HYDRO 2024
Hydrographic Conference

Taking into account more simply the environmental impact of hydrographic echosounders

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Context (1) : MFA Naval Sonar is incriminated

- **A global concern for 30+ years**:
  - Impact of anthropogenic acoustic noise upon marine life
  - Mainly marine mammals
- First events in the **1990s – cetacean strandings linked to naval sonar drills**
- Confirmed events
  - Bahamas, Greece, Canary…
  - Several tens of other probable events
- Usual configuration
  - Odontocetes (Beaked Whales…)
  - MFA sonars (2-4 kHz; long chirp signals)
- Consequences
  - ➢ Specific **mitigation measures**
  - ➢ Extended (without evidence) to **seismic sources**
  - ➢ Preliminary **impact studies, authorization** process…

Context (2) : LF Multibeam is put on the spot

- Madagascar, 2008: massive stranding (>100) of Melon-head Dolphins trapped in an estuary
- 2013: Expertise conclusion - ***« most plausible and likely » cause***
  = signals from a 12-kHz multibeam echosounder

  Southall et al, 2013. Final report of the Independent Scientific Review Panel investigating potential contributing factors to a 2008 mass stranding of melon-headed whales (Peponocephala electra) in Antsohihy, Madagascar.
- Strong adverse reactions of the public opinion & press
- Practical consequences:
  - Harmfulness suspicion ➔ LF MBES – and **all echosounders**
  - **Regulations & authorization process for echosounders**

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Risks for marine life caused by noise sources

Scale of severity

1. Audibility
   - *Detection above noise*
2. Behavioral reaction
   - *Disturbance*
3. Temporary injury
   - *Auditory - recoverable*
4. Permanent injury
   - *Auditory - definitive*
5. Physical trauma
   - *Possibly lethal*

Level of Scientific Knowledge

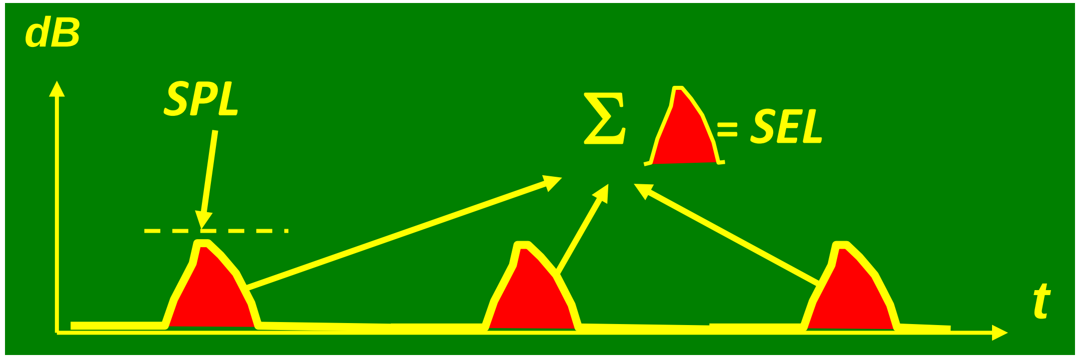
1. Marine Mammals
   - *Southall et al. 2019*
2. Fishes
   - *Popper et al. 2019*
3. Invertebrates
   - *Solé et al. 2023*

How to objectively quantify risks to marine life ?

Analysis of the **Received Sound Level** (e.g. caused by a sonar)

➔ Comparison w/ admissible **risk thresholds**

➔ Conclusion = **acceptability**, mitigation…



Expressed by two fundamental metrics :

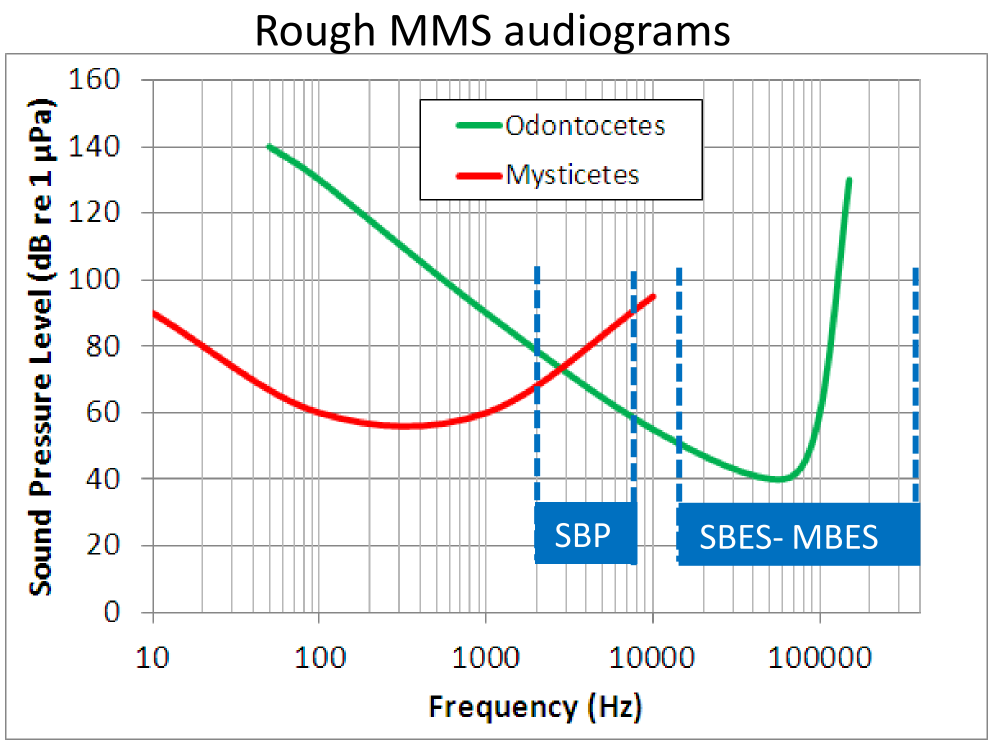
- **Sound Pressure Level (SPL)** = instantaneous intensity
- **Sound Exposure Level (SEL)** = cumulative energy / exposure

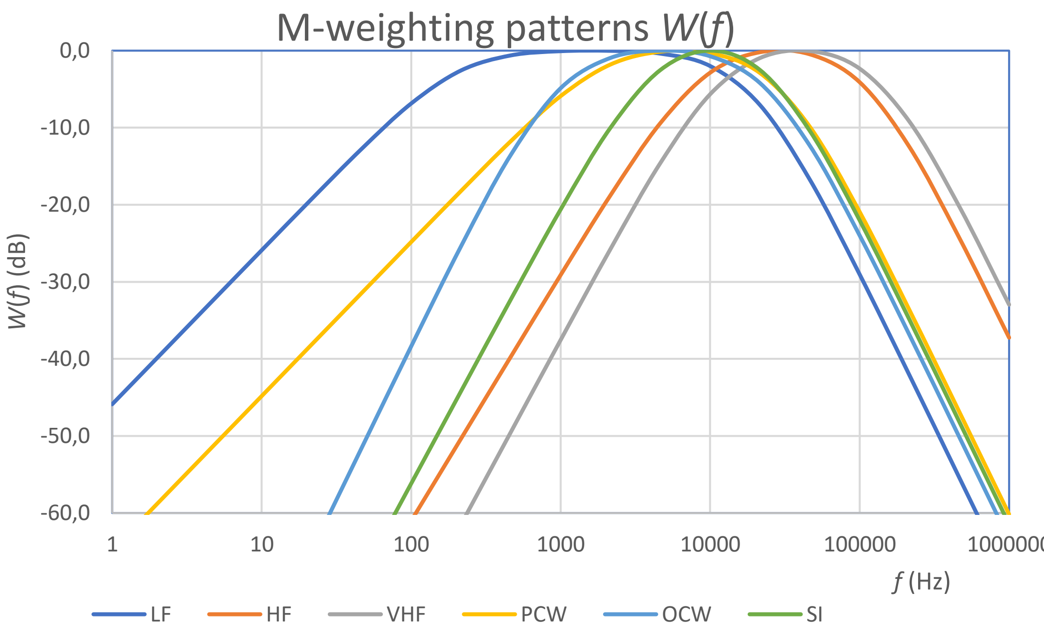
- **Risk thresholds** depend upon:
  - **Species** : anatomy, auditory response, frequency specialization/sensitivity
  - **Signal** frequency & type : impulsive / continuous, wide/narrow band…
  - **Risk type** to consider & **severity** level

Risks for Marine Mammals

- Several **hearing groups**:
  - Low Frequency (Mysticetes)
  - High Frequency (most Odontocetes)
  - Very High Frequency (some Odontocetes)
  - (Sirenians, seals, bears…)
- **M-weighting functions** / per group
- Various **risks thresholds**
  - **Behavioral** (measured at sea)
  - **TTS** (Temporary impairment, measured in lab)
  - **PTS** (Permanent injury, extrapolated)

See e.g. Southall & al. (2007) Aquatic Mammals 33(4): 411:522





Risk Thresholds for Marine Mammals

Excerpts from ***latest (2024) guidelines by NOAA/NMFS***
from synthesis works by Southall et al. & Finneran et al.

1. Auditory Risks

(Main) Cetacean Hearing Group	TTS Impulsive SPL Unweigh.	TTS Impulsive SEL M-Weigh.	TTS Non-Imp. SEL M-Weigh.	PTS Impulsive SPL Unweigh.	PTS Impulsive SEL M-Weigh.	PTS Non-Imp. SEL M-Weigh.
LF	216	168	177	222	183	197
HF	224	178	181	230	193	201
VHF	196	144	161	202	159	181

2. Behavioral Thresholds

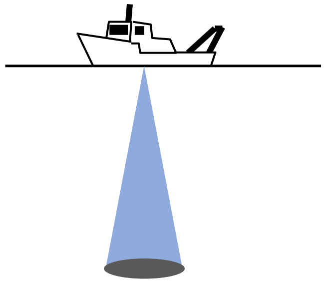
- Impulsive : SPL = **160** dB / 1µPa
- Non-Impulsive : SPL = **120** dB / 1µPa

Magnitudes / Echosounders
PTS ➔ SEL ≈ **200** dB /1µPa².s
TTS ➔ SEL ≈ **180** dB /1µPa².s

EchoSounder radiation ➔ *Sporadic* effects

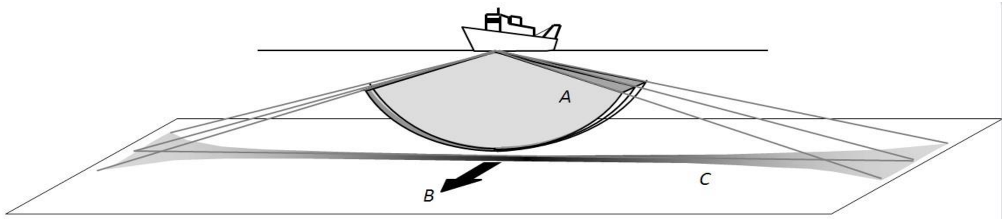
SBES, SBP

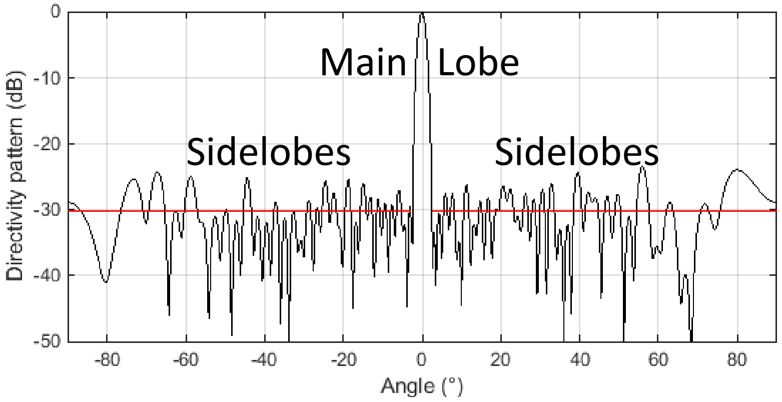
Conical beam (10°)



MBES

Fan-shaped sector(s) (1° x 150°)





Narrow main lobe (1° MBES)

Sidelobes = always present

- Naturally : < -13 to -18 dB
- With Beamformer : -20 to -30 dB

In **Space** (angle) :

- Narrow main beam ➔ low probability of interception
- Wide sidelobes ➔ continuous insonification - lower level

In **Time** :

- Short signals
- Slow ping rate

➔ Low duty factor (<1/100)

In **Frequency** :

- « High » frequencies (10s to 100s of kHz)
- Narrow-band signals (10 > Q > 100)

➔Low actual impact (despite high Source levels)

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Typical risk assesement preliminary study

- **MMs population** on the area
  - Species, seasonality, density…
  - Applicable risks thresholds
- **Acoustic systems** properties
  - Source level & directivity
  - Frequencies & bandwidths
  - Pulse rate & duration

} Survey conditions

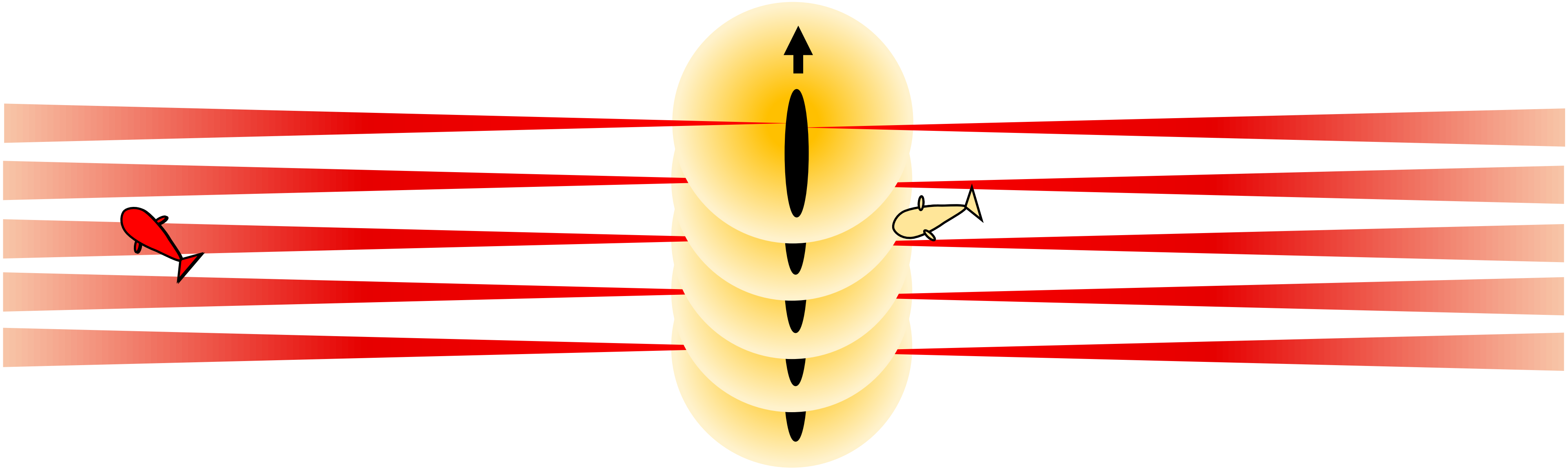
- Computation of **risk levels**
  - PTS, TTS, behavioral…
  - Threshold ranges / Statistical « takes »…

} Risk Modeling

- Resulting **decision**
  - ➢ Cruise permit (or not)
  - ➢ + Possible mitigation measures

} Regulatory

MBES insonification : main lobe & sidelobes



In a survey line configuration:

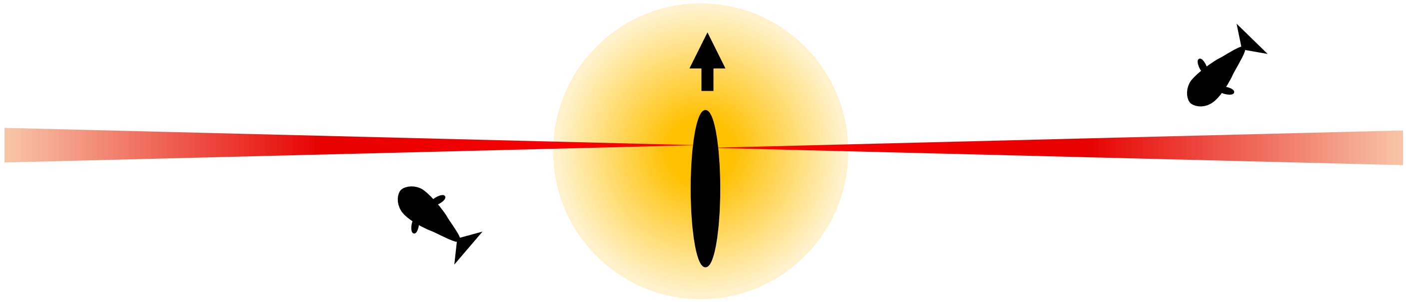
- Main-lobe insonification happens (here) about once during a survey line
- Probability decreases at short ranges and for slow ping rates
- Sidelobe insonification is always possible – at short ranges / low levels

SEL Modelling hypotheses :

- One (or few) direct ping in the main lobe
- Continuous radiation received from sidelobes

Computation Principle (simplified but sufficient)

$$SEL(R, f) = SL + DF + 10\log T - TL(R, f) = RT(M_m) - MW(M_m, f) \quad \text{for } \boldsymbol{R = R_{RT}}$$

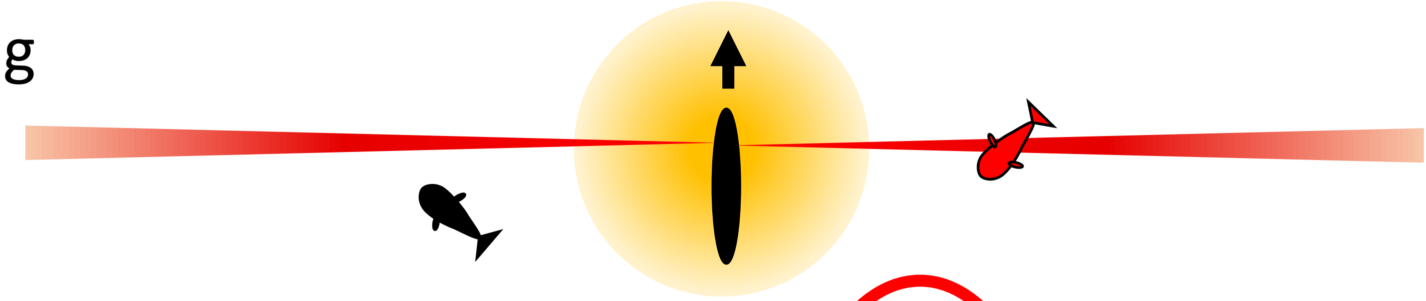


- ***SL*** = Sonar Source Level, in dB re 1µPa@1m
- ***DF*** = Sonar Directivity Function – Simplified ➔ 0 dB in mainlobe, -30 dB in sidelobes
- **10log*T*** = Energy integration over exposure time *T* (cumulated / 24 h ➔ 100-1000s)
- ***TL*** = 20log*R* + $\alpha.R$ = Transmission Loss at range *R* & signal frequency (absorption α)
- ***RT*** = Risk Threshold / reception, for a MM species & a given risk level (TTS, PPS…)
- ***MW*** = M-weighting term, depending on MM species M_m, and signal frequency *f*

Note: A (very) **conservative estimate**, since the MM is assumed at fixed range from the sonar for 24 h… More realistic algorithms are possible !

Case #1: Main Lobe Insonification : PTS upon SEL

- Highest source level
  - Nominal levels > actual (physical) levels – because of nearfield effect
- Very narrow beamwidth ➔ Low number of pings received (conventional =1)
- Short signals ➔ low SEL per ping
- SEL @1m = SL + 10logT
- RT = 200 dB (PTS magnitude)



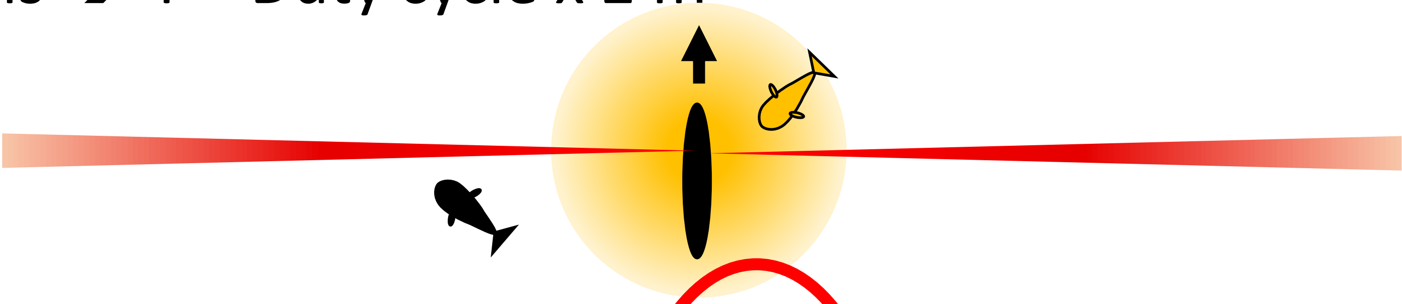
MBES	*f* (kHz)	*SL*	*T* (ms)	*SEL @1m*	R_{RT}
LF	12	240	100	< 230	**< 30 m**
MF	38	230	10	< 210	**< 3 m**
HF	100	220	1	< 190	**< 1 m**

➔ **Negligible** risk

Conservative : Near-field decrease neglected / M-weighting = off

Case #2 : Sidelobe Insonification : PTS upon SEL

- Typically -20 to -30 dB below main lobe level
- Wide angle radiation ➔ High number of pings received
- Numerous subsequent short signals ➔ T = Duty cycle x 24h
- SEL @1m = SL + 10logT
- RT = 200 dB (PTS magnitude)



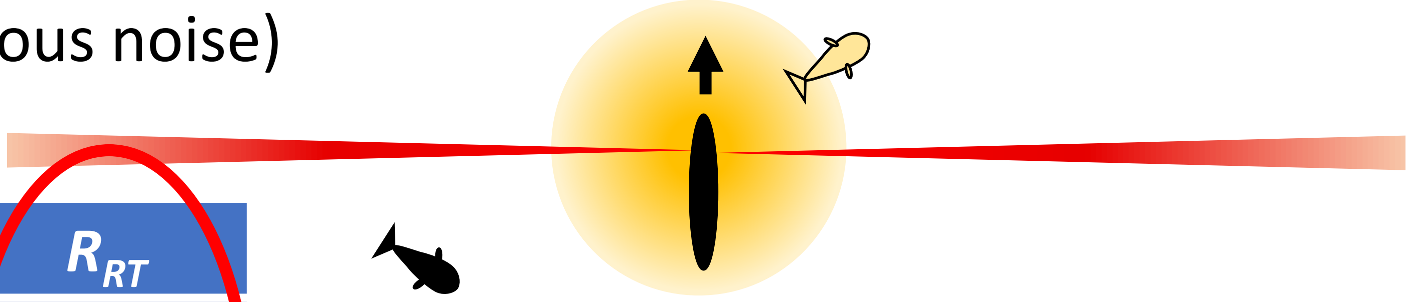
MBES	*f* (kHz)	*SL*	*Duty C.*	*SEL @1m*	R_{RT}
LF	12	210	1/100	< 240	**< 100 m**
MF	38	200	1/100	< 230	**< 30 m**
HF	100	190	1/100	< 220	**< 10 m**

➔ **Acceptable** risk

Conservative : Constant range/24 h – High Duty cycle - M-weighting = off

Case #3 : Sidelobe Insonification : Behavioral reaction

- Typically -20 to -30 dB below main lobe level
- Wide angle radiation → High probability of insonification
- RT = 120 dB (NMFS value, continuous noise)



MBES	*f* (kHz)	*SL*	R_{RT}
LF	12	210	**10 km**
MF	38	200	**1.8 km**
HF	100	190	**450 m**

→ **Moderate** risk

Conservative : continuous noise hypothesis

120 dB = disputable conventional threshold (no species/frequency dependence…)

Practical Results of Risk Analyses

- **VHF MBES** (200+ kHz) are **not really to be considered**
  - Out of the MMs' frequency range
  - (Relatively) low source levels, very short pulses (but high pulse rate)
  - Very high absorption rates
- **HF MBES** (70-150 kHz) cause **negligible risks**
  - Upper part of the MMs' freq range
  - Modest source level, short pulses
  - High absorption rate
- **LF & MF MBES** (12 – 50 kHz) raise **moderate risks**
  - High source level, in the hi-sensitivity range of all MMs classes
  - Short pulses, very low pulse rate

CONSISTENT RESULTS WHATEVER THE EIA STUDY

Towards a simplification ?

- Every new EIA implies **a new study of MBES risks**
  - ➢ always the same MM classes
  - ➢ a limited panoply of echosounders – especially for hydrography
  - ➢ **always the same conclusions** (if properly conducted)

- Such works could be **conducted once and for all**
  - ➢ For a **representative pannel of sonar** systems
  - ➢ Using the currently admitted **models and risk thresholds**
  - ➢ Under the control of major **regulator**(s) ➔ endorsing the results
  - ➢ Cooperation with **constructors**
  - ➢ Results to be widely disseminated and explained
  - ➢ To be reconsidered following future scientific advances

➔ **Possible systematic exoneration of echosounders classes or models ?**

Wrapping it all up

- Echosounders have been **widely used over ≈ one century**
- Sonar-caused **accidents did happen** - for specific naval sonars, animals and configurations
- Echosounders transmit **short narrow-band signals** at **medium to high frequencies**, inside **narrow Tx sectors**
- **Exposition in main lobe** at high level is only **sporadic** ; **sidelobe** insonification always happens but at lower levels
- Chances to **exceed risk thresholds** are **marginal** whatever the criteria
- **Behavioral** reactions are **possible** – as to many human activities – but largely **unpredictable**

To Conclude

- **Echosounding = more and more regulated** – more or less relevantly
- **Echosounding does NOT threaten whales!** *(but chemical pollution does - and fishing gear, plastic waste, naval sonar, ship traffic…!!!)*
- Authorization processes are heavy, redundant and most often **pointless for hydrographic echosounders**
- A **waste of time/ efforts/ money** for both applying **operators** & regulating **authorities**
- The **specific case of echosounders** should be reconsidered in this respect
  - **Exonerate** them from preliminary EIA ?
  - **Joint effort** : regulators & constructors ?
  - To be **suggested / supported by IHO** ?

QUESTIONS ???