Institution: University of St Andrews

Unit of Assessment: 5 – Biological Sciences

Title of case study: Mitigating environmental impacts of naval Sonar

1. Summary of the impact

Research by St Andrews scientists studying the effects of naval Sonar on marine mammals has had the following international impacts:

- **on the environment** by developing new ways to manage environmental risks of anthropogenic sound on marine mammals,
- **on public policy and defence** as research evidence changed US and European policy and criteria on impacts of Sonar on marine mammals, allowing US and European Navies to continue sonar training with reduced risk to whales,
- **on commerce** as a new product with a current sales value of £3.5 million has been commercialised to help navies to predict and manage risk to marine mammals.

2. Underpinning research

Marine mammals are difficult to study as they spend most of their lives underwater, often travel large distances in 3 dimensions and frequently have low population densities. St Andrews researchers at the Sea Mammal Research Unit (SMRU) including Professors **Ian Boyd**, **Phil Hammond**, **John Harwood** & **Peter Tyack** and Dr **Patrick Miller** have developed methods to overcome these difficulties, allowing research to evaluate the impact of threats such as anthropogenic sound on wildlife populations. They developed a theoretical approach to environmental risk assessment that involves identifying hazards, probability of exposure to the hazard, estimating the effects produced by different levels of exposure, and evaluating the benefits of different strategies to manage the risk **[1]**. The ability to estimate exposure to the hazard was enabled by the improvement at St Andrews of survey methods, generally involving visual identification, to estimate marine mammal population density and distribution **[2]**. A second crucial development in 2009 was the application of passive acoustic monitoring (PAM) to estimate the distribution and abundance of marine mammals **[3]**. This overcame the limitations of previous methods of visual identification for species that spend most of their lives underwater.

In 2004, St Andrews scientists articulated a new methodology designed to allow measurement of the effects of different levels of sound exposure on a marine mammal for the first time **[4]**, providing critical data to establish acoustic dose: behavioural response functions in the field. Using these methods, SMRU led major field experiments in 2007-08 to quantify effects of naval sonar on beaked whales. The major documented lethal effect of underwater sound on marine mammals has involved mass strandings of beaked whales during naval sonar exercises **[5]**. Therefore beaked whales formed a critical subject species for these experiments. Their cryptic deep-diving lifestyle necessitated the use of tags to record sound exposure and behavioural responses of individual animals throughout their dive cycle. Free-ranging beaked whales were exposed to simulated sonar sounds of US Navy anti-submarine sonars and the behaviour of the animals was measured against a carefully titrated dose of sound. Responses of beaked whales to simulated sonar were observed at exposure levels of about 140 dB re 1 µPa **[5]**.

These research methods have been extended to study the behavioural responses of other marine mammal species. **Miller** and **Tyack** are co-PIs of an experiment called 3S to determine the dose-response of several whale species in Norwegian waters to sonars deployed by the Dutch and Norwegian navies. This project used advanced physiological models to analyse dive responses of tagged whales of several species during controlled exposure experiments, allowing for the first time estimates of the risk of decompression sickness for whales exposed to sonar **[6]**.

3. References to the research

St Andrews contributors in BOLD. Employment dates in St Andrews: Professor Boyd 2001-present; Professor Hammond 1996-present; Professor Harwood 1996-present; Dr Marques 2007-present; Dr Thomas 1997-present; Dr Miller 2002-present; Dr Thompson 1996-present; Professor Tyack 2011-present

SMRU in St Andrews has published 546 papers in this area in the period 1996-2013, with over 10,000 citations (Scopus), of which the following are a representative cross-section with application to this impact. These are all published in international, peer-reviewed journals.

[1] Harwood, J. (2000) Risk assessment and decision analysis in conservation. *Biological Conservation* 95: 219-226 DOI: 10.1016/S0006-3207(00)00036-7. (46 citations).
[2] Hammond, PS, Berggren, P, Benke, H, Borchers, DL, Collet, A, Heide-Jørgensen, MP, Heimlich, S, Hiby, AR, Leopold, MF & Øien, N (2002). Abundance of harbour porpoises and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology* 39: 361-376. DOI: 10.1046/j.1365-2664.2002.00713.x (130 citations).
[3] Marques TA, Thomas L, Ward J, DiMarzio N, Tyack PL. (2009) Estimating cetacean population density using fixed passive acoustic sensors: An example with Blainville's beaked whales. *Journal of the Acoustical Society of America* 125:1982-1994. DOI: 10.1121/1.3089590 (48 citations).
[4] Tyack P**,** Gordon J, **Thompson D.** (2004) Controlled exposure experiments to determine the effects of noise on large marine mammals. *Marine Technology Society Journal* 37(4):41-53 DOI: 10.4031/002533203787537087 (10 citations).
[5] Tyack PL Zimmer WMX, Moretti D, Southall BL, Claridge DE, Durban JW, Clark CW, D'Amico A, DiMarzio N, Jarvis S, McCarthy E, Morrissey R, Ward J, **Boyd IL** (2011) Beaked Whales Respond to Simulated and Actual Navy Sonar. *PLOS ONE* 6: e17009 DOI: 10.1371/journal.pone.0017009 (30 citations).
[6] Kvadsheim PH, **Miller PJO, Tyack PL**, Sivle LD, Lam FPA, Fahlman A. (2012) Estimated tissue and blood N_2 levels and risk of in vivo bubble formation in deep-, intermediate- and shallow diving toothed whales during exposure to naval sonar. *Frontiers in Aquatic Physiology* 3(125):1-14. DOI: 10.3389/fphys.2012.00125 (3 citations).

4. Details of the impact

Impacts derived from the underpinning research include the removal of obstacles to naval training in anti-submarine warfare whilst reducing risk to whales and supporting development of a commercial product to manage risk of sounds from naval activities.

Enabling US Navy Sonar Operations whilst protecting marine mammals.
Evidence that Sonar can lead to lethal strandings of whales led to legislative and judicial restrictions on military sonar use. From 2001-2008, courts in the US repeatedly judged that the US Navy had not conducted adequate environmental reviews. The courts issued injunctions limiting the use of Sonar, which interfered with the navy's ability to train for anti-submarine warfare and to maintain readiness against submarine attacks **[S4]**.
In 2008 a court case involving naval Sonar training in Southern California waters was heard by the US Supreme Court **[S5]**. After these legal actions, the Navy committed to prepare Environmental Impact Statements (EIS) for Sonar use. The St Andrews research on the distribution of beaked whales and effects of exposure to anthropogenic noise made it possible to estimate the inherent risks. As the Deputy Assistant Secretary of the Navy (DASN) stated in 2013,

> "(St Andrews) *research assessing exposure and effects of sonar for beaked and other whales has provided the scientific bases for Environmental Impact Statements (EIS) for US Navy training and testing activities*" **[S1]**

These Environmental Impact Statements were approved by the regulator in the years following 2008, allowing the US Navy to operate naval sonars. Quoting DASN:

> "*The results of the research conducted by the St Andrews faculty and staff have played a vital role in the deliberations of the US Navy and the Navy's regulator, the National Marine Fisheries Service, to establish new behavioural risk criteria for anthropogenic sound exposure risk to beaked whales and other marine mammals*" **[S1]**

Beaked Whales Mass Stranded in the Canary Islands during a Naval Sonar Exercise in 2002 [credit: Vidal Martin]

Subsequent to the demonstration that beaked whales show strong responses to Sonar at levels of 140 dB re 1 µPa (reference 5 above), the US Navy modified its response criterion for beaked whales to this lower level to reduce the risks of exposure to harmful sound **[S6]**. In the period 2008-12 there have been no documented cases of mass strandings linked to US Navy Sonar **[S7]**.

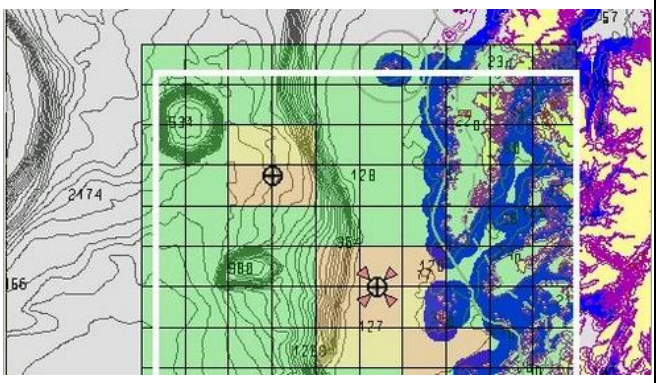
Mitigating the environmental harm caused by EU Navy Sonar

The St Andrews research has also had a direct impact on the operational practices of several European Navies. Uncertainty as to what exposures are risky, and lack of adequate monitoring and mitigation methods led the European Parliament to pass a resolution in 2004 calling for a moratorium on the use of intense naval sonar until this problem was resolved **(EU resolution 86-0089/2004).** The European Union Marine Strategy Framework Directive (MSFD), adopted in 2008, requires each member state to achieve good environmental status of their marine habitats, including the requirement that "*introduction of energy (including underwater noise) does not adversely affect the ecosystem*." **[S8]**. The Head of Marine Advice for the UK Joint Nature *Conservation* Committee states that:

> *"Particularly important St Andrews studies include those involving Patrick Miller, Ian Boyd and Peter Tyack demonstrated the reaction of whales to these underwater sounds … may lead to lethal physiological effects. This understanding has been crucial in the setting of policies by a number of Navies that will reduce the risk of further deaths. The research has also been important in gaining perspectives that have avoided over-regulation."* **[S2]**

SAFESIMM

A Navy cannot be effective without the use of Sonar. Since the operation of Sonar is an unavoidable activity, UK regulations require monitoring of marine mammals within a danger zone by Naval vessels. St Andrews research on marine mammal distribution allows predictions about animal densities in different areas around the globe to be made. This underpinning St Andrews science has led to the development of an established product: Statistical Algorithms for Estimating the Sonar Influence on Marine Megafauna (SAFESIMM) **[S9]**. SAFESIMM models marine mammal distribution and abundance, dive and movement behaviour, and sensitivity to sound and has been licensed to BAE Systems, which uses it as part of its Marine Environmental Risk Management Capability. SAFESIMM forms part of the 2117 sonar used by the Royal Navy for planning sonar exercises and used by commanders to judge the level of risk associated with planned



Safesimm screen capture from BAE systems website.

Sonar operations. If the risk is too high the tool presents a series of mitigation activities that can be used to reduce the level of risk and meet the requirements of UK and EU legislation. The Commercial Manager of Combat Systems for BAE Systems Maritime estimates the value of SAFESIMM on BAE sales to be "*of the order of £3.5 million based on the current contract value*". **[S3]**

In the words of the Head of Marine Advice for the UK Joint Nature Conservation Committee:

> *"St Andrews researchers have developed techniques for establishing the presence of marine mammals in an area using passive monitoring for underwater sounds made by the mammals. These techniques are now part of standard mitigation (…) during naval exercises in UK and some other EU waters."* **[S2]**

5. Sources to corroborate the impact

[S1] Letter from the Deputy Assistant Secretary of the US Navy (Environment). Corroborates impact of St Andrews research on Navy's ability to use Sonar.

[S2] Letter from Head of Marine Advice for the Joint Nature Conservation Committee. Corroborates impact of St Andrews research on standard mitigation during naval exercises internationally.

[S3] Email from the Commercial Manager, combat systems, BAE Systems Maritime – Naval Ships. Corroborates value of SAFESIMM contracts.

[S4] US Court injunction against the use of Sonar due to threats to marine mammals. http://cdn.ca9.uscourts.gov/datastore/opinions/2008/02/29/0855054o.pdf

[S5] US court case on naval Sonar in Californian waters. Winter v. Natural Resources Defense Council, 555 U.S. (2008). http://supreme.justia.com/cases/federal/us/555/07-1239

[S6] (2012) Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis. US NAVY SSC Pacific Technical Report. Corroborates change in Navy policy in response to known risk to marine mammal. http://www.dtic.mil/dtic/tr/fulltext/u2/a561707.pdf

[S7] Marine Mammal Strandings Associated with U.S. Navy Sonar Activities (2012). Corroborates no known strandings linked to naval Sonar in 2008-12. www.agriculturedefensecoalition.org/sites/default/files/file/us_navy/217_1_2012_U.S._Navy_Marine_Mammal_Strandings_Associated_With_U.S._Navy_Sonar_Activities_Website_April_2012_Draft_EIS_OEIS.pdf

[S8] Report from the Commission to the Council and the European Parliament. Contribution of the Marine Strategy Framework Directive (2008/56/EC) to the implementation of existing obligations, commitments and initiatives of the Member States or the EU at EU or international level in the sphere of environmental protection in marine waters. COM(2012) 662 final.

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0662:FIN:EN:PDF

[S9] SAFESIMM product described in http://www.baesystems.com/product/BAES_027473?_afrLoop=286444596923000