During both World War I and II, millions of sea mines were laid as a defensive barrier. It’s estimated that between 30 and 70% were not recovered. Add to this the unexploded torpedoes launched by submarines, surplus bombs jettisoned by both British and German planes and the poorly regulated munitions dumping practices which began during World War I and only ended a few years ago and the waters around the UK begin to resemble an explosive soup.

For decades, none of this was much of a problem. But the huge growth in offshore renewables (particularly off the east coast of Britain) in recent years means that seabed ordnance is now becoming a major headache.

It's almost impossible to say how much ordinance has been dumped in the world's oceans, but the OSPAR Commission, which works with the 15 countries (including Norway) that signed the Convention for the Protection of the Marine Environment of the North-East Atlantic, reported in 2010 that there were at least 151 known chemical weapons and munitions dumps in the North Atlantic.

The highest known concentration of munitions is in Beaufort's Dyke, a deep trench between Scotland and Northern Ireland, where an estimated 1 million tons of munitions have been dumped since the 1920s.

The regulatory and advisory challenges posed by unexploded ordnance (UXO) clearance

Dr Ewan W. J. Edwards
Renewables Science Advice Leader
Marine Scotland Science

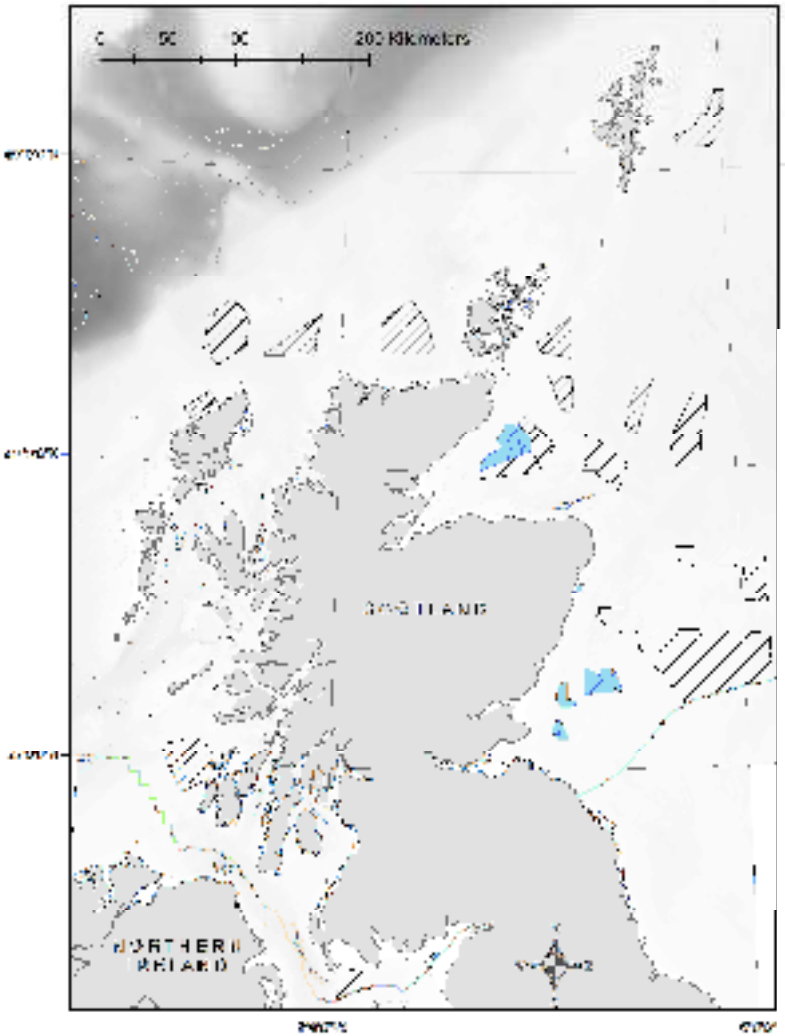
marine scotland science

Scottish Government
Riaghaltas na h-Alba
gov.scot

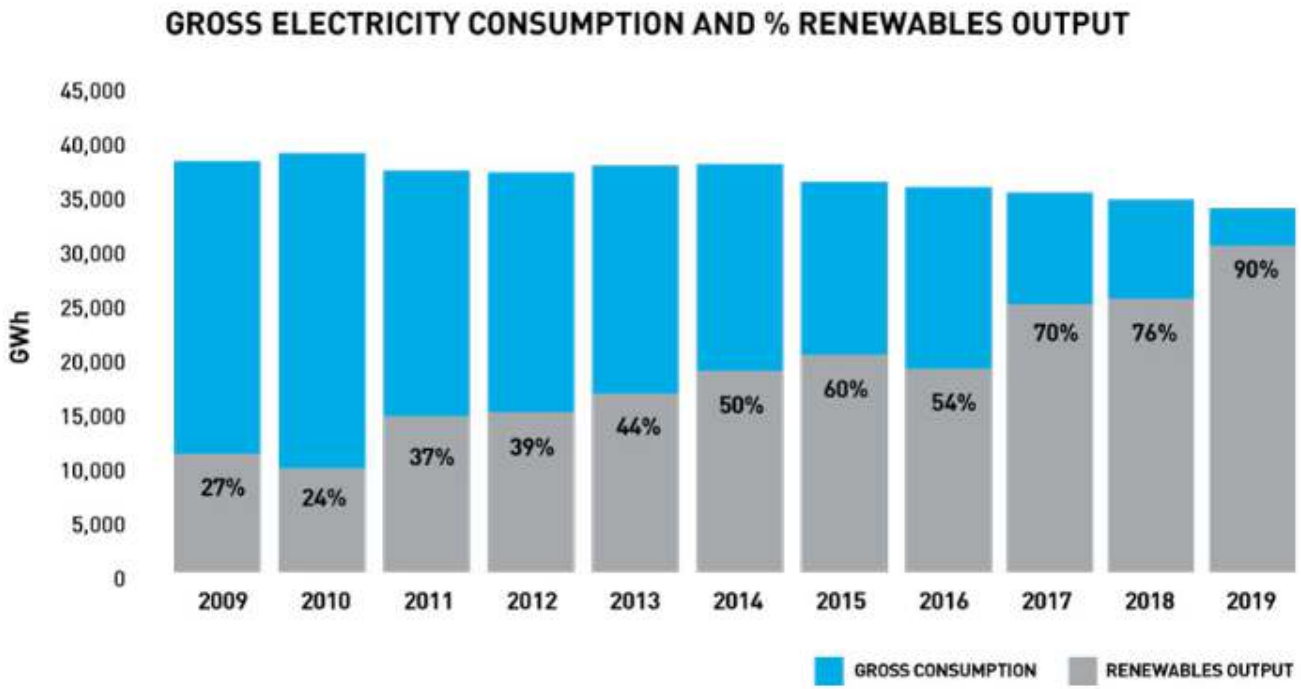
Outline of this talk

1. Introduction to the Scottish offshore wind industry
2. Where does UXO come from?
3. Recent UXO discoveries
4. Predicted noise levels
5. Potential environmental impacts
6. The Marine Noise Registry
7. Novel noise abatement methods

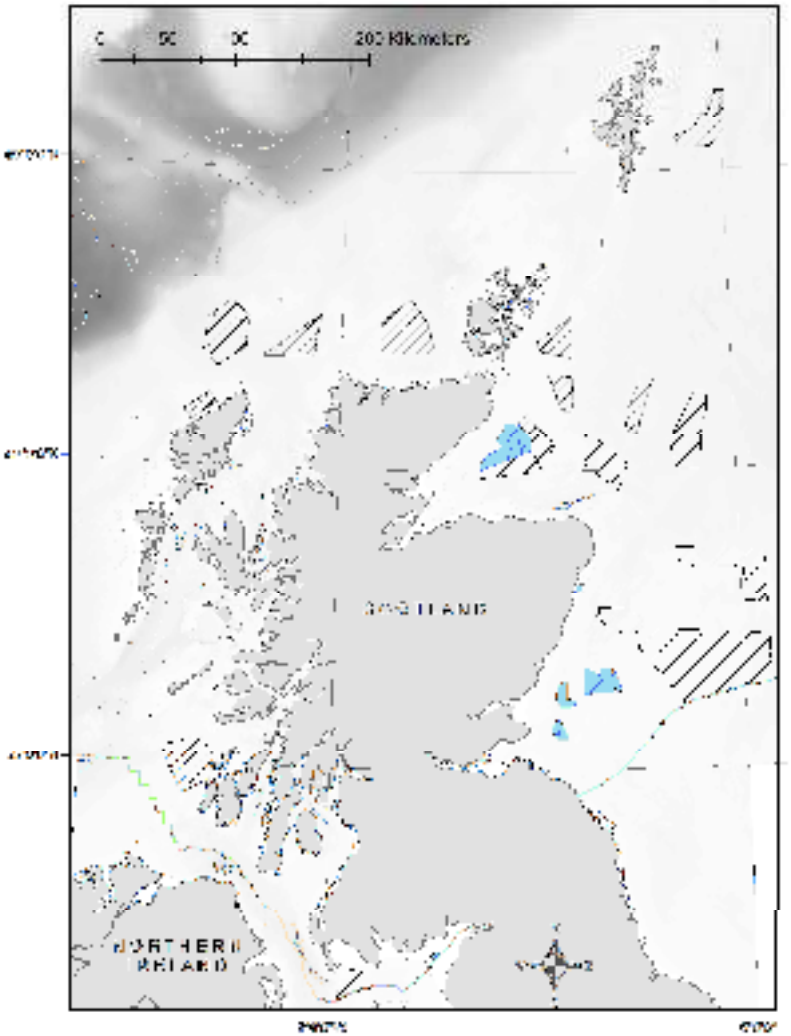
Offshore wind industry in Scotland



- 981 MW installed capacity (Q2 2020)
- 1,010 MW under construction
- 3,164 MW awaiting construction

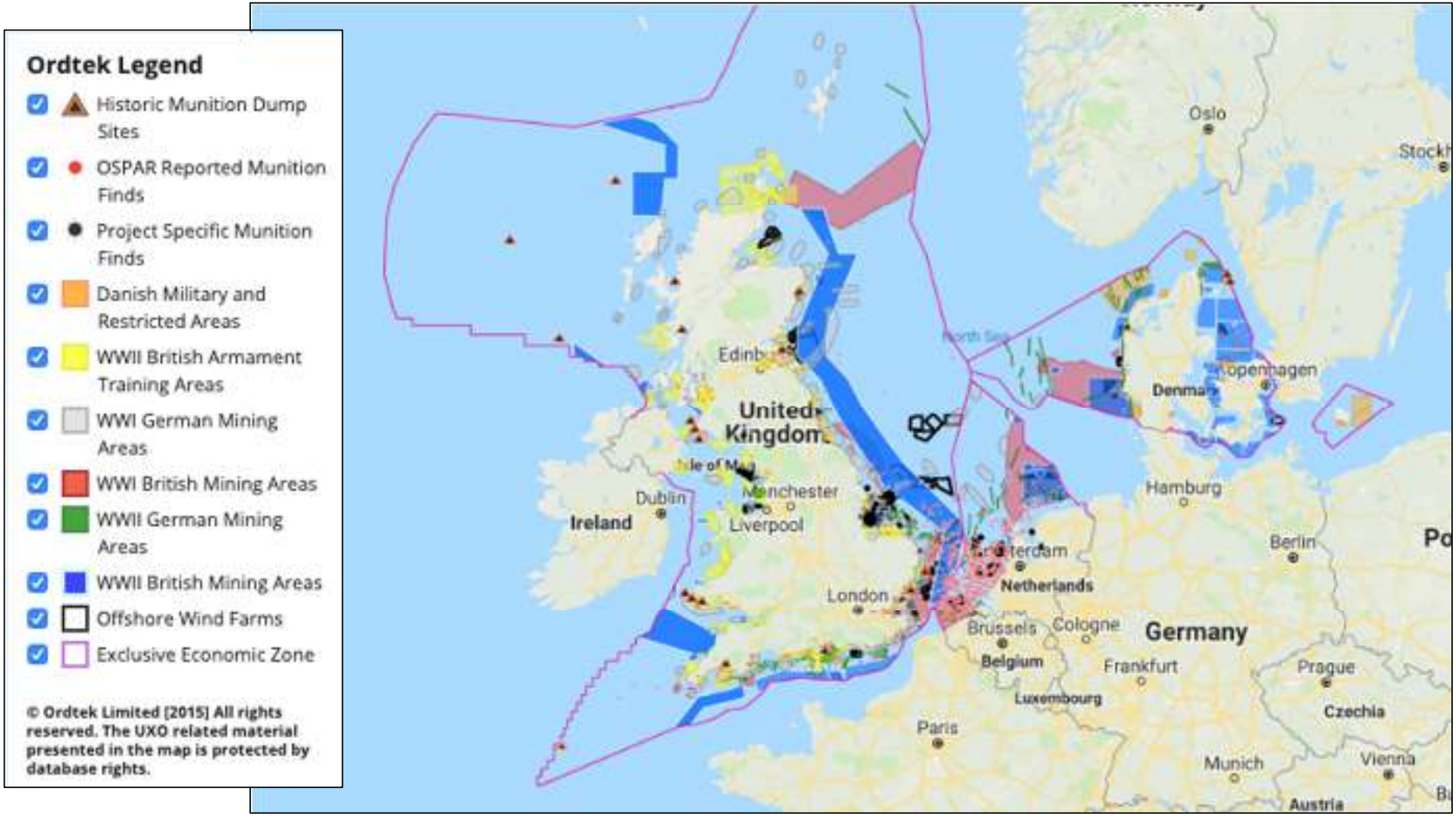


Offshore wind industry in Scotland



- 981 MW installed capacity (Q2 2020)
- 1,010 MW under construction
- 3,164 MW awaiting construction

Unexploded ordnance (UXO): where does it come from?



Source: https://www.ordtek.com/mine-map/

Support The Guardian

Available for everyone, funded by readers

Contribute → Subscribe →

News | Opinion | Sport | Culture | Life

UK ▸ UK politics Education Media Society Law Scotland Wales Northern Ireland

Boris Johnson

Bombs dumped in Irish Sea n
plan 'too dangerous'

Experts pour cold water on Boris Johnson's idea for Sco
Northern Ireland link

FLANDERSTODAY

Flanders
State of the Art

Friday 9 October 2020

Current affairs | Business | Politics | Innovation | Education | Art | Living

4
Mar '19

First World War munitions at bottom of North Sea leaking TNT

NEWSLETTERS
Sign up to read our regular email newsletters

NewScientist

News | Podcasts | Video | Technology | Space | Physics | Health | More | Shop | Tours | Events | Jobs

The WW2 bombs dumped off western Scotland washing up on beaches

HUMANS 18 November 1995 , updated 10 February 2020

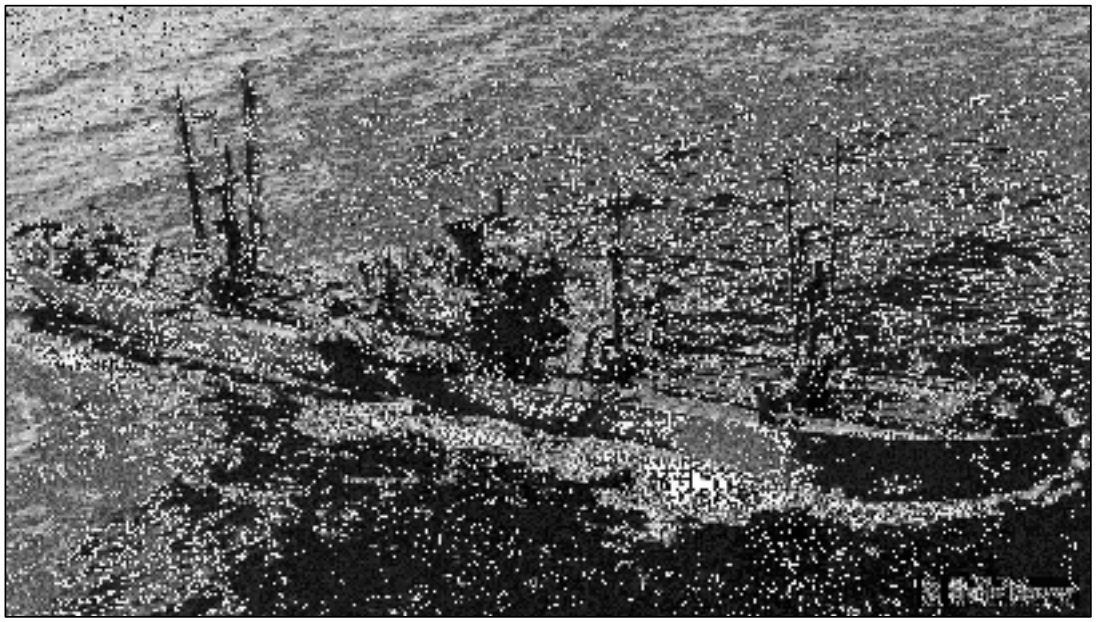
SS Richard Montgomery

WWII ammunition ship
Wrecked August 1944
2.4 km off Sheerness,
Isle of Sheppey, Kent, England

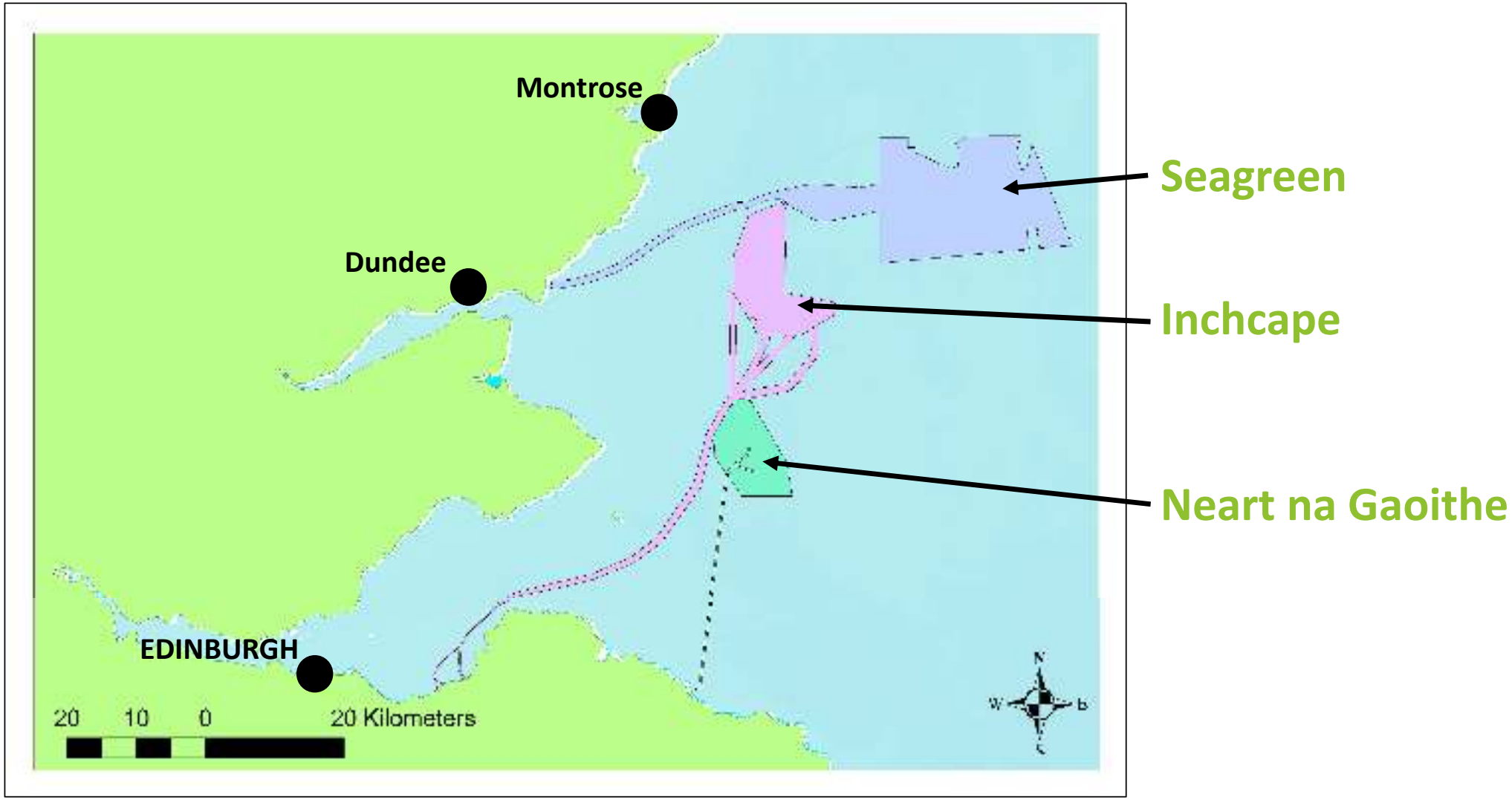
"According to a survey carried out in 2000 by the UK government's Maritime and Coastguard Agency (MCA), the ship likely contains a staggering assortment of more than 9,000 US-made explosives (1,400 tonnes).

These include 286 giant 2,000 lb 'blockbuster' bombs, 4,439 1,000 lb devices and – perhaps most worryingly of all – more than 2,500 cluster bombs."

(BBC News 28 October 2015)



Closer to home

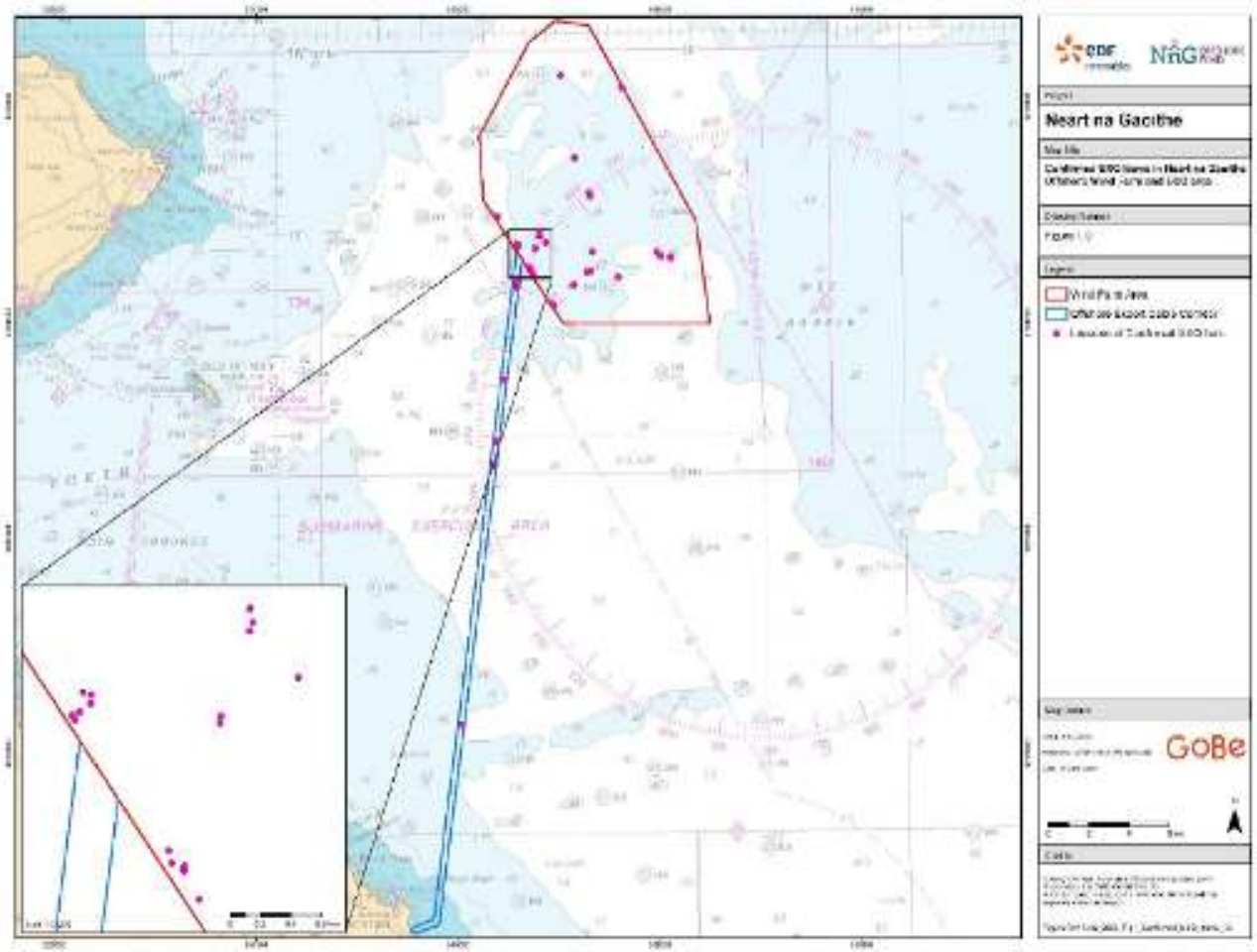


Neart na Gaoithe Offshore Wind Ltd

UXO surveys, Q1 2020

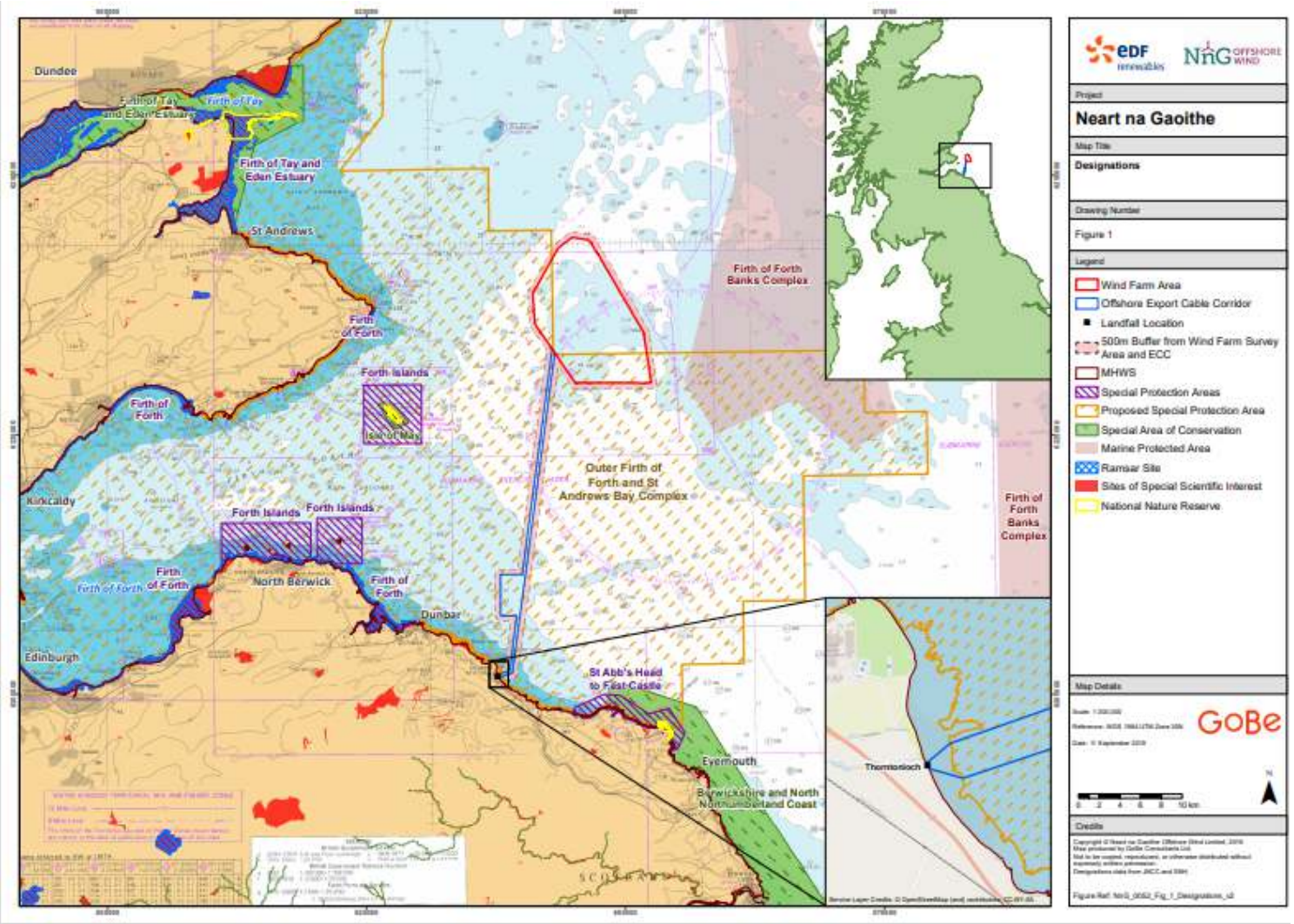
UXO clearance, Q2 2020

- Fifty-two UXO discovered
- 250 lb bombs (x 8)
- Anti-aircraft ammunition
- 15” projectiles
- Buoyant mine
- Sections of torpedo



(NNGOWL / GoBe Consultants)

Neart na Gaoithe Offshore Wind Ltd



(NNGOWL / GoBe Consultants)

Protected sites
e.g. Natura 2000,
nature conservation MPA

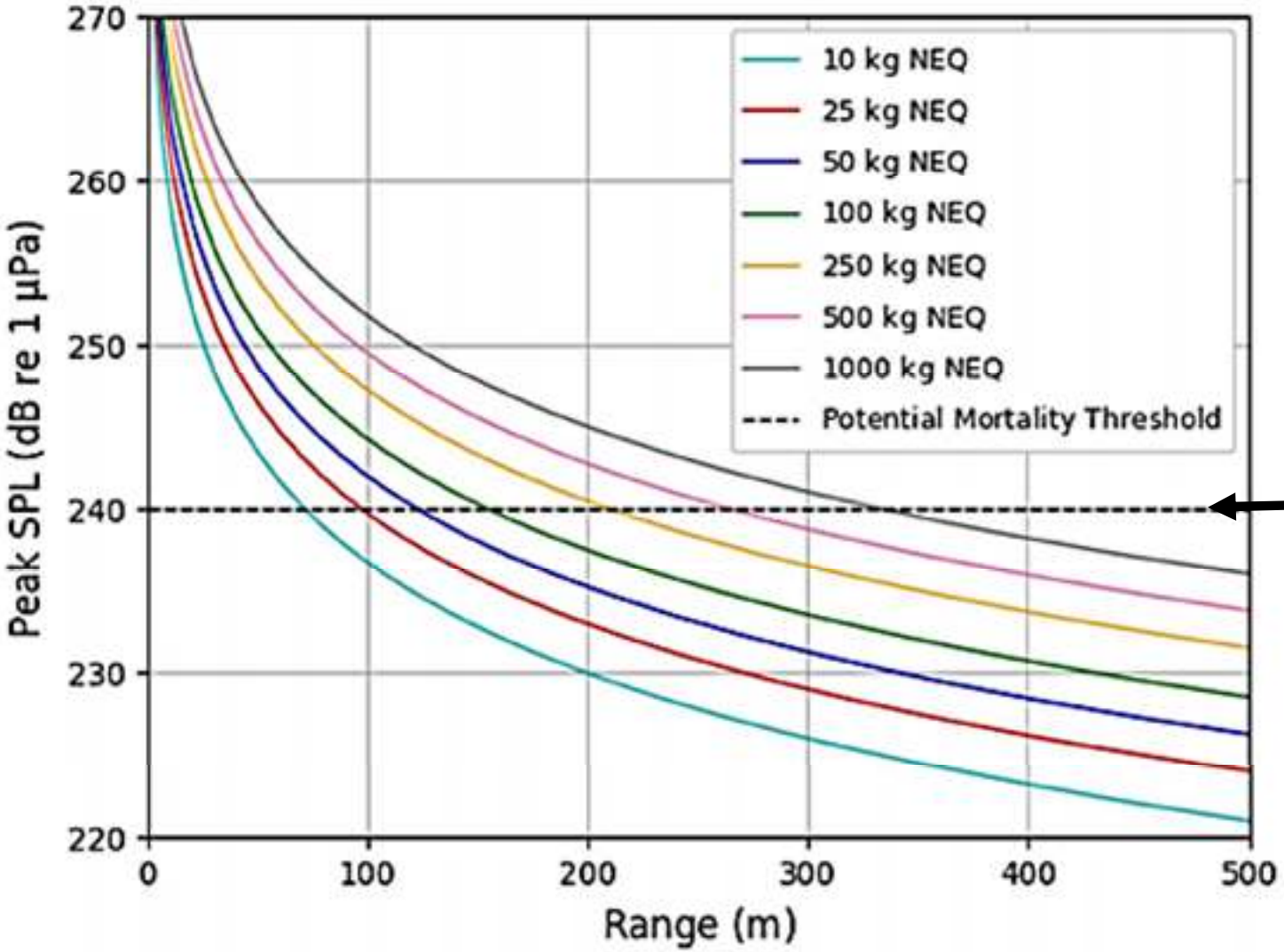
European Protected Species
i.e. all cetaceans

Priority marine features

Migratory/diadromous fish

Commercial fisheries
interests

Neart na Gaoithe Offshore Wind Ltd: UXO and marine mammals



Predicted sound pressure levels (zero-peak) from UXO detonations

Dashed line is threshold for potential mortality to marine mammals: 240 dB re 1 μPa

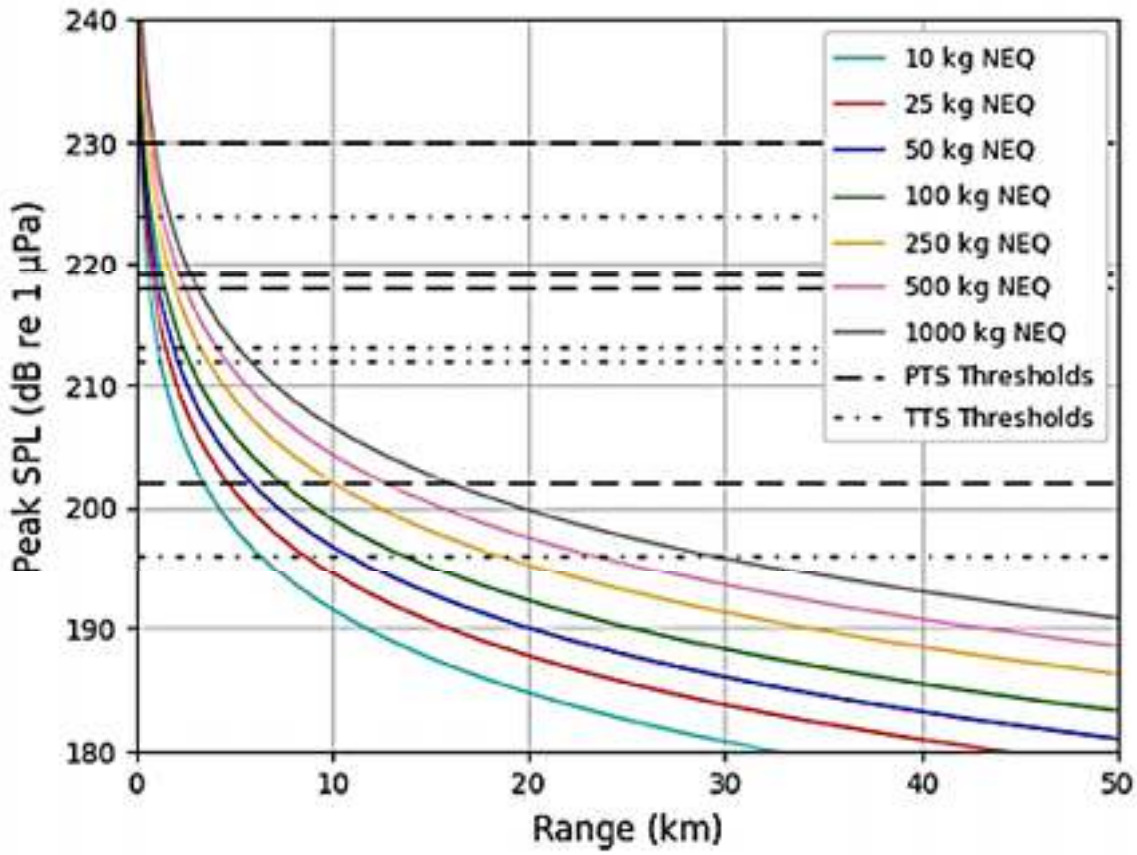
(NNGOWL / Genesis O&G Consultants)

Neart na Gaoithe Offshore Wind Ltd: UXO and marine mammals

Predicted range of impact for marine mammal species groups

Impact thresholds (NOAA, 2018)

Marine mammal hearing group	PTS threshold (dB re 1 μPa)	TTS threshold (dB re 1 μPa)
LF cetaceans (baleen whales)	219	213
MF cetaceans (delphinids)	230	224
HF cetaceans (porpoise)	202	196
Eared seals	218	170



(NNGOWL / Genesis O&G Consultants)

Neart na Gaoithe Offshore Wind Ltd: UXO and marine mammals

Predicted range of impact for marine mammal species groups

Sound Pressure Level (dB re 1 μPa)

and

frequency-weighted Sound Exposure Level (dB re 1 $\mu Pa^2 s$)

Marine mammal hearing group	Explosive weight (kg)	Distance (km) to PTS threshold **(Sound Pressure Level)**	Distance to PTS threshold **(weighted Sound Exposure Level)**
LF cetaceans (baleen whales)	10	0.6	0.9
	100	1.3	1.7
	1000	2.8	3.1
MF cetaceans (delphinds)	10	0.2	0.1
	100	0.4	0.1
	1000	0.9	0.2
HF cetaceans (porpoise)	10	3.4	1.8
	100	7.4	2.6
	1000	12.7	3.7
Eared seals	10	0.7	0.2
	100	1.4	0.4
	1000	3.1	0.7

(NNGOWL / Genesis O&G Consultants)

Neart na Gaoithe Offshore Wind Ltd: UXO and marine mammals

All cetaceans in EU waters are listed as European Protected Species (Annex IV of the Habitats Directive)

Protected throughout their range from intentional or reckless killing, injury or disturbance

Predicted impact range/radius of 12.7 km (SPL) or 3.7 km (weighted SEL) cannot be fully and effectively monitored for presence of cetaceans

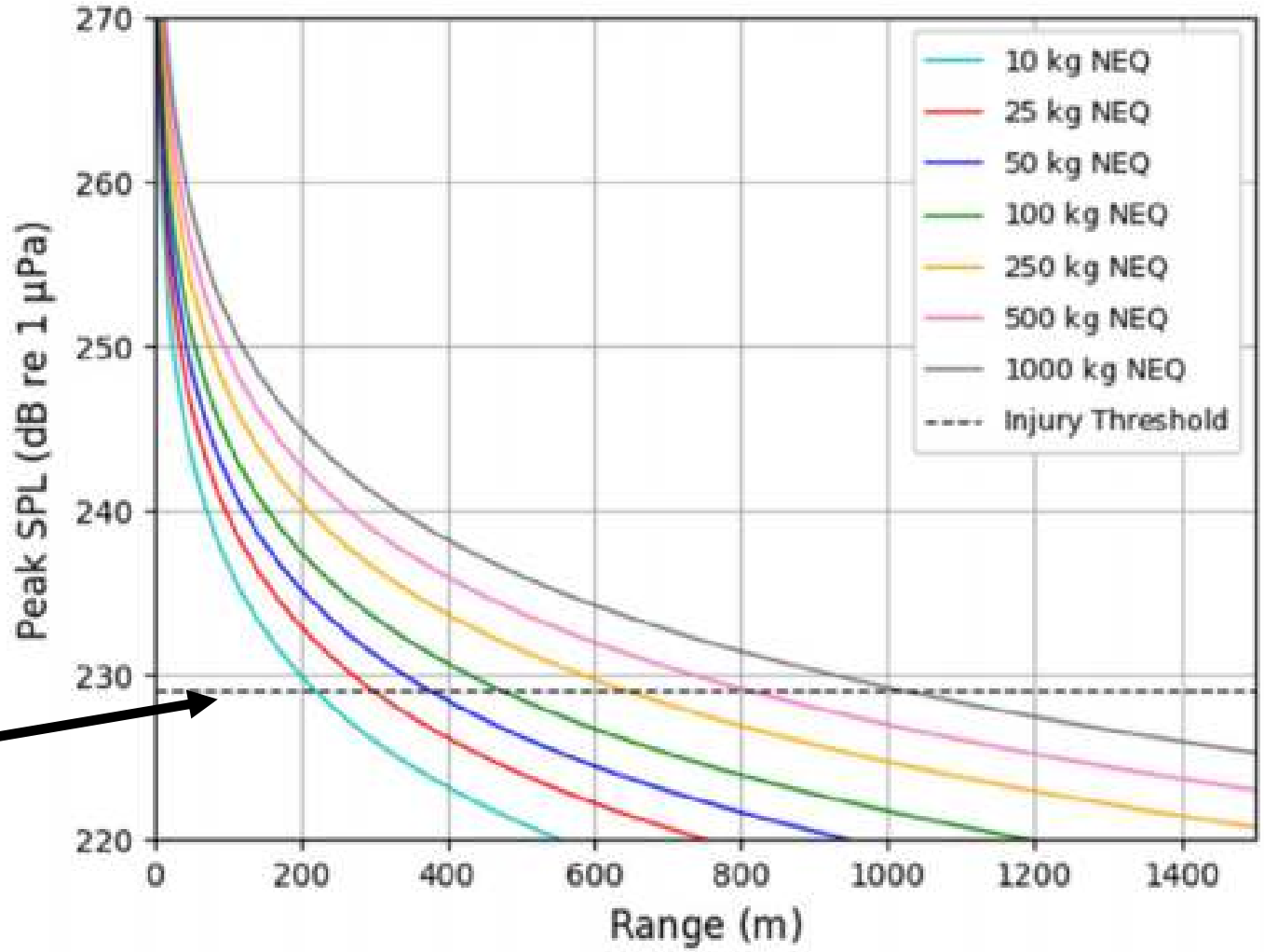
→ We cannot eliminate the risk of injury to individuals

Mitigation e.g. acoustic deterrents and scare charges may encourage animals to move away from injury zone

European Protected Species licences can be issued for disturbance and/or injury

Neart na Gaoithe Offshore Wind Ltd: UXO and fish

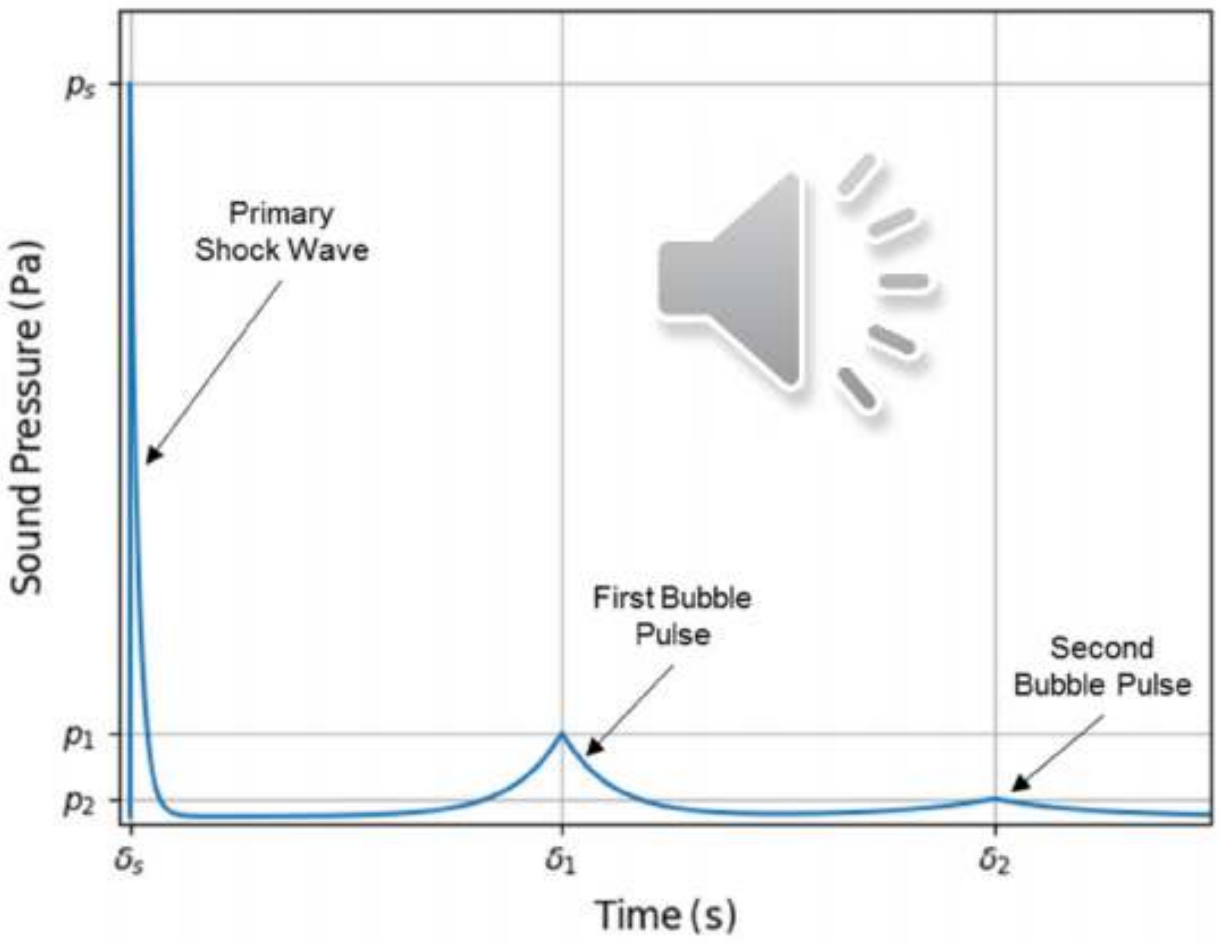
Predicted sound pressure levels (zero-peak) from UXO detonations



Dashed line is threshold for potential <u>mortality</u> to fish (Popper et al. 2014): 229 dB re 1 μPa

(NNGOWL / Genesis O&G Consultants)

Characteristics of underwater explosions



Idealised pressure waveform from an open water explosion.

(NNGOWL / Genesis O&G Consultants)

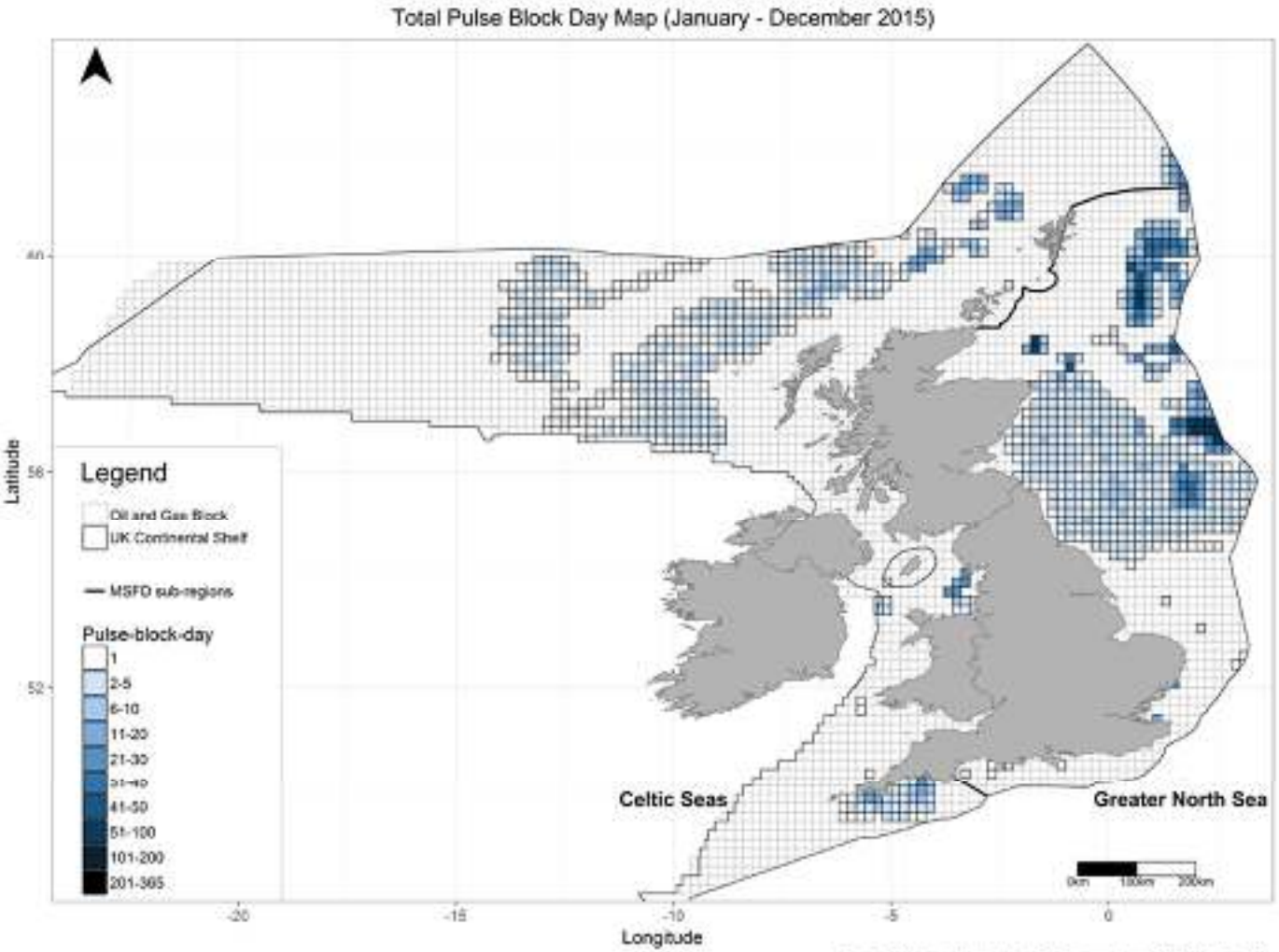
Explosions generate an impulsive sound

- Short duration
- Short rise time
- Single pressure peak
- Rapid decay
- May be repeated

- e.g. pile driving, seismic airgun, geophysical survey, **underwater explosion**

(Sound file is of an UXO clearance in the Moray Firth, recorded by Marine Scotland Science approx. 40 km from the blast site)

Marine Noise Registry



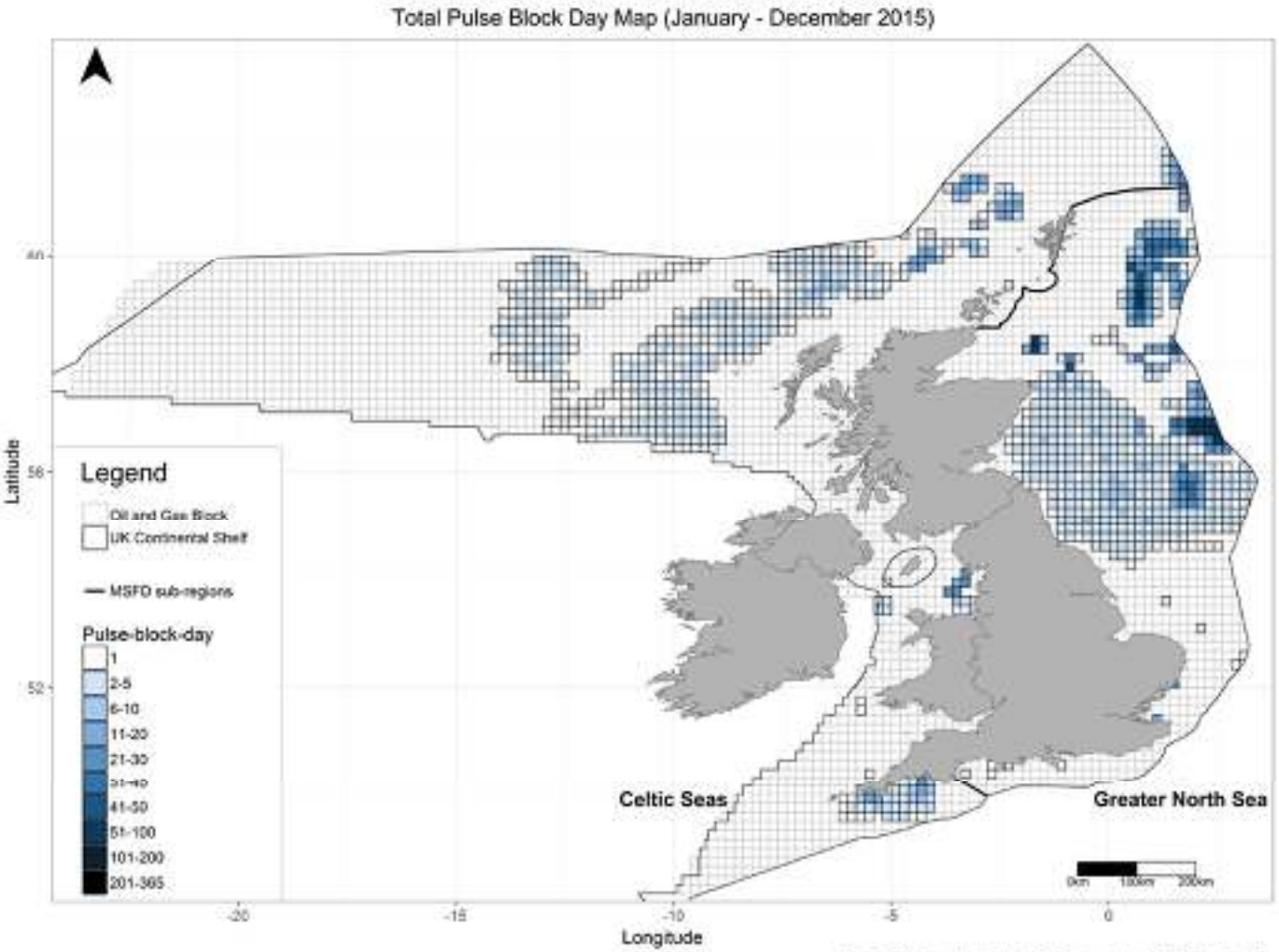
(JNCC)

- Developed by Defra and JNCC
- Record human activities that produce loud, low/mid frequency impulsive noise

- Monitoring of impulsive noise
- Define a baseline for impulsive noise in UK waters

- Required by EU Marine Strategy Framework Directive
- Commitment in UK Marine Strategy
- Reported to OSPAR

Marine Noise Registry



(JNCC)

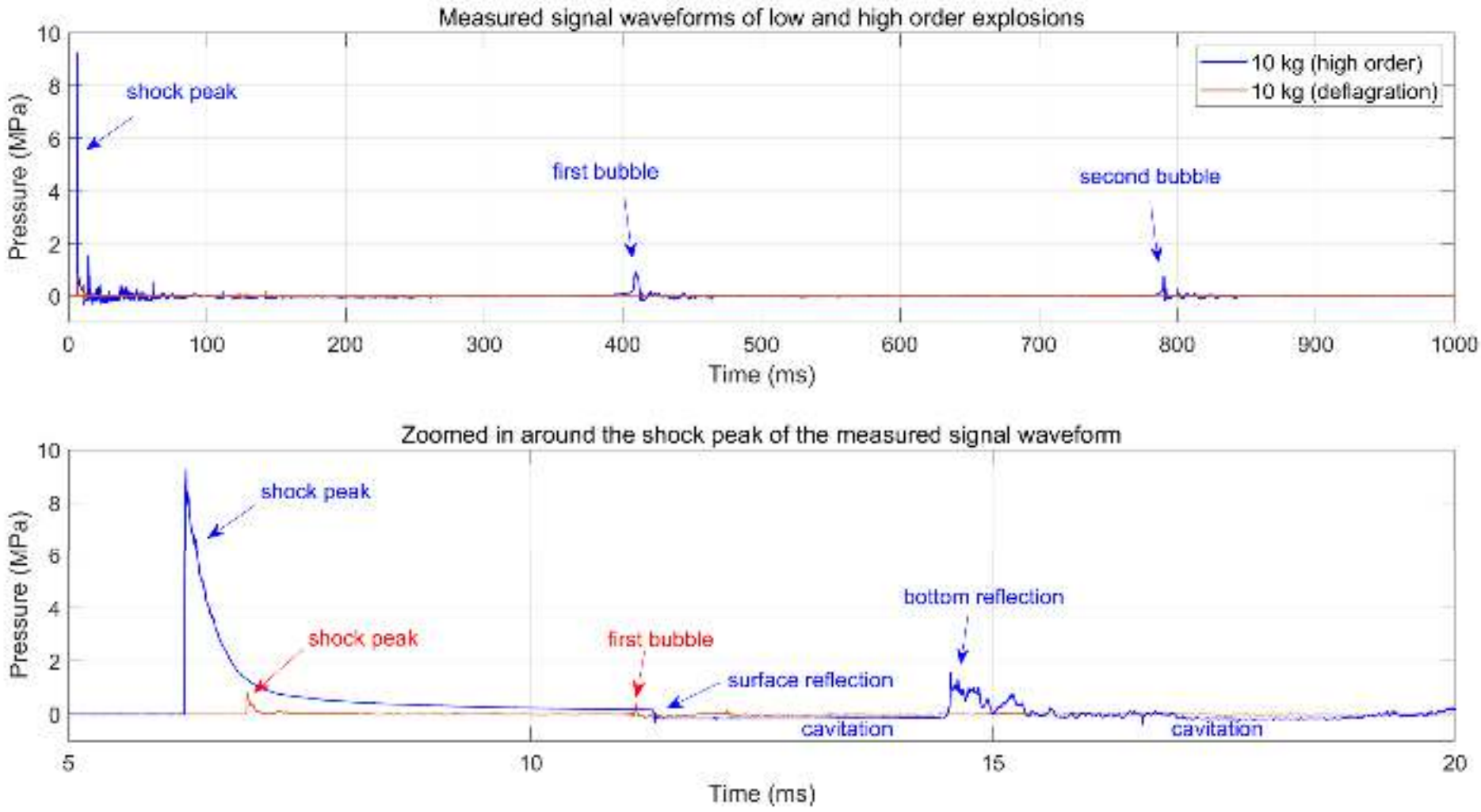
- Obligation on industry to report noisy activities
- Simple reporting format
  - Location
  - Dates of noisy activity
  - Source property data e.g. frequency, max airgun volume (seismic), max hammer energy (piling), **TNT equivalent (explosions)**
  - Sound Pressure Level
  - Sound Exposure Level
- Does not attempt to identify the scale of impact of the activity (no sound propagation modelled)

Noise abatement: low order (deflagration)

Shaped charge initiates rapid combustion but burning occurs at sub-sonic speeds (low-order) compared to detonation (high-order) where reaction occurs at supersonic speeds

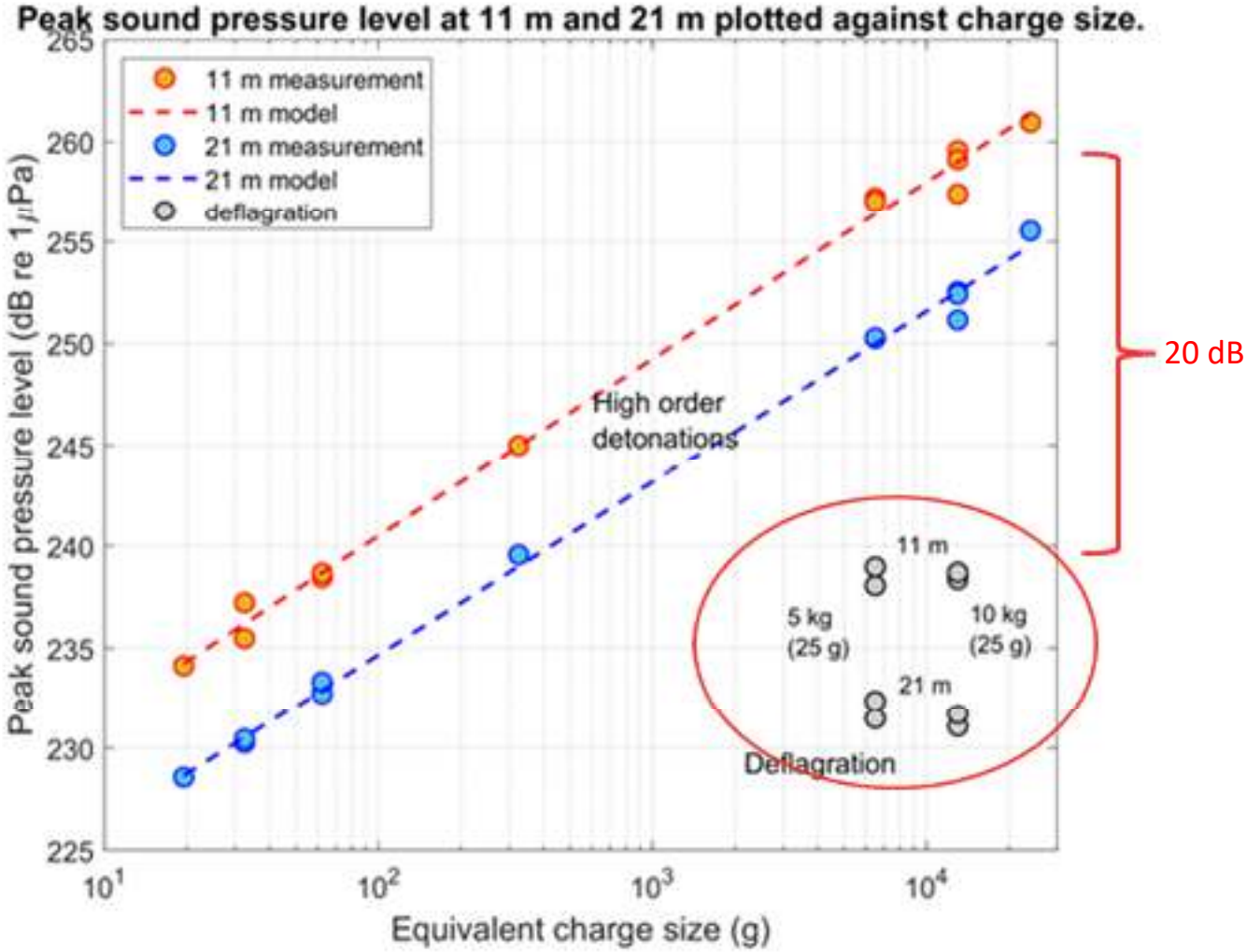
This is achieved using a smaller shaped charge that penetrates the shell by vaporizing a volatile metal cone that injects a plasma that initiates the deflagration burning.

Measured Waveform: Deflagration vs High order



Short-range pressure results

Peak sound pressure level (zero-peak)



UXO characterisation project: acoustic issues

- Low order deflagration can generate a much lower amplitude of peak sound pressure than high order detonation (by max. factor of 11 in trials)

- Deflagration peak sound pressure appears to be due **only** to the size of the shaped donor charge
  - output scales with donor charge size (in agreement with models)
  - enables acoustic output to be predicted for deflagration
  - for very large UXO, much larger reduction factors are possible (the maximum size of shaped charge is 250 g

UXO characterisation project: non-acoustic issues

- Chemical toxins
  - spread of combusted toxins more localised with deflagration
  - chemical contamination possible from non-combusted explosive
  - residual explosives must be safely removed
- Seabed destruction
  - much reduced with deflagration
- Logistics, procedures, safety issues, costs
  - very similar to high order - can use ROV or divers, costs likely similar…
- Reliability
  - data set not large enough to assess reliability in water yet
  - very high reliability claimed for deflagration in air (>95%)
- Education needed
  - new technique requires roll-out of procedures and good practice

UXO characterisation project: Phase 3 (current work)

- collection and analysis of offshore measurements by developers/researchers
- determination of the sound levels radiated during the UXO disposals as a function of range from the source and their relationship to exposure thresholds
- determination of the source levels of the explosions and the estimates of the effective charge size
- investigation of the use of scare charges
- evaluation of the effectiveness of acoustic models used for propagation of the radiated sound.

Thanks for listening!

Thanks for the contributions to the deflagration slides:
Stephen Robinson, NPL
Francesca Marubini, Hartley Anderson
John Hartley, Hartley Anderson
Paul Lepper, Loughborough

Acknowledgements for the Neart Na Gaoithe case study
(figures taken from publicly available application documents):
Neart na Gaoithe Offshore Wind Limited
GoBe Consultants
Genesis Oil and Gas Consultants
Pelagica Ltd

Ewan.Edwards@gov.scot
@ewaneddy
@marinescotland