

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

Recommendations for U-IoT standards



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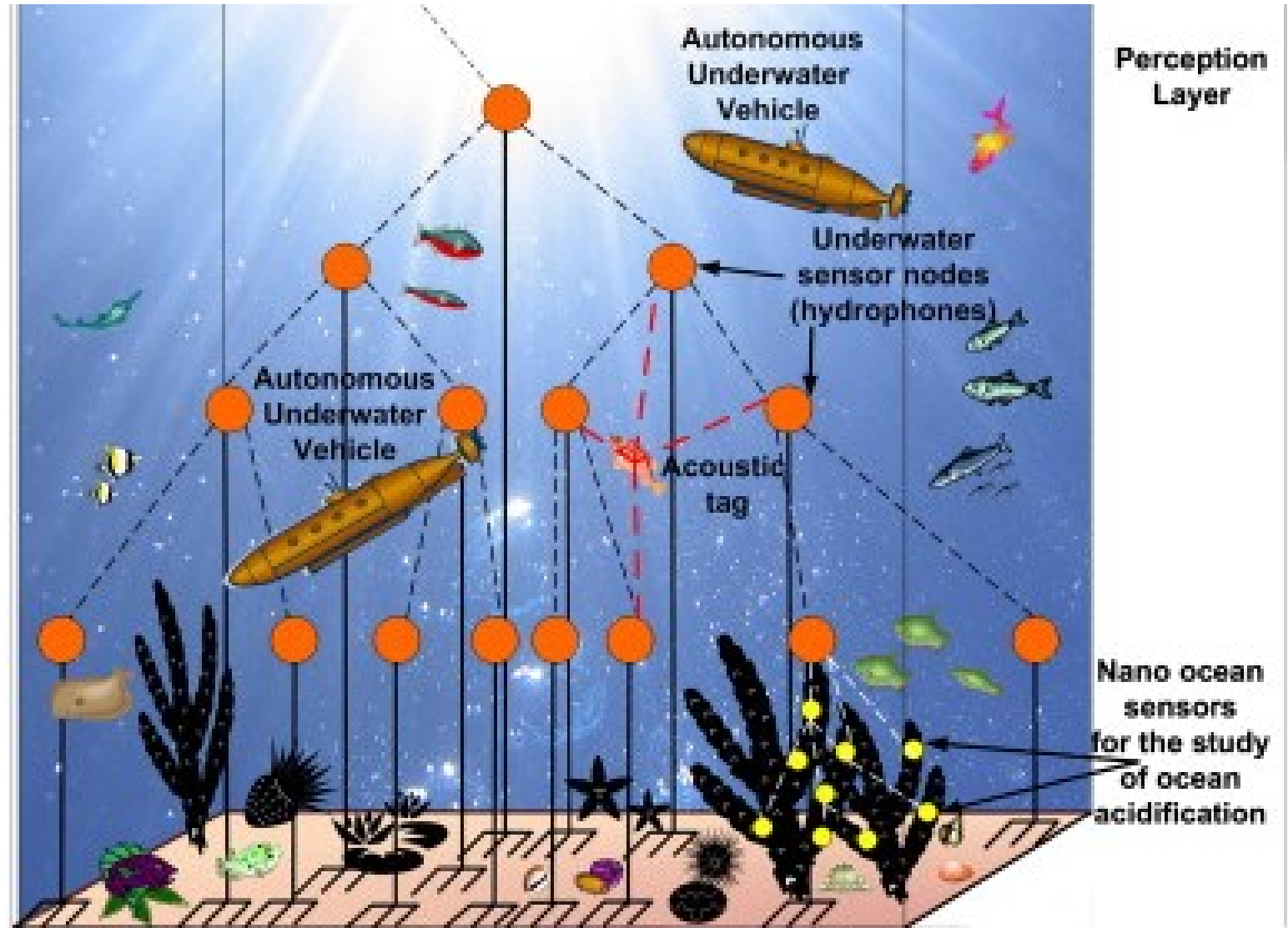
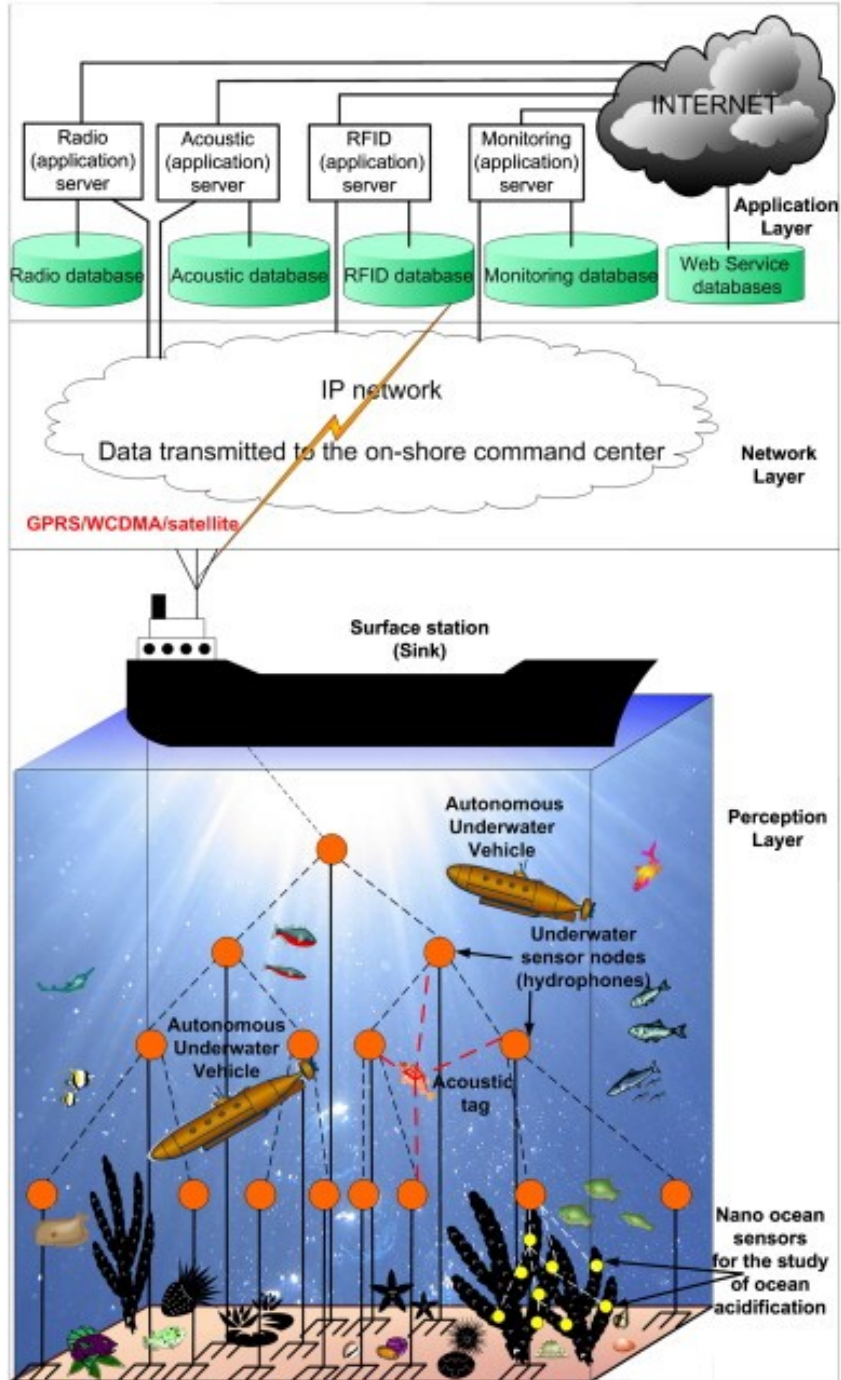


Bottlenose whales near Jan Mayen

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**
- **“Mammal-Friendly”** ← **standards could reduce impacts:**
- **minimize transmissions, use cables whenever feasible**
 - **minimum source level, higher frequency, directional transmission**
 - **avoid areas with sensitive species, age-classes**



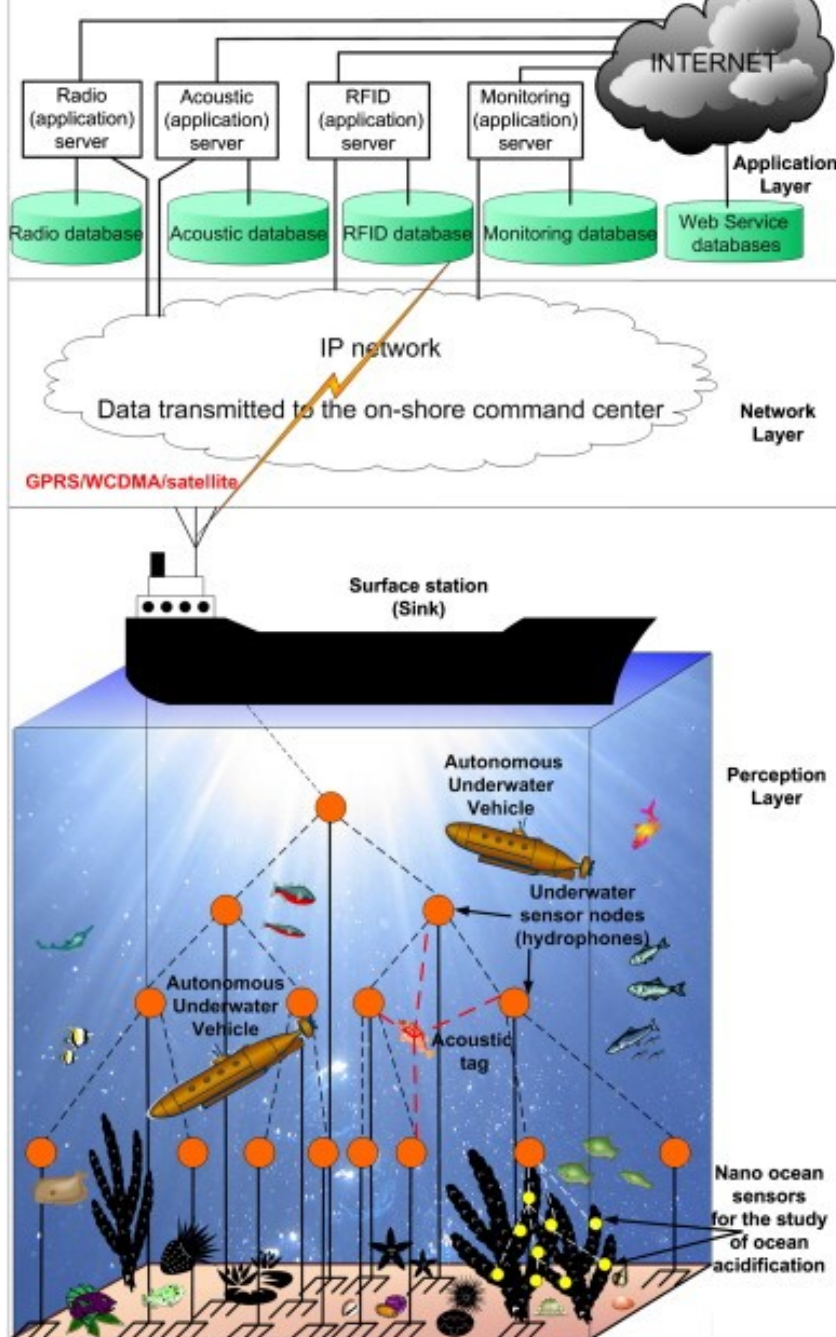


TABLE I THE DIFFERENCES BETWEEN TWSNS AND UWSNS

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

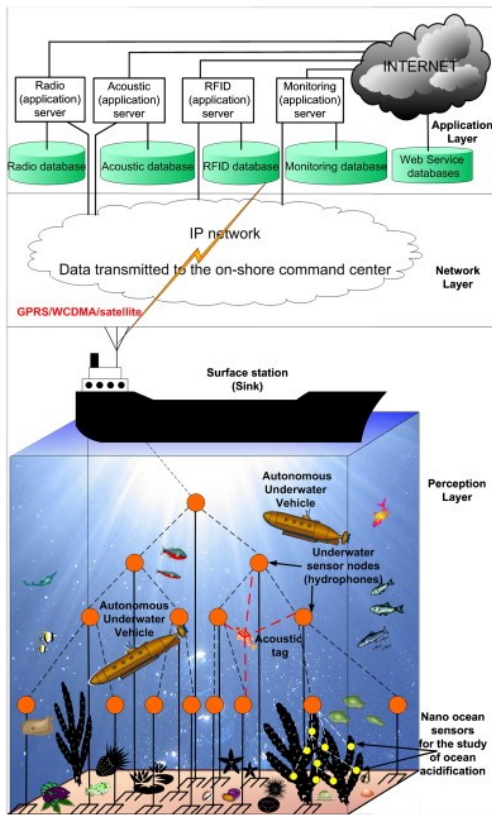
Potential harms:

radiation

Risk to Divers

Animals also use sound!

U-IoT can aid environmental monitoring



Domingo, 2012

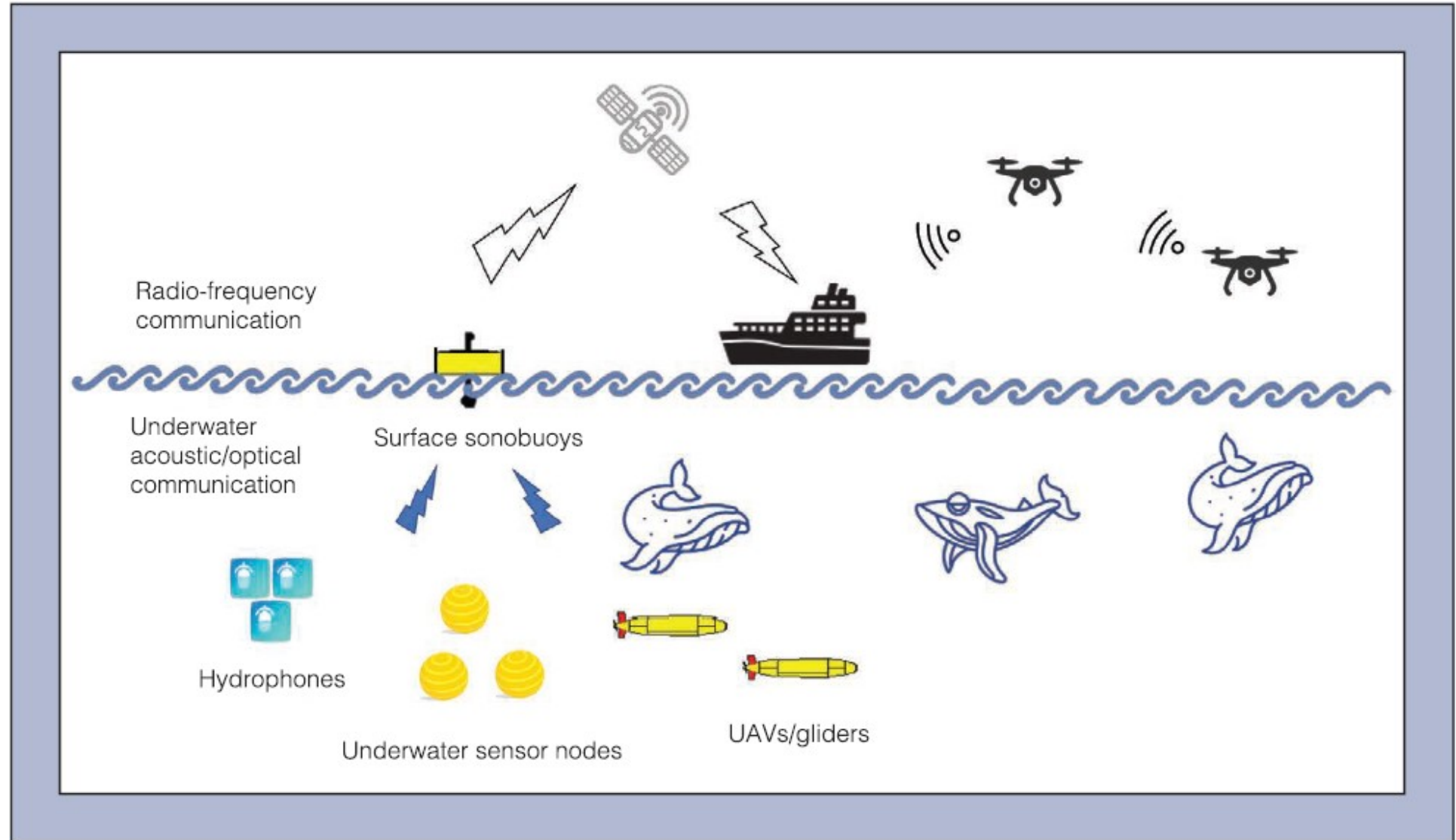
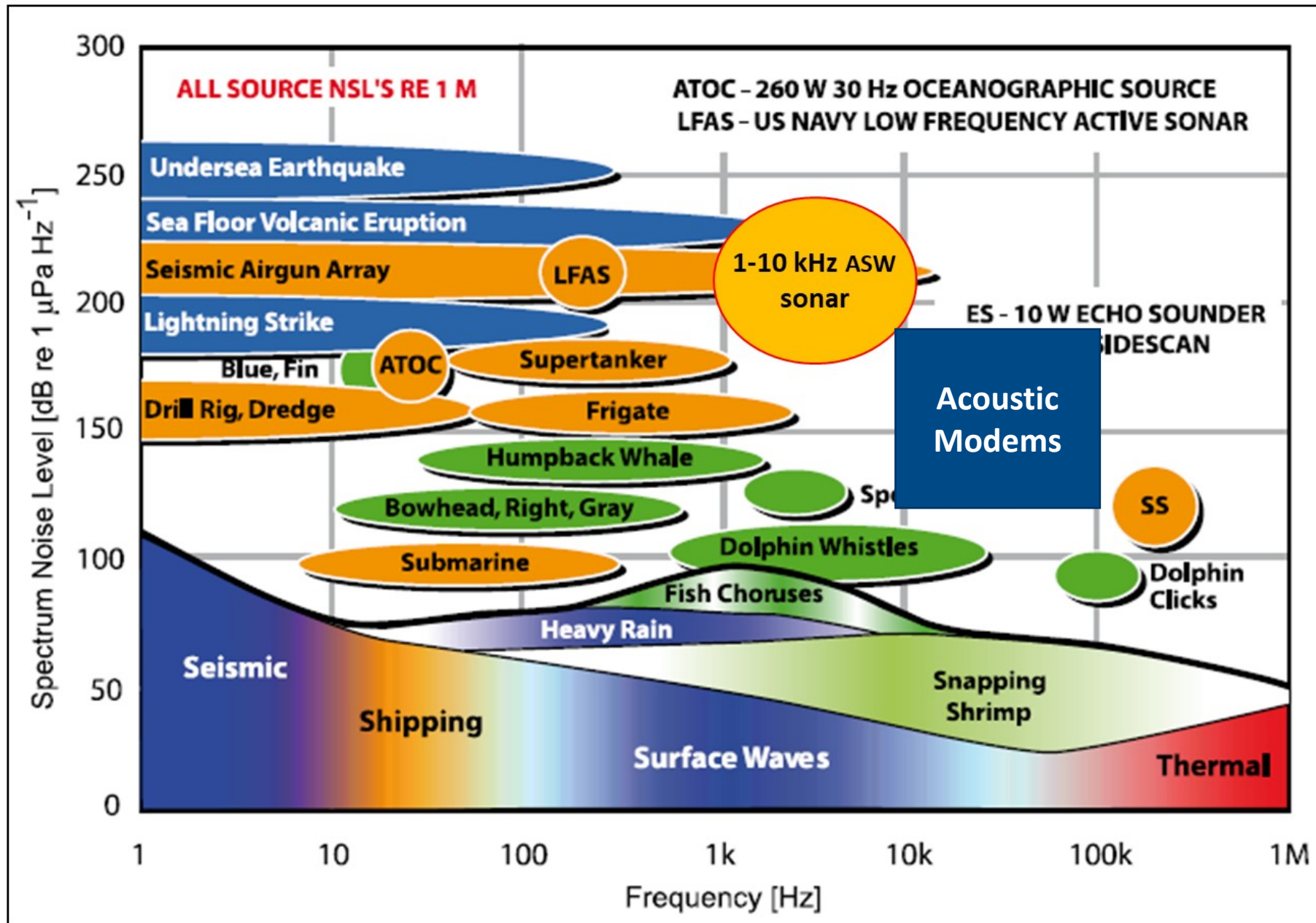


Fig. 2. Example of an IoT infrastructure for detection and monitoring of NARWs.

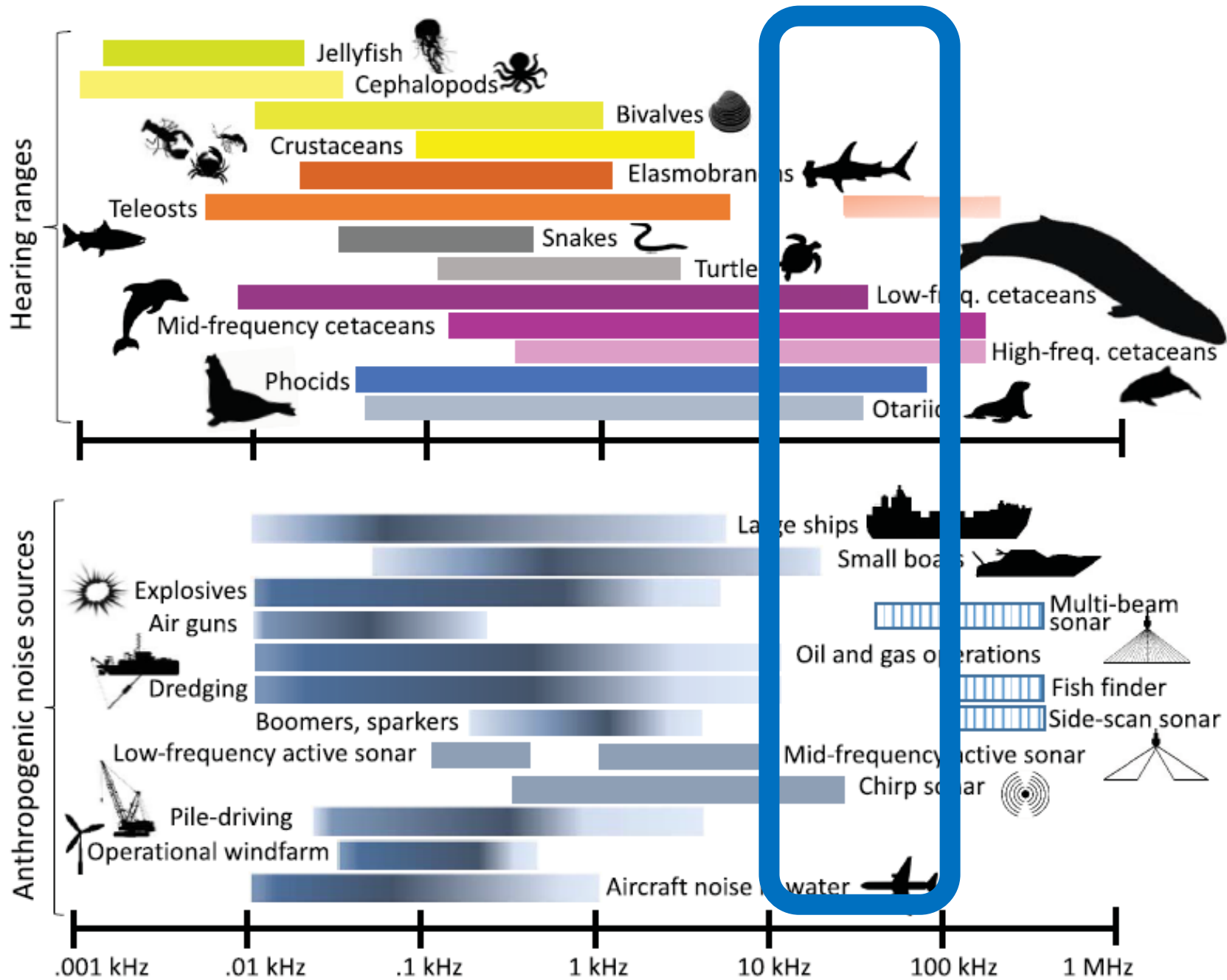
Coutinho and Bourkerche, 2021

Potential impact from acoustic signalling not addressed!

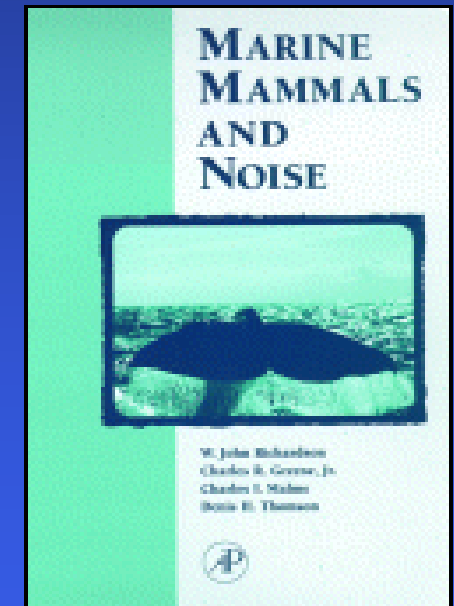
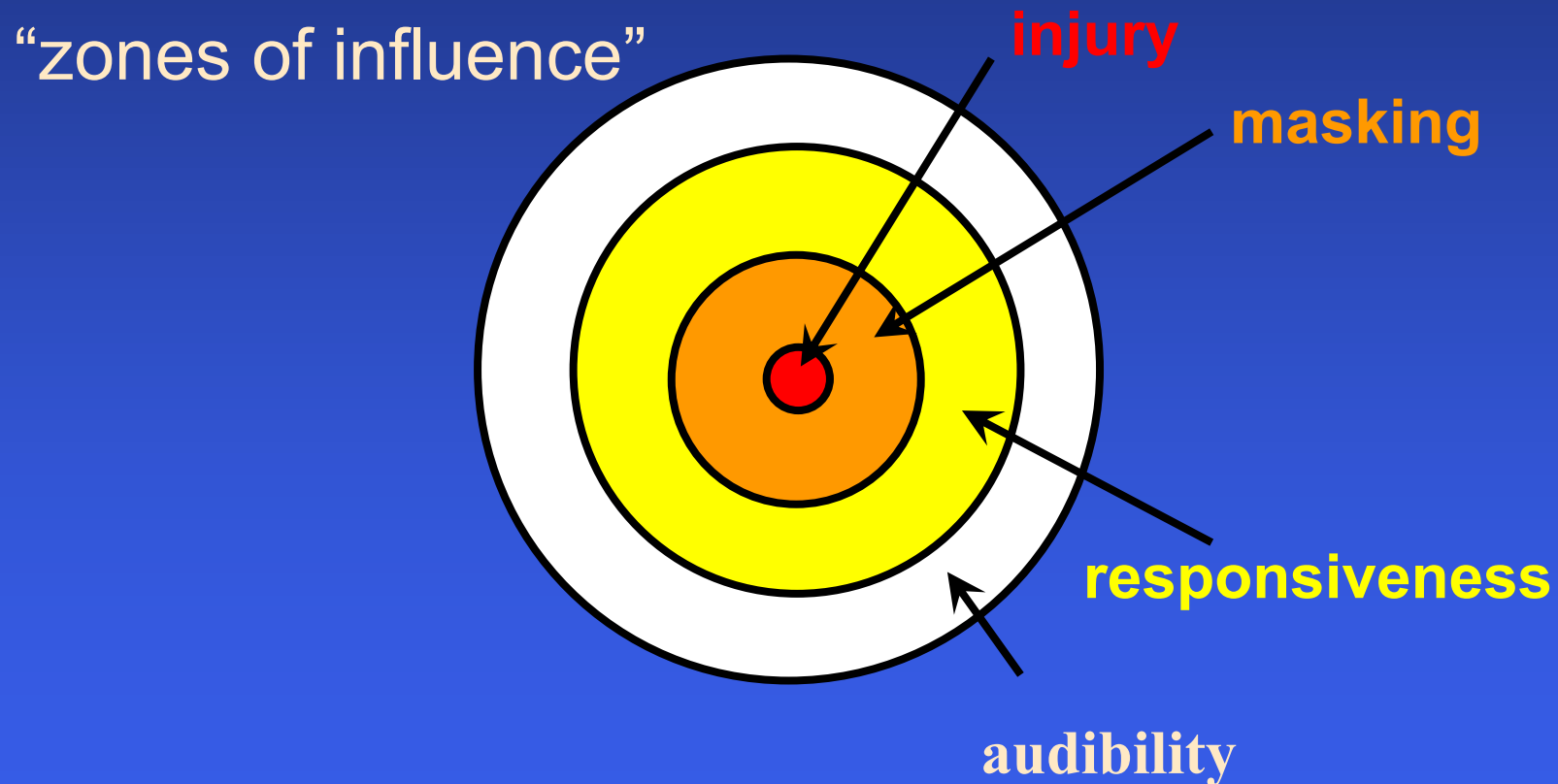
Problems	Solutions and Effective Methods	Paper Count	References Number
Transmission issues	Methods to preventing path loss and data loss in UIoT networks.	17	[240–256]
Environmental issues	Methods to solve unreliable channel conditions in UIoT networks.	10	[257–266]
	Methods to solve limited resources 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]



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



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



Richardson et al., 1998

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



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

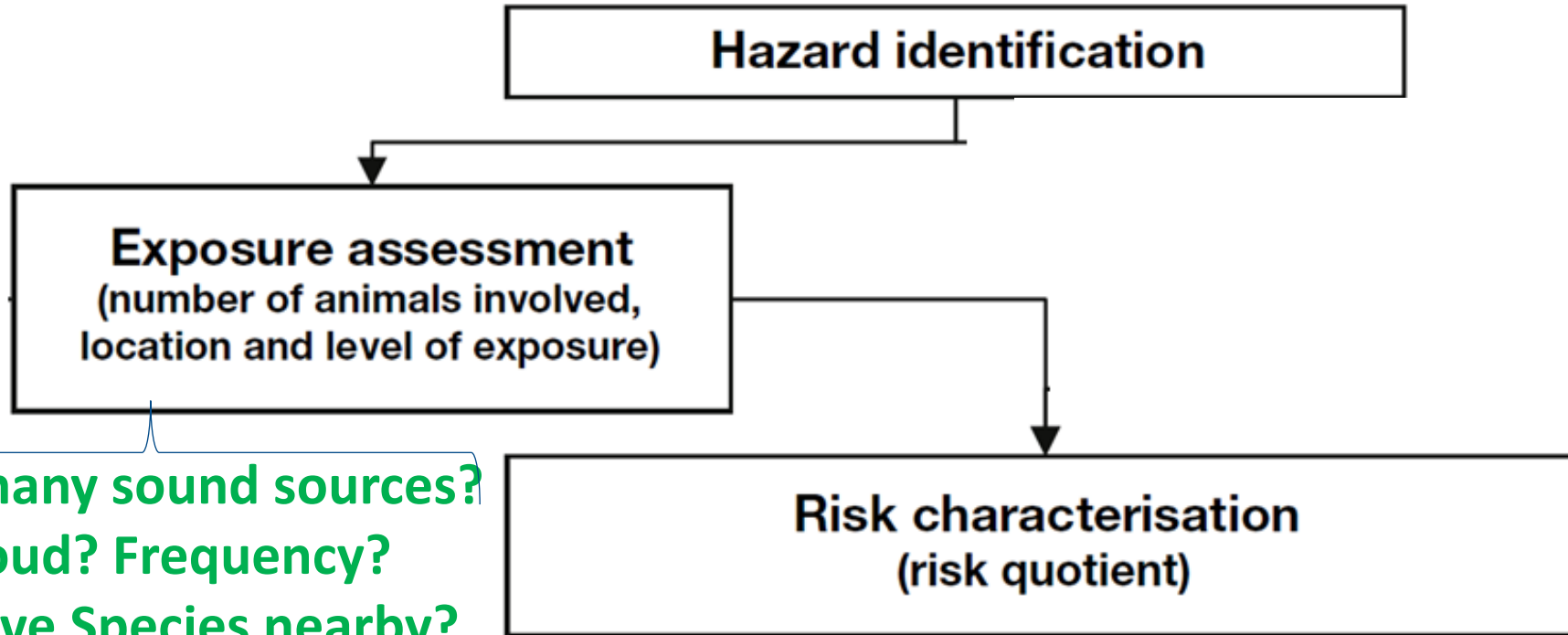


Forsvarsdepartementet
Boks 8126 Dep
00032 Oslo

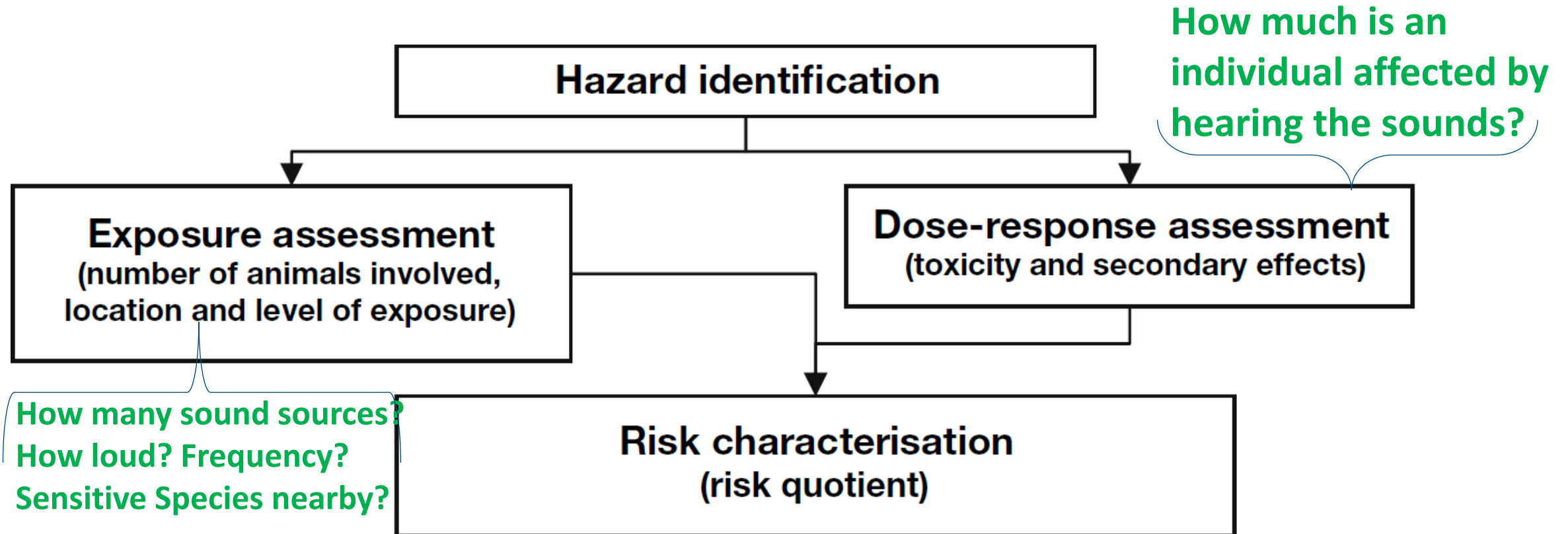
WWF-Norge Tlf: 22 03 65 00
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P. b. 6784 St.Olavs plass www.wwf.no
0130 Oslo EXLE 8.04.01 (Inst 3/5-01)
Norge FORSVARSDEPARTEMENTET
SAKNR: 01/01309-1
18. APR 2001
ARKBET: 070
KASSERES 5 KR
KASSERES 30 KR
BEV: 06.17.04.01

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

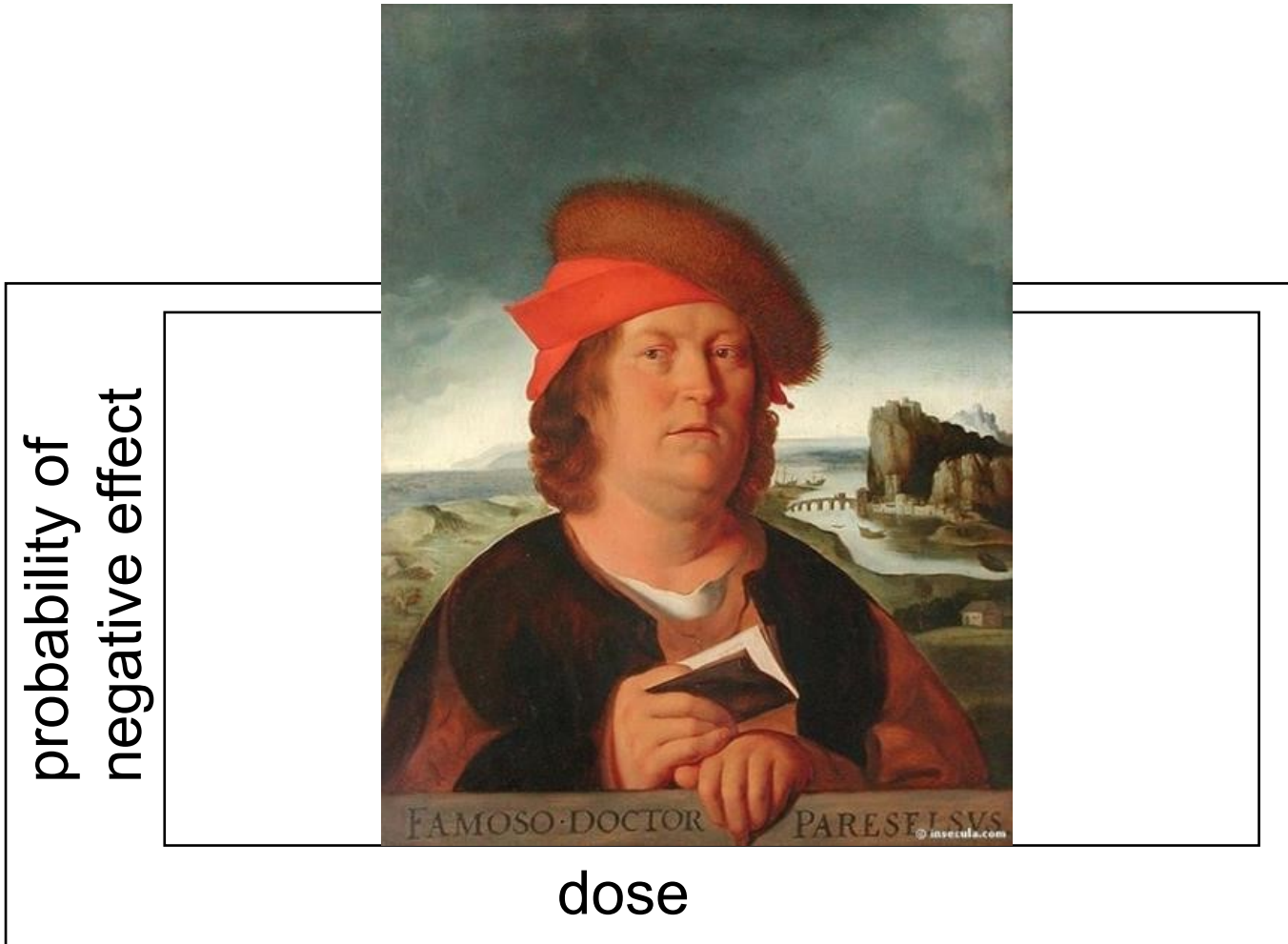
Risk assessment framework



Risk assessment framework



Dose-response: key for understanding impacts

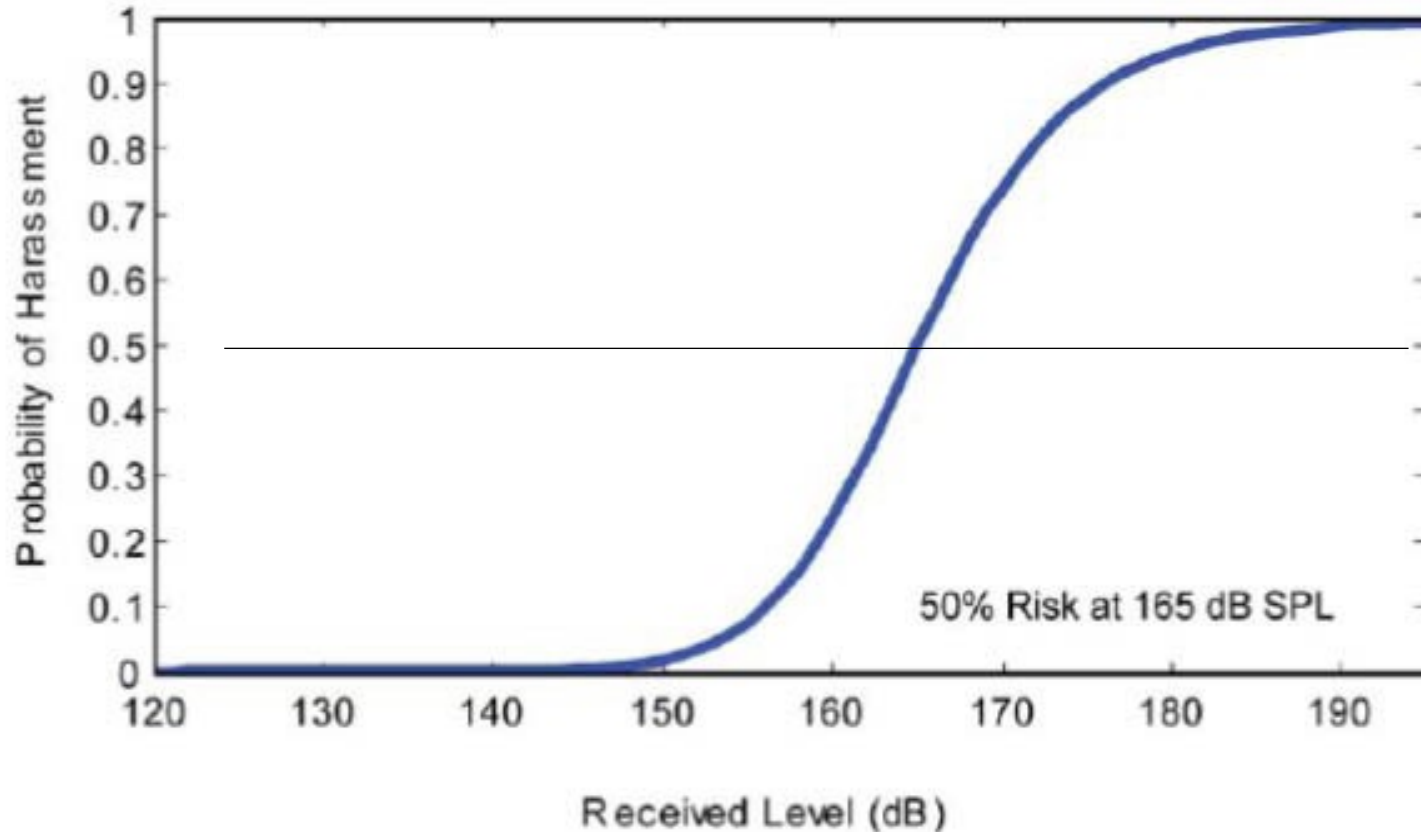


“All substances are poisons: there is none which is not a poison. The right dose differentiates a poison and a remedy.”

Paracelsus (1493-1541)

How loud is the sound at the animal?

Dose-response: key for understanding impacts

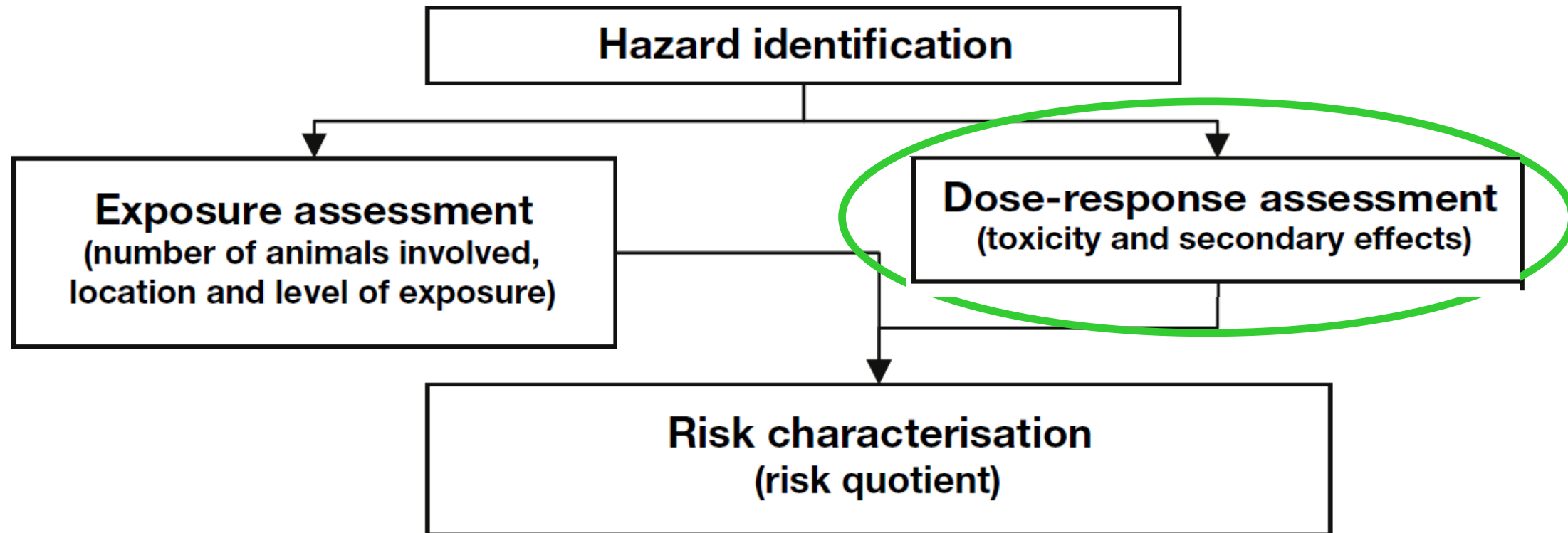


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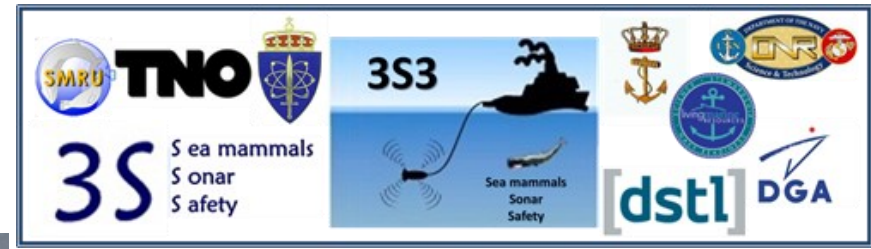
Harassing a cetacean is illegal in the USA.

Marine Mammal Protection Act

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



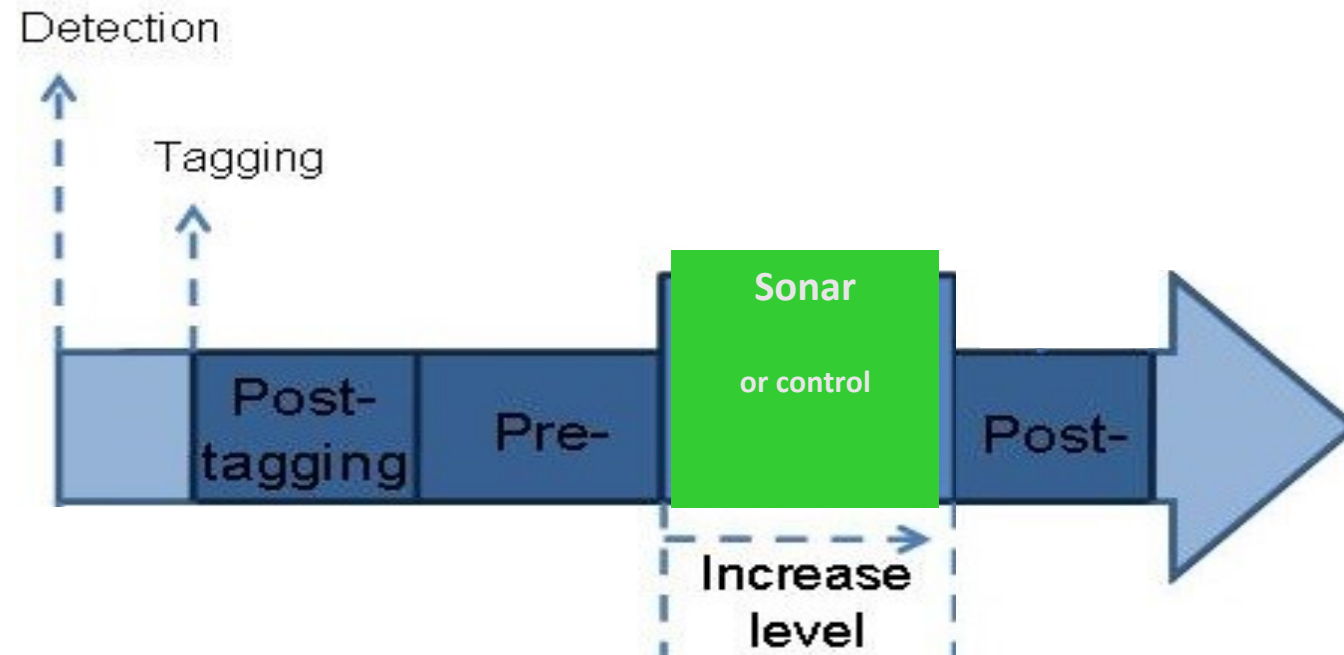
Sonar source



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

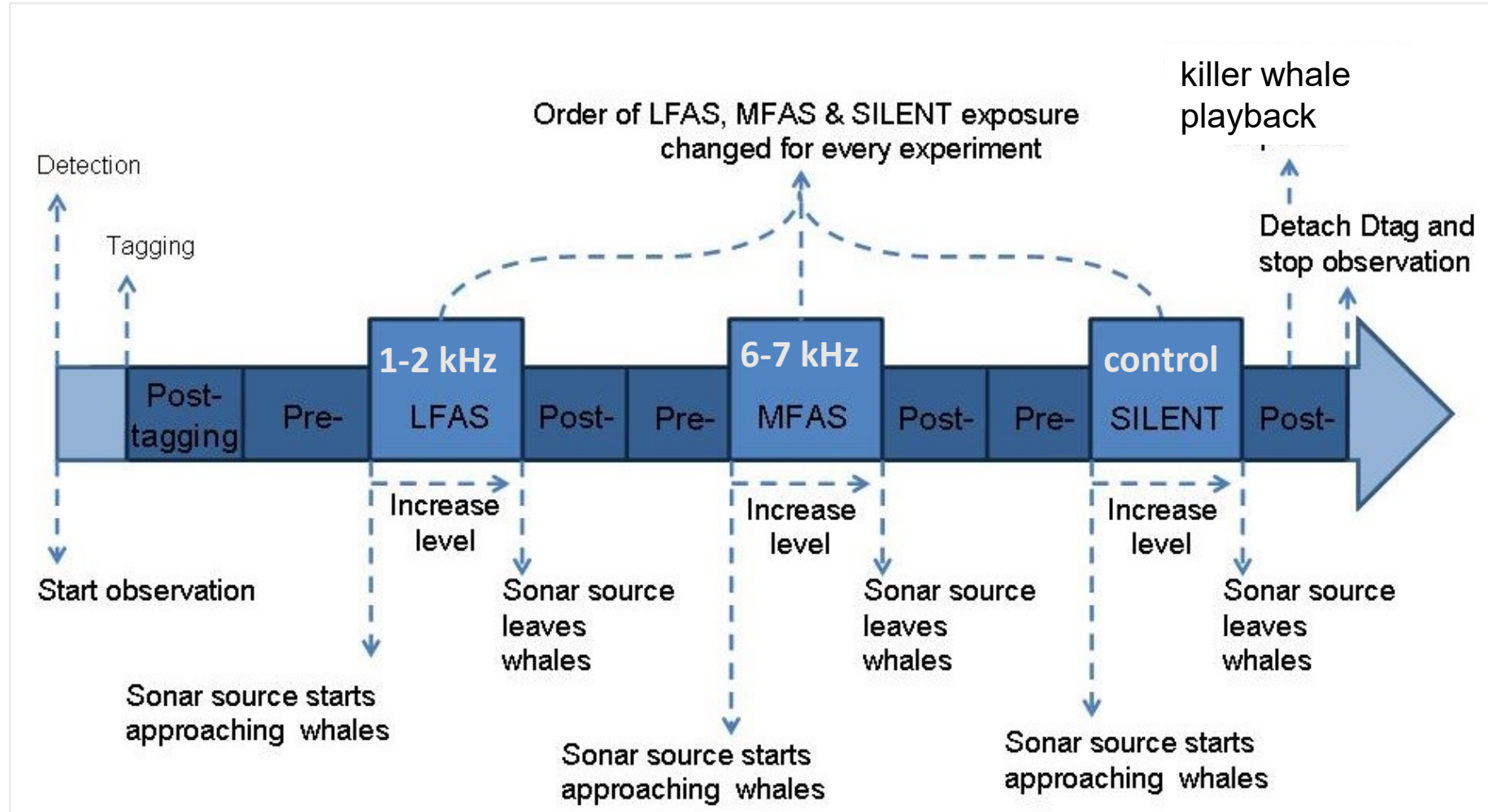
Behavioral Response Studies: Experimental design

single-exposure version



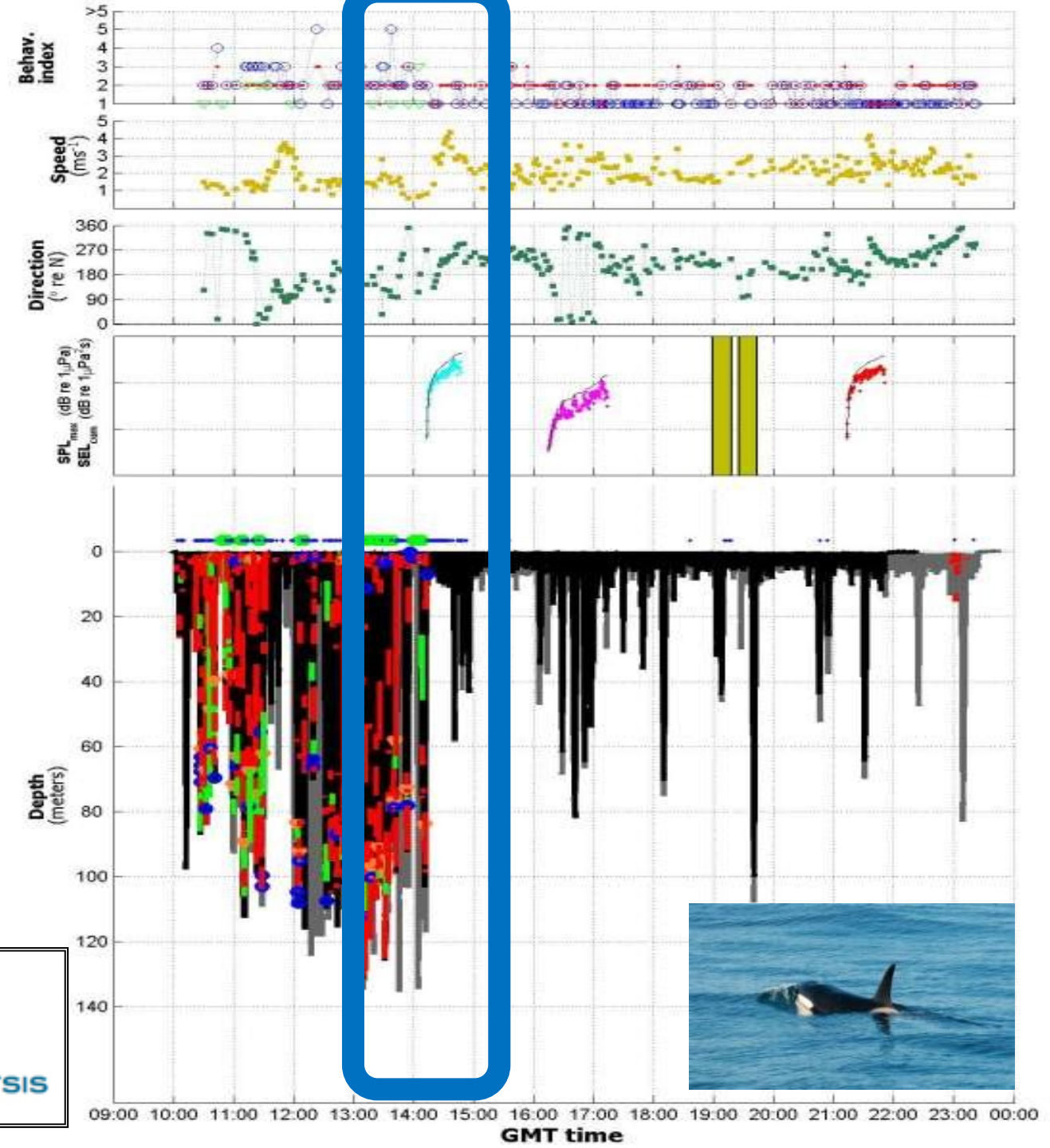
Behavioral Response Studies - Experimental design

Multiple-exposure version



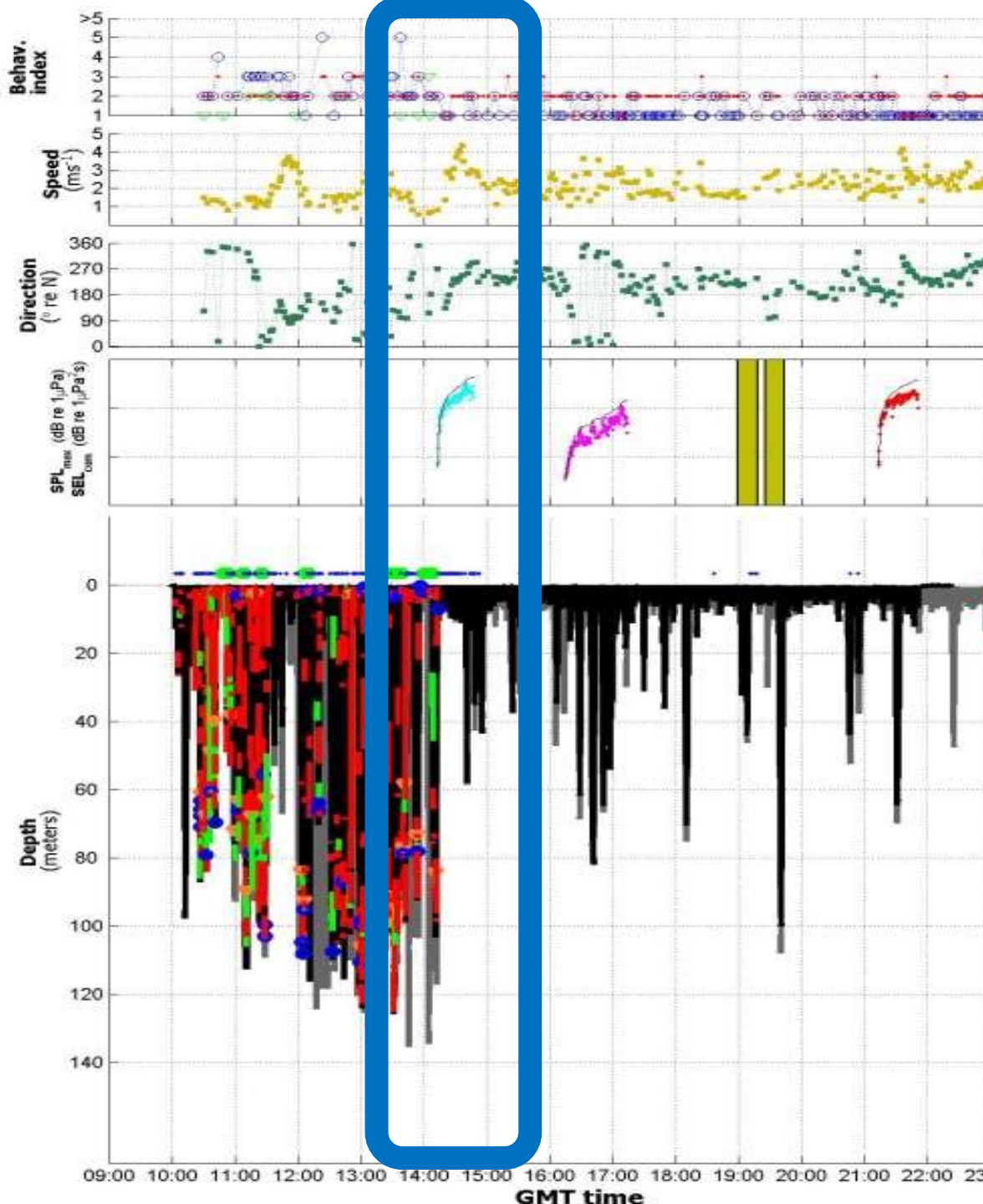
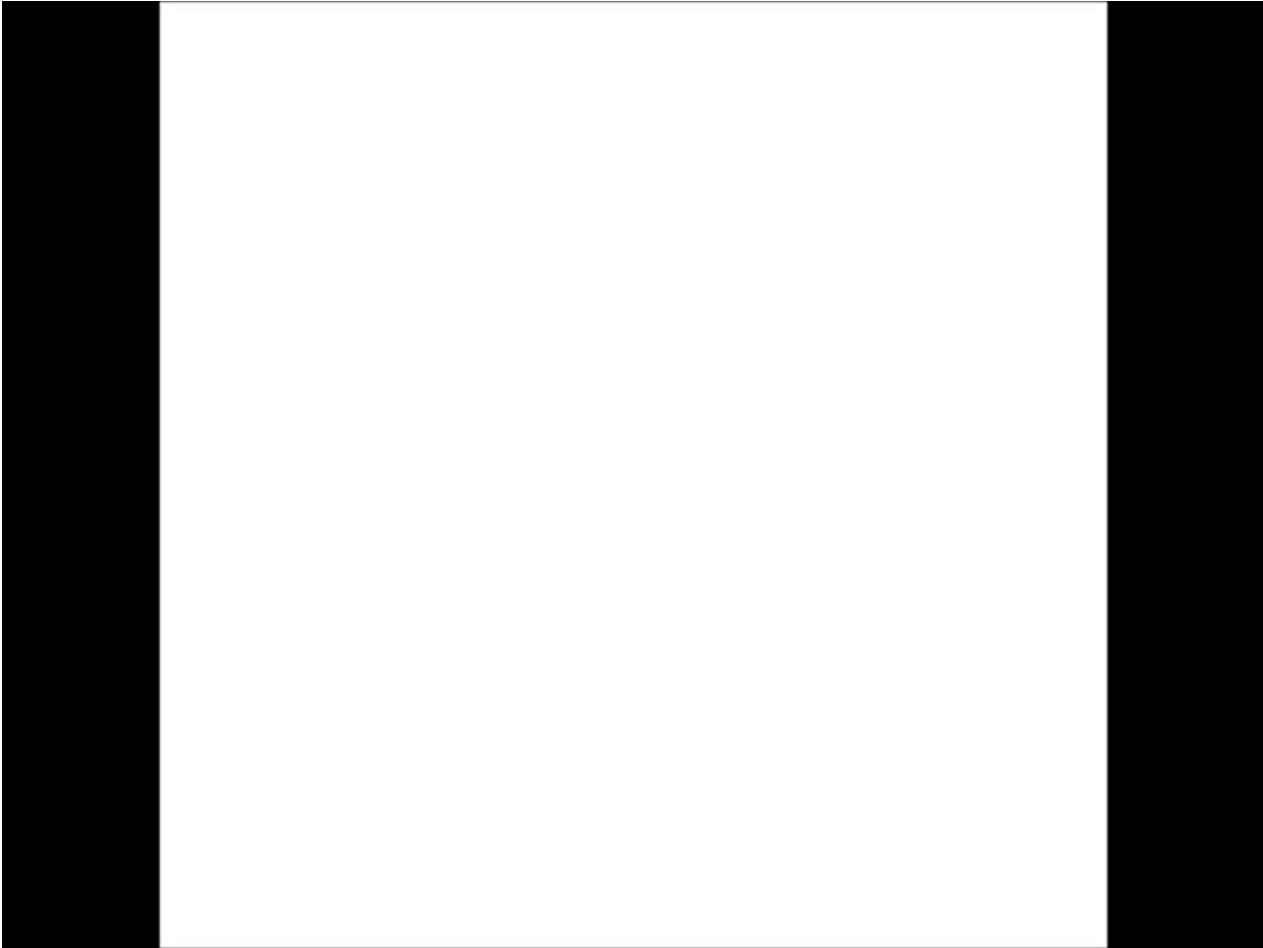
Rich observations

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



Behavioural Responses: disruption of ongoing behavior

8 km

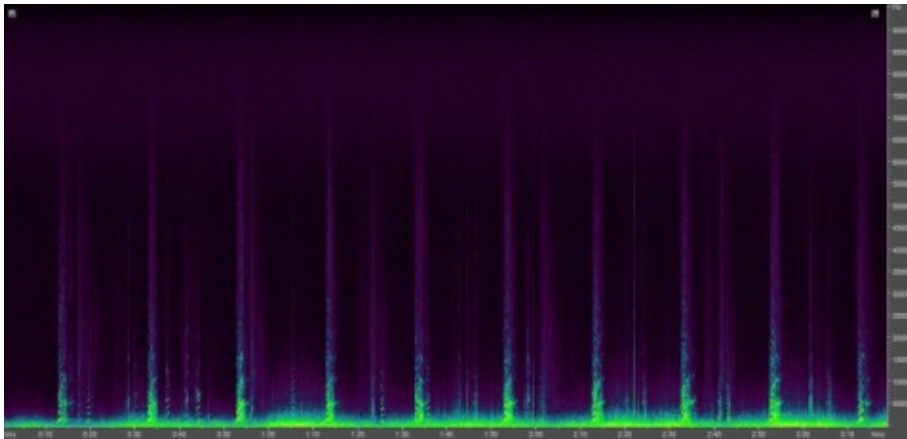


Behavioural Responses: disruption of ongoing behavior



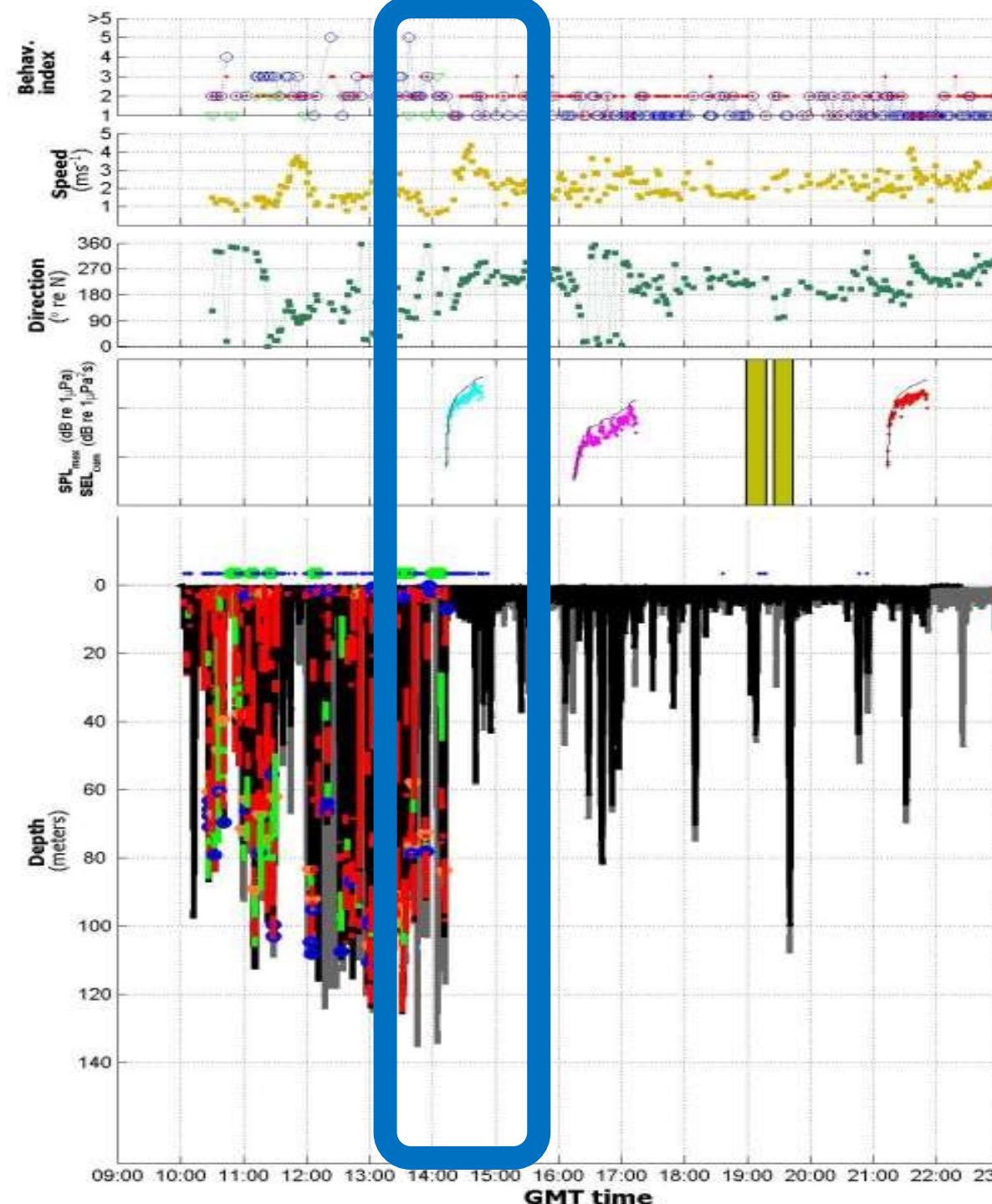
Ping-by-ping
calling

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



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

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



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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. Miller¹, P. H. Kvadsheim², F. P. A. Lam³, P. L. Tyack¹, C. Curé⁴, S. L. DeRuiter⁵, L. Kleivane², L. D. Sivle⁶, S. P. van Usselmuide³, F. Visser^{7,8}, P. J. Wensveen¹, A. M. von Benda-Beckmann³, L. M. Martín López¹, T. Narazaki¹ and S. K. Hooker¹

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



ECOSPHERE

Vol. 562: 211–220, 2016
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Individual, ecological, and anthropogenic influences on activity budgets of long-finned pilot whales

S. EQUINO,^{1,2}† D. SANCHEZ,^{3,4} S. DE RUITER,⁵ C. CURÉ,⁶ F. VESSE,^{7,8} L. THOMAS,² P. J. O. MILLER,¹ AND C. M. HARRIS²



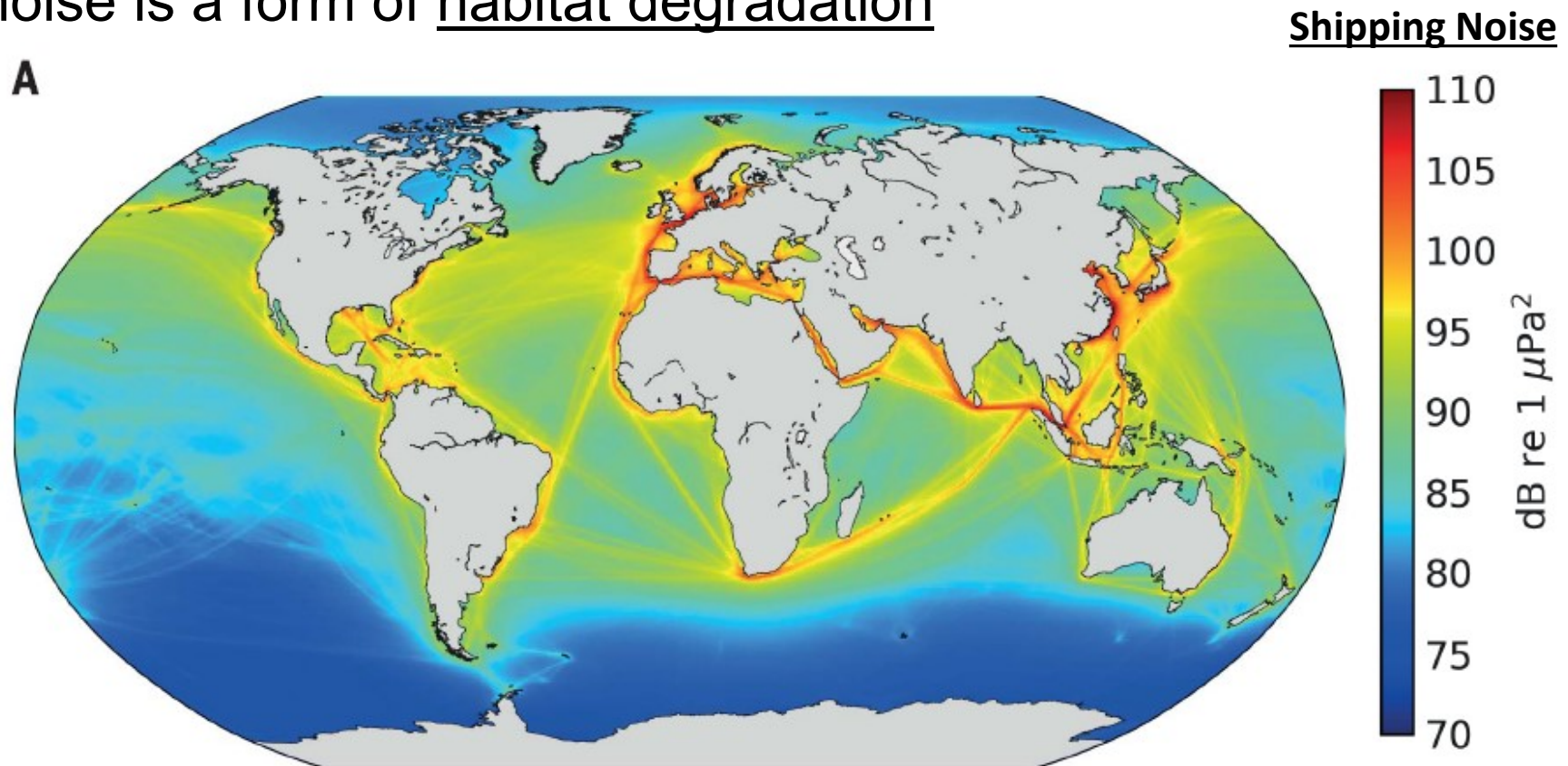
Naval sonar disrupts foraging in humpback whales

Lise Doksaeter Sivle^{1,*}, Paul J. Wensveen², Petter H. Kvadsheim³, Frans-Peter A. Lam⁴, Fleur Visser^{5,6}, Charlotte Curé⁷, Catriona M. Harris⁸, Peter L. Tyack², Patrick J. O. Miller²



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

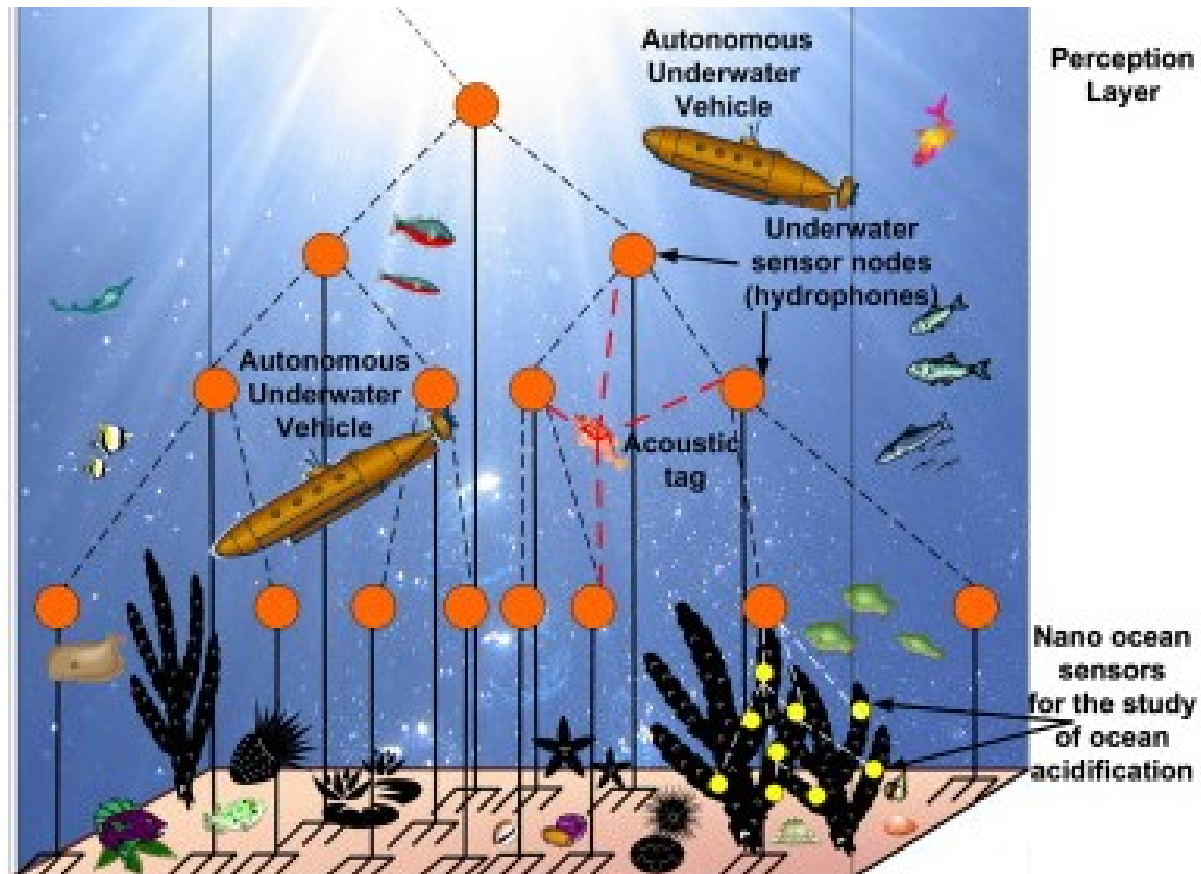


→ **“Mammal-Friendly” U-IoT** ←
standards that could reduce impacts:

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

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

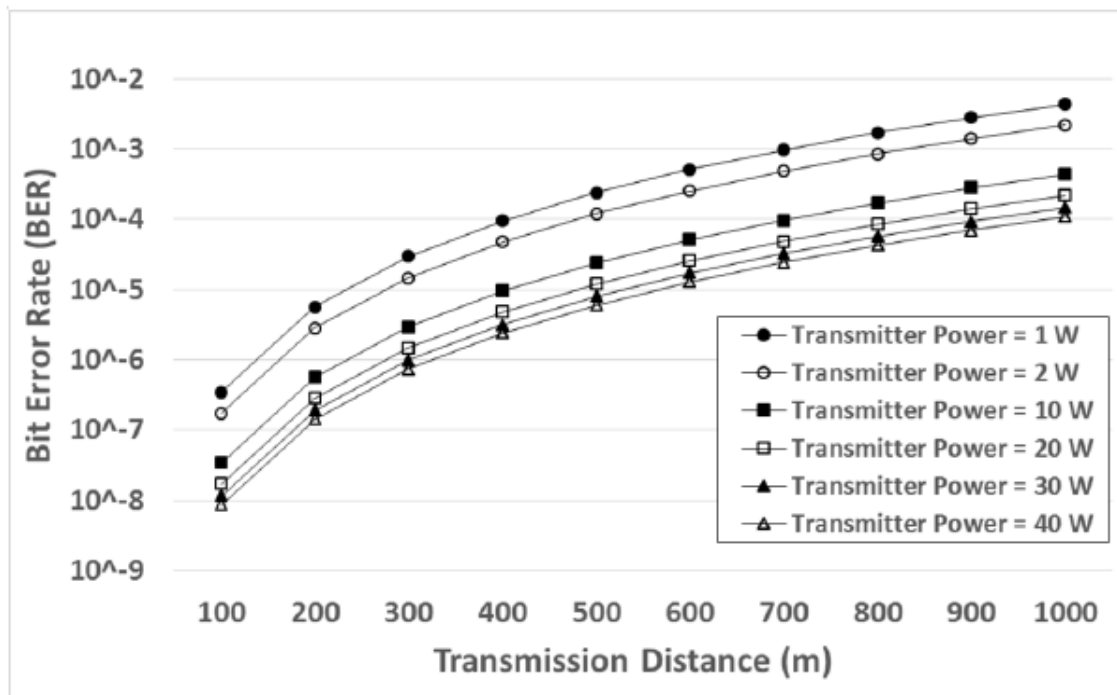
Data Modem Sound



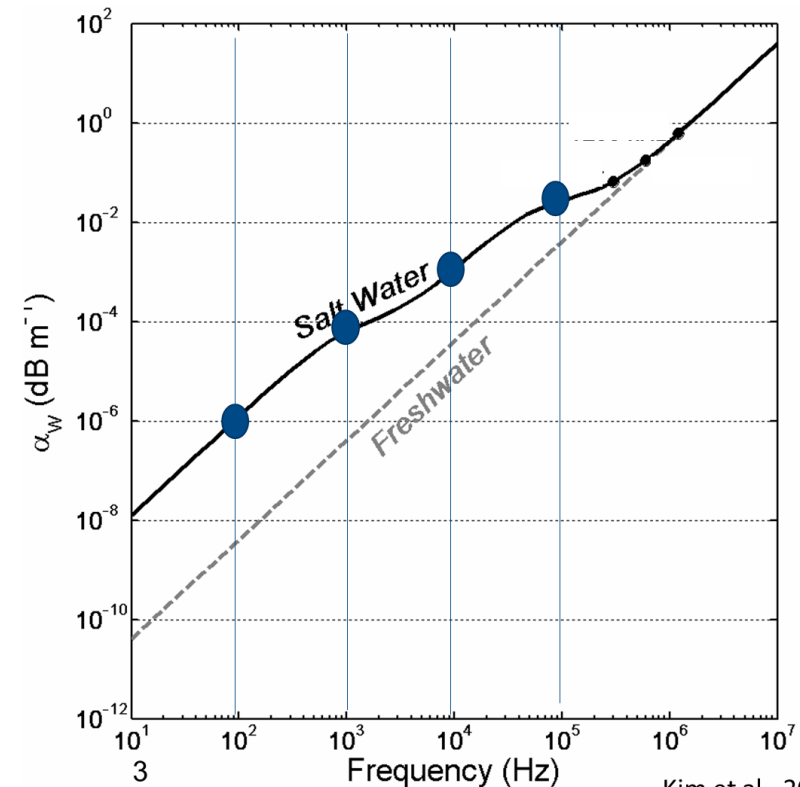
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- minimum source level, higher frequency, directional transmission



Kao et al., 2017



Kim et al., 2011

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Harbor porpoise



Beaked whales

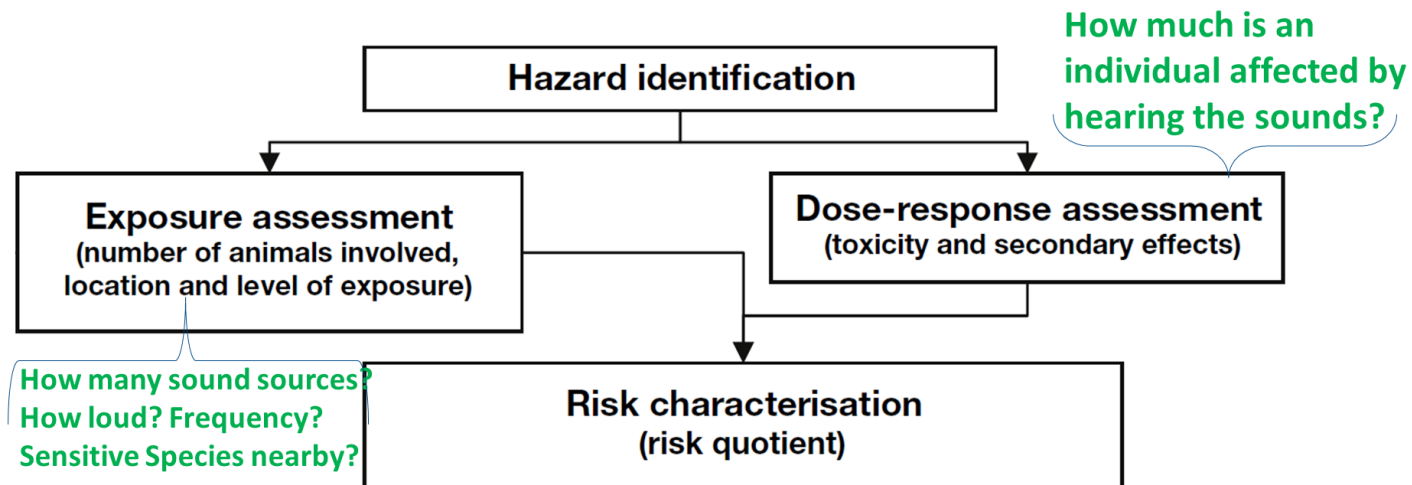


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Key Point 2: Environmental Impact Assessments should be done!





**Thank
you!!**