Institution: University of Aberdeen

Unit of Assessment: UOA7: Earth Systems and Environmental Sciences

Title of case study: Reducing environmental impacts and construction costs at offshore wind farms

Period when the underpinning research was undertaken: 2013-2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Paul Thompson	Professor of Zoology	1997 - Present
Barbara Cheney	Research Fellow	2005 - Present
Kate Brookes	Research Fellow	2009 - 2012
Isla Graham	Research Fellow	2011 - Present

Period when the claimed impact occurred: 2014-present

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact (indicative maximum 100 words)

The role of offshore renewable energy is essential to UK efforts both to meet climate change targets and to provide energy security. At the same time, legislative requirements are in place to protect the marine environment. This team at the University of Aberdeen has led a programme of interdisciplinary research to explore the responses of key marine mammal populations to different stages of wind farm construction and operation, assessing the extent to which animals may be injured or displaced. Their findings have underpinned the development of novel and safe approaches to mitigating the effects of piling noise, leading to a reduction in the environmental impacts on marine mammals, improvements in the economic viability of offshore renewable energy schemes, influencing industry guidelines, leading to changes in construction practices, and informing national and international decision-making.

2. Underpinning research (indicative maximum 500 words)

UK efforts to meet climate change targets and provide energy security depend critically on offshore renewables. However, there had been two key challenges: 1) developing new offshore infrastructure projects whilst meeting increasingly stringent environmental legislation; and 2) reducing the costs of construction so that the renewable energy sources can compete with conventional approaches. As part of a broad academic-industry collaboration, a team of Aberdeen marine mammal researchers, led by Prof Paul Thompson, has been working on these challenges for the last 15 years, with their work in the Moray Firth internationally recognized for providing unique insights into interactions between top predators and environmental perturbations. Earlier phases of work evaluated methods for studying spatio-temporal variation in marine mammal distribution around offshore development sites [**R1**], resulting in the development of novel assessment frameworks that underpinned wind farm planning consents.

These frameworks were informed by results from Thompson's earlier studies of broad-scale responses of small cetaceans to impulsive noise produced during oil and gas exploration surveys [**R2**]. Uncertainty remained over how animals respond to similarly loud noise sources generated when steel piles are hammered into the seabed to install the foundations for offshore wind turbines. Death or injury at close range, auditory damage from accumulated noise and behavioural disruption are risks to marine mammals.

This research challenge was exacerbated in 2016 when, following the threat of EU court action,

the UK government developed proposals for Special Areas of Conservation (SAC) for harbour porpoises. Several of these overlapped with consented offshore wind farms developments, two of which – Beatrice Offshore Windfarm Ltd (BOWL) and Moray Offshore Windfarm East Ltd (MOWEL) – were within the University of Aberdeen's Moray Firth study system. Precautionary management guidance from the Joint Nature Conservancy Council (JNCC), the UK statutory advisor, included proposals for spatio-temporal restrictions on piling activity based upon assumed displacement at 25 km. JNCC guidance also required independent observers to confirm that no cetaceans were observed prior to each piling event in order to mitigate near-field injuries. These proposals provided both economic and environmental challenges to developers and regulators. Potential delays to piling threatened project viability given vessel costs of around GBP250,000 per day. Environmentally, there had been criticism that JNCC guidelines provided inadequate protection from injury because of the observers' low detection rates for porpoises in offshore conditions.

To address these challenges, Thompson developed and led a strategic research programme and funding consortium to evaluate responses of key marine mammal populations to different stages of wind farm construction and operation. Critically, studies were designed to go beyond the consent monitoring typically required of developers. Instead, they focused on key uncertainties identified by academics, regulators and other stakeholders during the consenting process; measuring noise levels to validate acoustic propagation models used in consenting [**R3**] and characterising responses of marine mammals to these disturbances [**R4**]. By studying the extent to which animals may be injured or displaced during construction of the UK's first deep-water wind farm (BOWL), the programme tested and adapted current assessment and monitoring frameworks, reducing uncertainties for subsequent consenting rounds.

Parallel studies in the inner Moray Firth were conducted around a harbour extension at the Nigg Energy Park. These revealed only minor displacement of cetaceans in response to two different piling technologies [**R3**], but highlighted the need for underwater noise modelling methods to take account of local bathymetric conditions [**R4**]. This work was built upon during the 2017 installation of 84 deep-water turbine bases at BOWL. An extensive array of passive acoustic devices was deployed in a gradient design across a study area of >2000 km^2. This permitted the testing of assumptions used in regulatory assessments and mitigation procedures developed by Thompson and project engineers using risk-based assessments informed by the University of Aberdeen baseline studies.

Firstly, these tests measured and modelled levels of underwater noise in relation to the hammer-energies used to install piles for deep-water jacket foundations. Unlike previous studies at shallow water monopile foundations, noise levels were highest during piling "soft-starts" and, unexpectedly, levels reduced as piles were driven further into the sediment [**R5**]. Secondly, the tests quantified the extent of harbour porpoise displacement in response to the acoustic deterrent devices (ADDs) used to mitigate near-field (<250m) injury when piling is initiated. This demonstrated that, while this mitigation approach proved effective, strong responses of porpoises to ADDs at distances of > 20 km resulted in far-field disturbance well beyond that required for mitigating injury [**R5**]. In contrast, porpoise behavioural responses to pile driving diminished during the construction period and were always much lower than the 25 km threshold used in previous regulator guidance, and data were used to generate new "dose-response" curves to characterize harbour porpoise disturbance levels [**R6**]. The generality of these findings is now being assessed within the next phase of this strategic research programme, through the analysis of data from a replicate study conducted during the installation of 100 turbine foundations at the neighbouring 100-turbine MOWEL in 2019.

3. References to the research (indicative maximum of six references)

The quality of the research is deemed to be at least of 2* quality as corroborated by the following peer-reviewed, international publications (with Google Scholar **citations**):

[**R1**] Williamson, L.D., **Brookes, K.L**., Scott, B.E., **Graham, I.M**., Bradbury, G., Hammond, P.S. and **Thompson, P.M**. (2016) Echolocation detections and digital video surveys provide reliable estimates of the relative density of harbour porpoises. *Methods Ecol Evol*, 7: 762-769. https://doi.org/10.1111/2041-210X.12538 (**26**)

[**R2**] **Thompson P.M., Brookes K.L., Graham I.M.,** Barton Tim R., Needham Keith, Bradbury Gareth and Merchant Nathan D. (2013) Short-term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement of harbour porpoises. *Proc. R. Soc. B*.28020132001 http://doi.org/10.1098/rspb.2013.2001 (**102**)

[**R3**] **Graham, I. M.**, Pirotta, E., Merchant, N. D., Farcas, A., Barton, T. R., **Cheney, B**., Hastie, G. D., and **Thompson, P. M**. (2017). Responses of bottlenose dolphins and harbor porpoises to impact and vibration piling noise during harbor construction. *Ecosphere* 8(5):e01793. 10.1002/ecs2.1793. (**9**)

[**R4**] Farcas, A. **Thompson, P.M.** & Merchant, N.D. (2016) Underwater noise modelling for environmental impact assessment. *Environmental Impact Assessment Review*, 57:114-122 https://doi.org/10.1016/j.eiar.2015.11.012 (**94**)

[**R5**] **Thompson, PM, Graham, IM, Cheney, B,** Barton, TR, Farcas, A, Merchant, ND. (2020) Balancing risks of injury and disturbance to marine mammals when pile driving at offshore windfarms. *Ecol Solut Evidence*. 1:e12034. https://doi.org/10.1002/2688-8319.12034

[**R6**] **Graham I. M**., Merchant Nathan D., Farcas Adrian, Barton Tim R., **Cheney B**, Bono Saliza and **Thompson P. M.** 2019 Harbour porpoise responses to pile-driving diminish over time. *R. Soc. Open Sci*.6190335 http://doi.org/10.1098/rsos.190335 (**16**)

Funding:
2011-2012 Scottish Government, Rural and Environment Research and Analysis Directorate. GBP148,926 awarded to Thompson for *Methods for monitoring marine mammals at marine renewable energy developments*

2012-2016 Department of Business, Energy & Industrial Strategy, Hartley Anderson Ltd. GBP245,200 awarded to Thompson for *Assessing cetacean responses to pile driving noise*

2012-2024 Scottish Natural Heritage (now Nature Scot). GBP344,900 awarded to Thompson for *Bottlenose dolphin site condition monitoring in the Moray Firth SAC*

2014-2016 Highlands and Islands Enterprise. GBP65,085 awarded to Thompson for *Moray Firth Marine Mammals Monitoring Programme (MFMMMP)*

2014-2016 Crown Estate. GBP36,000 awarded to Thompson for *MFMMMP*

2014-2016 Scottish Government. GBP300,000 awarded to Thompson for *MFMMMP*

2014-2020 Beatrice Offshore Windfarm Ltd. GBP1,818,727 to Thompson for *MFMMMP*

2019-2022 Moray East Offshore Windfarm Ltd. GBP1,465,086 awarded to Thompson for *Marine Mammal Construction Monitoring*

4. Details of the impact (indicative maximum 750 words)

Aberdeen's programme of research exploring the responses of key marine mammal populations to different stages of wind farm construction and operation has led to a reduction of environmental impacts to those marine mammals, improved the economic

viability of offshore renewable energy schemes, influenced industry guidelines, leading to changes in construction practices, and informed national and international decision-making.

Reducing the environmental impacts on marine mammals

Working with developers' engineering teams and the findings from Aberdeen's large-scale field studies [**R1**]; new approaches for mitigating injury risk from piling noise were developed. These relied on routine integration of ADDs into engineering processes at BOWL, to disperse animals from near-field injury zones. Thompson led the development of risk-assessment [**S1i** pp110-141; **S1ii** pp p89-120] that satisfied regulators that this carefully controlled use of acoustic deterrents resulted in sufficiently low residual risk of injury, and was *"a key component of the approaches taken by the developers, and accepted by the RAG* [regional advisory group] *and the Regulator"* [**S2i**, **S2ii**], and trialed in the Moray Firth [**S3**]. The existence of Aberdeen's strategic marine mammal research programme provided the necessary framework for the required research and monitoring to be incorporated into the developer's Project Environmental Monitoring Plan [**S4**] and Prof Thompson managed the marine mammals monitoring programme (MMMP) pre- and during construction phases (2014-2021) [**S1**]. Results confirmed the efficacy of the mitigation approach but highlighted additional risks from far-field disturbance [**R5**]. These findings were rapidly adopted by Scottish regulators who in 2019 altered the required duration of ADD deployments during piling procedures at MOWEL [**S2**; **S3**; **S5**] to reduce unintended far-field disturbance.

Improving the economic viability of offshore renewable energy schemes

The Aberdeen-based approaches for mitigating injury risk also removed an existing requirement for visual marine mammal observers on piling vessels. Due to the research *"digital aerial surveys have almost completely replaced traditional methods for most population-scale surveys of marine wildlife, including marine mammals. Marine Scotland* [Scottish Government] *only recommends the use of this method to developers of offshore wind farms*" [**S6**]. Previously, significant uncertainties of engineering delays to e.g. due to poor weather preventing visual observations would extend construction schedules. This presented a key risk to the economic viability of offshore developments given the high daily cost of construction vessels. This work provided greater certainty over construction timescales and contributed to driving down project costs. Developers of the Moray windfarms saw impacts from this tighter integration of mitigation and engineering processes, resulting in *"greater certainty over timescales and contributed to an estimated* [*text removed for publication*] *reduction in construction costs"* for BOWL [**S3**]; and MOWEL having a "*more efficient piling campaign, a shorter programme, with a reduced predicted impact on marine mammals and estimated cost savings in excess on* [*text removed for publication*] [**S5**] with completion of each in 10 months, in contrast to anticipated two- and three-year schedules in their respective consent applications.

Influencing industry guidelines, leading to changes in construction practices

Research evaluating monitoring approaches at Moray Firth windfarms [**S1**] re-assured statutory advisors that they represent best practice, encouraging widespread use in the UK and beyond [**S2**; **S7**; **S8**]. Data from the studies reduced conservatism in assumptions over cetacean displacement, and the "dose-response" curves they generated underpinned environmental assessments for the next phase of offshore wind development for UK (e.g. Hornsea 3 and Moray West) [**S5**] and re-assessments for consented windfarms delayed by environmental court actions (eg. Seagreen and Inch Cape) [**S9**]. JNCC refer to the research [**R2**; **R6**] in their 2020 guidance for assessing noise disturbance in harbor porpoise SACs for England, Wales and Northern Ireland [**S10**].

Informing national and international understanding through galvanizing stakeholder interactions to find solutions

The Aberdeen research has informed broader understanding of the responses of key marine mammal populations to different stages of wind farm construction and operation nationally and

internationally. Approaches that Thompson developed working with MOWEL are informing their parent company *Oceanwinds*' stakeholder interactions at new developments within important marine mammal habitats including the Baltic Regions, Korea and Japan, and North and South America [**S5**]. In the US, Program Director for Ocean Acoustics within the government's National Oceanic and Atmospheric Administration has applied the Aberdeen research in decision-making processing, highlighting the work as "*field-leading*" and of "*central importance*" [**S11**].

Impacts beyond the region have been accelerated by Thompson's involvement in steering and advisory groups. Within the UK this has included the Offshore Renewables Joint Industry Project (ORJIP) on the Efficacy of Acoustic Deterrent Devices and consultancies for other UK developers; In the EU, through Vattenfall's DEPONS Project; in the US through activities of the Working Together to Resolve Environmental Effects of Wind Energy (WREN) Group. Cross membership of these different bodies and MFRAG led to requests from regulators for early dissemination of the initial data on the extent to which porpoises were displaced by piling noise at the BOWL development to fill a data gap identified during scoping of new consent applications. A confidential briefing paper (pre-publication data, [**R6**]) was provided by Thompson for BOWL, and key developers and regulators in September 2017, allowing the data to be incorporated into consent applications at other North Sea sites prior to publication in the formal peer-review literature.

The research of Prof Thompson and his leadership of MMMP has been lauded by the Joint Nature Conservation Committee (JNCC) - the statutory adviser to UK government on nature conservation – as "*useful for not just the Moray Firth wind farms and environment, but it has been used to inform environmental impact assessments and mitigation measures for other wind farms in the UK and beyond…as an example to follow in other parts of the UK"* [**S7**]. NatureScot – formerly, Scottish Natural Heritage – who advise the Scottish Government attribute the research to have helped get "*to where we are now, with three commercial windfarms consented in the Moray Firth … to bring knowledge and expertise to these discussions has enabled pragmatic and proportionate conversations to continue in the search of solutions. You and your team have built strong relationships across the group comprising of regulators, advisers, developers and their consultants. This has also resulted in talks at various national and international fora (Scotmer, WREN etc.) in demonstrating the research findings and helping to formulate future offshore policy and casework guidance not just in Scottish waters, but also beyond* [**S8**].

5. Sources to corroborate the impact (indicative maximum of 10 references)

S1. (i) BOWL – Piling Strategy – Nov 2015
(ii) Moray Offshore Renewables Ltd – Piling Strategy – 2016
S2. (i) MRAG vote agree to use the Aberdeen approach Oct 2015 Minutes
(ii)Testimonial - Head of Marine Scotland Science, Marine Scotland
S3. SSE (BOWL Developer) Testimonial - Director
S4. BOWL – Environmental Monitoring Programme – July 2017
S5. Ocean Winds (MOWEL/MORL Developer) – Testimonial – Managing Director, UK
S6. Hi-Def Aerial Surveying Consultant – Testimonial – Managing Director
S7. JNCC – Testimonial – Head of Marine Management
S8. NatureScot Testimonial - Marine Sustainability Manager/Sustainable Coasts and Seas
S9. Inch Cape Testimonial – Offshore Consents Manager
S10. JNCC 2020 Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs
S11. Testimonial - former Program Director of US Government Ocean Acoustics, National Oceanic and Atmospheric Administration