Institution: Bournemouth University

Unit of Assessment: 14

Title of case study: Using a computer model (MORPH) for environmental decision-making to balance the needs of birds and society

Period when the underpinning research was undertaken: 2007 – 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:
Professor Richard Stillman	Professor of Conservation Ecology	2007-current

Period when the claimed impact occurred: 2014 – 31 December 2020

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

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

MORPH is a computer model developed at Bournemouth University (BU) to predict the effects of human activity on coastal and wetland bird populations, enabling policy makers, planners and conservation organisations in the UK, Europe and the US to balance environmental protection with societal and economic needs. It has:

- Improved planning of coastal infrastructure and housing development, e.g. by offsetting the disturbance caused by 60,000 new homes by generating GBP3,400,000 for conservation.
- Enhanced sustainable shellfishery management, e.g. ending a 'boom-and-bust' economic cycle in the Dee estuary, bringing GBP883,000 on average per year to the local cockle fishing industry.
- Informed the practice and policy of conservation and regulatory organisations such as Natural England, enabling them to become more cost-effective.

Without evidence from MORPH, conservation priorities and funds would have been poorly directed, economic opportunities would have been lost and internationally protected birds would have been exposed to greater threat of habitat degradation, decline and local extinction.

2. Underpinning research (indicative maximum 500 words)

Policy makers, planners and managers need to foster economic growth (e.g. through recreation, port and housing development, shellfishing), while minimising negative impacts on legally protected bird species (e.g. UK Wildlife and Countryside Act, EU Birds Directive, USA Endangered Species Act). In the absence of evidence, the precautionary principle is usually applied, meaning that human activity and development, with its associated economic growth, can be prevented, even if there will ultimately be no negative effects on the birds. A robust method to predict how a diverse range of activities will affect the birds, to allow better-informed planning and management decisions has been lacking until our work.

Using unique computer modelling software, we filled this knowledge gap, and now provide the evidence-base for policy, planning and management of coastal and wetland bird habitats to allow human activities to coexist with the birds. Our breakthrough was to develop computer modelling software, MORPH, which can create virtual versions of real systems, including realistic ways in which animals respond to changes in their environment [R1, R2, R3]. The

detailed understanding of the behaviour and ecology of coastal and wetland birds incorporated into this model is derived from research conducted by BU and others (mainly former colleagues at Centre for Ecology and Hydrology Furzebrook / Winfrith) on diverse bird species globally [synthesised in R2, R3]. MORPH is a single piece of software but can simulate multiple systems, and inffect learns how to mimic different environmental conditions, species behaviour and physiology [R1]. This flexibility is key, as it means that MORPH can be applied rapidly to a diverse range of systems without any time-consuming changes to its underlying computer code.

MORPH is initially setup for present-day conditions for which the behaviour of birds in the real system is known [R2, R3]. Its predictions are compared to observations to determine whether it represents the system with sufficient accuracy to reliably inform decision-making [tests summarised in R2, R3]. The environment within MORPH is then changed to predict how changes in the real world may impact the birds, and the results used to inform decision making [R1]. MORPH is a rare example of a model that is able to make such predictions accurately [R2, R3], importantly relying on the fundamental evolutionary principle that both model and real birds will always behave in ways that maximise their chances of surviving and reproducing [R2, R3].

The application of MORPH is usually through research and/or consultancy, commissioned by stakeholders to understand the impacts of one or more types of environmental change that may affect a site [R4, R5]. Since 2007, MORPH has been used to model 25 bird species in 22 sites: in Australia, USA, Norway, Denmark, Germany, Netherlands, France, Spain, Scotland, Wales and England, funded by 22 organisations. Our website www.individualecology.com details all applications of MORPH, funders, publications, species modelled, issues addressed and conservation recommendations.

Typically, questions needing to be answered to inform decision-making are whether a change will adversely affect the birds [R4, R5], or which of a set of potential options will have minimal effects [R6]. The likely impact is usually measured by the proportion of birds able to survive in good enough condition to breed, as this determines population size – a key objective expressed within conservation legislation worldwide (e.g. Europe, USA, Australia).

MORPH is increasingly being used by industry, conservation NGOs and government organisations: (e.g. Inshore Fisheries Conservation Associations, Wildfowl and Wetland Trust, British Trust for Ornithology, Natural England, Natural Resources Wales, Local Authorities, United States Geological Survey) to improve the cost effectiveness of their work, set sustainable fishing quotas, and understand the impacts of new developments and human activity on the birds.

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

R1-6 were all subject to rigorous peer review.

R1. Stillman, R. A. (2008), "MORPH – An individual-based model to predict the effect of environmental change on animal populations," *Ecological Modelling*, 216, pp. 265-276. https://doi.org/10.1016/j.ecolmodel.2008.04.014

R2. Stillman, R. A. and Goss-Custard, J. D. (2010), "Individual-based ecology of coastal birds," *Biological Reviews*, 85, pp. 413–434. https://doi.org/10.1111/j.1469-185X.2009.00106.x

R3. Stillman, R. A., Railsback, S. F., Giske, J., Berger, U. and Grimm, V. (2015), "Making predictions in a changing world: The benefits of individual-based ecology," *BioScience*, 65, pp. 140-150. https://doi.org/10.1093/biosci/biu192

R4. Stillman, R. A., Wood, K. A., Gilkerson, W., Elkinton, E., Black, J. M., Ward, D. H. and Petrie, M. (2015), "Predicting effects of environmental change on a migratory herbivore," *Ecosphere*, 6, p. 114. http://dx.doi.org/10.1890/ES14-00455.1

R5. Stillman, R. A., Wood, K. A. and Goss-Custard, J. D. (2016), "Deriving simple predictions from complex models to support environmental decision-making," *Ecological Modelling*. 326, pp. 134-141. http://dx.doi.org/10.1016/j.ecolmodel.2015.04.014

R6. Goss-Custard, J. D., Bowgen, K. M. and Stillman, R. A. (2019), "Increasing the harvest for mussels *Mytilus edulis* without harming oystercatchers *Haematopus ostralegus," Marine Ecology Progress Series*, 612, pp. 101-110. https://doi.org/10.3354/meps12875

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

Improving regulation of infrastructure development and plans

Since 2014, MORPH's predictions have informed policy, planning and management associated with the impacts of housing developments, the loss of feeding habitat, and human activity on bird populations both in the UK and the US.

- An independent coastal partnership, the Solent Forum, commissioned BU to measure the potential impact of housing development on the wintering bird population of the Solent. MORPH predicted that increased levels of human activity from the construction of 60,000 additional houses up to 2034 could potentially increase the mortality of wading birds [E1a, p.4] in the region. Consequently, developers had to offset any negative effects by contributing between GBP356 to GBP927 per house built (depending on the number of bedrooms) [E1b] to fund conservation. From 2014 to 2020, those contributions totalled GBP3,400,000 [E1c], with the potential to reach approximately GBP34,000,000 by 2034* [E1a, p.16]. This was used to create Bird Aware Solent, a multi-award-winning partnership, which coordinates the use of the funding [E1d]. (*Using the baseline developer contribution of £564 x 60,000 houses = GBP33,840,000.)

- BU worked with government adviser Natural England (NE) to assess the effects of habitat loss and disturbance due to new developments on wildfowl populations. NE commented, that, as a result, it can "for the first time… predict whether [such] loss… might result in a decline in protected bird populations or affect their fitness." NE is currently developing new guidance for its staff which will save "a significant amount of time responding to planning consultations, whilst still ensuring the protection of designated wildfowl populations" [E2].

- In 2015, US-based conservation organisation Ducks Unlimited funded BU research into the effects of disturbance and habitat loss on black brant geese in Humboldt Bay, California [R4]. The subsequent findings formed a key piece of evidence for an impact assessment in 2016 of the environmental effects of the expansion of aquaculture activity by the Coast Seafood Company [E3].The final report stated: "…the Stillman model [MORPH] is the best science available to assess impacts of the project on brant" [E3].

Enhancing sustainable shellfishery management to allow economic growth while better conserving protected bird species

Since 2014, MORPH and its related research has informed the sustainable management of shellfisheries in the Wadden Sea, Netherlands – the world's largest unbroken system of intertidal sand and mud flats - the Dee Estuary, Burry Inlet and Three Rivers in Wales and England's Exe Estuary.

- During 2020, MORPH was used to determine whether the management of the Wadden Sea cockle fishery between 2007 and 2019 had been appropriate to maintain high survival rates of the oystercatcher, a confirmation required to allow cockle harvesting in 2020/21. The Programme Towards a Rich Wadden Sea, a Dutch umbrella organisation, stated: "The researchers applied the MORPH model that calculates how many cockles must be available in the Wadden Sea to meet the daily physiological nutritional needs of an oystercatcher…" [E4]. "All parties were satisfied with the quality and thoroughness of [the] study using the MORPH model. The two commissioning parties, Province of Fryslân

and the association of manual cockle fishers, OHV, were pleased with the outcome as proof that there was no concern to issue the fishing permit for season 2020/2021." [E5]

- The Marine Stewardship Council (MSC) has documented MORPH's role since 2014 in the management of Welsh cockle fisheries [E6a, p.3, E6b, pp. 6-9] and the Exe Estuary mussel fishery [E6c, p.4]. The 'bird model'/'bird food model' (BFM) referred to is an output from MORPH that assesses the quantity of shellfish that needs to remain after fishing to allow the oystercatcher, a protected shellfish-feeding bird species, to have high survival across Welsh cockle fisheries, as required by conservation legislation. MSC reports: "The Dee Estuary […] stock is assessed under the same "bird model" as all other cockle fisheries in Wales, including Burry Inlet" [E6a, p.3, E6d, p.6]. "BFM is run every year to identify the amount of cockle that is required for the birds including the oystercatcher over the winter period and the quota that the fishermen can take is agreed once enough food for the oystercatchers is identified" [E6b, p.8]. The use of the BFM in the 'Dee Estuary Cockle Fishery Order' has also brought financial benefits to the local cockle industry. Before the 2008 order, it "operated on a boom-and-bust cycle", with beds often shutting for a few years due to very low stocks, before being cleared out once they reopened, leading once again to closure. Since 2008, the beds are able to open every year, providing "up to six months' lucrative employment for 53 licensed cocklers" [E7]. From 2013-2015 the fishery was worth an estimated GBP883,000 on average per year [E7].

- A report by MSC on the Exe Estuary outlines BU's impact on mussel harvesting. MORPH predicted that creation of a new oystercatcher food source from shellfishery waste, or a 'discard bed', could offset negative effects of the harvesting. This was a condition for consent from NE for harvesting by Exmouth Mussels Ltd. "A discard bed is provided at the upper level of the shore – the area will be agreed between Exmouth Mussels and [NE], based on the [BU] report's advice." [E6c, p.4]

Improving evidence-informed efficiency, resource management and cost effectiveness of conservation organisations

- BU has equipped NE with models and knowledge to predict in-house the effect of land use change on bird populations. This enables them to conduct a more cost-effective assessment of impacts, without having to use costly external consultants. An example of NE's potential to use MORPH is to determine why there has been a reduction in the number of geese using the North Norfolk Coast Special Protection Area. "It has been assumed that this change in behaviour has been triggered by changes in agricultural practice. This modelling work will help determine whether the fitness of these birds has been impacted and will help develop remedies to this latest challenge." [E2]

- UK conservation charity Wildfowl and Wetlands Trust (WWT) used MORPH to diagnose the environmental causes of the population decline of the Bewick's Swan, currently listed as 'Endangered' in Europe. "A team of scientists from the UK and the Netherlands […] worked with Professor Stillman to use the MORPH model to determine that reduced food availability and increased competition were not the cause of population decline." This evidence "had a direct impact on conservation practice and policy, by directing the efforts of WWT and its partners away from undertaking costly changes to current land management practices in an attempt to increase food availability for the swans" [E8]. WWT has also started to develop individual-based models [IBMs] such as MORPH to predict the impacts of wind turbines on migratory birds. "Professor Stillman's ground-breaking work on individual-based models has produced a valuable tool that provides… the evidence we need to inform conservation action and policy in a rapidly changing world." [E8]

- The British Trust for Ornithology now routinely includes MORPH - or related IBM approaches - as one of its methods in conservation projects. They confirm that IBMs "provide a succinct method of analysing past and future scenarios within ecology from

the level of the individual", which is "vital in understanding the responses of populations to environmental pressures" [E9]. They attest that this approach complements their existing analytical methods, stating that – in collaboration with Stillman and others – they have used IBMs in projects on the Burry Inlet, Wales and the Humber estuary. They also confirmed that BU's work in developing IBMs "has enabled their wider application in applied ecological work, including our own work in ornithology" [E9].

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

E1:
1a. Bird Aware Solent. (2017). *Solent Recreation Mitigation Strategy*. [online] Available at: https://solent.birdaware.org/media/29372/Bird-Aware-Solent-Strategy/pdf/Solent_Recreation_Mitigation_Strategy.pdf [Accessed 2 February 2021] pp. 4, 16.
1b. Bird Aware Solent. (2020). *Bird Aware Solent - Developer contributions*. [online] Available at: https://solent.birdaware.org/article/28101/Developer-contributions [Accessed 2 February 2021].
1c. Bird Aware Solent. (2020). *Bird Aware Solent - Annual reports*. [online] Available at: https://solent.birdaware.org/article/28133/Annual-reports [Accessed 2 February 2021].
1d. Bird Aware Solent. (2021). *Bird Aware Solent - Our Strategy*. [online] Available at: https://solent.birdaware.org/strategy [Accessed 2 February 2021].

E2 Natural England. (2021). Email, 13 January.

E3: Humboldt Bay Harbor, Recreation and Conservation District, (2016). *Final Environmental Impact Report*. Humboldt Bay Harbor, Recreation and Conservation District, p.24.

E4: Programma Naar Een Rijke Waddenzee (2021). *Cockle Fisheries and Food Availability Oystercatchers*. [online] Available at: https://rijkewaddenzee.nl/nieuws/kokkelvissen-en-voedselbeschikbaarheid-scholeksters/ [Accessed 2 February 2021].

E5: Marine Ecology Consultant, Programme Towards a Rich Wadden Sea. (2021). Email, 11 January.

E6:
6a. Marine Stewardship Council. (2014). *MSC Variation Request*. Marine Stewardship Council.
6b. Seip-Markenstejn, C. (2018). *Dee Estuary Cockle Fishery*. Marine Stewardship Council.
6c. Tindall, C. and Gascoigne, D. (2015). *Exmouth Mussel Fishery*. ME Certification Ltd.
6d. Seip-Markenstejn, C. (2019). *Burry Inlet Cockle Fishery*. Control Union Pesca Ltd.

E7: HC Deb (19 July 2016). vol. 613, col. 803-805. Available at: https://hansard.parliament.uk/Commons/2016-07-19/debates/16071951000002/CocklingDeeEstuary [Accessed 2 February 2021].

E8: Wildfowl & Wetlands Trust. (2020). Letter, 29 November.

E9: British Trust for Ornithology. (2020). Letter, 27 November.