Seismic surveys in Greenland
An example of noise regulation at a cumulative level

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Content

Underwater acoustics and noise

Why is noise a problem in the sea?

Marine mammals and noise

Guidelines in Greenland

Noise in the context of Marine Spatial Planning

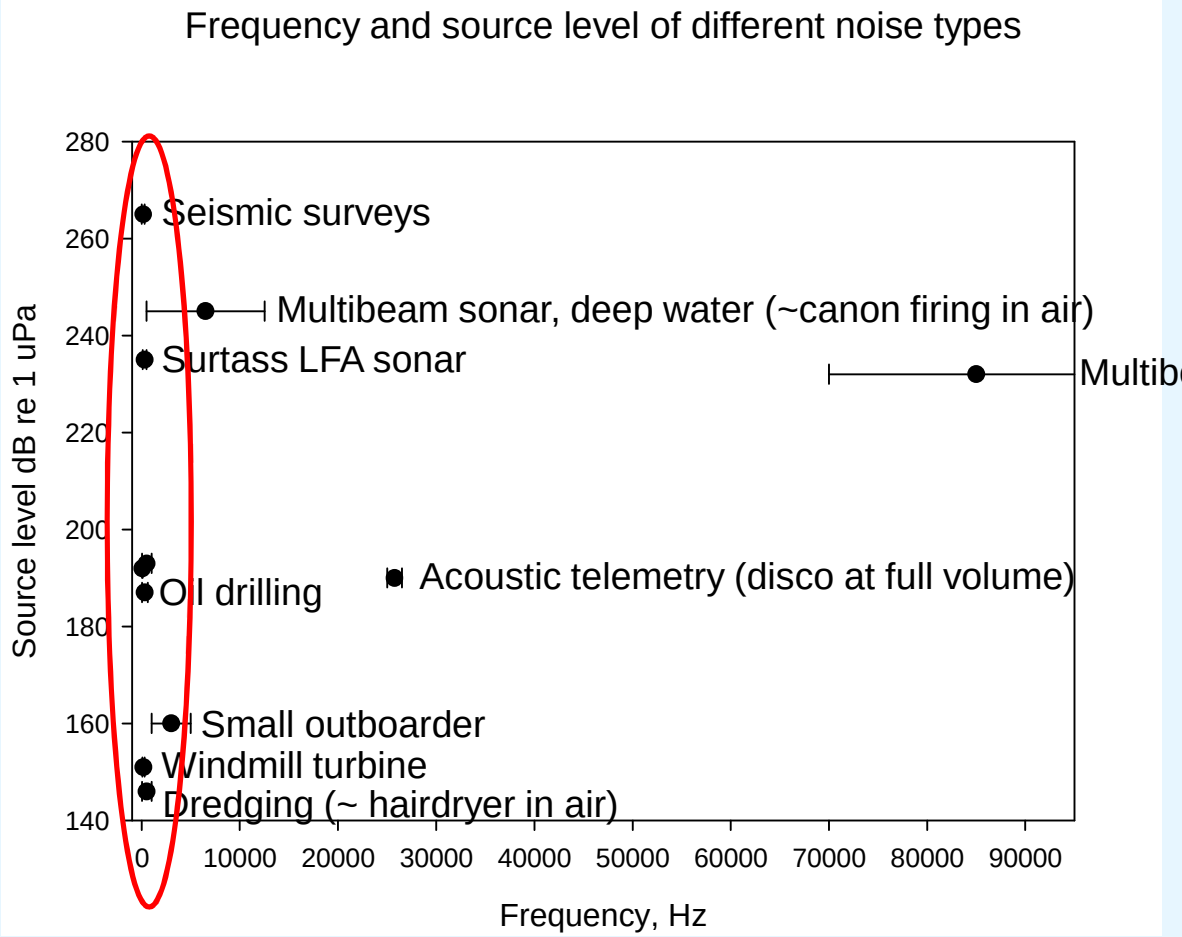
(IF TIME: Case study from Baffin Bay 2012)

Basic underwater acoustics - dBs

- **Sound is pressure waves**
- **Pressure is measured in dB – a logarithmic scale referenced to a certain unit.**
- **In water: dB re 1 µPa.**
- **In-air: dB re 20 µPa**
- **To convert water to air: (roughly) substract 62 dB from underwater measurements**
- **Sound velocity is about 3 times faster in water**
- **Sound attenuates much slower in water**

What is noise?

- **Simple, general definition not possible**
- **The same sound can be a signal for one, and noise for another**
- **Generally noise is at best unusable and carries no information**
- **At worst disturbing and dangerous**
- **Definition in the following:**
  - ***Noise is stimulation of receiver (external or internal) that contains no information usable for detection of signal***



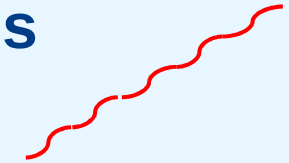
Note: Most anthropogenic noise is of very low frequency!

Data from: Richardson 1990, Finley 1990, Hildebrand 2009, Anon 2012, Kyhn et al. 2014

Propagation of noise

High frequency = small wavelengths

-> noise attenuates quickly



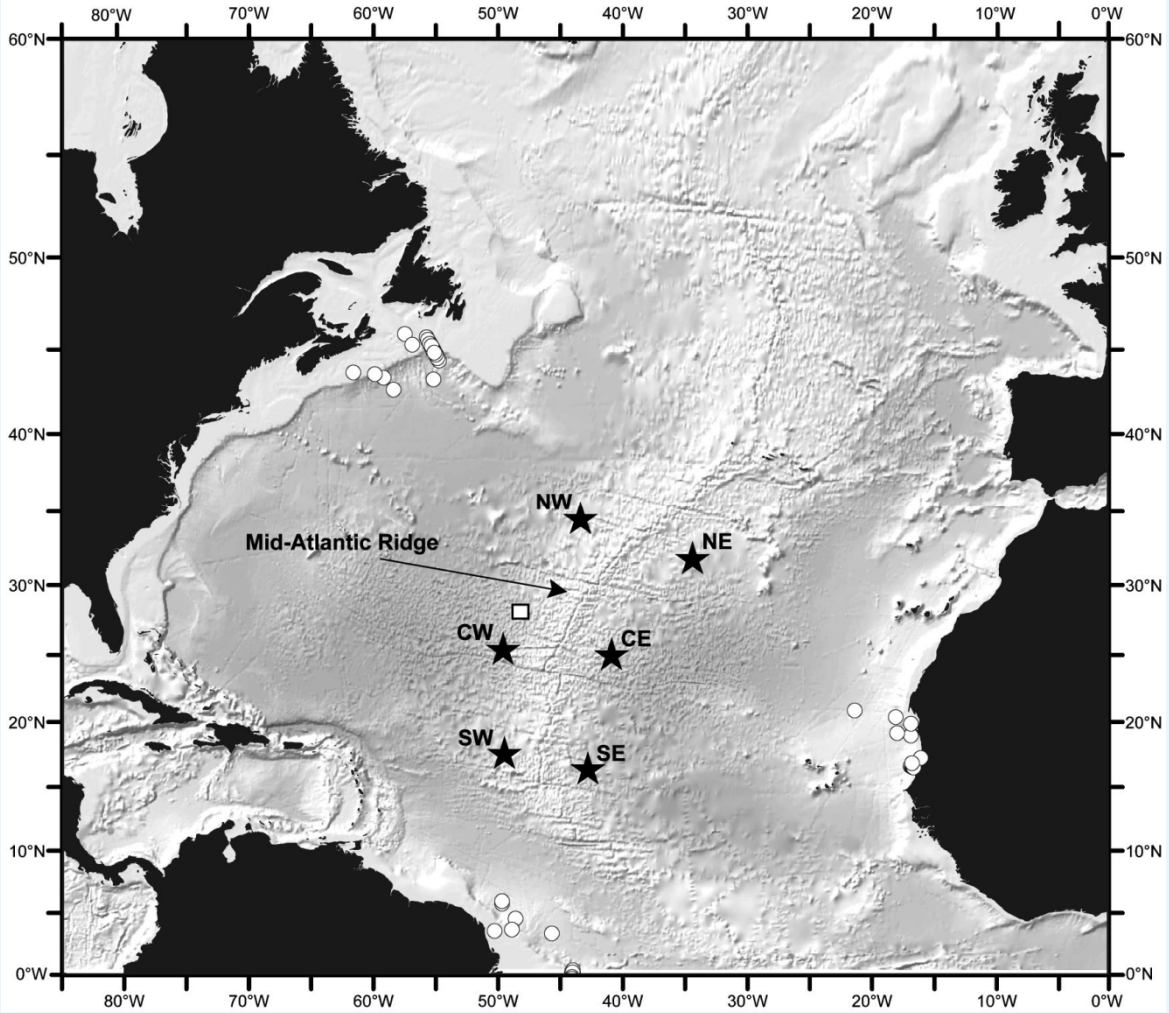
Low frequency = long wavelengths

-> noise attenuates very slowly

Low frequency noise travels very far

- ○ Seismic surveys
- ★ Hydrophones

Airgun pulses detected
More than 3000 km away!



Niukirk et al. 2004

Why is noise a problem at sea?

Many marine species of fish and marine mammals depend on acoustic cues for vital life functions:

- **Mating**
- **Foraging**
- **Orientation**
- **Avoiding predators**

These functions as well as normal behavior can be obstructed/disrupted by noise

Marine mammal reactions to noise

- **Increased level of stress hormones** (Romano et al. 2004, Rolland et al. 2012)
- **Horizontal displacement, many species** (e.g. Finley 1990 , Mate et al. 1994, Stone and Tasker 2006, Tougaard et al. 2009)
- **Changes in vocalization type, rate and intensity** (e.g. Finley 1990, Blackwell et al. 2013)
- **Decreased foraging activity** (e.g. Thompson et al. 1998; Pirotta et al. 2014)
- **Strandings (beaked whales)** (Gentry 2002, Malakof 2002,)

Marine mammal reactions to noise

- **Disturbance reactions: Reduced surface interval, dive duration and numbers of blows per surfacing (Malme et al. 1988)**
- **Decreased heart rate, changes in dive pattern (Thompson et al 1998)**
- **TTS, experimental (Finneran et al. 2002, Lucke et al. 2009)**
- **Hearing trauma and entanglements after blasts (Todd et al. 1995)**

Find out more: http://dontbeabuckethead.org/

Table 3. Proposed injury criteria for individual marine mammals exposed to "discrete" noise events (either single or multiple exposures within a 24-h period; see Chapter 2)

	Sound type		
Marine mammal group	Single pulses	Multiple pulses	Nonpulses
Low-frequency cetaceans	Cell 1	Cell 2	Cell 3
Sound pressure level	230 dB re: 1 μPa (peak) (flat)	230 dB re: 1 μPa (peak) (flat)	230 dB re: 1 μPa (peak) (flat)
Sound exposure level	198 dB re: 1 μPa^2-s (M_{lf})	198 dB re: 1 μPa^2-s (M_{lf})	215 dB re: 1 μPa^2-s (M_{lf})
Mid-frequency cetaceans	Cell 4	Cell 5	Cell 6
Sound pressure level	230 dB re: 1 μPa (peak) (flat)	230 dB re: 1 μPa (peak) (flat)	230 dB re: 1 μPa (peak) (flat)
Sound exposure level	198 dB re: 1 μPa^2-s (M_{mf})	198 dB re: 1 μPa^2-s (M_{mf})	215 dB re: 1 μPa^2-s (M_{mf})
High-frequency cetaceans	Cell 7	Cell 8	Cell 9
Sound pressure level	230 dB re: 1 μPa (peak) (flat)	230 dB re: 1 μPa (peak) (flat)	230 dB re: 1 μPa (peak) (flat)
Sound exposure level	198 dB re: 1 μPa^2-s (M_{hf})	198 dB re: 1 μPa^2-s (M_{hf})	215 dB re: 1 μPa^2-s (M_{hf})
Pinnipeds (in water)	Cell 10	Cell 11	Cell 12
Sound pressure level	218 dB re: 1 μPa (peak) (flat)	218 dB re: 1 μPa (peak) (flat)	218 dB re: 1 μPa (peak) (flat)
Sound exposure level	186 dB re: 1 μPa^2-s (M_{pw})	186 dB re: 1 μPa^2-s (M_{pw})	203 dB re: 1 μPa^2-s (M_{pw})
Pinnipeds (in air)	Cell 13	Cell 14	Cell 15
Sound pressure level	149 dB re: 20 μPa (peak) (flat)	149 dB re: 20 μPa (peak) (flat)	149 dB re: 20 μPa (peak) (flat)
Sound exposure level	144 dB re: (20 μPa)^2-s (M_{pa})	144 dB re: (20 μPa)^2-s (M_{pa})	144.5 dB re: (20 μPa)^2-s (M_{pa})

Note: All criteria in the "Sound pressure level" lines are based on the peak pressure known or assumed to elicit TTS-onset, plus 6 dB. Criteria in the "Sound exposure level" lines are based on the SEL eliciting TTS-onset plus (1) 15 dB for any type of marine mammal exposed to single or multiple pulses, (2) 20 dB for cetaceans or pinnipeds in water exposed to nonpulses, or (3) 13.5 dB for pinnipeds in air exposed to nonpulses. See text for details and derivation.

Southall et al. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations

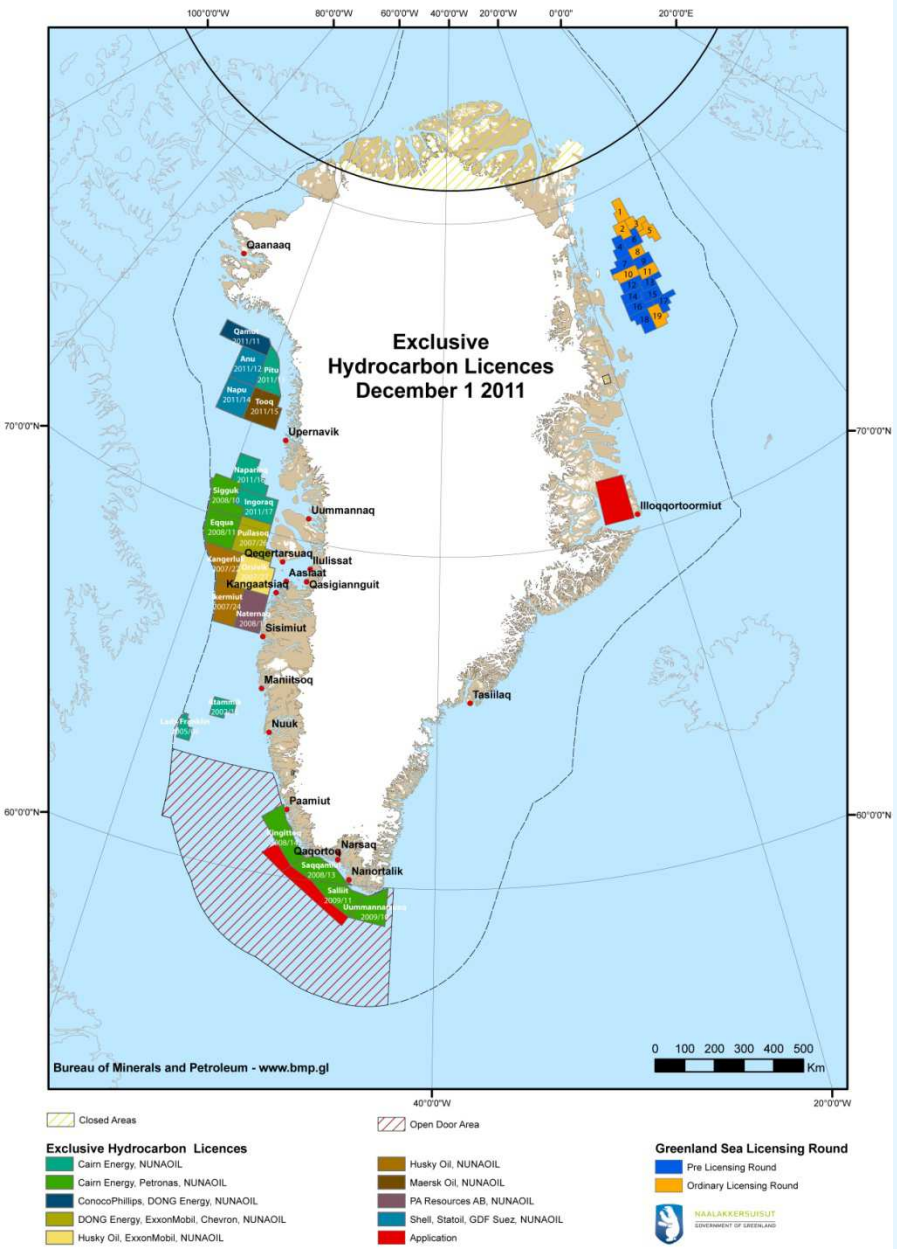
Summary

Anthropogenic noise is a problem because

- **It has multiple negative effects on marine life**
- **Most noise types are of low frequency**
- **Low frequencies travels very far**
- **Behavioral reactions/disturbances is to be expected at far ranges, but may not be observed.**

Greenland case study

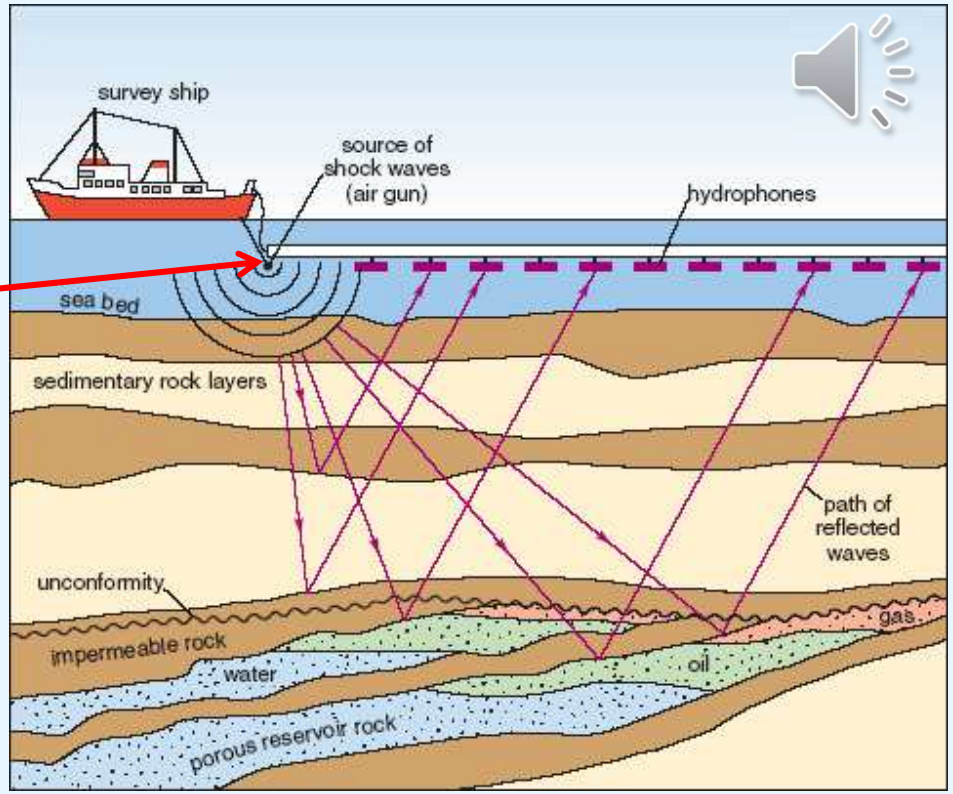
Greenland has opened for hydrocarbon exploration and licenses have been awarded to several companies.



First step towards oil exploration: Seismic surveys

Seimic surveys are used to envision the geographical layers 5-6 km under the sea bed in search for hydrocarbon

Array of ex
32 airguns
Shot every 10 sec
SL up to 265 dB
re 1 µPa (pp)



Streamers with
hydrophones
ex 10 km long

Regulation in Greenland: Seismic and drilling

(relevant for this workshop…)

Temporally closed areas

Sound exposure modeling by applicant

Cumulative sound exposure modeling from multiple applicants in the same area

Documentation of noise exposure by companies obtained during their activity

Temporally closed areas

Is the basic concept in the regulation

- **Generally seismic surveys are only permitted during the ice –free season (mid June – November)**
- **A number of areas are closed at specific times to protect vulnerable species. Areas are appointed for four marine species.**
- **Appointments are based on firm knowledge of each species' migration and seasonal occupancy.**

2 types of temporally closed areas

Closed areas:

- **Vulnerable period for the species. E.g. haulout, summer habitat or breeding colony.**
- **Permission for seismic activities should not be considered during this period**

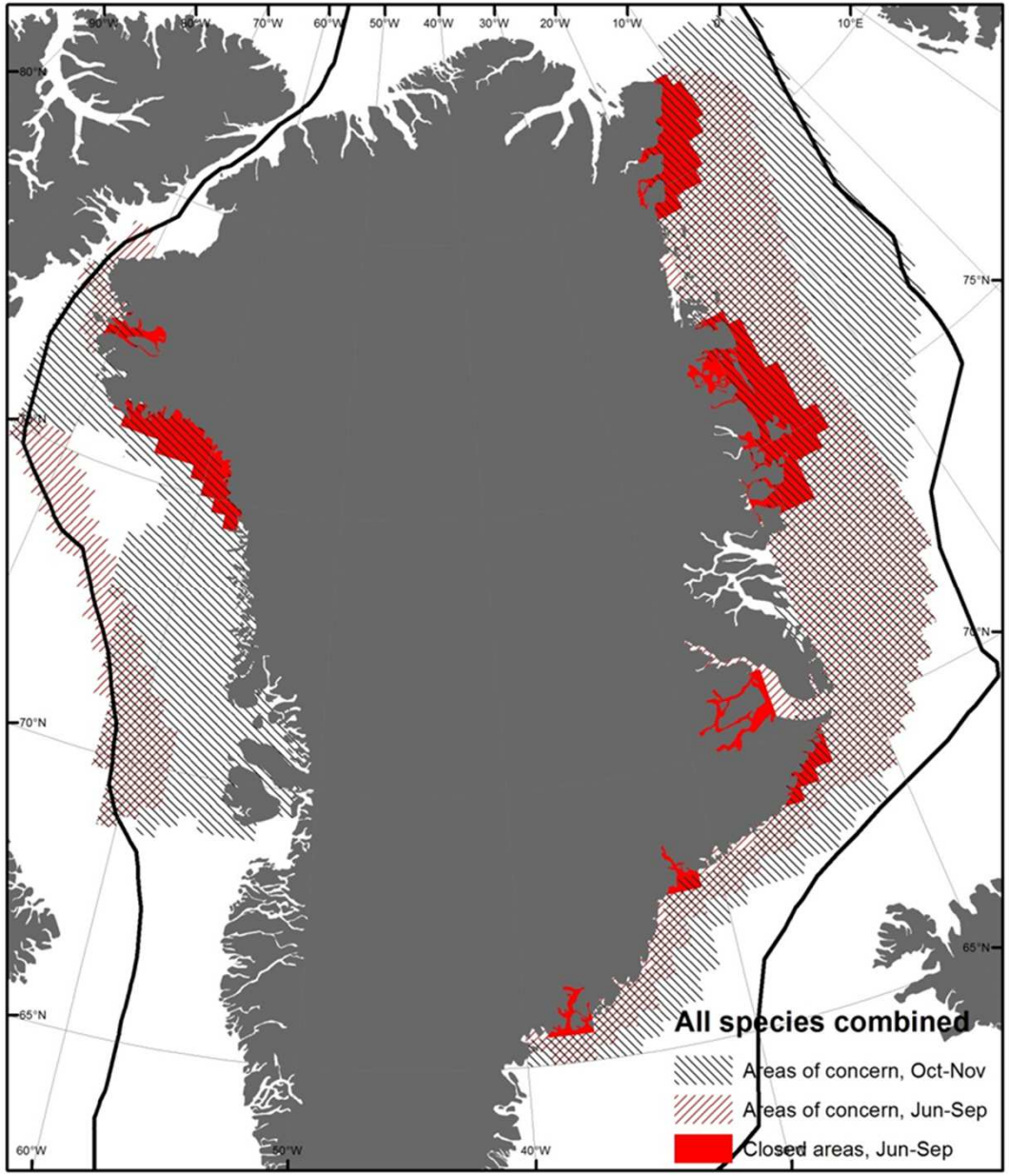
2 types of temporally closed areas

Areas of concern:

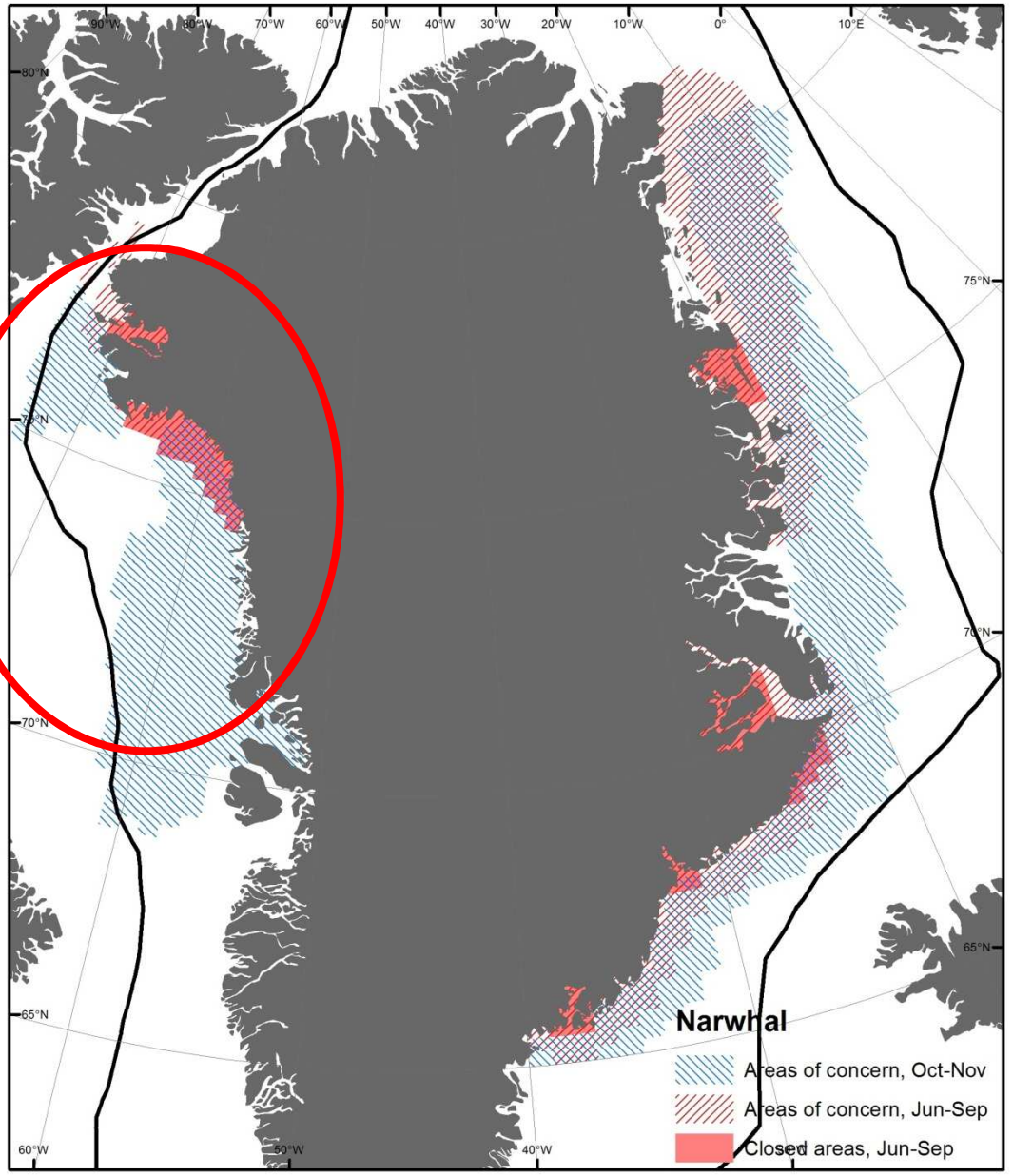
- **Area and period used for example for migration**
- **Area and time less critical for the species**
- **Permission for extensive activities (ex 2D seismic or sub bottom profiling) may be given if the activity is considered to have little effect on the species in question.**

Temporally closed areas in Greenland

Narwhal
Beluga
Bowhead whale
Walrus

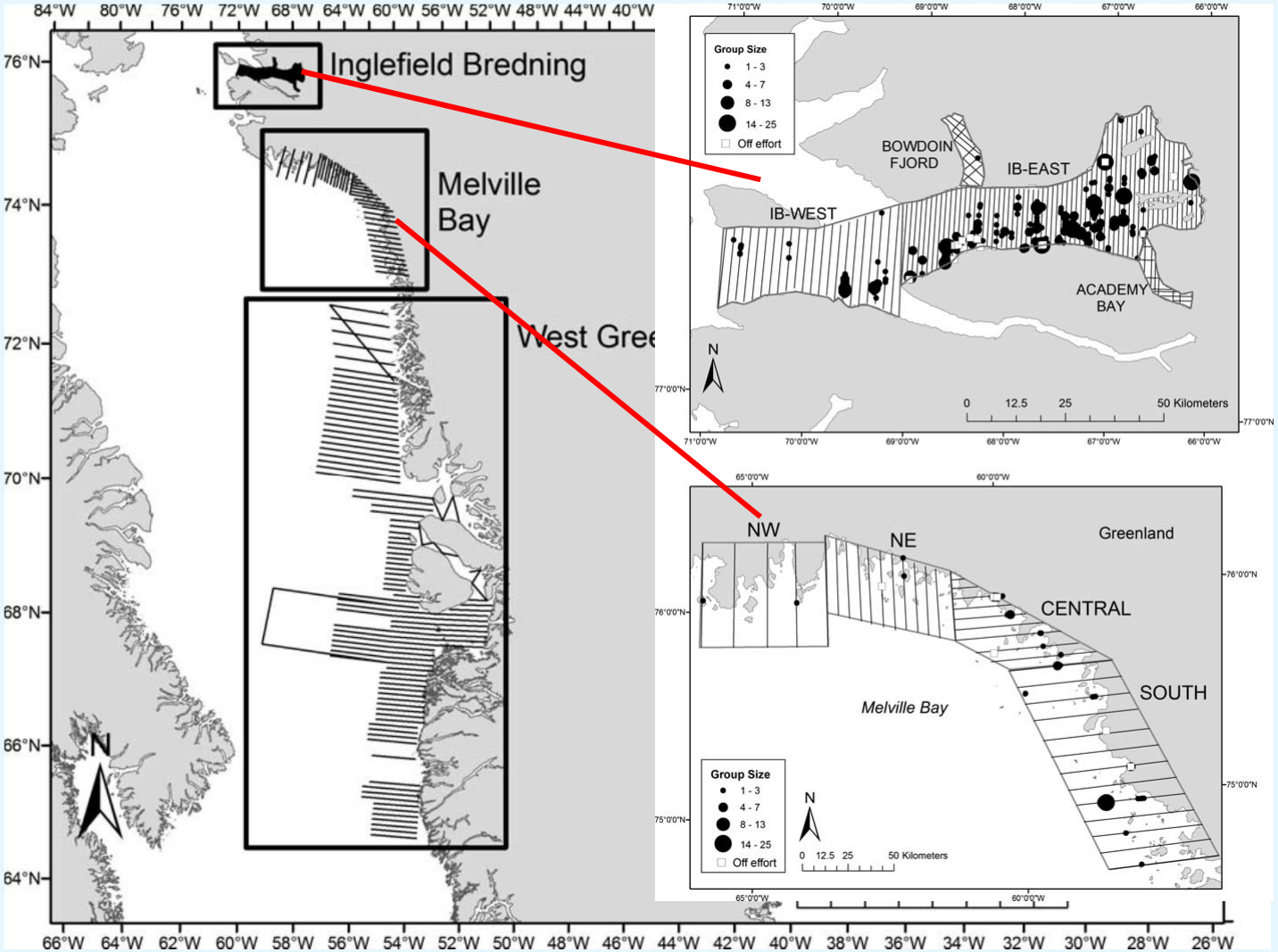


Narwhals, West Greenland



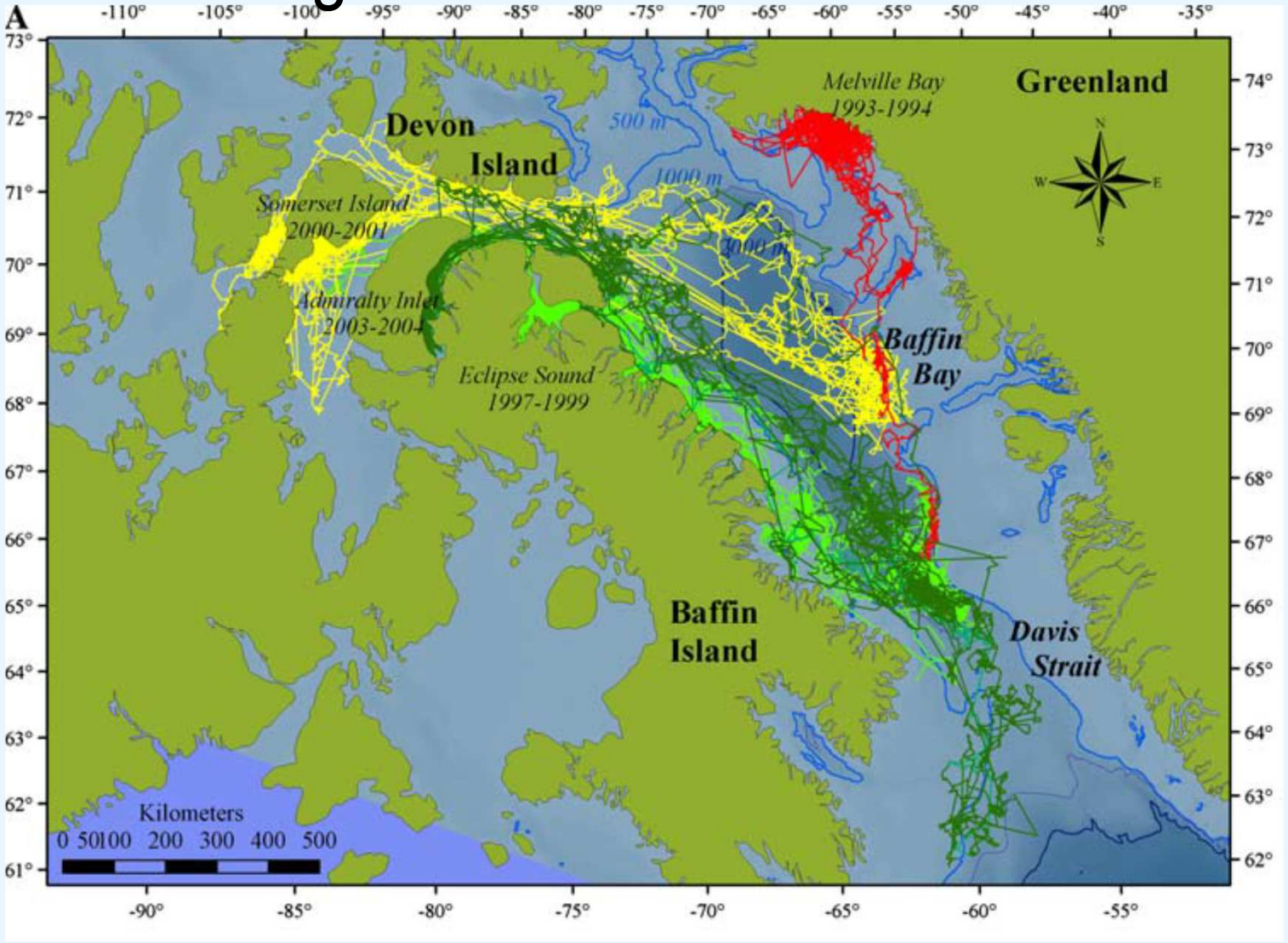
Kyhn et al. 2013

Aerial surveys



Heide-Jørgensen et al. 2010

Satellite tracking of narwhals



Dietz et al. 2008

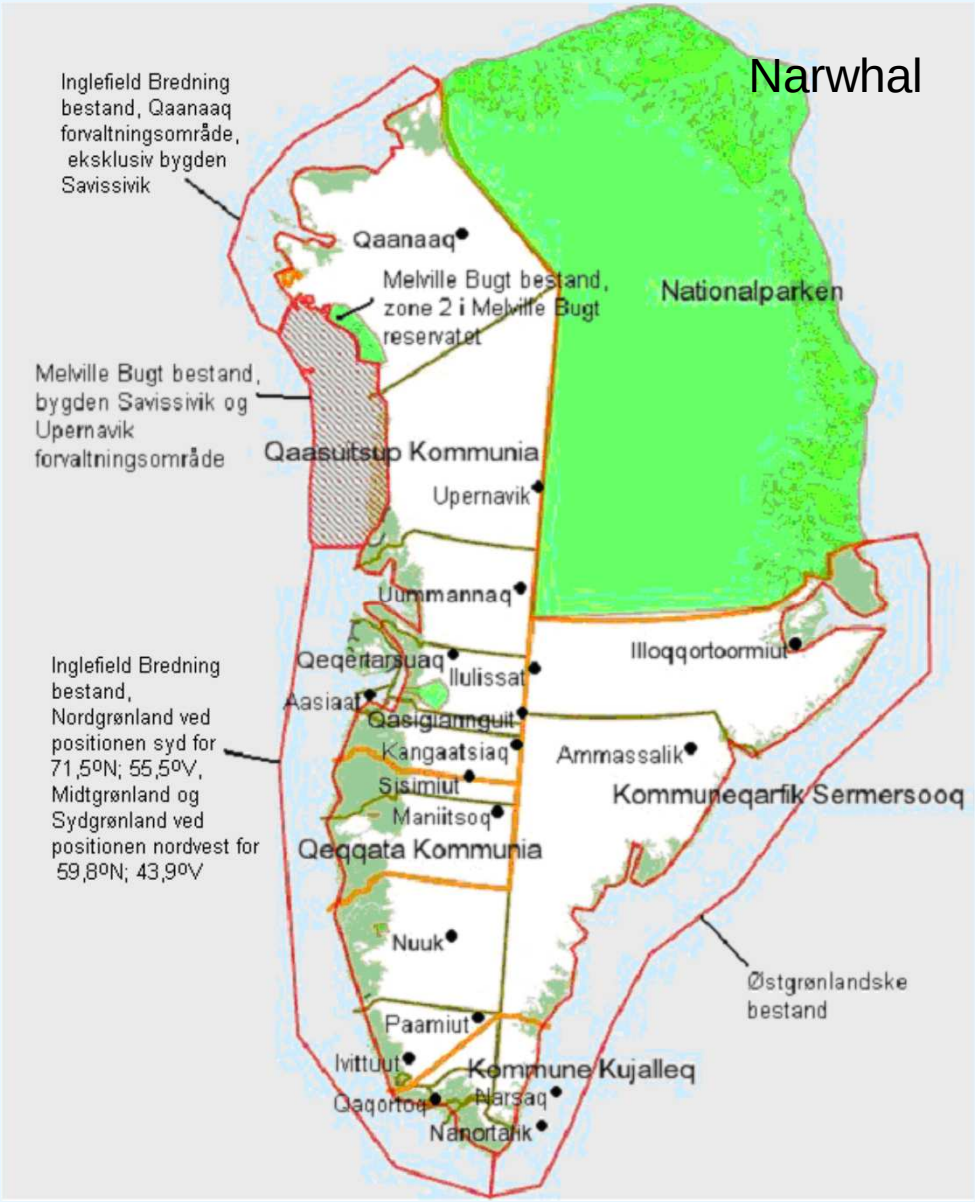
Species knowledge

Proper protection requires proper knowledge of

- **Meta-and subpopulations**
- **Migration**
- **Seasonal occupancy**

A species may require different levels of protection in different areas and at different times.

Hunting


Narwhal
Inglefield Bredning bestand, Qaanaaq forvaltningsområde, eksklusiv bygden Savissivik
Qaanaaq
Melville Bugt bestand, zone 2 i Melville Bugt reservatet
Nationalparken
Melville Bugt bestand, bygden Savissivik og Upernavik forvaltningsområde
Qaasuitsup Kommunia
Upernavik
Uummannaq
Inglefield Bredning bestand, Nordgrønland ved positionen syd for 71,5ºN; 55,5ºV, Midtgrønland og Sydgrønland ved positionen nordvest for 59,8ºN; 43,9ºV
Qeqertarsuaq
Ilulissat
Aasiaat
Qasigiannguit
Kangaatsiaq
Sisimiut
Maniitsoq
Qeqqata Kommunia
Illoqqortoormiut
Ammassalik
Kommuneqarfik Sermersooq
Nuuk
Østgrønlandske bestand
Paamiut
Ivittuut
Kommune Kujalleq
Qaqortoq
Narsaq
Nanortalik

Hunting

- **Animals must be protected from many different interests, ex. Hunting, tourism, ship strikes etc.**
- **Hunting is a serious issue in Greenland**
- **Hunting is based on spatial division of areas, hunting times and quotas, depending on species.**
- **Nature Reserves/National Park where species generally are protected (with some exceptions)**

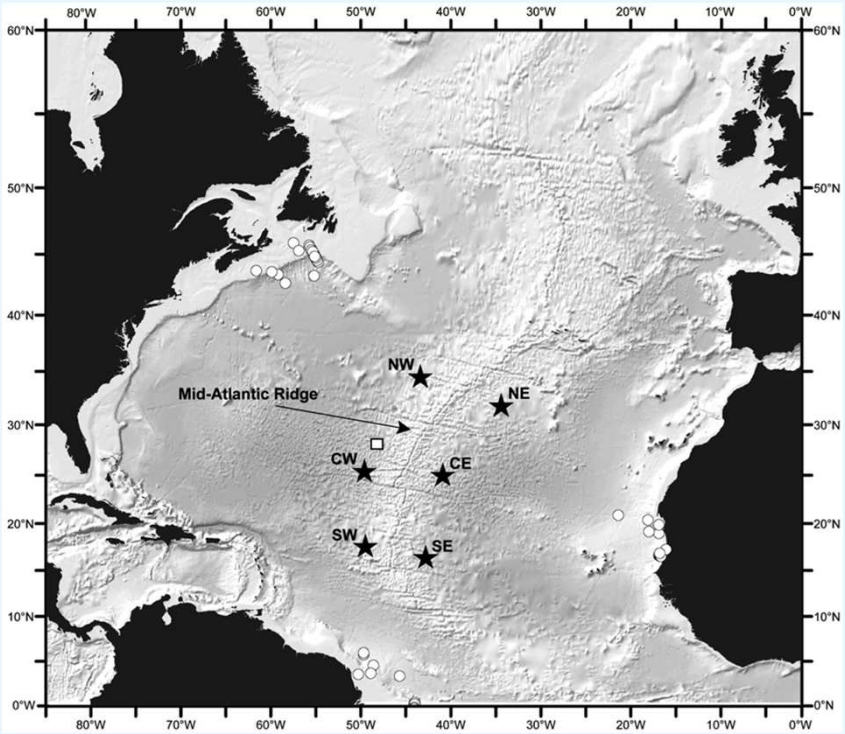
Protected areas must be evaluated regurlarily

- **New knowledge**
  - **E.g. Red List/IUCN Protection status, Effect of hunting.**
- **Climate change may change animal use of an area**
  - **Some fish species appear/disappear according to water temperature.**

Bowhead whale, Disko, F. Ugarte

Spatial restrictions not enough for noise

- **Noise travels beyond borders of closed areas**
- **-> Closed areas are not enough for protection against noise**



Niukirk et al. 2004

Greenland: Specific EIA requirements

"The EIA must provide direct mitigation solutions to reduce the effects of the seismic survey… in terms of

- **reduced acoustic output,**
- **increased directionality of airguns,**
- **reduced high frequency output,**
- **careful planning to avoid overlap with breeding or migrating animals, careful consideration of other planned activities in the same area**

The effects of the suggested mitigation must be documented. "

Greenland: Yearly application cycle

All applications and EIAs are received at the same time

- **Effects of each project can be evaluated at a cumulative level over a larger general area at the same time**
- **The applicants can be asked to cooperate on for example noise models, mitigation, temporally and spatially**
- **The mitigation suggested by the companies can be evaluated and compared and suggestions applied to all companies -> improves knowledge of managers**

EIA Predictive modeling

Sound exposure modeling for EIAs

- The EIA must contain state of the art modeling of expected noise pollution from the applied activity
- Companies applying for the same area, e.g. Baffin Bay, must prepare a cumulative noise model of expected noise pollution for the EIA
  - Advantage for the companies that they can prepare identical chapters for the EIA
  - Advantage for managers that they can evaluate effects across activities

Noise documentation

All companies granted permission must document their noise exposure during their activity

- **Over entire general area, where noise may creact disturbances (not only license area)**
- **Provides knowledge on actual noise propagation**
- **Provides data from areas with poor coverage**
- **Allows improvement of modeling by comparing with predictive modeling for the EIA**

Evaluation of noise recordings

Allows post assessment of actual exposure of animals in the inflicted area

- **Was the predictive modeling valuable?**
- **May a temporal closure be needed next season?**

Marine Spatial Planning in relation to noise

What was the problem?

- **Anthropogenic low frequency noise travels very far**
- **Many negative effects are known at a species/individual level**
- **For most species the effects - especially long term - are unknown. Almost nothing is known at a population level.**

Marine Spatial Planning in relation to noise

Suggestions for management

- **Reduced impact:**
  - **Technical advances**
  - **Plan well in advance in respect to sensitive species, areas and times**
  - **Requires firm knowledge of the species in the area/country**
  - **Use deterrent devices to keep species away from the noise (controversial and requires that animals react accordingly and can/will seek refuge in other appropriate areas**

Wright and Kyhn in Press (Conservation Biology)

Marine Spatial Planning in relation to noise

Suggestions for management

- **Application cycle**
  - **Access cummulative impacts**
  - **Joint mitigation**
  - **Temporal division of an area (companies take turn)**
  - **Spatial summation of noise**
    (the total impact from X projects is not simply X times the impact of a single project)

Wright and Kyhn in Press (Conservation Biology)

Marine Spatial Planning in relation to noise

Suggestions for management

- **Zero-sum management**
  - **The present level of disturbance is set as maximum allowable**
  - **No new activity is allowed unless existing activities are ended**
  - **(Probably unlikely in the Arctic, as the area is opening for new activities with climate change…)**

Wright and Kyhn in Press (Conservation Biology)

Marine Spatial Planning in relation to noise

Suggestions for management

- **Division of areas**
  - **Some areas recognized as less problematic in terms of wildlife**
  - **These areas could be appointed industrial business areas (shippings lane, trawling, dredging, wind farms and other that are less site specific)**
  - **Important wildlife areas appointed *Special Areas of Conservation*, closed for industrial activities.**

Wright and Kyhn in Press (Conservation Biology)

Thank you