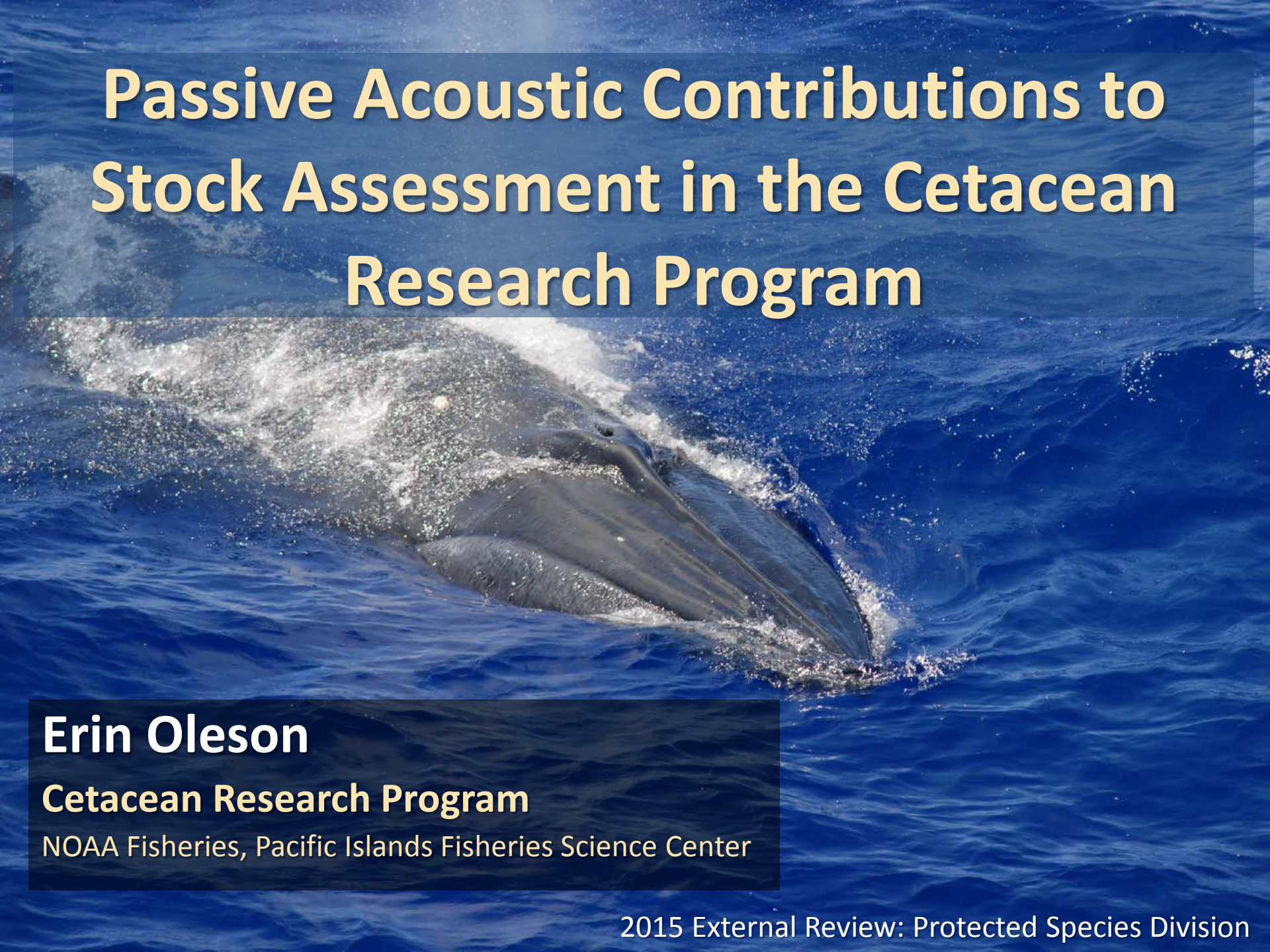
Passive Acoustic Contributions to Stock Assessment in the Cetacean Research Program



Erin Oleson

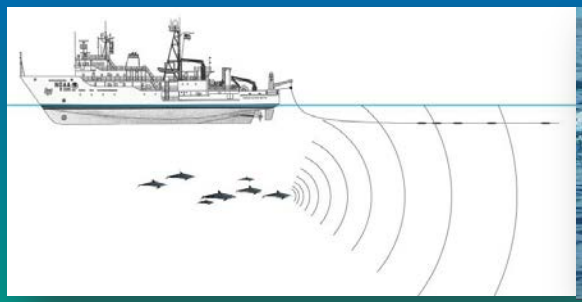
Cetacean Research Program

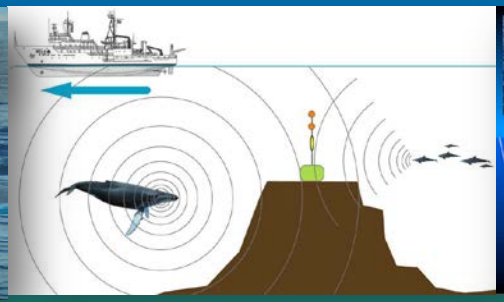
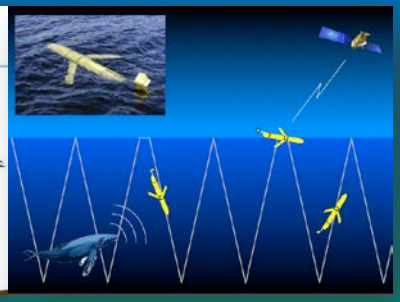
NOAA Fisheries, Pacific Islands Fisheries Science Center

2015 External Review: Protected Species Division

Passive acoustic techniques are a proven tool for cetacean monitoring

- Sounds travels further through water than light, such that most cetacean species use sound for foraging, communication, and navigation
- Poor sea conditions reduce visual detection, but have less impact on acoustic detection
- Autonomous systems provide for remote, long-term, mobile or stationary monitoring
- Today there is wide-spread use and development of highly capable systems to monitor species distribution, movements, habitat, abundance, and the impacts of ocean noise



CRP has invested significantly in using passive acoustics for cetacean assessment:

- Stock/species delineation: Beaked whale & blackfish discrimination, baleen whale population structure

- Distribution & seasonal variation: Pacific Islands Passive Acoustic Network, developing acoustically-equipped underwater gliders

- Abundance: Development of new array hardware & software tools to improve detection and enumeration, acoustic proxies for group size

Human-caused mortality & threats to recovery: Acoustic monitoring of the longline fishery, Characterization of ambient & anthropogenic noise

We also rely heavily on collaboration to advance the technology & our goals

Currently four Cooperative Institute, contract, and PhD student bioacousticians working within the Cetacean Research Program

Major collaborators-

- Scripps Institution of Oceanography
- Southwest Fisheries Science Center
- University of Hawaii Department of Ocean Engineering & Hawaii Institute of Marine Biology
- Hawaii Longline Association
- Cascadia Research Collective

Passive Acoustic Contributions to Cetacean Assessment

Species identification & Stock delineation

Acoustic discrimination of species and stocks provides the basis for all other passive acoustic assessment applications.

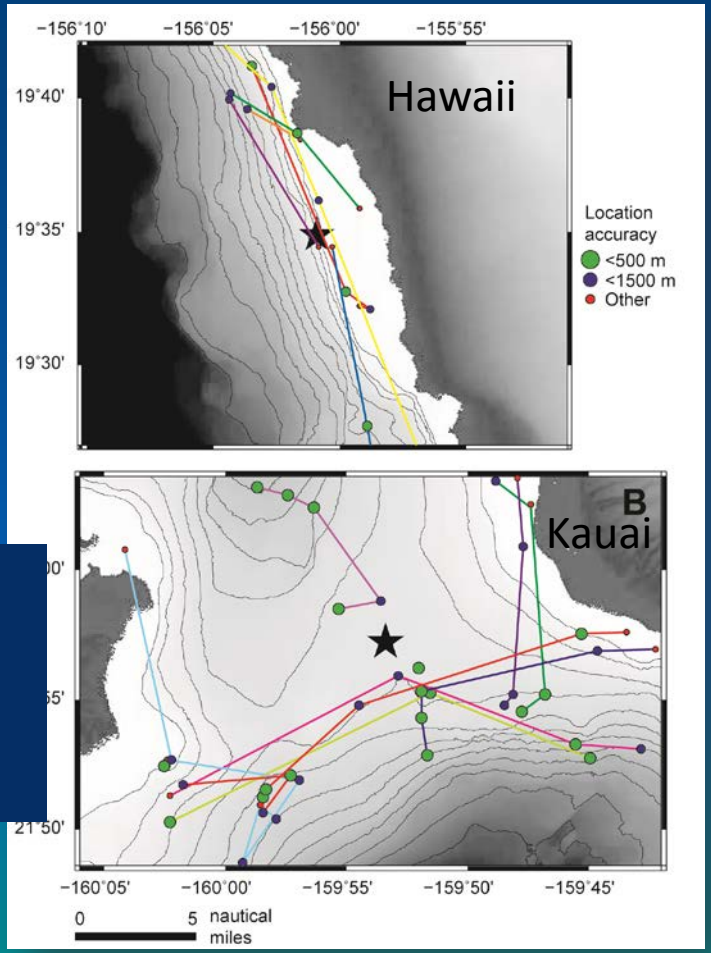
- Species discrimination using acoustic signals
  - Examples: Discrimination of blackfish & beaked whales using echolocation clicks
- Stock identification using acoustic signals
  - Example: Stock identification of Hawaiian false killer whales
  - Population differences in North Pacific fin whales
  - Geographic variation in Rissos' dolphins

CRP provides visually-verified single species recordings for community development of species and stock discrimination algorithms

False killer whale vs. pilot whale species discrimination using echolocation clicks

- False killer whales whistles are readily identifiable to species
- Click classification is complicated by recording system response
  - Requires calibrated sensors or system-specific classifiers

Click classification from calibrated Acoustic Network stations is possible through association of acoustic detections of satellite tagged whales.



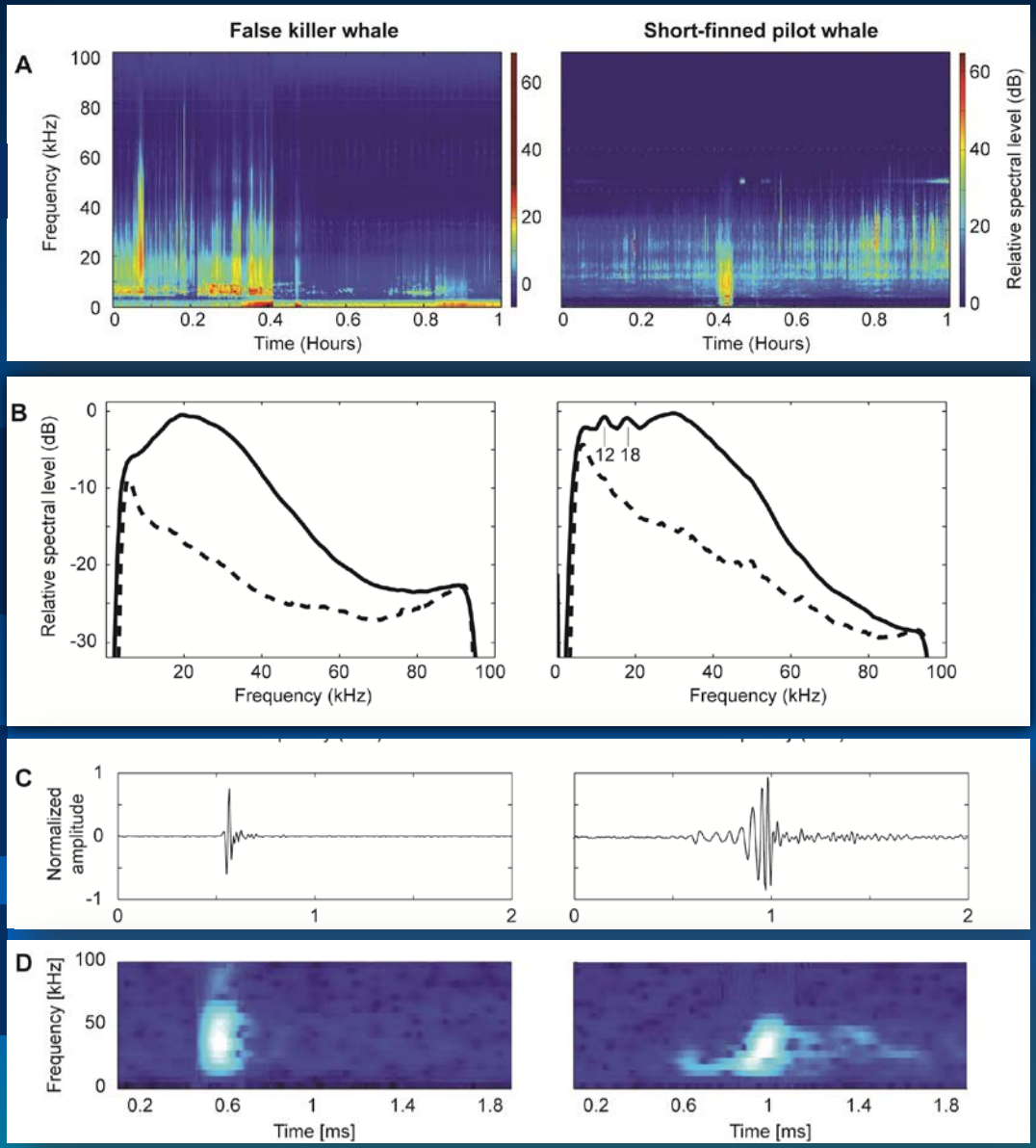
Baumann-Pickering, et al. False killer whale and pilot whale acoustic identification. ESR *in press.*

Raw data from tagged animals

Average spectra of echolocation clicks reveals spectral peaks and different bandwidth

Waveform measures indicate different click duration

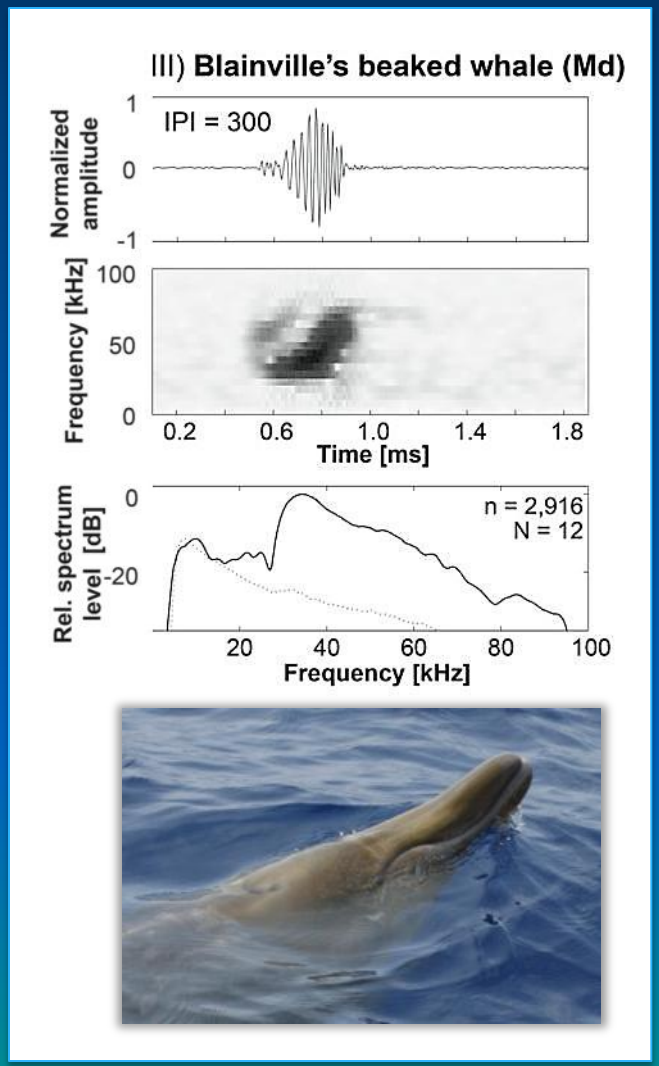
Spectrogram reveals differences in time-frequency structure

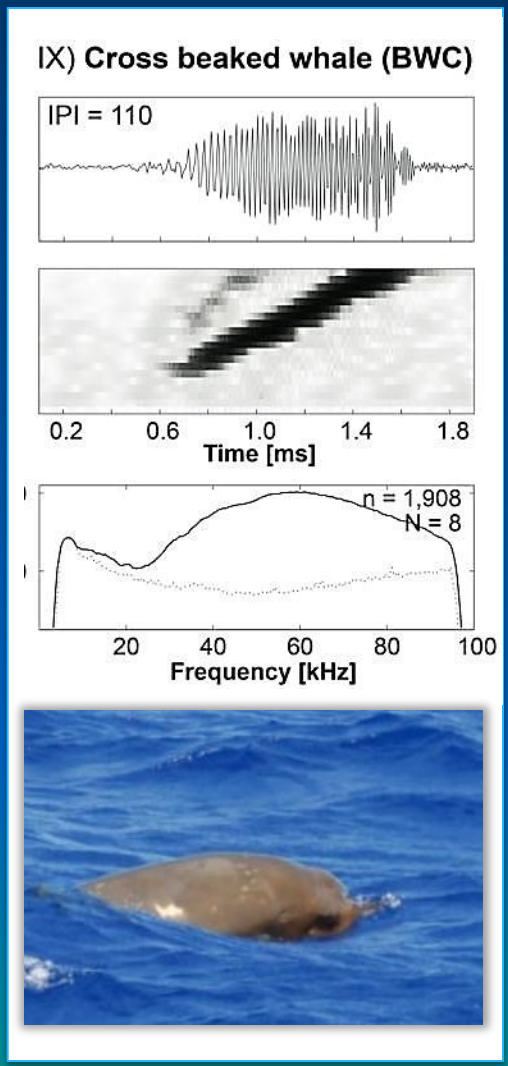


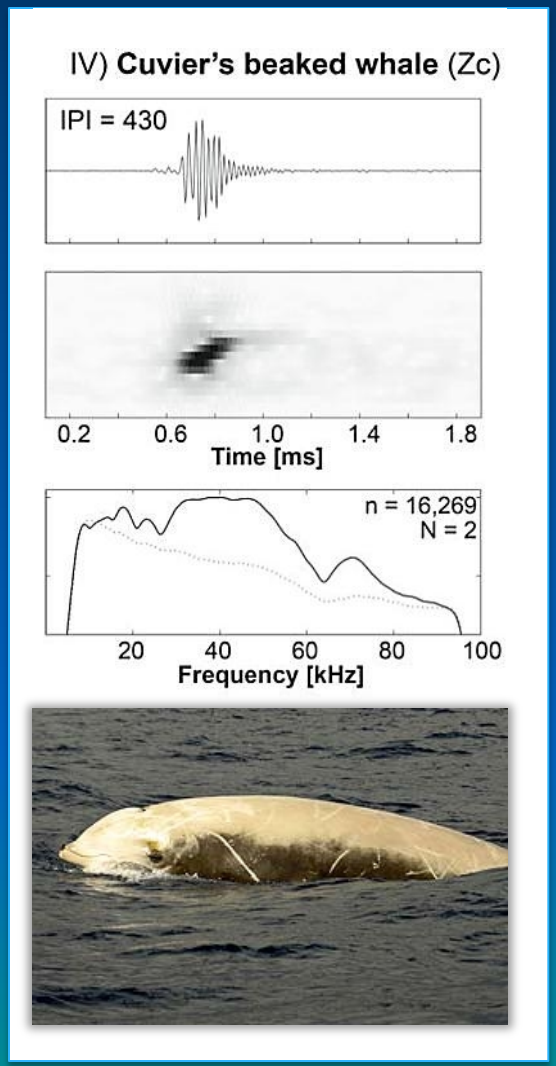
Acoustic features used to create Guassian Mixture Model-based classifier tested and trained with subsets of track data ➡ Mean error rate less than 8%.

Baumann-Pickering, et al. False killer whale and pilot whale acoustic identification. ESR *in press.*

Beaked whale clicks can be discriminated using the same methods

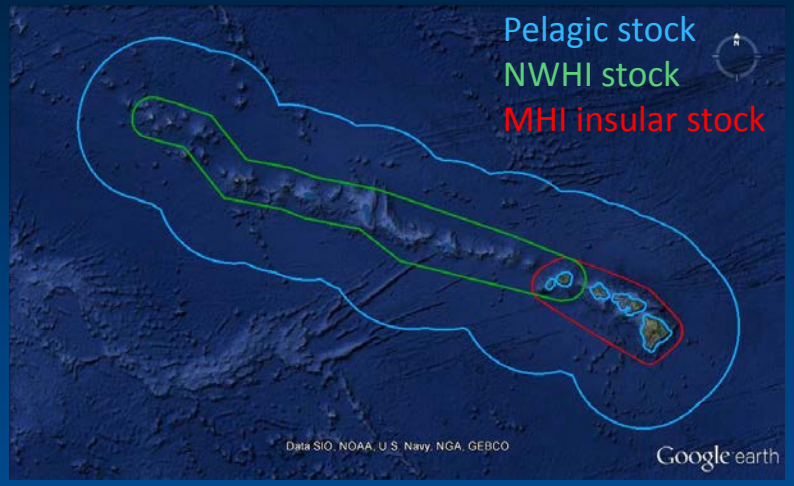






Baumann-Pickering *et al*. 2013. Species-specific beaked whale echolocation signals. JASA .

Discriminating false killer whale whistles to stock



Three sympatric stocks of false killer whales in Hawaiian waters

- Identification currently requires photos or genetic samples
- Acoustic discrimination could improve assessments

Approach:

- Extract whistles from acoustic encounters verified to stock
  - 5 encounters per stock, 30 whistles per encounter
- Measure 54 spectral and temporal variables from each whistle
- Conduct Random Forest analysis to find and test patterns in acoustic characters by stock.

Barkley, *ongoing Dissertation research*

Random Forest Analysis

4/5 for training data
(12 groups, 360 whistles)

NO OVERLAP

1/5 for test data
(3 groups, 90 whistles)

Pelagic stock
NWHI stock
MHI insular stock

Barkley, ongoing Dissertation research

Random Forest Classification Results

Classified Stock

True Stock

	Pelagic	NWHI	MHI	Total Groups
Pelagic	**80% (40)**	14% (7)	6% (3)	50
NWHI	54% (27)	28% (14)	18% (9)	50
MHI	4% (2)	0	**96% (48)**	50

Compiled results for 10 trials

- Some success with MHI & pelagic stocks
- With additional data classification success varies
  - Exploring sensitivity to group size, # whistles per encounter, unequal sample size, and other factors

Barkley, ongoing Dissertation research

Passive Acoustic Contributions to Cetacean Assessment

Stock distribution, including seasonality

Acoustic assessment of distribution has increased species inventories in regions with little survey effort and identified occurrence of cryptic species.

- Pacific Islands Passive Acoustic Network
- Occurrence analyses focus on rarely seen and/or Endangered species
  - Examples: Baleen whales & beaked whales across the central and western Pacific
  - Example: Identification of *Kogia occurrence*
  - Sperm whale & blackfish occurrence patterns

Pacific Islands Passive Acoustic Network:

Long-term monitoring across the central & western Pacific

Hawaii

CNMI

Wake

Johnston

Palmyra &
Kingman

Guam

Baker &
Howland

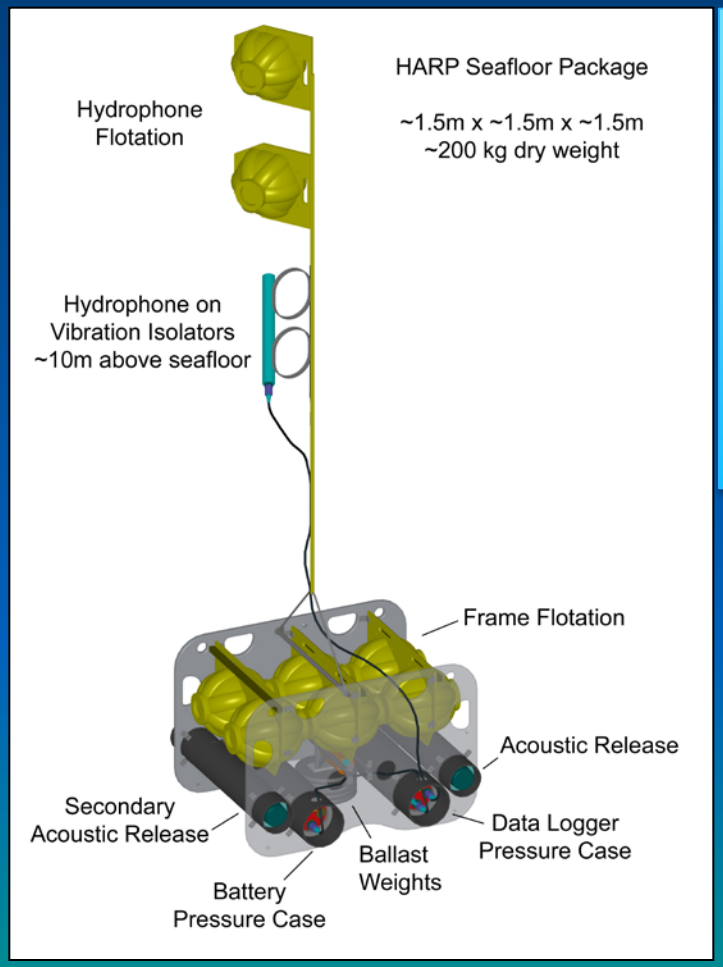
Jarvis

American
Samoa

★ Current monitoring sites

★ Previous monitoring sites

High-Frequency Acoustic Recording Packages (HARPs)



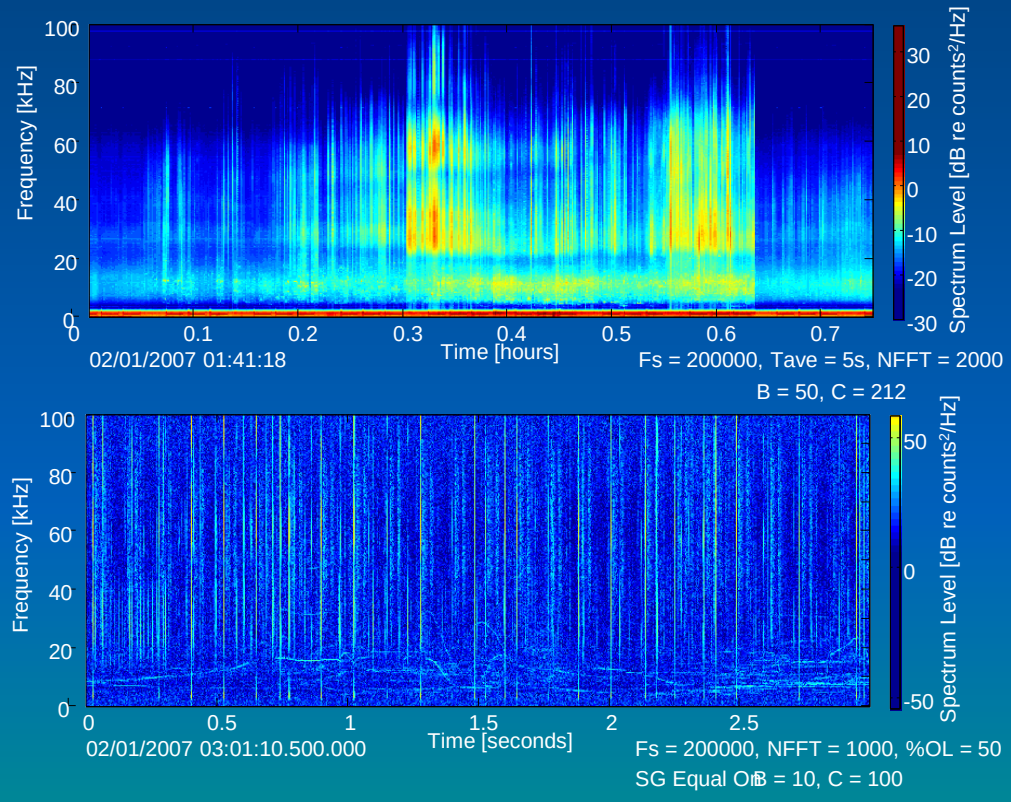
Capabilities:

- Acoustic sensing from 10 Hz to 100-160kHz
- Can record acoustic data for 2 months to 2 years
- Calibrated for measurements of ambient noise and sound received levels

CRPs primary tool for assessing broad spatial and temporal patterns of cetacean occurrence in the central and western Pacific

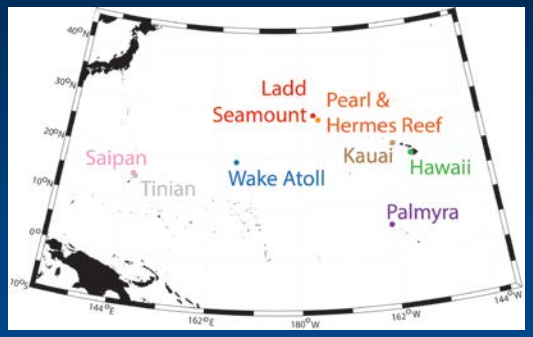
PIPAN Data Analysis

- Most analyses start with manual detection using long-term spectra to locate periods of calling



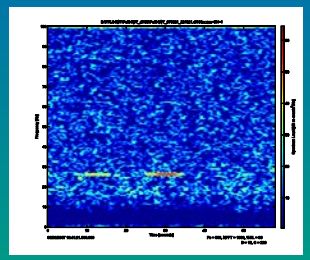
- Calls then extracted for additional analyses
  - Clicks automatically detected, classified manually against reference spectra
  - Whistles manually extracted for feature extraction & classification
  - Baleen whale signals marked manually

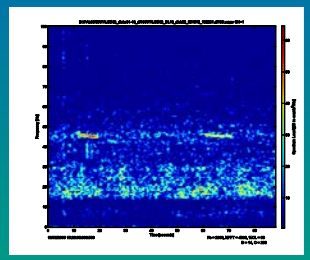
Baleen whales across the PIR

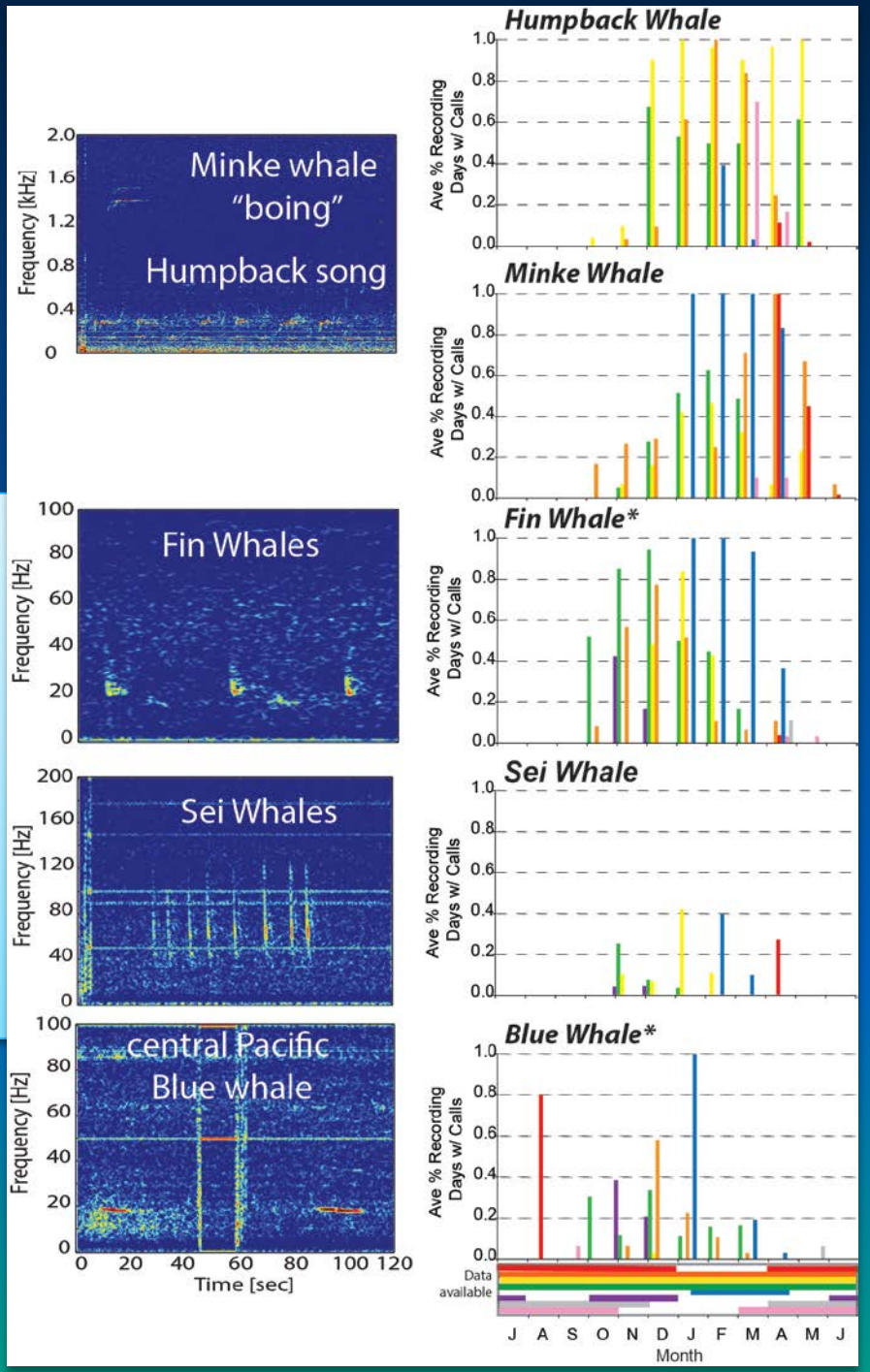


- All species more common at eastern sites
- Primarily in winter-time occurrence
- Blue whales within the Network year-round
- Gaps in recording effort hinder full assessment of seasonality

More than one population of blue whales at some sites

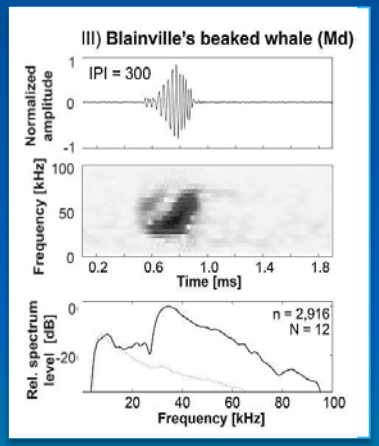




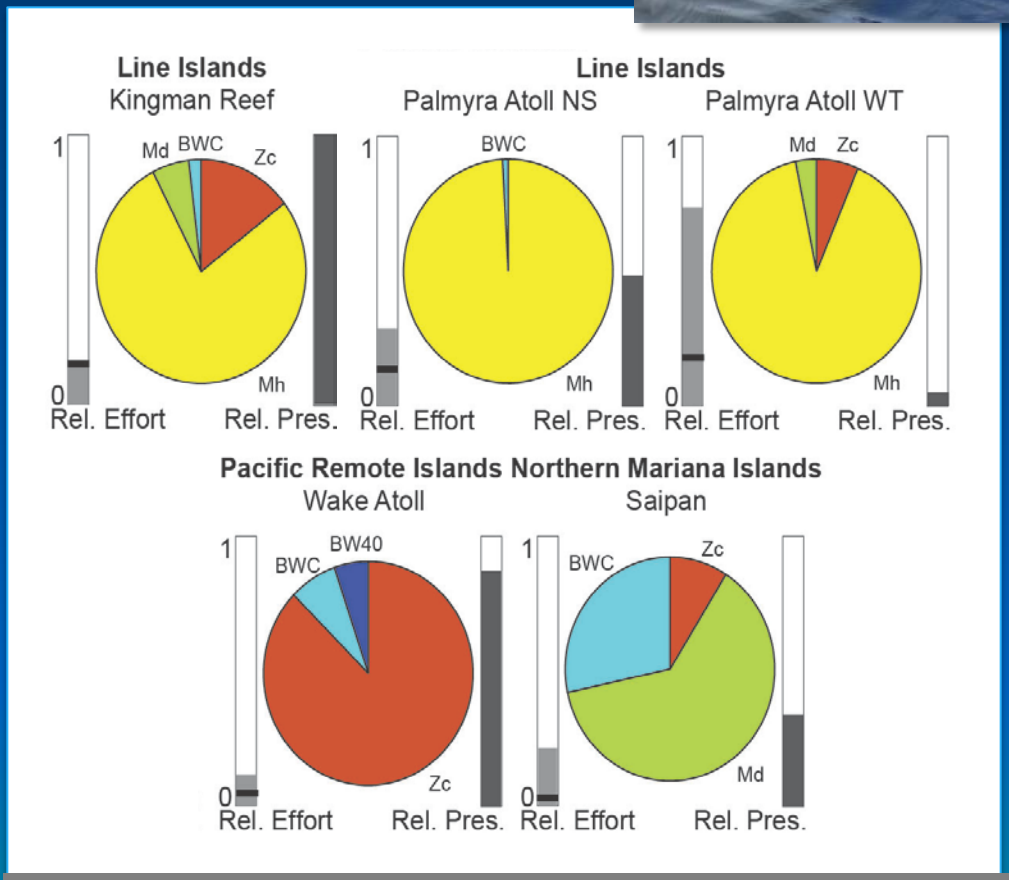


Acoustic Detection of Beaked Whales in Remote Regions

- Clicks automatically extracted from long-term record
- Use species-specific echolocation click features for classification



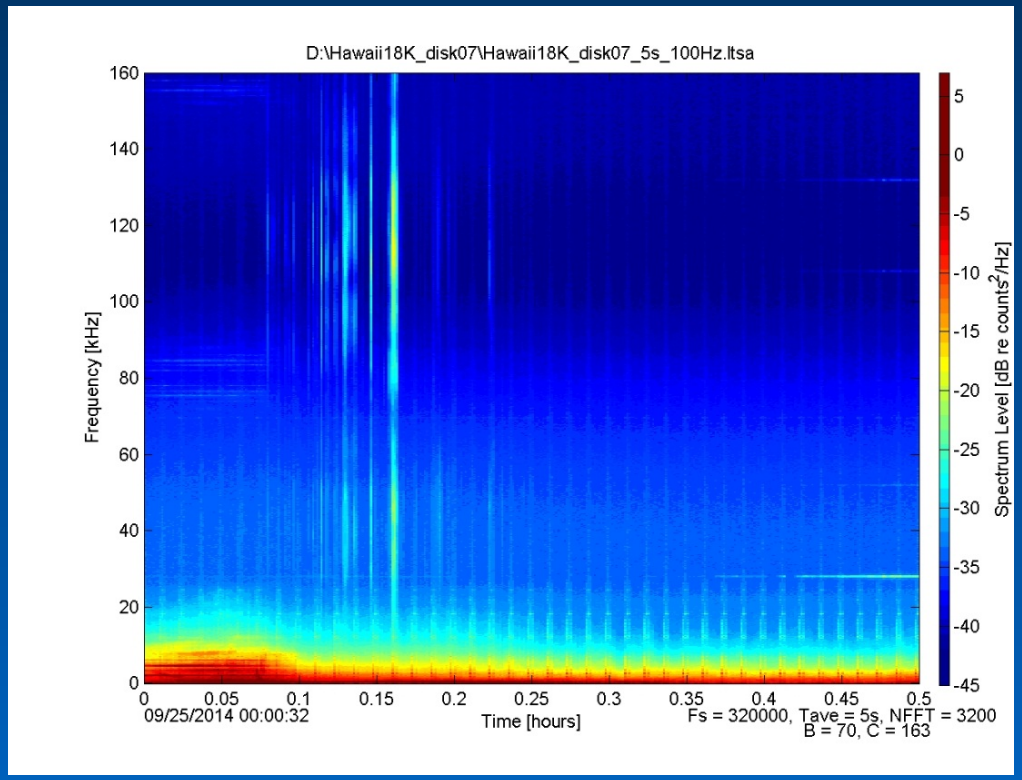
- Allows "rapid" assessment of beaked whale occurrence



Blainville's beaked whale (Md) "Cross" beaked whale (BWC)
"40kHz" beaked whale (BW40) Cuvier's beaked whale (Zc)
Deraniyagala's beaked whale (Mh)

Baumann-Pickering, *et al*. 2014. Spatio-temporal patterns of beaked whale echolocation signals in the North Pacific. PlosONE

Monitoring for *Kogia*



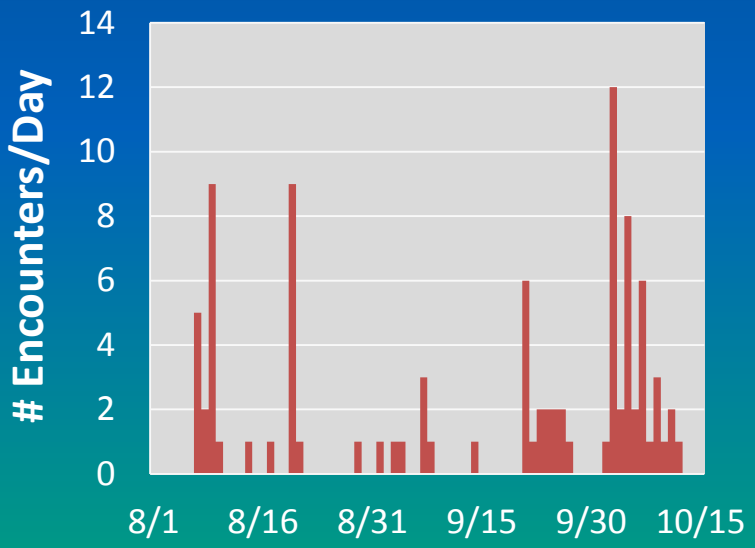
NOAA Ocean Acoustics Program supported the upgrade of one HARP to 320kHz sampling

August-October, 2014

➡ 98 encounters

HICEAS 2010

➡ 0 sightings



Can we reliably detect *Kogia* at standard 200kHz sample rate?

- Developed automated detector for encounters and individual clicks
- Compared detection rates between 320kHz and decimated 200kHz dataset
  - 92% of encounters sampled at 320kHz also detectable at 200kHz
- Confirmed *Kogia* occurrence at Hawaii, Kauai, Pearl & Hermes Reef, Kingman Reef, Wake Atoll
  - No *Kogia* detected at Palmyra
  - Encounters generally 1-4 minutes duration

Passive Acoustic Contributions to Cetacean Assessment

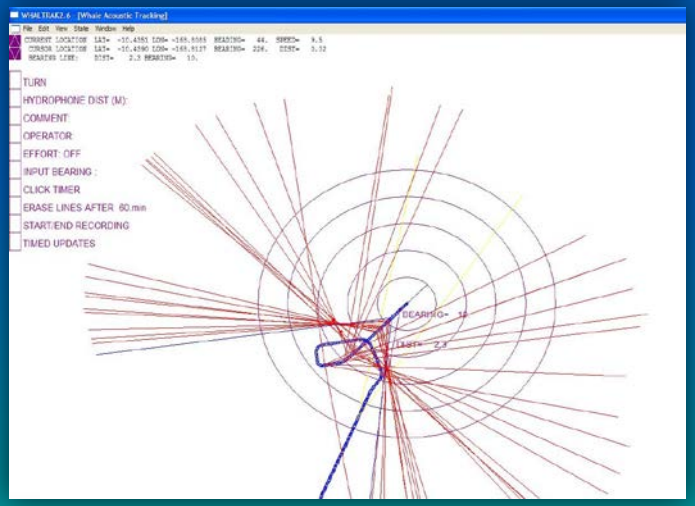
Abundance, productivity, and trends

Abundance estimation using acoustics requires robust detection & localization, species discrimination, understanding of call behavior and rates, & incorporation of many other nuances

- Development of new array hardware and software tools to improve detection and localization
  - Example: Tetrahedral array for improved localization accuracy
  - Example: Acoustically-equipped buoyancy and wave-driven underwater gliders augment visual surveys & guide survey design
- Incorporation of acoustic detections into habitat-based density models to increase sample size
- Acoustic proxies for group size

Towed hydrophone arrays augment standard visual surveys

- But there are limitations:
- Hydrophones in a line
  - Left – right ambiguity limits location accuracy
  - Must turn the ship to locate the school
- Requires time and distance for bearings to converge
  - Whales may have moved toward or away before localized
  - Visual and acoustic effort not always compatible



Cooperation bring progress...

With partners at SWFSC, SIO, and funds from ASTWG we set out to design the **Towed 'Tetrahedral' Hydrophone Array**

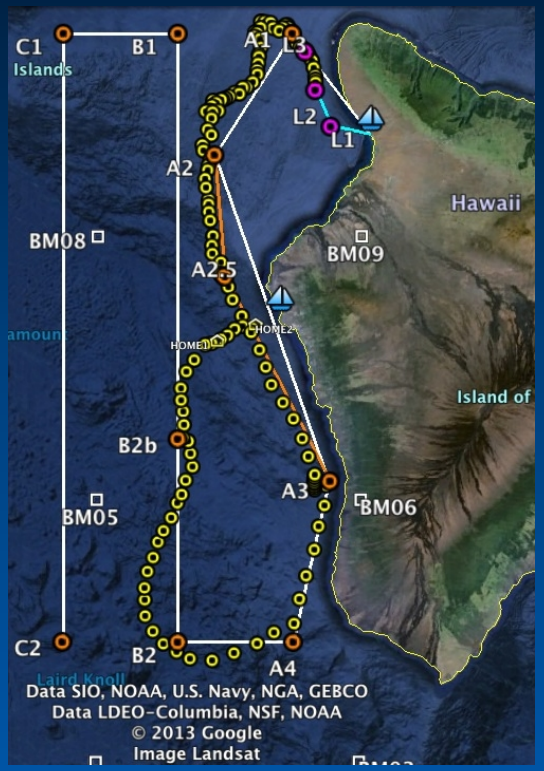
Design goals:

- Improve localization accuracy & efficiency
  - Resolve left/right and depth
  - Finer-scale acoustic tracking
- Capable of towing at survey speed (10kts)
- Low flow noise
  - Hydrodynamic design

Currently awaiting ASTWG SBIR award for development partner

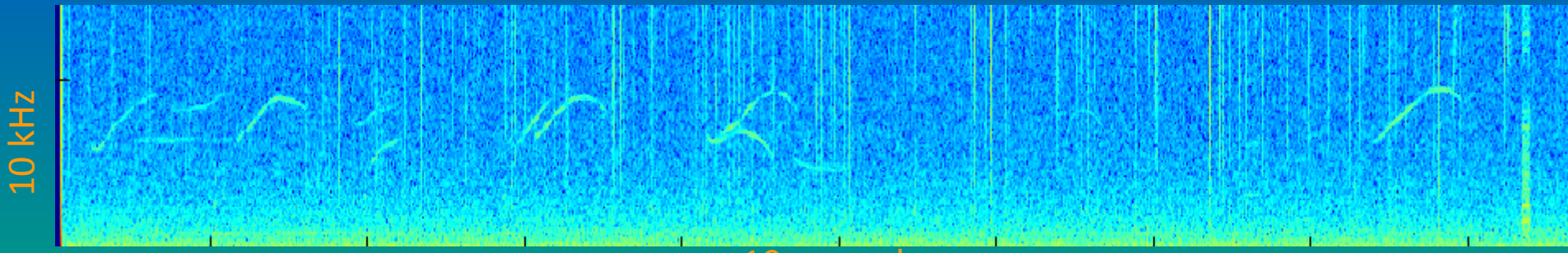
SeaGliders & Wave Gliders for Cetacean Assessment

Develop survey capability to direct future use of ship time



One successful mission to date, including detection of cetacean sounds

- Struggling for reasonable deployment durations given weight and power limitations
- Theoretical framework for assessing abundance doesn't exist



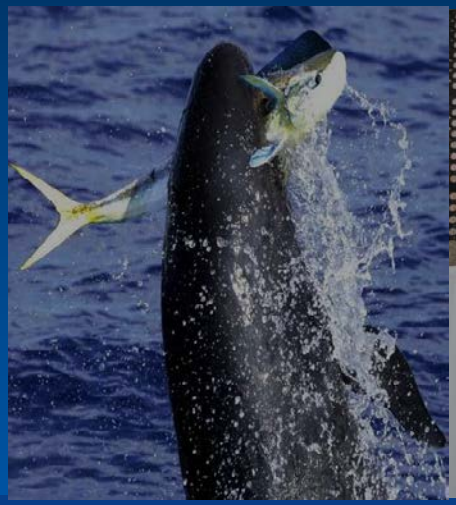
Passive Acoustic Contributions to Cetacean Assessment

Human-caused mortality & other factors impeding recovery

- Acoustic assessment of fishery interactions
  - Example: Alternative observation of cetacean-fishery interaction rates
  - Example: Examining the mechanism of fisheries interactions
- Description, evaluation, and response to anthropogenic noise
  - Annual and seasonal variations in ambient noise
  - Impacts of anthropogenic sounds on species distribution and behavior

Širović *et al.* 2013. Ocean noise in the tropical and subtropical Pacific Ocean. JASA

Acoustic assessment of interactions with the deep-set longline fishery



- False killer whales depredate fish at high rates
- Interactions create financial loss for fishermen and result in seriously injured or dead whales
- Observations of interactions are rare, fish heads are common
- Our hope: listening during fishing sets may reveal mitigation measures to reduce depredation & bycatch

With cooperation came innovation…

Together with the Hawaii Longline Association, engineers at Scripps Institution of Oceanography, and funds from BREP, we developed the **Longline Acoustic Monitor**

Specific design considerations:

- Continuous broadband (>100kHz) sampling
- Storage for > 15 days @ 15 hours/day
- Small & robust
- Saltwater switch, no at-sea programming
- Vibration isolation
- Flexible deployment orientation

Three phases:

1. Testing attachment mechanism & placement, and mitigating interference with setting & hauling of fishing gear
2. Charter deployments - multiple recorders on each set
   - Observer Program supported deployment & additional data collection
3. Voluntary deployment - single recorder on each set
   - Recorder provided through Observer Program following captain/owner agreement
   - Vietnamese translator assists with placements in that sector

- Where are whales detected within the set?
- How do they move through the gear?
- Are there acoustic cues to depredation?
- Are whales detected on sets with no catch depredation?

- 6 chartered trips in 2013-14
- 15 volunteer trips (so far) since mid-2014
- 140+ sets monitored to date

- False killer whale sounds detected in 24% monitored sets
- Catch depredation recorded on ~8% of monitored sets

Charter trips- Multiple recorders		
# of Sets monitored	**Sets w/ False killer whale whistles**	**Sets w/ depredation**
14	5	2
14	1	1
15	7	0
15	5	2
15	1	0
17	1	2
Volunteer trips- Single recorders		
7	0	1
7	0	2
7	0	0
6	0	0
3	1	0
7	2	0
127	**30**	**10**

Timeline of Fishing Operations

Time (total 15-18 hrs) →

Set ID

Trip1-set3

False killer whale whistle detections per instrument

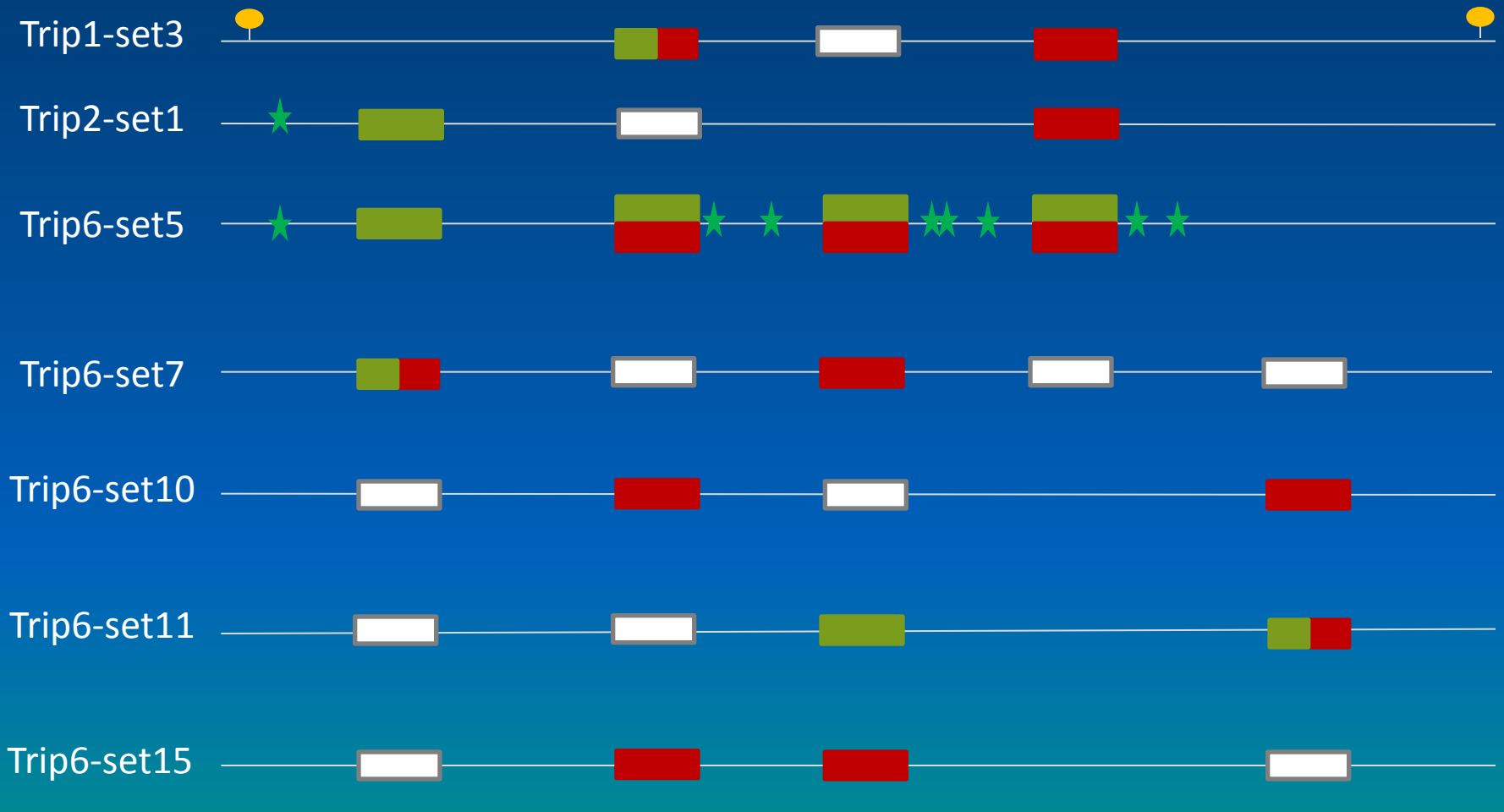
~40 nmi of longline gear

Timeline of Fishing Operations

Time (total 15-18 hrs) →

Set ID

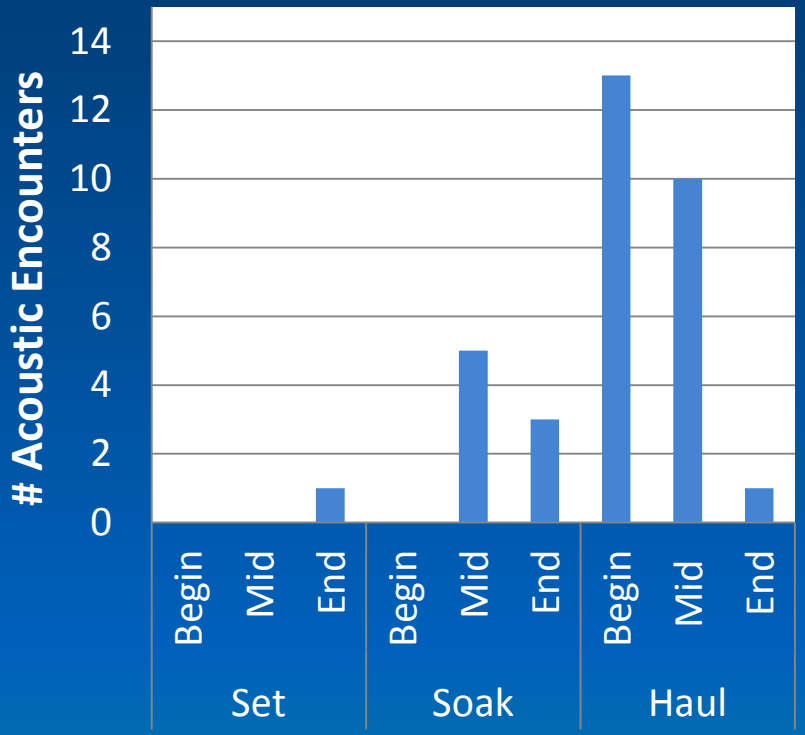
False killer whale whistle detections per instrument



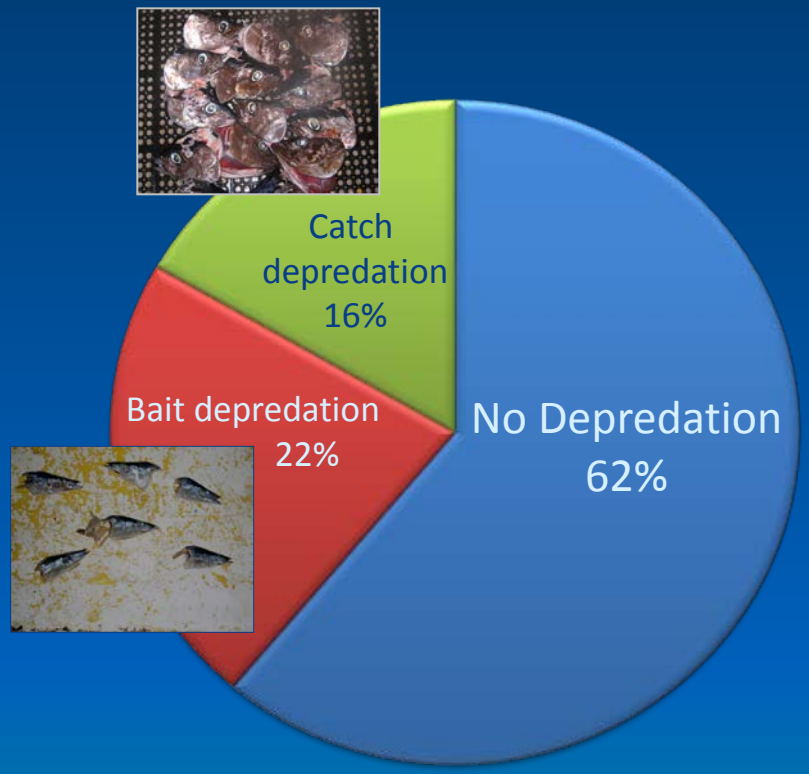
~40 nmi of longline gear

False Killer Whale Whistle Detections

Relative to timing of fishing operations



Relative to timing of observed depredation



- False killer whale detections peak during the haul
- And generally don't correspond with observed depredation
  - Bait depredation may be more common than reported

Acoustic monitoring of the fishery continues…

Using Sound to Understand How and Why Fishing Boats Get Whaled

Contact: Ali Bayless at ali.bayless@noaa.gov or (808) 725-5728/ (310) 801-7127

Why are we doing this research?

False killer whales are known to take catch and bait from the Hawai'i longline fishery at high rates in certain areas of the Pacific. Observations of these interactions are limited since most occur at night and animals are rarely seen. False killer whales make specific vocalizations that are easily detected and identified, which makes sound a great way of determining whether they are present around fishing gear. By monitoring the sounds associated with these interactions, we may better understand exactly what is attracting animals to the vessel and how we might be able to deter them. Sounds produced by gear and boats were found to attract sperm whales and killer whales in other fisheries, also supporting listening as a way to find a potential deterrent.

The Sound Recorder (a.k.a. **HARP**- High-frequency Acoustic Recording Package)

The HARP is a single unit that consists of a hydrophone (underwater microphone) and a pressure case housed in a black tube (pictured below). The package weighs approximately 30 pounds and is easily lifted and carried around on deck. It also contains a small float that allows the entire unit to remain neutrally buoyant in the water. The HARP is directly attached to the mainline, near the middle of the basket and then placed overboard to be activated by a saltwater switch.

Float for neutral buoyancy

Hydrophone and saltwater switch

Vacuum-sealed pressure case housing hard drive and battery

How you can get involved…

Help us collect sound data from your boat by deploying a HARP during normal fishing activities. If you are assigned an observer, you can choose to participate in the project by allowing the observer to bring the HARP onboard. The observer will be responsible for all data collection during deployments. After your participation, a summary of what we learned from the acoustic data obtained during the trip will be provided to you.

Please contact Ali Bayless if you have any questions or are interested in participating.

Sử dụng âm thanh để tìm hiểu vì sao các tàu đánh cá thường bắt phải cá voi

Liên hệ: Thuy Tran at thuyttt@hawaii.edu hoặc; (808)469-2218
Ali Bayless at ali.bayless@noaa.gov hoặc; (808) 725-5728/ (310) 801-7127

Vì sao chúng tôi thực hiện nghiên cứu này

Được biết cá voi hổ (cá hổ kình) là động vật ăn thịt cơ hội, thường bắt lại cá hoặc mồi từ các tàu đánh bắt thuỷ sản longline của Hawaii trong một số khu vực đánh bắt ở vùng biển Thái Bình Dương. Nghiên cứu quan sát về hiện tượng này còn rất hạn chế vì sự việc thường xảy ra vào ban đêm, và ít khi có cơ hội nhìn thấy chúng. Tuy nhiên, cá hổ kình thường phát ra loại âm thanh đặc trưng của loài khiến ta rất dễ rò và xác định. Đây là cách tốt nhất để chúng ta biết liệu cá hổ kình có đang nằm trong khu vực tàu đang đánh cá hay không. Bằng việc giám sát thông qua phát hiện âm thanh liên quan đến những tương tác của loài cá này khi gần tàu, chúng ta có thể hiểu tốt hơn vì lý do gì các loại động vật thường lại gần các phương tiện đánh bắt và bằng cách nào chúng ta có thể ngăn cản điều này. Âm thanh do động cơ và tàu phát ra thường thu hút cá voi nhà táng và cá hổ kình và một một số loài cá khác nhưng đồng thời tiếng động này cũng ngăn cản việc nghe và phát hiện sự tiếp cận của đàn cá.

Thiết bị thu âm (HARP – thiết bị thu âm thanh tần suất cao)

Thiết bị HARP là một máy thu âm thanh dưới nước, được bảo vệ trong một ống kín, màu đen (như mô tả trong hình). Thiết bị này nặng gần khoảng 30 pounds, thuận tiện di chuyển đi lại trên tàu. Thiết bị cũng gắn phao giúp cho thiết bị có thể nổi một nửa trên mặt nước. Bộ phận thu nhận âm thanh nên được gắn trực tiếp vào dây cáu chính (mainline), gần giữa rổ (basket) và khi hạ thuỷ nó sẽ được kích hoạt nhờ cảm ứng với nước biển.

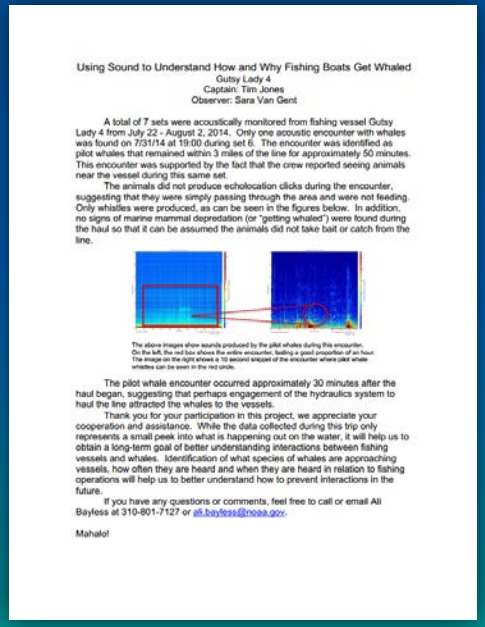
Bạn được khuyến khích tham gia vào nghiên cứu của chúng tôi bằng cách…

Hỗ trợ nhóm nghiên cứu thu thập số liệu âm thanh thông qua việc cài đặt thiết bị HARP trong quá trình thực hiện các hoạt động đánh bắt cá. Nếu bạn muốn cử một người giám sát, bạn cho phép người giám sát mang thiết bị HARP lên tàu và người được cử giám sát sẽ giúp chúng tôi lắp đặt và quản lý thiết bị trong suốt quá trình hạ thuỷ. Sau khi thu thập dữ liệu từ thiết bị, chúng tôi sẽ phản hồi lại những dữ liệu, thông tin âm thanh thu được trong suốt hành trình của chuyến đi.

Nếu bạn muốn tham gia hỗ trợ nghiên cứu cho dự án, và bạn có câu hỏi gì, xin vui lòng liên hệ với Ali Bayless.

Trip summaries are provided to captains within 1 week of return, including:

- # sets monitored
- # sets with cetacean sound
- Relation to observed depredation



Using Sound to Understand How and Why Fishing Boats Get Whaled

Gutsy Lady 4
Captain: Tim Jones
Observer: Sara Van Gent

A total of 7 sets were acoustically monitored from fishing vessel Gutsy Lady 4 from July 22 - August 2, 2014. Only one acoustic encounter with whales was found on 7/31/14 at 19:00 during set 6. The encounter was identified as pilot whales that remained within 3 miles of the line for approximately 50 minutes. This encounter was supported by the fact that the crew reported seeing animals near the vessel during this same set.

The animals did not produce echolocation clicks during the encounter, suggesting that they were simply passing through the area and were not feeding. Only whistles were produced, as can be seen in the figures below. In addition, no signs of marine mammal depredation (or "getting whaled") were found during the haul so that it can be assumed the animals did not take bait or catch from the line.

The above images show sounds produced by the pilot whales during this encounter. On the left, the red box shows the entire encounter, lasting a good proportion of an hour. The image on the right shows a 10 second snippet of the encounter where pilot whale whistles can be seen in the red circle.

The pilot whale encounter occurred approximately 30 minutes after the haul began, suggesting that perhaps engagement of the hydraulics system to haul the line attracted the whales to the vessels.

Thank you for your participation in this project, we appreciate your cooperation and assistance. While the data collected during this trip only represents a small peek into what is happening out on the water, it will help us to obtain a long-term goal of better understanding interactions between fishing vessels and whales. Identification of what species of whales are approaching vessels, how often they are heard and when they are heard in relation to fishing operations will help us to better understand how to prevent interactions in the future.

If you have any questions or comments, feel free to call or email Ali Bayless at 310-801-7127 or ali.bayless@noaa.gov.

Mahalo!

- Project announcements are being circulated to fishermen
- The announcement was translated to Vietnamese
- To date, ~40 boats have agreed to participate (out of ~135 total boats)

Acoustic Contributions to Assessment Summary

- **Successes:**
  - Engaged in productive and extensive partnerships resulting in development of new hardware & software for PIR species & assessment needs
  - Identified species and stock-level differences in acoustic calls forming the baseline for acoustic assessments of high priority species
  - Documented species occurrence using the Acoustic Network in regions with sparse or no visual survey coverage
  - Using acoustic monitoring to improve understanding and development of mitigation strategies for cetacean interactions with the longline fishery
- **Challenges:**
  - Acoustic datasets can be massive. Analyses are time consuming, especially when approached manually.
  - CRP must rely on partnerships to advance acoustic assessment.
  - Many species calls are not yet described or reliably classified. Impact of behavior on call characters and calling rates is largely unknown.

We're just getting started …

- Partners:
  - SWFSC: Jay Barlow, Shannon Rankin, Karin Forney & Elizabeth Becker
  - SIO: Simone Baumann-Pickering, Ana Širović, John Hildebrand, Anne Simonis, Ryan Griswold & Sean Wiggins
  - UH: Lora Van Uffelen, Bruce Howe & Erik Franklin
  - Jupiter Research Foundation: Beth Goodwin
  - Cascadia Research Collective: Robin Baird

- Funding: NMFS BREP, ASTWG, NOAA Ocean Acoustics Program, NMFS Assessment Methods Working Group, & Take-Reduction Program, U.S. Navy Pacific Fleet