Section A

Institution: University of St Andrews

Unit of Assessment: UoA 05: Biological Sciences

Title of case study: Seal population dynamics research underpins the fulfilment of statutory obligations and the sustainable management of these indicators of marine environmental health

Period when the underpinning research was undertaken: 2000 - 31 December 2020

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

Name(s):	Role(s) (e.g. job title):	Period(s) employed by HEI:
Debbie JF Russell	Senior Research Fellow	01 December 2008 – present
Dave Thompson	Senior Research Scientist	01 September 2000 – present
Chris Morris	Aerial Survey Technician	30 July 2009 – present
Mike Lonergan	Senior Research Fellow	14 January 2001 – 28 February 2014
John Harwood	Professor	01 February 1996 – present
Paddy Pomeroy	Senior Research Scientist	01 September 1998 – present
Sophie Smout	Lecturer	18 August 2003 – present

Period when the claimed impact occurred: 1 August 2013 – December 2020

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

Section B

1. Summary of the impact

The UK hosts approximately 40% of the world's grey seals and 30% of the eastern Atlantic subspecies of harbour seal. These species are used by the UK and European governments as indicators of marine environmental health. Their management requires balancing their conservation and welfare with the sustainable use of marine environments, including the realisation of blue economy goals and minimisation of fishery-seal conflict. Seal population dynamics research conducted by the Sea Mammal Research Unit (SMRU) at the University of St Andrews comprises an integrated programme of bespoke surveys (Figure 1), mathematical and statistical model development and fieldwork to provide contemporary information on seal demographic rates, abundance and population trajectories. This output has been essential for the UK Government and other European nations to comply with the statutory reporting and assessment requirements of national and international legislation. The research has enabled the effective sustainable management of the marine environment including (1) the setting of safe limits on numbers of seals that can be shot to protect fish welfare and economic return at fish farms, and (2) enhanced seal welfare and conservation by facilitating selection of

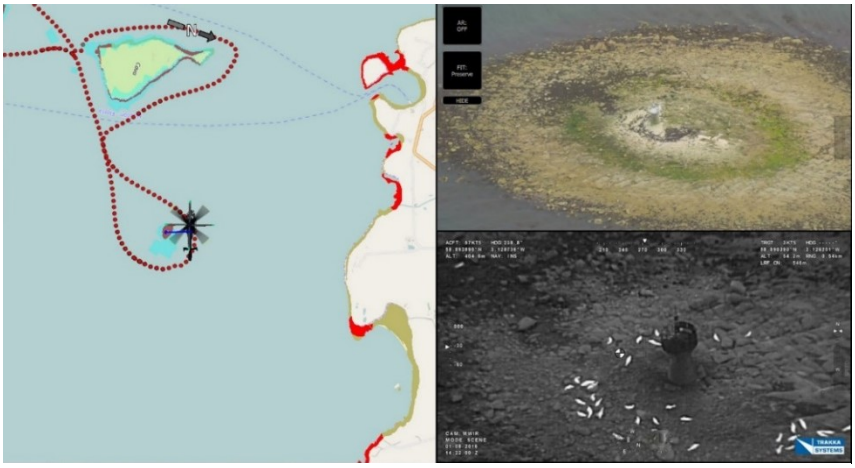

Figure 1. Map (showing helicopter track and location) and associated digital and infrared images from a SMRU harbour seal aerial survey.

key haulout sites (where seals rest between trips to sea), which are designated for legal protection from harassment.

2. Underpinning research

SMRU's seal population dynamics research comprises an integrated programme of bespoke aerial surveys, mathematical and statistical model development, and breeding-colony based research. This research on harbour and grey seals has allowed SMRU to provide contemporary estimates of UK seal demographic rates, abundance and population trajectories with robust measures of associated uncertainty, which are essential for effective management.

Harbour seals [R1]
SMRU research data provides a multi-decadal time series of harbour seal abundance covering >95% of UK haulout sites**.** Since 2016, aerial surveys were conducted using a multi-sensor (infra-red, high resolution DSLR, video) gimbal-led imaging system and associated software; this novel survey system was customised and optimised for seal surveys based on SMRU guidance [figure 1; R1]. In the early 2010s, an innovative statistical model was developed, using animal-borne telemetry tag data to estimate the proportion of the population hauled out and thus available to count during the surveys [R1], enabling counts to be converted into total population size (with associated uncertainty limits). SMRU modelled the series of population abundance to estimate trends, revealing dramatic declines in some regions (up to 10.4% per annum) [2018; R1].

Grey seals
SMRU surveys the majority of UK grey seal breeding colonies (which account for approximately 80% of UK pup production) biennially to generate a time series of pup production estimates. Since 2012, these aerial surveys have been conducted using high resolution digital still cameras in SMRU's bespoke motion compensation mount. Once born, pups only remain on breeding colonies for a short period compared to the long breeding season. Critically, this means that the number of pups born cannot be calculated from a single survey; multiple surveys are therefore conducted over a season at each colony. SMRU developed a model that combines life-history information (e.g., the age at which pups leave the colony) with these repeated counts to generate a birth curve, allowing estimation of pup production (and associated confidence limits) [R2]. These pup production estimates were analysed to examine trends in pup production both on regional and colony levels, revealing large variation in colony trends which do not match the regional trajectories [2019; R2]. In addition, an analytical framework was developed to integrate disparate data to generate two population estimates (2008 and 2014) that are independent from the pup counts; along with data from grey seal haul out surveys, data from animal-borne telemetry devices developed by SMRU's Instrumentation Group [2011, R3], and tidal data were used to estimate the proportion of the population available to count during the surveys.

To estimate a time series of population size (with confidence limits) and trajectories, an age-structured Bayesian population dynamics model was developed (through a collaboration between SMRU and the USTAN Centre for Research into Ecological and Environmental Modelling) [R4]. A modified version of this novel method of population estimation was subsequently used to estimate seal populations in North America. The input data for the UK model is the time series of pup production estimates [R2] and the two independent estimates of population size [R3] described above. The model also relies on prior information on grey seal demographic parameters (e.g., survival, birth rates) from SMRU colony-based studies [e.g., R5]. The model output, which includes posterior estimates of the demographic parameters, revealed the majority of regions have reached carrying capacity with evidence for delayed density dependence mediated through pup survival [R4]. On a European scale, it has been difficult to compare grey seal population sizes and trends because estimation methods differ between countries. SMRU developed a comparable index of pup production and adapted the Bayesian population model to include the majority of grey seal survey data collected across Europe [R6]. This allowed generation of comparable population estimates and trends at multiple spatial scales within and across countries.

3. References to the research (USTAN School of Biology staff are highlighted in **bold)**

All of these research outputs are published in highly regarded peer-reviewed journals or have undergone a process of rigorous review by an international committee of recognised experts in population research, the Special Committee on Seals (SCOS). The outputs listed are representative of a much larger body of work spanning from 2000 to present.

[R1] **Thompson** D, Duck C, **Morris** C, **Russell** DJF (2019) The status of harbour seals in the United Kingdom. *Journal of Aquatic Conservation: Marine and Freshwater Ecosystems* 29(S1):40–60. DOI: 10.1002/aqc.3110

[R2] **Russell** DJF, **Morris** CD, Duck CD, **Thompson** D, Hiby L (2019) Monitoring long-term changes in UK grey seal *Halichoerus grypus* pup production. *Journal of Aquatic Conservation: Marine and Freshwater Ecosystems* 29(S1), 24–39. DOI: 10.1002/aqc.3100

[R3] **Lonergan** ME, Duck CD, **Thompson** D, Moss S. McConnell BJ (2011) British grey seal (*Halichoerus grypus*) abundance in 2008: an assessment based on aerial counts and satellite telemetry. *ICES Journal of Marine Science*, 68, 2201–2209. DOI: 10.1093/icesjms/fsr161

[R4] Thomas L, **Russell** DJF, Duck CD, **Morris** CD, **Lonergan** M, Empacher F, **Thompson** D, **Harwood** J (2019) Estimating the size of the UK grey seal population between 1984 and 2010. *Journal of Aquatic Conservation: Marine and Freshwater Ecosystems*. 29(S1), 6–23. DOI: 10.1002/aqc.3134

[R5] **Smout** S, King R, **Pomeroy** P (2011) Integrating heterogeneity of detection and mark loss to estimate survival and transience in UK grey seal colonies. *Journal of Applied Ecology,* 48(2), 364-372. DOI: 10.1111/j.1365-2664.2010.01913.x

[R6] **Russell** DJF, Hanson N, Thomas L (2016) Marine Strategy Framework Directive: Estimating the European Grey Seal population. Special Committee on Seals Briefing Paper 16/09. http://www.smru.st-andrews.ac.uk/files/2017/04/SCOS-2016.pdf

4. Details of the impact

Outputs from SMRU's seal population dynamics research were used to fulfil the requirements of national legislation and international conservation agreements and underpinned the development of sustainable management strategies. The importance of SMRU's rigorous underlying research for these impacts is illustrated by our supporting letters from the Deputy Director, International Marine, of Defra [S1], the Head of Marine Ecosystems of NatureScot (statutory advisor to the Scottish Government; formerly Scottish Natural Heritage) [S2] and the Director of Marine Scotland (Scottish Government) [S3]. Defra stated SMRU's research has "*made a considerable and highly regarded contribution to Defra's ability to inform on the management of these iconic species within the UK and to its European partners.*" [S1]. NatureScot stated "*SMRU's cutting edge research has been central to the marine conservation status assessments and future plans for Scotland's seas*". [S2]

Fulfilling UK and international policy requirements

On a national level, SMRU [e.g., R1-R3, R5] and joint SMRU/CREEM [R4] research on seal population dynamics underpins advice on seal populations and management provided to UK and devolved governments via the NERC Special Committee on Seals (SCOS; an independent committee of external experts in the field), fulfilling NERC's obligations under the UK Conservation of Seals Act (1970) [S1] and the Marine (Scotland) Act (2010) [S2, S3]. This advice was generated annually between 2013 and 2020. NatureScot states that SMRU's research "*sustains and enhances efforts to meet the conservation objectives for one of Scotland's most valued natural assets. Without the research we would not be able to demonstrate objectives have been met or that future plans are being formulated within the appropriate context.*" [S2]

At a European level, SMRU [e.g., R1-R3, R5] and joint SMRU/CREEM [R4, R6] research enabled the UK to fulfil its legislative obligations for the EU Habitats Directive, Marine Strategy

Framework Directive (MSFD), and the OSPAR Convention [S1, S2, S3]. NatureScot stated that the UK submission (2019) for the EU Habitat Directive "*relied on the population abundance and trend information provided by SMRU, without which the UK would have been in breach of European law*" [S2]. The statuses of European seal populations were assessed as biodiversity indicators under both the MSFD and OSPAR Convention in 2017. SMRU research enabled the fulfilment of the associated UK obligations as evidenced by NatureScot [S2]: "*The data and interpretation have also been central to reporting on the UK's progress towards Good Environmental Status under the UK Marine Strategy (previously referred to as the Marine Strategy Framework Directive) as both seal species are top predator biodiversity indicators.*" In addition, SMRU research enabled assessments to be conducted on a European level. Indeed Defra recognised the importance of the grey seal population dynamic model developed with CREEM [R1, R5, R6]: "*SMRU's involvement and support for the OSPAR Intermediate Assessment in 2017 was also well received as they were able to synthesise the data for seals across all the European partners (the UK being the lead for this indicator) through their unique population dynamics model*" [S1].

Conservation and management of seal populations

SMRU research outputs provide UK and devolved governments with information on grey and harbour seal populations that is essential for effective conservation and management decisions. This is evidenced by NatureScot [S2] who stated: "*It is difficult to over emphasise the importance of SMRU's work to SNH and Scottish Government in ensuring that adequate protection and conservation objectives are met based on the best available scientific advice.*"

A key example of specific management measures implemented as a direct result of SMRU research is seal licences. Seal predation on salmon has a significant monetary impact on river anglers and fish farms and is a welfare issue for farmed fish. For example, a ten-year study on two thirds of Scottish salmon farms found that reported seal predations equated to annual losses of GBP2,500,000 (https://www.gov.scot/publications/evaluating-assessing-relative-effectiveness-acoustic-deterrent-devices-non-lethal-measures/pages/3/). The EU Habitats Directive dictates that management practices must not jeopardise the 'favourable conservation status' of seals. The UK's Conservation of Seals Act (1970) allowed unregulated shooting outside the breeding season, with potentially significant, unintentional impacts on regional populations, e.g., a major decline due to unregulated shooting in the Moray Firth. To facilitate population management that both protects fisheries and maintains conservation objectives, the Marine (Scotland) Act 2010 banned the shooting of seals in Scotland without a licence. Based on the latest population research by SMRU [R1, R3], annual safe upper limits on the number of seals that could be removed from a population without risk of causing a long-term population decline were calculated. Annually, between August 2013 and December 2020, this allowed Marine Scotland's Seal Licensing Division to set rigorously defined limits on the number of licenced removals of seals, and for the impact of seal predation on fish welfare and economic return to be minimised in an environmentally sustainable manner [S4]. Indeed in 2019, Marine Scotland [S3] stated: "*The information it* [SMRU] *provides in support of the Scottish seal management licensing system… has been critical. It is required for making decisions on seal licences."* NatureScot [S2] stated that information on seal populations provided by SMRU "*has been critical in ensuring the safeguarding of the populations by helping determine that the number of licences issued to shoot seals under the Marine (Scotland) Act, in a given year, are within the limits that will maintain the conservation status of the different species*." SMRU's research meant that regulators could rapidly respond to ensure appropriate levels of protection to vulnerable populations. For example, in 2018 although licences were applied for, none were granted for regions (north and east coasts of Scotland) that SMRU's research had shown to be in dramatic decline, but over 100 licences were granted for areas of population stability or growth [S5].

Seal welfare

The Protection of Seals (Designated Sea Haul-out Sites) (Scotland) Order 2014 resulted in the protection of 194 key seal breeding and resting sites at which intentional harassment can result

in fines of up to GBP5,000 and 6 months in prison. These sites were identified on the basis of SMRU's seal research [S6]. NatureScot [S3] said: "*This research has been critical to the improvement of the conservation of seals around Scotland, particularly in assisting with the designation of seal haulout sites around Scotland*." The designations have resulted in a decrease in disturbance associated with activities, such as certain tree felling and extraction on the shoreline, and seaweed harvesting, which have been conducted once appropriate mitigation measures were in place (e.g. https://tinyurl.com/yxwwgwmu). Disturbance is an animal welfare issue; it causes distress and can have energetic consequences especially during the annual moult and in the breeding season when it can directly cause pup mortality. Since the Order has been in place, one accessible mainland site has seen its first ever pups born there.

5. Sources to corroborate the impact

[S1] Letter from Defra (Deputy Director, International Marine)

[S2] Letter from NatureScot – formerly Scottish Natural Heritage (Head of Marine Ecosystems)

[S3] Letter from Marine Scotland (director)

[S4] https://www.gov.scot/publications/seal-licensing-frequently-asked-questions/ , pp. 6 and 7

[S5] https://www.gov.scot/publications/marine-licensing-seal-licensing-records-2011-present/pages/2018/, p. 5

[S6] https://www.gov.scot/binaries/content/documents/govscot/publications/factsheet/2019/11/marine-scotland-topic-sheets-marine-mammals/documents/seal-haul-out-sites-updated-june-2017/seal-haul-out-sites-updated-june-2017/govscot%3Adocument/seal-haul-out.pdf