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Notes

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Acoustic observation of the reaction of rough-toothed dolphin (*Steno bredanensis*) to vocalizations, most likely from killer whales (*Orcinus orca*), off Kaua'i

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From 4 to 14 August 2017 researchers from Cascadia Research Collective undertook a field project off the western shore of Kaua'i.[2] This field exercise, like several others in recent years, was conducted in collaboration with engineers from the Marine Mammal Monitoring on Navy Ranges (M3R) program (Jarvis *et al.* 2014). The U.S. Navy's Pacific Missile Range Facility (PMRF) has a large array of 219 bottom-mounted hydrophones located off the west side of Kaua'i. This array of hydrophones allows for passive acoustic monitoring of marine mammals over an area of approximately 2,500 km^2. The M3R system at PMRF has the ability to automatically detect, classify and localize certain acoustically active animals and also allows trained operators to monitor the acoustic activity on each hydrophone individually *via* real-time spectrogram displays. The "wide-angle" view provided by simultaneously monitoring hundreds of sensors affords a unique perspective on animal vocal activity and movements across the range. During Cascadia's field exercise, M3R engineers relayed animal location and

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[2]Available at http://www.cascadiaresearch.org/hawaiian-cetacean-studies/August2017.

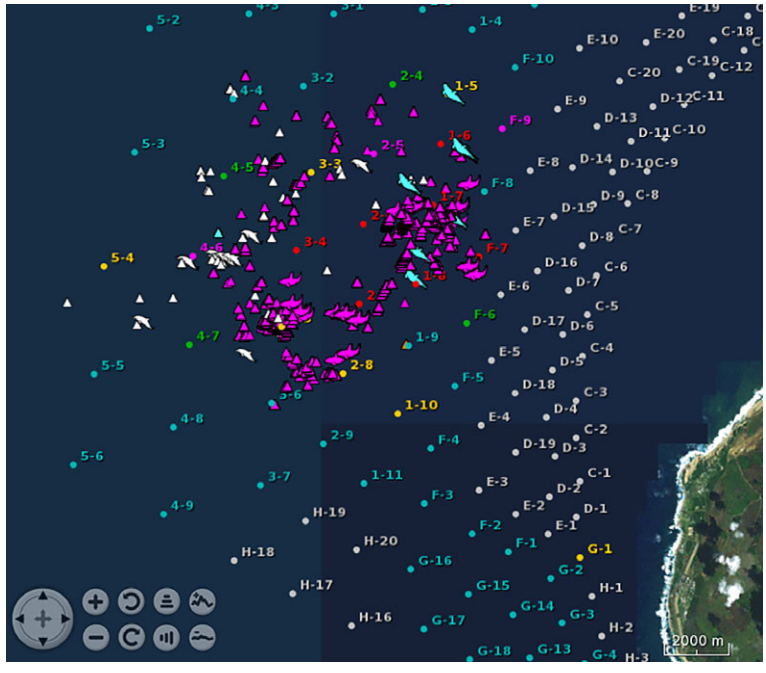

Figure 1. M3R display from 1829Z on 6 Aug 2017 shows a 25 min history of localizations from a dispersed group of rough-toothed dolphin (magenta icons) over the eastern PMRF range. The alphanumeric labels indicate the locations of range hydrophones. White icons are localizations from (unclassified) dolphin whistles and the cyan icons are localizations from dolphin clicks mislabeled as beaked whale by M3R's automated click classifier. This dispersed group covered approximately 9 km from north to south and 7 km from east to west. It is illustrative of the rough-toothed dolphin activity repeatedly observed both acoustically and visually, over the 4 d prior to presumed killer whale event.

species information to Cascadia researchers *via* radio in efforts to aid their on-water sighting of and encounters with species of interest.

7 August 2017 was the fourth day of effort for the researchers onboard the Cascadia RHIB as well as for the M3R engineers in the PMRF Range Operations Center. Like the three previous days, the most prevalent acoustic activity on the range hydrophones that morning was that of rough-toothed dolphin (*Steno bredanensis*). Every day of the effort thus far, M3R displays had shown a large area of dispersed groups of rough-toothed dolphins easily covering some 8–10 km north to south and 7–8 km east to west over the eastern PMRF hydrophones (Fig. 1). The Cascadia RHIB had encountered and worked with two of these subgroups, collecting identification photos. Although not a priority species for this particular field exercise, rough-toothed dolphins are the species most regularly sighted by Cascadia researchers on the PMRF range area.[3]

[3]Personal communication from R. W. Baird, Cascadia Research, 218 1/2 W 4th Avenue, Olympia, WA 98501, 19 June 2018.

Meanwhile the M3R detection and classification algorithms had recorded a near-constant cacophony of rough-toothed dolphin clicking on the nearby hydrophones.

At approximately 2129 Z (1129 HST) on 7 August, a high frequency down-sweep call was observed on an M3R spectrogram display (Fig. 2). The M3R operators recognized this call as being similar to the down-sweep calls seen in visually verified recordings of killer whales (*Orcinus orca*)

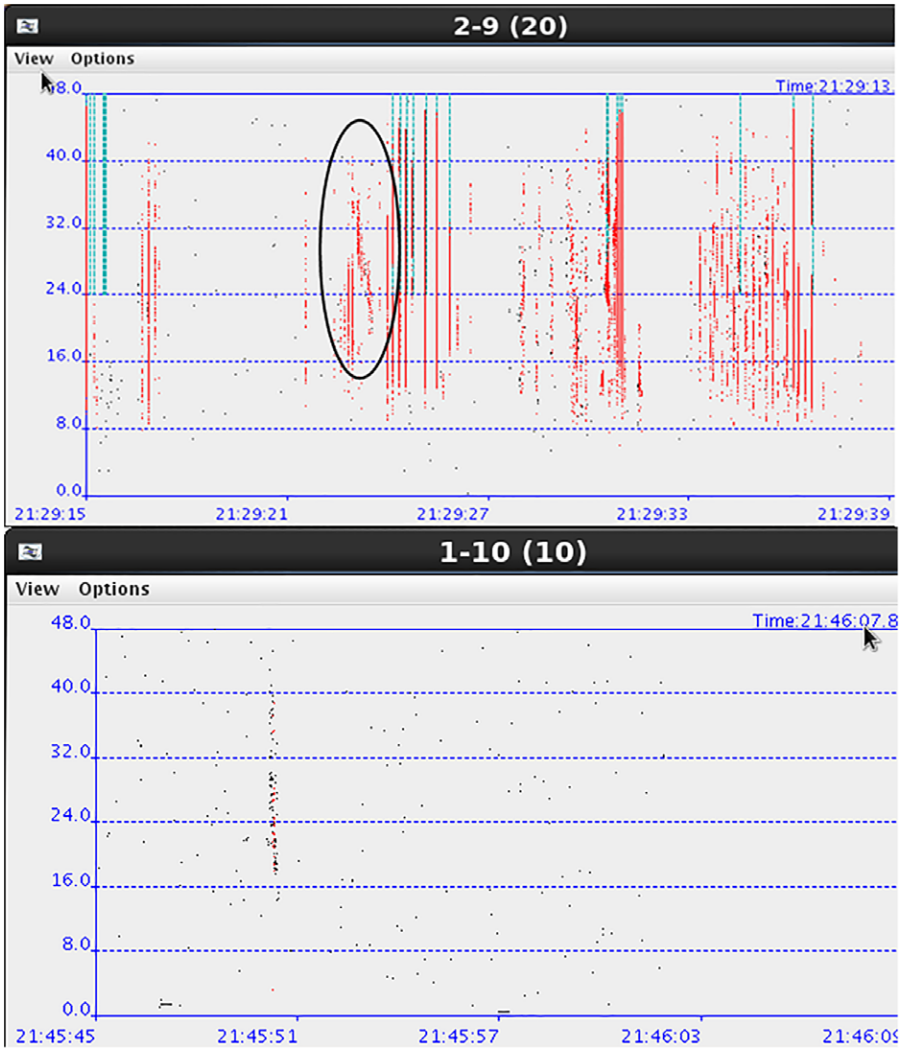

Figure 2. High frequency down-sweep calls thought to be from killer whale(s) as observed on M3R real-time spectrogram displays. (above) Circled is the call received on hydrophone 2-9 at 21:29:25 Z and (below) call received on hydrophone 1-10 at 21:45:51 Z. The vertical axis is frequency in kHz and the horizontal axis is time in HH:MM:SS.

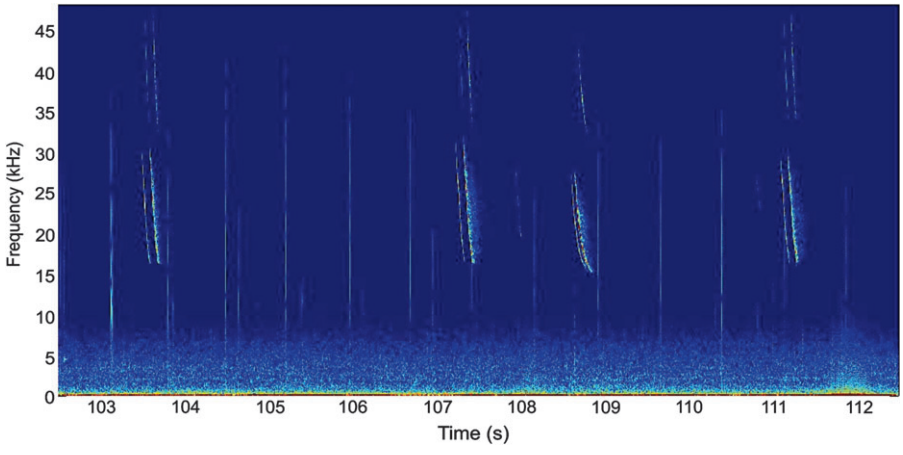

Figure 3. Spectrogram of down-sweep whistles and clicks from a visually verified recording of killer whales made by the author at the U.S. Navy's SCORE range off San Clemente Island, California, in January 2013. The down-sweeps extend from approximately 30 kHz down to approximately 16 kHz with first harmonics visible above 35 kHz. The clicks have peak energy below 20 kHz and an interclick interval (ICI) of approximately 0.7 seconds.

recorded off southern California at the U.S. Navy's Southern California Offshore Range (SCORE) in January 2013 (Fig. 3). The calls, which swept from above 32 kHz down to approximately 16 kHz, were also consistent with the ultrasonic down-sweep whistles from killer whales described in Filatova *et al.* (2012) and in Simonis *et al.* (2012). Almost immediately, the

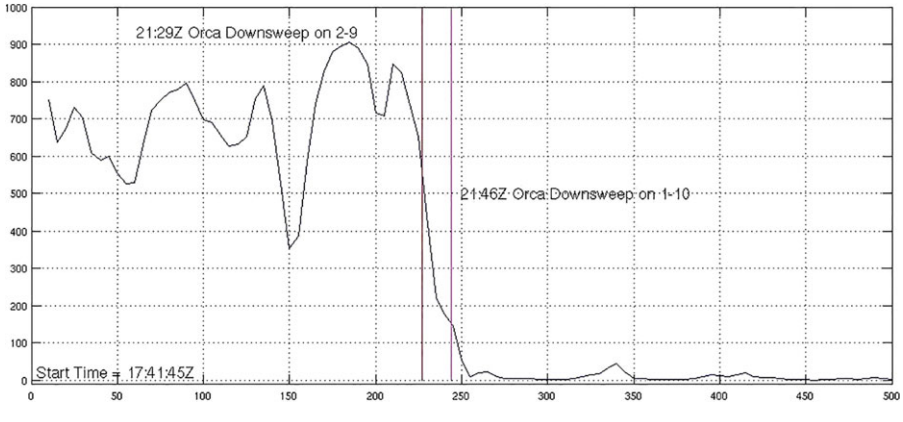

Figure 4. 7 August 2017 from 17:41:45 Z to 01:52:00 Z (07:41:45 to 15:52:00 HST). The total number of dolphin-class detections made by M3R's automated classifier per minute from hydrophones 1-8, 1-9, 1-10, 1-11, 2-7, 2-8, 2-9, 3-4, 3-5, 3-5, 3-7 *vs.* time (in minutes). Red and magenta lines indicate the approximate times that the presumed killer whale high frequency down-sweeps were observed on M3R spectrogram displays.

nearly incessant rough-toothed clicking stopped. This abrupt and severe reduction of acoustic activity is evident in Figure 4. Additionally, within minutes of the first call, the widely dispersed dolphin localizations became tightly clustered, spanning less than ~1 km across (Fig. 5). All the eastern PMRF range hydrophones remained quiet over the next 2.5 h. The Cascadia RHIB approached the area of hydrophone 2-9, where the first down-sweep call was heard, at approximately 1137 HST and found a group of five rough-toothed dolphins. This is consistent with the cluster of rough-toothed localizations shown in Figure 5. The research vessel remained in that area until 1149 but the killer whale calls could not be localized by M3R. Little direction could be offered to the RHIB in its search and no killer whales were sighted.

During the quiet period a few scans of what appeared to be killer whale clicks were seen on the hydrophones (Fig. 6). These clicks were consistent with the visually verified recordings of killer whales made at SCORE in January 2013 (Fig. 3) as well as the killer whale clicks described in Au *et al.* (2004). Killer whales have been sighted in these

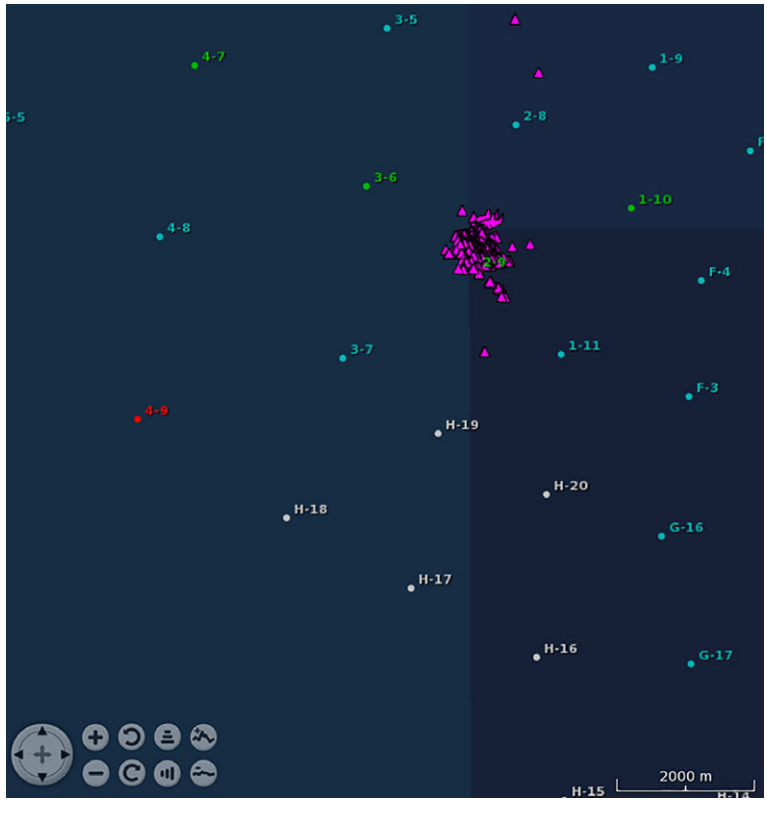

Figure 5. Localizations from M3R at 2147Z on 7 Aug 2017 approximately 18 min after presumed killer whale down-sweep was first observed. The localizations appear tightly clustered relative to previously dispersed distribution.

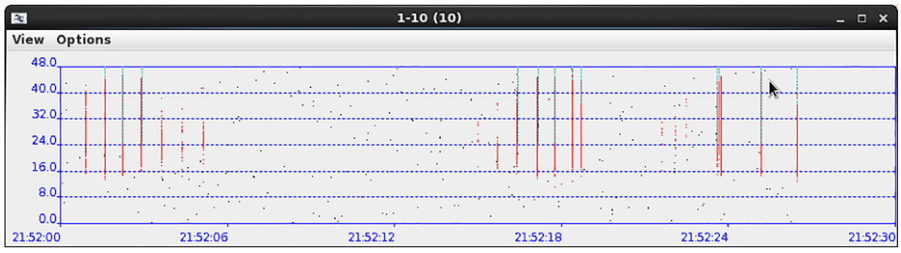

Figure 6. M3R spectrogram display of clicks presumed to be from a killer whale. The vertical axis is frequency in kHz and the horizontal axis is time, HH:MM:SS. ICI is approximately 0.7 s.

waters (Baird *et al.* 2006) and high frequency down-sweep calls similar to those in Figures 2 and 3 were observed on other PMRF hydrophones 2 d later. It is evident that these rough-toothed dolphins responded very suddenly and very strongly to something. Their apparent response of going quiet, closing ranks, and fleeing the area, all of which we observed acoustically, is consistent with reactions seen during other, visually observed dolphin/killer whale encounters (Baird 2016).

By simultaneously monitoring a large number of sensors, M3R was able to provide a macro view of cause and effect for this encounter that would likely not have been evident from monitoring a single hydrophone or smaller sensor field. This wide-area view provided by M3R has also been used in efforts to assess of response of certain marine mammals to mid-frequency active sonar (Martin and Martin 2015, McCarthy *et al.* 2011, Tyack *et al.* 2011). However, as noted by Tyack *et al.* (2011), some animals can exhibit a predator-avoidance response as profound as a sonar-avoidance response. While observing this acoustic encounter was interesting on its own, being able to recognize a predator-avoidance response through passive acoustic monitoring is also important for interpreting PAM studies of marine mammal responses to sonar and other anthropogenic disturbance.

Acknowledgments

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