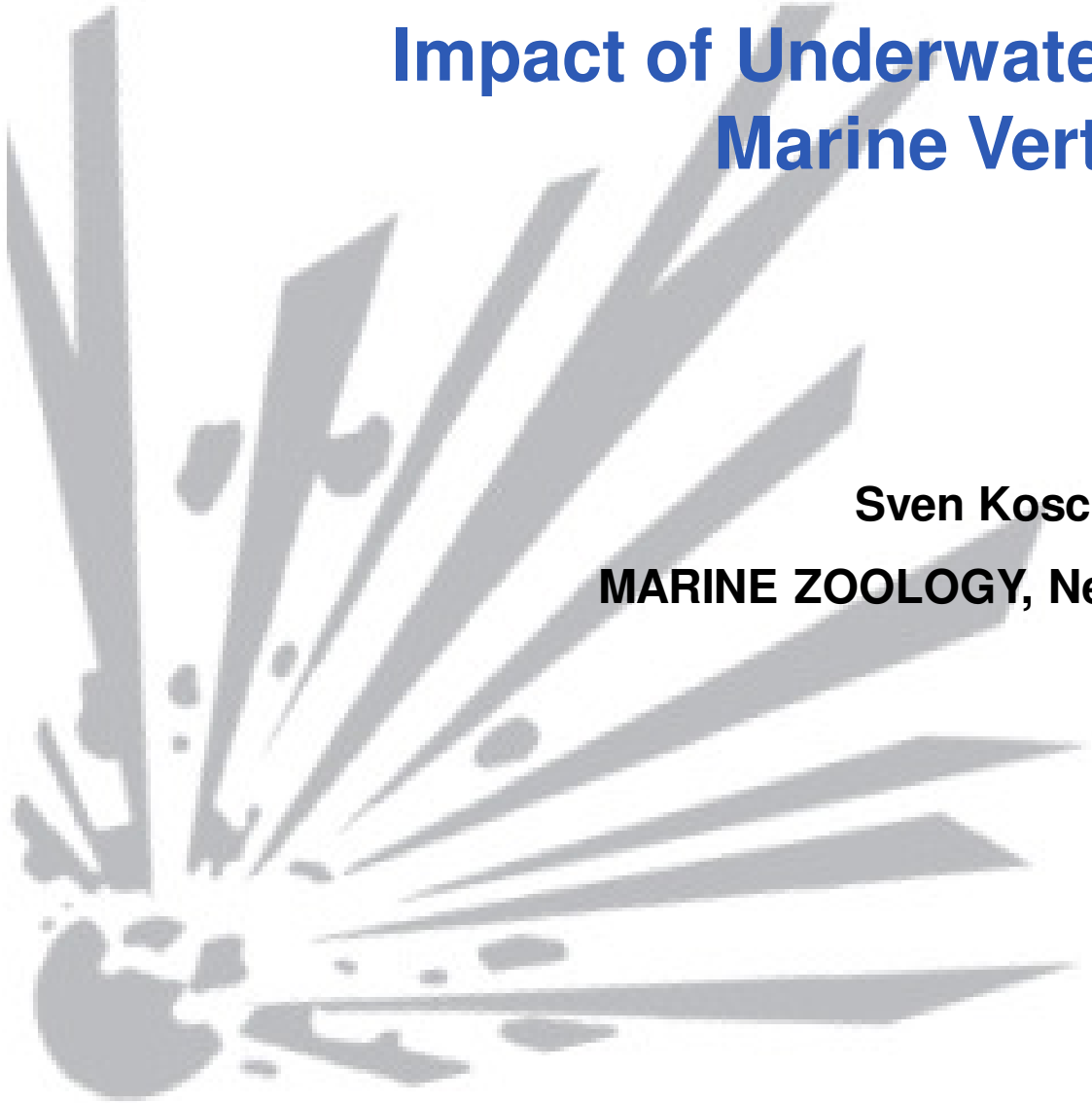
Impact of Underwater Detonations on Marine Vertebrates

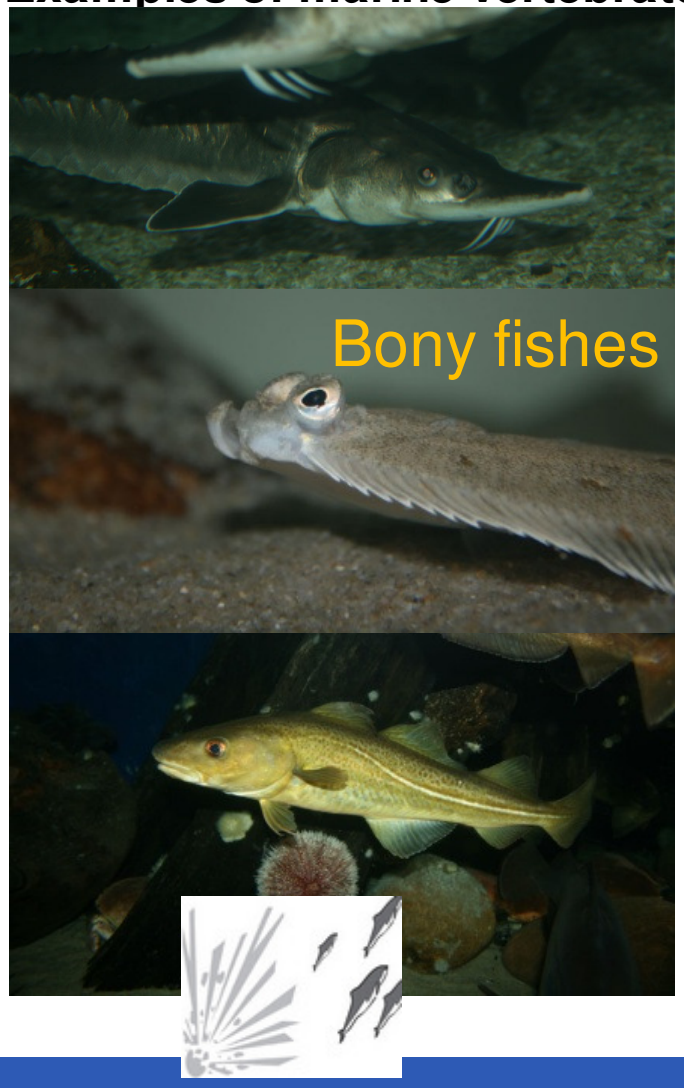


Sven Koschinski

MARINE ZOOLOGY, Nehmten, Germany

Impact of Underwater Detonations on Marine Vertebrates

Examples of marine vertebrates



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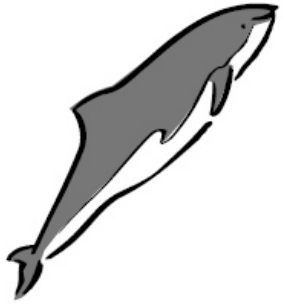

Impact of Underwater Detonations on Marine Vertebrates

Examples of marine vertebrates

© sk, Fjord&Baelt Kerteminde DK

Impact of Underwater Detonations on Marine Vertebrates

Examples of marine detonations

Blast fishing

- Illegal fishery
- Small „beer bottle charges“
- Ammonium and potassium nitrate + kerosene
- Schooling fish killed or stunned
- Devastating to reef ecosystems

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Impact of Underwater Detonations on Marine Vertebrates

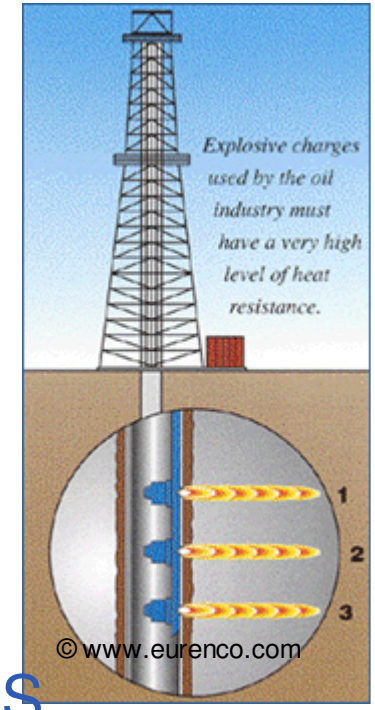
Examples of marine detonations

© U.S. Coast Guard/Marine Photobank

© U.S. Minerals Management Service

Oil and Gas industry

- Accidents (Drilling in munitions contaminated waters, and their interaction with subsurface infrastructure)
- Perforating charges for oil well completion (at great depths)
- Wellhead removal
- Platform decommissioning
- effect not well documented (MMS 2003)
- Seismic testing might detonate dumped ammunition



© www.eurenco.com

Impact of Underwater Detonations on Marine Vertebrates

Examples of marine detonations

blasting of Flood Rock, East River NYC
1885 – charge: 150 t

Rock demolition blasting

Impact of Underwater Detonations on Marine Vertebrates

Examples of marine detonations

Military purposes

Underwater explosion – ship shock trials

© *martec.com*

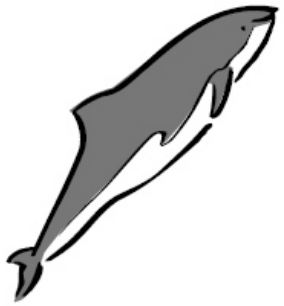
Mine demolition training (training site Schönhagen; © A. *Pfander*)

Impact of Underwater Detonations on Marine Vertebrates

Examples of marine detonations

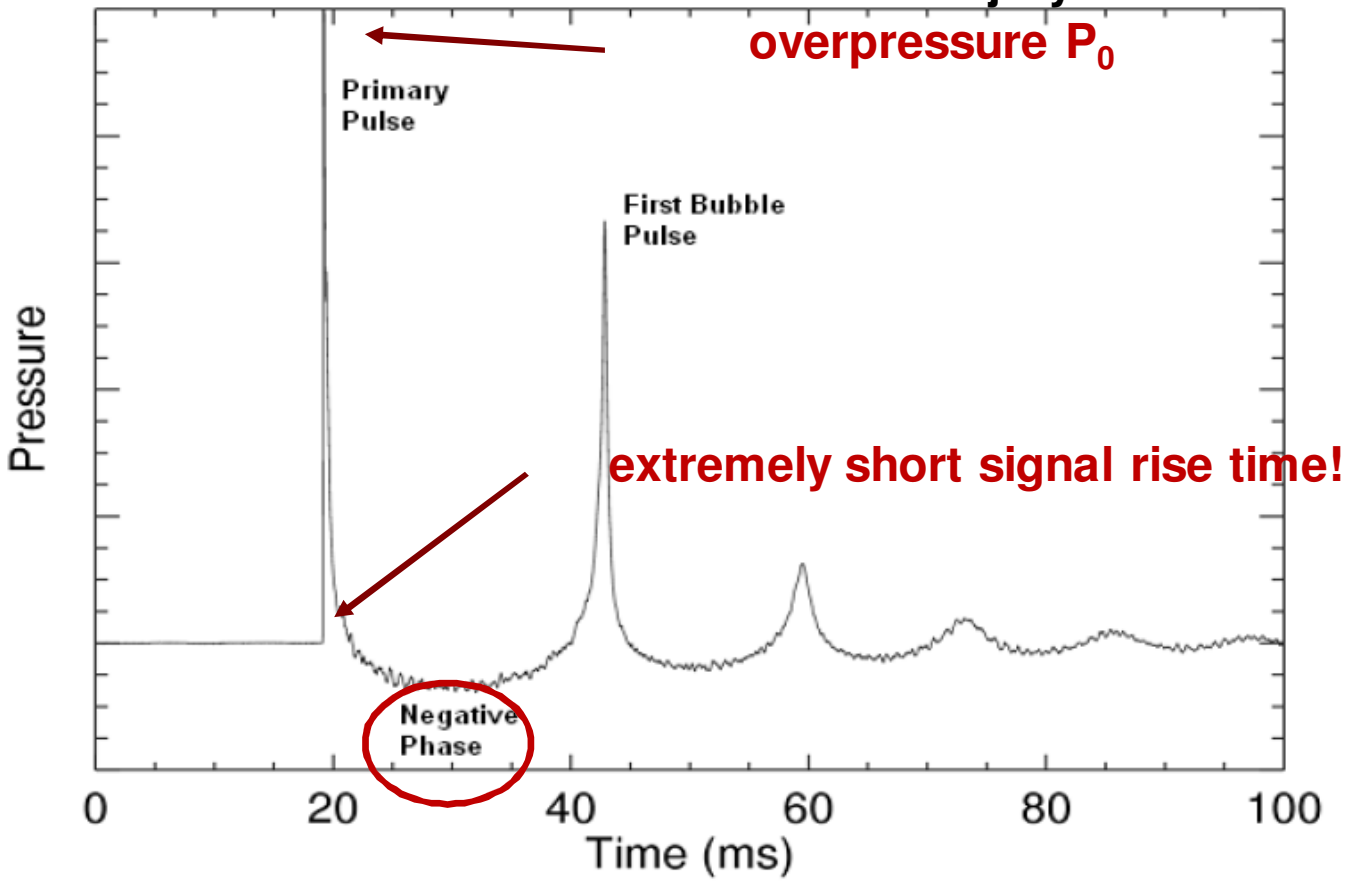
„Traditional“ treatment of UWUXO

Detonations of UWUXO –
Sassnitz 15 March und 2 October 2007
Heidkate October 2005-2006 (33 detonations)
(*Kampfmittelräumdienst SH, Uwe Sturm*)

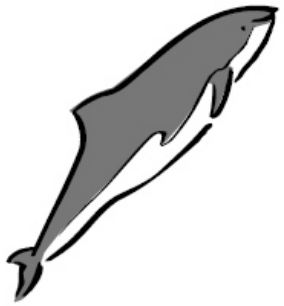


Impact of Underwater Detonations on Marine Vertebrates

Acoustic reasons for injury

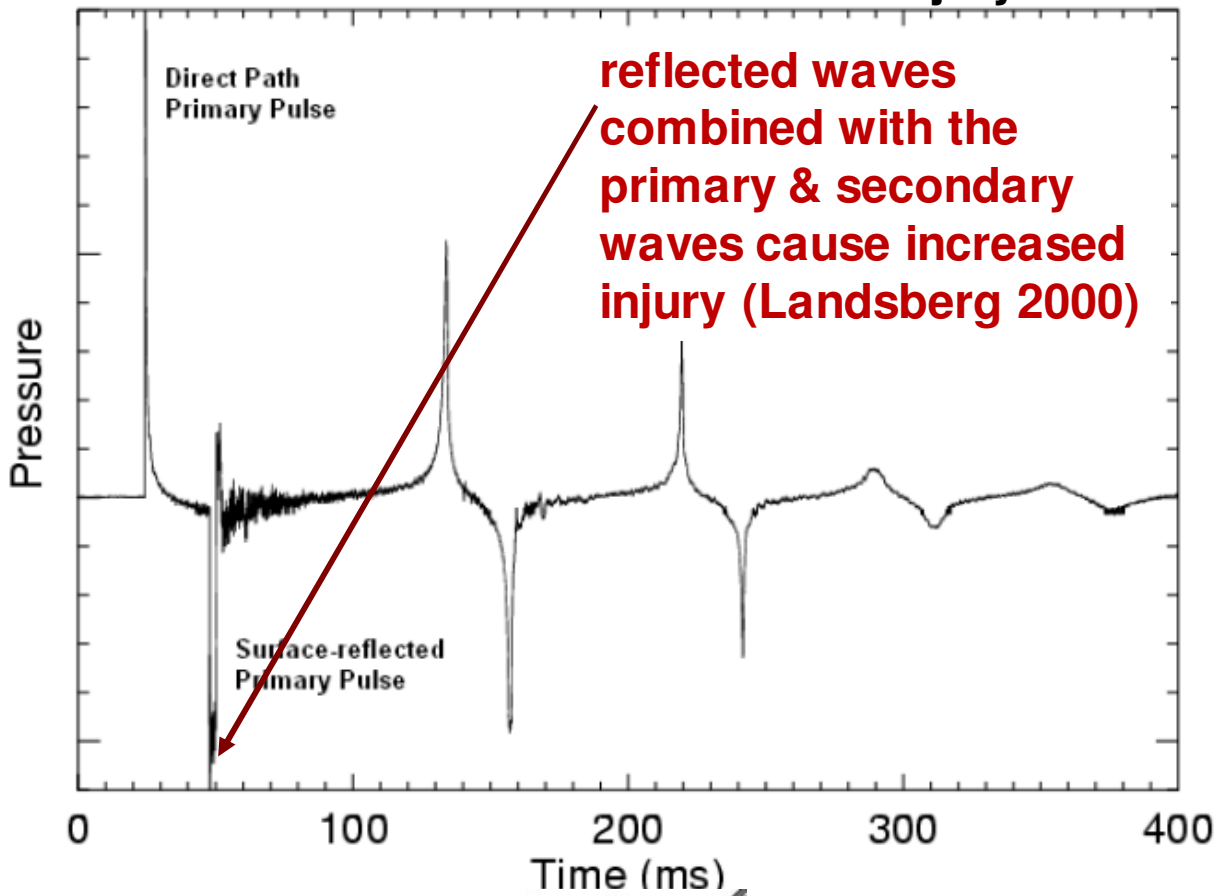


0,82 kg SUS (*MMS 2003*)



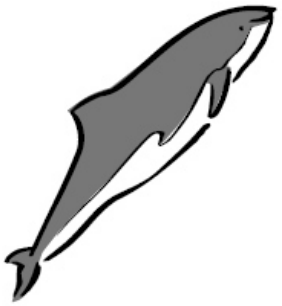
Impact of Underwater Detonations on Marine Vertebrates

Acoustic reasons for injury



reflected waves combined with the primary & secondary waves cause increased injury (Landsberg 2000)

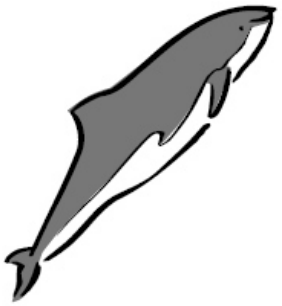
0,82 kg SUS (*MMS 2003*)



Impact of Underwater Detonations on Marine Vertebrates

Acoustic reasons for injury

- Very high-amplitude pressure pulses may cause differential tissue displacement disrupting cells and tissues of different density (e. g. muscle vs. fat; MMS 2003).
- The pressure of the blast wave is transmitted directly through the body as it is of similar consistency to water. Molecules are displaced especially in gas filled cavities capable of compression. Damage occurs at the gas water interfaces. The gas is instantaneously compressed and tissues at these interfaces are torn or shredded. Damage occurs in the lungs, intestines, sinus & ear cavities (Landsberg 2000)
- Compression of the thorax by the shock wave causes rapid increase in blood pressure leading to rupture of blood vessels e. g. in the brain (MMS 2003)

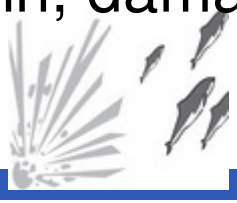


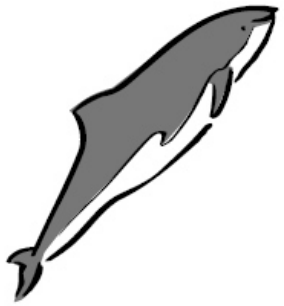
Impact of Underwater Detonations on Marine Vertebrates

Types of injury

PBI: Primary Blast Injury

- massive injury of tissues with different acoustic impedance (e. g., gas-filled structures: lungs, swim bladders, air sacs, ear cavities, intestines)
- fat embolism (e. g. destruction of acoustic jaw fats in toothed whales)
- haemorhages in the brain and ears
- injuries in middle and inner ear caused by blast overpressure: rupture of ear drum, fracture of ossicular chain, damage to basilar membrane





Impact of Underwater Detonations on Marine Vertebrates

Types of injury

acoustic trauma

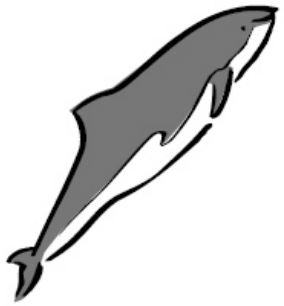
- physiologic exhaustion of sensory cells (fatigue of stereocilia), TTS

- loss of hair cell bodies and neuronal degeneration, PTS

Auditory effects such as TTS and PTS may occur beyond the "safety range"

little information about sublethal impacts, particularly on the auditory system

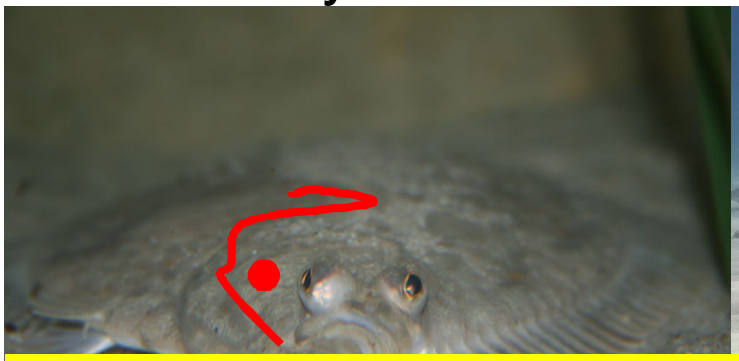
Richardson et al. 1995

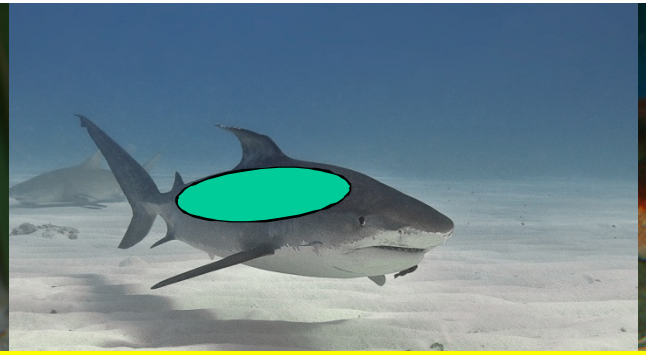


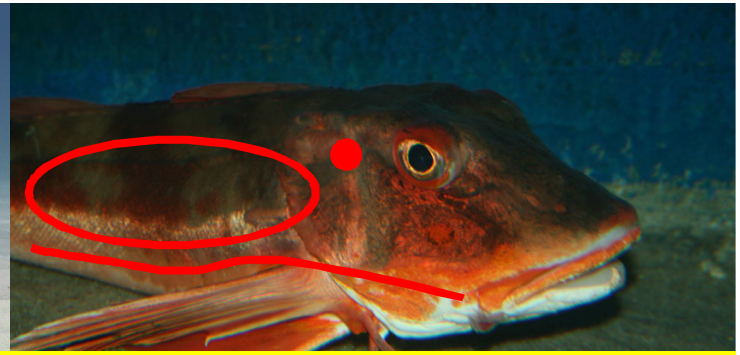
Impact of Underwater Detonations on Marine Vertebrates

Injury to fishes

- At very close range, underwater explosions are lethal to most fish species regardless of size, shape, or internal anatomy
- At greater distances, species with gas-filled swim bladders suffer higher mortality than those without swim bladders
- Only 3 % of killed fish float to the surface (MMS 2003)

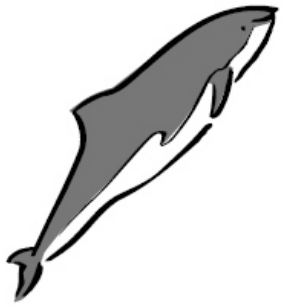






- No information on sharks (fatty liver serves as „swimbladder“) → fat embolism?
- Effects to larval stages go unnoticed

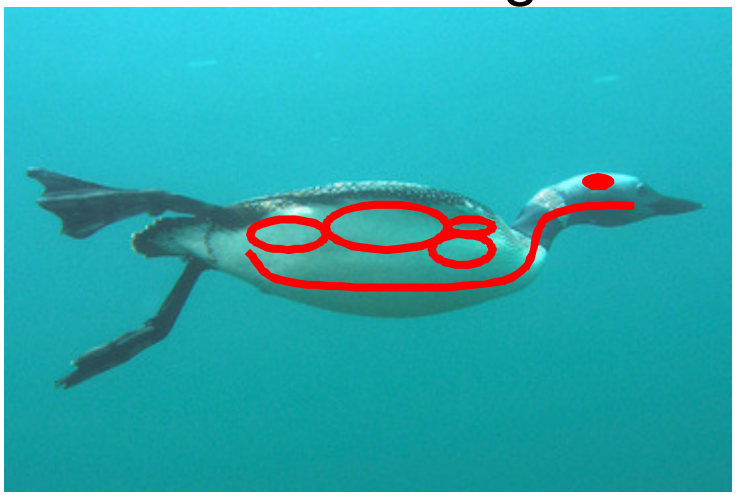
photo credit (shark) :2010 Terry Goss, Terry Goss Photography USA/Marine Photobank

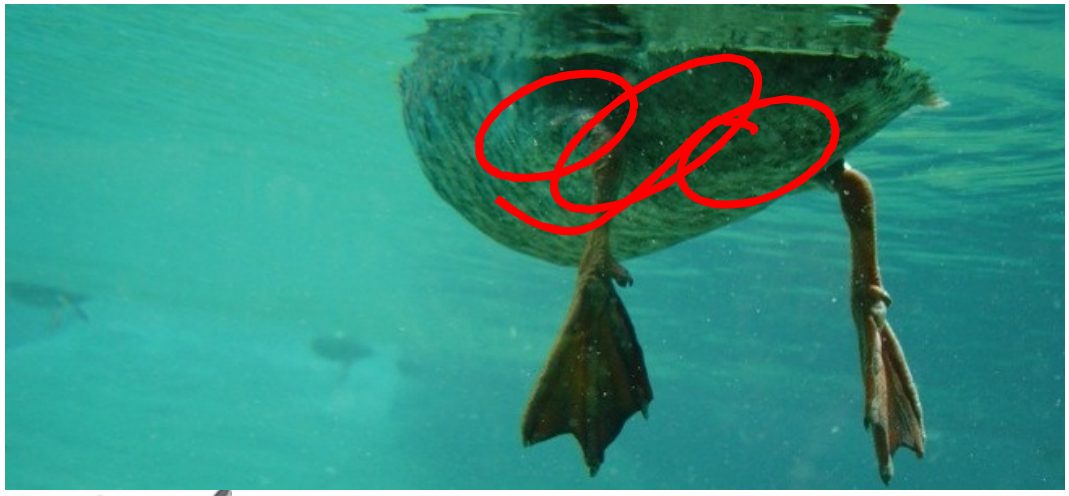


Impact of Underwater Detonations on Marine Vertebrates

Injury to seabirds

- Diving birds may be highly susceptible to blast injuries
- No adaptation to high pressure in contrast to deep diving whales
- Birds have a large air sac system and air-filled ear cavities
- Even in swimming birds the air sacs are affected as pressure is transmitted through the thoracic wall





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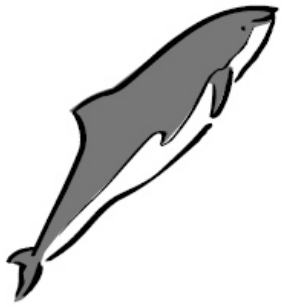
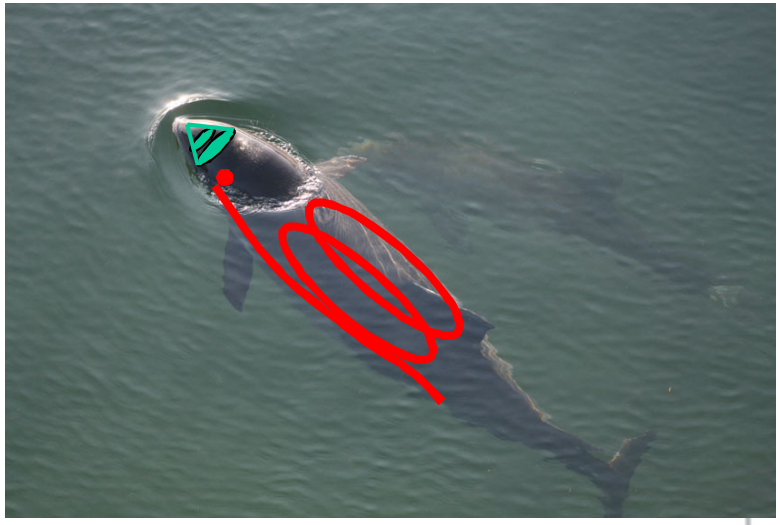
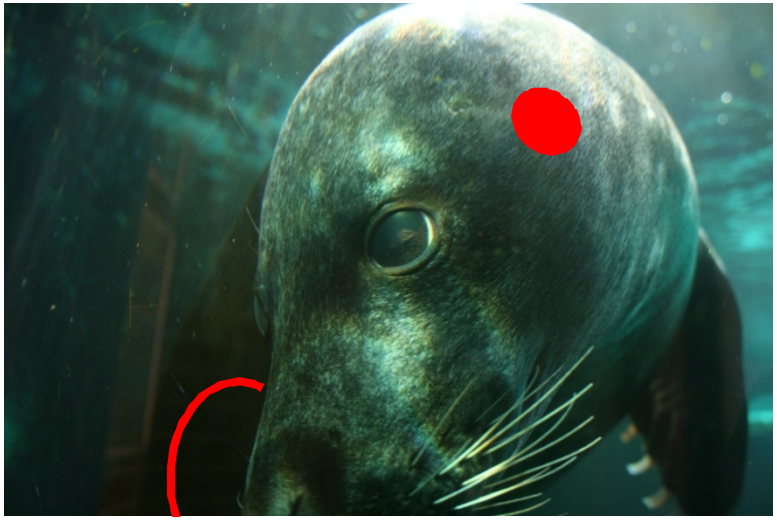


Impact of Underwater Detonations on Marine Vertebrates

Injury to marine mammals

- Ear cavities
- Lungs, nasal sacs
- Gastrointestinal tract
- Fat my be mobilized in the blubber, acoustic jaw fats and acoustic lenses of toothed whales→ fat embolism





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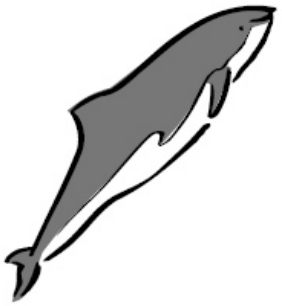


Impact of Underwater Detonations on Marine Vertebrates

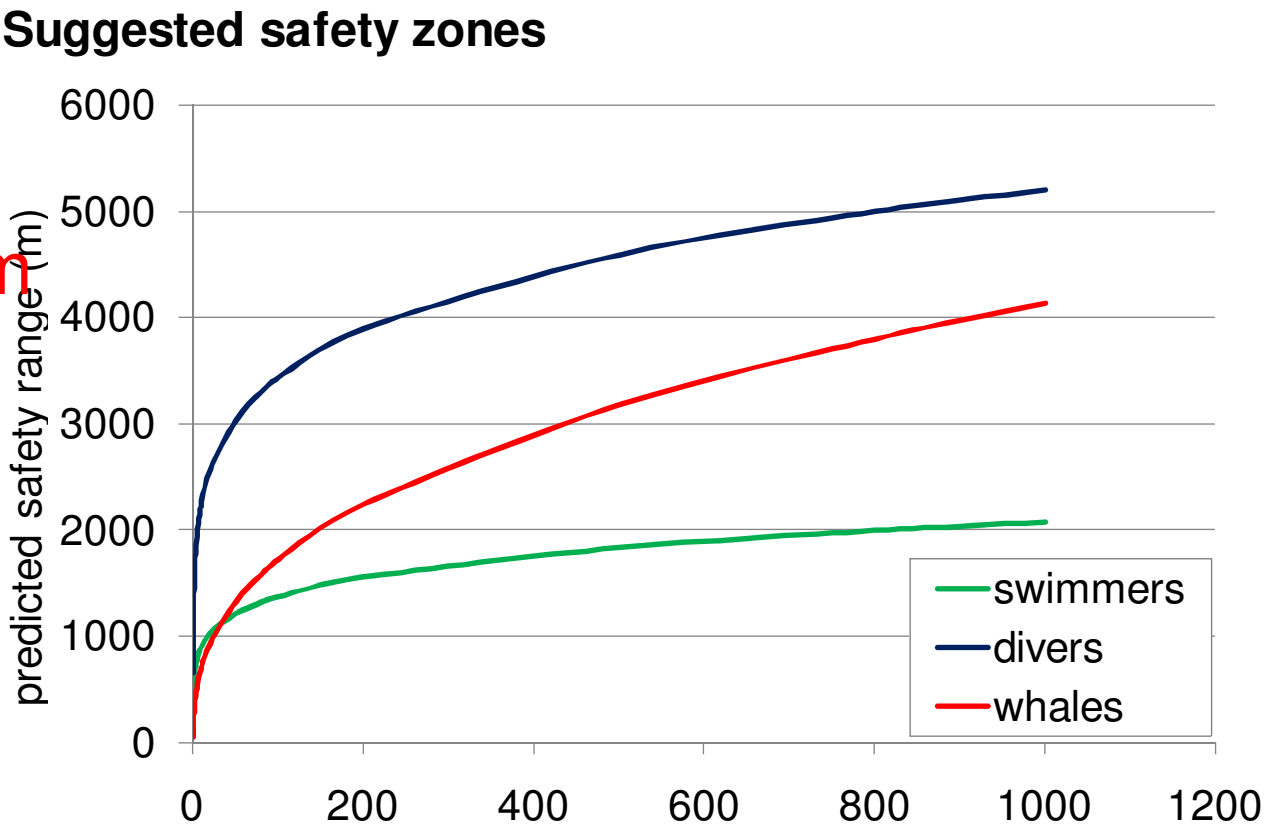
350 kg:

1,7 km - 4,3 km - 2,8 km

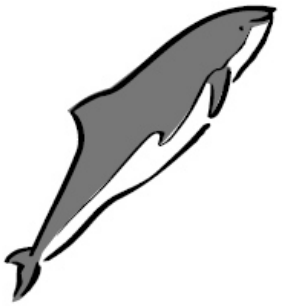
20 g:

297 m - 742 m - 68 m

© Sandy Dubpernel



=high probability of lethal or severe injury



Impact of Underwater Detonations on Marine Vertebrates

Suggested safety zones

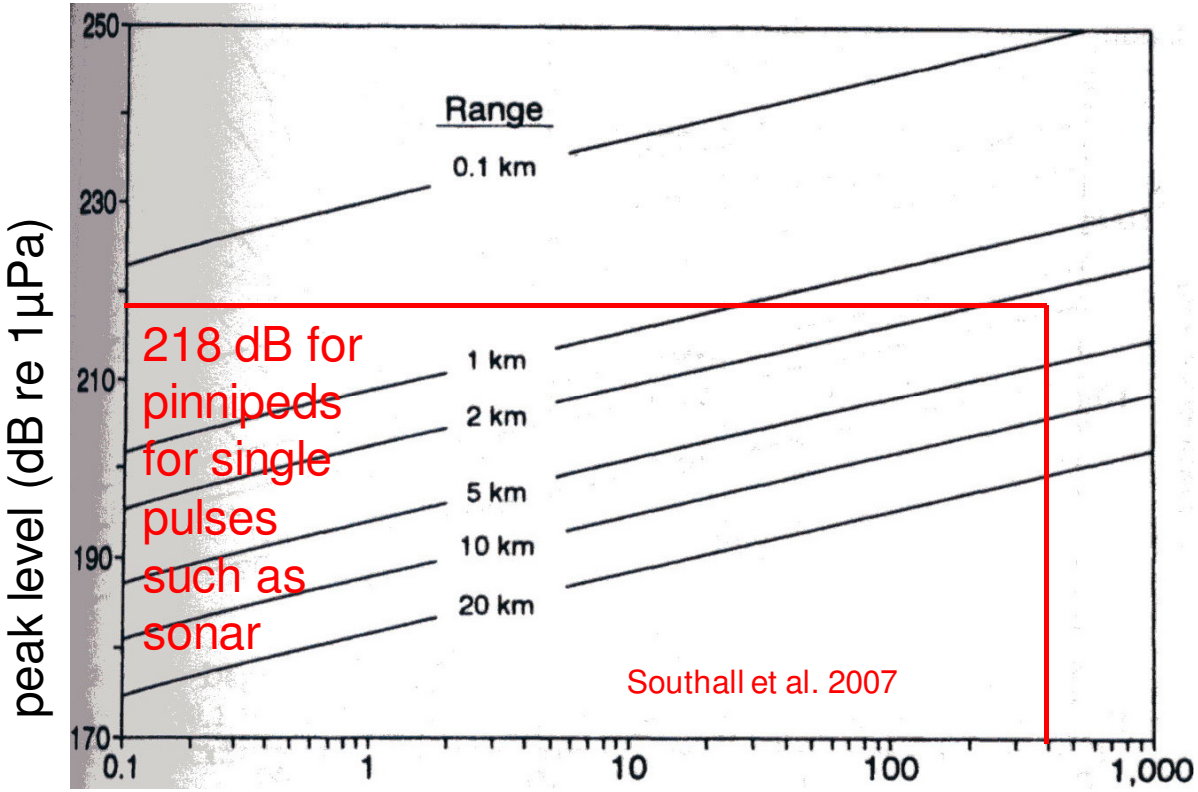
350 kg:

1,7 km - 4,3 km - 2,8 km

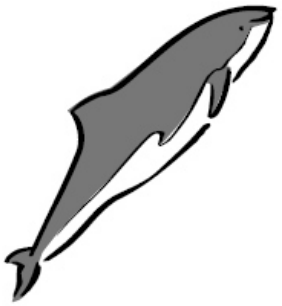
20 g:

297 m - 742 m - 68 m

Thiele & Stepputat 1998



Richardson et al. 1995



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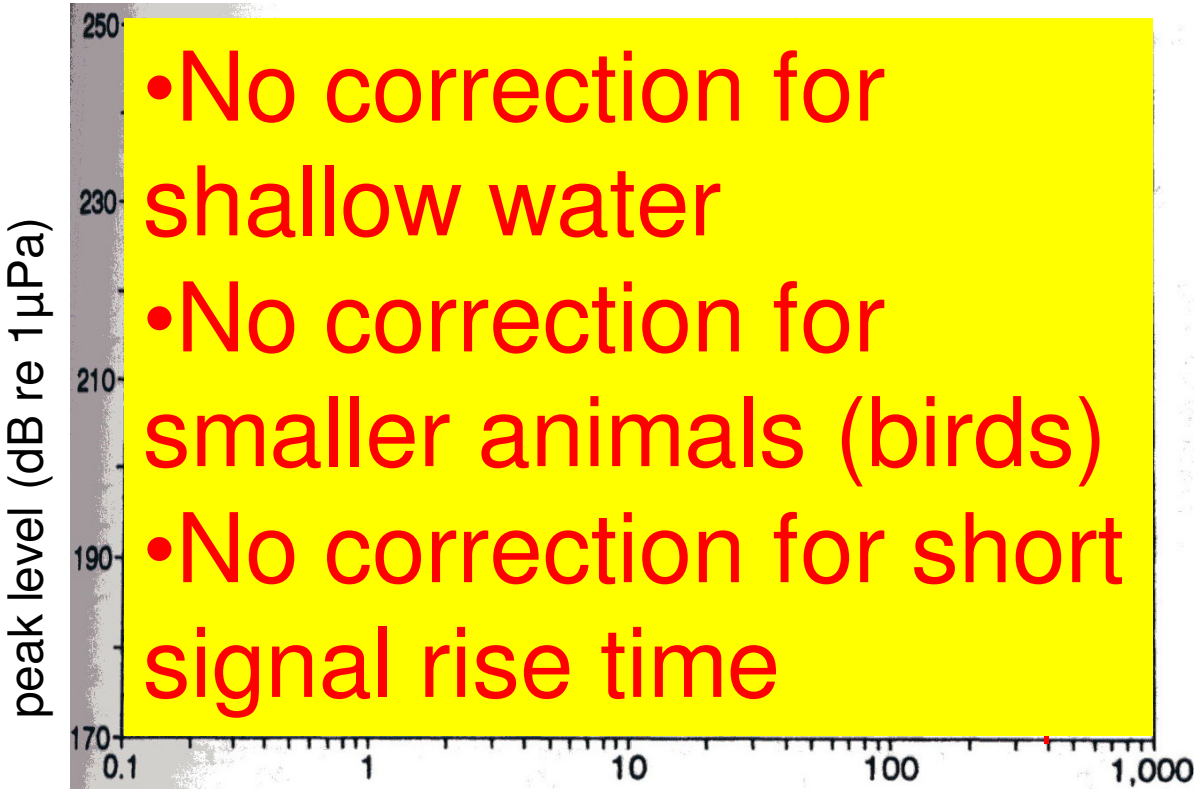


- No correction for shallow water
- No correction for smaller animals (birds)
- No correction for short signal rise time

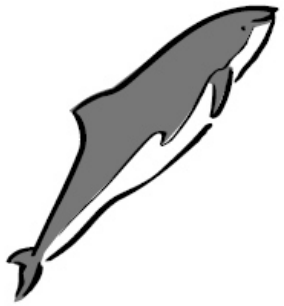
Richardson et al. 1995

Impact of Underwater Detonations on Marine Vertebrates

Suggested safety zones

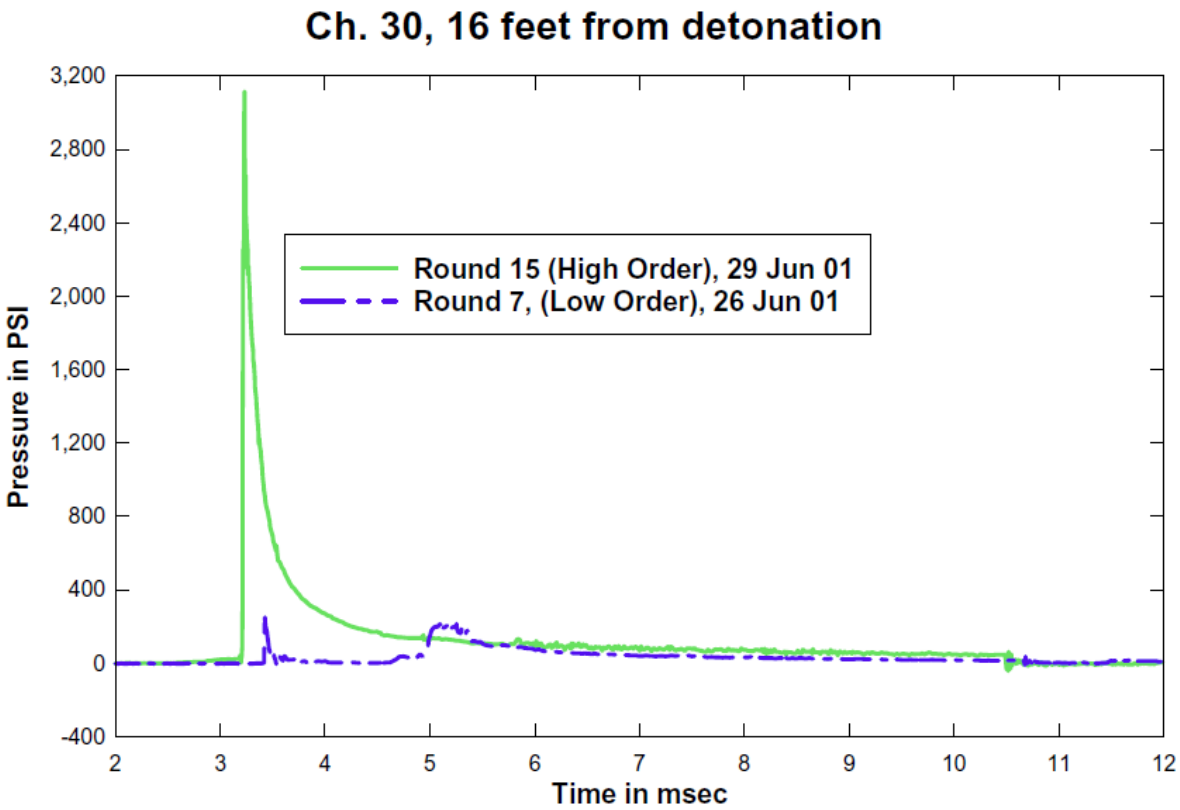
Safety ranges to prevent serious injury may be realistic for whales but

- we need to consider additional factors and other species.
- Information on sublethal impacts is urgently needed!

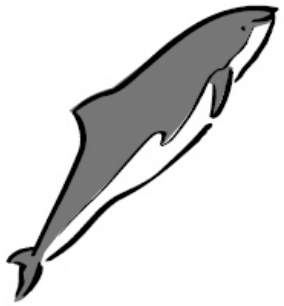


Impact of Underwater Detonations on Marine Vertebrates

Low Order Detonation as an Alternative?



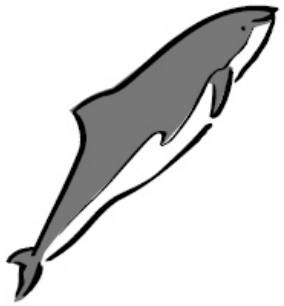
Low-order detonations lack the rapid rise and exponential decay of pressure that is characteristic of high-order detonations (ESTCP 2002).



Impact of Underwater Detonations on Marine Vertebrates

Low Order Detonation as an Alternative?

- Intentional Low Order Detonations are an alternative means to the traditional High-Order-Detonation procedure referred to as “Blow-in-Place” (BIP). Both procedures are used for the disruption of submerged unexploded ordnance that is considered unsafe to move.
- Low Order Detonations mitigate the shock wave and other effects compared to BIP.
- But on average, in new ammunition more than 25% of the original explosive fill was recovered after a low-order detonation (ESTCP 2002).
- A lot of UWUXO have been saturated with water over decades. These often detonate low-order unintentionally adding significantly to the waste stream and being transferred into the food chain.



Risks to porpoises from detonation of world war II ammunition

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