



National Military Fish and Wildlife Association Workshop

Acoustic Criteria and Thresholds for Marine Species

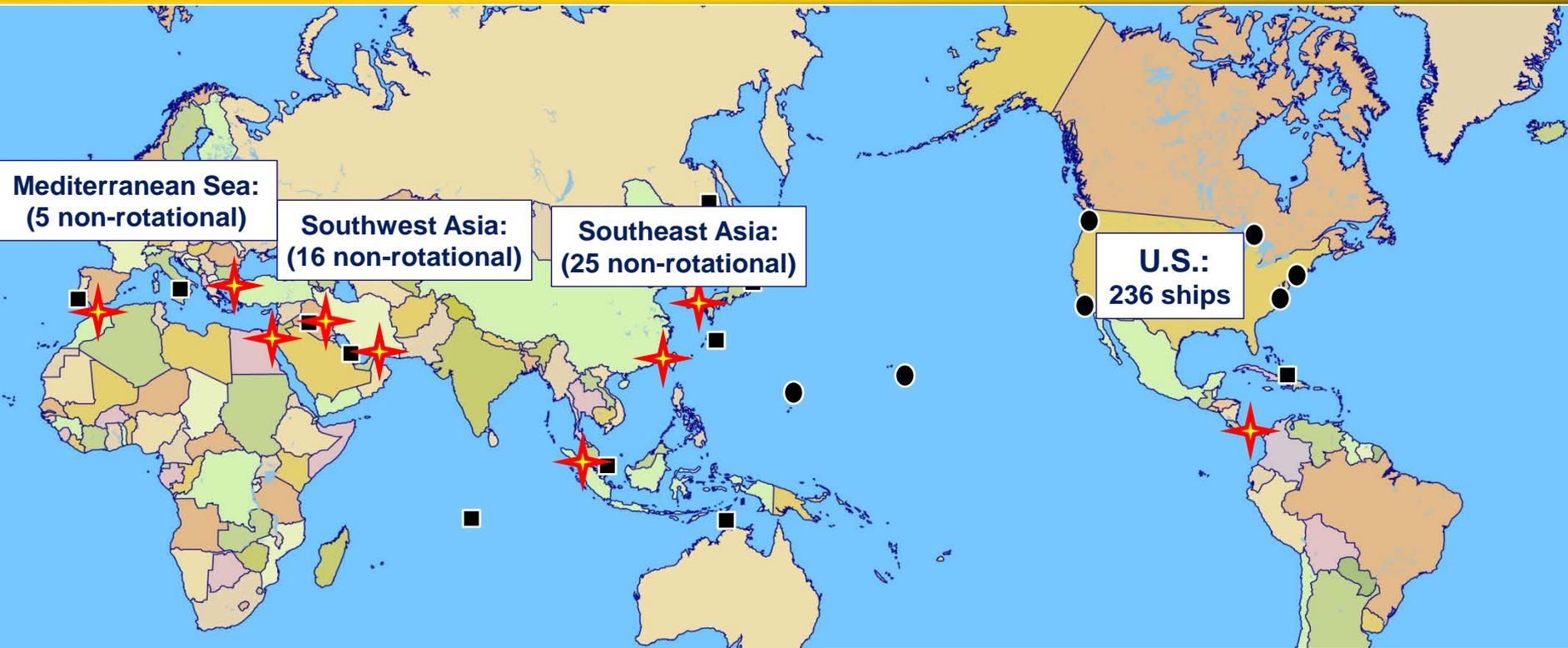
Jene Nissen

U.S. Fleet Forces Command

Environmental Readiness Division



Today's Navy: OPERATE FORWARD



- Bases – Where our forces are permanently assigned
- Places – Where we maintain a naval presence
- ★ Crossroads – Where the world's maritime traffic flows

Totals: 282 Ships; 3700+ Aircraft; 325K Active Duty; 98K Reserve; 267K Civil Service

Deployed: 55 Ships (20%)

Underway: 29 ships (10%) (local operations/training)

Updated: March 26, 2018

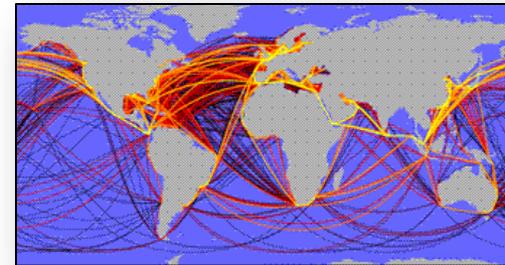
Where it Matters, When it Matters



Why Does Navy Train?

Mission: Maintain, train and equip combat-ready military forces capable of winning wars, deterring aggression, and maintaining freedom of the seas (Title 10 of U.S. Code)

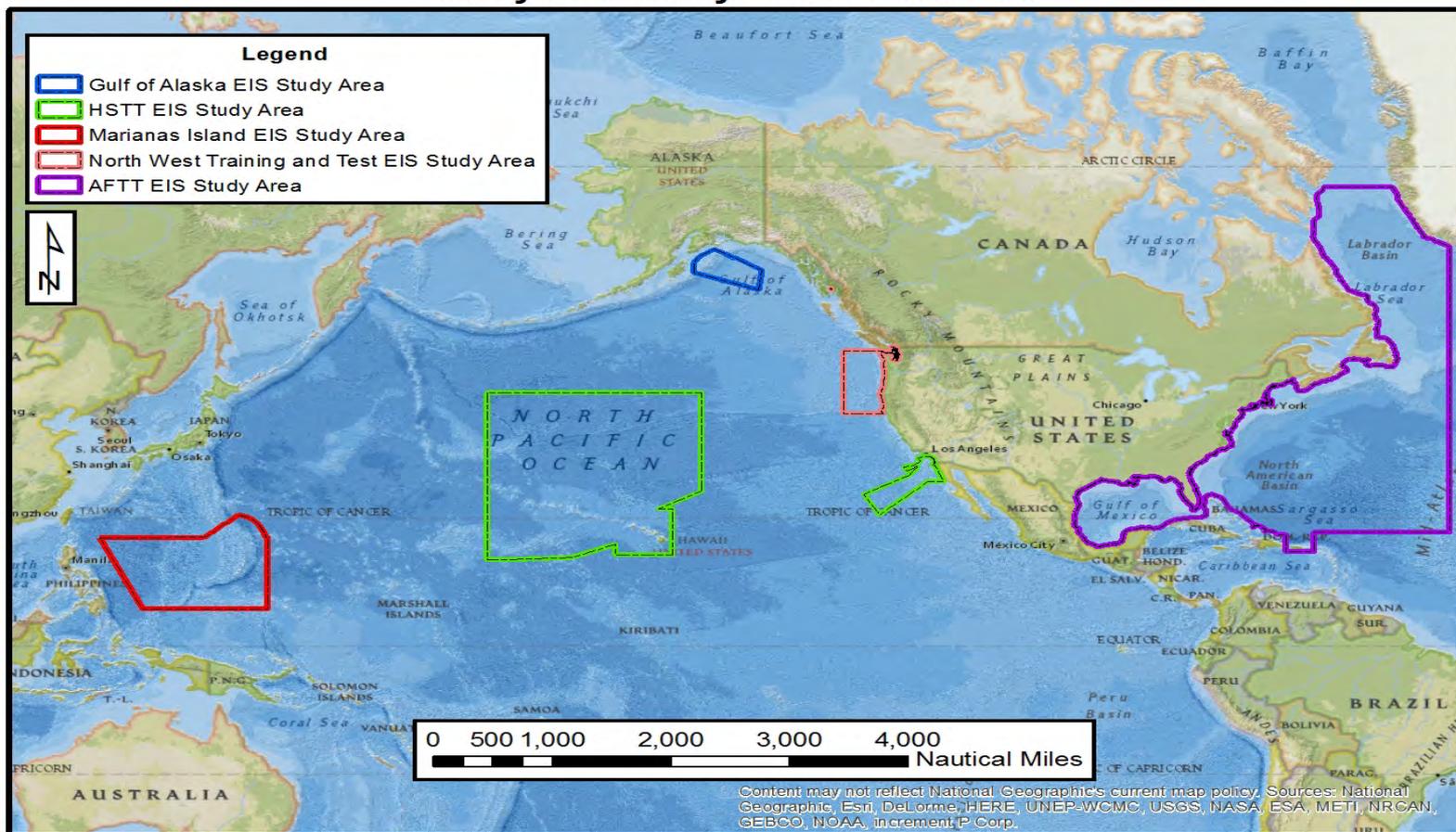
- **Why Navy must conduct live, realistic training at sea:**
 - Defeat enemy threats
 - Protect and enable global trade & US economic interests
 - Prepare Sailors for combat & maintain critical skills
 - Proliferation of quiet, modern submarines and other technologies by adversaries worldwide
 - Assess performance of new & emerging technologies





Phase II/III At Sea Study Areas

Navy EIS Study Areas Phase III

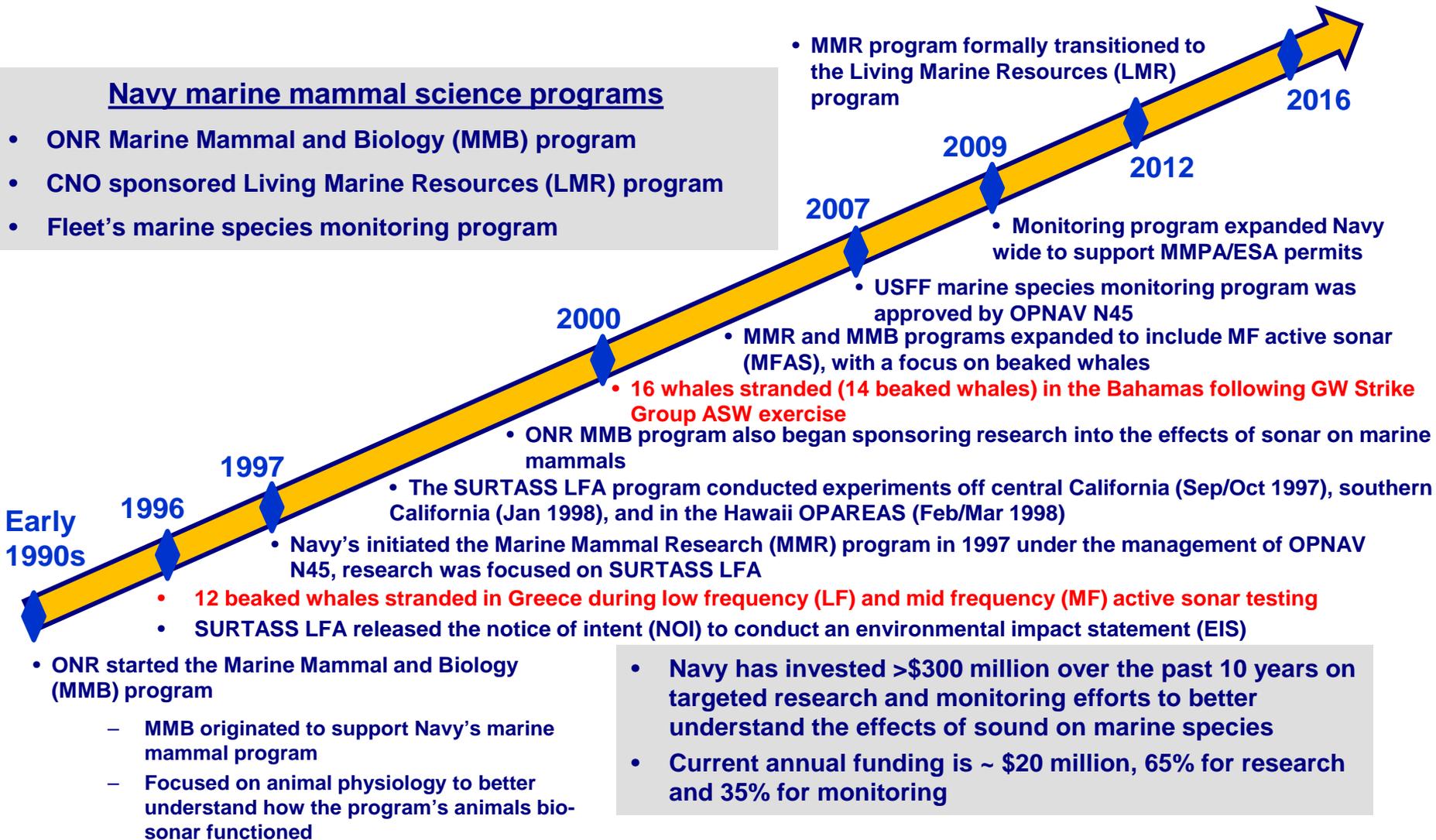




Navy Marine Mammal Research History

Navy marine mammal science programs

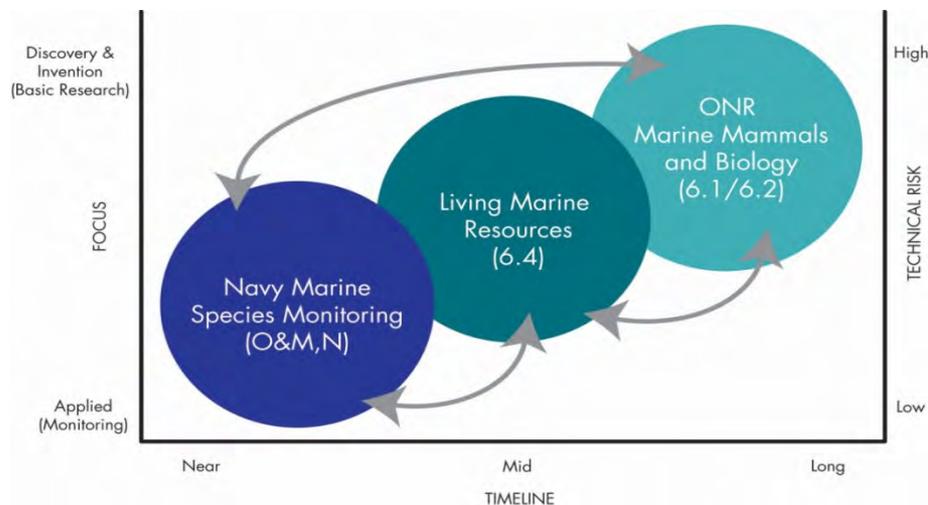
- ONR Marine Mammal and Biology (MMB) program
- CNO sponsored Living Marine Resources (LMR) program
- Fleet's marine species monitoring program





Navy Marine Mammal Science Programs

- **ONR Marine Mammals and Biology program supports 6.1 and 6.2 basic and applied research**
 - Supports basic and applied research and technology development related to understanding the effects of sound on marine mammals
- **The LMR program supports 6.4 applied research**
 - Develops, demonstrates, validates, and assesses data and technology solutions to study living marine resources and fill critical data gaps within the Navy's at-sea environmental compliance process
- **Navy marine species monitoring program supports collection and analysis of scientific data in areas, or areas similar to, where Navy trains**
 - Collect and analyze data regarding the occurrence, abundance, and baseline behavior of marine species in Navy training areas, as well as the effects and consequences of Navy activities on marine species
 - A requirement of the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) permits
- **There is coordination across all three programs**





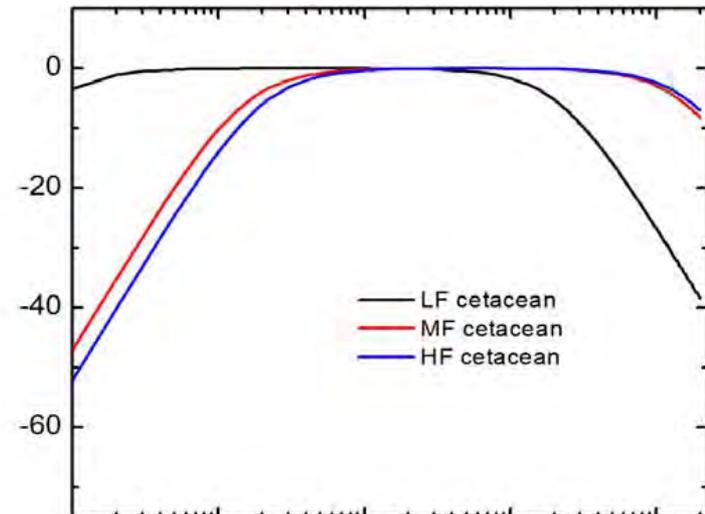
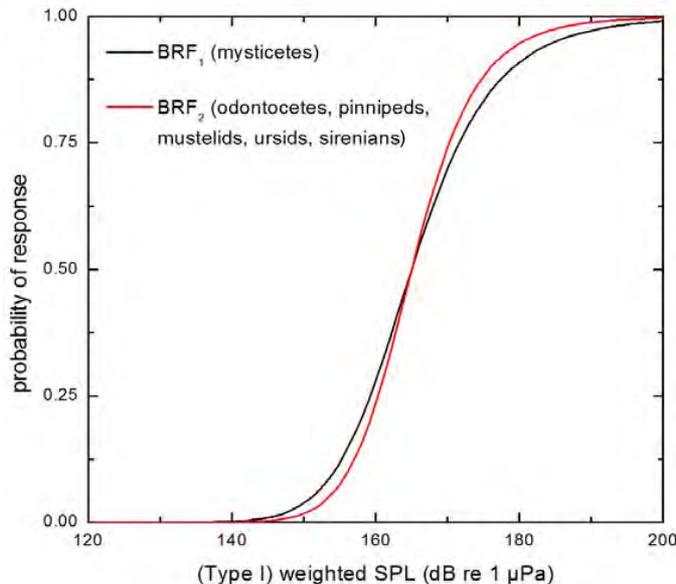
Effects to Marine Species

- **Effects**
 - **Physiological**
 - Mortality, injury, hearing impacts
 - Quantitative
 - **Behavioral**
 - Severity of reaction
 - Consequences
 - Qualitative and quantitative
- **Physiological impacts for marine species focuses on sound and pressure**
 - **Mortality and non-auditory injury based on impulsive source (blast) studies in 1960's and 1970's on terrestrial animals**
 - **Sonar has not been shown to cause direct injury except for possible hearing impairment**
 - **Sound can cause permanent threshold shift (PTS)**
 - PTS is a permanent reduction in hearing sensitivity over specific frequency range
 - Animal must be very close to the source (10's of yards for the SQS-53)
 - **Sound can also cause temporary threshold shift (TTS)**
 - TTS is a temporary reduction in hearing sensitivity over specific frequency range
 - Animal must be close to the source (100's of yards for the SQS-53)



Current Behavioral Criteria

- To estimate potential behavioral disturbance for previous analyses, Navy developed a behavioral response function (BRF)
- This BRF was in use 2007 to 2013 and based on three data sources:
 - Behavioral observation notes during TTS/PTS experiments (Finneran and Schlundt 2004)
 - Sound field reconstruction from SHOUP sonar associated with behavioral responses of killer whales in PACNORWEST (DoN 2003; Fromm 2009)
 - Right whale behavioral responses to an alert stimuli with mid-frequency components (Nowacek et al., 2004)
- When calculating exposures, there was also a weighting function that applies to the BRF





Acoustic Criteria Development

- **Marine mammal and sea turtle affects criteria are required in the Navy Acoustic Effects Model (NAEMO) to estimate potential physiological and behavioral sound exposures**
 - Based on best available science
 - Development is coordinated with NMFS for their concurrence
 - Significant investment by Navy to develop
- **Two types of criteria**
 - Physiological
 - Behavioral



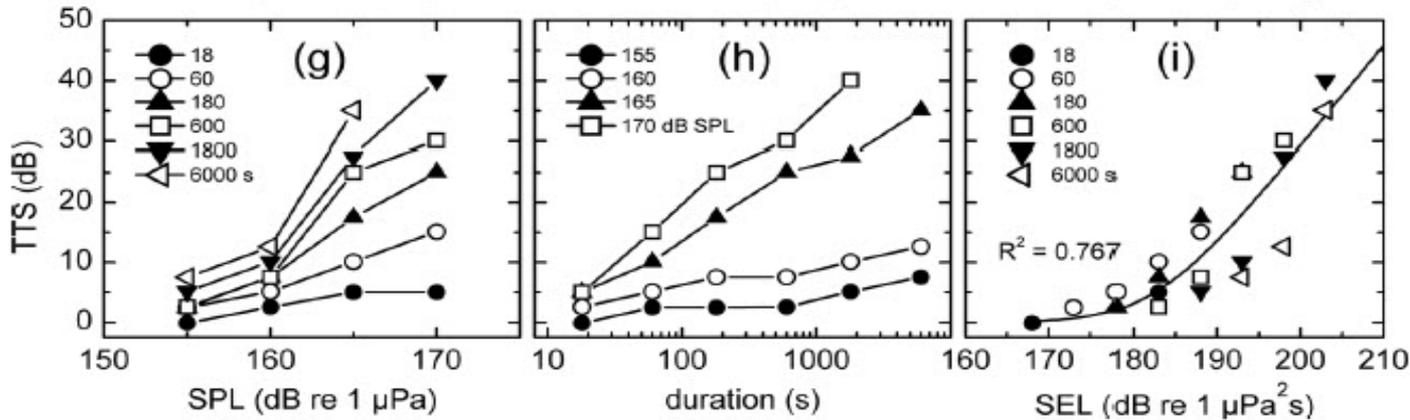
Physiological Criteria Development

- **Physiological**

- Permanent threshold shift (PTS)*
- Temporary threshold shift (TTS)*
- Controlled sound exposure tests on trained animals
- Navy marine mammal program and other scientists
- Science primarily funded by LMR and ONR



Finneran 2015



* These shifts are to a portion of the hearing range and not a shift over the whole hearing range, nor are animals completely deaf at that frequency



Threshold Shift Criteria

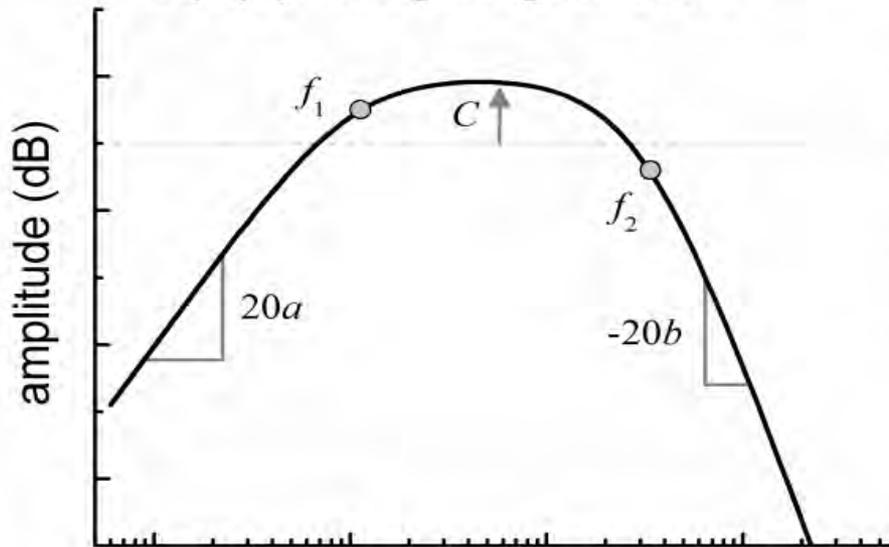
- **Temporary (TTS) values were derived from exposing trained animals to fatiguing sounds and periodically measuring their hearing sensitivity**
 - Measured at multiple frequencies with increasing source levels
- **Permanent (PTS) values then derived from the TTS values**
 - Assumed 40 dB of TS could result in PTS, sonar PTS threshold is 20 dB SEL
 - Based on data from terrestrial animals and human studies on hearing loss
 - No marine mammals experienced PTS from the studies
- **Weighting functions are integral to the PTS/TTS criteria**
 - Weighting functions are designed to emphasize frequencies (i.e., to add “weight”) where a species is most sensitive and to de-emphasize frequencies (i.e., subtract weight) where a species is not as sensitive
 - Weighting functions are derived in humans from subjective loudness tests, this is difficult to do with marine mammals and frequency dependent TTS experiments
 - Marine mammal weighting functions are estimated based on the animals hearing range, frequency dependent TTS studies, and equal loudness curves
 - Most studies used to develop these functions have been funded by Navy



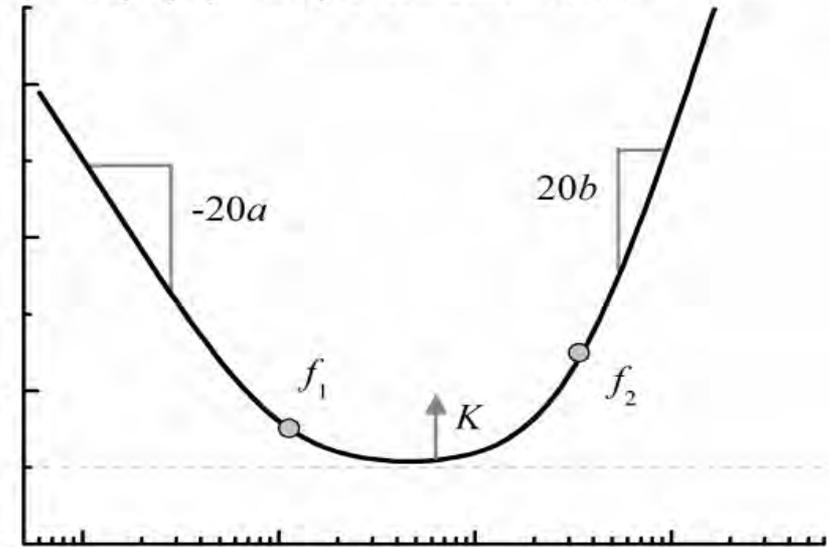
Weighting & Exposure Functions

- For frequencies within an animals best hearing range, lower sound pressure levels (SPL) are needed to produce TTS

Eq. (1) - weighting function



Eq. (2) - exposure function



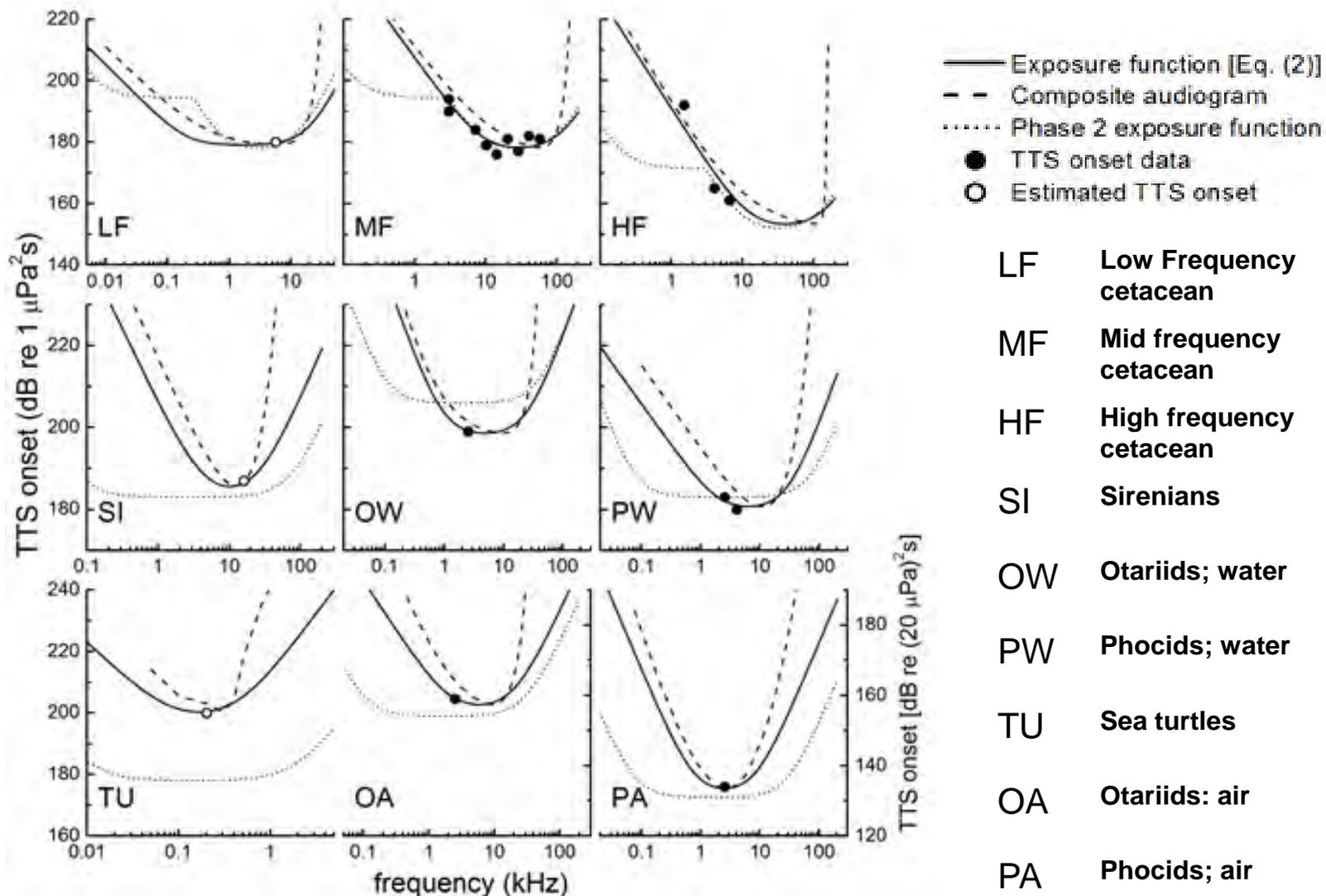
frequency

$$W(f) = C + 10 \log_{10} \left\{ \frac{(f/f_1)^{2a}}{\left[1 + (f/f_1)^2\right]^a \left[1 + (f/f_2)^2\right]^b} \right\}$$

$$E(f) = K - 10 \log_{10} \left\{ \frac{(f/f_1)^{2a}}{\left[1 + (f/f_1)^2\right]^a \left[1 + (f/f_2)^2\right]^b} \right\}$$



TTS Exposure Functions





Updated Criteria

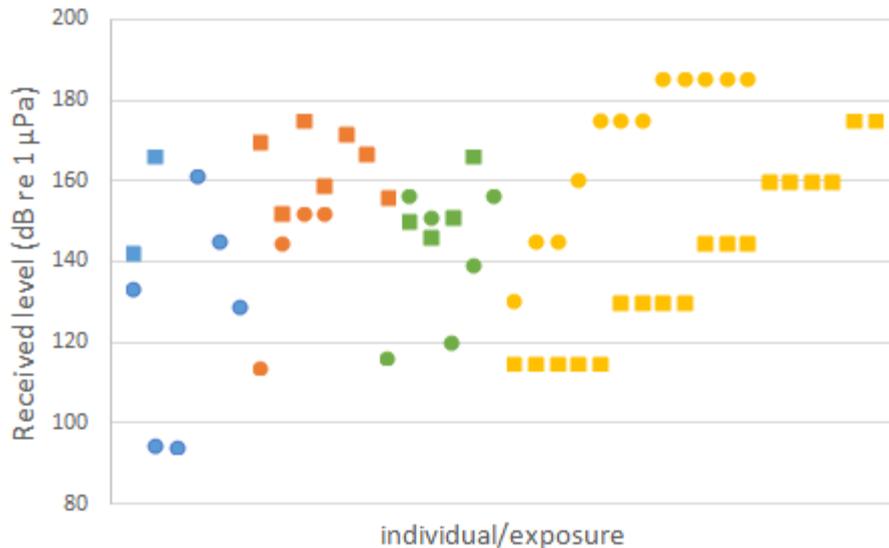
- Based on new science, the renewal of current MMPA/ESA permits (Atlantic Fleet Training and Testing (AFTT) in progress), Navy is updating the criteria
- The TTS/PTS weighting functions and thresholds have been updated
 - NMFS has based their PTS/TTS criteria on Navy's work
 - Updated science resulted in a slight reduction in thresholds (less sound required to cause TTS/PTS)
 - Went through NMFS peer review process, scientifically defensible
- The BRFs have been updated based on new science from the AUTEK, 3S and SOCAL behavioral response studies (BRS), studies on captive animals, and other data on wild animals
- The BRF also accounts for context (distance, behavior, previous experience, etc.), meaning that at similar received levels, the animals are more reactive for close sources versus far sources
 - Implemented distance cut-offs

Criteria updated to reflect new science

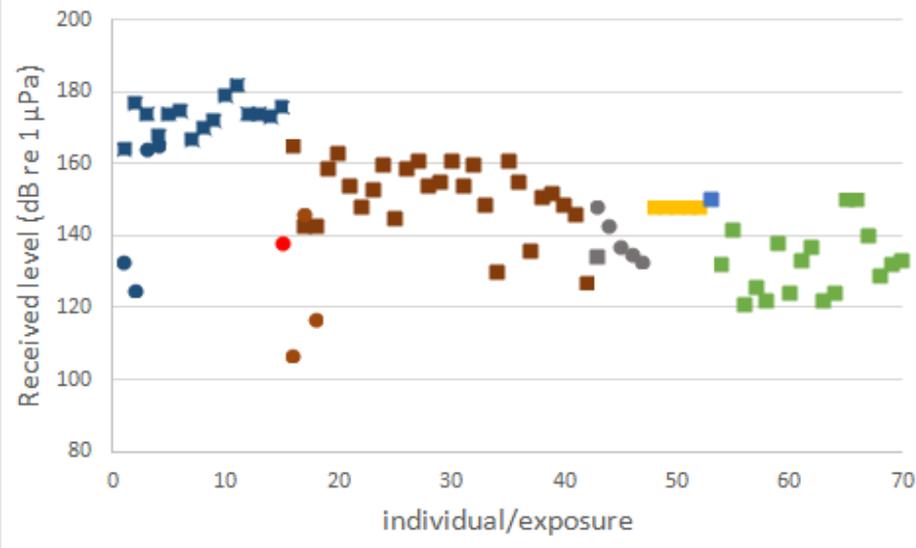


Behavioral Response Function (BRF) Development

- The new BRFs were developed by compiling response data from the behavioral response data, measuring the receive levels when animals reacted
- Also considered literature where animals reacted less, or not at all, at similar received levels for distant sources
- Worked with University of St Andrews to provide statistically sound methods for combining disparate behavioral data sets; methodology went through scientific review
- Resulted in lower thresholds than current criteria, partially negated by taking into account context



Received levels of Odontocete responses (in circles) or maximum received levels when there was no response (in squares). killer whales: blue; pilot whales: orange; sperm whales: green; bottlenose dolphins: yellow

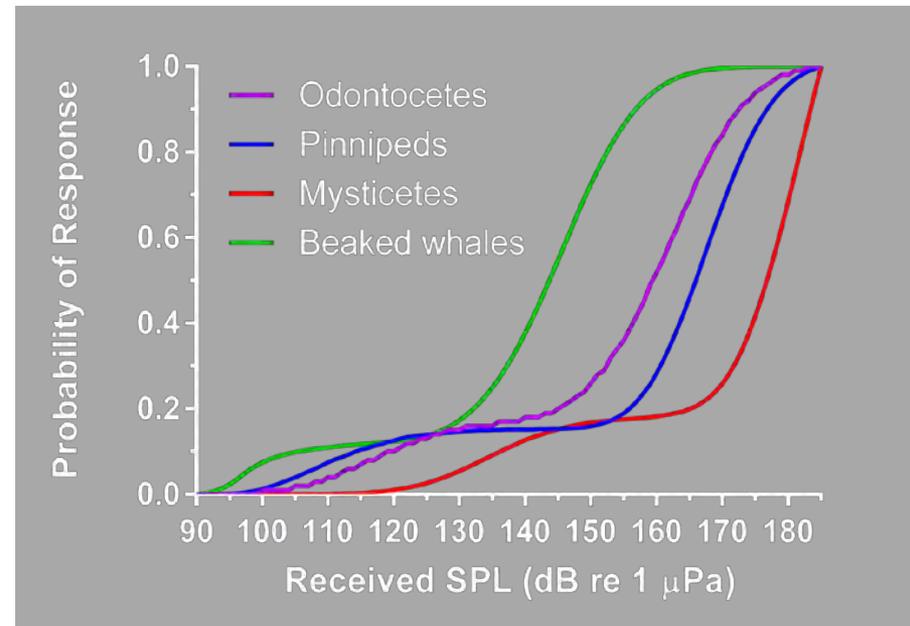
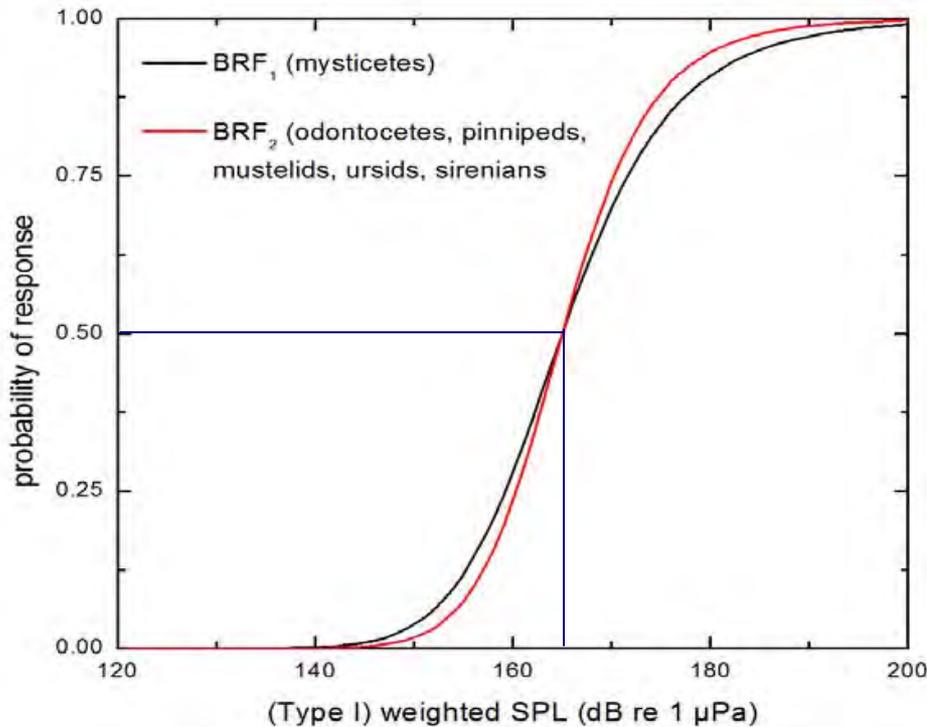


Received levels of Mysticete responses (in circles) or maximum received levels when there was no response (in squares). Humpbacks: dark blue; minke whale: red; blue whales: brown; NARW: gray; fin whales: yellow; blue whale: light blue; humpback: green.



Current vs New BRF

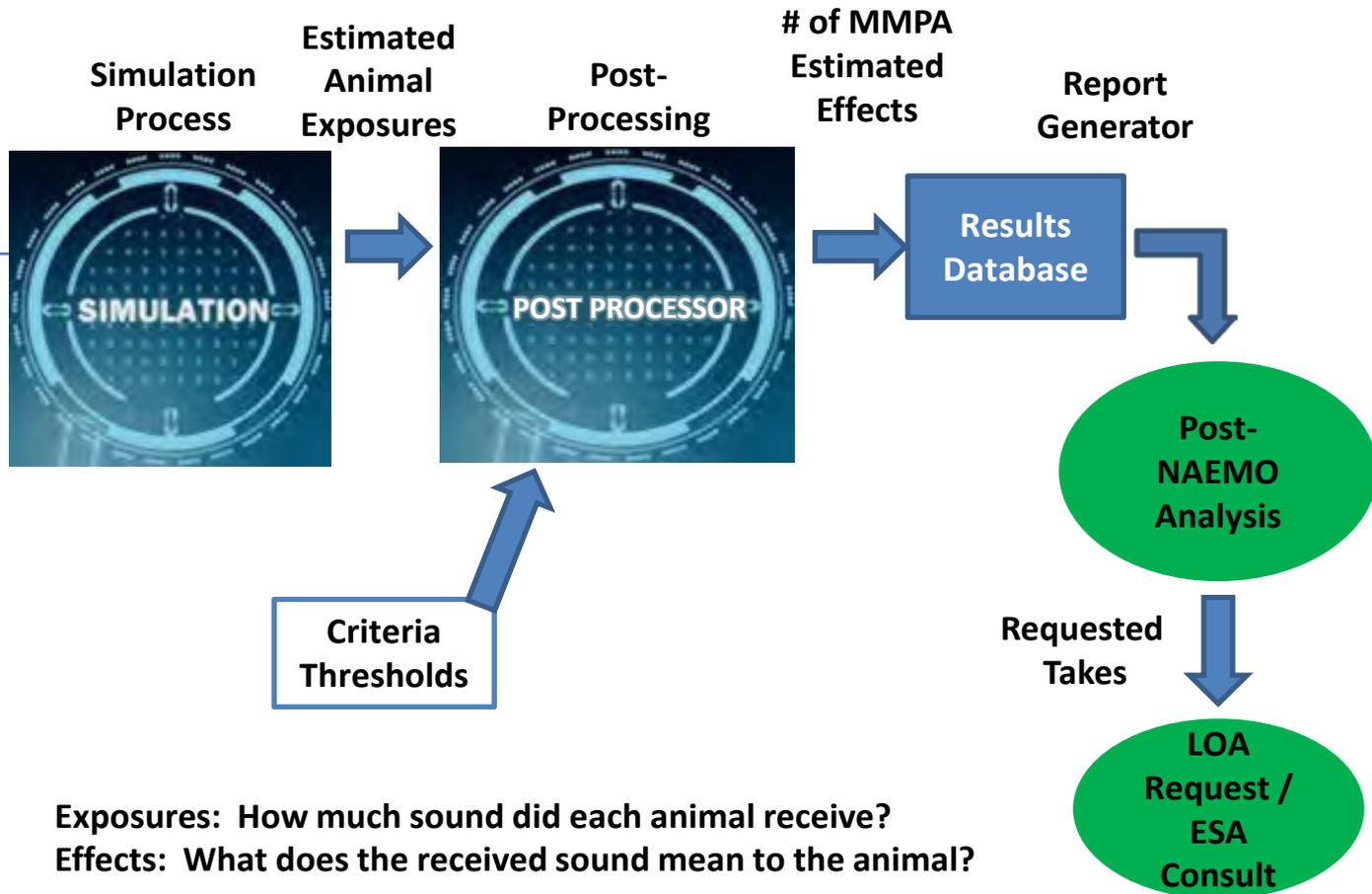
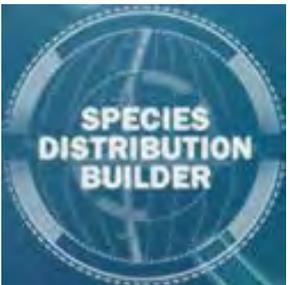
- The curve determines the probability of response / proportion of animals responding at a given dose [or received level]
- New BRF also has a lower floor, ~ 100 dB vice 120 dB





Navy Acoustic Effects Model (NAEMO)

Scenarios/Events





Effects Analysis

- **Qualitative and quantitative assessment of exposures to determine “takes”**
- **There two types of takes in the MMPA**
 - **Level A: Injury or mortality**
 - **Injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild**
 - **Level B: Harassment**
 - **Disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behavioral patterns are abandoned or significantly altered**
- **Avoidance and mitigation effectiveness are used to reduce Level A exposures**
 - **PTS for acoustic sources, non-auditory injury/mortality for explosive sources**
 - **Zones of potential injury are small**
- **Determining Level B takes is more subjective, as the terms “abandoned” and “significantly altered” are not defined**
 - **Current and previous permits assumed NAEMO output met definition, however, too conservative resulting in the over-estimation of takes**
 - **Navy and NMFS are working to better define for Phase III analyses**



Key Take-Aways

- **Without scientifically defensible compliance analyses, Navy will lose training and testing space**
- **Lost training space will impact USFF's ability to achieve required readiness**
- **Science must be current and relevant**
- **Navy has made a significant investment in the science**
- **While there have been significant advancements made, our knowledge is still very limited**
- **New science development, especially behavioral response, is critically needed**



Acknowledgements

- **References:**

- **Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III) – June 2017**
- **Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles – May 2017**
- **U.S. Navy Marine Species Density Database Phase III for the Atlantic Fleet Training and Testing Area – March 2017**
- **Dive Distribution and Group Size Parameters for Marine Species Occurring in the U.S. Navy's Atlantic and Hawaii-Southern California Training and Testing Areas – May 2017**
- **U.S. Navy Marine Species Density Database Phase III for the Hawaii-Southern California Training and Testing Study Area Technical Report – October 2017**

- **Acknowledgements:**

- **SPAWAR Pacific**
- **NUWC Division Newport**
- **NAVFAC Atlantic**
- **NAVFAC Pacific**



Questions?



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