Cetacean Assessment using Passive Acoustics:

Promising advances and some lingering limitations

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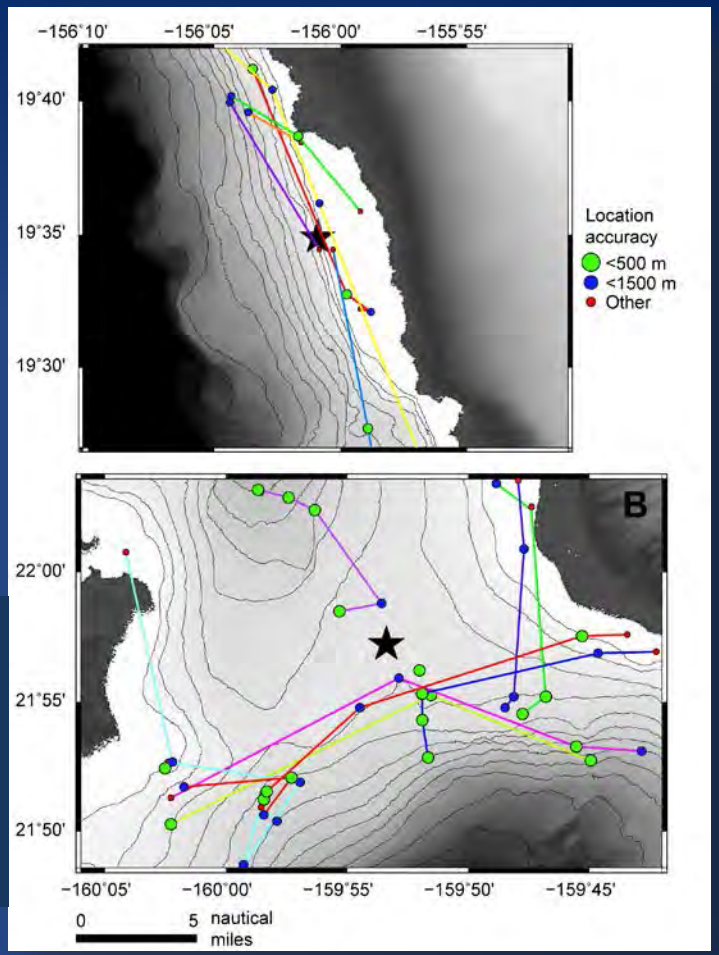
Identifying false killer whales acoustically

- False killer whale whistles are readily identifiable to species
  - ROCCA (Oswald *et al.* 2007) can ID FKWs with >90% accuracy
    - But what about echolocation clicks
    - And, can we classify whistles to *stock*
- Use data from recordings in the presence of false killer whales, pilot whales, and other delphinids to build classifiers

Combine satellite tracks with fixed monitoring sites to increase sample size

- In addition to “visually-verified” recordings, satellite-tagged animals may also provide reference signals for acoustic ID



Acoustic detections associated with passage of tagged false killer whales near Hawaii and Kauai
- Sorted into high versus low confidence

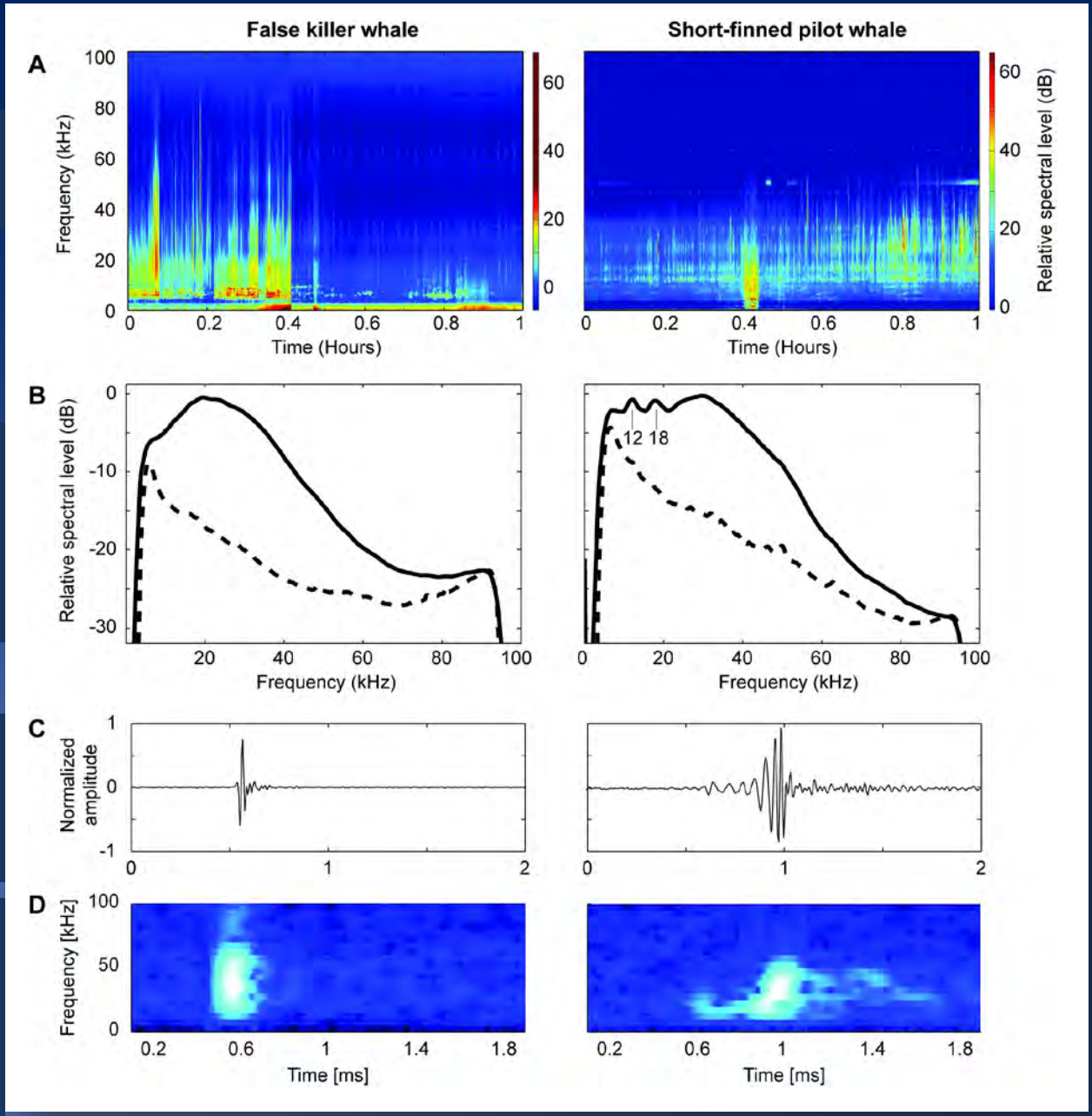
Baumann-Pickering, et al. False killer whale and pilot whale acoustic identification. ESR *in review.*

Raw acoustic data from tagged animals

Average spectra of echolocation clicks reveals spectral peaks and different bandwidth

Waveform measures of individual clicks indicate differing click duration

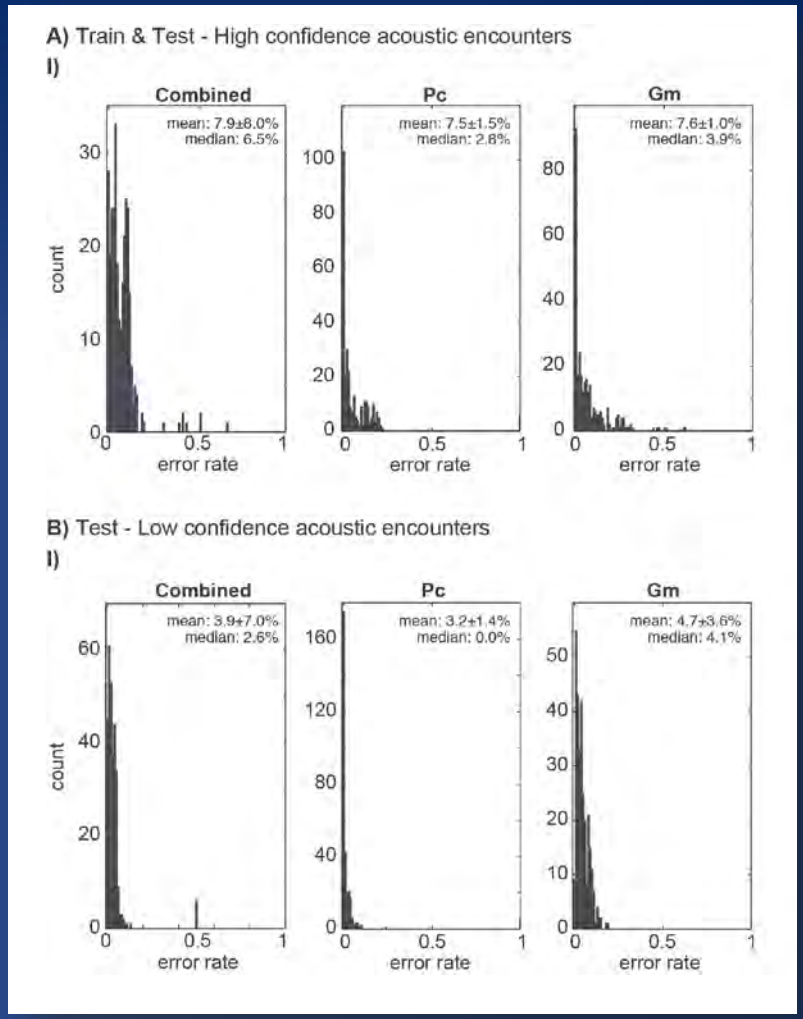
Spectrogram of individual clicks show differences in time-frequency structure



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

False killer whale vs. pilot whale click classification

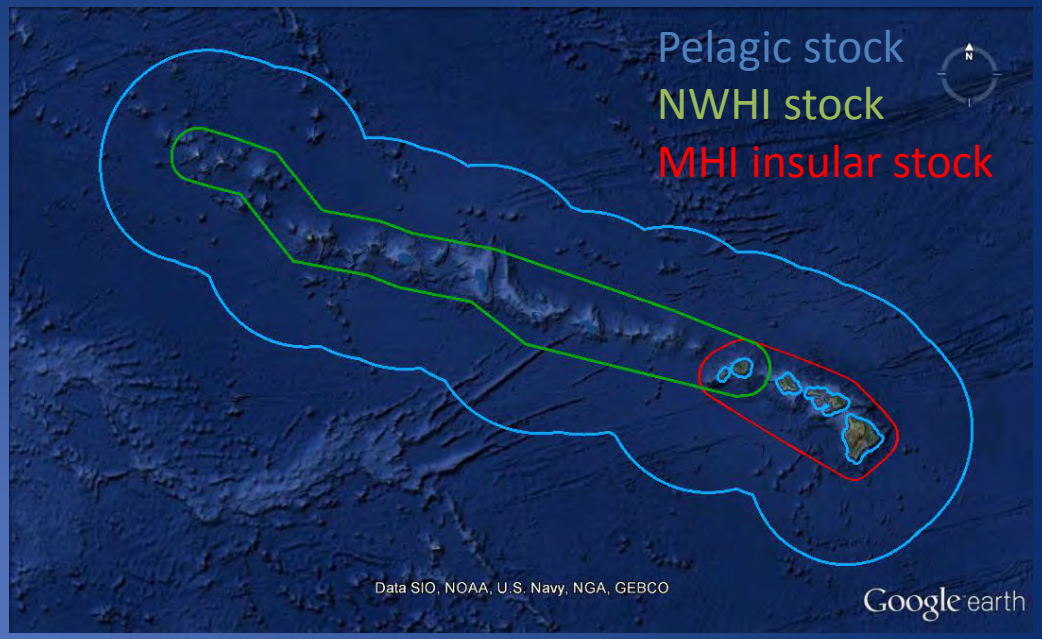
- The combination of acoustic features were used in a Guassian Mixture Model framework to test the accuracy of classification to species
- Satellite tracks with relatively low confidence were not used to train the classifier, but rather only for testing its success rate
- The classifier has a mean error rate less than 8%
- Caveat: classification error rates are susceptible to variations in the frequency response of the recording system



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

Discriminating false killer whale whistles to stock

- There are 3 sympatric stocks in Hawaiian waters
  - If we cannot distinguish them acoustically, our ability to use acoustic detections is limited



Whistles characters do not appear to be sensitive to recording system variation

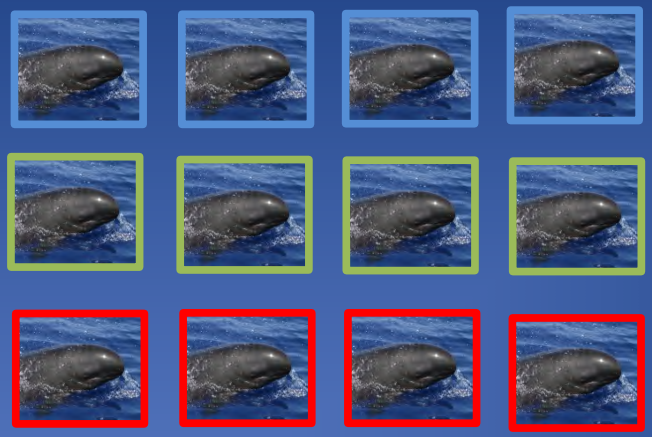
Discriminating false killer whale whistles to stock

- Using whistles collected from a variety of efforts, including tagged whales
- Used whistles from 5 encounters per stock, 30 whistles per encounter
- Measured 54 variables from each whistle. Random forest analysis classified whistles from each group to stock based on whistle characters.

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)

Barkley, ongoing Dissertation research

Random Forest Group Classification Results

Compiled Results for 10 trials

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

Barkley, ongoing Dissertation research

False Killer Whale Whistle Discrimination

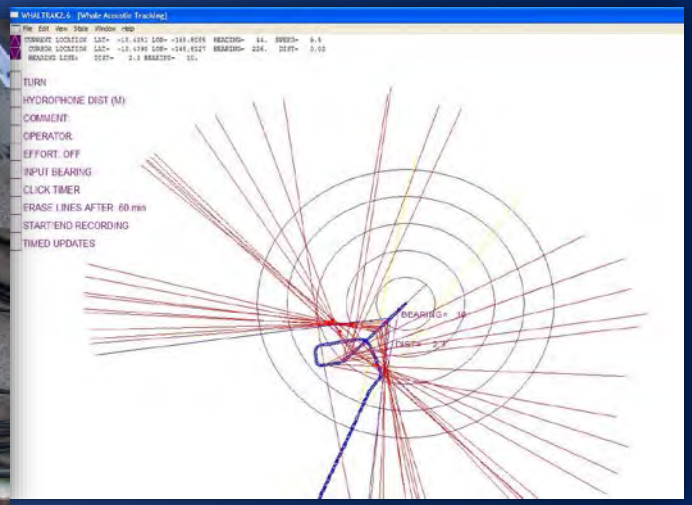
- Results are very promising for MHI insular and pelagic stock discrimination.

- BUT- as we add new data, classification success seems to vary
  - Need to explore dependence on group size, number of whistles per encounter, and sensitivity to unequal sample size

Barkley, ongoing Dissertation research

Technology Development in Real-time Acoustic Monitoring

- Hydrophones in a line
  - Limits location accuracy – can't tell left from right
  - 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 survey methods don't always allow for acoustics to work efficiently



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 looking for new partners through ASTWG SBIR initiative

Acoustic Monitoring of the Longline Fishery

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. Deployments with gear experts on charter vessels to test attachment mechanism and placement, recorder reliability, and assess interference with setting and hauling process
2. Charter deployments of multiple recorders on each set
   - PIRO Observer refurbished instruments, captain took data on instrument deployment location when observer off-duty
3. Single instrument deployments on volunteer basis
   - Instrument provided on observed trips if captain has agreed in advance

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

- 6 chartered trips in 2013-14
- 11 volunteer trips (so far) since mid-2014
- 125+ sets monitored to date
- All bouts of cetacean sound extracted for species classification

- False killer whale sounds detected in < 25% 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**

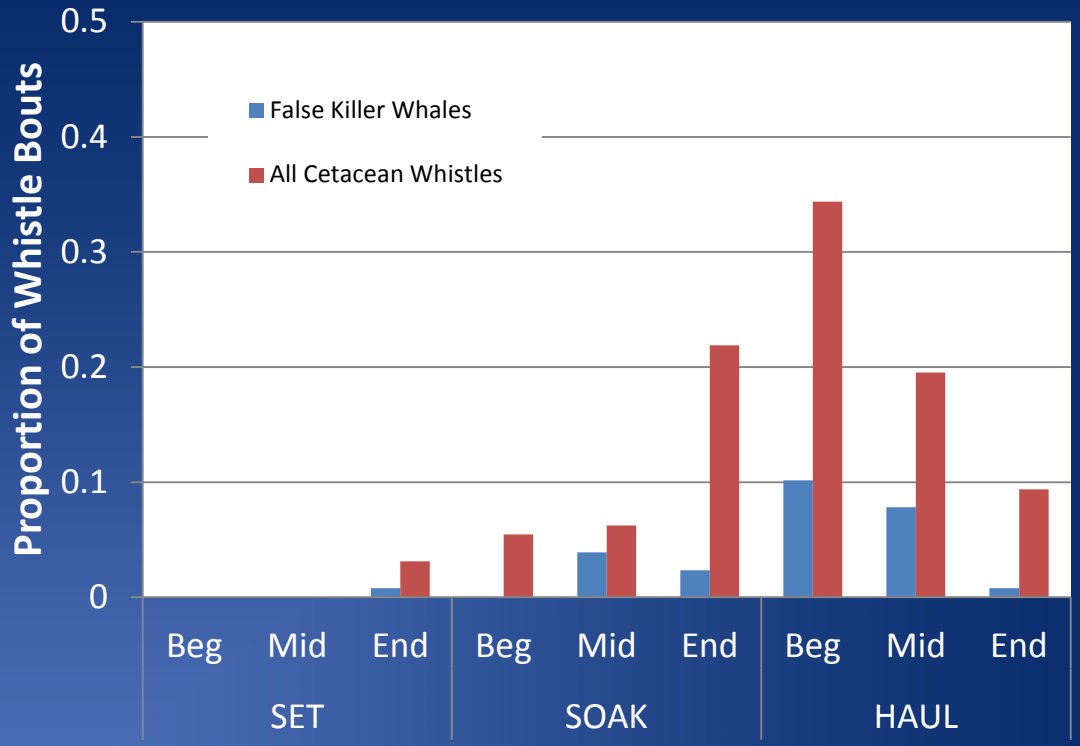
Click vs. Whistle Classification

Charter trips

# Calling bouts classified as FKW	'FKW' Whistle bouts	'FKW' Click bouts	% Agreement when Clicks & Whistles present
17	7	13	67%
3	3	3	100%
13	2	13	50%
10	4	4	33%
2	1	2	0%
9	8	9	33%

- Relatively poor agreement between whistle and click classifications.
  - Recorder noise may be interfering with click classifications
  - Whistle classifications have high statistical confidence

Timing of Whistle Detections



- Cetacean detections are most common from the end of the soak through the haul
- False killer whale detections peak during the haul

Timeline of Fishing Operations

Time (total 15-18 hrs) →

Set ID

Trip1-set3

False killer whale whistle detections per instrument

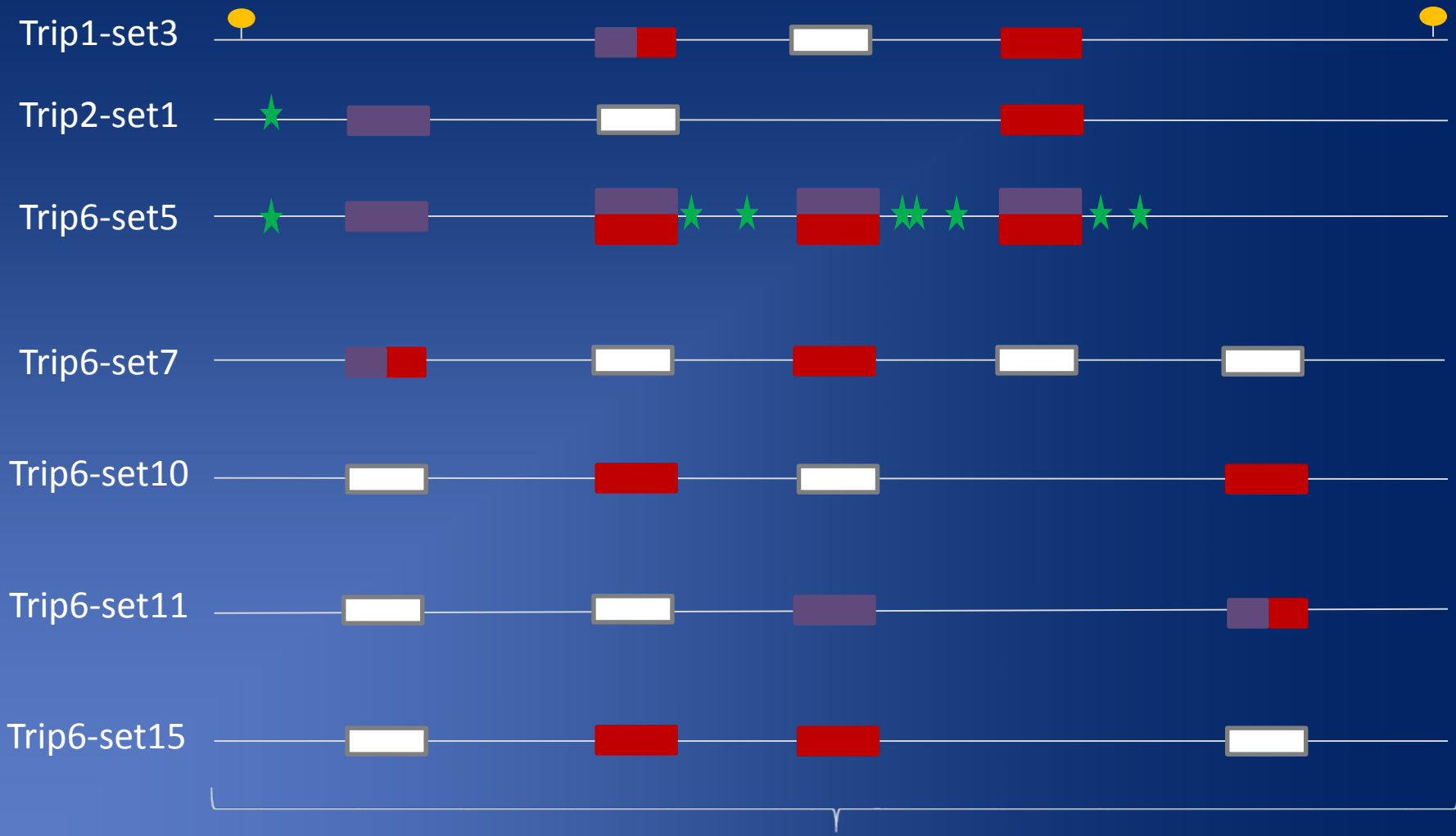
~40 nmi of longline gear

Timeline of Fishing Operations

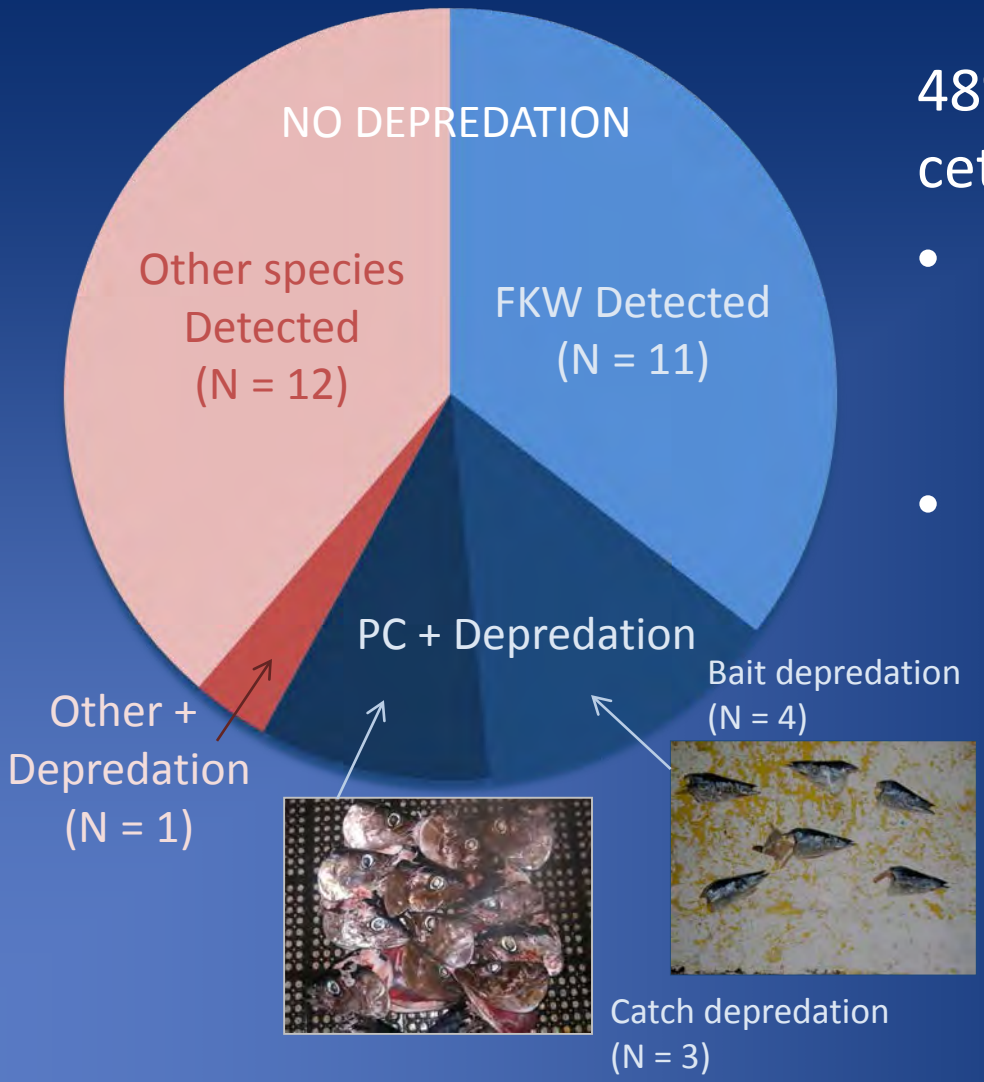
Time (total 15-18 hrs) →

Set ID

False killer whale whistle detections per instrument



Detection relative to fish depredation (by set)- charters only



48% of analyzed sets have cetacean sounds:

- 58% of sets with acoustic detections are false killer whales
- Most sets with cetacean detections do not show signs of bait or catch removal
  - 7 of 18 sets for FKW
  - 1 or 13 sets for ‘Other’

So far…

- False killer whales are detected ~3x more often than catch depredation is recorded
  - Are whales just near the gear or are they depredating bait?
- Most encounters with false killer whales are during the soak and haul
- When detected across multiple instruments, later detections are generally further from the boat

The project 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 thuytt@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 hồ (cá hổ kình) tấn công vật ăn thịt cơ hội, thường bắt lại cá hoặc cắt 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 rõ 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 rõ hơn về lý do gì các loại động vật thường tới gần các phương tiện đánh bắt và bằng cách nào chúng ta có thể ngăn cản điều này. Âm thanh do động cơ và thuyền phát ra thường thu hút cá voi nhà táng và cá hổ kình và một một số loại cá khác nhưng động 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 cửa 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 bỏ thuyền mở sẽ được kích hoạt nhờ cảm ứng với nước biển.

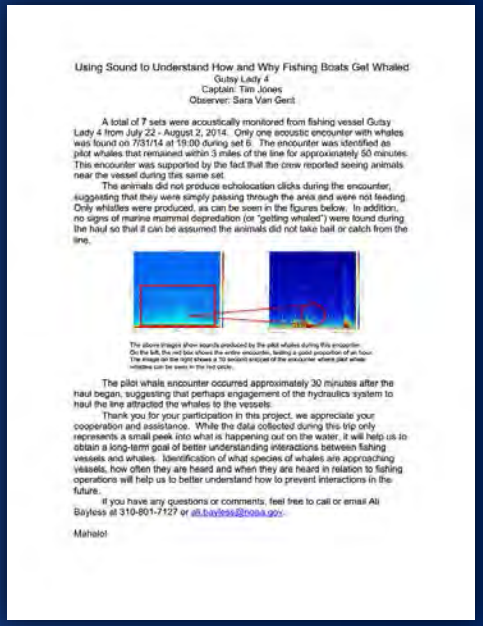
Bạn được khuyến khích tham gia vào nghiên cứu của chúng tôi bằng cách…

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 có 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 thuyền. Sau khi thu thập dữ liệu từ thiết bị, chúng tôi sẽ phân tích 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 after they 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 Gerd

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 310-801-7727 or ali.bayless@noaa.gov.

Mahalo!

- Project announcements are being circulated to fishermen at the dock
- The announcement was translated to Vietnamese and a native Vietnamese speaker has been assisting in direct discussion with that segment of the fishery
- To date, 32 boats have agreed to participate (out of ~135 total boats)

What's next?

Analysis:

- Investigate mismatch between whistle & click classifications
- Characterize non-cetacean sounds
- Examine timing of gear and boat sounds relative to false killer whale detections

Project:

- Continue recruiting vessels to participate
- Access Korean sector of the fishery
- Instrumentation upgrades-
  - Increase reliability
  - Reduce instrument noise
  - Increase recording duration

We're just getting started …

- Partners:
  - Yvonne Barkley, Karlina Merkens & Ali Bayless (PIFSC)
  - Simone Baumann-Pickering, Ana Širović, John Hildebrand, Anne Simonis & Sean Wiggins (SIO)
  - Robin Baird (Cascadia Research Collective)
  - BREP, ASTWG, NOAA Ocean Acoustics Program, NMFS Assessment Methods Working Group, and Take-Reduction Program
  - U.S. Navy Pacific Fleet