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Integrating remote sensing methods to measure baseline behavior and responses of social delphinids to Navy sonar

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Award Number: N00014-17-1-3132 (to SEA; see note below)
http://sea-inc.net/2017/10/06/tagless-brs-from-the-field-update/

NOTE: This project involves a close collaboration among researchers from SEA, NOAA Fisheries Southwest Fisheries Science Center (SWFSC), Cascadia Research Collective (CRC), and Kelp Marine Research (KMR). The ONR grant referenced was issued to SEA and includes subcontracts to CRC and Kelp. Additional support for the project was provided under two separate ONR awards issued to SWFSC (PI: Dr. John Durban - N00014-18-IP-00021) and CRC (PI: John Calambokidis – N00014-17-1-2887). This annual report for the overall project is intended to serve as the annual report for each of these awards.

A separate ONR award to SWFSC (PI: Dr. Nick Kellar) to investigate potential physiological stress responses to noise was coordinated with this project following discussions with the ONR Marine Mammal Program Manager. This coordination is described here, but a separate annual report for this project is being submitted.

LONG-TERM GOALS

I. Develop integrated, cross-disciplinary methods to characterize typical (undisturbed) behavioral parameters of smaller delphinid cetaceans (common, bottlenose, Risso's dolphins) that occur in large numbers in Navy range areas using shore- or vessel-based visual observers, aerial photogrammetry, and remote-deployed acoustic recorders.

II. Obtain direct measurements of group behavioral changes, spacing, movements, vocal behvaior, and stress hormone responses, if any, resulting from experimentally controlled simulated Navy mid-frequency active sonar (MFAS) using controlled exposure experiments (CEEs).

III. Obtain biopsy samples for use in a collaborative research project with SWFSC to measure stress hormone levels.

OBJECTIVES

This report summarizes the first field season of this proof-of-concept project to test and evaluate the integration of various remote sampling methods to study the baseline behavior and behavioral response of small delphinid cetaceans without the use of tag sensors placed on individuals. Given the completely novel nature of this approach for studying group behavioral dynamics using an integration of some established and some new and evolving methods, the objectives for this first field season were relatively straightforward. Essentially, we aimed to: 1) determine whether and under what conditions we could realistically apply these methods to address these questions for the focal species in quest and, if so; 2) adapt and apply methods in conducting initial CEEs with and without MFAS to begin to evaluate the nature of potential responses. Specific objectives were identified for both spring and fall field efforts, each of which is described separately in terms of accomplishments and lessons-learned below.

Spring 2017 field effort objectives: Conduct in-the-field proof-of-concept trials of data collection methods and integration, with simulated CEE sequences (no experimental sound transmissions) in order to: (1) Evaluate conditions under which group behavior may be successfully measured within individual data collection methods and (2) evaluate complementary aspects and integration of different remote sampling methods.

Fall 2017 field effort objectives: Apply methods and lessons-learned from spring effort to revise data collection and analytical methods for measuring baseline behavior and (2) Conduct MFAS (simulated sonar source) and control CEE sequences on focal species with priority order being common (both long- and short-beaked), bottlenose, and Risso's dolphins, respectively.

APPROACH

Building on pilot field efforts and observations with some delphinid species that our team has been involved in with previous ONR and other Navy supported behavioral response studies in southern California (see: Southall *et al*., 2013) and successful related studies in the Azores, we developed and implemented a novel integration of several established remote sampling methods to quantify behavior in several smaller delphinid species (common dolphin (*Delphinus delphis* and *Delphinus capensis*), bottlenose dolphin (*Tursiops truncatus*), and Risso's dolphins (*Grampus griseus*), which are given in specified priority order. This integration was designed to enable the measurement of both baseline behavior as well as the evaluation of potential responses to simulated mid-frequency active sonar (MFAS) using controlled exposure experiments (CEEs). The nature of the resulting data are categorically different from previous response studies involving tagging of single individuals. Beyond the fact that getting tags to stay on individuals of these species has proven infeasible to date, these social species typically occur in groups and group members likely interact in their response to external stimuli (Visser *et al*., 2014; 2016). As such, the group, or part of the group, is likely a particularly relevant unit of behavioral analysis, in addition to individual behavior of one or a few group members. We are explicitly identifying group behavioral state in evaluating potential responses to disturbance, although it is acknowledged that our methods are likely most effective for documenting near-surface social interaction and group behavior rather than studying sub-surface feeding behavior. The identification of behavioral state as a relevant contextual covariate is clearly important (*e.g.*, Southall et al., 2016) and is being explicitly considered within response analyses.

We developed, evaluated, and adapted a novel combination of shore- and vessel-based visual sampling, unmanned aerial systems (UAS) for aerial photogrammetry, and remote-deployed passive acoustic sensors to document specific aspects of baseline (undisturbed) behavior and potential responses during CEEs involving either no sound transmissions (control sequences) or MFAS exposure from a simulated 53C sonar source used in previous CEEs for the SOCAL-BRS project (Southall *et al*., 2012).

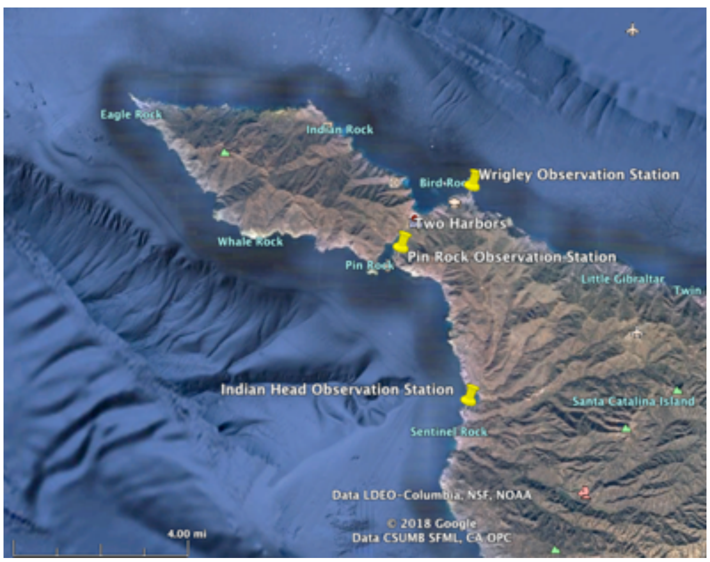
Overall Field Configuration

Field operations occur from three different vessel platforms, as well as a shore-based visual observer team. These include:

- *M/V Magician* (20 m recreational dive boat with home port in San Pedro, CA; http://magicianscuba.com/): serves as centralized/base vessel for at-sea team; UAS base of operations; visual observation platform

- *RHIB Musculus* (Cascadia Research 7.33 m Hurricane): serves as sound source vessel for MFAS CEEs; primary photo ID/biopsy sampling option; visual observation platform
0)
- *RHIB Ziphid* (Cascadia Research 5.9 m Hurricane): PAM base of operations; visual observation platform; secondary photo ID/biopsy sampling option

- *Shore-based visual team*: Wrigley based mobile operations to allow two observation locations (east-facing Wrigley Station; west-facing Indian Head harbor observer station). Note: on several occassions when animals were further from either observation station, members of the shore-based visual team were pulled onto the Magician to conduct behavioral observers from a boat-based observer platform.



Behavioral Data Collection Methods and Protocols

Group-level behavioral observations were obtained using visual observeration, photogrammetric and passive acoustic methods. The behavior of small delphinids can be challenging to study, because of large group sizes, dynamic aggregations and fast and fluent movement patterns. Given these characteristics, even moderate duration (>10 min) tracking of a specific individual or even a clearly defined group, within a larger aggregation is practically impossible using conventional tagging, visual observations or acoustic tracking alone. Therefore we developed, applied, and adapted a cross-disciplinary, integrated approach specifically tailored to investigate larger aggregations and group dynamics that includes: (1) shore-based or boat-based visual observations; (2) aerial photogrammetry methods using images collected from small unmanned aerial systems (UASs); and (3) passive acoustic monitoring (PAM) methods.

Some of the methods and remote sampling technologies described in this proposal are well established (*e.g.*, visual sampling; PAM), while others (*e.g.*, aerial photogrammetry of group characteristics from UASs) are new and emerging. However, their integration to study baseline behavior and potential behavioral responses of groups of free-ranging cetaceans in a CEE context is completely novel. Many of the initial steps relating to Objectives I and II relate to the development of the integrated data collection and analysis required to evaluate the feasibility and potential limitations of reliably measuring group responses for species in which behavior may commonly change quickly and regularly. Our experiences are discussed below in terms of an honest evaluation of the efficacy and potential limitations of integrating several different behavioral sampling methods for these gregarious species.

The initial field effort during the spring phase of this project thus focus primarily on the integration of visual, photogrammetric and acoustic sampling methods to measure baseline behavior of subject species in different settings during relatively similar daytime hours. These contrasts included different physical locations (selected from considerable field experience in these areas in the SOCAL-BRS project) and other relevant parameters such as variable wind and sea state conditions and variable observer heights for shore-based observers and altitude of UAS flights. Finally, deployment strategies of remote-deployed acoustic recorders in relation to the variable movement patterns of these cetacean species to ensure high quality acoustic recordings of animals without having their deployment affect the behavior of animals was tested and evaluated.

Shore-based visual team

Observations were conducted from elevated cliffs on Catalina Island, specifically near Two Harbors, Catalina harbor, and at the Indian Head station in areas where all three focal species regularly occur close to shore. The shore-based team consisted of 4 observers to conduct visual observations with high-power binoculars, spotting scopes, and record locations using theodolites. A data recorder archived information of both types in custom tracking software. Target groups were located using survey effort, scanning the research area until a suitable group had been located. In some cases, shore-based tracking observations during CEEs were infeasible, (*e.g.*, due to lack of target species in the research area) and a portion of the shore team moved offshore to conduct comparable visual focal follow observations from one of the research vessels.

Visual observations were made at two different spatial resolution scales: coarse scale (recording behaviora metrics at level of the whole group), and fine-scale, recording detailed movement metrics of a part of the group (see below). Visual observers recorded both types of observations from the observation platform, with sampling methods designed to complement the spatial resolution of photographic measurements from the UAS (see below).

Shore-based focal follows consisted of relatively brief (30-60 minute) visual tracking of a target groups, in comparable time windows either completely without exposure (baseline behavior), or during CEEs. Two observer-modes were used to collect data on two different scales: 1) traditional focal follow observations and 2) novel group-movement tracking. Focal follow observations were conducted with an experienced observer tracking the behaviour of the entire group, where possible. During focal follows, the following parameters were recorded each minute: group size, spread, clustering, synchrony of movement (within-group directionality) and presence/absence of behavioural events (e.g. breaches). Focal follow tracking provides data at relatively coarse scales, identifying the degree of aggregation, synchrony and cohesion at the level of the group. Conversely, fine-scale observations of movement and behaviour were recorded with theodolite tracking, providing a comparable level of spatial resolution to UAS photogrammetry at higher elevations.

Tracking the movement of commonly fast-moving, gregarious and diving animals is challenging and precludes the use of several traditional movement tracking techniques (*e.g.,* longer-term tracking of one individual or smaller group). We therefore developed novel methods relying on many consecutive but short tracks of nearby small groups within the larger target group. Observers tracked one individual or a small clustered group of individuals for at least three consecutive location records, thenshifted to a nearby individual or small group. This procedure was repeated until the end of the observation. For each short track, the following parameters were calculated: group direction, speed (mean ± SD) and directionality. Together, the individual short tracks show the overall movement pattern of the group over the course of the follow. Location records within one short track were sampled at regular, short intervals (<1 minute). The aim and purpose of this method was to test the potential to record small delphinid movements quantitatively and reliably for longer periods, which was evaluated within the context of the higher resolution UAS data obtained for a portion of the group.

Aerial UAS photogrammetry

Recent advances in the use of small unmanned aerial systems (UAS) offer new opportunities to augment traditional visual observations (*e.g.*, Koski *et al*., 2009; Hodgson *et al*., 2012). Some of these earlier applications have involved relatively larger fixed-wing vehicles, but new technologies with smaller aircraft are now facilitating a wider range of practical applications. Durban et al. (2015) described the successful use of a small, unmanned hexacopter (APH-22; Aerial Imaging Solutions) to obtain high-resolution photographs to measure killer whales (*Orcinus orca*) at sea, and this tool has now been successful used by these investigators during several field studies (>3000 flights total) involving a variety of whale and dolphin species over the past two years (*e.g*. Durban *et al*. 2016). For this study, the UAS team from NOAA/SWFSC adopted the use of a larger octocopter (APO-42, Aerial Imaging Solutions) that has similar flight, telemetry and photographic systems to the established APH-22 hexacopter, but has eight motors to enable more stable flight in higher wind conditions, is larger in size (42” across) to provide greater visibility for longer range flight missions and can carry multiuple lithium polymer batteries to enable flights >30 minute duration. As with the hexacopter, the octocoper can be safely hand-deployed and recovered on boats. A Micro Four-Thirds system camera mounted on the octocopter captures images with a ground-resolved distance of <1.4 cm to 2cm (from an altitude range of 30 to 60m, respectively) across the entire flat and undistorted field of view. An onboard laser altimeter enables measurements in pixels to be scaled to true size with an average accuracy of ~2cm from 60-30m, respectively. As a result, the images are sharp enough to differentiate individual animals and resolve differences in individual morphometric and spacing.

We successfully used this UAS system to complement shore- and vessel-based visual survey teams and to provide high-resolution measurement of individual and group movement behavior in studying the normal behavior and potential responses to sound of all three focal delphinid cetaceans. Such integration with conventional visual sampling and PAM methods (discussed below) in measuring the dynamic behavior of small, potentially fast-moving groups of cetaceans in the field has not been previously conducted. A significant component of this project, particularly in the spring field effort simply lied in the testing, evaluation, and application of these new methods as tools to empirically document aspects of behavior in unique ways. Initial deployments evaluated the appropriate elevation for different types of spatial resolution on focal groups in complementing visual survey data.

UAS operations from the M/V Magician, showing hand-deloyments and catches of the APO-42 Octocopter.

Higher-altitude photogrammetry (45-60m) provided images for the quantification of spatial distribution, cohesion, movement speed, and movement synchrony of at least one defined subgroup within the larger group that was being tracked by shore-based focal follows. Lower-altitude photogrammetry (30-45m) enabled higher-resolution photogrammetry measurements of the length of the target animals (see Durban *et al*., 2015, 2016). Individual morphometrics were collected to describe the size structure of the focal UAS sub-group: length will be related to age using published length/age relationships for each species. Inference about age class may ultimately be used as key covariates for controlling and interpreting behavioral differences between groups and potential responses to sound.

Passive acoustic monitoring

Passive acoustic recordings were obtained using drifting, remote-deployed Loggerhead SNAP recorders with HTI-96 hydrophones (48 kHz sampling rate; flat frequency response in range of dolphin sounds) suspended to a depth of 10 m under shock-mounted surface floats with GPS tracking devices. High capacity (256 GB) flash memory allow continuous acoustic sampling and rapid offloading of large volumes of acoustic data. Three separate PAM recorders were strategically-placed and recovered from either RHIB *Ziphid* (in alsmost all instances) or from the *Magician* within the observation area based on the behavior and direction of travel of the focal group.

Group vocal activity, including call presence/absence, call type, and measurements of call rates, were determined from PAM recordings using standardized methods and multiple observers blind to experimental conditions in order to obtain broad-scale metrics of vocal behavior and potential responses to sound exposure by comparing control and experimental (exposure) periods.

Photo-ID

Photo-identification of individual animals was conducted outside the behavior sampling period (primarily during approaches for biopsies, see below), to help document the group/individuals present. This can be an effective method for tracking individuals, especially for bottlenose and Risso's dolphins, and cataloging the individuals that use these waters. This information is important to determine where observations or playbacks involve the same group of animals in multiple experiments, which was done on several occassions. While less effective for common dolphins, as opposed to bottlenose and Risso's, this will still be potentially useful in some cases for this species as well. Photo-ID will also be used to try and document the individuals biopsied although again this will be most effective for bottlenose and Risso's dolphins.

Biopsy sampling

Biopsy samples were collected using conventional methods (small cross-bows) during either non-CEE periods or at variable times post-exposure following CEEs from groups of animals known to be exposed to MFAS. Post-sampling commenced not earlier than 30 min following CEEs and occurred at variable intervals (not continuously) for up to approximately 3h post sound exposure.

CEE Protocols

Methods for conducting controlled exposure experiments (CEEs) using the behavioral sampling methods described were generally similar to those used in SOCAL-BRS (see Southall *et al*., 2012). Given the generally transient nature of these species and the limited areas that can likely be effectively monitored from a fixed shore station and a limited number and acoustic recorders, and given the desire to track individuals within a single UAS flight, the overall time scale of CEEs was reduced in time relative to the tagged animal exposures in SOCAL-BRS to 10-min pre-exposure, exposure (or control), and post-exposure periods; total CEE sequences were thus 30-min in total duration.

The simulated MFAS source deployed from the RHIB *Musculus* is the same as used in SOCAL-BRS. No experimental ramp-up of source levels was used for this project - all exposures occur at a constant level (212 dB re: 1uPa). The absence of an experimental ramp-up is more representative of realistic Navy sonar sources. All experimental protocols and mitigation requirements (e.g., source shut-down for any marine mammal coming within 200m of the source when active) were identical to those used in SOCAL-BRS (see Southall et al., 2012; 2013) and were consistent with all requirements of NMFS permit #19116 to B. Southall. Prior to CEEs, sources were positioned at a range determined from in situ propagation model estimates of 130-160 dB re: 1uPa received levels at the focal group.

WORK COMPLETED

We provide a summary of the accomplishments and provide a separate evaluation of effort of both logistical and research accomplishments for both the spring and fall 2017 field efforts for this project:

SPRING FIELD EFFORT: SYNTHESIS AND ACCOMPLISHMENTS (Logistics and Methodology):

- Weather conditions workable all days with no major storm events. However some limited sighting conditions for shore-based teams (fog/clouds) and on-water conditions generally poorer than expected for these areas in that typical afternoon winds came up earlier and put premium on am effort.
- Animal sightings on both east and west side operational areas off north end of Catalina exceeded expectations. Regular sightings of workable groups of all three species with observation stations adapted to multiple locations
- Successful coordination and field operations using the *M/V Magician*. This was a new and smaller platform for us in these kinds of studies and it worked well logistically for the UAS team and visual observers. Resolved that chief sci should be positioned from here for CEEs
- Successful radio communications and coordination across research teams on four platforms; some challenges with level of radio communication required relative to concerns about swamping VHF channels and made some adjustments
- Successful coordination with Wrigley Institute as a base of operations for the shore visual observation team station and mooring all research boats most nights
- Successful local coordination and approvals from both the Catalina Island Company (owns the land for Two Harbors (east side) visual station) and Catalina Island Conservancy (owns the land for Indian Head (west side) visual station).
- Good interactions with interested local parties regarding the project to provide information publicly.

SPRING FIELD EFFORT: SYNTHESIS AND ACCOMPLISHMENTS (Research Achievements):

- Careful, step-wise application and integration of different methods throughout, with extensive post-hoc discussion and evaluation across teams
- Successful and safe UAS flights completed for all focal species:
  - 25 total flights (13 common [10 *D.capensis*, 3 *D.delphis*], 6 bottlenose, 6 Rissos)
  - 23,000+ calibrated photo images collected across all focal species
- Successfully tracked and images distinct subgroups across entire flights (>20 mins).
- Shore-based visual team successfully tracked focal groups of all three species from monitoring stations on both sides of Catalina using theodolites for focal tracks and reticle binoculars for larger group distribution and behavior.
- Acoustic recordings obtained with buoys for focal groups of all three species. We identified challenges and limitations of this method and the need to utilize PAM from strategic recorder deployments in different experimental phases.
- Several dozen successful biopsy samples obtained across all focal species (mostly common dolphins) during no noise exposure (baseline) conditions.
- Ten complete before-during-after mock exposure CEE sequences were conducted, including strategic positioning of the sound source vessel to meet experimental objectives and mitigation/permit requirements.

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FALL FIELD EFFORT: SYNTHESIS AND ACCOMPLISHMENTS (Logistics and Methodology):

- Weather conditions were limiting on several afternoons and precluded CEEs entirely on two of ten days. As in the spring effort, this put a premium on early am effort. However, on two days conditions were suitable for multiple CEEs within days.
- Animal sightings again quite regular with good candidate groups detected on every field day. All four focal species were detected and tracked on the east side in good proximity to observation stations. Common and bottlenose dolphins were tracked on the west side, but many out of shore visual range.
- Field configuration and communications worked well with several additional functions and roles. Chief scientist coordinating operations from *Magician* worked well. Retained configuration of *Magician* as UAS platform, Ziphid deploying PAM buoys directed from chief sci, and adapted *Musculus* to serve as sound source platform.
- Successful completion of full CEE sequences, but source failure due to false leak detection alarm resulted in premature termination of 3 of 6 MFAS transmissions
- Successful coordination again with Wrigley Institute logistics and coordination with Catalina Island Conservancy.
- Busy periods on weekends and Buccaneer Day festival meant some periods with many other boats around. Like 4 July weekend, would be better to avoid these.

FALL FIELD EFFORT: SYNTHESIS AND ACCOMPLISHMENTS (Research Achievements):

- Adapted and applied novel field methods developed in spring effort within experimental context to conduct first-ever MFAS CEEs for common and bottlenose dolphins

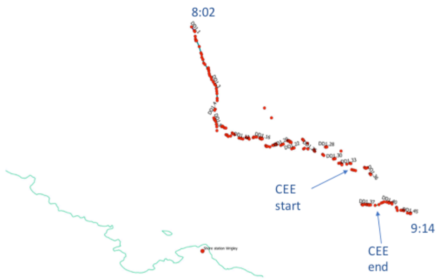
- 9 total CEE sequences (6 MFAS; 3 control) with common dolphins (4 MFAS; 2 control) and bottlenose dolphins (2 MFAS; 1 control)
- Extended UAS flights >30 minutes with additional battery configurations, to encompass full CEE experimental design
- Safe, successful UAS flights completed for three focal species:
  - Selective UAS deployments in field conditions expected to be successful
  - *14 total flights (8 common dolphin [7 D.delphis, 1 D.capensis, 6 bottlenoses)*
    - *40,000+* calibrated photo images collected across all focal species
    - Extensive and complex analytical effort required and ongoing
- Successful theodolite tracks and focal group behavioral sampling from shore-based visual team for all three species. Fog/haze were limiting for some periods and groups too far offshore on west side, but successful transition of behavioral focal follows to vessel-based platform
- Calibrated acoustic recordings of animal vocalizations and MFAS obtained with PAM buoys all CEE sequences. Positioning was greatly improved based on adaptation from lessons-learned during spring field effort. Analysis is complex and challenging, but progressing well.
- >70 successful biopsy samples obtained for common and bottlenose dolphins; most following known noise exposure at strategically-selected post-exposure periods

RESULTS

We documented baseline (undisturbed) group behavior of four delphinid cetacean species (Objective I), investigated potential behavioral responses to MFAS (Objective II) using group-level behavioral observations (visual, photogrammetric, and acoustic), and collected biopsy samples in unexposed and CEE-exposed animals (Objective III)). We provide here examples of the types of detailed behavioral measurements that were obtained from each sampling platform for selected CEEs and provide an evaluation of lessons-learned in terms of logistical feasibility and field operations. Detailed analyses of behavioral responses are ongoing, with observations about the nature and magnitude of response in these species requiring additional future CEEs to obtain larger sample sizes and test various exposure contexts. Given that this is a feasibility, proof-of-concept study, we focus here primarily on the types of data obtained with examples of analyses from each remote sampling element and lessons-learned and new capabilities from this novel technology integration, rather than focusing on specific aspects of behavioral response. A third field phase in summer 2018 will provide additional CEE results, with our 2018 annual report providing a comprehensive evaluation of observations of the initial behavioral response results from both the fall 2017 and spring 2018 field operations.

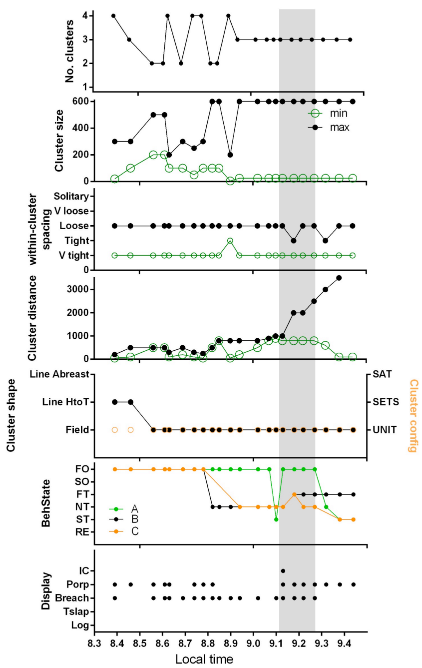
Results example: Long-beaked Common Dolphin Group Track (Shore-based visual team)

* Theodoloite track of a group of common dolphins before, during, and after a MFAS CEE.



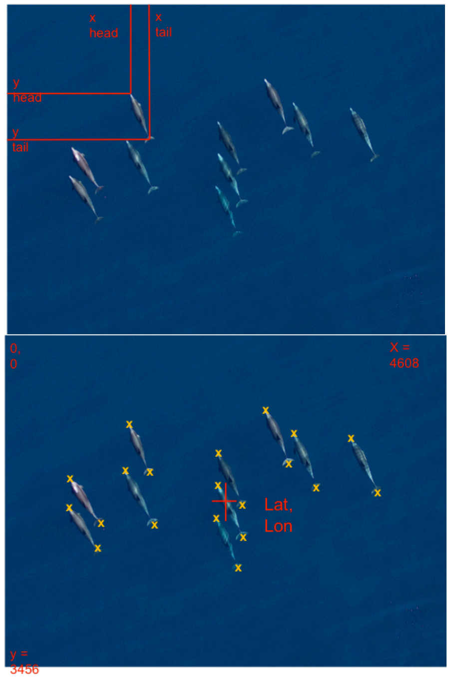
Results example: Common Dolphin Behavioral Focal Follow (Shore-based visual team)

* Behavioral focal follow observations of multiple clusters of common dolphins within larger group during a MFAS CEE (outlined in grey).



Results example: Short-Beaked Common dolphin Photogrametry Methods (UAS team)

* Detailed analysis of known individual position in XY space enables high-resolution measurements of length, spacing, heading of individuals within a focal group. Pixel XY then converted to real space by latitude and longitide coordiates of frame center, altitude and real size of frame footprint.

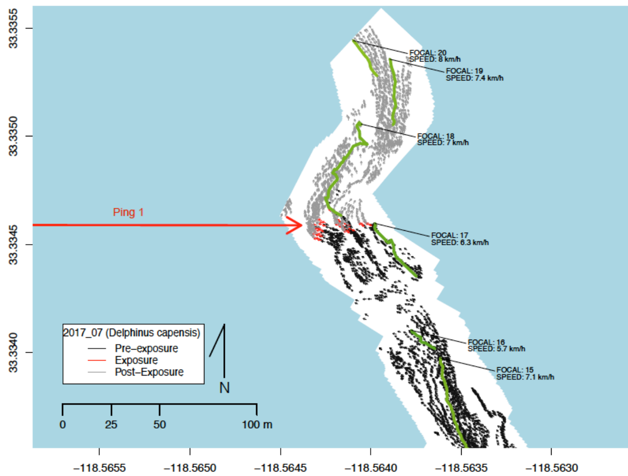


Results example: Determination of Focal Individual Speed (UAS team)

* Analysis of sequential photos in which individuals may be distinguished and tracked in XY space enables calculation of focal individual speed for finite periods, given time between frames and tracking of XY in real space

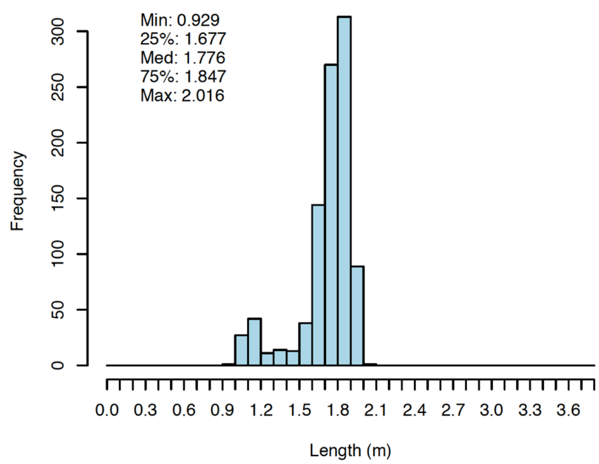
Results example: Long-beaked Common Dolphin Group Tracking and Focal Individual Speed (UAS)

* Sequential imaging of all subgroup individuals (individual arrows represent spacing and heading of individuals) as well as focal speed for focal individuals (colored lines) before and during the first ping of a MFAS CEE. The white area indicates the UAS-field of view (i.e., area captured within each frame).



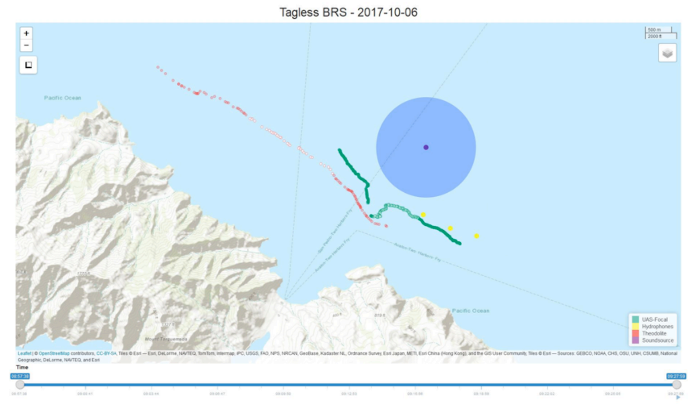
Results example: Short-beaked Common Dolphin within group length estimates (UAS)

* Photogrammetrey measurements of individual length measurements from just one flight over a focal subgroup.



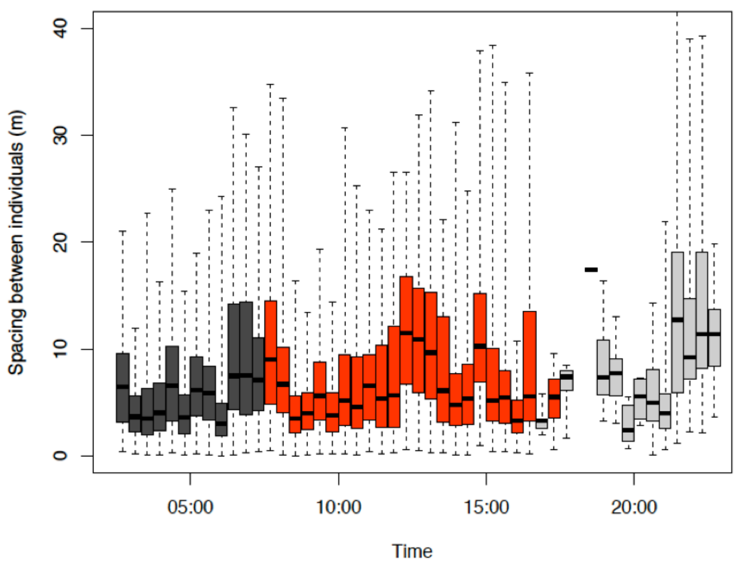
Results example: Integrated Long-beaked Common Dolphin Group Tracking During CEEs (Shore-Based, UAS, PAM Teams)

* Integrated image of whole group track (from theodolite, red), focal subgroup track (from UAS, green), relative to orientation of PAM hydrophones (yellow) and experimental sound source (blue) during MFAS CEE



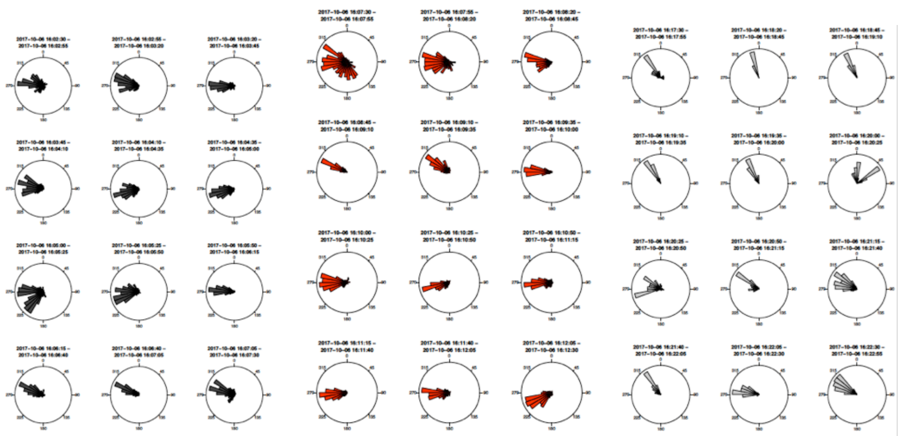
Results example: Long-beaked Common Dolphin Measures of Inter-Individual Spacing (UAS team)

* Box plots of median spacing between individual common dolphins during sequential 25s periods before (dark gray), during (red), and post-exposure (light gray).



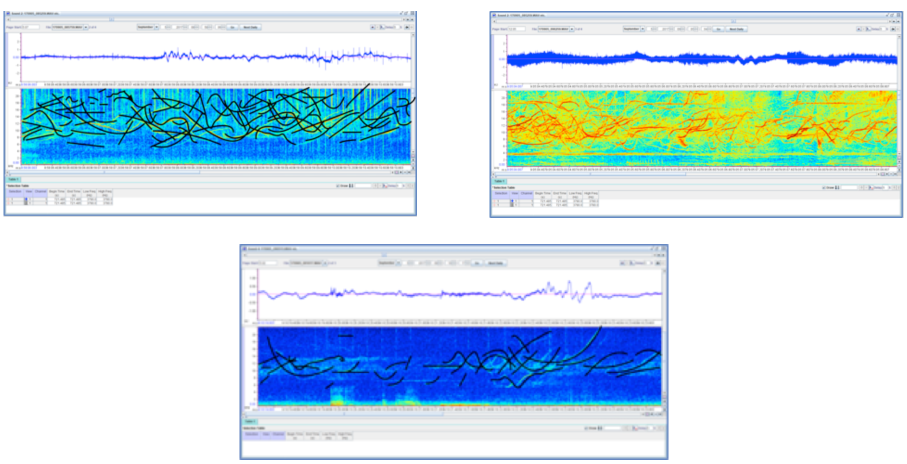
Results example: Long-beaked Common Dolphin Measurements of Individual Heading (UAS team)

* Rose histograms for sequential 25s intervals showing relative orientation of all individuals within focal sub-group for pre-exposure (left), exposure (middle – red), and post-exposure (right).



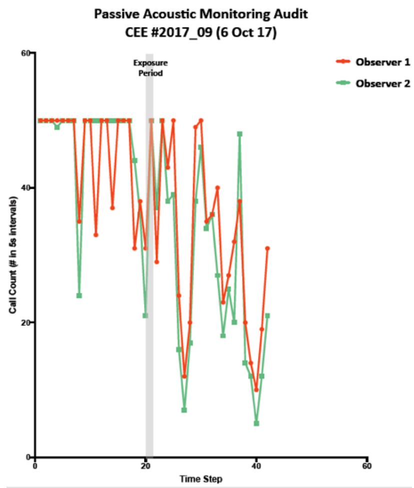
Results example: Long-beaked Common Dolphin Group Vocal Behavior Analysis (Passive acoustic team)

* Quantification of group vocal activity with whistle contour tracing for 5s samples randomly selected from sequential 30s windows during MFAS CEE before (top left), during (top right) and post-exposure (bottom).



Results example: Common Dolphin Group Vocal Behavior Analysis (Passive acoustic team)

* Quantification of group vocal activity (call counts) for 5s samples randomly selected from sequential 30s windows during MFAS CEE by two independent observers.



RESULTS: SUMMARY AND LESSONS LEARNED (SPRING):

Overall assessment (Spring)

- Field configurations and new smaller vessel platform as base of operations worked very well
- Abundant sightings of all three species in multiple areas of overall study region – site selection was very effective
- Weather conditions can definitely be limiting given the teams and tools being used. UAS operations were limited on many afternoons and one day altogether due to high winds. Shore visual teams were unable to work one entire day due to dense fog.
- The nature of this project is coastal and other vessels can potentially interfere with animals and influence animal behavior for short periods. This is manageable, but avoiding weekends and especially near 4 July would be advisable
- Many lessons learned on both PAM buoy and sound source deployments relative to animal tracks. Both are best ahead of but somewhat offset from the focal group track. We made major strides in learning how to do this for different focal groups.
- Because CEEs are short windows and only one will be conducted per day on each side of Catalina, patience and selectivity on when/how to conduct CEEs will be required to succeed.
- Common dolphins, especially in diffuse groups of hundreds, are the hardest to sample and observe responses; given their typically smaller group sizes and recognizable individuals, bottlenose and Risso's dolphins are somewhat easier

- Successful data collected for all four species – extensive baseline movement data and ten simulated CEE sequences
- Even short experimental periods generate large amounts of data. Smart and strategic analytical methods will be required in processing

Shore-based visual team (Spring)

- Effective in maintaining theodolite tracks and group behavior for full CEE sequences
- Worked well at multiple locations and were able to measure height and calibrate using RHIB tracks
  - Wrigley side excellent for sightings and conditions.
  - Indian Harbor also worked well; vessel ops may be more limited with swell/wind, but animals may stay in range and track longer given configuration of land.
- Able to track large groups and also use UAS octacopter as an anchor to mark focal subgroups.
- Fog and glare were occasional limiting factors

UAS team (Spring)

- Worked well with the boat and the crew for safe operations.
- Able to stay over the same subgroup of larger aggregations fior the duration of flights (>20 mins).
- Only did 24-26 min UAS sequences but confident can extend to 30+ mins with 4 battery configuration
- Some operations were limited by swell and wind conditions
- Some concern about interference to video downlink from various systems, including potentially adding transmitting AIS from Magician. We conducted an AIS test using Musculus which seemed promising in terms of not interfering with UAS operations and could let us have Magician more visible to RHIBs

Passive acoustics team (Spring)

- Successful deployments around and audited recordings of social sounds and clicks for all three focal species
- Least weather-dependent of all behavioral sampling methods
- For traveling animals, three buoys are required such that one can be primary in each CEE phase
- Deployments of drifting buoys requires strategic positioning to find the right balance of being near animals during CEE periods and avoiding any potential disturbance of groups in deploying them; should expect some real CEEs for which recorders are too far from focal group
- Analytical methods for auditing social call rates look promising for all species, including large groups, although this will be labor-intensive in analysis even with some automated methods

Biopsy sampling (Spring)

- Successfully obtained biopsy samples for all focal species. We met goals for sampling in common dolphins, but was much more challenging for Risso’s dolphins
- Subsequent efforts should focus on obtaining larger sample sizes in common/bottlenose dolphins

- Modifications of sampling approaches for common dolphins in gear and methods worked well
- Clear behavioral responses in both sampled animal and others in group observed. We have concerns about pre-CEE sampling within focal groups because of these responses. Some further discussion required, but exploring alternative ways to obtain baseline (no noise) samples with which to compare post-CEE samples other than direct sampling before CEEs.

Results/evaluation: LESSONS LEARNED (FALL):

Overall assessment (Fall)

- Successful monitoring of broad-scale and relatively fine-scale aspects of group behavior proven in spring field effort without CEEs was effectively adapted and transitioned to CEE design
- Overall vessel/team configuration for CEEs was effective. Retaining *Magician* as UAS platform with Musculus as sound source platform then transition to biopsy sampling worked well.
- West side Catalina options were more limiting in fall. Increased swell relative to front side was again experienced, but on several instances candidate groups were well off shore and out of range of Indian Head shore observation station
- Successful transition of visual observers for behavioral group focal follow sampling from *Magician* provides options for working in areas outside range of shore-stations. This gives up theodolite tracking, but can enable operations in areas out of range or novel locations (*e.g.*, off Avalon) to provide additional options. Theodolite tracking can be maintained from the shore based platforms to provide data the behavior of groups at larger distance from the CEE location.
- For 2018 field effort, recommend adding an end-of-day standard summary to post-hoc field meetings. This would include summary information across all teams to confirm timing, group and cluster size/ID, behavioral state during CEEs and other metadata. This has been compiled at the end of field phases, but a standardized, within-day synthesis is recommended. Several specific recommended changes to integrated CEE maps as well

CEE Methods (Fall)

- Application of CEE methods generally comparable to other BRS' was effective. Analyses are ongoing, but preliminary results suggest some strong responses with possible species and context dependency
- At-sea positioning and coordination with *Magician*-based chief scientist explicitly directing PAM buoy deployments from *Ziphid* and generally guiding *Musculus* who then determines it's own precise positioning relative to animals also worked well after some initial trials.
- Obviously need sound source for simulated MFAS that is more reliable than experienced in fall effort
- Need to continue evaluating options for CEEs in different areas and for within-areas over multiple days. This is an empirical question that will require more events than available at present. The ability to move to additional areas, including off the south of Catalina would be significant.

- Following fall field operations and based on many of the lessons-learned, our research team put together a decision matrix intended to guide subsequent CEEs based on contextual/environmental conditions. The below matrix is intended to provide an honest assessment of the kinds of conditions that are likely to result in succussful or unsuccesful implementation of the methods developed in this feasibility study for the species evaluated. Conditions in green are considered conducive to success, while those in red are unlikely to result in successful monitoring and CEEs.

species	Location	group size	behavioral state	conditions	group comp	visibility	proximity to vessels
Delphinus delphis	front	50-100	slow travel - rest - feeding	beau0-3	fluid groups		no vessels
	back	super group	fast travel	beau>3	mixed w/ Tt	glare- fog- haze	vessels near ***
Delphinus capensis	front	50-100	slow travel - rest - feeding	beau0-3	fluid groups		no vessels
	back	super group	fast travel	beau>3	mixed w/ Tt	glare- fog- haze	vessels near ***
Tursiops truncatus	front	10-20	slow travel - rest - feeding	beau0-3	alone		no vessels
	back	scattered sub-groups	deep feeding	beau>3 ***	mixed	glare- fog- haze	vessels near
Grampus griseus	front	any	slow travel - rest	beau0-3	promenade		no vessels
	back		deep feeding	beau>3 ***	mixed w/ Tt	glare- fog- haze	vessels near

Shore-based visual team (Fall)

- Field conditions (fog, glare) and distance of groups to shore was more limiting than spring effort. Several CEEs lacked shore-based sampling, but adaptations to put behavioral focal follow at-sea
- Ensure times marked when vessels first encounter groups (research vessels and mark incidentals)
- Tracking 2nd or 3rd group in addition to UAS focal group is important to provide a more comprehensive picture, but need to ensure that switches between groups is captured/accounted
- Obtaining as much baseline data on key parameters from tracks (location, speed, heading) is important for eventual comparisons within species baseline and within CEEs
- Key point is confirming behavioral state for primary focal group from UAS team data; Need concurrence on behavioral state during CEEs, which is best described from UAS observations

UAS team (Fall)

- Experienced team led decisions for safe and successful UAS operations in coordination with CEEs; several efforts were belayed due to marginal conditions but good, safe balance

- Addition of battery capacity resulted in 30+ min UAS sequences, covering all CEE phases
- Analyses have revealed that maintaining consistent UAS altitude within each flight is critical so the image footprint remains constant
- These CEEs have generated a tremendous amount of data on group behavior and behavioral response, by analyzing individual animal positions.
- Analysis is very intensive and beyond what was expected, but significant progress made
- Results yield clear graphical illustrations of animal position and clear responses in some cases (avoidance), but also quantitative metrics of speed, heading, spacing, and clustering.

Passive acoustics team (Fall)

- Positioning of buoys with *Ziphid* directed explicitly by chief sci on *Magician* was very successful and resulted in both better location relative to animals and less apparent disturbance to groups
- Recorders continued to be mostly effective and durable; additional integration of fine-scale GPS tracking using SPOT tracers on buoys; enables comparative spatial analysis of calibrated RLs at known points relative to modeled levels for mobile groups at known positions
- Improvements in color coding of recorders, buoys markers, sound cards, and SPOT trackers identified for 2018
- Audits of group vocalizations are challenging in some conditions, especially for large common dolphin groups with many overlapping vocalizations. Group vocal behavior over defined time periods is clearly the right analysis, but based on inter-individual reliability and difficulty in raw counts where many calls, categorical analyses with three observers are being conducted

Biopsy sampling (Fall)

- Successfully obtained biopsy samples during control periods (no MFAS) and during multiple MFAS CEEs at known/strategically selected time periods pos-CEE
- Visual observers from *Magician* and shore team can provide critical support to biopsy team in maintaining contact with known exposed groups and identifying other groups in area
- While analyses are ongoing, preliminary results show promise in identifying potential physiological signals from MFAS CEEs that should be discernable from potential sampling effects
- Initial analyses of all 2017 data should be complete prior to 2018 field effort and will be useful in guiding strategic post-CEE sampling times

IMPACT/APPLICATIONS

This project has successfully demonstrated the ability to monitor both broad-scale and relatively fine scale aspects of group behavior in several common delphinid cetaceans that have typically proven difficult or impossible to monitor with conventional tag sensors. There is particular interest in measuring behavior and behavioral responses of these species to military sonar systems, in part because they are commonly exposed in many Navy sonar operational areas and because due to their large numbers they comprise substantial proportions of estimated impacts (“takes”) of marine mammals from Navy training operations. Most previous assessments of sonar impacts in these species have come from anecdotal or uncontrolled observations rather than quantitative methods. The progress made in this feasibility study opens new doors to provide a more quantitative basis for the Navy to meet it's mandated environmental compliance requirements and more accurately estimate the environmental effects of operations for some of the most common species exposed to sonar operations.

The significant advancements, adaptations in approaches based on lessons-learned, and integration of methods and analyses made during this project has proven the concept of using multiple remote-sensing methods other than tag sensors. Given the highly social nature of these species and their typically large group sizes, we believe that such methods to quantify group behavior are in fact more relevant to understanding baseline and disturbed behavior in these species that would be the case even if tag technologies were available for these small delphinids. This two-year feasibility study is just a start in beginning to quantify behavioral responses to sonar in these species – subsequent efforts could be developed to measure responses to real MFAS sonar operations using these methods, and also inreasing the sample size of experimental and real exposures to evaluate context-specific responses.

RELATED PROJECTS

As noted above, this project involves a close collaboration among researchers from SEA, NOAA Fisheries Southwest Fisheries Science Center (SWFSC), Cascadia Research Collective (CRC), and Kelp Marine Research (KMR). The ONR grant referenced was issued to SEA and includes subcontracts to CRC and Kelp. Additional support for the project was provided under two separate ONR awards issued to SWFSC (PI: Dr. John Durban - N00014-18-IP-00021) and CRC (PI: John Calambokidis – N00014-17-1-2887). This annual report for the overall project is intended to serve as the annual report for each of these awards.

A separate ONR award to SWFSC (PI: Dr. Nick Kellar) to investigate potential physiological stress responses to noise was also coordinated with this project following discussions with the ONR Marine Mammal Program Manager. This project is entitled "Measuring stress hormone levels and reproductive rates in four dolphin species relative to mid-frequency active sonar exposure within the greater region of the SOAR range, San Clemente Island, California (Award number: N00014-17-IP-00068 (1400620596)). This study examines blubber hormone levels in free-ranging dolphins (Delphinus delphis, D. capensis, Tursiops truncatus, and Grampus griseus) in areas adjacent to the U.S. Navy's Southern California Anti-submarine warfare Range (SOAR) with the intent to integrate these physiological measurements with behavioral response information in efforts to evaluate the potential effects of sonar on cetaceans. Measurements of reproductive and corticosteroid hormones from a massive sample size (n = 1436) of previously collected biopsies combined with sampling associated with controlled known exposures is providing data to examine the relationships between the following factors: 1) exposure to mid-frequency active sonar (MFAS – a potential disturbance), 2) measures of physiological stress (potential link between disturbance and population effects), and 3) reproductive rates (the population consequence).

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