Photo credit: H. Moors-Murphy

Research and conservation of whales: needs for near real-time acoustic monitoring, a DFO Science perspective

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Fisheries and Oceans Canada
Pêches et Océans Canada
Canada

Introduction

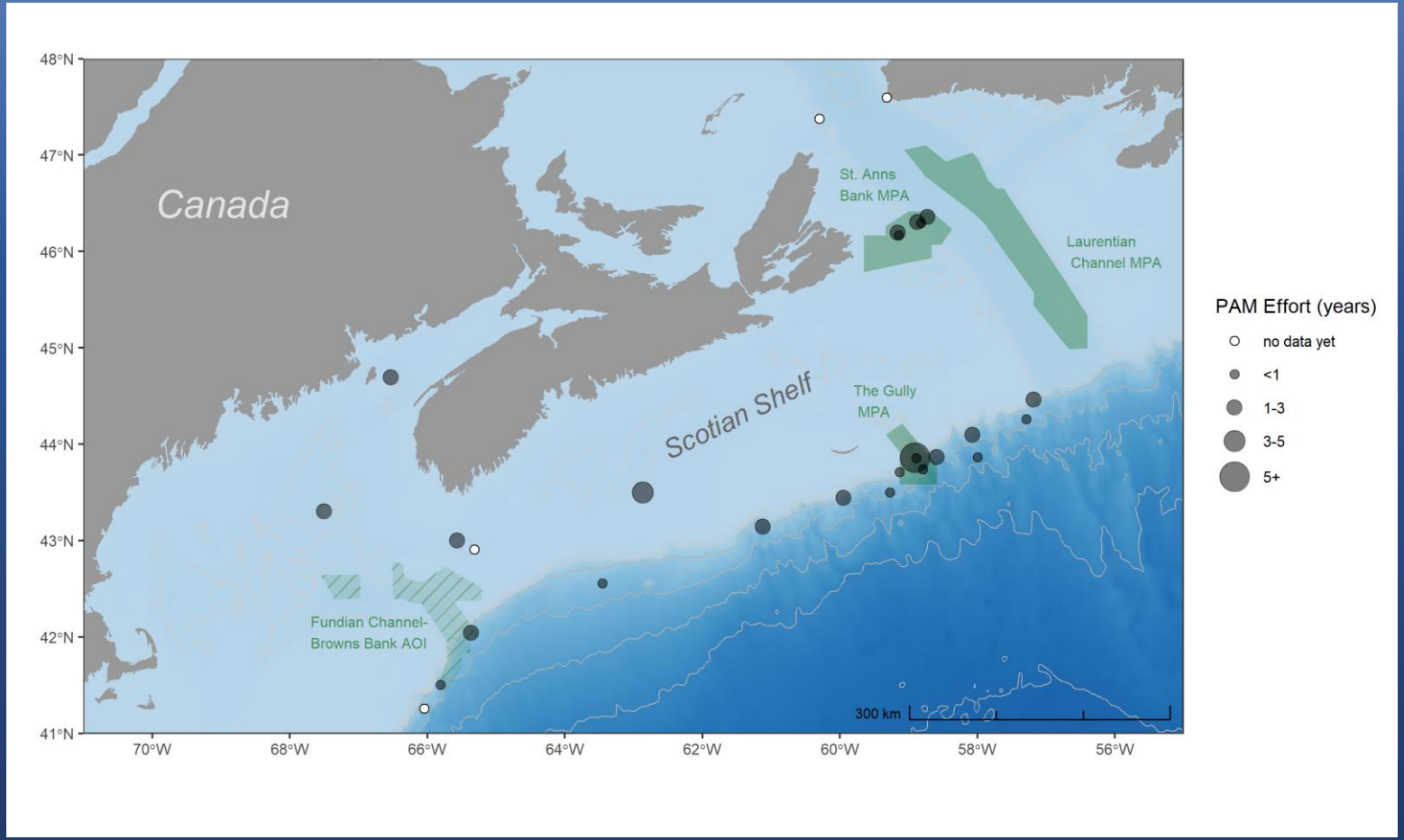
- PAM is widely used by DFO Science to support marine mammal research, monitoring and management needs
  - Long-term monitoring provides info on occurrence and behavior over space and time, used to assess risk and develop mitigation measures
  - Near real-time monitoring provides info on species presence within a general area over the past few hours-days, supports implementation of management activities over time scales of days-weeks
  - Real-time monitoring provides info on the current location of individuals within an area, supports implementation of immediate mitigation measures/actions to avoid/reduce impacts over times scales of minutes-hours

Long-Term Monitoring Efforts and Needs

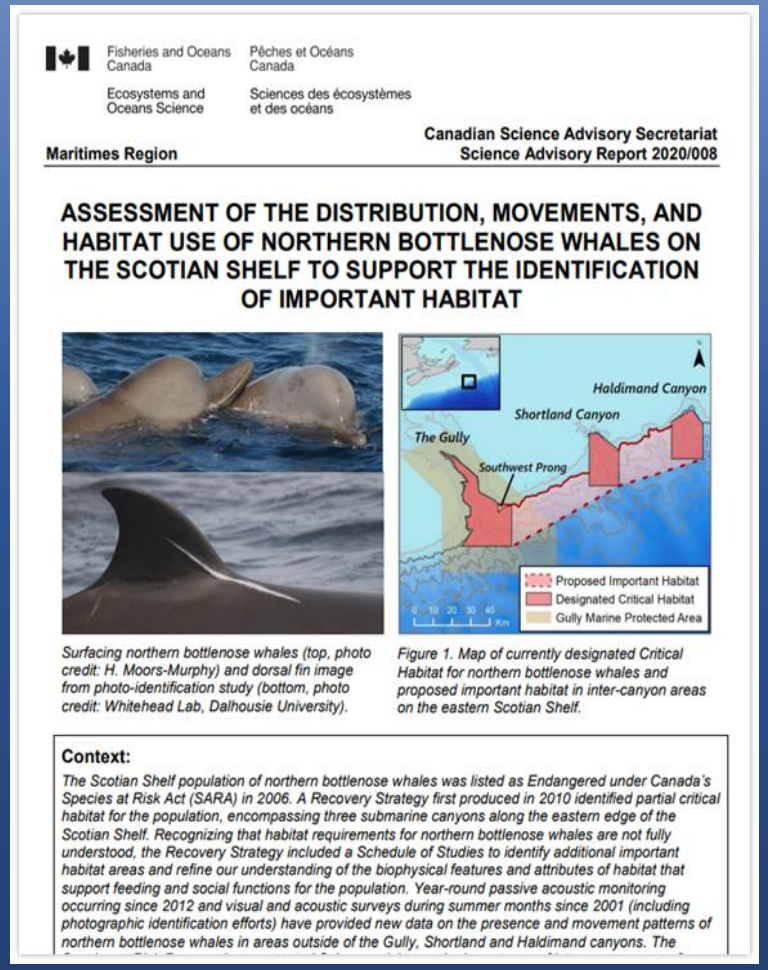
- Archival recorders have been in use for many years by DFO off eastern and western Canada to collect data on cetaceans

For example:

- This map shows number of years of acoustic recordings collected from sites off Nova Scotia by DFO Maritimes Region
- PAM effort has grown from just under 1000 recording days/year in 2012-2013 to more than 3000 recording days in 2018-2019



Long-Term Monitoring Efforts and Needs



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Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2020/008

ASSESSMENT OF THE DISTRIBUTION, MOVEMENTS, AND HABITAT USE OF NORTHERN BOTTLENOSE WHALES ON THE SCOTIAN SHELF TO SUPPORT THE IDENTIFICATION OF IMPORTANT HABITAT

Surfacing northern bottlenose whales (top, photo credit: H. Moors-Murphy) and dorsal fin image from photo-identification study (bottom, photo credit: Whitehead Lab, Dalhousie University).

Figure 1. Map of currently designated Critical Habitat for northern bottlenose whales and proposed important habitat in inter-canyon areas on the eastern Scotian Shelf.

Context:

The Scotian Shelf population of northern bottlenose whales was listed as Endangered under Canada's Species at Risk Act (SARA) in 2006. A Recovery Strategy first produced in 2010 identified partial critical habitat for the population, encompassing three submarine canyons along the eastern edge of the Scotian Shelf. Recognizing that habitat requirements for northern bottlenose whales are not fully understood, the Recovery Strategy included a Schedule of Studies to identify additional important habitat areas and refine our understanding of the biophysical features and attributes of habitat that support feeding and social functions for the population. Year-round passive acoustic monitoring occurring since 2012 and visual and acoustic surveys during summer months since 2001 (including photographic identification efforts) have provided new data on the presence and movement patterns of northern bottlenose whales in areas outside of the Gully, Shortland and Haldimand canyons. The

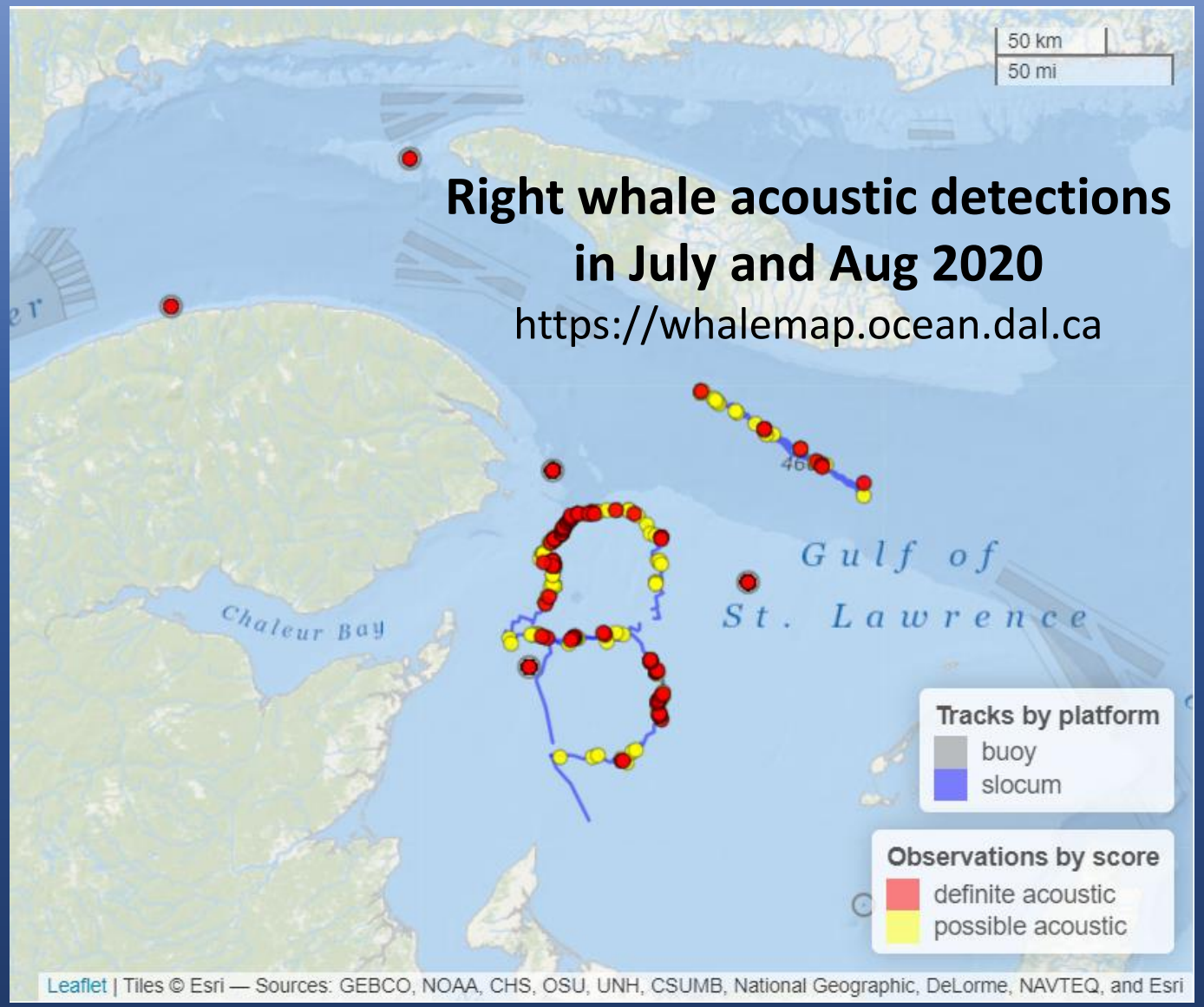
- Archival PAM data is being used to:
  - Assess species presence, distribution, movement patterns and habitat use
  - Increase understanding of seasonal and annual variability in occurrence
  - Help identify important habitats
  - Monitor potential impacts (such as changes in acoustic behavior) associated with the occurrence threats
  - Develop mitigation measures for anthropogenic activities occurring in/near cetacean habitat
  - Inform marine spatial planning activities and species at risk recovery measures
  - And more…

Long-Term Monitoring Efforts and Needs

- The “big data” problem
  - Lots of data associated with these PAM efforts
  - Automated detection and classification algorithms applied
  - Data processing and validation involves some level of manual effort
    - Need confidence in results
    - Detector performance can vary by species, site, time of year, and with local environmental conditions, background noise and presence of other calling species
  - There is a need for reliable and more efficient analysis tools
    - Need to understand performance in varying conditions

Near Real-Time Monitoring Efforts and Needs

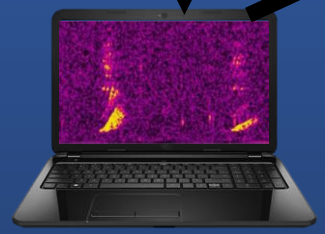
- PAM detections are being used to support management actions (for right whales) off eastern Canada
- Current platforms incorporated
  - Viking buoys equipped with acoustic recorders (lead: Y. Simard, DFO Quebec)
  - Slocum gliders with PAM packages (leads: C. Taggart, Dalhousie & K. Davies, UNBSJ)



Near Real-Time Monitoring Efforts and Needs

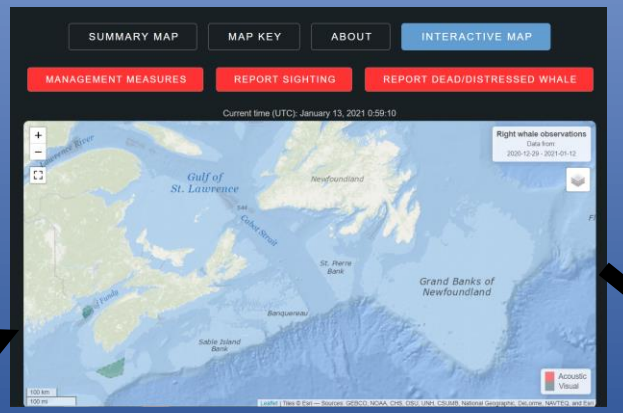
Platforms collect and process acoustic data

Processed data associated with detections are sent to shore (within hours)



All detections are validated by an analyst and false detections are removed (daily)

Acoustic detection data uploaded to WhaleMap (daily)

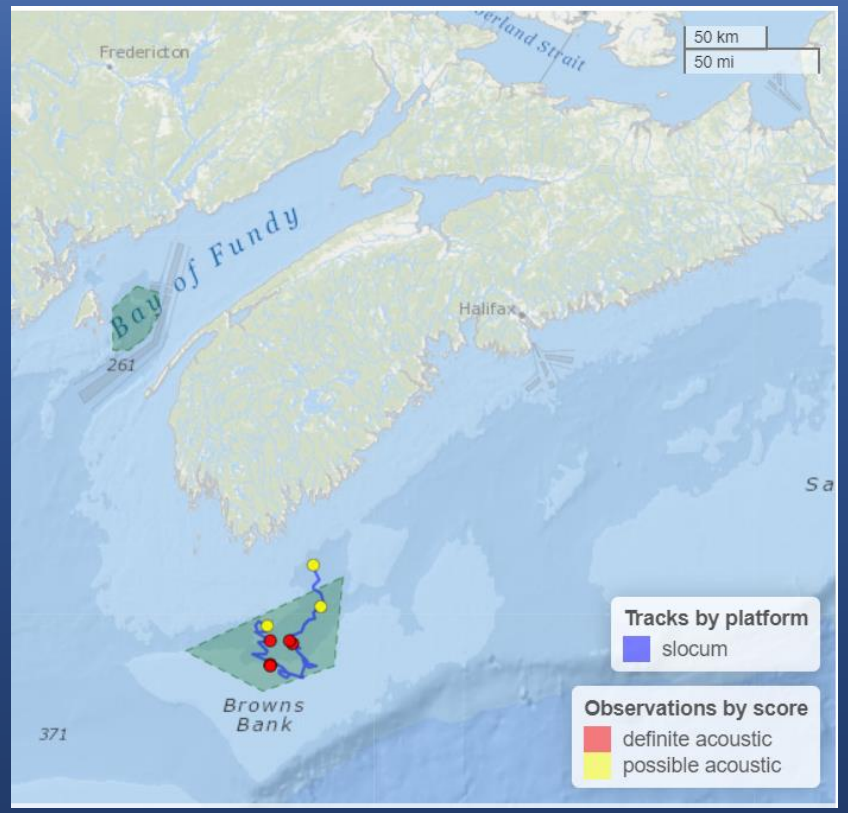


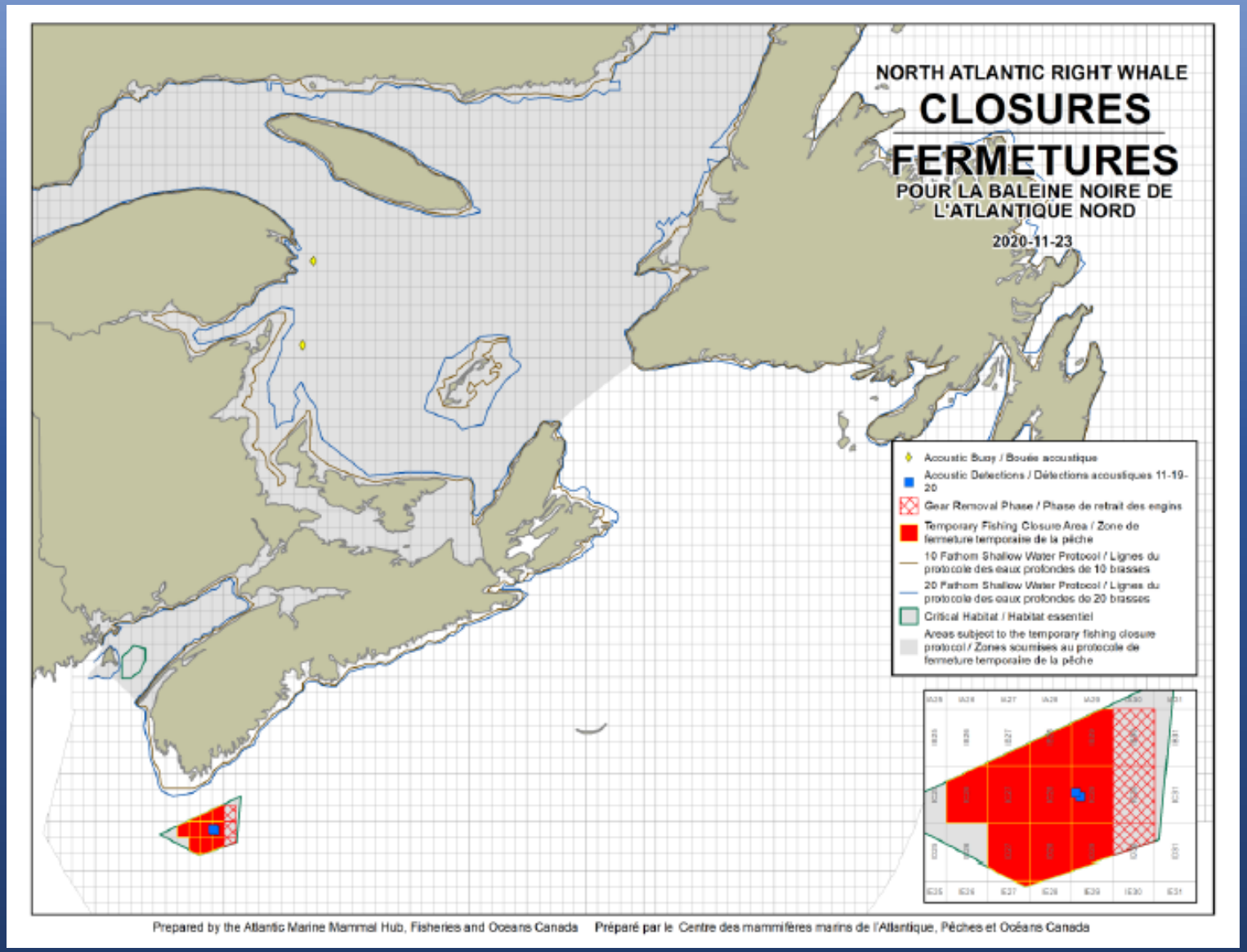
WhaleMap auto-generates a report that includes confirmed detections and send to managers (every morning)

Management actions determined and implemented (within hours-days) and remain in place for days-weeks

Near Real-Time Monitoring Efforts and Needs

E.g., Definite right whale acoustic detections in Roseway Basin NARW CH in late Nov 2020 result in fishery closures





Near Real-Time Monitoring Efforts and Needs

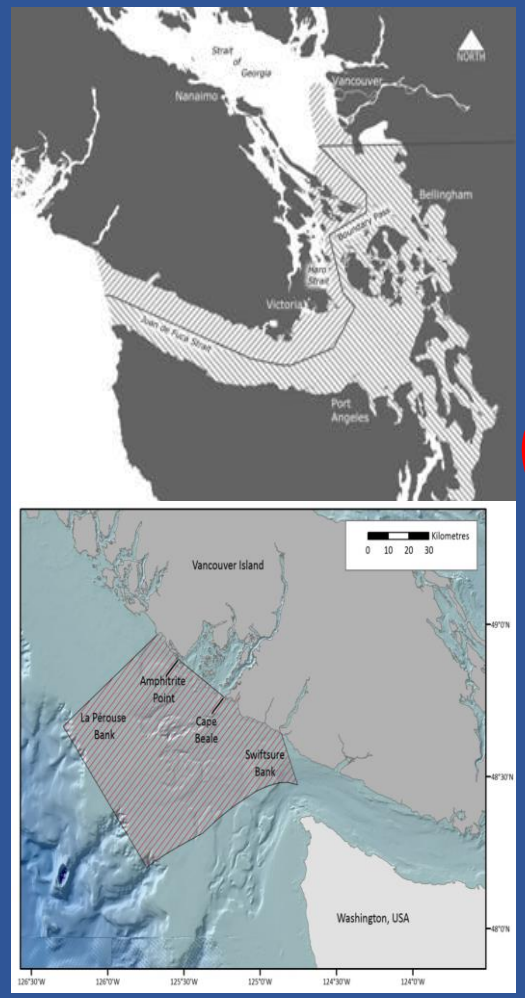
Photo credit: H. Moors-Murphy

- Management actions initiated over hours-days
- Requires high confidence in detections (all acoustic detections validated and confirmed)
- Reliable and more efficient analysis tools will enhance current programs
- Important to understand performance of tools

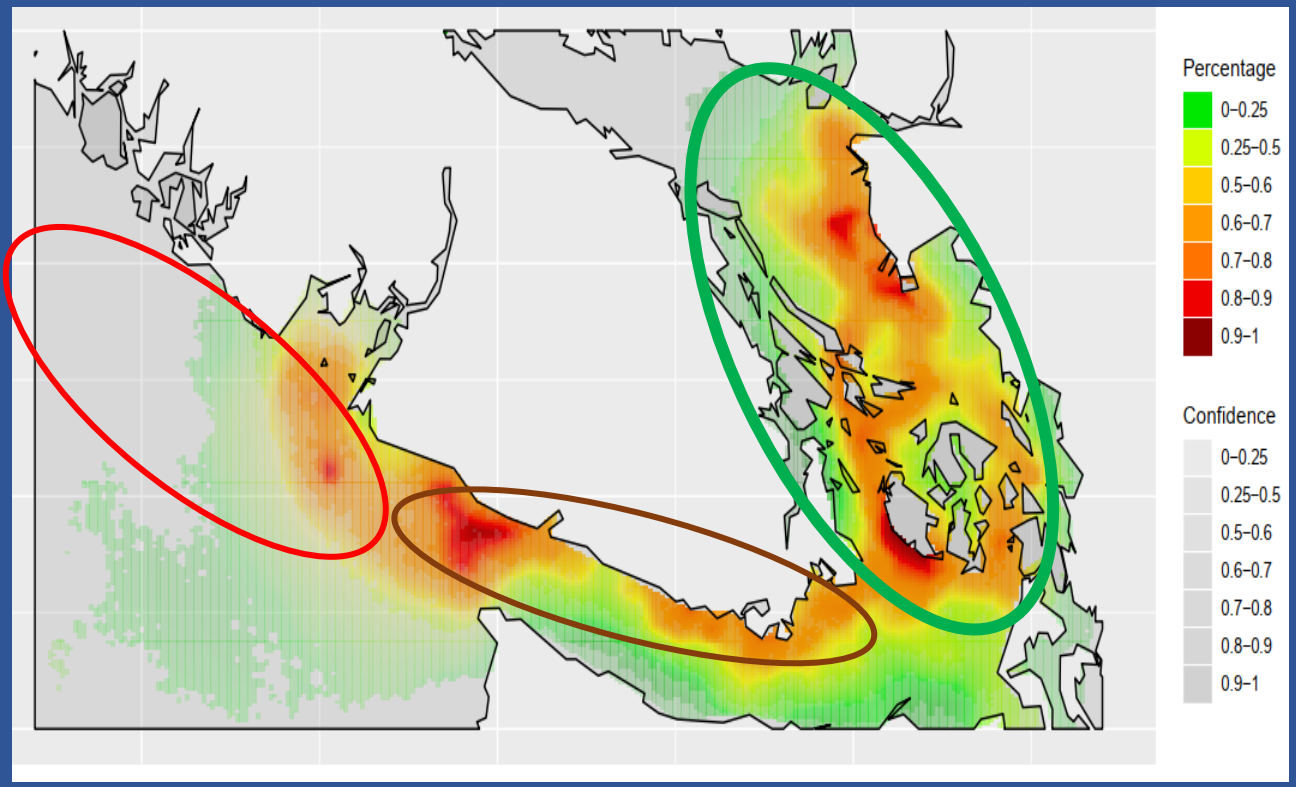
Real-Time Monitoring Efforts and Needs

- Whale detection/tracking systems for risk mitigation, for example:
  - Oil spill response to reduce risk of whales entering contaminated areas
  - Alert ships of whale presence to reduce risk of physical disturbance including ship strikes
  - Implement dynamic ‘vessel no-go’ zones to reduce physical/acoustic disturbances in important habitat
  - Monitor whale and vessel activity in ‘biological sanctuaries’ for compliance with conservation measures
  - Monitoring safety zones during loud noise producing activities (e.g. seismic surveys, military sonar exercises, pile driving activities, underwater explosions, etc.)
- Need detections over time scale of minutes-hours
- High detection precision (low number of false detection) is beneficial while high recall (low number of missed detections) is essential!

e.g., Southern Resident Killer Whale Detection and Tracking Needs



SRKW habitat use patterns based on relative probability of effort corrected sightings density (upper 30%), Thornton et al, in prep; Watson et al 2020



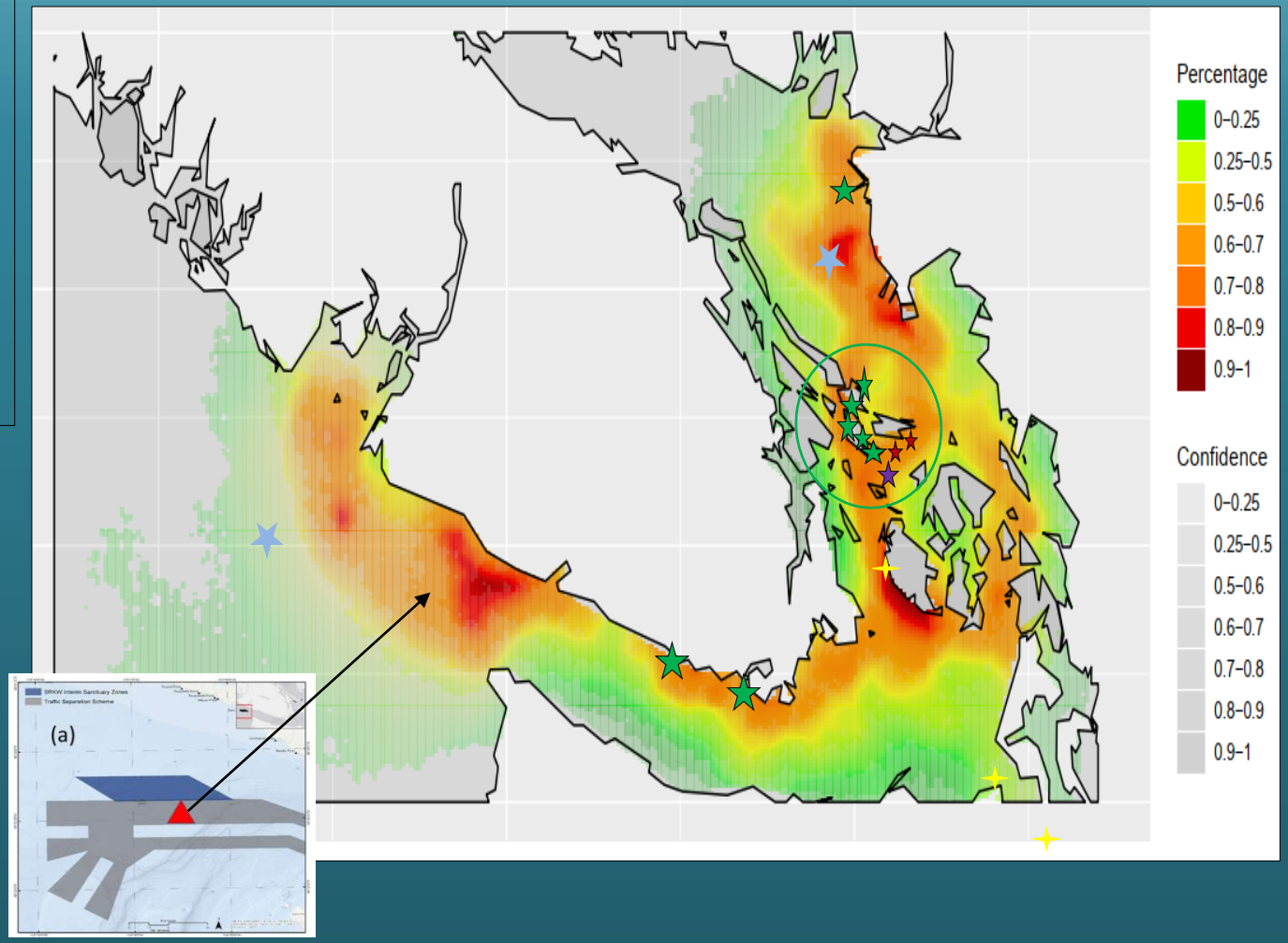
- Green ellipse depicts area with high monitoring effort, brown with low to medium effort and red ellipses depict areas with currently relative little monitoring effort

Shore-Cabled Real-Time Acoustic Whale Monitoring Systems

- Passive Acoustic Monitoring (PAM) Stations (real-time acoustic streams)
- PAM stations consists of 1-4 shore cabled hydrophones (either digital or analog sensors)

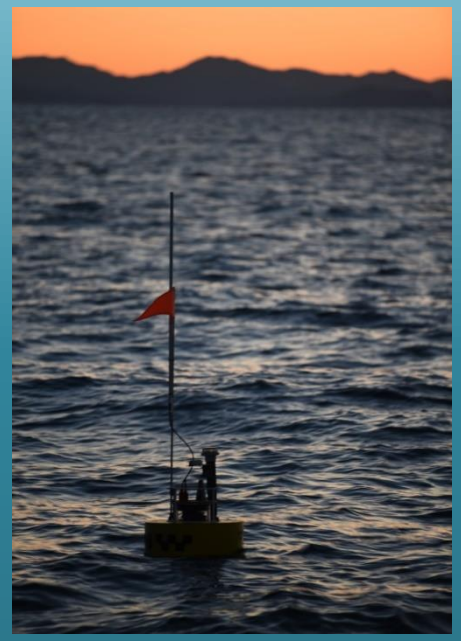
1. DFO Fisheries Management – Whale Tracking Network (WTN) - 10+ PAMs
2. Saturna Island Marine Research Education Society (SIMRES) – 2 PAMs
3. Orcasound Network - 3 PAMs
4. JASCO Underwater Listening Station (ULS 2 PAM arrays)
5. Ocean Network Canada

- Some systems have real-time automated detection/classification of whale calls integrated, e.g. the WTN, JASCO's ULS and Orcasound
- System installation and maintenance cost from low to high depending location (shallow versus deep water nearshore versus offshore) and system capacity (frequency range and data quality).
- High background noise for some nearshore/shallow systems



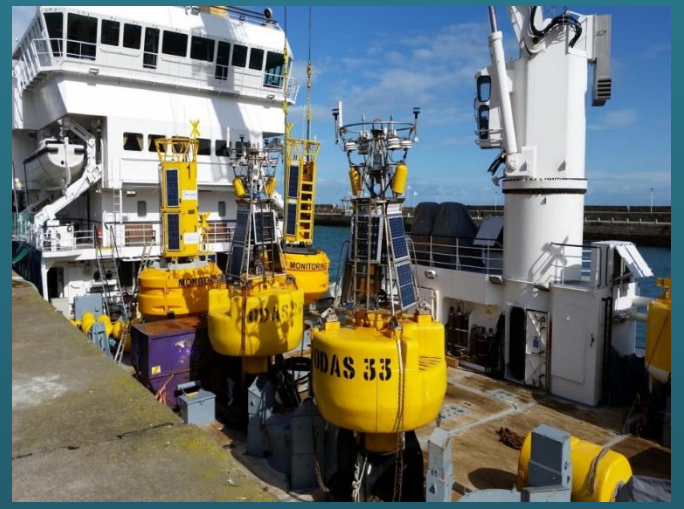
Different PAM Systems and Their Acoustic Detection Capabilities

Single Moored Cabled Hydrophone: Inshore/Offshore, Presence/ Absence



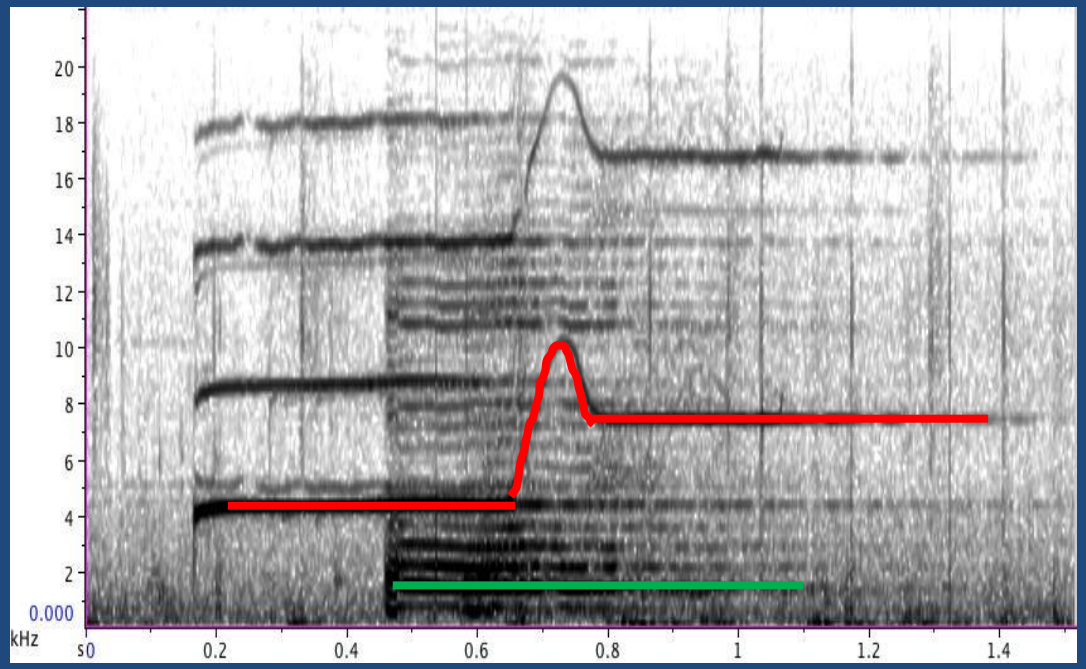
Autonomous Drift Buoy with vertical array and automated detection capabilities and transmitters: Inshore/Offshore: presence/absence and some range estimation

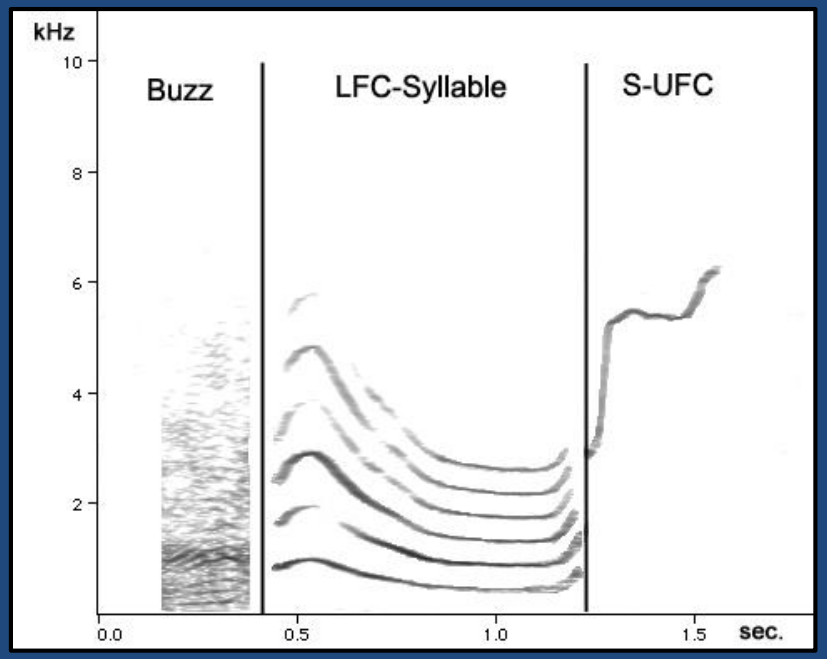
Tetrahedral Cabled Hydrophone Arrays: Inshore/Offshore, Signal directionality tracking and signal range estimation with single and multiple units



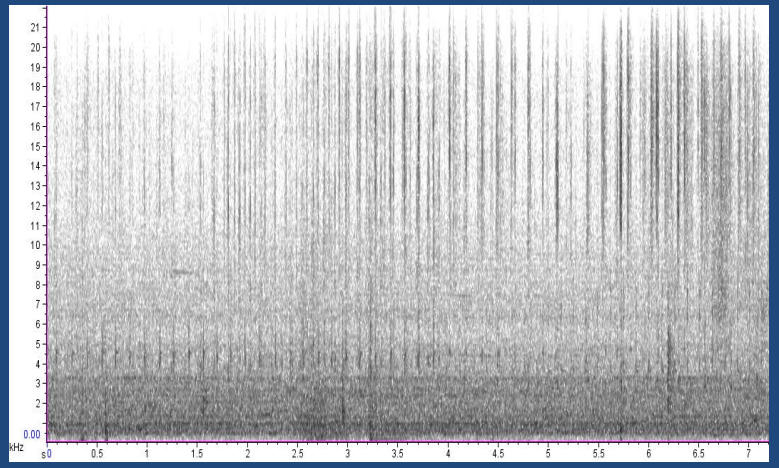
Moored Buoy systems equipped with hydrophone arrays and automated detection software : Inshore/Offshore- range estimation and tracking capability with single and multiple units

Killer Whale Acoustics

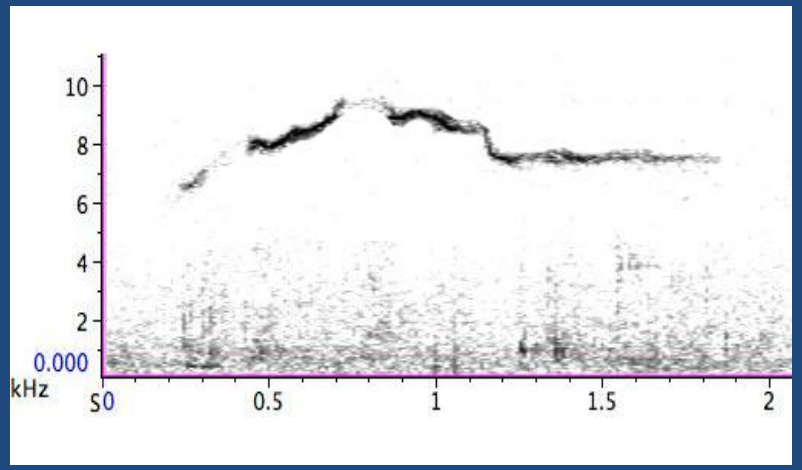




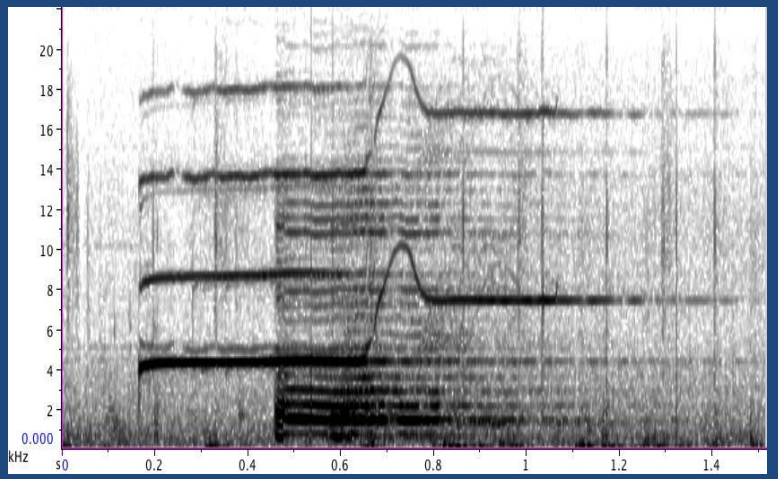
Clicks



Whistle

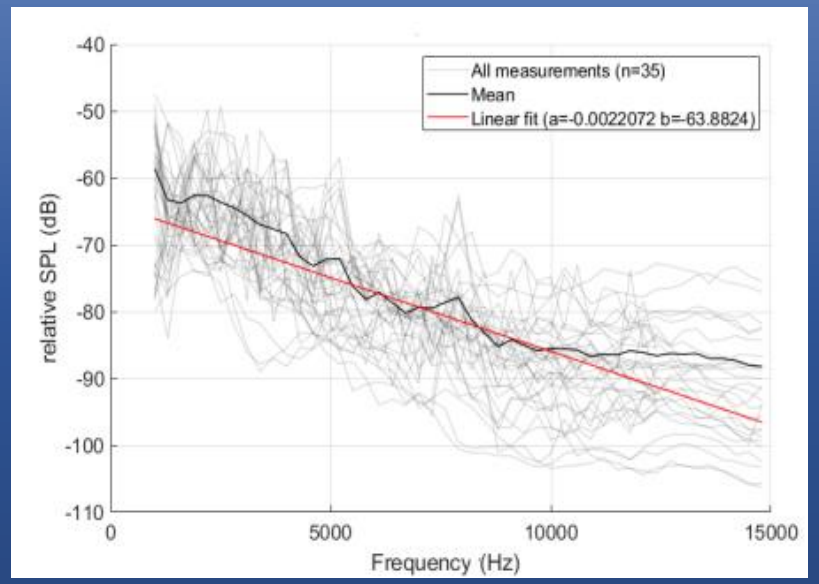


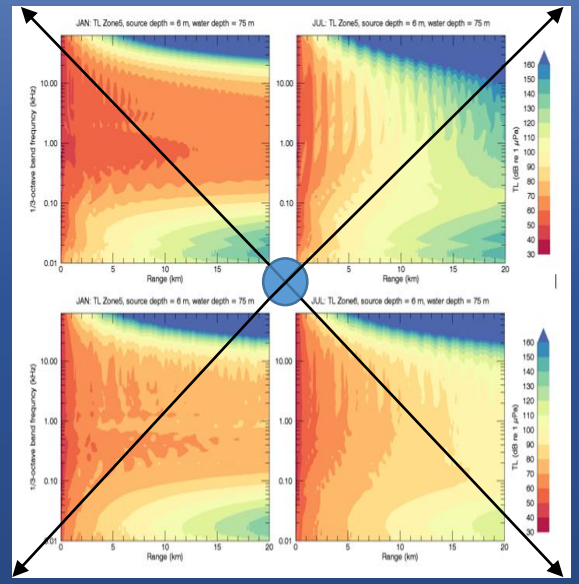
Call

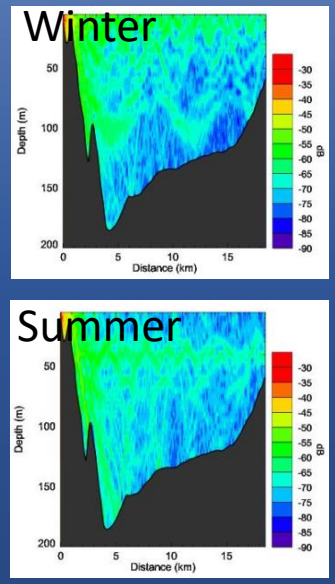


Detection Limits – Environmental Effects on Monitoring Success

- **Detection Range** is not a constant but varies with call source level, caller depth, noise levels, as well as location and time (sound speed variation)







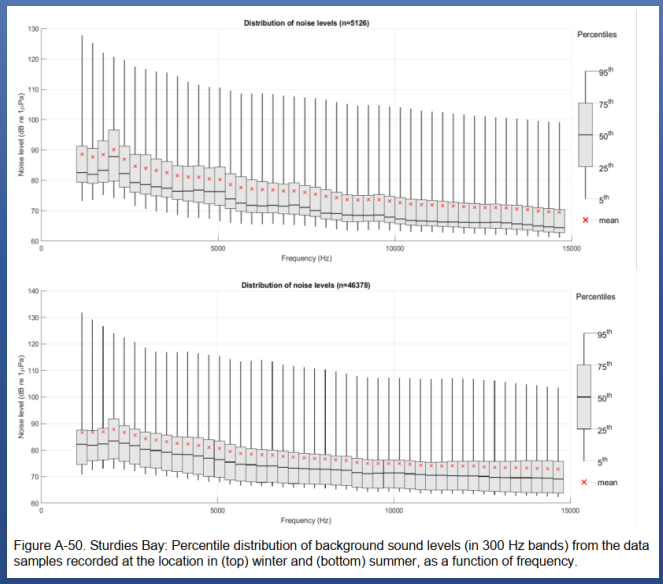


Figure A-50. Sturdies Bay: Percentile distribution of background sound levels (in 300 Hz bands) from the data samples recorded at the location in (top) winter and (bottom) summer, as a function of frequency.

Call Source Level

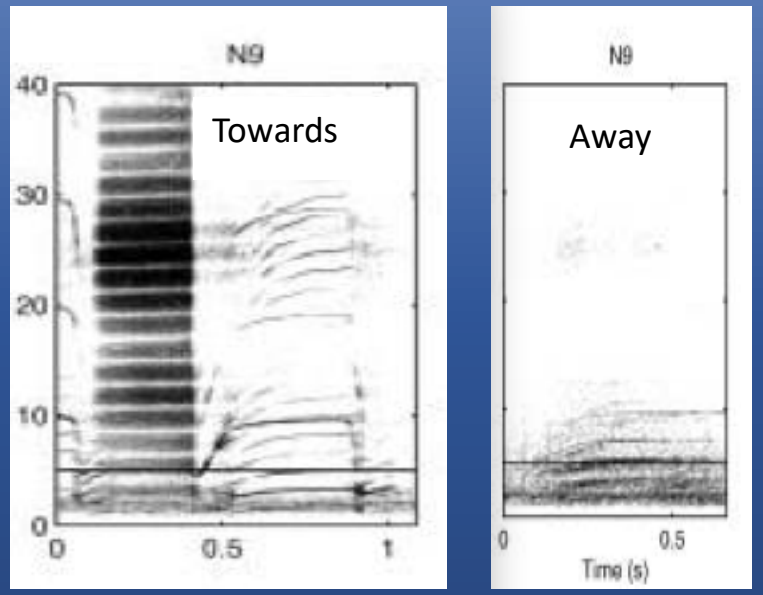
Propagation Loss

Noise Level

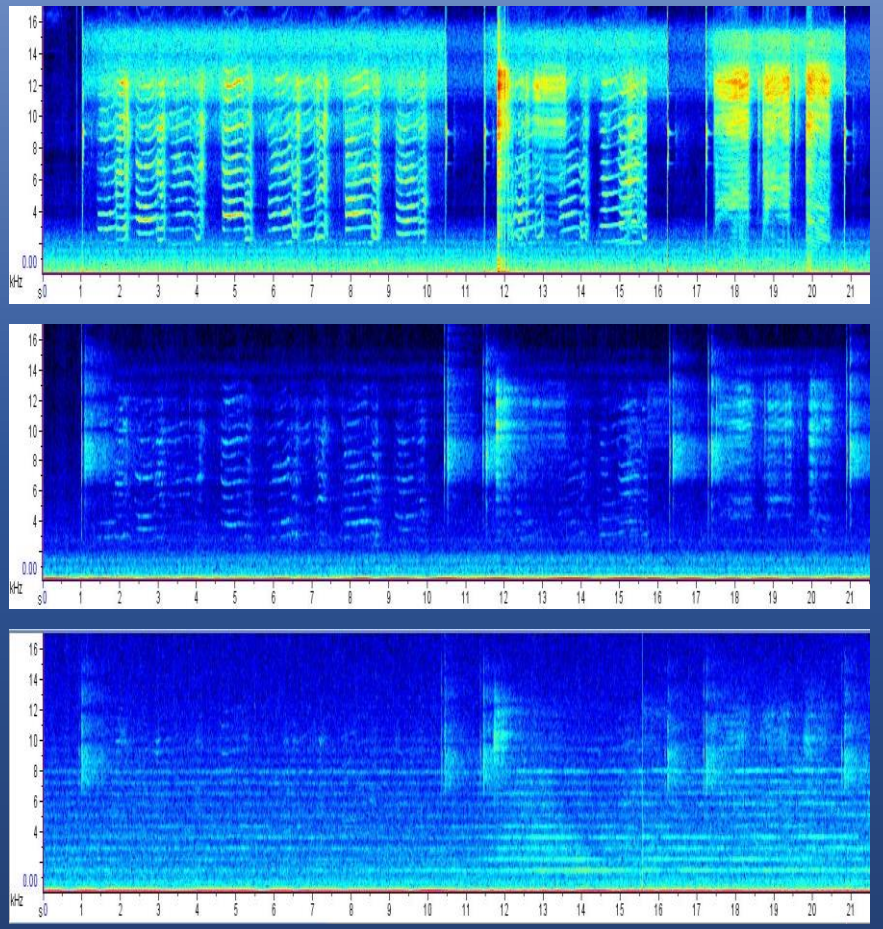
Call source levels and ambient noise analysis figures taken from Mouy et al. 2020 ‘Modelling Acoustic Detection Ranges of Resident Killer Whales’

Detection Limits – Signal Propagation Affects Monitoring Success

- **Detectability** is not a constant over detection range but varies due to variability in spectral signal distortion and frequency dependent signal propagation



Directivity of higher frequencies in killer whale calls (Miller 2006)



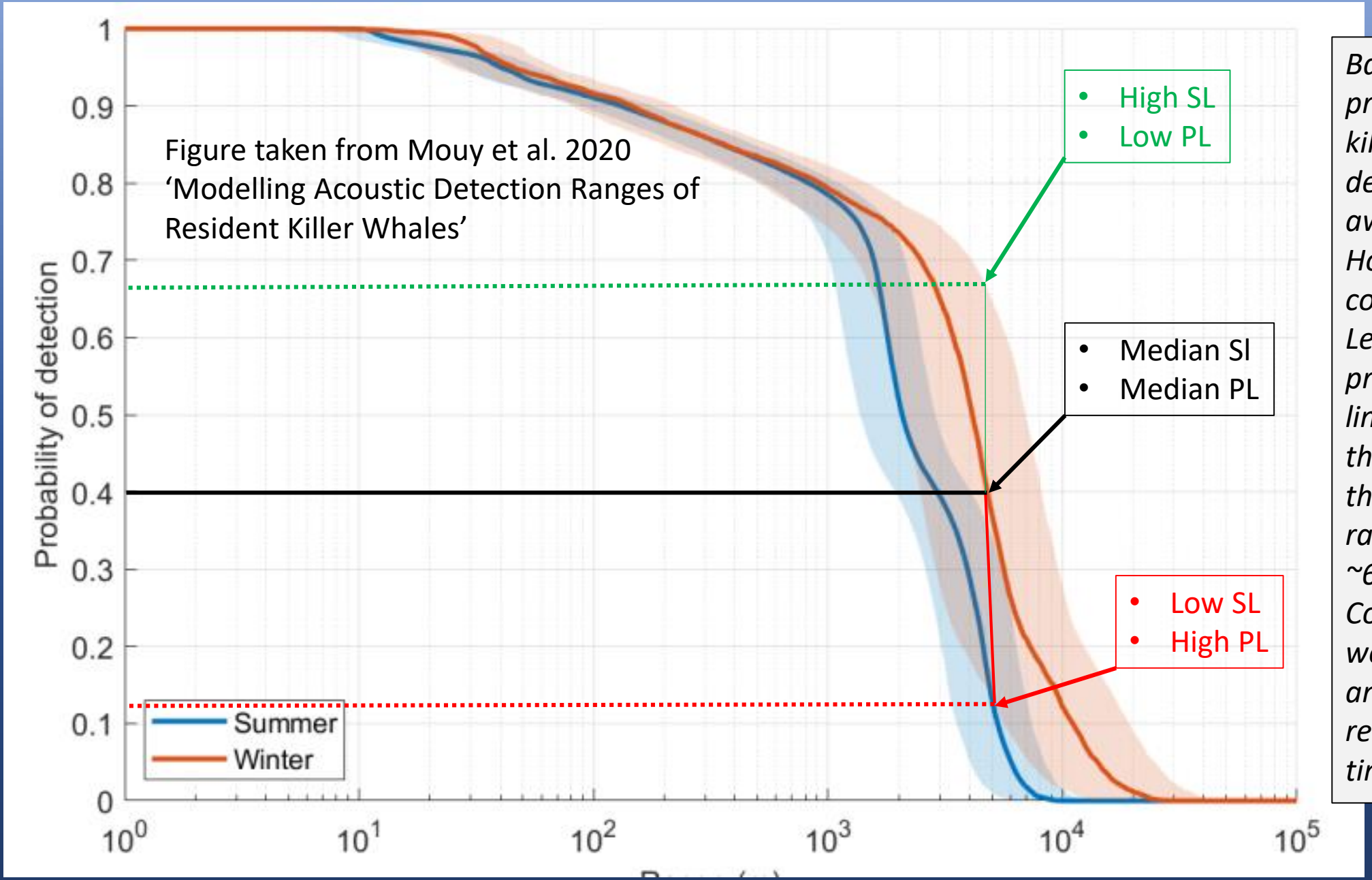
@ 1m

@ 270m

@ 520m during vessel transit

Spectral Propagation Loss and Noise

Detection range probability of an automated detector of a PAM location in less than 20m depth in Sturdies Bay, Galiano Island



Based on the median probability, in winter, killer whale calls can be detected up to 5km away 40% of the time. However, under ideal conditions (high Source Level [SL] and low propagation loss [PL] linked to the depth of the vocalizing animal), the same detection range can be reached ~67% of the time. Conversely, under the worst conditions (low SL and high PL), it is only reached ~13% of the time

Take Home Messages

- More efficient and reliable detectors are a plus for PAM efforts in general!
- Detector performance settings needed are based on objective/application
  - Low missed calls rates may be required for studies focused on species occurrence (though low false alarm rates increase analysis efficiency and lowers manual verification)
  - Low false alarm rates are generally important for management needs (though reducing missed calls also important in risk mitigation)
- Clear understanding of detector performance and limitations is needed
  - When and where, including on what platforms, do detectors perform adequately for management purposes and when should they not relied upon as management tools
  - How easily can they be applied to new datasets, in different environments - what are the limits
- Need higher classifier accuracy to differentiate species with similar call features, especially when callers are further away from the hydrophone or when it is noisy (e.g. killer whales versus humpback whales)
- Note: PAM provides information on minimum presence, but not 100% effective (e.g., will always miss silent animals)