TTS & behavioral response studies with harbor porpoises related to naval sonar: Use of results for regulation & mitigation

Ron Kastelein & many team members

SEAMARCO

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SEAMARCO

SEA MAMMAL RESEARCH COMPANY

Why focus on harbor porpoises ?

A) Sensitive hearing, wide frequency hearing range

B) Low behavioral response threshold SPLs

C) Large distribution area in Northern Hemisphere

Structure of talk

TTS studies & BRS research

- Why?
- Studies conducted with harbor porpoises
- Importance of results for regulation & mitigation
- Planned research with harbor porpoises

Why TTS research ? (Driving force)

TTS onset SELs and growth rates are used to estimate PTS onset SELs which are used as underwater sound criteria by regulators to prevent hearing injury

TTS sub-studies

- Determine affected hearing frequencies
- TTS growth related to SPL, duration, duty cycle
- Determine time for hearing to recover

TTS measurement session

1) Pre-exposure hearing test
2) Fatiguing noise exposure
3) Post-exposure hearing tests

Control sessions

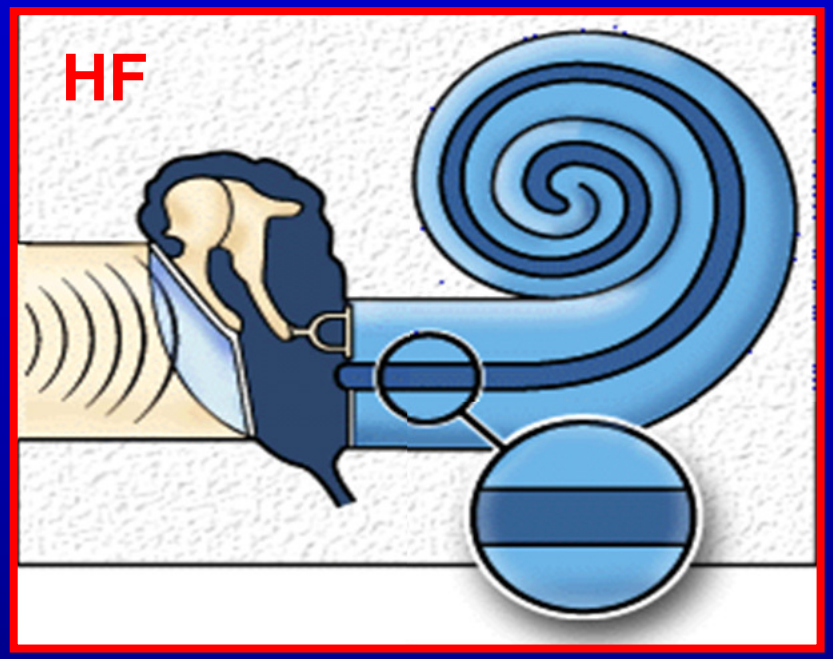
Control sessions are conducted without the fatiguing noise to get insight in the fluctuations of the hearing thresholds, due to time of day and methodology.

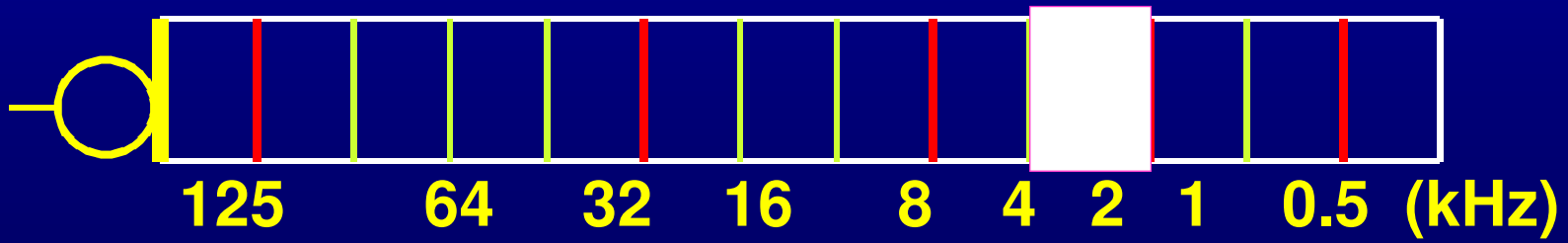
Effort

1 session per day to prevent hearing damage

(data collection is labor-intensive & slow)

Hearing frequency most affected (i.e., highest TTS)

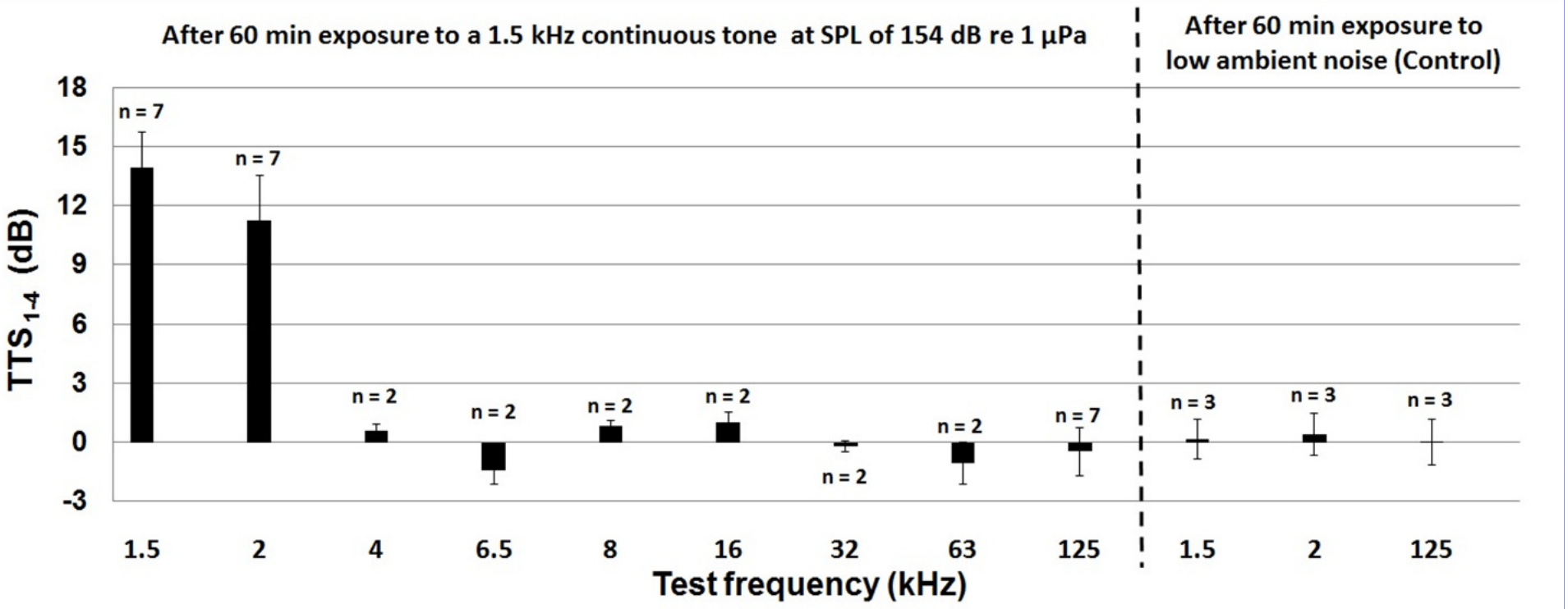




Filter bands in cochlea

TTS studies with LFAS (1-2 kHz) & MFAS (6-7 kHz) (Netherlands Ministry of Defense)

Affected hearing frequencies

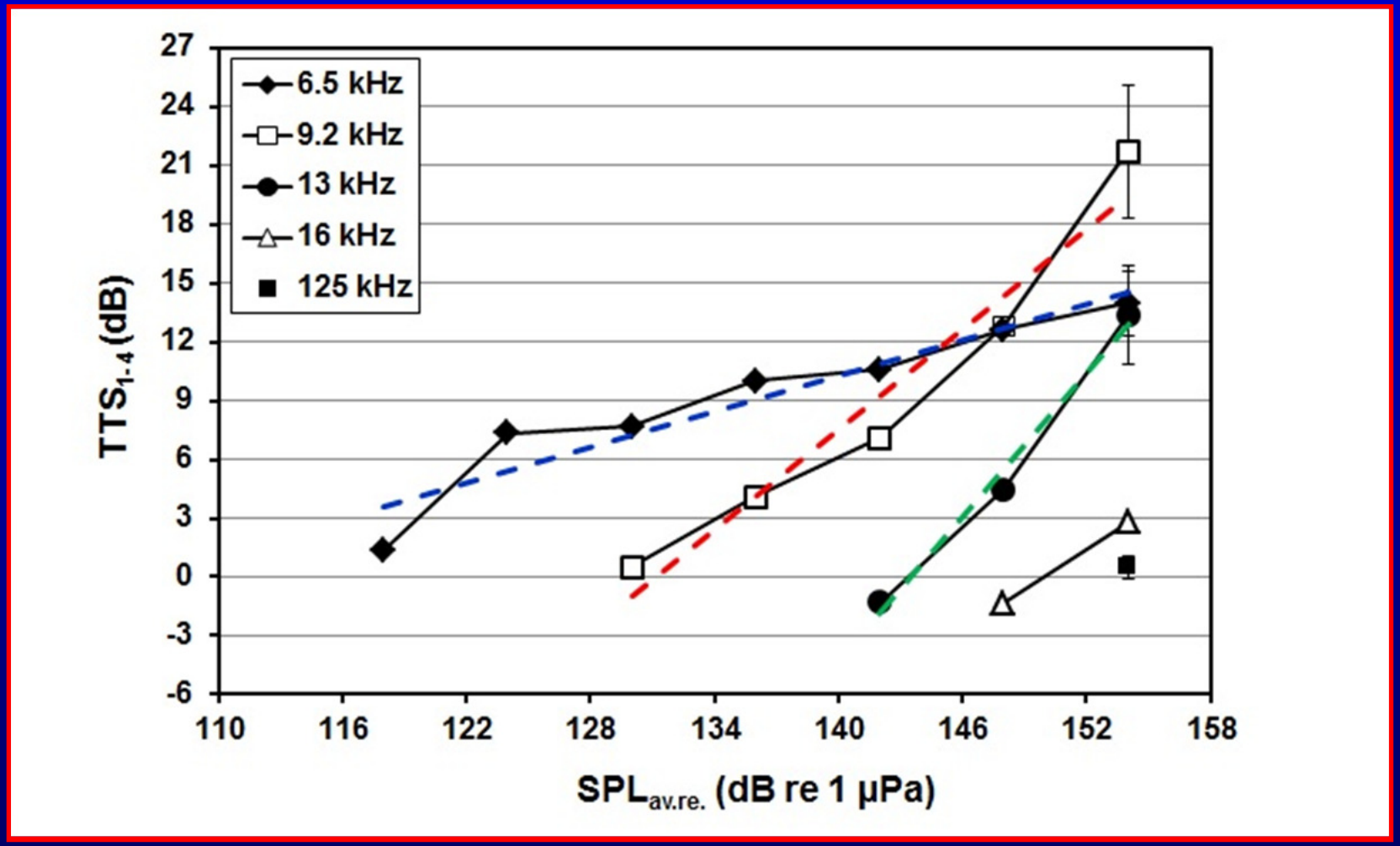


Highest TTS at frequency of fatiguing noise (1.5 kHz)

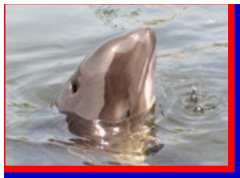
Porpoise echoloc. frequency (~125 kHz) not affected

Affected hearing frequencies

Fatiguing noise: 6.5 kHz CW

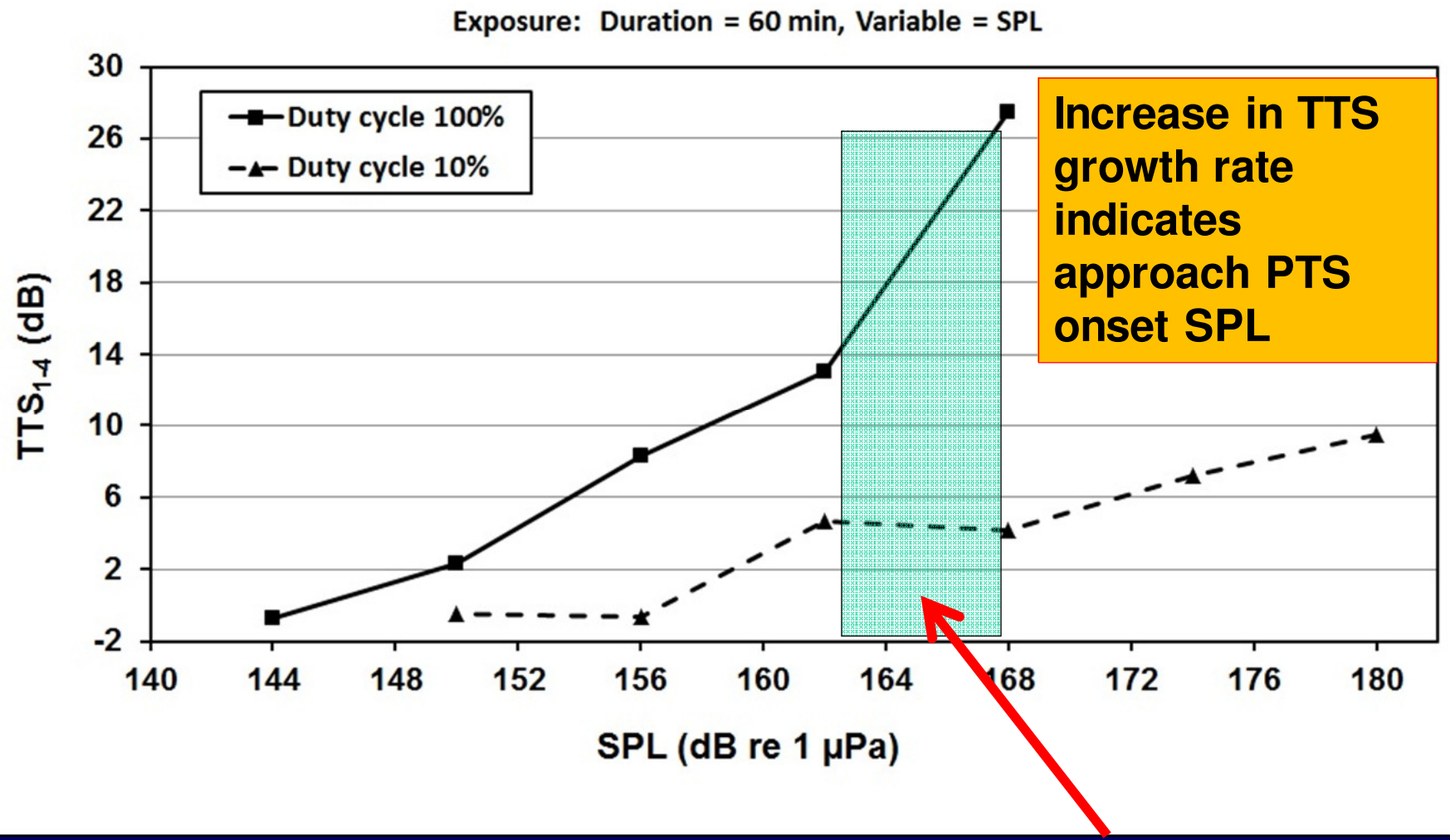


Most affected frequency depends on received SPL



TTS growth due to increase of SPL

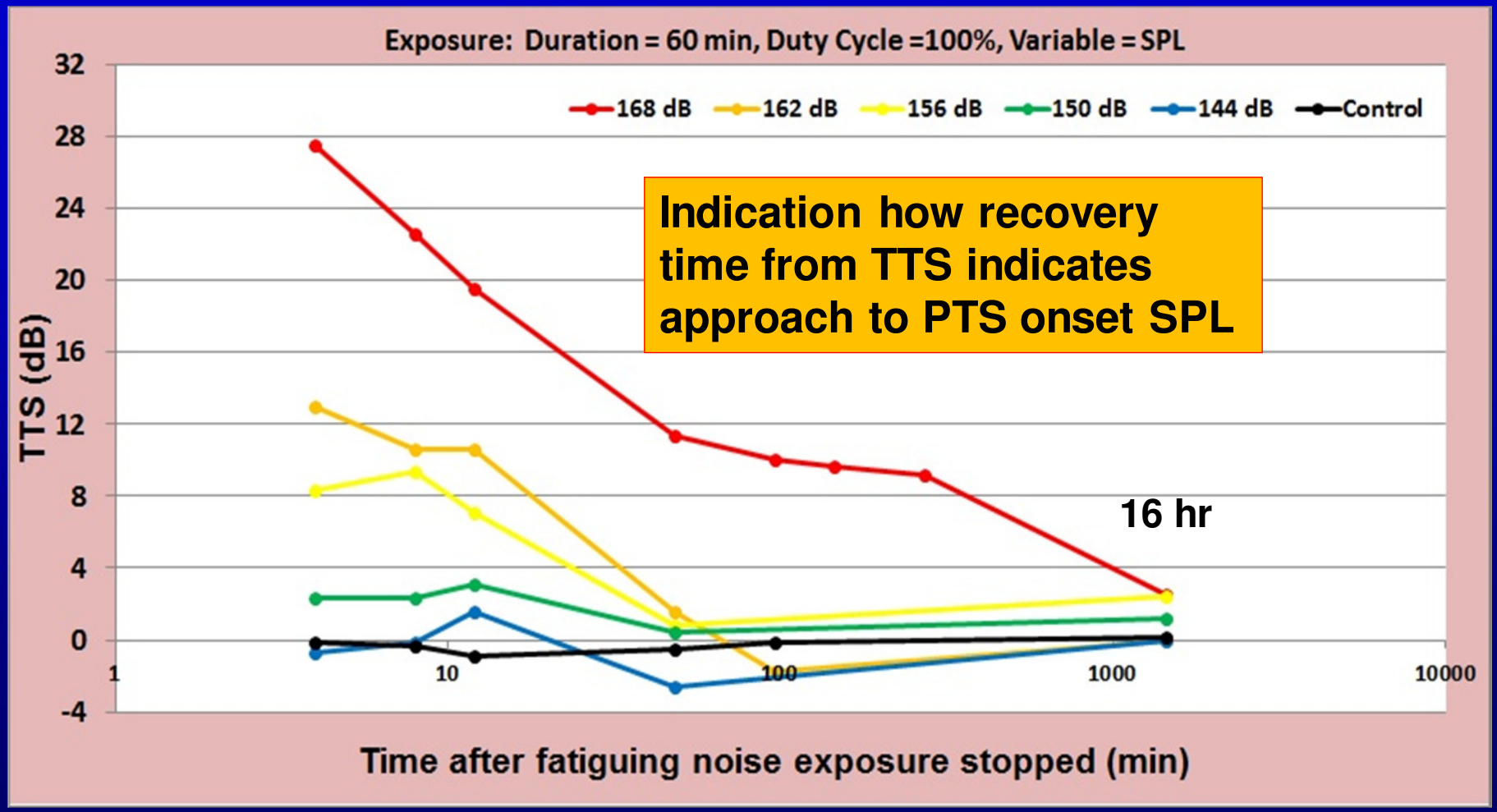
Fatiguing noise: 1-2 kHz down-sweeps



Region of critical level for 100% duty cycle

Recovery of hearing

After 1-2 kHz sweeps, 100% duty cycle

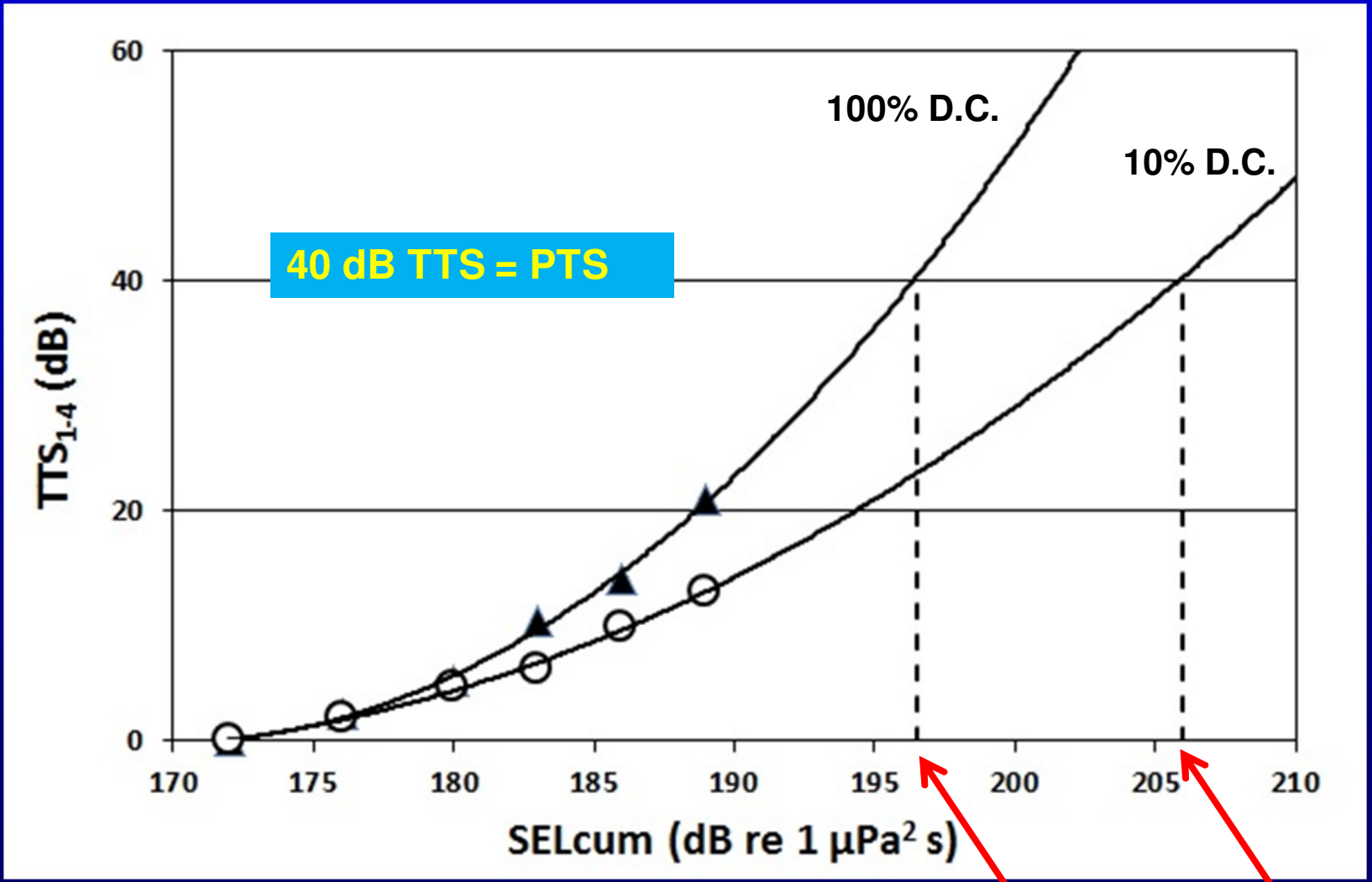


Above critical level, much longer recovery

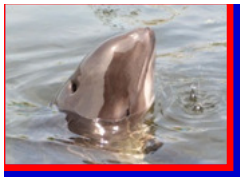
Getting near the danger zone (near PTS)

Est. of PTS onset SEL_{cum} based on TTS growth curves

(Fatiguing noise: 6-7 kHz sweeps)



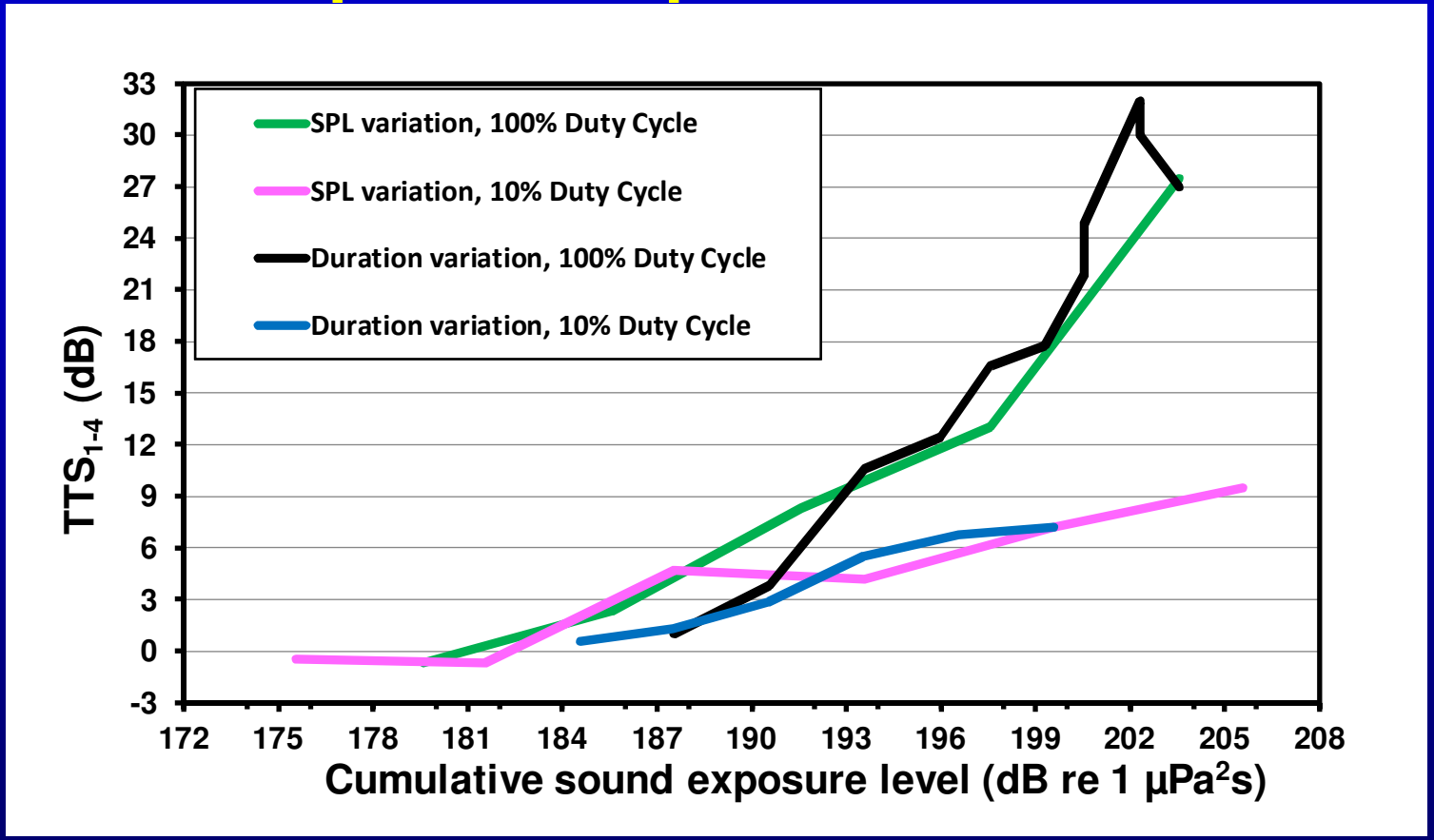
PTS onset SEL_{cum}: 196 206



Equal energy model (prediction of TTS)

Duration - SPL

Exposure expressed as SEL_{cum}

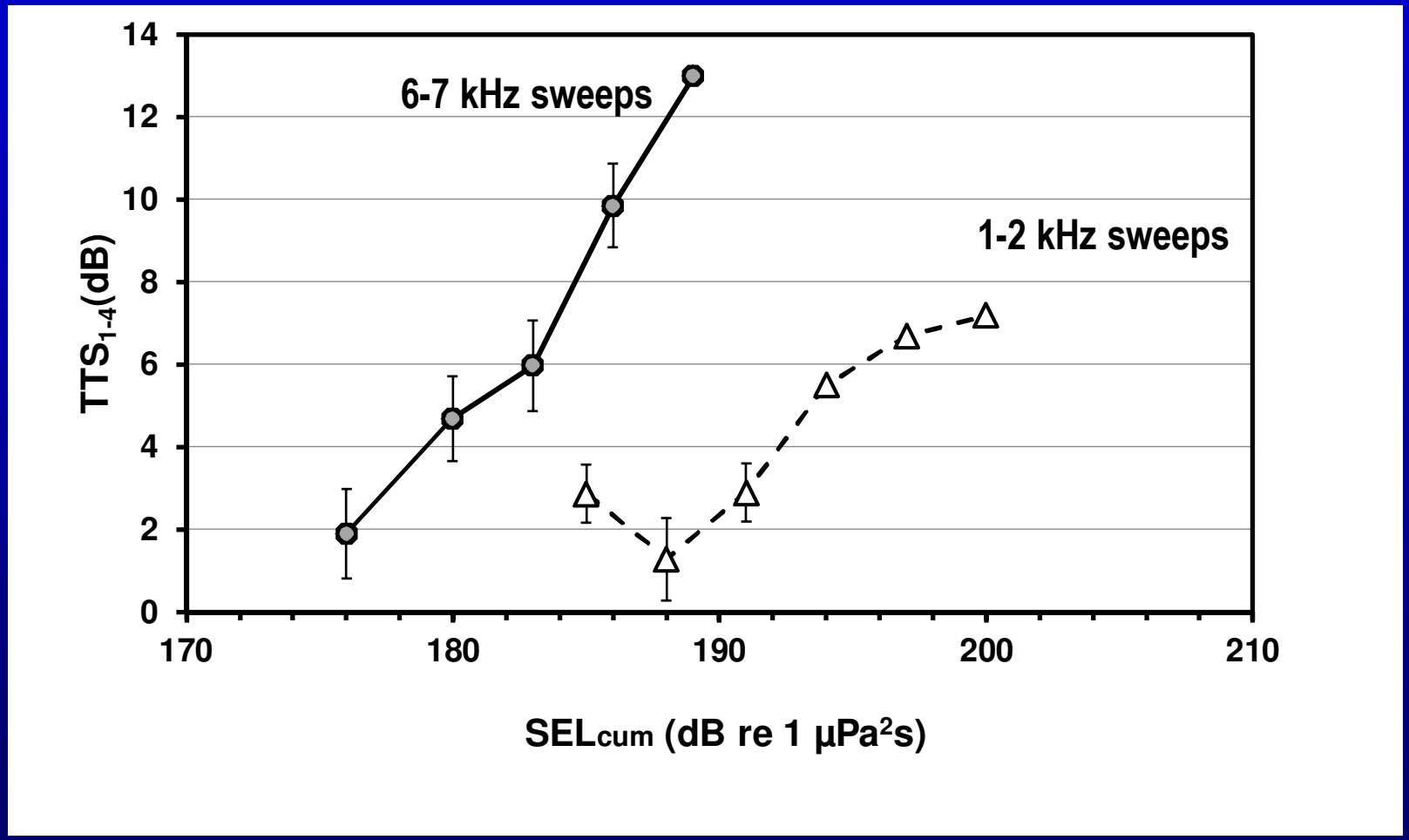


Inter-pulse intervals play a major role in TTS induced

- **Hearing may partly recover during inter-pulse intervals**
- **It determines the sound energy per time unit (Leq)**

Effect exp. freq. on TTS onset SEL_{cum} & growth rate

Comparison LFAS and MFAS results (10% D.C.)



Harbor porpoise hearing is more prone to TTS after exposure to 6-7 kHz than to 1-2 kHz sweeps

Importance results TTS studies for regulation

Future underwater sound criteria to prevent PTS should:

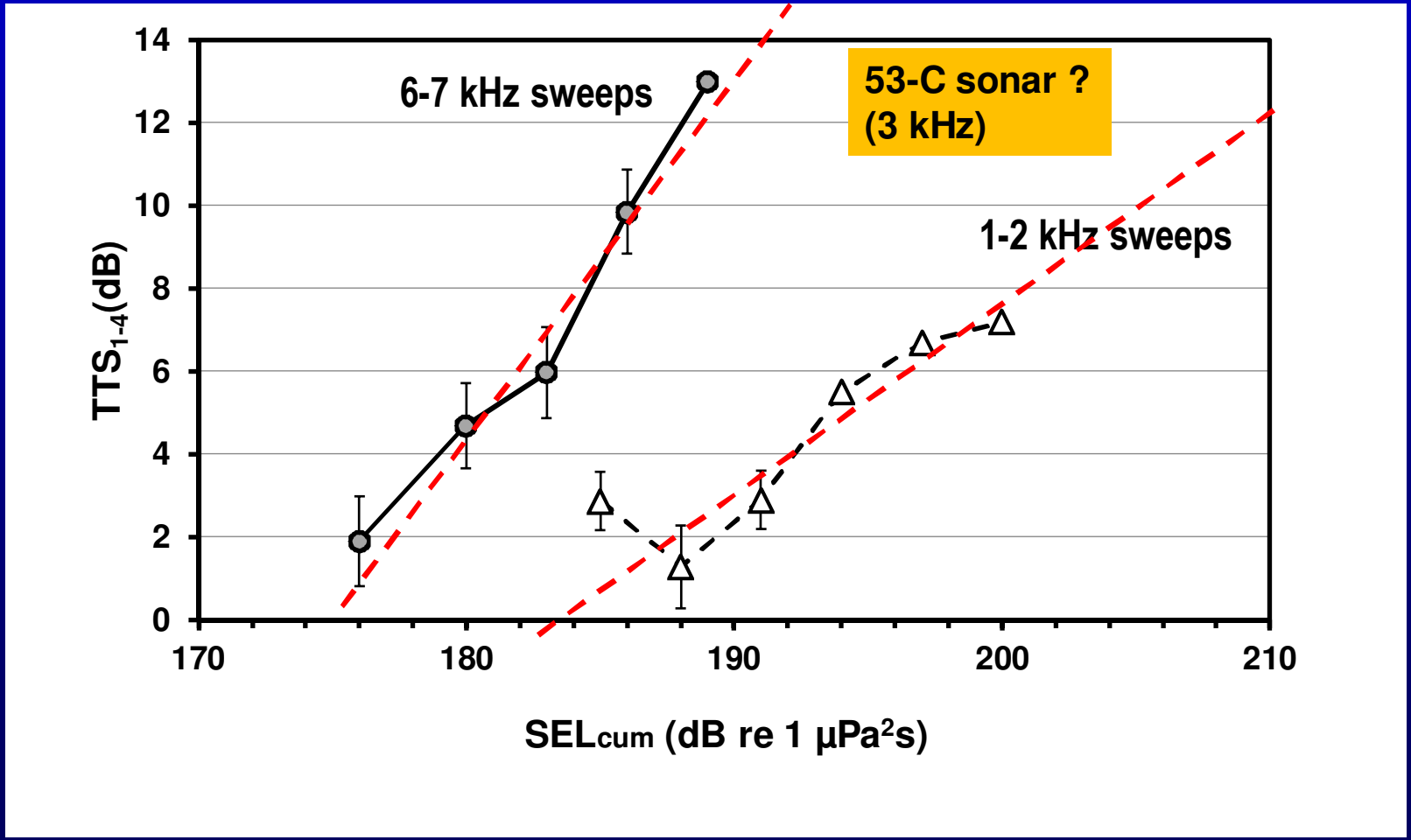
- **Specify not only SEL_{cum} , but also duty cycle.**
- **Specify the frequency (spectrum) of the sounds.**
- **Take into account affected hearing frequencies.**
- **Specify ecological most relevant frequency hearing ranges of marine mammal species.**

Importance results sonar TTS studies for mitigation (for porpoises, possibly all odontocetes)

- **Reduce the duty cycle**
- **Lower the frequency**
- **Reduce the level of harmonics**

Planned TTS research with harbor porpoises

TTS growth due to 53-C sonar of the US navy (3 kHz) (LMR program)

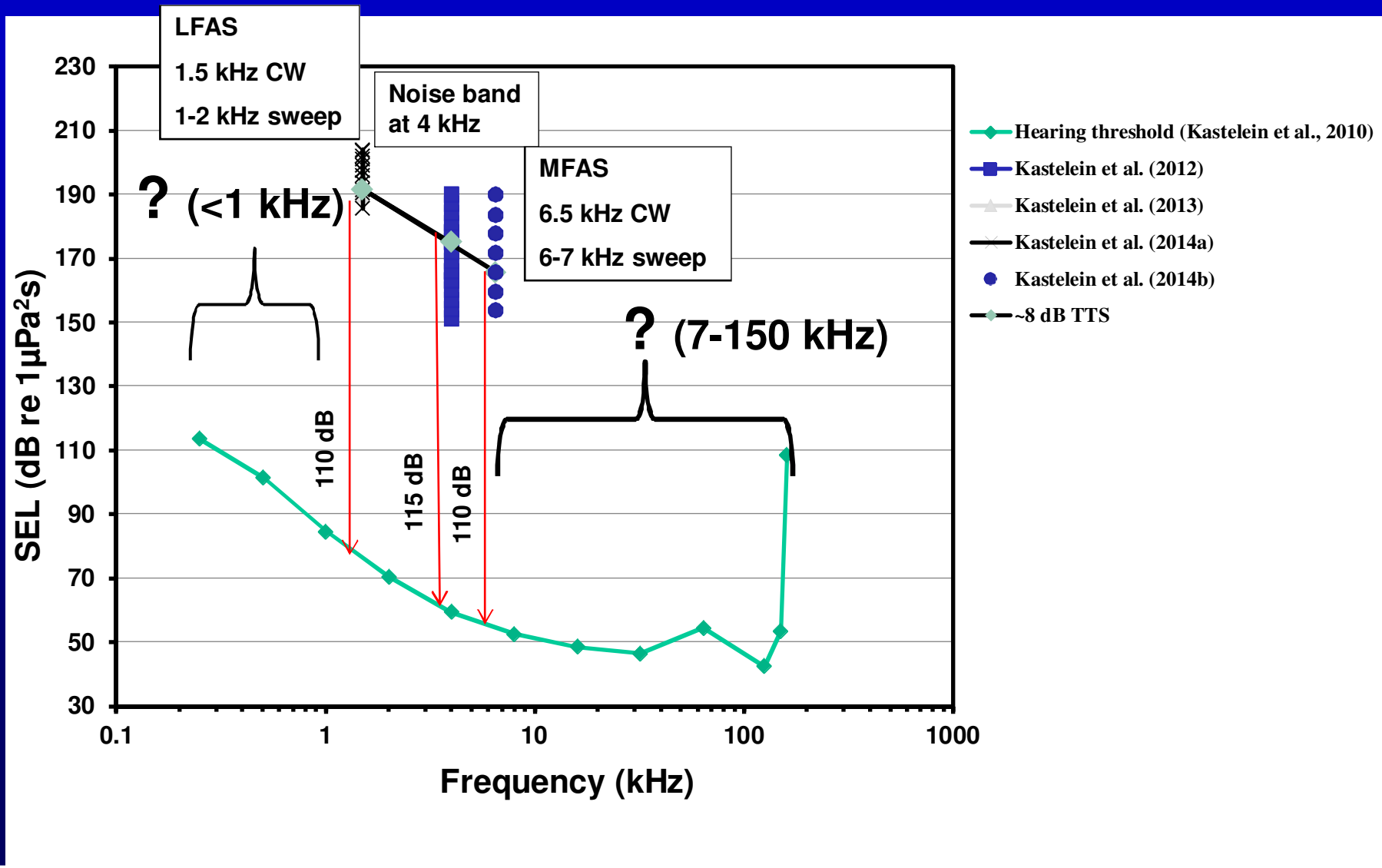


TTS in harbor porpoises due to impulsive sounds such as those produced during seismic surveys and explosions

JIP program of IOGP (TNO, SEAMARCO)

Research needed:
Equal-TTS contours harbor porpoises

(Example: SELcum causing 8 dB TTS; all 1 hr exposures,100% DC)



Why behavioral response studies (BRS) ?

Usually only a small number of animals is close enough near a high energy sound source to get a PTS.

However, a much larger number of animals respond behaviorally to high energy sound sources, as the behavioral threshold SPL is often lower than the SPL in PTS onset SEL.

Behavioral response studies (BRS) in pool with porpoises (Netherlands Ministry of Defense)

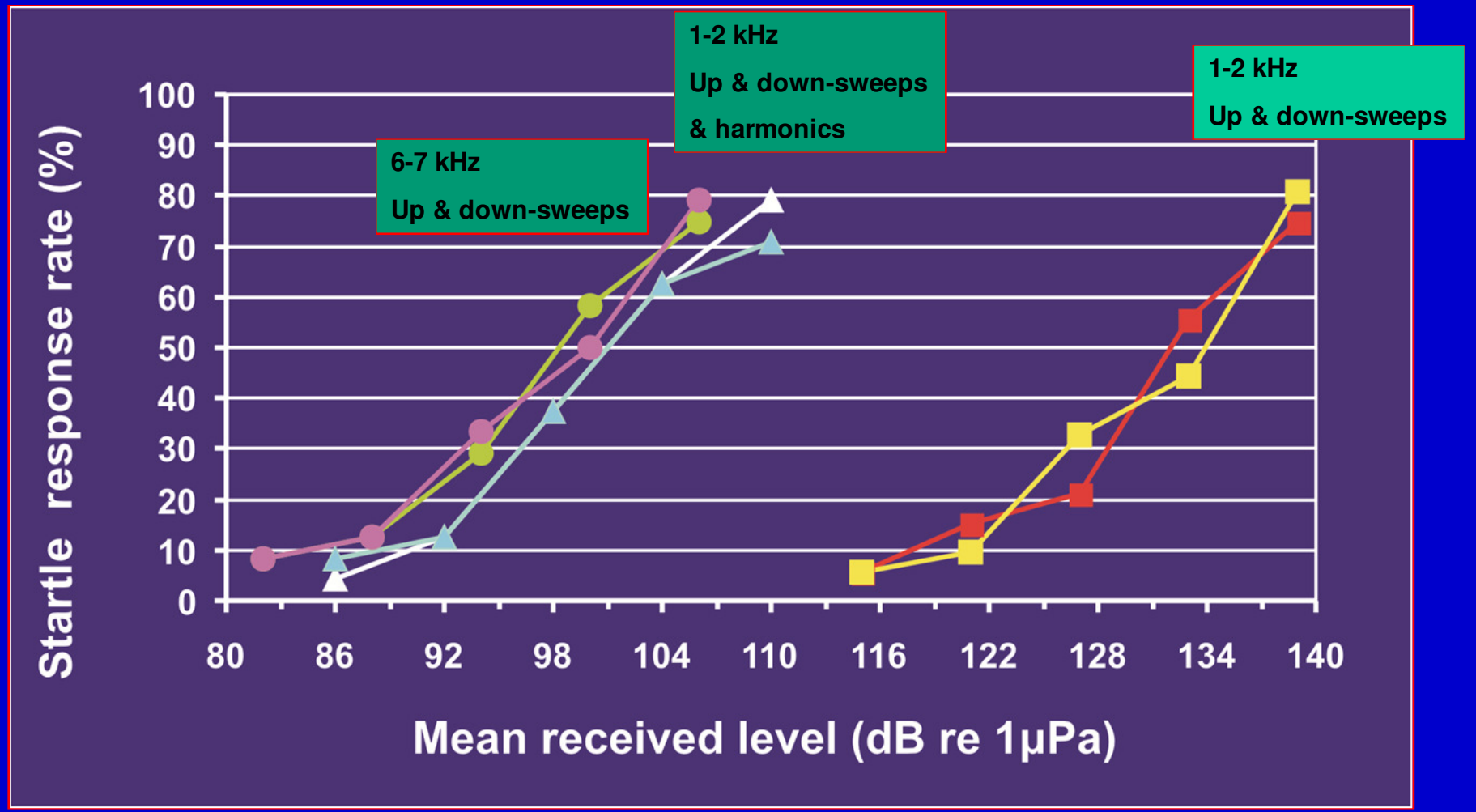
- Received levels of single sonar sweeps causing a startle response in 50% of pres. (LFAS: 1-2 kHz and MFAS: 6-7 kHz).


- Received levels of series of sweeps causing behavioral responses (LFAS: 1-2 kHz and MFAS: 6-7 kHz) (19% duty c.).

- Effect simulated Sea State noise on effect of series of 6-7 kHz up-sweeps (MFAS) on behavior.

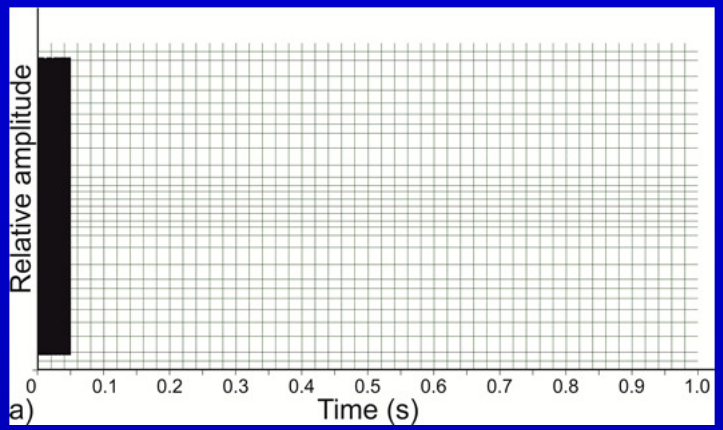

- Received levels of series of 4 HELRAS signals causing behavioral responses (8% duty cycle).

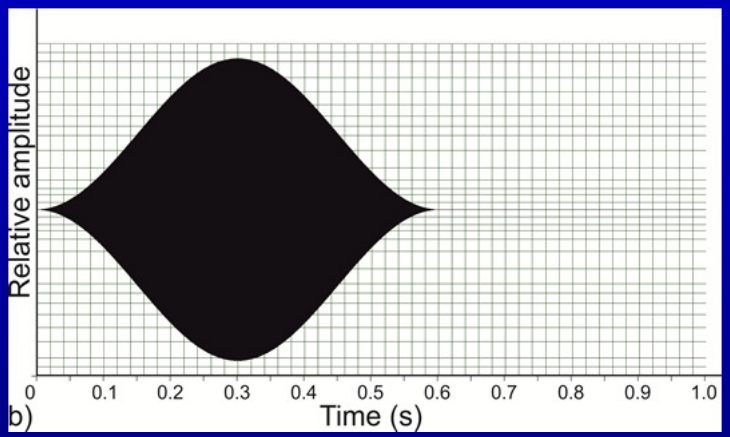
Startle response threshold level (single emission)

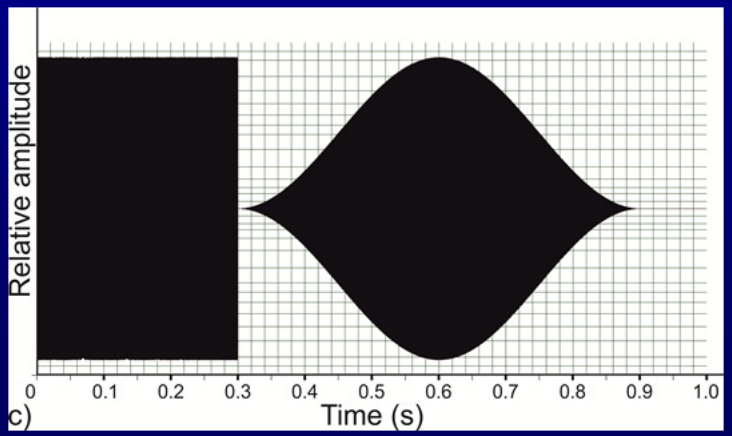


1-2 kHz without harmonics needs to be loud to cause effect

Concl.: LFAS can be louder than MFAS, avoid harmonics







BRS for Swedish Ministry of Defense (25 kHz)

Specify parameters of d.c.: signal duration & interval

50% duty cycle

The lower series has more effect on behavior

Importance of BRS results for regulation

Underwater sound criteria to reduce behavioral responses should:

- Not only specify SPL, but also direction of sweep
- Specify the frequency (spectrum) of the noise (or weight the level).
- Differentiate between continuous sounds & intermittent sounds.
- If intermittent, specify the duty cycle. More importantly, specify inter-pulse interval.

Importance of sonar BRS results for mitigation (for harbor porpoises, possibly other odontocetes)

- Use continuous sounds instead of intermittent
- If intermittent, increase the inter-pulse interval
- Use noise instead of tones or sweeps
- Lower the frequency
- Produce down-sweeps instead of up-sweeps

Planned sonar BRS with harbor porpoises

BRS with 53-C sonar sounds of US navy at various duty cycles and under various background noise levels (LMR program)

Funding agencies:

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Thank you for your attention !

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Research for marine conservation

researchteam@zonnet.nl