First acoustic documentation of non-traditional Arctic species in the Bering and Chukchi Seas

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First acoustic documentation of non-traditional Arctic species in the Bering and Chukchi Seas

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Warming in the Arctic region is three times the rate of the global average with summer sea ice declining 11.5% per decade since 1979 (Comiso & Hall 2014). This drives ice-obligate and ice-associated marine mammal species northward and opens space for temperate species to also shift poleward. Larger and more rapid shifts are to be expected, especially if the Arctic is predicted to be ice free in the summers by the 2030s (Kwok et al. 2009, Wang & Overland 2012). Previous research shows several traditionally Arctic marine mammal species (bowhead, gray, and beluga whales; and bearded and ribbon seals) adjust their distributions, mating, and migrating behaviors concurrently with ice cover changes, such as ice retreating midwinter compared to being continuously present (Grebmeier & Dutton 2000; Miksis-Olds et al. 2013; Miksis-Olds & Madden 2014; Hauser et al. 2016). Passive acoustic monitoring (PAM) was key in these studies.

Until recently, PAM was constrained by power capacity and storage-limited sampling rates (typically up to 44.1 kHz), leading to intermittent Arctic acoustical studies of only species that vocalize below 22 kHz. For any species that vocalizes higher than 22 kHz, distribution and presence/absence studies have been limited to visual surveys, stranding data, and whaling records. The technology in Passive Acoustic Listeners (PALs) has expanded recording possibilities to higher sampling rates (100 kHz) with year-round duty cycling for power saving capabilities in cold waters (Nystuen 1998). The first high-frequency acoustic dataset from the Arctic Ocean is now a decade long and has been manually analyzed. Some high frequency vocalizations of non-traditionally Arctic species have been found in this dataset. While not prolific, these samples suggest the possibility that temperate species have begun moving poleward, and visual survey efforts in the future should consider watching for these particular species to validate and refine the acoustic observations presented here.

PALs were deployed as part of larger vertical mooring assemblages by NOAA's EcoFOCI program in the Bering and Chukchi Seas at four locations for parts of all years between Sept 2007 to Sept 2017 (Table 1). Mooring labels and locations were: M2 at 56°52.202' N, 164°03.935' W; M5 at 59°54.646' N, 171°43.854' W; M8 at 62°11.62' N, 174°40.06' W; and CH at 67°54.671' N, 168°11.695'

W. The first three were in the Bering Sea; the fourth was in the Chukchi Sea. All sites were on a continintental shelf about 70 m deep, and the sensors were suspended approximately 10 m above the ocean floor.

Table 1: Available Data – a timeline of PALs deployed at four sites in the Bering and Chukchi Seas. "X" denotes data available for at least part of the year.

Site	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
M2		x	x	x	x	x	x			x	x
M5	x	x	x	x	x	x	x	x	x	x	x
M8						x	x				
CH										x	x

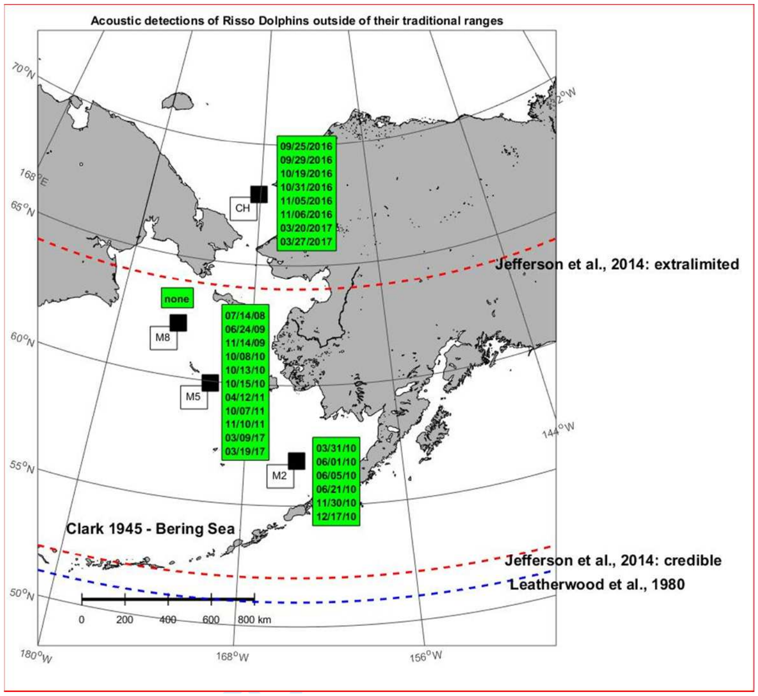
The PALs sampled at 100 kHz using a low-noise HTI-96-MIN hydrophone and recorded 4.5 second .wav files when the internal algorithm detected a target signal. As a result, up to 21 files were recorded daily, and many contained clicks, buzzes, and whistles of several odontocete species. Most of these clicks and buzzes were from sperm whales, beluga whales, killer whales, and/or too faint to be classified as anything but an unidentifiable odontocete. Some, however, had peak and notch patterns resembling those produced by Risso's dolphins and Pacific white-sided dolphins as reported by Soldevilla et al. (2008) and Northern right whale dolphins similar to those from Rankin et al (2007). Acousticians with experience detecting and classifying such species using a variety of recording instruments were contacted for guidance (pers comms A. Bowles, S. Coates, E. Griffiths, E. Henderson, M. Lammers, B. Martin, and M. Soldevilla)[i]. Detections of these species are particularly interesting given the historical knowledge of their temperate-only distributions.

Risso's dolphins have only been visually reported north of the 51^{st} parallel once (Clark 1945), resulting in Leatherwood et al. (1980) reporting this sighting as spurious. The Leatherwood et al. (1980) Risso's dolphin study performed visual surveys from May through September on ships of opportunity with the fur seal research program through NMFS and identified a reasonable northern species limit at the 52^{nd} parallel. These months align with information in the gray literature that any Risso's dolphins sighting north of the 42^{nd} parallel occurred between March and October during warm-water intrusions (Brueggeman 1989). Jefferson et al. (2014) followed with the most comprehensive study of sighting and capture records starting with 1939 observations made by Vibe (1950) through 2012. They noted six single-animal sightings between the 52^{nd} and 64^{th} parallels worldwide but considered those "extralimited" and concluded that "research in [the Bering Sea] has been extensive and only a handful of records have been documented…there is no evidence that [Risso's dolphins] reach as far North as the Aleutian Islands or extend into the Bering Sea."

It is notable that the Jefferson et al. (2014) study concluded with records from 2012 when a cold climatic regime in the Bering Sea that started in 2009 shifted to a warm climatic regime (Stauffer et al. 2015). These four cold climate years from 2009-2012, and particularly 2012, saw more expansive and thicker ice that retreated later, stratifying the water column earlier and more tightly coupling the biomass of primary production with hydrographic conditions (Stauffer et al. 2015). During cold climate years, fisheries are controlled by bottom-up mechanisms and biomass is transported to benthic instead of pelagic fishery populations (Stauffer et al. 2015). These shifts increase the availability of food for many marine mammal species.

Also in 2012, but on a much larger geographic scale, the Pacific Decadal Oscillation (PDO) shifted from a six-year negative phase to a strong positive phase. In fact, 2008 and 2012 marked the most negative PDO values recorded in the previous six decades (Mantua et al. 1997). Usually, a negative PDO brings slight warm water anomalies (0.0 degrees C in the East to +0.2 degrees C in the West) to the Bering Sea, but the regional cold and warm climatic regimes are more influential than these slight PDO anomalies. Because the three species discussed in this note traditionally inhabit waters south of the Aleutian Archipelago where the PDO is the dominant driver as compared to the Bering Sea climate regimes farther north, it is relevant to highlight that a negative PDO produces relatively large warm water anomalies (up to +0.8 degrees C) in the western Gulf of Alaska and most of the Northern Pacific. While the Bering Sea was in a cold climatic regime from 2009-2012, the PDO was in a negative (warm water in the Gulf of Alaska / North Pacific) phase from 2006 to 2012. With warmer waters expanding the inhabitable temperature range northward because of a negative phase PDO, and a cold regime in the Bering Sea providing more food, the two processes are likely working in tandem to grant non-traditional Arctic species more access into the Arctic corridor.

During the cold water regime in the Bering Sea prior the 2012 shift, Risso's dolphins were acoustically detected at M2 six times in the summer and fall of 2010, and a few times per year (usually in the fall) at M5 from 2008 to 2011. They were not detected again until 2017 (Fig. 1) following the 2014 to 2016 warm climate regime that began attenuating after a warm peak in 2015 (Duffy-Anderson et al. 2017). In fact, nearly all of the clicks and buzzes from non-traditional Arctic species occurred in the PAL datasets from 2008-2012, then abruptly disappeared, only to return in 2017 again as the PDO also eased out of its strong positive phase. In the Chukchi, which did not have high-frequency acoustic data collection until 2016, Risso's dolphins were detected six days in the fall of 2016 and twice in late March of 2017.



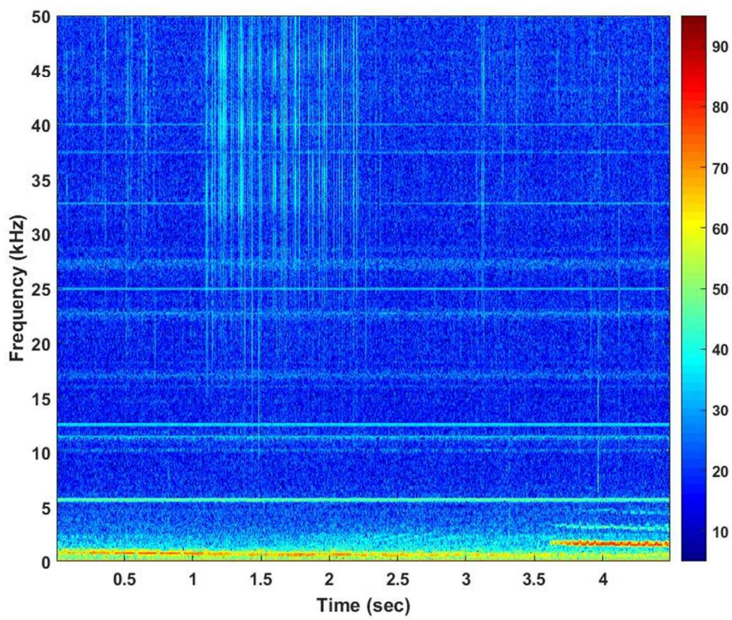
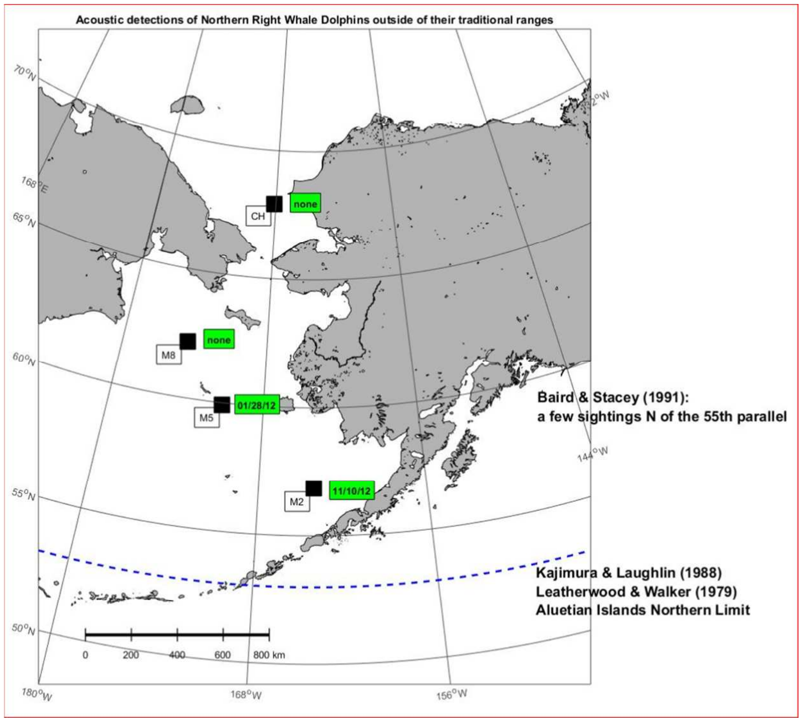


Figure 1: (top) Map of acoustic detections attributed to Risso's dolphins at sites M2, M5 and CH with dotted lines denoting historical range extents. (bottom) A spectrogram from March 31, 2010 at M2 of clicks attributed to Risso's dolphins because peaks and notches are centered near the expected frequencies reported in Soldevilla et al (2008).

The Northern right whale dolphin (*Lissodelphis borealis*) is a cool-temperate species that prefers water temperatures between 7.8 – 18.9 degrees C (Leatherwood & Walker 1979; Forney & Barlow 1998).

In the most recent review of their distribution by Baird & Stacey (1991), the authors considered visual sighting records until 1988. They concluded that aside from a few sightings in the Gulf of Alaska North of the 55th parallel, and one in the Central Aleutian Islands (Kajimura & Loughlin 1988), that British Colombian waters are the outermost limits of the species' normal distribution and "the large number of records in recent years [off British Colombia] either indicates an unusual extension into northern waters, or … reflects increases in sighting effort." This may still be largely true because only two acoustic detections (one each at M2 and M5) in the PAL datasets could be Northern right whale dolphins (Fig. 2). Again, these occurred in 2012 near the end of a cold regime in the Bering Sea that coincided with a turn from a negative PDO phase.



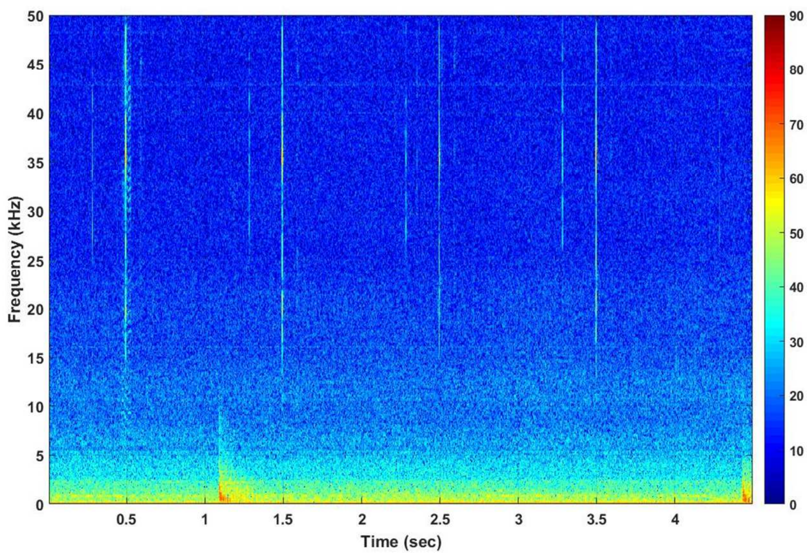
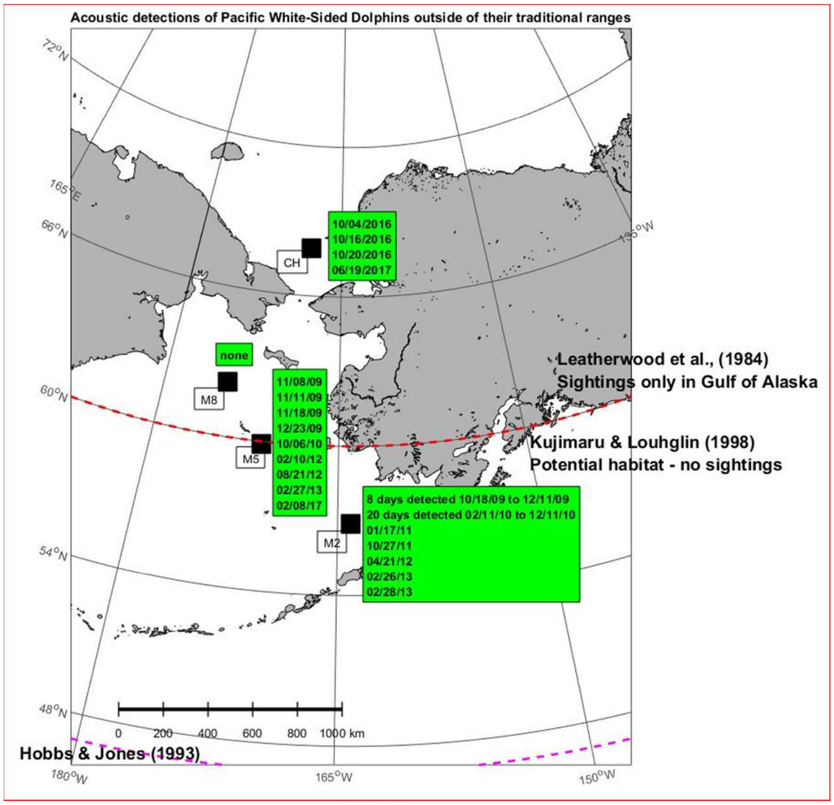


Figure 2: (top) Map of the acoustic detections attributed to Northern right whale dolphins at sites M2 and M5 with dotted lines denoting historical range extents. (bottom) A spectrogram from November 10, 2010 at M2 of a downsweeping, richly harmonic click/buzz at 0.5 seconds with is characteristic of Northern right whale dolphins (despite being masked by the ping of another instrument on the mooring).

The Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) is another temperate water species that has been sighted more often up to the 61st parallel (the northern-most point) in the Gulf of Alaska (Leatherwood et al. 1984). Although the Leatherwood et al (1984) study did not enter the Bering Sea, they assert that white-sided dolphins usually do not go beyond the Aleutian Islands, while Kajimura & Loughlin (1988) state there are a few records from the Southern portion of the Bering Sea. Other studies point out that warming waters throughout the Pacific are shifting white-sided dolphin distributions elsewhere. Dahlheim & Towell (1994) found an increase in their presence in near-shore waters of Southeast Alaska and suggested warmer-than-average sea surface temperatures as the driving force. Similarly, Salvadeo et al. (2010) found that the white-sided dolphin southern range limit in the Gulf of California is moving poleward away from warming tropical-like water temperatures.

In the PAL datasets, Pacific white-sided dolphins were the most commonly detected of the non-traditional Arctic species (Fig. 3). At M2, they were detected for eight days in the fall of 2009, twenty days throughout 2010, and once or twice annually until 2013. At M5, they were detected a few times a year between 2009 until February 2013, then disappeared until a single occurrence in early 2017. In the Chukchi, four days contained detections of Pacific white-sided dolphins: three in October 2016, and one in mid-June of 2017.



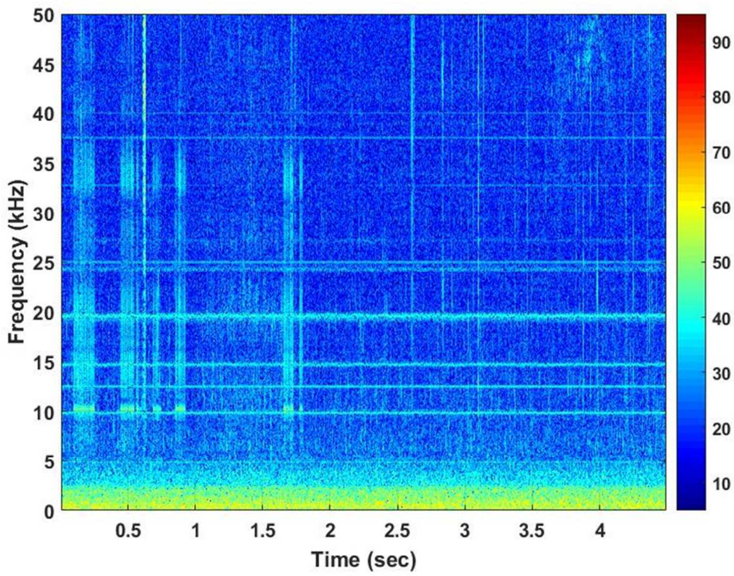


Figure 3: (top) Map of acoustic detections attributed to Pacific white-sided dolphins at M2, M5 and CH with dotted lines denoting historical range extents. (bottom) A spectrogram of buzzes with peaks and notches as expected for Pacific white-sided dolphins according to Soldevilla et al (2008).

Relying on visual surveys for tracking distribution changes in Arctic species is difficult because ships cannot sail during inclement weather as ice moves in and out. Therefore, passive acoustic surveys are vital for filling in the blanks about animal presence when visual surveys cannot be conducted. Because of technological limitations, passive acoustic monitoring studies in the Arctic Ocean with a high enough sampling rate to detect the echolocation signals of non-traditionally Arctic species have been limited. With PALs, though, that has changed. This high-frequency-sampling acoustic study over the last decade suggests that Pacific white-sided dolphins, Risso's dolphins, and Northern right whale dolphins (in order of extremity) are shifting into Arctic waters during years of significant warm water invasion from the Gulf of Alaska and cold regimes in the Bering Sea. Visual and acoustic surveyors in the coming years should take extra effort to verify and refine these habitat shifts.

Acknowledgements

Thank you to the NOAA personnel who have deployed, recovered, and transported the PALs for nearly a decade. Without their efforts, this dataset would not exist. We are also incredibly grateful for the advice from colleagues who specialize in high-frequency-vocalizing species for their guidance on identifying clicks, buzzes, trains, creaks, etc. Work supported by the Office of Naval Research on award number N000140810391.

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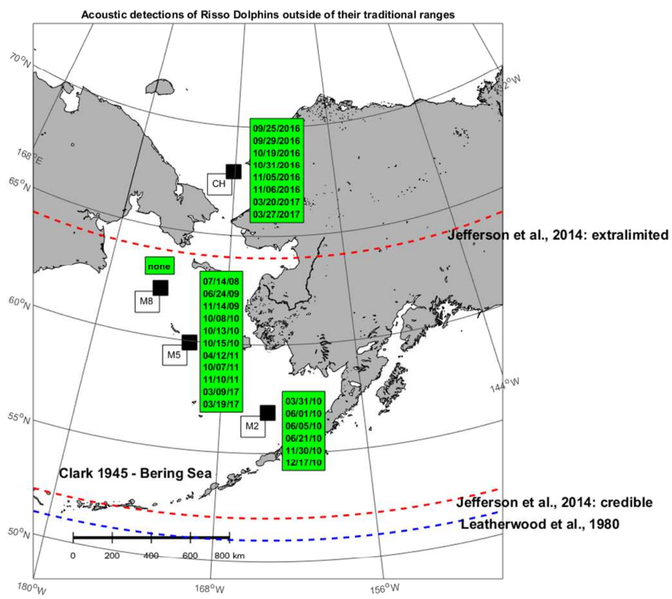

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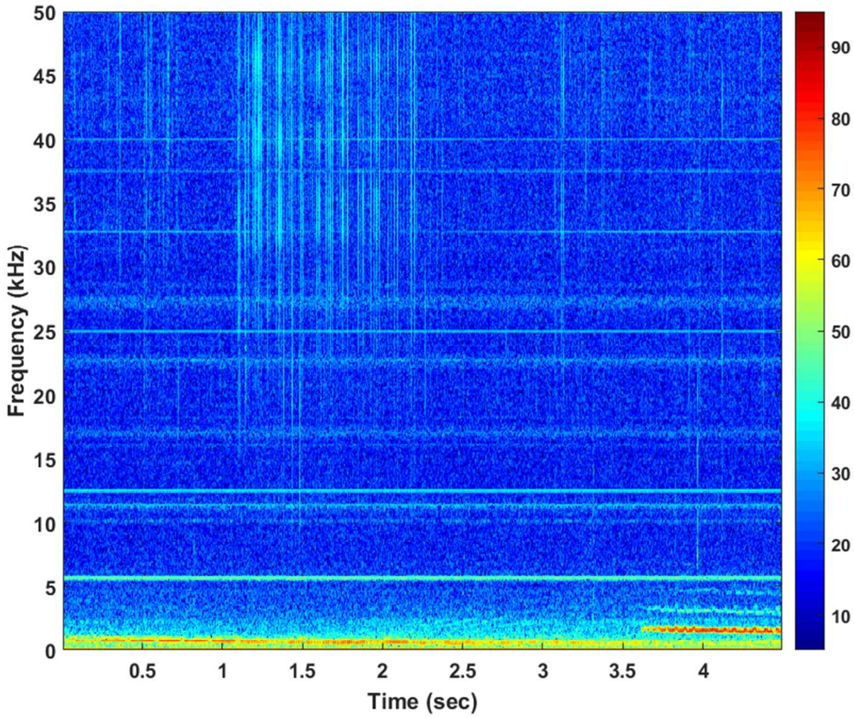

Figure 1: (bottom) A spectrogram from March 31, 2010 at M2 of clicks attributed to Risso's dolphins because peaks and notches are centered near the expected frequencies reported in Soldevilla et al (2008).

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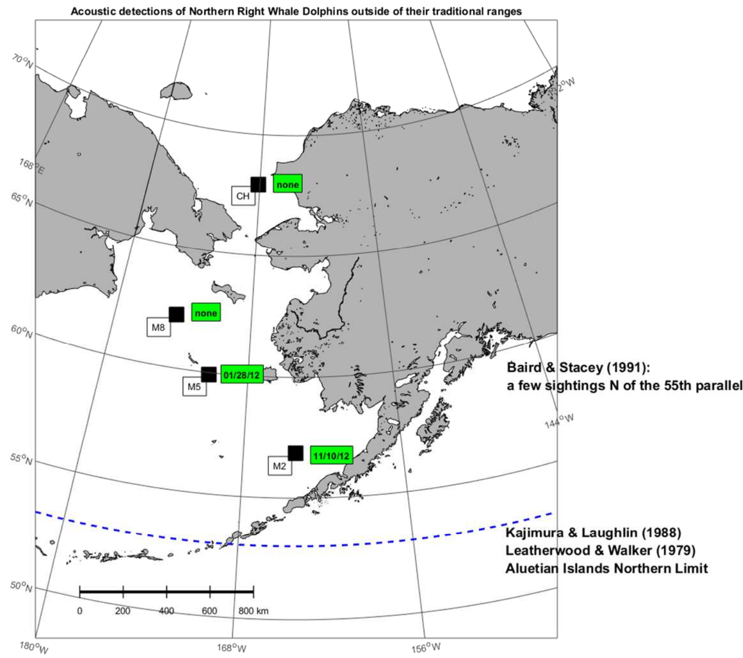

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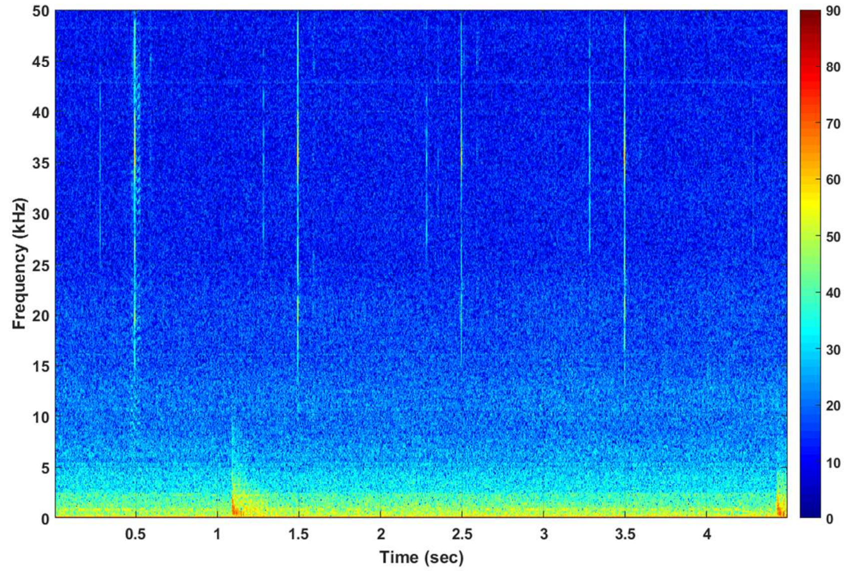

Figure 2: (bottom) A spectrogram from November 10, 2010 at M2 of a downsweeping, richly harmonic click/buzz at 0.5 seconds with is characteristic of Northern right whale dolphins (despite being masked by the ping of another instrument on the mooring).

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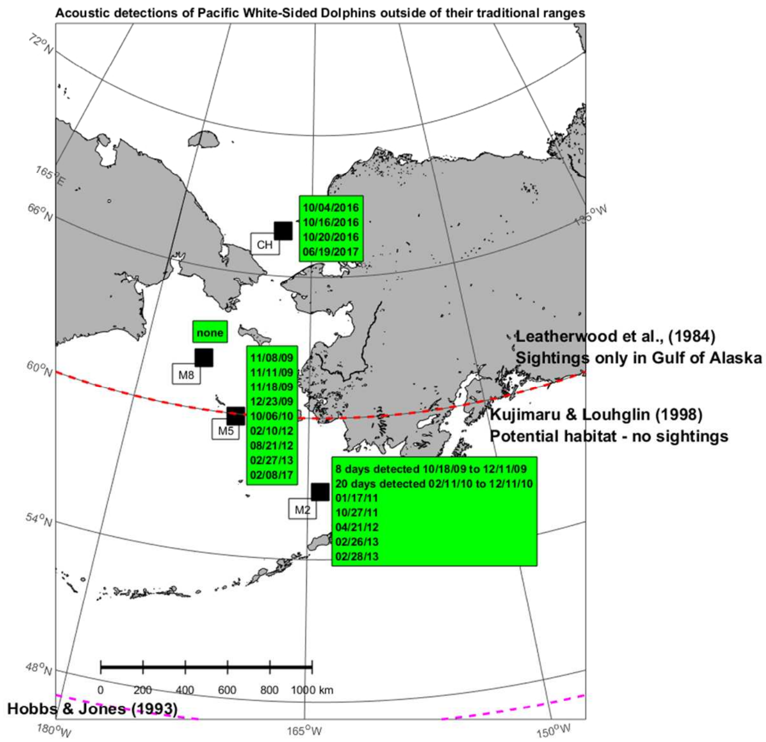

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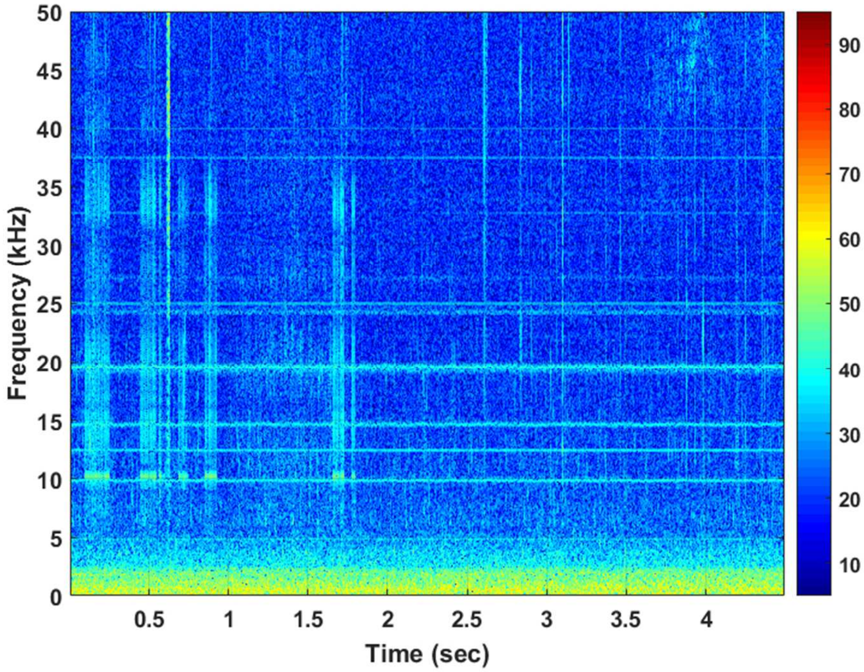

Figure 3: (bottom) A spectrogram of buzzes with peaks and notches as expected for Pacific white-sided dolphins according to Soldevilla et al (2008).

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