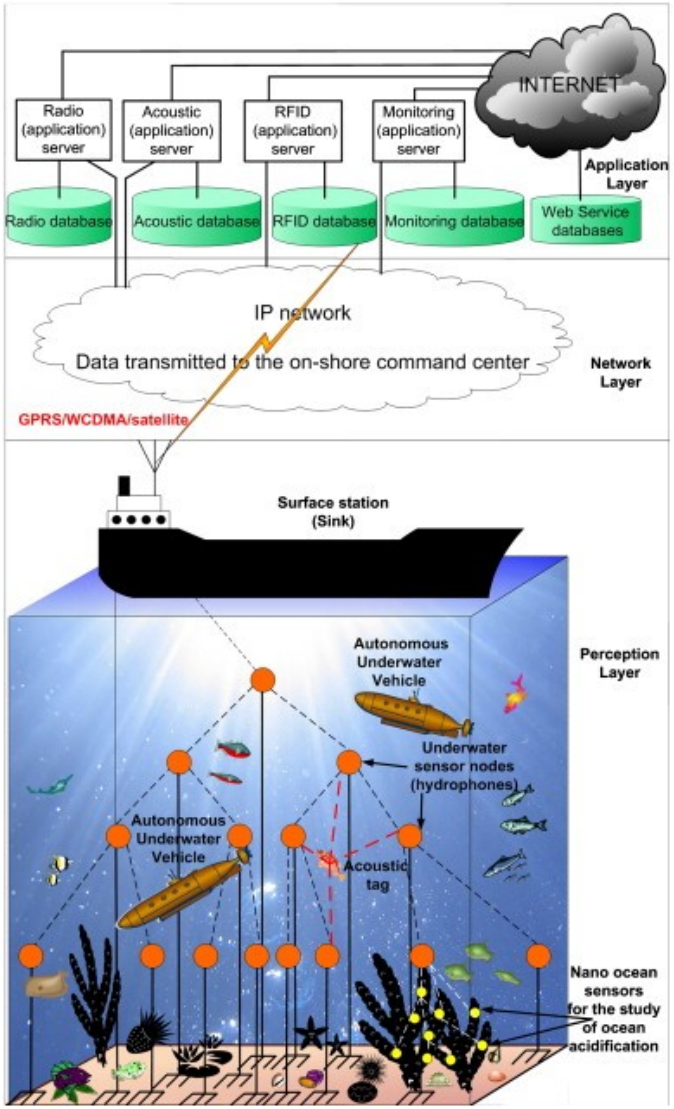
Research approaches to quantify the effects of underwater noise on cetaceans:

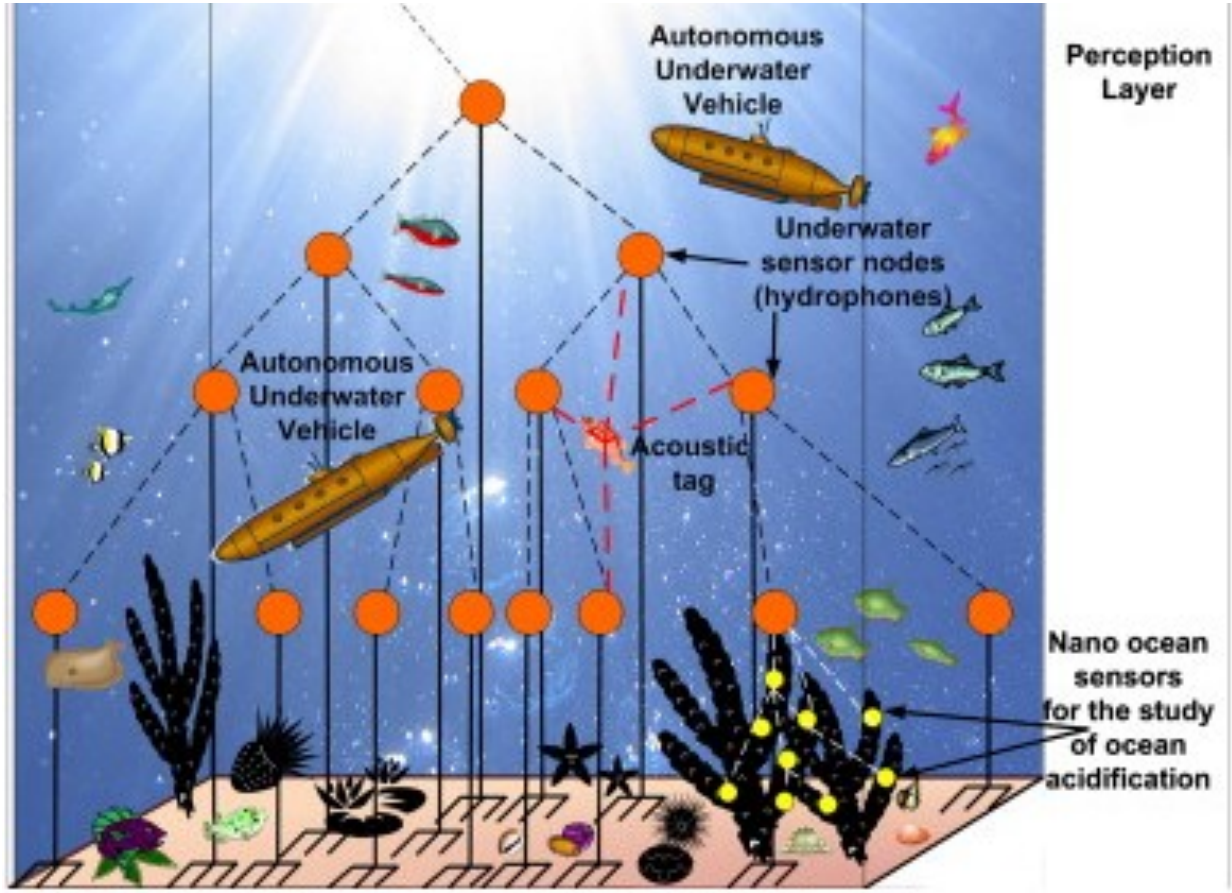
Recommendations for U-IoT standards

- **Sound is important underwater, useful for communication!!**
- **U-IoT standards ignore potential impacts of acoustic transmissions**
  - **human divers, animals that use sound**
- **Cetacean (whales and dolphins) and seals hear well in data bands, can (possibly illegally) harass marine mammals and lead to negative impacts**
  - **avoidance and feeding cessation are common responses**

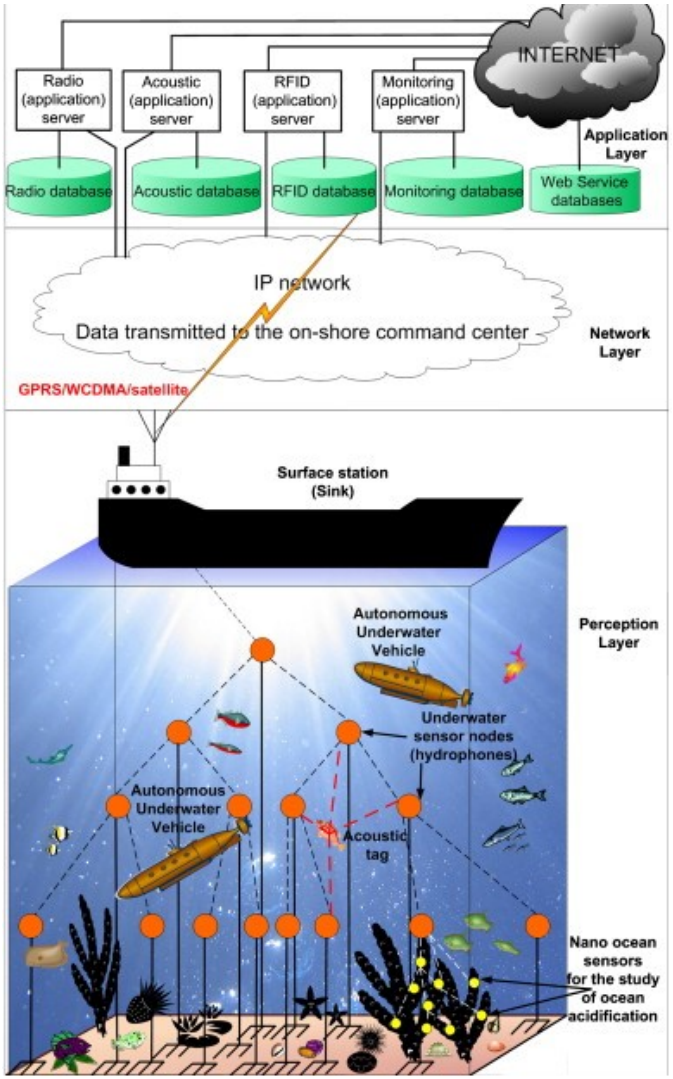
→ **<u>"Mammal-Friendly"</u>** ← **standards could reduce impacts:**

- **minimize transmissions, use cables whenever feasible**
- **minimum source level, higher frequency, directional transmission**
- **avoid areas with sensitive species, age-classes**





Domingo, 2012



Domingo, 2012

TABLE I THE DIFFERENCES BETWEEN TWSNS AND UWSNS

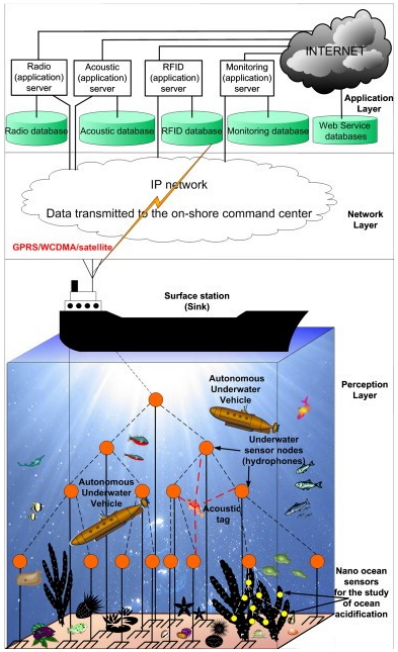
Features	TWSNs	UWSNs
Transmission Media	Radio Wave	Sound Wave
Propagation Speed	300,000,000 m/s	1,500 m/s
Transmission Range	10-100 m	100 m-10 km
Transmission Speed	~250 kbps	~10 kbps
Difficulty to Recharge	Depend on Applications	Difficult
Mobility (of nodes)	Depend on Applications	High
Reliability (of links)	Depend on Applications	Low

Potential harms: **radiation** **Risk to Divers**

Animals also use sound!

Kao et al., 2017

U-IoT <u>can</u> aid environmental monitoring



Domingo, 2012

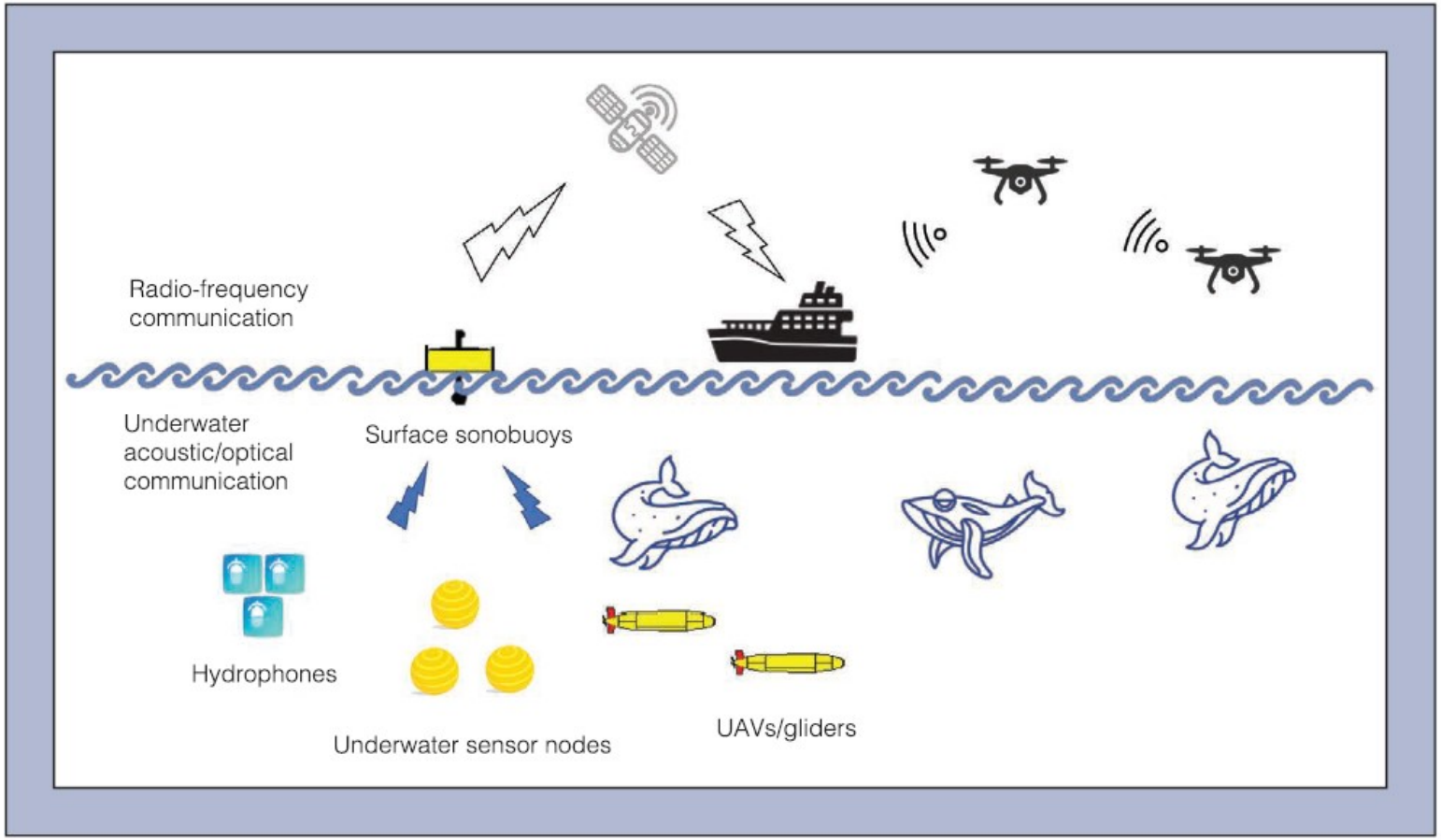


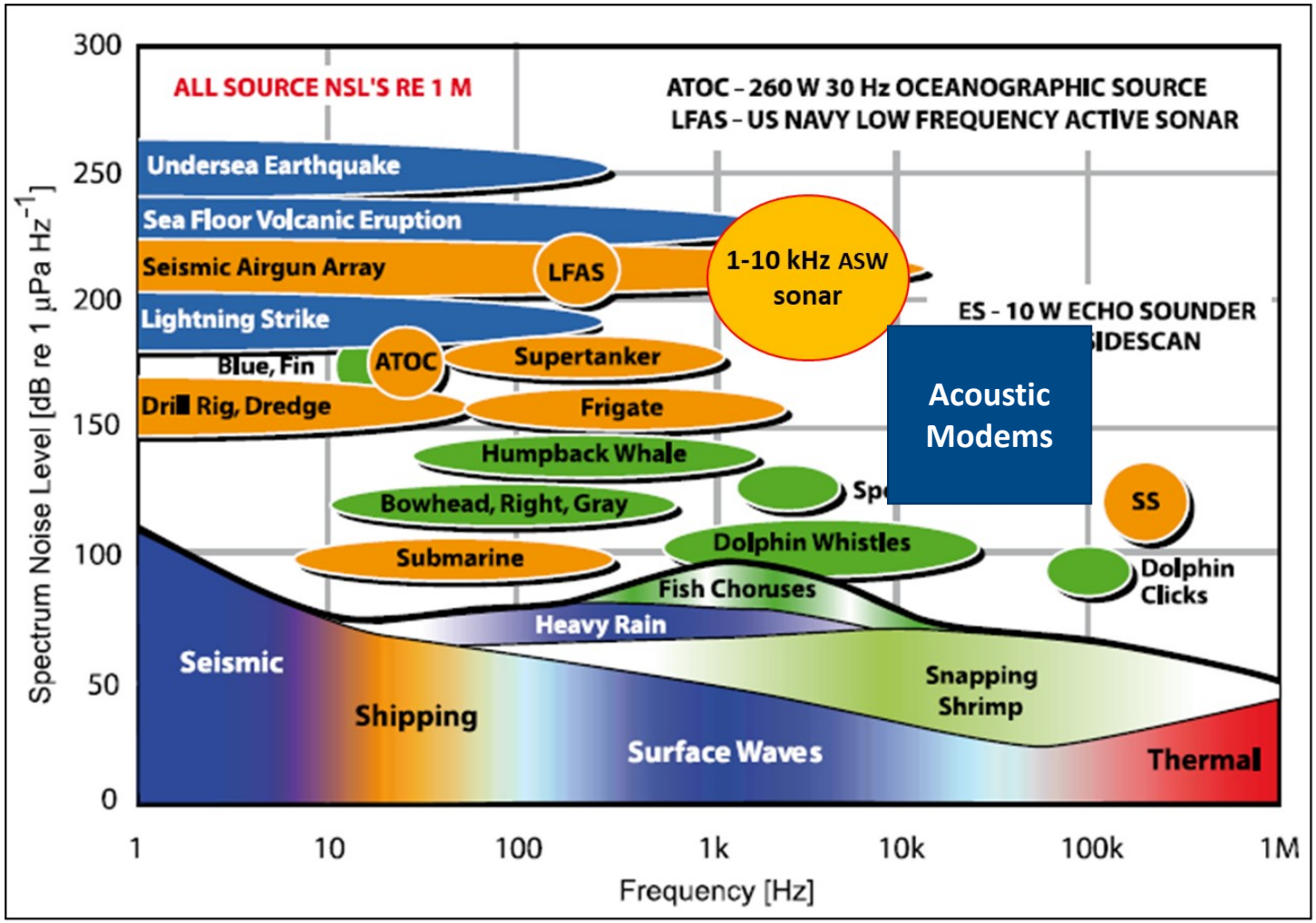
Fig. 2. Example of an IoUT infrastructure for detection and monitoring of NARWs.

Coutinho and Bourkerche, 2021

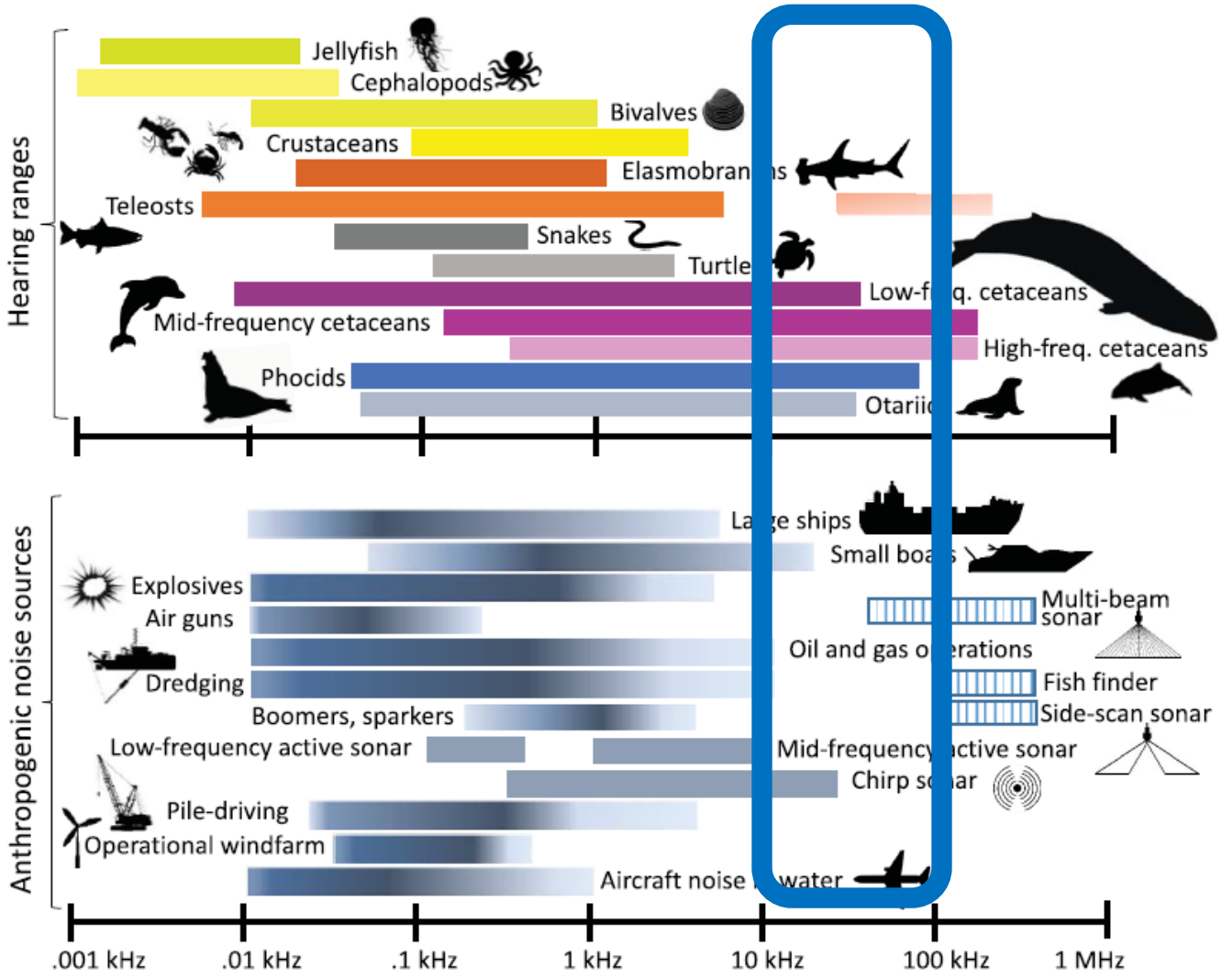
Potential impact from acoustic signalling not addressed!

Problems	Solutions and Effective Methods	Paper Count	References Number
Transmission issues	Methods to preventing path loss and data loss in UIoT networks.	17	[240–256]
Environmental issues	Methods to solve unreliable channel conditions in UIoT networks.	10	[257–266]
	Methods to solve limited resources in UIoT networks.	15	[26,54–64,267–269]
Insecure environment issues	Methods used to support trust management, security management, hardware protection, etc., in UIoT networks.	19	[42,107,113,270–285]
Cost issues	Lost cost design approaches for UIoT networks	15	[87–101]
Channel noise issues	Methods to prevent ambient noise, mammals noise, other environmental noise in UIoT networks. Methods to predict noise level in UIoT networks.	12	[71–82]
Damages in UIoT devices	Methods to prevent internal or external damages of UIoT devices.	9	[26,286–292]
Device or network configuration issues	Methods supporting self-configuration or auto-configuration mechanism for devices in UIoT networks.	4	[26,104–106]

Delphin et al., 2021



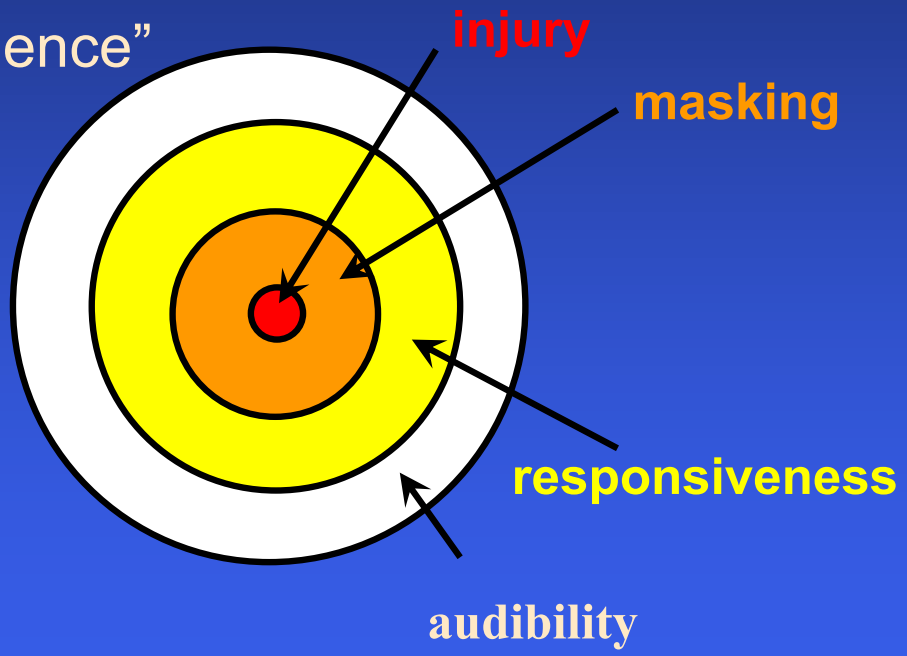
Adapted from Boyd et al., 2008 ESF Marine Board – Oxford 2005

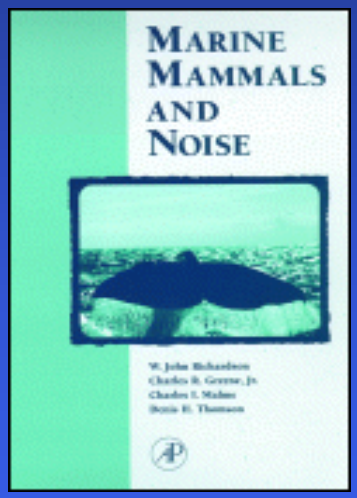


Duarte et al., 2021

U-IoT data transmissions: not the first noise source to face the concern of effects on Marine Mammals

"zones of influence"

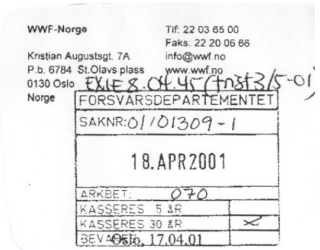




Richardson et al., 1998

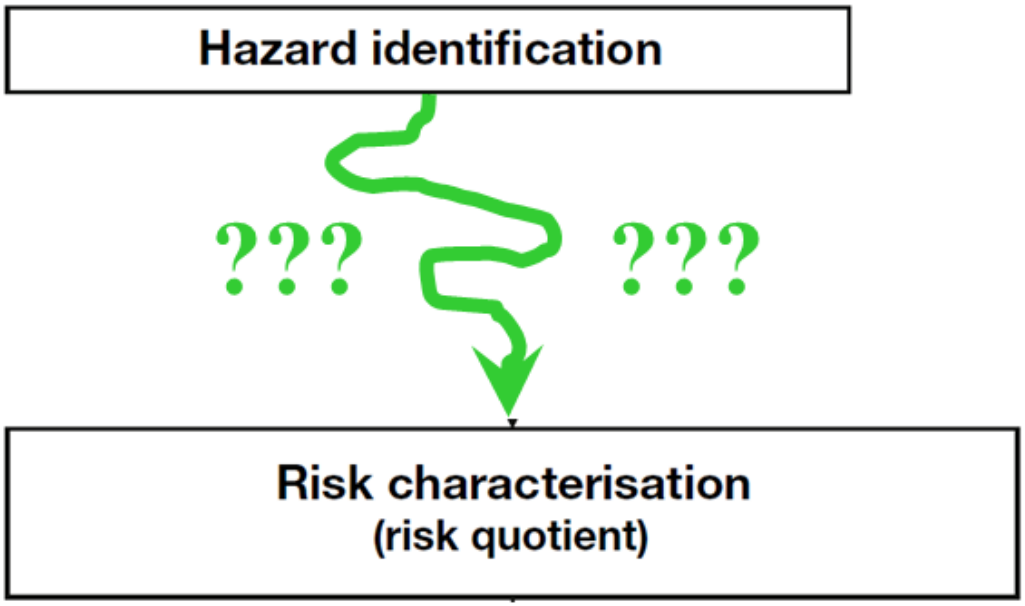
Beaked whales being removed from the beach after a mass stranding, Canary Islands, 2002

Navy sonar: widely recognized that sonar can impact behaviour / physiology in a harmful way

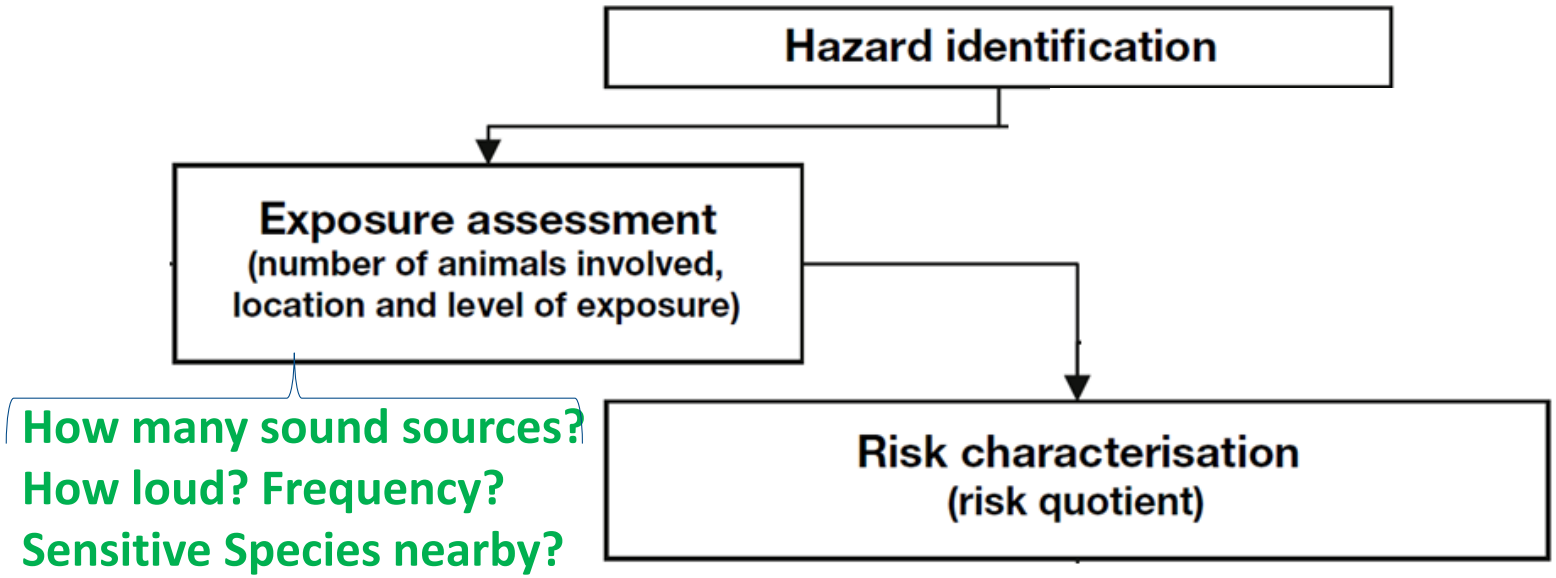


ICES, 2005; NRC, 2005; IACMST, 2006; Nowacek *et al*., 2007; Southall *et al*., 2007; 2009; Boyd *et al*., 2008

Risk-assessment framework

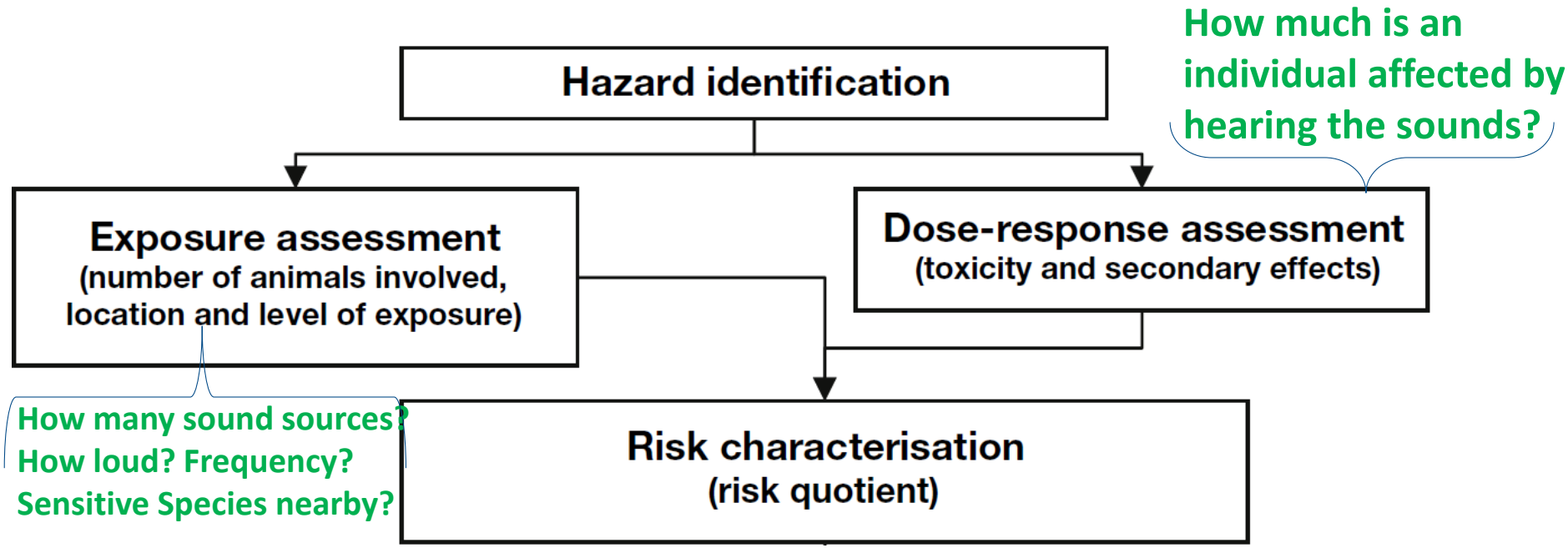


Risk assessment framework

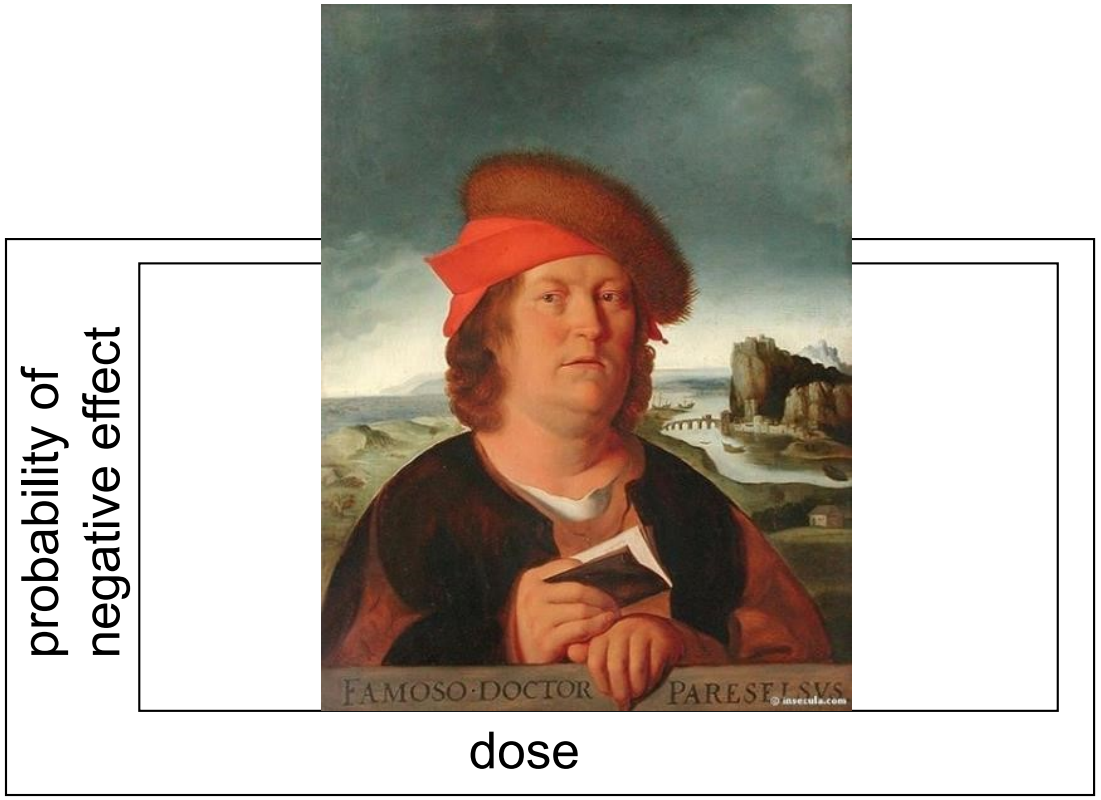


Boyd et al., 2008 ESF Marine Board – Oxford 2005

Risk assessment framework



Dose-response: key for understanding impacts

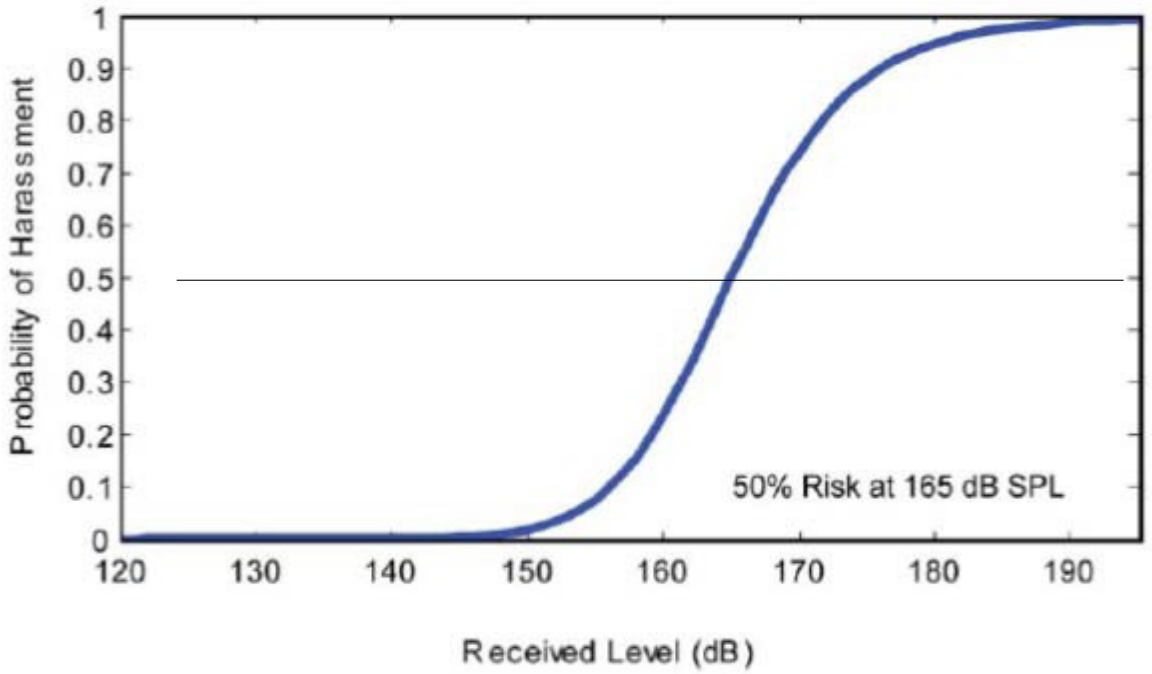


How loud is the sound at the animal?

"All substances are poisons: there is none which is not a poison. The right dose differentiates a poison and a remedy."

Paracelsus (1493-1541)

Dose-response: key for understanding impacts

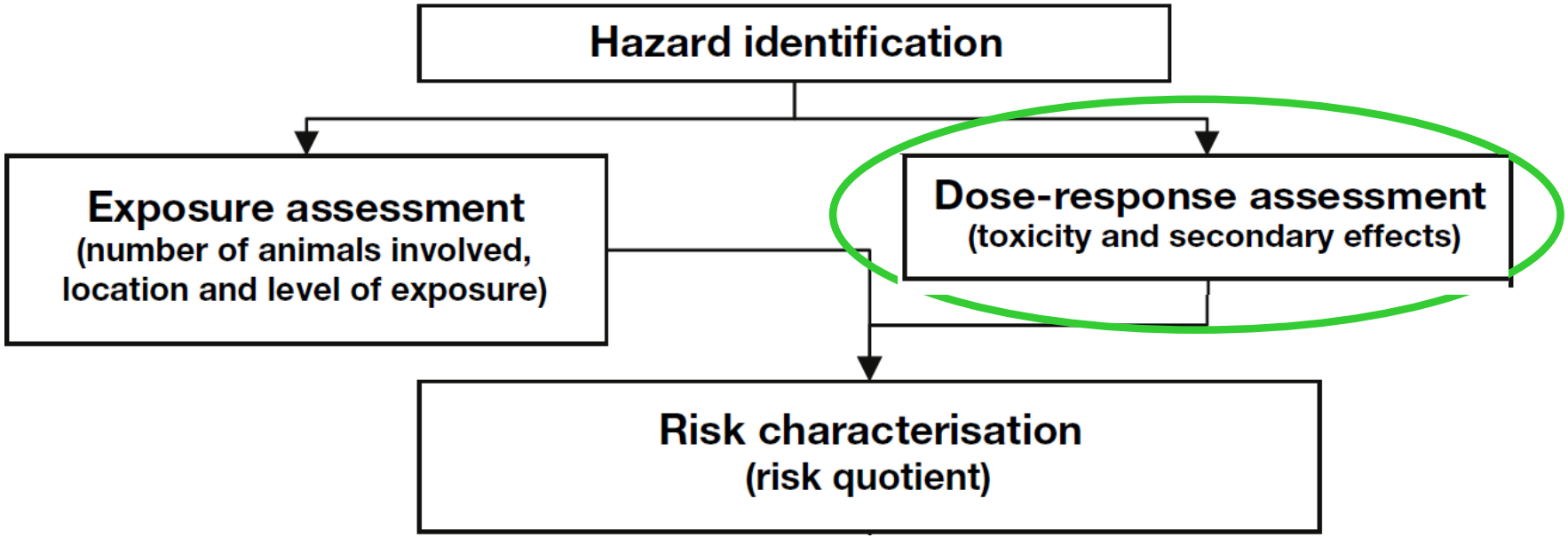


How loud is the sound at the animal?

Harassing a cetacean is illegal in the USA.

Marine Mammal Protection Act

US Navy EIS (2008)



US Navy EIS (2008)

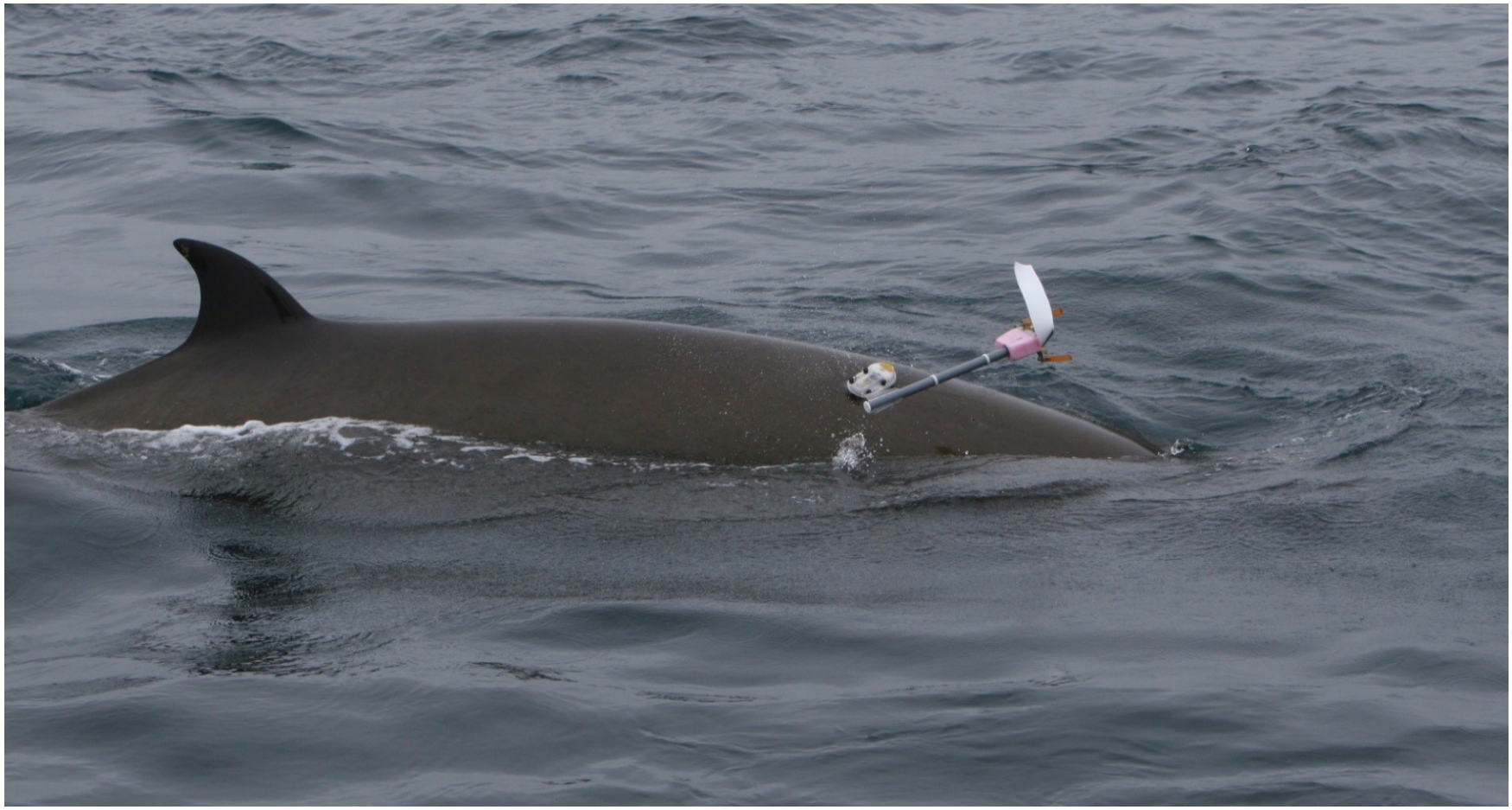
Behavioural Response Studies

Sound and movement recording tag

Tag a random 'representative' whale subject

Tagged focal whale visual observations:
- **location &**
- **social context**
- **mitigation**

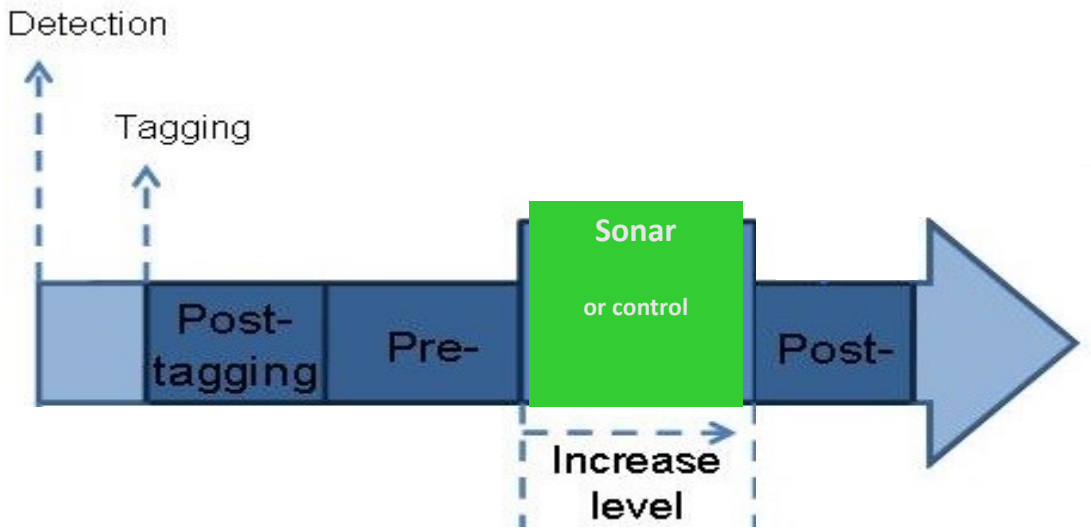
1-2 kHz
'LFAS'
214 dB max source level



Dtag deployed onto northern bottlenose whale
at 15m distance using ARTS launching system

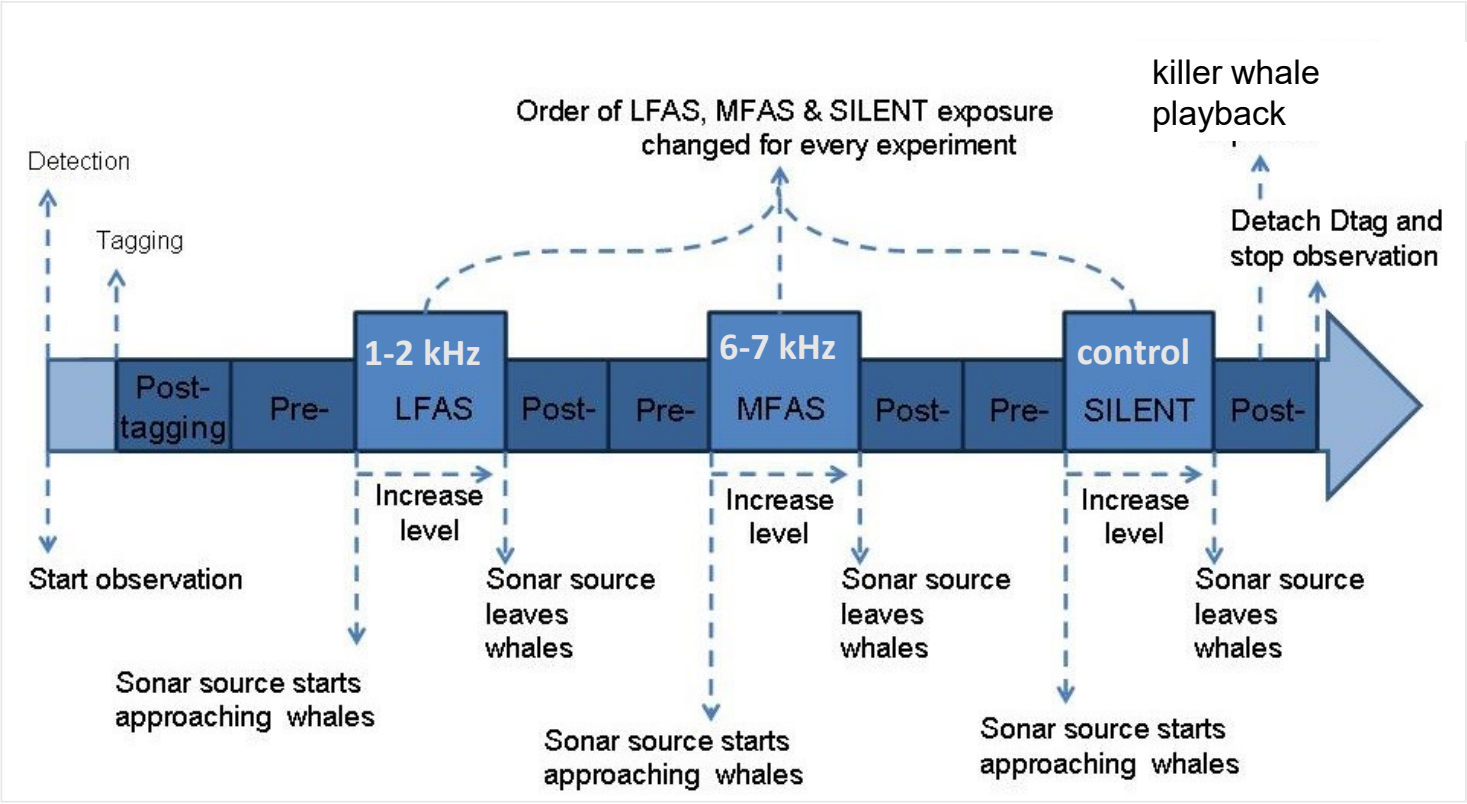
Behavioral Response Studies: Experimental design

single-exposure version



Behavioral Response Studies - Experimental design

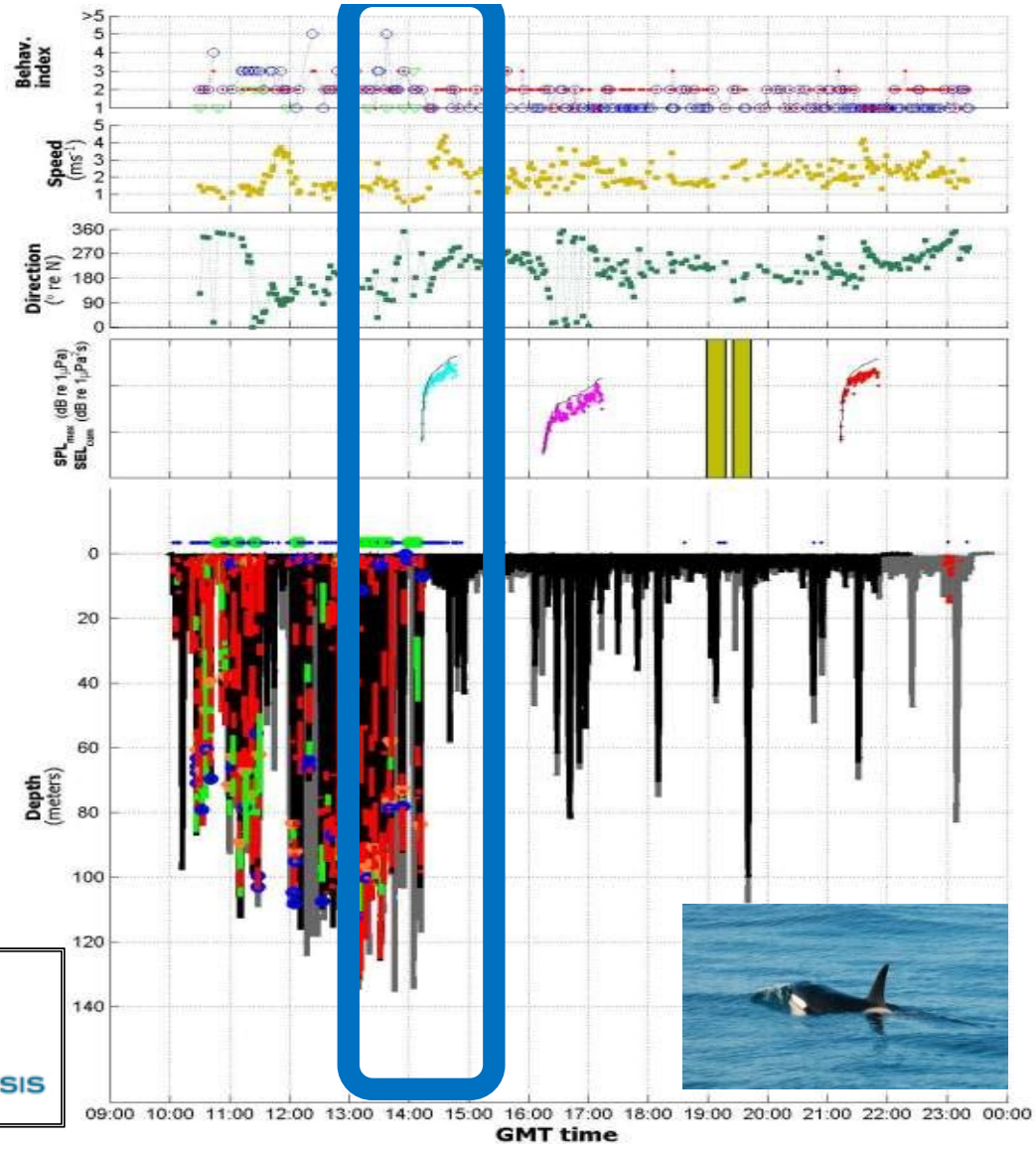
Multiple-exposure version



Rich observations

- natural patterns
- multi-variate, time-series
- cross / auto-correlation

- Analytical challenge!!!

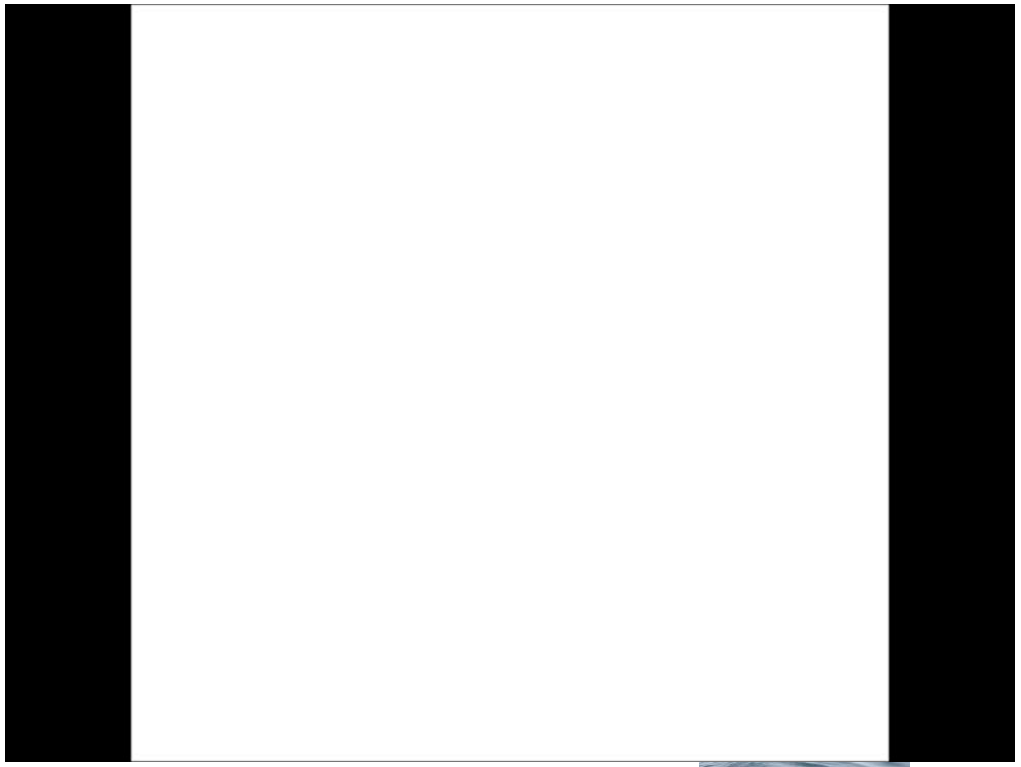


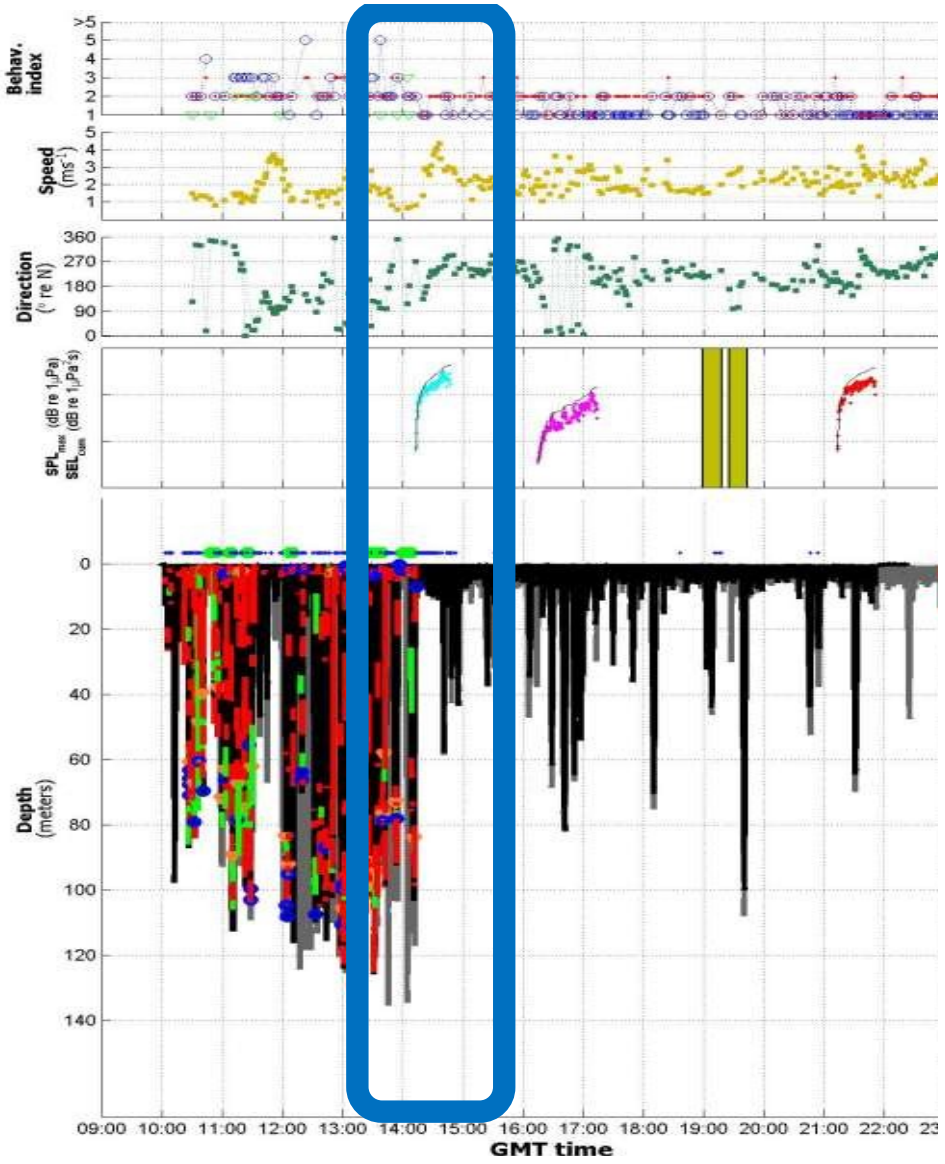
MOCHA

MULTI-STUDY OCEAN ACOUSTICS HUMAN EFFECTS ANALYSIS

Behavioural Responses: disruption of ongoing behavior

8 km

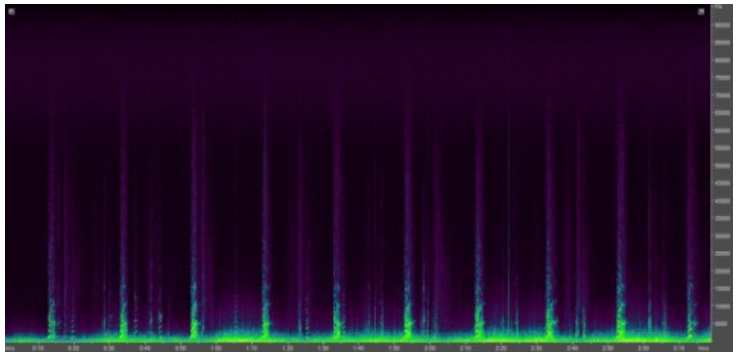


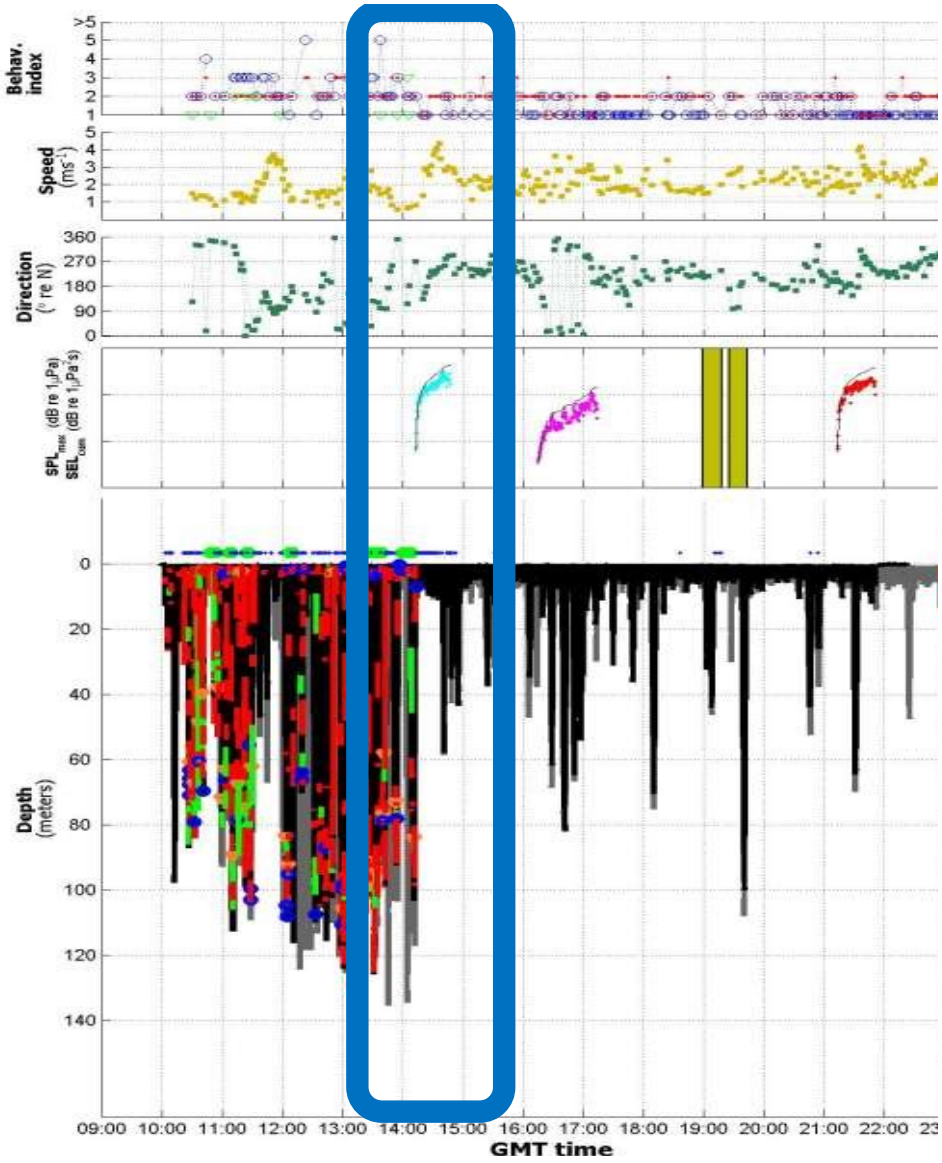


Behavioural Responses: disruption of ongoing behavior

Responses started:
94dB re 1Pa
(very low level)

Ping-by-ping calling





Dose-response relationships for the onset of avoidance of sonar by free-ranging killer whales

Miller et al., 2014. J Acoust Soc Am

What Behavioral Response Studies have taught us: and what it means for U-IoT

What Behavioral Response Studies have taught us: and what it means for U-IoT

- Cessation of feeding and avoidance of NOISE is common

  → Adding noise is a form of habitat degradation

Ecological Applications, 26(1), 2016, pp. 77–93

Sperm whales reduce foraging effort during exposure to 1–2 kHz sonar and killer whale sounds

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Research

Cite this article: Miller PJO et al. 2015 First indications that northern bottlenose whales are sensitive to behavioural disturbance from anthropogenic noise. R. Soc. open sci. 2: 140484. http://dx.doi.org/10.1098/rsos.140484

Received: 9 December 2014
Accepted: 8 May 2015

First indications that northern bottlenose whales are sensitive to behavioural disturbance from anthropogenic noise

P. J. O. Miller[1], P. H. Kvadsheim[2], F. P. A. Lam[3], P. L. Tyack[1], C. Curé[4], S. L. DeRuiter[5], L. Kleivane[2], L. D. Sivle[6], S. P. van IJsselmuide[3], F. Visser[7,8], P. J. Wensveen[1], A. M. von Benda-Beckmann[3], L. M. Martín López[1], T. Narazaki[1] and S. K. Hooker[1]

Dose-response relationships for the onset of avoidance of sonar by free-ranging killer whales

esa ECOSPHERE

Vol. 562: 211–220, 2016
doi: 10.3354/meps11969

MARINE ECOLOGY PROGRESS SERIES
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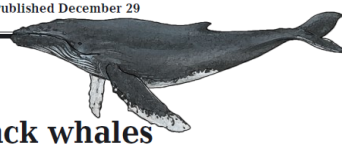
Published December 29



Individual, ecological, and anthropogenic influences on activity budgets of long-finned pilot whales

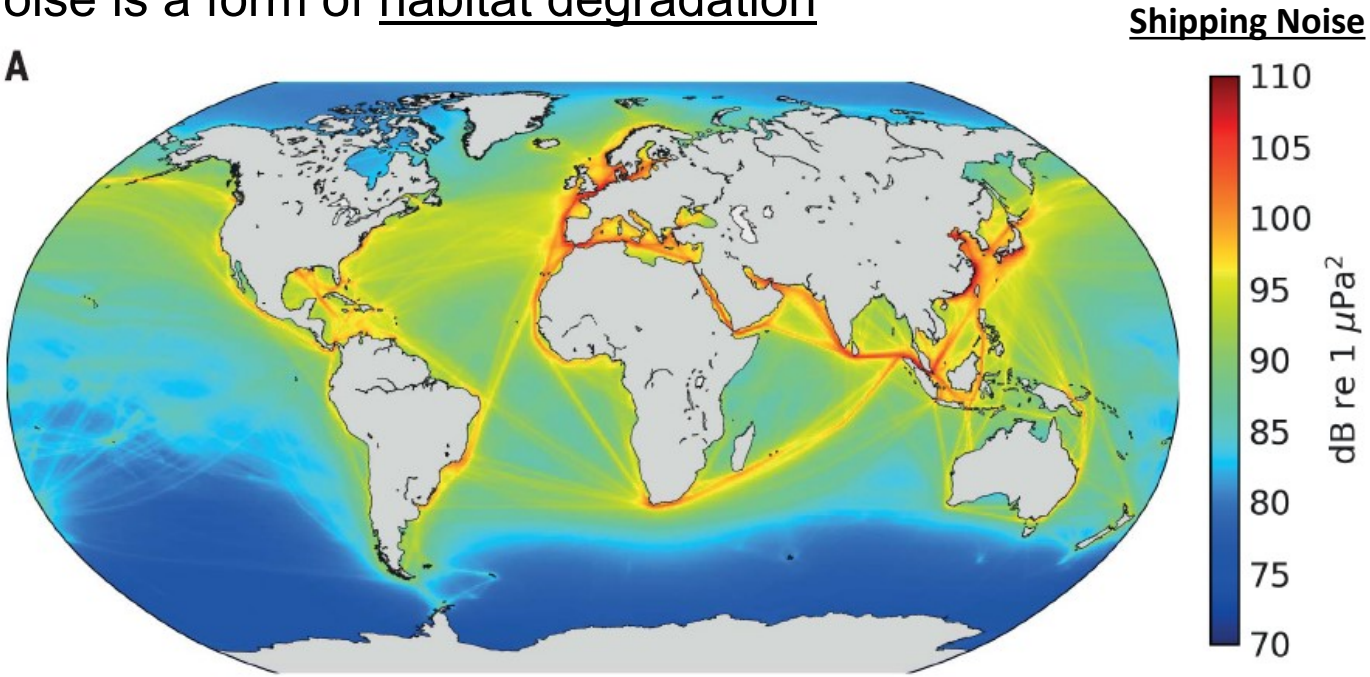
S. Isojunno, D. Sadykova, S. DeRuiter, C. Curé, F. Visser, L. Thomas, P. J. O. Miller and C. M. Harris

Naval sonar disrupts foraging in humpback whales

Lise Doksæter Sivle[1,*], Paul J. Wensveen[2], Petter H. Kvadsheim[3], Frans-Peter A. Lam[4], Fleur Visser[5,6], Charlotte Curé[7], Catriona M. Harris[8], Peter L. Tyack[2], Patrick J. O. Miller[2]

What Behavioral Response Studies have taught us: and what it means for U-IoT

- Cessation of feeding and avoidance of the sounds is common
  → Adding noise is a form of habitat degradation



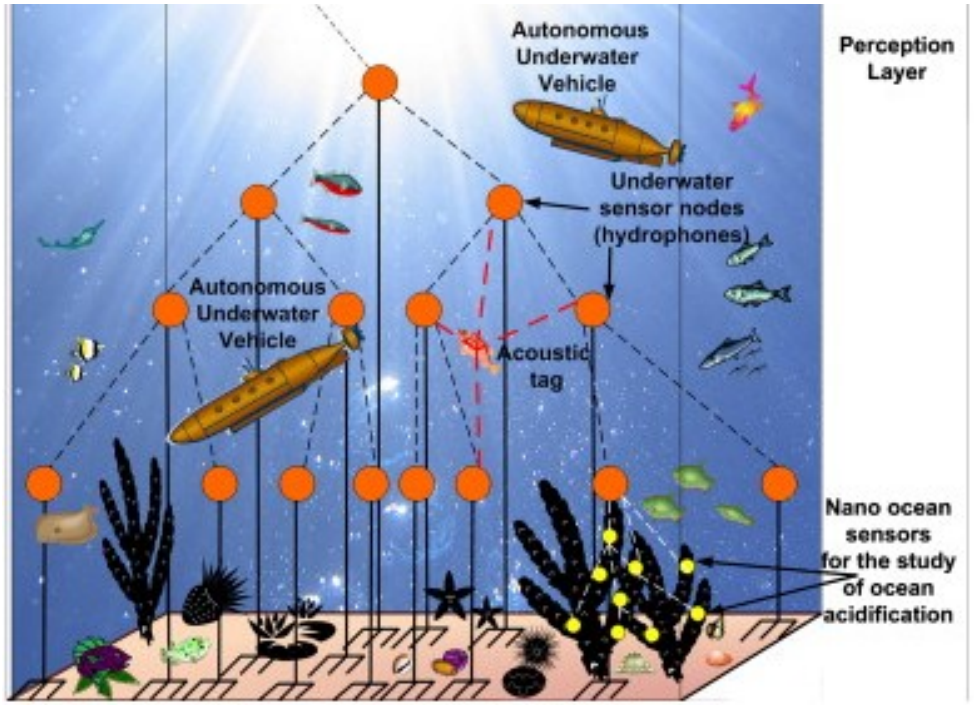
Duarte et al., 2021

→ “Mammal-Friendly” U-IoT ←
standards that could reduce impacts:

Key Point 1: every transmission has an “environmental cost”

- **minimize transmissions, use cables whenever feasible (relay to surface sinks)**

Data Modem Sound



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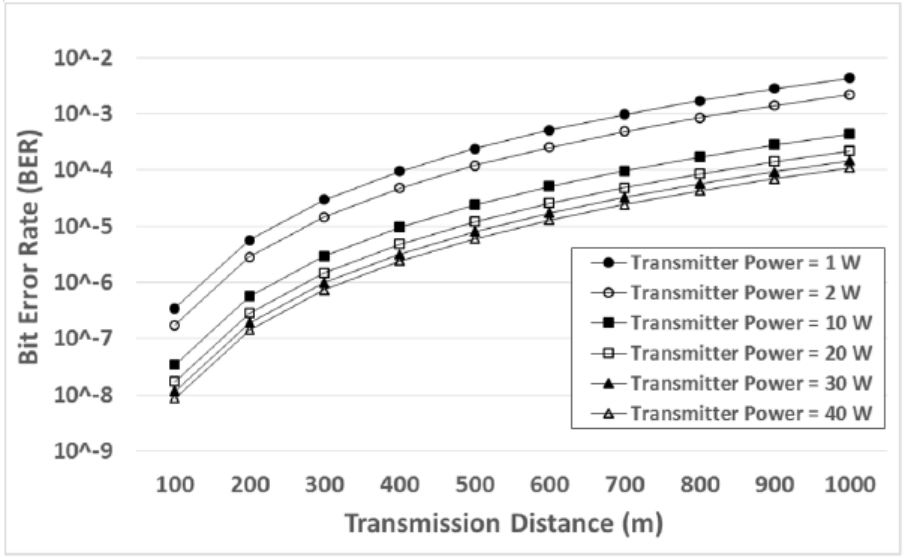
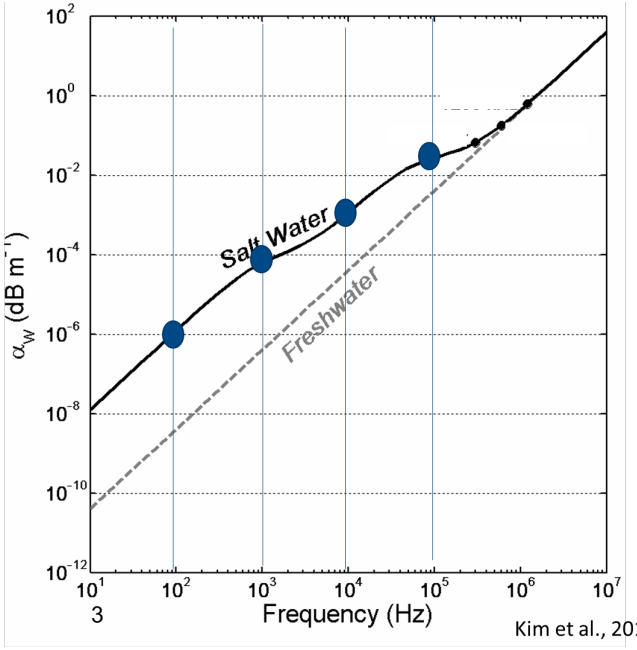


Kao et al., 2017



Kim et al., 2011

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- **avoid areas with sensitive species, age-classes**

Harbor porpoise

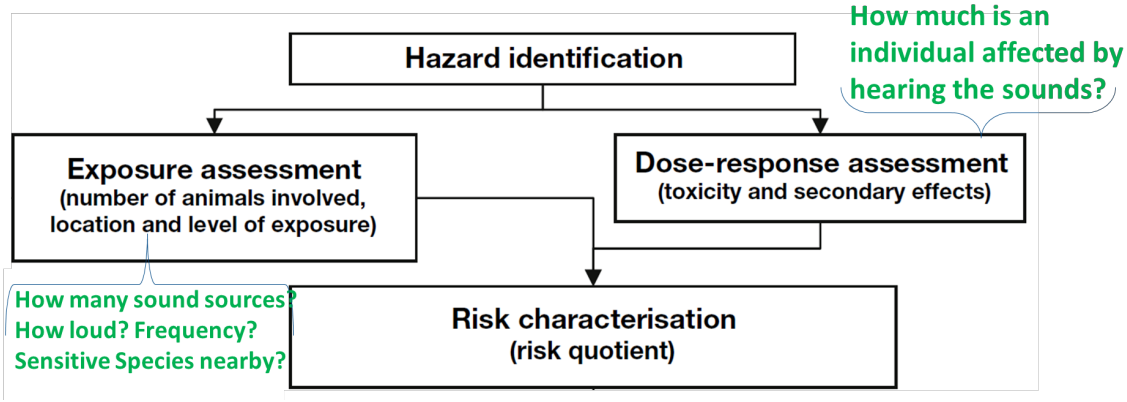
Beaked whales

→ “Mammal-Friendly” U-IoT ←
standards that could reduce impacts:

Key Point 1: every transmission has an “environmental cost”

- **minimize transmissions, use cables whenever feasible**
- **minimum source level, higher frequency, directional transmission**
- **avoid areas with sensitive species, age-classes**

Key Point 2: Environmental Impact Assessments should be done!




Thank
you!!