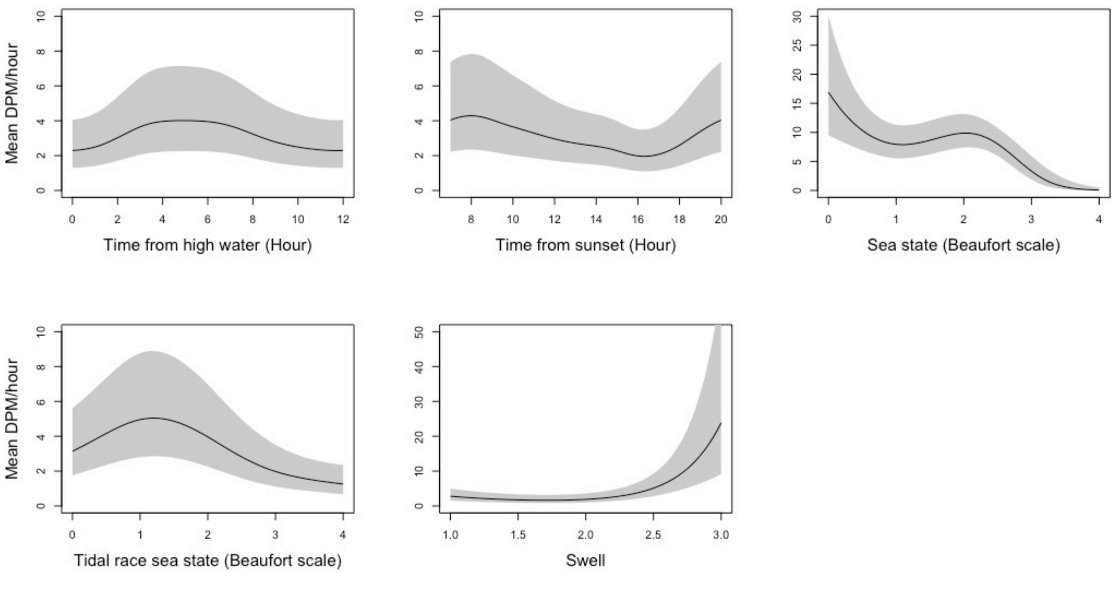

Fig 7. Smooth graphs from the final model for each variable expressed as mean detection positive minutes per hour (DPM/hour) for the harbour porpoise vantage point survey at Strumble Head. The 95% confidence limits are indicated by the grey areas.

Case Study 2: Wales Wide Acoustic Analysis

Harbour porpoise were detected in all locations within the sampling period, although there was clear variation in the mean detection positive minutes per hour (DPM) around Wales (Figure 8). The most significant variables in the model included; location, month, sea temperature, dolphin presence; followed by time from high water, time from sunrise, and hour of the day (Appendix 6). The model summary is presented in table 7.

Deployment location was an important influential covariate on porpoise detections. The highest detections occurred in South Wales: Skomer (M 3.02 DPM/hr, SD 7.37), Strumble Head (M 10.14 DPM/hr, SD 7.37) and Oxwich (M 1.22 DPM/hr, SD 4.27). The lowest detection rate occurred near New Quay Llanina Reef (M 0.17 DPM/hr, SD 1.54).

In Wales, harbour porpoise detections peaked at the start of spring, between March (M 4.76 DPM/hr, SD 9.50) and April (M 4.27 DPM/hr, SD 9.14) and then decreased throughout the summer, averaging 0.31 DPM/hr (SD 2.37), before increasing again in the winter (M 1.77 DPM/hr, SD 5.50). Spring detections varied at the different locations between 0.17 DPM/hr (SD 1.25) at New Quay fish factory and 6.85 DPM/hr (SD 10.61) at Strumble Head. Strumble Head, Oxwich, Skomer and New Quay porpoise detections decreased before June, averaging 0.13 DPM/hr (SD 0.88) (Fig 9a).

In general, harbour porpoise detections were highest between 19:00 and 21:00 (M 2.06 DPM/hr, SD 6.07) and between 02:00 and 06:00 (M 2.00 DPM/hr, SD 6.61) (Fig 8 & 9b). Strumble Head had the highest average DPM per hour (February 11.15 DPM/h, SD 12.65; March 8.64 DPM/hr, SD 11.70); followed by Skomer (March 5.94 DPM/h, SD 11.40; April 4.31 DPM/h, SD 7.91). The highest hourly DPM per hour in Strumble Head occurred at 04:00 and 02:00 (8.42 DPM/hr, SD 13.37; 8.14 DPM/hr SD 13.83) and Skomer at 19:00 and 20:00 (4.95 DPM/hr, SD 9.62; 4.77 DPM/hr, SD 8.92).

Table 7. The summary from the final model of C-POD detections for harbour porpoise in Wales.

Smooth terms	Edf	Df	F-Value	P-Valu	Parametric coefficients	Estimate	Std error	T-Value	P-Value
Month	7.051	8.00	15.044	<2e-16	Intercept	-0.83799	0.25808	-3.247	0.00117
Hour	3.071	4.00	3.270	0.000226	Dolphin presence	-0.46308	0.08541	-5.422	5.93e-08
High water difference	5.267	6.00	9.947	2.21e-12	Location (New Quay FF)	0.33204	0.29713	1.117	0.26379
Sunrise difference	1.677	2.00	5.287	0.000207	Location (New Quay R)	-2.41353	0.30427	-7.932	2.19e-15
Sunset difference	3.566	6.00	1.857	0.001589	Location (Oxwich)	0.62262	0.25216	2.469	0.01355
Temperature	14.525	17.02	8.542	<2e-16	Location (Skomer)	1.71543	0.24674	6.952	3.64e-12
					Location (Strumble Head)	1.86665	0.25210	7.404	1.34e-13

R-sq.(adj) = 0.148 Deviance explained = 34.4% fREML = 70105 Scale est. = 2.3997 n = 52307

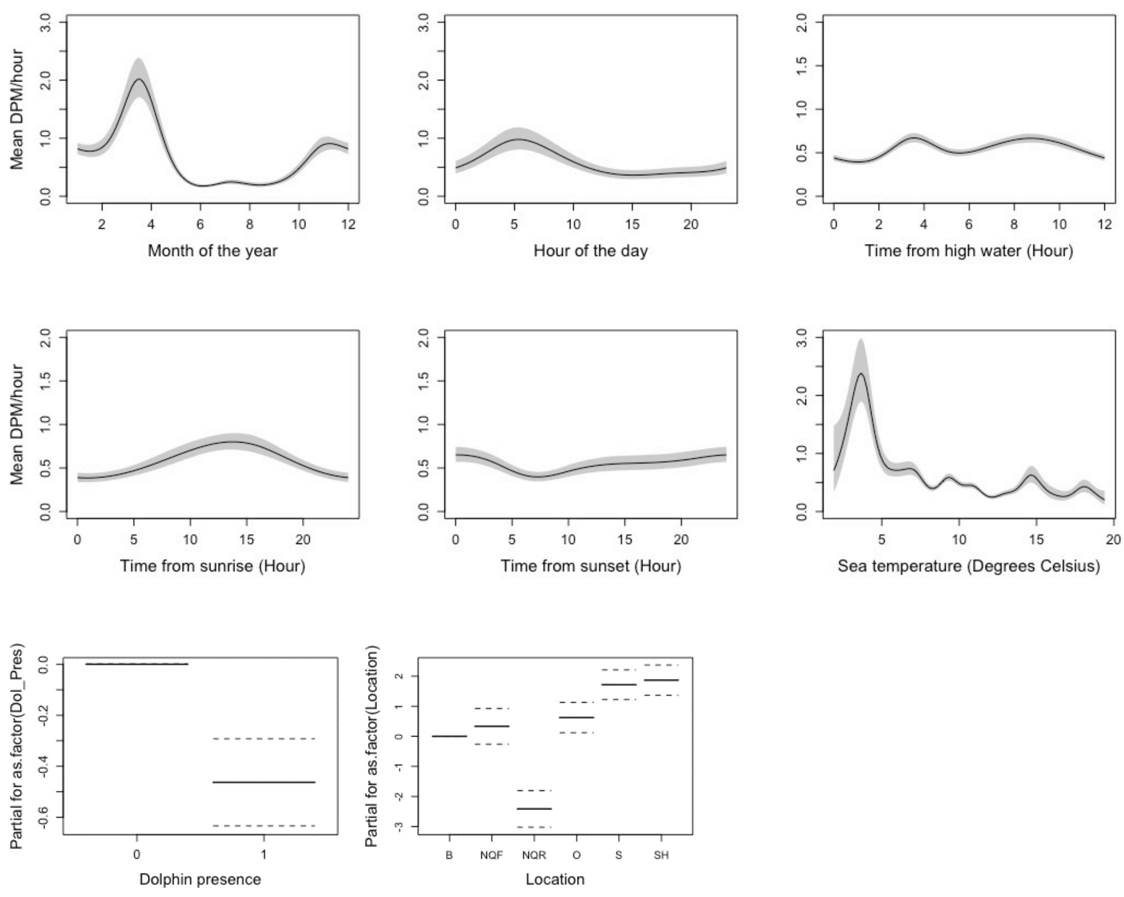

Fig 8. Smooth graphs from the final C-POD detection model for each variable expressed as mean detection positive minutes per hour (DPM/hour) in Wales. The 95% confidence limits are indicated by the grey areas.

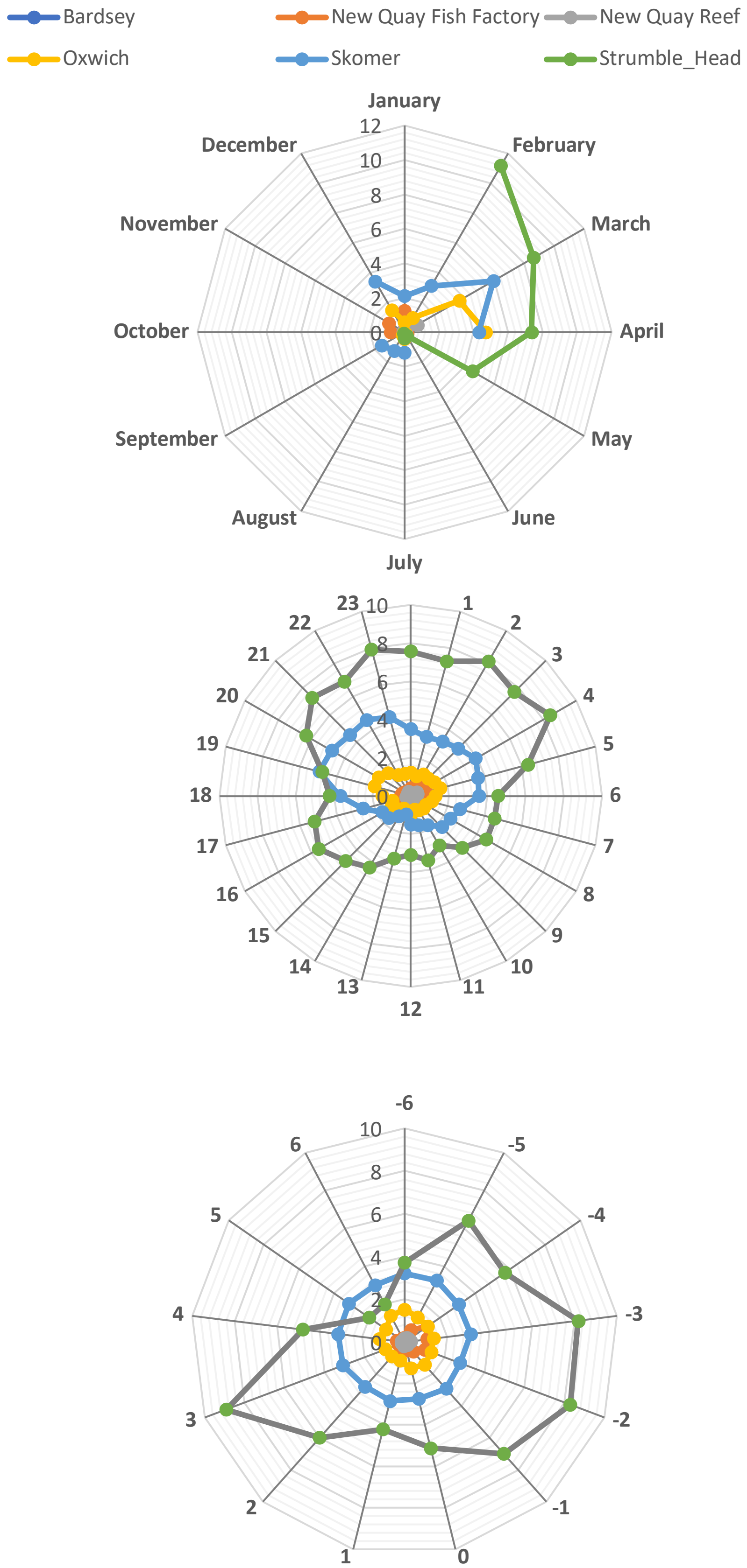

Fig 9. Mean harbour porpoise detection positive minutes per hour for (a) Month, (b) Hour of the day, and (c) Hour after high water.

Discussion

This study set out to recommend a standardised vantage point methodology that could be easily adopted for long term monitoring of cetaceans by various volunteer organisations in Wales, assess the feasibility of an acoustic monitoring project in the region and highlight how the two types of data could be analysed for a systematic collaborative monitoring project. This required investigating barriers to collaborative working and the potential solutions to make this feasible. The primary findings of the study highlighted a desire for the formation of a working group and standardised methodology by cetacean researchers. Following the field trials of the various protocols a scan methodology has been developed to make pooling data easier and more straight forward. The findings of the acoustic trial highlighted the ability of researchers to pool C-POD data to detect harbour porpoise hotspots within South Wales and compare seasonal, diel and tidal variations at different locations. This is particularly relevant in the recent interest in marine renewable energy (MRE) developments at various locations around Wales (Nuuttila, Bertelli, et al., 2017; Transition Bro Gwaun, 2011). This has led to increased demand for baseline data to assess current population status of coastal cetaceans. In addition, there is a need to design surveys to acquire data for assessing and mitigating against potential negative impacts from future developments (Hutchnison, 2017).

Barriers to Collaboration

Questionnaire participants differed in their opinions on what the primary accomplishments would be within cetacean conservation which likely led through to differing research objectives being highlighted as one of the three main barriers to collaborative working (Nuno et al., 2014; Robins et al., 2011). The primary barrier for cross organisational collaboration found in this study was personality differences. A participant stressed that some individuals need to relinquish egos that are interfering with conservation aims. Other studies have indicated that interagency conflict is an important barrier to consider as some agencies forced to relinquish their power or professional expertise refused to contribute, which can lead to duplication of research (Grant & Quinn, 2008). A key example of this is the conservation of the grizzly bear recovery in the United States and Canada, where collaborative attempts have been made by many agencies but had not been successful due to agency cultures, direct intervention by politicians and budget constraints (Primm, 2003). The Interagency Grizzly Bear Committee (IGBC) was created to coordinate management between federal and state agencies, however Grant & Quinn (2008) interviewed stakeholders on factors influencing collaborative attempts and interviewees raised concerns that the IGBC would not make use of data produced by other agencies, which led to a duplication of research. Subsequently, individuals were frustrated with continuing within the historic cultural framework and strived to reduce conflict with other organisations. Developing personal relationships and information sharing was identified in this study as the most important solution to overcome collaborative barriers in Wales. It appears that the success of the conservation network in the past has been determined by a few key individuals, but many of the current marine mammal scientists who contributed to the survey are keen to make alliances and work towards wider conservation goals. Values and beliefs at institutional and individual levels have been seen as a positive factor for active co-operation and common long-term personal relationships a key factor in collaborative working (Daniel, Pinel, & Brooks, 2013; Grant & Quinn, 2008).

The survey results highlighted that an established monitoring programme and working group set up by NRW would help repair the fragmented network in Wales by bringing together stakeholders and providing a forum for personal relationships to develop. In addition, a working group would enable the development and, diversification of research objectives while yielding a higher return of investment (Belaire et al., 2011; Kark et al., 2015). An international working group had been established to facilitate discussions in a scientific forum on aquatic macrophytes with the purpose of communication and collaboration amongst different stakeholders (Arts et al., 2010). The steering group was composed of 12 scientists and during the initial meeting 40 scientists engaged with the group on current work proposals. Likewise, after a recognised need for better coordination amongst avian scientists The Partners in Flight monitoring working group was formed with the goal to collect long term data on the abundance of bird species (Bart, 2005). In 2004 the group published an extensive series reviewing the conservation status of 448 bird species in Canada and the United States and identified that for all species continent wide monitoring was a priority and suggested the best means of filling the data gaps (Dunn et al., 2005). In Wales a marine mammal monitoring group was established by CCW and run for a few meetings before dwindling (C Benson 2018, pers.comm., 23 March). The findings show a renewed interest in establishing a similar network that could provide a positive forum to develop relationships between terrestrial and aquatic scientists and diverse stakeholders to foster adaptive management practices and new analytical tools and outputs, thus improving overall research results (Medema, Furber, Adamowski, Zhou, & Mayer, 2016; Minton et al., 2017; Ogburn et al., 2017; Sandström & Rova, 2010; Schuett, Selin, & Carr, 2001).

Currently only a third of Welsh cetacean data collected is contributed to a national or regional database, however the questionnaire highlights that the majority of those interested in collecting acoustic data would be willing to share within a collated database. The questionnaire unveiled a historic problem of data access in Wales, which is not exclusive to cetaceans or Welsh organisations. For example, ecologists studying seagrasses are currently working towards a coordinated global observation system to mitigate against anthropogenic pressures (Duffy et al., 2019; Miloslavich et al., 2018). Alongside technological challenges for sharing data, sociological challenges exist (Reichman, Jones, & Schildhauer, 2011). If data is being held by a 'competing' organisation or there are inadequate rewards, then the sociological challenges directly impacts the desire to share (Grant & Quinn, 2008). Reichman, Jones, & Schildhauer (2011) states that ecologists have not seen intrinsic benefits to sharing data in the past because it was not seen as worthwhile or standard practice, but this is rapidly changing with many journals introducing policies requiring data from published papers to be archived providing the potential for data to be repurposed (Whitlock, 2011) A study participant stated they would be willing to share data if it was to be held by an independent organisation. A solution for this would be that NRW established novel vantage point and acoustic databases and managed these independently of any regional organisation.

Four key principles for good data management have been described by Wilkinson (2016), data should be: findable, accessible, interoperable and reusable. Successful global databases have allowed users to retain ownership of their data, have control of public access and require submitted data to undergo a review process (e.g. Movebank - animal tracking database, Wikelski & Kays, 2018). Genbank (genetic sequence database) also provide the option to delay the release of new submissions for a specified period of time at the request of the author when it may compromise their on-going work (National Centre for Biotechnology Information, 2019). The establishment of a regional database by the Integrated Marine Observing System's Animals Tracking Facility, which collects movement patterns of various taxa using an array of acoustic receivers around Australia, enabled research on previously unknown connectivity of populations between regions (Hoenner et al., 2017). Using an open-science approach and collating datasets, we can ask vital research questions and re-use existing data in the grander context for broader scale research (Soranno et al., 2015). Within Wales, this could be assigned to one of the Welsh universities, providing funding was allocated. Current collaboration projects between SEACAMS 2 and STCIC, SWF, WDC makes this a viable option for becoming an intermediary to store static acoustic monitoring data (H Nuuttila 2018, pers.comm., 23 February), providing funding for this was allocated, potentially through NRW.

Government agencies and scientific bodies are now starting to explore data management for publicly funded experiments and long-term stewardship plans (Whitlock, 2011;

Wilkinson, 2016) During 2017 SEACAMS 2 at Swansea University started to create a relational database on the open source PostgreSQL platform to effectively store and retrieve acoustic monitoring data (N Franconi 2017, pers.comm., 11 November). The database currently holds C-POD train details (individual cetacean click train information) and detection positive minutes per hour data from C-POD.exe for all deployments carried out at Skomer, Strumble Head and Swansea Bay (N Franconi 2019, pers.comm., 19 June). The database has the potential to become a primary repository for acoustic monitoring data in Wales (H Nuuttila 2017, pers.comm., 11 November). The database was designed to manage complex query, maximise metadata inclusion, eliminate data redundancy and duplication while ensuring stability, data integrity and accuracy (Campbell, Urbano, Davidson, Dettki, & Cagnacci, 2016; Soranno et al., 2015; N Franconi 2019, pers.comm., 19 June). Cooperatively collecting data and making it available to researchers and organisations would enable studies to aid designation of MPAs; advances in species biology, ecology, health and disease; and governance and legislation which the majority of participants (n=11, 92%; n=9, 75%; n=7, 58% respectively) selected as primary accomplishments in cetacean conservation (Bailey et al., 2009; Gallus et al., 2012; Geary, Walter, Leberg, & Karubian, 2018; Hoenner et al., 2017).

Limitations of the barrier analysis have to be considered. The sample size for questionnaire participants was small and did not include every individual responsible for collecting cetacean data in Wales, although in reality there are not many organisations involved, so by default this was always going to be limited. With the small number of responses it is not possible to see the industry or underlying biases they may have, therefore, skewed perceptions of barriers and solutions to overcome collaborative working may have occurred (Brace, 2008). Due to survey constraints, only 10 questions could be asked, therefore for future analysis the author suggests that this should be increased to enable one point per question to further minimise leading questions, minimise the processing required by respondents, fatigue and satisficing (Brace, 2008; Krosnick & Presser, 2010).

Determining Standard Vantage Point Protocol

A questionnaire participant indicated that a standardised vantage point protocol was overdue and would help harmonise collaborative working between organisations. There is often a lack of necessary expertise to design and undertake distance sampling surveys and current economics mean it can be unaffordable to finance extensive or repeated surveys (Marsden et al., 2016). When it is not possible to use distance sampling techniques, encounter rates have been deemed more appropriate when sampling species that are highly mobile with patchy distribution and when sampling is challenging due to survey logistics and limited resources (Linkie, Chapron, Martyr, Holden, & Leader-Williams, 2006; Marsden et al., 2016; Rovero & Marshall, 2009; Samejima, Ong, Lagan, & Kitayama, 2012). Marsden et al., (2016) compared encounter rates and line transect distance sampling techniques to produce density estimates for grey parrots (*Psittacus* spp.) in Central and West Africa. The author determined that encounter rates were a reasonable surrogate for distance sampling with little concern for producing negatively biased density estimates. Similarly, Ruette, Stahl, & Albaret, (2003) stated that point and line transects were a good substitute for spotlight counts of terrestrial mammals such as red foxes (*Vulpes vulpes*) but due to survey logistics line transects would result in better estimates. However, the author highlighted the limitations of using roads as transect lines and noted the possible bias from a density gradient.

To produce easily comparable encounter rates between different observation sites method four was the preferred protocol by volunteer observers and scored highest in the comparison rubric, however, it did lack important environmental variables that would impact perception bias (Evans et al., 2015; Evans & Hammond, 2004). Therefore, the addition of wind direction and tidal race sea state using the Beaufort scale was deemed important to record because the overall sea state was not consistent over the survey areas with the presence of tidal streams. Although not all surveys will be conducted by a tidal race, cliff tops are often preferred observation sites in this area because of high vantage points, and therefore taking account the potential tidal eddies or other features imposed by headlands is an important part of the environmental assessment (Evans & Hammond, 2004). The chosen amended method minimised recounting the same individual multiple times, the need to track individual animals; it produced standardised distance estimates to minimise bias between observers; prevented fatigue and observer distractions, all of which had been previously suggested by WDC observers as important (V James 2018, pers.comm., 12 February; S Eisfeld-Pierantonio 2018, pers.comm., 25 May). Morrison (2016) reviewed 59 vegetation survey articles with inferences on observer error and found that 92% of the articles showed that observer error was statistically significant due to either perceptibility bias, misidentification or estimation error. The chosen method in this study was considered easily achievable by teams of staff and volunteers with a variety of expertise levels in cetacean observations to minimise all three error types described and is recommended here as the standardised vantage point methodology for this region.

The selected method provides the opportunity to collect simple behavioural data using just the 'dominant group behaviour' which is recommended for standard surveys (Evans & Hammond, 2004). Attempting to collect too much detail from very short encounters can take a lot of observer time and is typically relatively subjective and can lead to erroneous descriptions, especially when observers are inexperienced. In primate studies, focal sampling (tracking an individual's behaviour for a standard time) has been described as the most accurate method for measuring behavioural activity budgets, however a study by Gilby, Pokempner, & Wrangham (2011) highlighted that scan sampling produced statistically similar foraging rates to focal follows for group level scans. The main aim of comparative data collection is really to assess population distribution and abundance in a larger scale, and behavioural information (other than foraging) is not really that relevant (Anderwald et al., 2013). Therefore, categorising dominant group behaviour will provide basic information on site usage which could be explored if required in later studies. There is, however, also an option to recall more specific behaviours for detailed behavioural studies, which also should be standardised, in order to allow for comparison if necessary, so it makes sense to agree on a set of well described behaviours for all studies (Appendix 3).

In terrestrial studies it is often relatively straight forward to survey within a known area and thus to calculate the study area from either known home ranges, area of interest or site accessibility (Du Preez, Loveridge, & Macdonald, 2014; Marques et al., 2010; Tobler, Carrillo-Percastegui, Zúñiga Hartley, & Powell, 2013). However, when surveying marine environments from land it is challenging to calculate the actual observable area as this will depend on the observers ability, the height above sea level, and there are often no boundaries to show actual distances (Nuuttila, 2015). This report offers a very simplified way to estimate potential area covered by observers at different sites, which allows a better comparison of encounter rates between different studies. As such, the areas and the encounter rates attained from two sites used here were unfortunately still incomparable, as there were unfortunately no porpoises sighted in New Quay and no dolphins seen in Strumble Head during the study period. The observed areas based on maximum sighting distances are very much biased on the size and behaviour of the target species (Buckland et al., 2001). Bottlenose dolphins (seen in New Quay) are at least four times the size of harbour porpoises plus they exhibit typically very aerial behaviours, often jumping right out of water (Lusseau, 2006). In contrast porpoises tend not to jump right out and their small dorsal fins makes them sometimes very inconspicuous to the observer (Marubini, Gimona, Evans, Wright, & Pierce, 2017).

One way to minimise this bias is to examine the distance histograms and estimate a detection probability curve on each dataset, to determine the distance where the observer capacity seems to decrease to the point where as many animals are missed inside the area, than are sighted outside (the effective detection distance) (Buckland et al., 2001). As explained in detail earlier, this will not be able to give us true detection probability, because it cannot be assumed that animals are equally distributed in the scan area (Buckland et al., 2015). It is accepted that this is not the case near the shore or cliff, where very few individuals are typically ever seen (Mackenzie et al., 2013; Oedekoven et al., 2014). We can use it to ascertain where the outer limit of our observations may be. Using a graph to look at distribution of sightings is definitely better than guessing, and if there is an opportunity to conduct visual or acoustic boat-based line-transect pilot surveys in any of the proposed vantage point sites, the question of animal distribution within the survey area can be addressed (Buckland et al., 2001; Evans & Hammond, 2004).

Capture recapture models (SECR) using camera traps have been utilised at different locations to 'scan' for low density species and ad hoc estimates of the survey areas added to calculate the comparable abundance estimates over different terrestrial geographic regions (Noss et al., 2012; Obbard, Howe, & Kyle, 2010; Tobler et al., 2013). However, for the first time in this area, this study provided cetacean encounter rates for an open population with unknown home ranges related not just time spent observing but also the area observed, which can be used to compare to species encounter rates at other sites in the future, even if they could not be used to compare between New Quay and Strumble Head at this point in time.

Studies that report sightings rate typically portray this in % of scans with positive detections, or by number of animals recorded per scan (Pierpoint, 2008). If the scan duration is the same, and a similar area is covered (from a similar height) we could attempt to compare sightings rates, but as mentioned in the introduction, this is rarely the case. Pierpoint (2008) used 5 minute scans, in a confined area of Ramsey sound and reported mean animal counts of 1.55 (SD =2.27, N =1189 scans) during the flood tide and 0.18 animals during the ebb (SD = 0.89, N = 377 scans). In comparison, sightings rates per scan were 2.12 in Strumble head (SD = 2.29, N = 232 scans).

The recommended method would produce easily comparable encounter rates (number of individuals/total survey time/approximate area observed) for Wales when it is not possible to detangle the imperfect detection process and possible animal density gradient (Mackenzie et al., 2013; Marques et al., 2010; Oedekoven et al., 2014). Marques et al. (2010) highlights that large bias will occur in samples that are not randomised and proposes an approach for overcoming non-uniform distribution around a linear feature, in the study it worked best when the Irish hares had higher density around the feature (road) than away. Similarly, studies have explored the suitability of using roads for line transects for primate studies and have found this varies by species and therefore concluded that roads were unsuitable for this purpose (Hilário, Rodrigues, Chiarello, &

Mourthé, 2012). Erxleben et al. (2011) overcame the density gradient of Wild Turkeys (*Meleagris galopavo*) association with roads by identifying periods in which road surveys would produce generally unbiased estimates. However with cetaceans the density gradient is currently unknown for coastal species and may vary with species, location and time of day (Nuuttila, 2015). To understand density gradients at a specific location Buckland, Marsden, & Green (2008) suggests data is collected perpendicular to the feature causing the gradient. This would be challenging along a cliff edge, however conducting a simultaneous surveys from a boat perpendicular to the feature would help account for this and aid more reliable density estimates (Dawson et al., 2008). Due to cost this would not be possible for all the areas surveyed by individuals conducting citizen science projects, but if a cross-Wales standardised methodology was to be pursued and encouraged by NRW, it should be possible to conduct a one-off pilot survey to determine (at least approximately) some of this variability during distance sampling methodology.

Using the simplified method to estimate approximate observation areas will add to the comparability of data across sites, and add to the usefulness of encounter rate data from different sites in Wales to produce readily interpretable data even for sites where only casual observations take place (Anderwald et al., 2013; Reid et al., 2003). Evans & Hammond (2004) states that encounter rates would be a suitable abundance index provided that variables that impact detectability are measured and that protocol is standardised as much as possible which was the primary objective of this study.

Detecting Accurate Distances

These results show that errors in measurement during line transect surveys are small enough to be negligible, however the bias appears more apparent for point transect surveys. These findings are similar to those by Borchers et al. (2010), who suggests true distance and estimated distances should be gathered simultaneously during sampling for GLM or GAM modelling. Results indicate observers tended to overestimate distance to animals. Williams et al., (2007) found similar results and applied correction factors to the visual estimates but they varied between observers and the author therefore stressed the need to train observers extensively prior to the survey to minimise variance between the observers. Furthermore, correction factor methods has been shown to be successful in line transect surveys to correct bias, however it does not work as well in point transects (Borchers et al., 2010). For point transect projects where observers change frequently in citizen science projects or internships standardising distance estimates by eye becomes challenging and therefore other methods to estimate distances should be sought in those circumstances.

Theodolites are costly and often unattainable by all NGOS's and laser range finders have a maximum distance threshold and are not suitable for using on the water, therefore reticule binoculars are deemed the most suitable method for standardising distance estimates (Buckland et al., 2015). In the context of this study, creating an affordable protocol which could be used by both experienced and inexperienced observers in different localities was the primary priority.

Case Study 1: Trialling the Standard Vantage Point Protocol

The analysis of the visual dataset highlighted the importance of recording appropriate environmental covariates, when undertaking cetacean vantage point monitoring. At Strumble Head and Bardsey Sound this means collecting information on the tidal race as there are complex tidal streams that vary throughout the tidal cycle (Pingree & Griffiths, 1978; Transition Bro Gwaun, 2011) and affect porpoise sightability. It's these tidal characteristics and resulting prey availability that have been suggested key to harbour porpoise presence. (Marubini, Gimona, Evans, Wright, & Pierce, 2017; Pierpoint, 2008; Transition Bro Gwaun, 2011). This study emphasizes the importance of incorporating this variable when surveying at a site with tidal streams present.

Most cetacean studies are typically conducted in sea state 3 or below (Evans & Hammond, 2004) and the findings of this report confirm this association between increased sea state and decreased detection rates for small cetaceans, as there was clear decline in sightings when the tidal race sea state and general sea state exceeded two on the Beaufort scale. In fact, harbour porpoise surveys should be avoided in sea states greater than 2 (when any white caps appear) as the perception bias increases significantly (Evans & Hammond, 2004).

Interestingly, the opposite occurred when swell height increased, although it is thought that increased swell would increase perception bias similarly to increasing sea state (Barlow, Gerrodette, & Forcada, 2001; Evans & Hammond, 2004). The current survey period was short which may account for this finding, but it is possible that swell is increasing mixing at the surface which is an important habitat feature as seen with other cetaceans (Ferrero, Hobbs, & Vanblaricom, 2002). Due to the poor detectability of harbour porpoise it is obvious that robust survey data is unattainable in all but the calmest of weather, which may occur rarely in certain coastal locations. Estimating availability and perception bias can improve abundance estimates through double observations, mark recapture models, assessing species dive patterns and environmental conditions as seen with marine turtles (Fuentes et al., 2015). This should be a focus for research in areas where sea states are rarely below 2. In addition, the introduction of SAM devices in areas with tidal streams, turbid areas or frequent higher sea states would plug the gap in data collection unachievable by land-based observations (Simon et al., 2010; Williamson, Brookes, Scott, Graham, & Thompson, 2017), which are typically limited to day light and summer months due to higher incidents of poor weather and limited daylight during winter.

Case Study 2: Wales Wide Acoustic Analysis

With an interest in acoustic monitoring by 70% of survey participants, it appears there is a growing awareness in applying acoustic techniques in practical conservation. Bioacoustics are frequently being used for more vocalising taxa including, wolves, elephants, primates, birds and bats (Alquezar & Machado, 2015; Blumstein et al., 2011; Fischer, Noser, & Hammerschmidt, 2013; Passilongo, Mattioli, Bassi, Szabó, & Apollonio, 2015; Zeppelzauer, Hensman, & Stoeger, 2015). Case study two highlighted how data from multiple C-PODs could be used to record cetaceans from different locations in coastal waters around Wales to show temporal and spatial trends. This study showed that there was variation in harbour porpoise detections, specifically in relation to diel and tidal patterns. Evidently harbour porpoise detections decrease during the daytime at all sites which had been suggested in previous studies (Carlström, 2005; Nuuttila, Courtene-Jones, et al., 2017; Williamson et al., 2017). Therefore, observers conducting vantage point surveys in the day are sampling when animals are potentially present in fewer numbers (Evans & Hammond, 2004; Nuuttila, Courtene-Jones, et al., 2017). This combined with detection bias may cause cetacean populations to be significantly underestimated when using vantage point surveys alone (Evans, 1994; Oedekoven et al., 2014).

C-PODs can be used to record year-round unlike vantage point surveys because of poor weather conditions or volunteer availability (Evans & Hammond, 2004). They enable researchers to detect diel, seasonal and annual variations without relying on observers and are useful as an additional detection method (Akamatsu et al., 2008; Nuuttila, Courtene-Jones, et al., 2017; Zeppelzauer et al., 2015). This analysis supports previous studies showing that there is a decrease in harbour porpoise presence during the prime time to survey cetaceans in Wales: the summer months (Evans & Hammond, 2004; Nuuttila, Bertelli, et al., 2017; Simon et al., 2010; Sostres Alonso & Nuuttila, 2014). Skomer is inaccessible during the winter when residents of the island disembark in the autumn (Wildlife Trust of South and West Wales, 2018). Likewise, it is understood that harbour porpoise feed seasonally with surface dwelling fish in summer months and fish at deeper depths during the winter and thus become less obvious to an observer (Santos et al., 2004). Introducing acoustic monitoring would enable animals to be detected lower in the water column and year-round provided they were vocalising and within range of the device (Sostres Alonso & Nuuttila, 2014).

Without year-round data collection, conservationists are likely to miss a fine scale shift or decline in porpoise abundance as existing UK baseline data from European Seabirds at Sea, Sea Watch and SCANS were either opportunistic or conducted over a short time period (Brereton et al., 2014; Evans & Hammond, 2004; Reid et al., 2003). By recording cetaceans in multiple locations in Wales through a series of SAM devices it would be possible to detect whether there are declines in all areas or whether the populations are shifting around Wales (Marques et al., 2012; Nuuttila et al., 2018; Stevenson et al., 2014). Furthermore, multiple SAM devices deployed at the same time would be beneficial to gain an overall snapshot of the population (Evans & Hammond, 2004), which is directly comparable between sites to produce an overview of cetacean activity in Wales. Similar studies have been conducted along the East coast of Scotland (The East Coast Marine Mammal Acoustic Study) (Brookes, Bailey, & Thompson, 2013; Merchant et al., 2016), inner Moray Firth (Graham et al., 2017), Australia (Hoenner et al., 2017) and the Baltic (Gallus et al., 2012). These arrays rely on less man power than land watches alone and would provide more data than the SCANS census enabling finer scale studies (Hammond et al., 2017). However, there is significant cost in buying acoustic equipment with C-PODs retailing at £2970 per device (Chelonia Limited., 2019), the cost associated with deployment and maintenance on the devices. Similar studies have typically received significant financial contribution to conduct such monitoring which would also be required for a Wales-wide project (Brookes, Bailey, & Thompson, 2013; Gallus et al., 2012; Graham et al., 2017).

Despite the costs, logistically it would be feasible to conduct a Wales wide monitoring program simply using a series of C-PODs deployed around the Welsh coast, providing collaboration between various organisations. The main effort involved with this type of data collection is the deployment and retrieval of the device unlike the daily management required for vantage point watches (Evans & Hammond, 2004). There is a significant investment in the cost of the C-POD and the means for deploying; working collaboratively with other organisations would be beneficial to keep costs minimal and share resources (Minton et al., 2017). So far, the most extensive acoustic monitoring in Wales on temporal and spatial scale was the SWF and NRW (CCW at the time) acoustic monitoring project in Cardigan Bay SAC (Simon et al 2010; Nuuttila et al. 2017). Other larger projects have included the Gower Marine Mammal project, (Watkins & Colley, 2004) and the monitoring conducted in Swansea Bay in support of the Swansea Bay Tidal Lagoon project (Nuuttila, Bertelli et al. 2017). There are also commercial projects that have deployed SAM such as various windfarms projects, but whose data, or reports are not publicly available (4COffshore, 2019). To better understand cetacean distribution, habitat use and abundance, calibrated SAM devices should be deployed both in known hotspots as well as novel sites to fill geographical gaps where we currently know very little of species presence and habitat use (Baines & Evans, 2012; Reid et al., 2003).

Conclusion

Current cetacean vantage point surveys pose challenges during comparative statistical analysis. This project was undertaken firstly, to design and test a practical and achievable standardised methodology for research organisations with a variety of trained and untrained staff. Secondly the project's aim was to assess both visual and acoustic survey encounter rates at various sites currently monitored and to make recommendations for a regional acoustic monitoring project. The results of the survey questionnaire support the idea that a standardised methodology would be welcomed by organisations and would facilitate collaborative research. However, the restrictions of vantage point surveys mean there are large gaps in data sets because of the requirement to survey in calm weather and within daylight hours. The introduction of a collaborative regional acoustic monitoring project would plug the data gaps and could provide year-round cetacean monitoring. The findings for the acoustic trial highlighted the ability of C-PODs to detect harbour porpoise hotspots within South Wales and seasonal, diel and tidal variation at different locations. An acoustic database would be imperative for a C-POD project and storage, maintenance and data review by NRW or outsourced to a Welsh university would ensure that competing interests between organisations are not impacting data collection. A natural progression of this work is to analyse other cetaceans detected by the C-PODs; investigate detection rates around Wales and open the discussion with organisations on a Wales wide collaborative acoustic and visual survey project. However, the collaborative findings of this study are not unique to Wales and can be further applied to many regions where there is a disconnect between ecological stakeholders and in the management of various species.

Appendix 1: Questionnaire

I, Rhian Forrest am conducting an MRes project to understand how feasible it would be to set up a regional, long term cetacean study in Wales. Therefore, I am sending this questionnaire to organisations and individuals conducting vantage point, acoustic, photo identification cetacean data collection to gain background information on any current socioeconomic reasons on the current data collection and storage.

For further information on the study please contact Rhian Forrest, 930753@swansea.ac.uk.

By completing the questionnaire, you are confirming that you understand the nature of the research and are voluntarily providing a response. You can exit the survey at any time but cannot withdraw any responses that have been made at the point of exit. If you wish to erase your responses before exiting, you will need to backtrack through the survey and delete each response manually.

It is important for you to know that Survey Monkey is a web-survey company that is located in the U.S.; this company is subject to U.S. laws and in particular, the Patriot Act, which allows the U.S. government to access the records of internet service providers. No personal identifiers will be collected in this survey, but it is possible that the views and opinions you expressed may be accessed and linked to you without your knowledge or consent. In an effort to maintain anonymity, during the design of this survey, the option to collect your computer IP address has been disabled. The security and privacy policy for Survey Monkey can be found at the following link: [https://www.surveymonkey.com/mp/policy/privacy-policy/]

1. What do you perceive as accomplishments in cetacean conservation? Tick all that apply.
    a. Advances in species biology, ecology, health and disease.
    b. Increased co-ordinated collaboration.
    c. Awareness raising, educational and promotional activities
    d. Designation of Marine Protected Areas.
    e. Sharing of data.
    f. Governance and legislation.
    g. Other (please specify)
2. Do you conduct vantage point surveys within Wales? Please select one.
    a. Yes, within an organisation for a specific project.
    b. Yes, within an organisation for long term monitoring.
    c. Yes, independently.

    d. No.
    e. Other (please specify)
3. What type of land surveys do you conduct?
    a. Scan.
    b. Timed.
    c. Photo-identification.
    d. Incidental.
4. Have you or your organisation previously collected acoustic data from static acoustic monitoring devices?
    a. Yes, within Wales. Please specify locality.
    b. Yes, outside Wales. Please specify locality.
    c. No.
5. Do you anticipate introducing acoustic monitoring within your research objectives in the foreseeable future?
    a. Yes, in the near future.
    b. Yes, but have limitations in access o resources and/ or the equipment required for deployment.
    c. No.
    d. It is something I would like to explore.
6. Is vantage point survey, photo identification or acoustic data collected by yourself or organisation available in either a national or regional database?
    a. Yes, supplied to a national/regional database and readily available.
    b. Yes, supplied to a national/ regional database and available on request.
    c. No, but readily available.
    d. No, available on request.
    e. No.
7. Would you consider sharing acoustic data into a regional Wales database?
    a. Yes.
    b. No.
    c. Undecided.
    d. Not applicable.
8. Have you or your organisation collaborated with other organisations in Wales on a cetacean project previously?
    a. Yes, the collaboration worked well.
    b. Yes, but would not consider again in the future.
    c. No, but would be open to this in the future.

d. No.

9. Please identify any barriers that may have prevented collaborative working with other Welsh organisations. Tick all that apply.
    a. Locality.
    b. Differing research objectives.
    c. Personality differences.
    d. Funding competition.
    e. Other (please specify)
10. Please highlight any viable solutions o overcoming collaborative barriers. Tick all that apply.
    a. Coordinated research.
    b. Information sharing.
    c. Expanding research interests.
    d. Developing personal relationships.
    e. Independent organisation involvement.
    f. Other (please specify).
11. Do you foresee any additional barriers or have additional comments regarding a regional, long term harbour porpoise study in Wales?

Appendix 2: Case Study 1 - Method and Materials

During the trial of vantage point methodologies, method number four was found to be the protocol best suited for use at different sites, and for ease of use in citizen science and long-term monitoring projects when ranked against all methods currently in use in Wales as discussed in the results section.

Method four was then trialled between May and July 2018 at Strumble Head, Pembrokeshire. A new survey form was designed based on the methodology supplied by the organisation with additional environmental variables appropriate for measuring the sea state in areas with tidal races; such as at Strumble Head and Bardsey Sound (Appendix 3). The variable wind direction was also added to the recording form, this was present in all other methodologies, but was absent from method four (Table 2). A key for all environmental parameters and a behavioural ethogram was developed. Cardigan Bay Marine Wildlife Centre had a well-established cetacean ethogram and behavioural categories which became the framework for the behavioural key in this study. Behaviours are recorded in two categories: dominant group behaviour and specific individual behaviour. This enabled the observer to only use the specific category when confident a specific behaviour was being observed, such as tail slapping or fish being eaten.

The protocol required using reticule binoculars (Bynolt Searange II 7 x 50) to scan the survey area within a 10-minute interval. Within Strumble Head the survey area was between 280 – 050°; New Quay Pier 315 – 125° and Bardsey Sound 170 – 270°. Surveys were done by a minimum of two trained observers below Beaufort Scale 4, no precipitation and the ability to detect the horizon. Due to surveyor availability 72 10-minutes scans were single observer with a Dictaphone. One observer scanned the survey area from left to right, forward to backwards slowly through the binoculars and recited sightings to the recorder. The environmental conditions were noted at the beginning of the scan and when environmental conditions changed. The observer was alternated every 10 minutes to prevent fatigue.

Appendix 3: Finalised Vantage Survey Methodology

- 2 observers required (1 observer, 1 recorder).
- Effort changed every 10 minutes to avoid fatigue.
- Maximum scan area of 180 degrees (usually between 132 – 154 degrees depending on location).
- Sector slowly scanned for 10 minutes from left to right forwards to backwards.
- Recorder completes effort form every 10 minutes or when conditions change.
- When animals are sighted the observer relays information to the recorder and then carries on scanning the remainder of the area.
- If the same animals are sighted again in the next scan inform the recorder of the re-sighting.
- Encounter rate = number of individual animals / survey duration (hours).

Effort form key

Visibility		**Sea State and Race – as beaufort scale**		**Group Structure**	
P	Poor <1km	0	Glassy, calm	C	Compact
M	Moderate 1-5km	1	Ripples, no crests	D	Dispersed
G	Good 6-10km	2	Small wavelets, glassy crests	SG	Sub-groups
EX	Excellent 11+km	3	Large wavelets, crests begin to break	L	Linear group
		4	Small waves, frequent white horses	R	Rank

Swell: <1m, 1 – 2m, <2m
Wind direction: Direction wind is originating.
Precipitation: None, drizzle, light rain, showers, heavy rain.
Cloud Cover: Cover in eighths.

Sightings form key

Reticules: Count intervals on reticular binoculars from the animal to the horizon.
Angle: Use the angle provided by the reticular binoculars.

Dominant group behaviour		**Specific behaviour – if known**			
T	Travel	TR	Regular Traveling	HA	Heading away from a vessel
P	Porpoising	TF	Fast Travelling	HT	Heading towards a boat
FO	Foraging	TD	Travelling - with long dives, thought to be foraging	BR	Bow-riding
M	Milling	FS	Feeding – fish seen		
S	Socialising	ML	Milling – Logging		
		MS	Milling – Slow surface movements		
		MD	Milling - Long dive thought to be foraging		
		B	Breach		
		TS	Tail slap		
		SR	Surface Rush		
		SD	Seabirds diving		
		UNK	Unknown		

Cetacean ethogram	
Travel	Regular surfacing with evident directional movement.
Regular traveling	Consistent speed in a specific direction with regular dive intervals.
Fast travelling	Travelling in a determined direction at speed with frequent surfacing and leaps or high intensity.
Traveling dive	Diving while traveling, thought to be foraging while on the move.
Porpoising/ leaping	Forward leaping out of the water while swimming.
Foraging	Determined frequent dives with little directional travel.
Feeding	Foraging behaviour with fish species seen.
Milling	Irregular dive intervals with little directional movement and very slow swimming.
Logging	Staying stationary at the surface.
Breach	Leaping out of the water.
Tail slap	Forcefully slapping of the fluke on surface waters.
Head slap	Like tail slap but with the head.
Surface rush	High intensity or frenzied activity at the surface.
Socialising	More than one dolphin in close association; can appear aggressive with flukes thrashing.
Bow-riding	Swimming in the bow of the boat when in motion.

EFFORT FORM - Every 10 minutes or a change in conditions. | **Observers:**

Location: | **Cliff Height:** | **Date:** ___/___

Lat/Long:

Start time	End time	Sea State	Race	Swell (m)	Wind Direction	Precipitation	Cloud Cover (/8)	Visibility	Glare? Angle	Boat Activity

SIGHTINGS FORM - Scan 280 degrees to 50 degrees

Observer initials	Start time (BST)	Species	Reticules	Angle at 1st Sighting (True)	Group Size				Dominant group behaviour	Group Structure	Specific Behaviour	Direction of travel	Resighting
					Best Estimate	Adults	Juveniles	Calves					

Appendix 4: Case Study 1 – Results

Table 8. The effect of each vantage point survey variable: by removal from the full model for harbour porpoise at Strumble Head. P-Value was obtained from the full model and R^2, deviance explained and AIC from the stepwise analysis.

Covariate	P-Value	Adj R^2	Deviance explained	Deviance explained change	AIC	AIC Change
High water difference	*	0.103	13.3	-3.5	1092.138	2.84
Sunset difference	.	0.112	14.2	-2.6	1092.589	3.291
Swell	.	0.111	12.7	-4.1	1094.599	5.301
Sea State	.	0.122	13.9	-2.9	1093.382	4.084
Tidal race sea state	**	0.0514	4.52	-12.28	1110.342	21.044
Boat presence		0.15	17.7	0.9	1086.394	-2.904

Appendix 5: Case Study 2 – Detailed Methods and Materials

Bardsey Sound

Bardsey Sound is a stretch of water between the tip of the Llyn peninsula and Bardsey Island three kilometres away (Natural Resources Wales, 2015a). The Llyn Peninsula extends 48 kilometres from the mainland to the south west, encompassing Cardigan Bay from the North (Natural Resources Wales, 2015a). There are areas of rougher water, surge gullies and shallows varying from 6 - 30 m, which provide good feeding spots for cetaceans (Natural Resources Wales, 2015a). Some of the strongest tidal races in the Irish sea occur in the sound, running up to nine knots, making it an ideal environment for harbour porpoise feeding in high energy tidal sites (Pierpoint, 2008).

A C-POD was deployed on the 8^{th} July 2018 and collected on the 27^{th} July in Bardsey Sound near the headland at Uwchmynydd and recorded for 21 days (Fig 2) with the aim of collecting acoustic and vantage point data simultaneously.

New Quay

New Quay is situated within Cardigan Bay; with the Llyn Peninsula to the North and Strumble Head to the South. It's a shallow bay (less than 60 m depth) within two SAC's Cardigan Bay SAC and West Wales Marine SAC. The bay is made up of gravel and mud and experiences high wave action sweeping from the Atlantic, and low tidal currents within the bay (Evans, 1995; Natural Resources Wales, 2015b).

C-PODs were deployed in two locations in New Quay: near the Quay Fresh and Frozen Foods fish factory and Llanina Reef (Fig 2). The data was supplied by Cardigan Bay Marine Wildlife Centre for the purpose of comparing harbour porpoise detections in case study two.

Oxwich

Oxwich is on the South Gower Peninsula to the east of Swansea Bay (Fig 2). Swansea Bay is an embayment with an anticlockwise eddy, divergence zone to the east, and rectilinear tidal currents offshore in the Bristol Channel (Collins, Ferentinos, & Banner, 1979). Oxwich has eddies formed by the incoming tide, and has a similar topography and hydrodynamics to Swansea Bay. The Bay is composed of glacial till, sand and silt over bedrock (Nuuttila, Bertelli, et al., 2017).

Acoustic data loggers were deployed by SEACAMS2 in Oxwich bay to maximise porpoise detections by ensuring its locality to main shipping lanes, dredging and fishing areas were minimised (Nuuttila, Bertelli, et al., 2017). The original C-POD data files for 2015 and 2017 were provided by SEACAMS2 for this study.

Skomer

Skomer Island is a Marine Nature Reserve and Marine Conservation Zone located less than a mile from the coast of South Pembrokeshire (Fig 2). The seabed is a combination of sandstone and mudstone with water depths up to 54 m on the western side and strong tidal races at the northern entrance to Jack Sound (Natural Resources Wales, 2015c).

C-PODs were supplied by SEACAMS2 and deployed by divers around Skomer Island during 2017. The original C-POD data was donated by SEACAMS2 for this study.

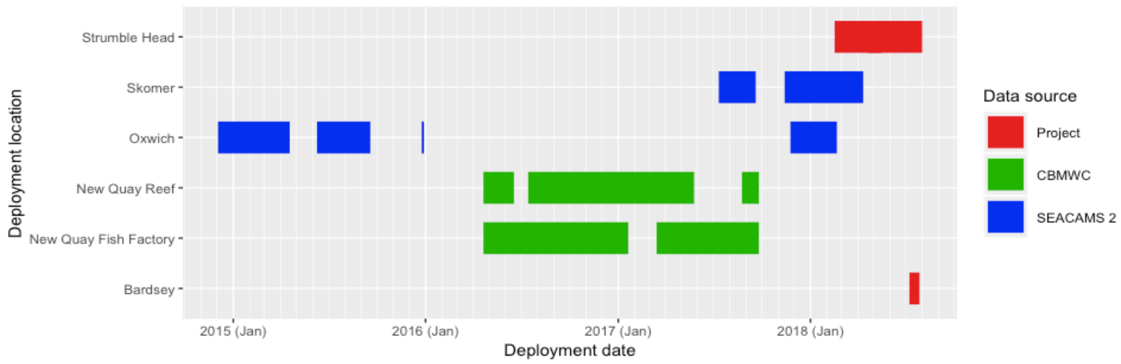

Fig 10. C-POD deployment and retrieval schedule with data source indicated by red (collected during the project), green (CBMWC) and blue (SEACAMS 2).

Strumble Head

Strumble Head is a headland in Northern Pembrokeshire near Southern Cardigan Bay (Fig 2). There are deep channels between the headland and Strumble Bank (approx. 3km from Strumble Head) shaped by strong tidal currents with flow speeds of 4.2kts at high water depositing sand and sediment. Strumble Head has a topography made of sand and shingle with a medium depth of 30-60 m; the bank is a shallower sandy gravel bar (<30 m) with higher wave stress (Natural Resources Wales, 2015b).

A C-POD was deployed from the 16th February 2018 and recorded until the 16th May, recording cetacean detections for 90 days in Strumble Head, Pembrokeshire. A second C-POD was deployed on the 19th April and collected 26th June 2018, the SD card came loose and stopped recording on the 16th May 2018 and collected 26 days of data. This was treated as a duplicate recording and not included in the analysis for this case study. On collection of the C-POD a new SD card was inserted and re- deployed immediately and collected on the 1st August 2018 (Fig 10).

Table 10. The effect of each variable from removing each covariate from the full model for harbour porpoise at Bardsey Sound, New Quay, Oxwich, Skomer and Strumble Head. P-Value was obtained from the full model and R2, Deviance explained and AIC from the analysis.

Covariate	P-Value *	R2 Value	Deviance explained %	Deviance explained change	AIC	AIC Change
Bardsey						
Day		0.0115	11.3	0.9	273.7573	-2.1804
Hour (UTC)		0.00907	8.4	-2	276.4983	0.5606
High water difference		0.0103	10.8	0.4	275.5562	-0.2815
Sunrise difference		0.0111	9.32	-1.08	276.3406	0.4029
Sunset difference		0.00923	8.72	-1.68	276.4741	0.5364
Tidal range		0.0158	12.9	2.5	274.1796	-1.7581
Dolphin presence		0.0111	10.3	-0.1	274.0421	-1.8956
New Quay						
Month	***	-0.0145	28	-5.2	13694.5	277.51
Hour (UTC)	***	0.0653	33.1	-0.1	13422.56	5.57
High water difference	***	0.0449	31	-2.2	13534.51	117.52
Sunrise difference	**	0.0647	33	-0.2	13424.59	7.6
Sunset difference	**	0.0637	33.4	0.2	13407.6	-9.39
Tidal range	.	0.0635	32	-1.2	13471.45	54.46
Temp	***	0.0596	30.3	-2.9	13563.48	146.49
Dolphin presence	***	0.0515	32.2	-1	13467.42	50.43
Location	***	0.0469	25.6	-7.6	13862.48	445.49
Oxwich						
Month	***	0.0137	3.45	-18.25	26425.39	1508.84
Hour (UTC)	***	0.118	21.3	-0.4	24938.87	22.32
High water difference	***	0.114	21.1	-0.6	24956.19	39.64
Sunrise water difference	**	0.119	21.3	-0.4	24939.24	22.69
Sunset difference	***	0.115	21.6	-0.1	24918.41	1.86
Tidal range	***	0.0852	20.8	-0.9	24983.34	66.79
Dolphin presence		0.116	21.6	-0.1	24915.25	-1.3
Skomer						
Month	***	0.066	8.73	-3.07	30848.25	257.88
Hour (UTC)	***	0.0876	11.7	-1.01	30598.08	7.71
High water difference	***	0.0874	11.8	0	30590.22	-0.15
Sunrise difference	***	0.0874	11.8	0	30590.29	-0.08
Sunset difference	***	0.0847	10.9	-0.9	30659.57	69.2
Tidal range		0.0912	11.7	-0.1	30589.93	0.44
Temp	***	0.0804	11.1	-0.7	30642.62	52.25
Dolphin presence	*	0.09	11.7	-0.1	30592.81	2.44
Strumble						
Month	***	0.129	12.5	-29	25844.24	2525.6
Hour (UTC)		0.2	41.5%	0	23318.64	0
High water difference	***	0.228	34.7	-6.8	23894.56	575.92
Sunrise difference	**	0.19	41.4%	-0.1	23327.88	9.24
Sunset difference	**	0.205	41.2	-0.3	23342.16	23.52
Tidal range	***	0.177	40	-1.5	23450.25	131.61
Dolphin presence	.	0.2	41.4	-0.1	23323.68	5.04

*RStudio Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table 11. Final model summaries for harbour porpoise C-POD detections at New Quay, Oxwich, Skomer and Strumble Head.

Smooth terms	Edf	Df	F-Value	p-Value	Parametric coefficients	Estimate	Std error	T-value	P-Value
A. New Quay									
Month	8.260	9.357	4.774	1.05e-06	Intercept	-0.5302	0.1165	-4.550	5.39e-06
Hour (UTC)	2.376	6.000	1.475	0.00134	Dolphin Presence	-0.6230	0.1339	-4.654	3.27e-06
High water difference	5.058	10.000	3.917	1.06e-08	Location	-2.7556	0.1317	-20.926	<2e-16
Sunrise difference	3.187	13.000	1.039	8.11e-05					
Tidal range	4.849	5.954	2.052	0.05483					
Sea temperature	9.196	10.983	3.957	8.55e-06					
B. Oxwich									
Month	7.7474	7.978	70.487	<2e-16	Intercept	-0.68368	0.06173	-11.07	<2e-16
Hour (UTC)	3.1279	4.000	3.507	9.21e-06					
High water difference	2.1981	3.000	5.498	0.000112					
Sunrise difference	5.0665	10.000	1.369	0.001773					
Sunset difference	0.5606	8.000	0.264	1.13e-05					
Tidal range	2.1121	2.641	8.775	5.81e-05					
C. Skomer									
Month	1.964	1.996	23.711	8.44e-11	Intercept	0.8416	0.0673	12.507	<2e-16
Hour (UTC)	4.161	9.000	2.531	1.92e-06	Dolphin Presence	0.5825	0.2347	2.482	0.0131
Sunset difference	6.754	16.000	2.006	8.89e-08					
Temp	5.199	6.473	15.559	<2e-16					
D. Strumble Head									
Month	5.618	5.921	177.697	<2e-16	Intercept	0.2832	0.1038	2.730	0.00636
High water difference	5.932	6.000	56.858	<2e-16	Dolphin presence	0.4187	0.2274	1.841	0.06562
Sunrise difference	3.717	6.000	2.258	0.00156					
Sunset difference	3.073	4.000	3.056	0.00212					
Tidal range	1.000	1.000	54.127	2.14e-13					

A. R-sq.(adj) = 0.0655 Deviance explained = 34.1% fREML = 27608 Scale est. = 1.9407 n = 22192
B. R-sq.(adj) = 0.115 Deviance explained = 21.7% fREML = 15561 Scale est. = 1.1449 n = 14106
C. R-sq.(adj) = 0.0905 Deviance explained = 12% fREML = 11713 Scale est. = 1.4987 n = 9688
D. R-sq.(adj) = 0.137 Deviance explained = 42.8% fREML = 7526.9 Scale est. = 1.3624 n = 5544

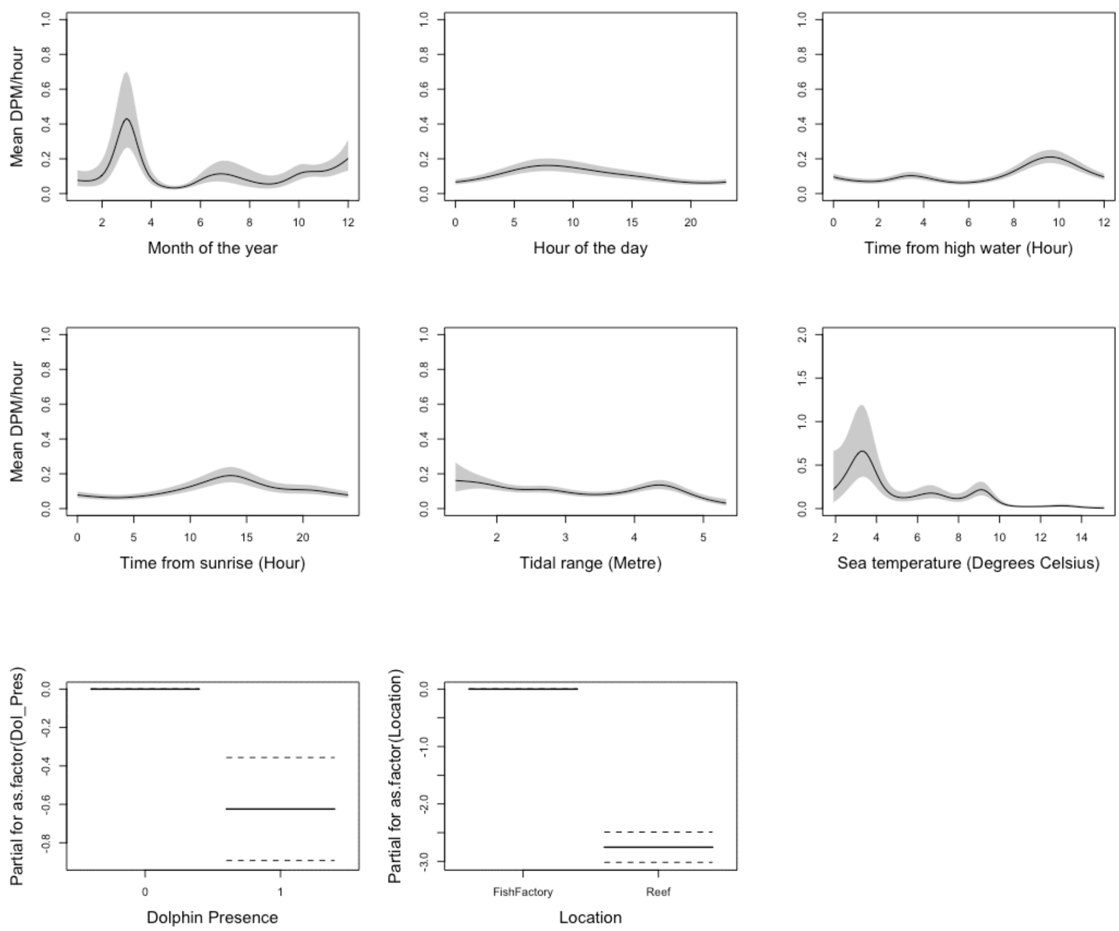

Fig 11. The final model for the fitted relationship of New Quay harbour porpoise C-POD detections from the GAM/BAM standard errors. The 95% confidence limits are indicated by the grey areas.

Oxwich

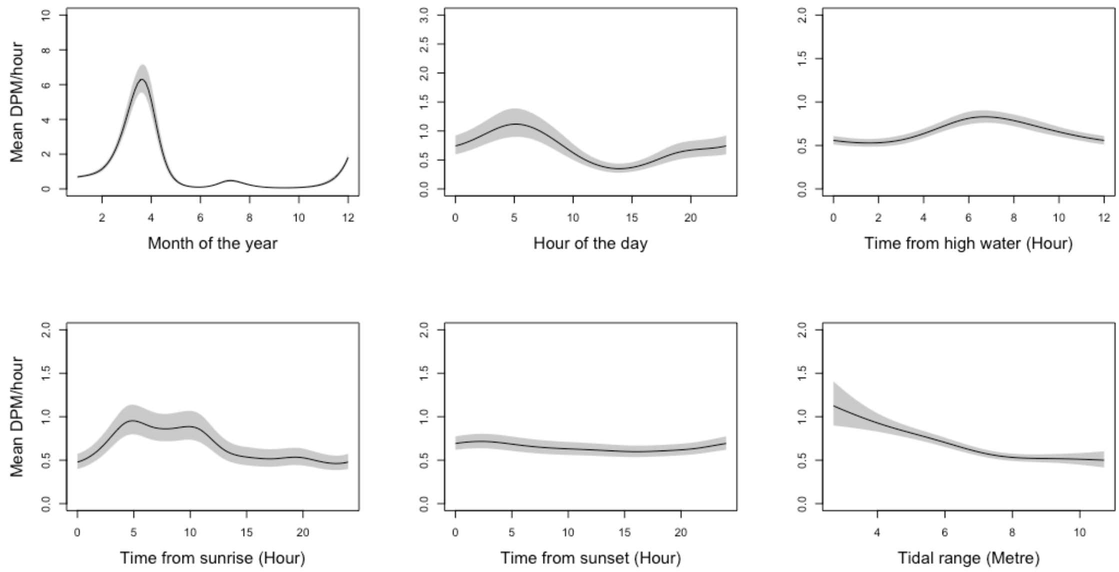

Fig 12. The final model for the fitted relationship of Oxwich harbour porpoise C-POD detections from the GAM/BAM standard errors. The 95% confidence limits are indicated by the grey areas.

Skomer

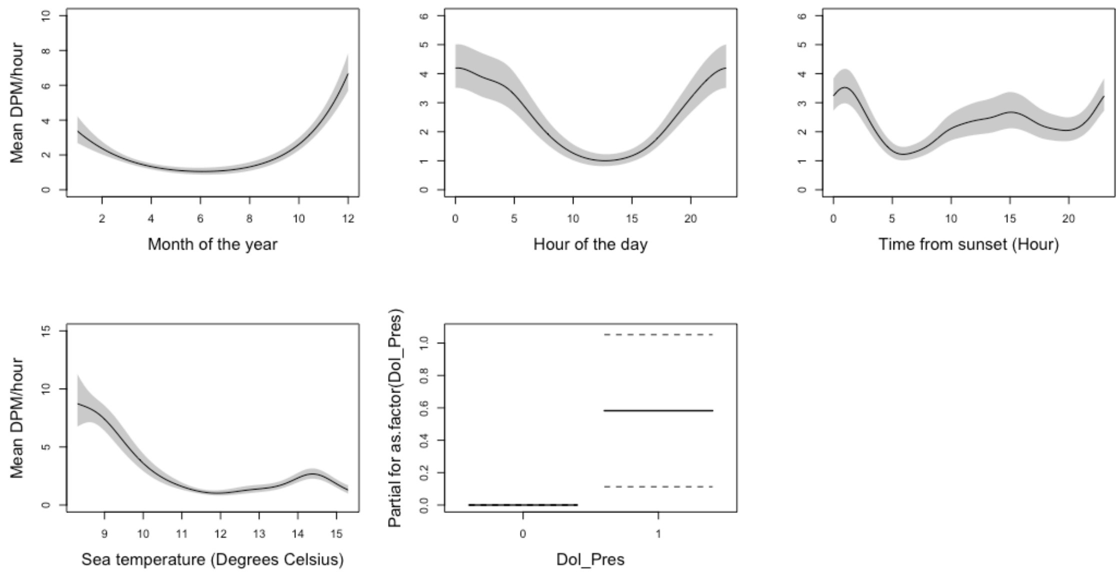

Fig 13. The final model for the fitted relationship of Skomer Island harbour porpoise C-POD detections from the GAM/BAM standard errors. The 95% confidence limits are indicated by the grey areas.

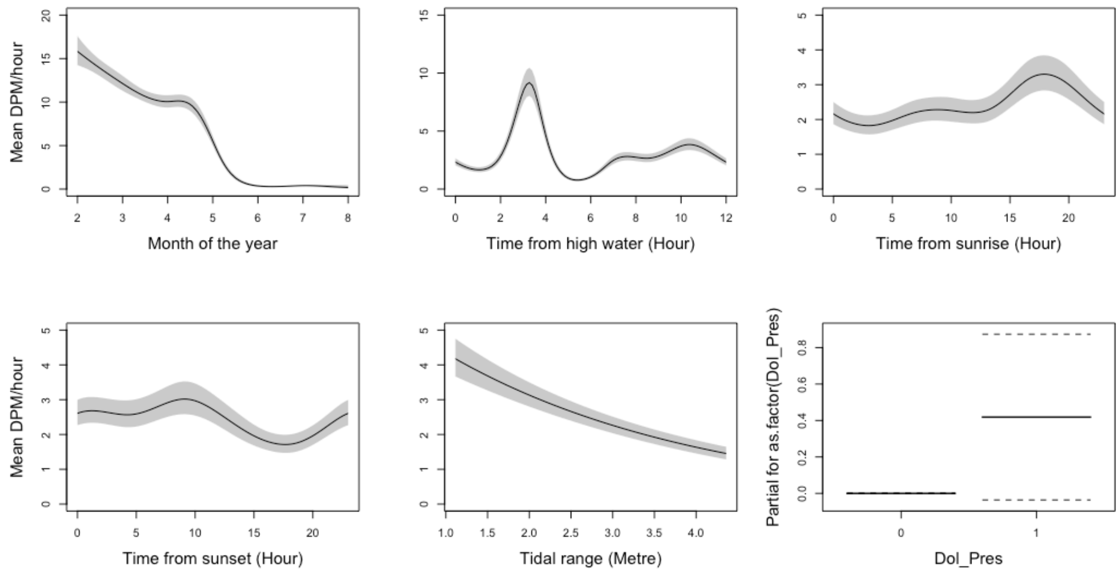

Fig 14. The final model for the fitted relationship of Strumble Head harbour porpoise C-POD detections from the GAM/BAM standard errors. The 95% confidence limits are indicated by the grey areas.

References

4COffshore. (2019). Atlantic Array Phase One Offshore Wind Farms. Retrieved March 20, 2019, from https://www.4coffshore.com/windfarms/atlantic-array-phase-one-united-kingdom-uk42.html

Aguilar-Støen, M., & Dhillion, S. S. (2003). Implementation of the Convention on Biological Diversity in Mesoamerica: Environmental and developmental perspectives. *Environmental Conservation*, *30*(2), 131–138.

Akamatsu, T., Matsuda, A., Suzuki, S., Wang, D., Wang, K., Suzuki, M., … Oota, K. (2005). New stereo acoustic data logger for free-ranging dolphins and porpoises. *Marine Technology Society Journal*, *39*(2), 3–9.

Akamatsu, T., Teilmann, J., Miller, L. A., Tougaard, J., Dietz, R., Wang, D., … Naito, Y. (2007). Comparison of echolocation behaviour between coastal and riverine porpoises. *Deep-Sea Research II*, *54*, 290–297.

Akamatsu, T., Wang, D., Wang, K., Li, S., Zhao, X., Barlow, J., … Richlen, M. (2008). Estimation of the detection probability for Yangtze finless porpoises (*Neophocaena phocaenoides asiaeorientalis*) with a passive acoustic method. *The Journal of the Acoustical Society of America*, *123*(6), 4403–4411.

Alldredge, M. W., Simons, T. R., & Pollock, K. H. (2007). A Field Evaluation of Distance Measurement Error in Auditory Avian Point Count Surveys. *Journal of Wildlife Management*, *71*(8), 2759–2766.

Alquezar, R. D., & Machado, R. B. (2015). Comparisons Between Autonomous Acoustic Recordings and Avian Point Counts in Open Woodland Savanna. *The Wilson Ornithological Society*, *127*(4), 712–723.

Anderwald, P., Ansamann, I., Baines, M., Baulch, S., Evans, P. G. H., Nuuttila, H. K., & Pesante, G. (2013). *Cetacean monitoring effort carried out by voluntary NGOs in UK waters*. Retrieved from http://jncc.defra.gov.uk/pdf/480.web.pdf

Arts, G., Davies, J., Dobbs, M., Ebke, P., Hanson, M., Hommen, U., … Poulsen, V. (2010). AMEG: The new SETAC advisory group on aquatic macrophyte ecotoxicology. *Environmental Science and Pollution Research*, *17*(4), 820–823.

Authier, M., Commanducci, F. D., Genov, T., Holcer, D., Ridoux, V., Salivas, M., … Spitz, J. (2017). Cetacean conservation in the Mediterranean and Black Seas:

Fostering transboundary collaboration through the European Marine Strategy Framework Directive. *Marine Policy*, *82*(November 2016), 98–103.

Baghli, A., & Verhagen, R. (2003). The distribution and status of the polecat Mustela putorius in Luxembourg. *Mammal Review*, *33*(1), 57–68.

Bailey, H., Clay, G., Coates, E. A., Lusseau, D., Senior, B., & Thompson, P. (2010). Using T-PODs to assess variations in the occurrence of coastal bottlenose dolphins and harbour porpoises. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *20*, 150–158.

Bailey, H., Mate, B. R., Palacios, D. M., Irvine, L., Bograd, S. J., & Costa, D. P. (2009). Behavioural estimation of blue whale movements in the Northeast Pacific from state-space model analysis of satellite tracks. *Endangered Species Research*, *10*, 93–106.

Baines, M. E., & Evans, P. G. H. (2009). *Atlas of the marine mammals of Wales*. *CCW Monitoring Report No. 68.* Retrieved from http://www.seawatchfoundation.org.uk/wp-content/uploads/2012/08/IRISH-SEA-ATLAS.pdf

Baines, M. E., & Evans, P. G. H. (2012). *Atlas of the marine mammals of Wales*. *CCW Marine Monitoring Report No. 68. 2nd edition*. Retrieved from http://www.seawatchfoundation.org.uk/wp-content/uploads/2015/05/ATLAS-Marine-Mammals-of-Wales-FINAL.pdf

Baird, J., Armitage, D., Bodin, Ö., Schultz, L., Plummer, R., & Dzyundzyak, A. (2017). Is adaptive co-management delivering? Examining relationships between collaboration, learning and outcomes in UNESCO biosphere reserves. *Ecological Economics*, *140*, 79–88.

Barker, S. M., & Williamson, J. E. (2010). Collaborative photo-identification and monitoring of grey nurse sharks (*Carcharias taurus*) at key aggregation sites along the eastern coast of Australia. *Marine and Freshwater Research*, *61*(9), 971–979.

Barlow, J., Gerrodette, T., & Forcada, J. (2001). Factors affecting perpendicular sighting distances on shipboard line-transect surveys for cetaceans. *Journal of Cetacean Research and Management*, *3*(2), 201–212.

Bart, J. (2005). Monitoring the Abundance of Bird Populations. *The Auk*, *122*(1), 15–

25. Retrieved from http://www.jstor.org/stable/4090345

Beever, E. A. (2006). Monitoring biological diversity: Strategies, tools, limitations, and challenges. *Northwestern Naturalist*, *87*, 66–79.

Belaire, J. A., Dribin, A. K., Johnston, D. P., Lynch, D. J., & Minor, E. S. (2011). Mapping stewardship networks in urban ecosystems. *Conservation Letters*, *4*(6), 464–473.

Benson, D. A., Cavanaugh, M., Clark, K., Karsch-Mizrachi, I., Ostell, J., Pruitt, K. D., & Sayers, E. W. (2013). GenBank. *Nucleic Acids Research*, *41*, D36–D42.

Blumstein, D. T., Mennill, D. J., Clemins, P., Girod, L., Yao, K., Patricelli, G., … Kirschel, A. N. G. (2011). Acoustic monitoring in terrestrial environments using microphone arrays: Applications, technological considerations and prospectus. *Journal of Applied Ecology*, *48*(3), 758–767.

Booth, C., & Lacey, C. (2014). *Static acoustic monitoring for harbour porpoise and dolphins in and around the proposed Navitus Bay offshore wind park using C-PODs*. Retrieved from https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010024/EN010024-000863-6.2.2.11.4 Volume B Chapter 11 Marine Mammals Appendix 11.4 Marine Mammal Noise Impact Assessment.pdf

Borchers, D. L., Marques, T. A., Gunnlaugsson, T., & Jupp, P. (2010). Estimating distance sampling detection functions when distances are measured with errors. *Journal of Agricultural, Biological, and Environmental Statistics*, *15*(3), 346–361.

Borchers, D. L., Pike, D. G., Gunnlaugsson, T., & Víkingsson, G. A. (2009). Minke whale abundance estimation from the NASS 1987 and 2001 aerial cue–counting surveys taking appropriate account of distance estimation errors. *NAMMCO Scientific Publications*, *7*, 95.

Boström, M. K., Krog, C., Kindt-Larsen, L., Lunneryd, S. G., & Wahlberg, M. (2013). Acoustic activity of harbour porpoises (*Phocoena phocoena*) around gill nets. *Aquatic Mammals*, *39*(4), 389–396.

Bouton, S. N., & Frederick, P. C. (2003). Stakeholders' perceptions of a wading bird colony as a community resource in the Brazilian Pantanal. *Conservation Biology*, *17*(1), 297–306.

Brace, I. (2008). *Questionnaire design: how to plan, structure and wite survey material for effective market research*. *Applied Ergonomics* (Second edi). London, United Kingdom: Kogan Page Limited.

Brereton, T., MacLeod, C., Wall, D., Macleod, K., Cermeño, P., Curtis, D., … Pinn, E. (2014). *Monitoring cetaceans in UK and adjacent waters : current and potential uses of Atlantic Research Coalition (ARC) data (2009). JNCC Report No. 481*. Retrieved from http://jncc.defra.gov.uk/pdf/Report481_web.pdf

Brookes, K. L., Bailey, H., & Thompson, P. M. (2013). Predictions from harbor porpoise habitat association models are confirmed by long-term passive acoustic monitoring. *The Journal of the Acoustical Society of America*, *134*(3), 2523–2533.

Buckland, S. T., Anderson, D., Burnham, K., Laake, J. L., Borchers, D. L., & Thomas, L. (2001). *Introduction to distance sampling: estimating abundance of biological populations*. New York: Oxford University Press.

Buckland, S. T., Marsden, S. J., & Green, R. E. (2008). Estimating bird abundance : making methods work. *Bird Conservation International*, *18*, S91-108.

Buckland, S. T., Rexstad, E. A., Marques, T. A., & Oedekoven, C. S. (2015). *Distance sampling: Methods and applications*. London: Springer International Publishing.

Buckland, S. T., & York, A. E. (2009). Abundance estimation. In F. Perrin, William, B. Wursig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (2nd ed., pp. 2–3). Oxford: Academic Press.

Campbell, H. A., Urbano, F., Davidson, S., Dettki, H., & Cagnacci, F. (2016). A plea for standards in reporting data collected by animal - borne electronic devices. *Animal Biotelemetry*, *4*(1).

Carlström, J. (2005). Diel variation in echolocation behavior of wild harbor porpoises. *Marine Mammal Science*, *21*(1), 1–12.

Chelonia Limited. (2014). *The Software User Guide for CPOD.EXE*. Retrieved from http://www.chelonia.co.uk/cpod_downloads.htm

Chelonia Limited. (2016). *C-POD User Guide*. Retrieved from http://www.chelonia.co.uk/cpod_downloads.htm

Chelonia Limited. (2019). Prices and Ordering. Retrieved February 13, 2019, from http://www.chelonia.co.uk/prices_and_ordering.htm

Chelonia Limited. (2018). Design History. Retrieved August 2, 2018, from http://www.chelonia.co.uk/design_history.htm

Chen, S. X. (1998). Measurement errors in line transect surveys. *Biometrics*, *54*(3), 899–908.

Chen, S. X., & Cowling, A. (2001). Measurement errors in line transect surveys where detectability varies with distance and size. *Biometrics*, *57*(3), 732–742.

Clement, M. J., Rodhouse, T. J., Ormsbee, P. C., Szewczak, J. M., & Nichols, J. D. (2014). Accounting for false-positive acoustic detections of bats using occupancy models. *Journal of Applied Ecology*, *51*(5), 1460–1467.

Collins, M., Ferentinos, G., & Banner, F. T. (1979). The hydrodynamics and sedimentology of a high (tidal and wave) energy embayment (Swansea Bay, Northern Bristol Channel). *Estuarine and Coastal Marine Science*, *8*(1), 49–74.

Cox, M. J., Borchers, D. L., & Kelly, N. (2013). Nupoint: An R package for density estimation from point transects in the presence of nonuniform animal density. *Methods in Ecology and Evolution*, *4*(6), 589–594.

Dähne, M., Gilles, A., Lucke, K., Peschko, V., Adler, S., Krügel, K., … Siebert, U. (2013). Effects of pile-driving on harbour porpoises (Phocoena phocoena) at the first offshore wind farm in Germany. *Environmental Research Letters*, *8*(2), 16.

Dähne, M., Verfuß, U. K., Brandecker, A., Siebert, U., & Benke, H. (2013). Methodology and results of calibration of tonal click detectors for small odontocetes (C-PODs). *The Journal of the Acoustical Society of America*, *134*(3), 2514–2522.

Danbolt, M., McLanaghan, R., Moscrop, A., Boisseau, O., Lewis, T., & Lacey, C. (2010). Encounter rates of cetaceans in the Mediterranean Sea and contiguous Atlantic area. *Journal of the Marine Biological Association of the United Kingdom*, *90*(08), 1589–1599.

Daniel, J. R., Pinel, S. L., & Brooks, J. (2013). Overcoming barriers to collaborative transboundary water governance. *Mountain Research and Development*, *33*(3), 215–224.

Dawson, S., Wade, P., Slooten, E., & Barlow, J. (2008). Design and field methods for sighting surveys of cetaceans in coastal. *Mammal Review*, *38*(1), 19–49.

de Boer, M., Eisfeld, S., & Simmonds, M. P. M. P. (2012). The Fine-Scale Habitat Use of Risso's Dolphins off Bardsey Island , Cardigan Bay (UK). In *Proceedings of the first European Cetacean Society workshop on Risso's dolphin, Galway, 25 March 2012* (p. 6).

de Boer, M., & Simmonds, M. P. (2003). WDCS/Greenpeace Survey Report: Small cetaceans along the coasts of Wales and southwest England. *WDCS Science Report. Whale and Dolphin Conservation Society (WDCS), Brookfield House, 38 St Paul St., Chippenham, Wiltshire SN15 1LJ, UK. 43pgs. 2003.*, (February 2015), 43.

de Boer, M., Simmonds, M. P. M. P., Reijnders, P. J. H., & Aarts, G. (2014). The influence of topographic and dynamic cyclic variables on the distribution of small cetaceans in a shallow coastal system. *PLOS ONE*, *9*(1), e86331.

Deecke, V. B., Ford, J. K. B., & Slater, P. J. B. (2005). The vocal behaviour of mammal-eating killer whales: Communicating with costly calls. *Animal Behaviour*, *69*(2), 395–405.

Dénes, F. V., Silveira, L. F., & Beissinger, S. R. (2015). Estimating abundance of unmarked animal populations : accounting for imperfect detection and other sources of zero inflation, 543–556.

Dénes, F. V., Tella, J. L., & Beissinger, S. R. (2017). Revisiting methods for estimating parrot abundance and population size. *Emu*, *118*(1), 67–79. Retrieved from https://doi.org/10.1080/01584197.2017.1401903

Di Tullio, J. C., Gandra, T. B. R., Zerbini, A. N., & Secchi, E. R. (2016). Diversity and distribution patterns of cetaceans in the subtropical Southwestern Atlantic outer continental shelf and slope. *PLoS ONE*, *11*(5), 1–24.

Du Preez, B. D., Loveridge, A. J., & Macdonald, D. W. (2014). To bait or not to bait: A comparison of camera-trapping methods for estimating leopard *Panthera pardus* density. *Biological Conservation*, *176*(August 2016), 153–161. Retrieved from http://dx.doi.org/10.1016/j.biocon.2014.05.021

Duffy, J. E., Benedetti-Cecchi, L., Trinanes, J., Muller-Karger, F. E., Ambo-Rappe, R., Boström, C., … Yaakub, S. M. (2019). Toward a Coordinated Global Observing System for Seagrasses and Marine Macroalgae. *Frontiers in Marine Science*, *6*(July).

Dunn, E. H., Altman, B. L., Bart, J., Beardmore, C. J., Berlanga, H., Blancher, P. J., … Will, T. C. (2005). *High priority needs for range-wide monitoring of North American landbirds*. *Partners in Flight Technical Series*. Laurel, MD. Retrieved from http://pubs.er.usgs.gov/publication/2002817

Dyndo, M., Wišniewska, D. M., Rojano-Doñate, L., & Madsen, P. T. (2015). Harbour porpoises react to low levels of high frequency vessel noise. *Scientific Reports*, *5*, 1–9. https://doi.org/10.1038/srep11083

Erxleben, D. R., Butler, M. J., Ballard, W. B., Wallace, M. C., Peterson, M. J., Silvy, N. J., … Dominguez-Brazil, M. K. (2011). Wild Turkey (Meleagris gallopavo) association to roads: Implications for distance sampling. *European Journal of Wildlife Research*, *57*(1), 57–65.

Eskesen, I. G., Teilmann, J., Geertsen, B. M., Desportes, G., Riget, F., Dietz, R., … Siebert, U. (2009). Stress level in wild harbour porpoises (Phocoena phocoena) during satellite tagging measured by respiration, heart rate and cortisol. *Journal of the Marine Biological Association of the United Kingdom*, *89*(5), 885–892.

European Commission. (1992). Council Directive 92/43/ECC on the conservation of natural habitats and of wild fauna and flora. *Official Journal of the European Union*, *94*(1259), 40–52.

Evans, P.G.H. (1976). An analysis of sightings of Cetacea in British waters. *Mammal Review*, *6*(1), 5–14.

Evans, P.G.H. (1985). Report of the European Cetacean sightings workshop. *Aquatic Mammals*, *11*(3), 75–88.

Evans, P.G.H. (1994). A comparison of visual and acoustic techniques for surveying harbour porpoises. In Peter G.H. Evans (Ed.), *Proceedings of the eight annual conference of the european cetacean society, Montpellier, France 1994* (pp. 172–173). Lugano, Switzerland.

Evans, P.G.H. (1995). Whales, dolphins and porpoises. In J. H. Barne, C. F. Robson, S. S. Kaznowska, & J. P. Doody (Eds.), *Coasts and seas of the United Kingdom*

Region 12 Wales : Margam to Little Orme (pp. 137–140). Peterborough: Joint Nature Conservation Committee.

Evans, P.G.H., & Hammond, P. S. (2004). Monitoring Cetaceans in European waters. *Mammal Review*, *34*(1–2), 131–156.

Evans, P.G.H., Pierce, G. J., Veneruso, G., Weir, C. R., Anderwald, P., & Santos, M. B. P. (2015). *Analysis of long-term effort-related land-based observations to identify whether coastal areas of harbour porpoise and bottlenose dolphin have persistent high occurrence and abundance*. *JNCC report No. 543*. Peterborough. Retrieved from http://jncc.defra.gov.uk/pdf/Report 543_web.pdf

Ferrero, R. C., Hobbs, R. C., & Vanblaricom, G. R. (2002). Indications of habitat use patterns among small cetaceans in the central North Pacific based on fisheries observer data. *The Journal of Cetaceans Research and Management*, *4*(3), 311–322.

Fischer, J., Noser, R., & Hammerschmidt, K. (2013). Bioacoustic field research: A primer to acoustic analyses and playback experiments with primates. *American Journal of Primatology*, *75*(7), 643–663. https://doi.org/10.1002/ajp.22153

Foddy, W. (1994). *Constructing questions for interviews and questionnaires*. Cambridge: Cambridge University Press.

Forney, K., Redfern, J., Becker, E., Barlow, J., Gentemann, C., & Foley, D. (2011). Forecasting cetacean abundance patterns to enhance management decisions. *Endangered Species Research*, *16*(2), 97–112.

Fox, J., & Weisberg, S. (2011). An {R} Companion to Applied Regression, Second Edition. Thousand Oaks CA: Sage.

Fuentes, M. M. P. B., Bell, I., Hagihara, R., Hamann, M., Hazel, J., Huth, A., … Marsh, H. (2015). Improving in-water estimates of marine turtle abundance by adjusting aerial survey counts for perception and availability biases. *Journal of Experimental Marine Biology and Ecology*, *471*, 77–83. Retrieved from http://dx.doi.org/10.1016/j.jembe.2015.05.003

Gallus, A., Dähne, M., Verfuß, U. K., Bräger, S., Adler, S., Siebert, U., & Benke, H. (2012). Use of static passive acoustic monitoring to assess the status of the ' Critically Endangered ' Baltic harbour porpoise in German waters. *Endangered*

Species Research, *18*, 265–278.

Geary, B., Walter, S. T., Leberg, L., & Karubian, J. (2018). Condition-dependent foraging strategies in a coastal seabird : evidence for the rich get richer hypothesis. *Behavioural Ecology*, 1–8.

Gilby, I. C., Pokempner, A. A., & Wrangham, R. W. (2011). A direct comparison of scan and focal sampling methods for measuring wild chimpanzee feeding behaviour. *Folia Primatologica*, *81*(5), 254–264.

Graham, I. M., Pirotta, E., Merchant, N. D., Farcas, A., Barton, T. R., Cheney, B., … Thompson, P. M. (2017). Responses of bottlenose dolphins and harbor porpoises to impact and vibration piling noise during harbor construction. *Ecosphere*, *8*(5), e01793.

Grant, J. A., & Quinn, M. S. (2008). Factors influencing transboundary wildlife management in the North American ‘ Crown of the Continent .’ *Journal of Environmental Planning and Management*, *50*(6), 765–782.

Gregory, P. R., & Rowden, A. a. (2001). Behaviour patterns of bottlenose dolphins (*Tursiops truncatus*) relative to tidal state, time-to-day, and boat traffic in Cardigan Bay, West Wales. *Aquatic Mammals*, *27*(2), 105–113.

Guerrero, A. M., Mcallister, R. R. J., & Wilson, K. A. (2015). Achieving cross-scale collaboration for large scale conservation initiatives. *Conservation Letters*, *8*(2), 107–117.

Guisan, A., Edwards, T. C., & Hastie, T. (2002). Generalized linear and generalized additive models in studies of species distributions : setting the scene. *Ecological Modelling*, *157*, 89–100.

Hammond, P., Lacey, C., Gilles, A., Viquerat, S., Börjesson, P., Herr, H., … Øien, N. (2017). *Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys*. Retrieved from https://synergy.st-andrews.ac.uk/scans3/files/2017/05/SCANS-III-design-based-estimates-2017-05-12-final-revised.pdf

Hilário, R. R., Rodrigues, F. H. G., Chiarello, A. G., & Mourthé, Í. (2012). Can roads be used as transects for primate population surveys? *Folia Primatologica*, *83*(1), 47–55.

Hoekendijk, J. P. A., de Vries, J., van der Bolt, K., Greinert, J., Brasseur, S., Camphuysen, K. C. J., & Aarts, G. (2015). Estimating the spatial position of marine mammals based on digital camera recordings. *Ecology and Evolution*, *5*(3), 578–589.

Hoenner, X., Huveneers, C., Steckenreuter, A., Simpfendorfer, C., Tattersall, K., Jaine, F., … Harcourt, R. (2017). Data Descriptor : Australia's continental-scale acoustic tracking database and its automated quality control process. *Scientific Data*, *5*(180206).

Holmberg, J., Norman, B., & Arzoumanian, Z. (2009). Estimating population size, structure, and residency time for whale sharks *Rhincodon typus* through collaborative photo-identification. *Endangered Species Research*, *7*(1), 39–53.

Hooper, B. P., Mcdonald, G. T., & Mitchell, B. (1999). Facilitating integrated resource and environmental management: Australian and Canadian perspectives. *Journal of Environmental Planning and Management*, *42*(5), 747–766.

Hughes, R. M., & Peck, D. V. (2008). Acquiring data for large aquatic resource surveys: the art of compromise among science, logistics, and reality. *Journal of the North American Benthological Society*, *27*(4), 837–859.

Hutchnison, I. (2017). *ORJIP Ocean Energy. The forward look; an ocean energy environmental research strategy for the UK. Report to: The Crown Estate, Marine Scotland, Welsh Government, Scottish Natural Heritage and Natural Resources Wales*. Retrieved from http://www.orjip.org.uk/sites/default/files/ORJIP Ocean Energy Forward Look 3 FINAL.pdf

Jacobson, S. K., Sieving, K. E., Jones, G. A., & Van Doorn, A. (2003). Assessment of farmer attitudes and behavioral intentions toward bird conservation on organic and conventional Florida farms. *Conservation Biology*, *17*(2), 595–606.

Johnson, M., Madsen, P. T., Zimmer, W. M. X., de Soto, N. A., & Tyack, P. L. (2006). Foraging Blainville's beaked whales (*Mesoplodon densirostris*) produce distinct click types matched to different phases of echolocation. *Journal of Experimental Biology*, *209*(24), 5038–5050.

Johnston, D. W., Westgate, A. J., & Read, A. J. (2005). Effects of fine-scale oceanographic features on the distribution and movements of harbour porpoises *Phocoena phocoena* in the Bay of Fundy. *Marine Ecology Progress Series*, *295*, 279–293.

Kark, S., Tulloch, A., Gordon, A., Mazor, T., Bunnefeld, N., & Levin, N. (2015). Cross-boundary collaboration: key to the conservation puzzle. *Current Opinion in Environmental Sustainability*, *12*, 12–24.

Katz, J. S., & Martin, B. R. (1995). What is research collaboration? *Research Policy*, *26*, 1–18.

Kéry, M., & Schmid, H. (2004). Monitoring programs need to take into account imperfect species detectability. *Basic and Applied Ecology*, *73*, 65–73.

Kiszka, J., Macleod, K., Van Canneyt, O., Walker, D., & Ridoux, V. (2007). Distribution, encounter rates, and habitat characteristics of toothed cetaceans in the Bay of Biscay and adjacent waters from platform-of-opportunity Data. *ICES Journal of Marine Science*, *64*(5), 1033–1043.

Kranstauber, B., Cameron, A., Weinzerl, R., Fountain, T., Tilak, S., Wikelski, M., & Kays, R. (2011). The Movebank data model for animal tracking. *Environmental Modelling and Software*, *26*(6), 834–835.

Krosnick, J. A., & Presser, S. (2010). Question and Questionnaire Design. In *Handbook of Survey Research* (Second edi, pp. 263–313). Yorkshire, United Kingdom: Emerald Group Publishing Limited.

Krueger, T., Page, T., Hubacek, K., Smith, L., & Hiscock, K. (2012). The role of expert opinion in environmental modelling. *Environmental Modelling and Software*, *36*, 4–18. https://doi.org/10.1016/j.envsoft.2012.01.011

Kuemmerlen, M., Stoll, S., Sundermann, A., & Haase, P. (2016). Long-term monitoring data meet freshwater species distribution models: Lessons from an LTER-site. *Ecological Indicators*, *65*, 122–132.

Kyhn, L. A., Tougaard, J., Amundin, M., Stenback, J., Teilmann, J., & Wennerberg, D. (2008). Validating passive acoustic monitoring data loggers by visual observations. *The Journal of the Acoustical Society of America*, *123*(5), 3208.

Kyhn, L. A., Tougaard, J., Thomas, L., Duve, L. R., Stenback, J., Amundin, M., … Teilmann, J. (2012). From echolocation clicks to animal density—Acoustic sampling of harbor porpoises with static dataloggers. *The Journal of the Acoustical Society of America*, *131*(1), 550–560.

Legault, A., Theuerkauf, J., Baby, E., Moutin, L., Rouys, S., Saoumoé, M., … Gula, R. (2013). Standardising distance sampling surveys of parrots in New Caledonia. *Journal of Ornithology*, *154*(1), 19–33.

Lerczak, J. A., Hobbs, R. C., & Evans, P. G. H. (1998). Calculating sighting distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys. *Marine Mammal Science*, *14*(3), 590–599.

Li, S., Akamatsu, T., Dong, L., Wang, K., Wang, D., & Kimura, S. (2010). Widespread passive acoustic detection of Yangtze finless porpoise using miniature stereo acoustic data-loggers: A review. *The Journal of the Acoustical Society of America*, *128*(3), 1476.

Lindenmayer, D. B., & Likens, G. E. (2009). Adaptive monitoring: a new paradigm for long-term research and monitoring. *Trends in Ecology and Evolution*, *24*(9), 482–486.

Linkie, M., Chapron, G., Martyr, D. J., Holden, J., & Leader-Williams, N. (2006). Assessing the viability of tiger subpopulations in a fragmented landscape. *Journal of Applied Ecology*, *43*(3), 576–586.

Lusseau, D. (2006). Why do dolphins jump? Interpreting the behavioural repertoire of bottlenose dolphins (*Tursiops* sp.) in Doubtful Sound, New Zealand. *Behavioural Processes*, *73*(3), 257–265.

Mackenzie, M., Scott-Hayward, L., Oedekoven, C., Skov, H., Humphreys, E., & Rexstad, E. (2013). *Statistical modelling of seabird and cetacean data: Guidance Document*. Scotland. Retrieved from http://www.scotland.gov.uk/Resource/0046/00460870.pdf

Marques, T. A. (2004). Predicting and correcting bias caused by measurement error in line transect sampling using multiplicative error models. *Biometrics*, *60*(3), 757–763.

Marques, T. A., Buckland, S. T., Bispo, R., & Howland, B. (2013). Accounting for animal density gradients using independent information in distance sampling surveys, 67–80.

Marques, T. A., Buckland, S. T., Borchers, D. L., Tosh, D., & McDonald, R. A. (2010). Point Transect Sampling Along Linear Features. *Biometrics*, *66*(4), 1247–1255.

Marques, T. A., Thomas, L., Martin, S. W., Mellinger, D. K., Ward, J. A., Moretti, D. J., … Tyack, P. L. (2012). Estimating animal population density using passive acoustics. *Biological Reviews*, 000–000.

Marsden, S. J., Loqueh, E., Takuo, J. M., Hart, J. A., Abani, R., Ahon, D. B., … Valle, S. (2016). Using encounter rates as surrogates for density estimates makes monitoring of heavily-traded grey parrots achievable across Africa. *Oryx*, *50*(4), 617–625.

Marubini, F., Gimona, A., Evans, P. G. H., Wright, P. J., & Pierce, G. J. (2017). Habitat preferences and interannual variability in occurrence of the harbour porpoise *Phocoena phocoena* off northwest Scotland. *Marine Ecology Progress Series*, *381*, 297–310.

McDonald-Madden, E., Baxter, P. W. J., Fuller, R. A., Martin, T. G., Game, E. T., Montambault, J., & Possingham, H. P. (2010). Monitoring does not always count. *Trends in Ecology and Evolution*, *25*(10), 547–550.

McGrew, W. C., Marchant, L. F., & Phillips, C. A. (2009). Standardised protocol for primate faecal analysis. *Primates*, *50*(4), 363–366.

Medema, W., Furber, A., Adamowski, J., Zhou, Q., & Mayer, I. (2016). Exploring the potential impact of serious games on social learning and stakeholder collaborations for transboundary watershed management of the St . Lawrence River Basin. *Water*, *8*(175).

Mellinger, D. K., Stafford, K. M., Moore, S. E., Dziak, R. P., & Matsumoto, H. (2007). An overview of fixed passive acoustic observation methods for cetaceans. *Oceanography*, *20*(4), 36–45.

Merchant, N. D., Brookes, K. L., Faulkner, R. C., Bicknell, A. W. J., Godley, B. J., & Witt, M. J. (2016). Underwater noise levels in UK waters. *Scientific Reports*, *6*(1), 1–10.

Miller, D. L. (2017). Distance: Distance Sampling Detection Function and Abundance Estimation. Retrieved from https://cran.r-project.org/package=Distance

Miller, D. L., Rexstad, E., Thomas, L., Marshall, L., & Laake, J. L. (2014). Distance Sampling in R. *Journal of Statistical Software*, *VV*(II), 1–30.

Miloslavich, P., Bax, N. J., Simmons, S. E., Klein, E., Appeltans, W., Aburto-Oropeza, O., … Shin, Y. J. (2018). Essential ocean variables for global sustained observations of biodiversity and ecosystem changes. *Global Change Biology*, *24*(6), 2416–2433. https://doi.org/10.1111/gcb.14108

Minton, G., Kema Kema, J. R., Todd, A., Korte, L., Maganga, P. B., Migoungui Mouelet, J. R., … Nguélé, G. K. (2017). Multi-stakeholder collaboration yields valuable data for cetacean conservation in Gamba, Gabon. *African Journal of Marine Science*, *39*(4), 423–433.

Morrison, L. W. (2016). Observer error in vegetation surveys: A review. *Journal of Plant Ecology*, *9*(4), 367–379.

Muheim, R., Henshaw, I., Sjöberg, S., & Deutschlander, M. E. (2014). BirdOriTrack: A new video-tracking program for orientation research with migratory birds. *Journal of Field Ornithology*, *85*(1), 91–105.

Nadon, M. O., & Stirling, G. (2006). Field and simulation analyses of visual methods for sampling coral cover. *Coral Reefs*, *25*(2), 177–185.

National Centre for Biotechnology Information. (2019). What is GenBank? Retrieved February 11, 2019, from https://www.ncbi.nlm.nih.gov/genbank/

Natural Resources Wales. (2015a). *Marine character areas: MCA 13 Llŷn Peninsula. Aand Bardsey Island Location and boundaries Key Characteristics*. Retrieved from https://www.naturalresources.wales/media/674491/mca-13-llyn-and-bardsey-island_final.pdf

Natural Resources Wales. (2015b). *Marine character areas: MCA 17 outer Cardigan bay*. Retrieved from https://www.naturalresources.wales/media/674494/mca-16-cardigan-bay_south_final.pdf

Natural Resources Wales. (2015c). *Marine character areas: MCA 18 West Pembrokeshire coastal waters and islands*. Retrieved from https://www.naturalresources.wales/media/674496/mca-18-west-pembrokeshire-coastal-waters-and-islands_final.pdf

Nichols, J. D., Thomas, L., & Conn, P. B. (2009). *Modeling Demographic Processes In Marked Populations*. Maryland, USA: Springer Science+Business Media. Retrieved from http://link.springer.com/10.1007/978-0-387-78151-8

Noss, A. J., Gardner, B., Maffei, L., Cuéllar, E., Montaño, R., Romero-Muñoz, A., …

O’Connell, A. F. (2012). Comparison of density estimation methods for mammal populations with camera traps in the Kaa-Iya del Gran Chaco landscape. *Animal Conservation*, *15*(5), 527–535.

Nuno, A., Bunnefled, N., & Milner-Gulland, E. J. (2014). Managing social–ecological systems under uncertainty: implementation in the real world. *Ecology and Society*, *19*(2).

Nuuttila, H. K. (2015). *Review of cetacean monitoring guidelines for Welsh wave and tidal energy developments. SEACAMS Project Report. Ref.201-D70-D74.* Retrieved from http://www.marineenergywales.co.uk/wp-content/uploads/2016/01/SEACAMS-Nuuttila_Marine-mammal-guideline-review_final-report-2015.pdf

Nuuttila, H. K., Bertelli, C. M., Mendzil, A., & Dearle, N. (2017). Seasonal and diel patterns in cetacean use and foraging at a potential marine renewable energy site. *Marine Pollution Bulletin*, *129*(2), 633–644.

Nuuttila, H. K., Brundiers, K., Dähne, M., Koblitz, J. C., Thomas, L., Courtene-Jones, W., … Hiddink, J. G. (2018). Estimating effective detection area of static passive acoustic data loggers from playback experiments with cetacean vocalisations. *Methods in Ecology and Evolution*, *2018*, 1–10.

Nuuttila, H. K., Courtene-Jones, W., Baulch, S., Simon, M., & Evans, P. G. H. (2017). Don’t forget the porpoise: acoustic monitoring reveals fine scale temporal variation between bottlenose dolphin and harbour porpoise in Cardigan Bay SAC. *Marine Biology*, *164*(3).

Nuuttila, H. K., & Mendzil, A. (2014). *Development of marine mammal observation methods for vantage Point surveys in Ramsey sound. SEACAMS Project Report 2014-D75*. Retrieved from https://www.researchgate.net/publication/279885287_Development_of_marine_mammal_observation_methods_for_vantage_Point_surveys_in_Ramsey_sound

Obbard, M. E., Howe, E. J., & Kyle, C. J. (2010). Empirical comparison of density estimators for large carnivores. *Journal of Applied Ecology*, *47*(1), 76–84.

Oedekoven, C. S., Mackenzie, M. L., Scott-Hayward, L. A. S., & Rexstad, E. (2014). *Marine Scotland science report 05/14 Statistical modelling of seabird and cetacean data: Literature review*. Marine Scotland Science. Scotland. Retrieved from https://www2.gov.scot/Topics/marine/Publications/publicationslatest/Science/MSSR/2014/0514

Ogburn, M. B., Harrison, A., Whoriskey, F. G., Cooke, S. J., Flemming, J. E. M., Torres, L. G., & Drew, J. A. (2017). Addressing challenges in the application of animal movement ecology to aquatic conservation and management. *Frontiers in Marine Science*, *4*(70).

Parekh, H. S., Thakore, D. G., & Jaliya, U. K. (2014). A Survey on Object Detection and Tracking. *International Journal of Innovative Research in Computer and Communication Engineering*, *2*(2).

Passilongo, D., Mattioli, L., Bassi, E., Szabó, L., & Apollonio, M. (2015). Visualizing sound: Counting wolves by using a spectral view of the chorus howling. *Frontiers in Zoology*, *12*(1), 0–9. Retrieved from http://dx.doi.org/10.1186/s12983-015-0114-0

Paxton, C. G. M., Mackenzie, M., Rexstad, E., & Thomas, L. (2016). *Revised Phase III Data Analysis of Joint Cetacean Protocol Data Resources C.G.M. JNCC Report No.517*. Retrieved from http://archive.jncc.gov.uk/pdf/Report_517_web.pdf

Peters, C., Schreiber, D., Guay, M., & Baedell, S. (2015). *The Ultimate Guide to Forms and*. Zapier Inc.

Pierpoint, C. J. . (1993). Observations of harbour porpoise in Ramsey Sound Dyfed. *European Research on Cetaceans*, (7), 39–42.

Pierpoint, C. J. . (2008). Harbour porpoise (*Phocoena phocoena*) foraging strategy at a high energy, near-shore site in south-west Wales, UK. *Journal of the Marine Biological Association of the United Kingdom*, *88*(6), 1167–1173.

Pingree, R. D., & Griffiths, D. K. (1978). Tidal fronts on the shelf seas around the British Isles. *Journal of Geophysical Research*, *83*(C9), 4615.

Pirotta, E., Thompson, P. M., Miller, P. I., Brookes, K. L., Cheney, B., Barton, T. R., … Lusseau, D. (2014). Scale-dependent foraging ecology of a marine top predator modelled using passive acoustic data. *Functional Ecology*, *28*(1), 206–217.

Primm, S. A. (2003). A Pragmatic Approach to Grizzly Bear Conservation. *Conservation Biology*, *10*(4), 1026–1035.

Reichman, O. J., Jones, M. B., & Schildhauer, M. P. (2011). Challenges and opportunities of open data in ecology. *Science*, *331*(6018), 703–705.

Reid, J. B., Evans, P. G. H., & Northridge, S. P. (2003). *Atlas of Ceteacean: distribution in north-west European waters*. Retrieved from http://jncc.defra.gov.uk/page-3881.

Richman, N. I., Gibbons, J. M., Turvey, S. T., Akamatsu, T., Ahmed, B., Mahabub, E., … Jones, J. P. G. (2014). To see or not to see: Investigating detectability of ganges river dolphins using a combined visual-acoustic survey. *PLoS ONE*, *9*(5).

Riley, M., Soutyrina, S., Miquelle, D., Hayward, G., Goodrich, J., & Buskirk, S. (2017). Comparison of methods for estimating Amur tiger abundance. *Wildlife Biology*, *1*(00253).

Robbins, J. R., Brandecker, A., Cronin, M., Jessopp, M., McAllen, R., & Culloch, R. (2015). Handling dolphin detections from C-PODs, with the development of acoustic parameters for verification and the exploration of species identification possibilities. *Bioacoustics*, *25*(2), 99–110.

Robins, G., Bates, L., & Pattison, P. (2011). Network governance and environmental management: conflict and cooperation. *Public Administration*, *89*(4), 1293–1313.

Rödel, M., & Ernst, R. (2004). Measuring and monitoring amphibian diversity in tropical forests. I. An evaluation of methods with recommendations for standardization, *10*(1), 1–14.

Rovero, F., & Marshall, A. R. (2009). Camera trapping photographic rate as an index of density in forest ungulates. *Journal of Applied Ecology*, *46*(5), 1011–1017.

RStudio Team. (2016). RStudio: Integrated Development for R. Boston, MA: RStudio, Inc.

Ruette, S., Stahl, P., & Albaret, M. (2003). Applying distance-sampling methods to spotlight counts of red foxes. *Journal of Applied Ecology*, *40*(1), 32–43.

Samejima, H., Ong, R., Lagan, P., & Kitayama, K. (2012). Camera-trapping rates of mammals and birds in a Bornean tropical rainforest under sustainable forest management. *Forest Ecology and Management*, *270*, 248–256.

Sandström, A., & Rova, C. (2010). Adaptive co-management networks : a comparative analysis of two fishery conservation areas in Sweden. *Ecology and Society*, *online*.

Santos, M. B. P., Pierce, G. J., Learmonth, J. A., Reid, R. J., Ross, H. M., Patterson, I. A. P., … Beare, D. (2004). Variability in the diet of harbor porpoises (*phocoena phocoena*) in scottish waters 1992-2003. *Marine Mammal Science*, *20*(1), 1–27.

Sarnocinska, J., Tougaard, J., Johnson, M., Madsen, P. T., & Wahlberg, M. (2016). Comparing the performance of C-PODs and SoundTrap/PAMGUARD in detecting the acoustic activity of harbor porpoises (*Phocoena phocoena*). *Proceesings of Meetings on Acoustics*, *27*. Retrieved from http://asa.scitation.org/doi/abs/10.1121/2.0000288

Schmeller, D. S., Musche, M., Penner, J., Klotz, S., Müller, F., Kühn, I., … Frenzel, M. (2017). The next generation of site-based long-term ecological monitoring: Linking essential biodiversity variables and ecosystem integrity. *Science of The Total Environment*, *613–614*, 1376–1384.

Schuett, M. A., Selin, S. W., & Carr, D. S. (2001). Making it work: Keys to successful collaboration in natural resource management. *Environmental Management*, *27*(4), 587–593.

Simon, M., & Heide-Jorgensen, M. P. (2007). Cue rates for common minke , fin and humpback whales in West Greenland. *Journal of Cetacean Research and Management*, (January).

Simon, M., Nuuttila, H. K., Reyes-Zamudio, M. M., Ugarte, F., Verfuß, U. K., & Evans, P. G. H. (2010). Passive acoustic monitoring of bottlenose dolphin and harbour porpoise, in Cardigan Bay, Wales, with implications for habitat use and partitioning. *Journal of the Marine Biological Association of the United Kingdom*, *90*(08), 1539–1545.

Soranno, P. A., Bissell, E. G., Cheruvelil, K. S., Christel, S. T., Collins, S. M., Fergus, C. E., … Webster, K. E. (2015). Building a multi-scaled geospatial temporal ecology database from disparate data sources : fostering open science and data reuse. *GigaScience*, *4*(28).

Sostres Alonso, M., & Nuuttila, H. K. (2014). Detection rates of wild harbour porpoises and bottlenose dolphins using static acoustic click loggers vary with depth. *Bioacoustics*, *24*(2), 101–110.

Sousa-Lima, R. S., Norris, T. F., Oswald, J. N., & Fernandes, D. P. (2013). A review and inventory of fixed autonomous recorders for passive acoustic monitoring of marine mammals. *Aquatic Mammals*, *39*(1), 23–53.

Southall, B., & Novacek, D. (2009). Acoustics in marine ecology: innovation in technology expands the use of sound in ocean science. *Marine Ecology Progress Series*, *395*, 1–3.

Stevenson, B. C., Borchers, D. L., Altwegg, R., Swift, R. J., Gillespie, D. M., & Measey, G. J. (2014). A general framework for animal density estimation from acoustic detections across a fixed microphone array. *Methods in Ecology and Evolution*, *6*, 38–48.

Thompson, M. E., Schwager, S. J., & Payne, K. B. (2010). Heard but not seen: An acoustic survey of the African forest elephant population at Kakum Conservation Area, Ghana. *African Journal of Ecology*, *48*(1), 224–231.

Thompson, M. E., Schwager, S. J., Payne, K. B., & Turkalo, A. K. (2010). Acoustic estimation of wildlife abundance: Methodology for vocal mammals in forested habitats. *African Journal of Ecology*, *48*(3), 654–661.

Tobler, M. W., Carrillo-Percastegui, S. E., Zúñiga Hartley, A., & Powell, G. V. N. (2013). High jaguar densities and large population sizes in the core habitat of the southwestern Amazon. *Biological Conservation*, *159*, 375–381.

Transition Bro Gwaun. (2011). *Fishguard tidal power feasibility study: TBG Report 04/10/11*. Retrieved from http://www.marineenergywales.co.uk/wp-content/uploads/2016/01/Fishguard-tidal-power-feasibility-study-TBG-use.pdf

Tregenza, N. J. . (1999). A new tool for cetacean research - a fully submersible click detector. In *Proceedings of the European Cetacean Society Annual Meeting*. Las Palmas, The Canary Islands, Spain.

Veness, C. (2019). Calculate distance, bearing and more between Latitude/ Longitude Points. Retrieved June 12, 2019, from http://www.movable-type.co.uk/scripts/latlong.html,

Verfuß, U. K., Honnef, C. G., Meding, A., Dähne, M., Mundry, R., & Benke, H. (2007). Geographical and seasonal variation of harbour porpoise (Phocoena phocoena) presence in the German Baltic Sea revealed by passive acoustic monitoring. *Journal of the Marine Biological Association of the United Kingdom*, *87*(1), 165–176.

Wahlberg, M. (2002). The acoustic behaviour of diving sperm whales observed with a hydrophone array. *Journal of Experimental Marine Biology and Ecology*, *281*(1–2), 53–62.

Watkins, H., & Colley, R. (2004). *Harbour Porpoise Occurrence Carmarthen Bay - Gower Penninsula -Swansea Bay*. Retrieved from http://www.actinia.co.uk/gmmp/report-041215/SWWP_REPORT_02_05.pdf

Watson, A. P., & Gaskin, D. E. (1983). Observations on the ventilation cycle of the harbour porpoise *Phocoena phocoena* (L.) in coastal waters of the Bay of Fundy. *Canadian Journal of Zoology*, *61*, 126–132.

Westgate, A. J., Head, A. J., Berggren, P., Koopman, H. N., & Gaskin, D. E. (1995). Diving behaviour of harbour porpoises, *Phocoena phocoena*. *Canadian Journal of Fisheries and Aquatic Sciences*, *52*(5), 1064–1073.

White, P. C. L., Jennings, N. V., Renwick, A. R., & Barker, N. H. L. (2005). Questionnaires in ecology: A review of past use and recommendations for best practice. *Journal of Applied Ecology*, *42*(3), 421–430.

Whitlock, M. C. (2011). Data archiving in ecology and evolution: Best practices. *Trends in Ecology and Evolution*, *26*(2), 61–65.

Wikelski, M., & Kays, R. (2018). Movebank: archive, analysis and sharing of animal movement data. World Wide Web electronic publication. Retrieved February 11, 2019, from https://www.movebank.org/node/2

Wildlife Trust of South and West Wales. (2018). Skomer Warden Job Description. Retrieved February 13, 2019, from https://www.welshwildlife.org/wp-content/uploads/2018/06/Skomer-Warden-job-description-2018.doc

Wilkinson, M. D. (2016). The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*, *3*(160018), 1–9.

Williams, R., Leaper, R., Zerbini, A. N., & Hammond, P. S. (2007). Methods for investigating measurement error in cetacean line-transect surveys. *Journal of the Marine Biological Association of the United Kingdom*, *87*, 313–320.

Williamson, L. D., Brookes, K. L., Scott, B. E., Graham, I. M., & Thompson, P. M. (2017). Diurnal variation in harbour porpoise detection — potential implications for management. *Marine Ecology Progress Series*, *570*, 223–232.

Wood, S. N. (2011). Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. *Journal of the Royal Statistical Society*, *73*(1), 3–36.

Zamora-marín, J. M., Zamora-lópez, A., Calvo, J. F., & Oliva-paterna, F. J. (2019). Comparing detectability patterns of bird species in small ponds using hierarchical modelling.

Zeppelzauer, M., Hensman, S., & Stoeger, A. S. (2015). Towards an automated acoustic detection system for free-ranging elephants. *Bioacoustics*, *24*(1), 13–29.

Zimmer, W. M. X., Johnson, M. P., Madsen, P. T., & Tyack, P. L. (2005). Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*). *The Journal of the Acoustical Society of America*, *117*(6), 3919–3927.

Zuur, A. F., Ieno, E. N., & Elphick, C. S. (2010). A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution*, *1*(1), 3–14.

Glossary

Count Rate	CR = Number of animals sighted / duration of the scan
Detection Function	The relationship between distance and the probability of detection. G(x) = the probability of detecting an animal, given that it is at distance x from the observer.
Perception Bias	When the animal is overlooked by the observer.
Availability Bias	When the animal is not available to be surveyed, because its underwater.