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Further evidence of humpback whale presence in deep tropical ocean during the breeding season: confirmation and extension of acoustic detections between Hawaii and Mexico

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During winter humpback whales converge on tropical breeding grounds characterized by shallow, warm seas. In the eastern half of the North Pacific two such breeding grounds are located along the shorelines and shallows of Mexico, and in mid-ocean around Hawaii, separated by 4,500-6,000 km of deep ocean basin. A 2018 acoustic survey by an autonomous Wave Glider from Hawaii eastward towards Mexico, at breeding ground latitudes (circa 20°N) and during peak breeding season, discovered singing whales *between* these locations near continuously out to mid-ocean - the first evidence of this latitudinal, tropical deep-water distribution. We report the results from a 2021 study which replicated the first half of the 2018 route and extended the survey to Isla Clarión, the westernmost breeding ground of Mexico. The portion of the 2021 survey replicating the earlier course resulted in markedly similar, near-continual detection of humpback whales from Hawaii out 2,161 km (over 1,000 nm) to mid-ocean. Detections occurred on 29 of the first 37 days eastbound from South Point Hawaii (vs. 30 of 35 days in 2018), with up to 3,000 calls a day, including multiple simultaneous singers. The 2021 extension (non-replicative portion) from mid-ocean eastward produced intermittent detections to Isla Clarión. The results, combined with recent reports of photo-identified individuals which traveled between Mexico and Hawaii in one winter season, indicate a recurring tropical offshore presence between these traditional breeding grounds - its extent and purpose to be determined.

KEYWORDS

humpback whale, *Megaptera novaeangliae*, song, autonomous acoustic survey, wave glider, tropical deep ocean, Hawaii, Mexico

Introduction

During winter humpback whales migrate to tropical breeding grounds characterized by shallow seas and warm sea temperatures (e.g., Rasmussen et al., 2007). In the eastern half of the North Pacific these include the shorelines and shallows of Mexico and Hawaii (Rice, 1978; Urbán and Aguayo, 1987; Calambokidis et al.,2008). Satellite tags, while limited in number relative to the overall population, indicate that the migratory routes between high latitude feeding grounds and these low latitude breeding grounds follow a roughly straight line from departure to destination (Mate et al., 1998; Mate et al., 2007; Lagerquist et al., 2008; Mate et al., 2020). That is, whales migrate from feeding grounds around the North Pacific Rim directly to breeding grounds such as Hawaii or Mexico (or vice versa) – regions separated by 4,500-6,000 km of deep ocean basin.

A 2018 underwater acoustic survey detected humpback whales in this deep ocean basin *between* these Mexico and Hawaii locations. This was the first leg of the Humpback Pacific Survey (HUMPACS) by autonomous Wave Glider (WG) Europa in January and February 2018 (Darling et al., 2019b). In this survey, humpback whale calls were heard eastward of Hawaii (at circa 20°N) for 2,184 km (1,179 nm) into the mid-tropical northeast Pacific and were recorded on 30 of the 35 days it took the WG to reach this mid-ocean point. While the purpose of HUMPACS program was to explore the winter tropical distribution of humpback whales beyond the known assemblies – discovering this degree of offshore presence well into mid-ocean at this latitude was unexpected.

This being the first such survey on this route in this season, there was no available context for these findings. Proposed explanations included: 1) that it was an anomaly; 2) that whales were following a previously undocumented migratory route traveling directly south until reaching a suitable temperature band and then making a dogleg east or west on a course to the known Hawaii or Mexico areas; 3) that this was an offshore breeding assembly without the shallow water habitat requirement; or 4) that whales may be travelling between these shallow breeding areas within one winter, as was suggested by a report of a whale that travelled between Mexico and Hawaii in 1986 (Forestell and Urbán, 2007).

Humpback whale presence in deep tropical ocean became more curious during the second leg of the HUMPACS study in 2019, a mirror image of the 2018 survey with its course set westward from Hawaii (rather than eastward) towards the western Pacific breeding areas. Again, humpback whale songs were detected in deep ocean 1,728 to 1,974 km (about 1,000 nm), west of Hawaii (Darling et al., 2020) While the same four explanations may apply in the western tropical North Pacific – unlike in the northeast Pacific, there are shallow water destinations (potential breeding habitat) at mid-ocean islands, atolls, and sea mounts although use of these have not, or rarely been, documented (Pitman and Darling, 2022).

This 2021 acoustic survey expanded on the initial 2018 survey from Hawaii towards Mexico – with the route now running the full distance from the breeding assembly in Hawaii to the westernmost Mexico assembly at Isla Clarión in the Revillagigedo archipelago (Urbán and Aguayo, 1987). The objective was to further explore humpback whale presence in deep tropical ocean and appraise the four explanations posed in the initial survey.

Methods

This was the fourth survey in the North Pacific using the autonomous Wave Glider (WG) Europa for purpose of detecting humpback whales through passive listening for their song. Detailed descriptions of the Wave Glider, its instrumentation, and survey methodology are provided in earlier publications (Goodoni et al, 2018; Darling et al., 2019b; Darling et al., 2020; Lammers et al., 2023). Its components and propulsion system are demonstrated at www.liquid-robotics.com/wave-glider/how-it-works/ (Liquid Robotics, Inc, 2018).

An Ocean Sonics icListen SB2-Ethernet digital hydrophone was used in all of the four surveys (sampling rate range from 1 kHz to 512 kHz; frequency response 10Hz to 100 kHz +/-3dB; sensitivity of -171dBV re: 1 uPa). Recording (sampling rate of 32 kHz, 24-bit depth) was designed to be continual 24/7, in one-minute.WAV files stored in two separate 4 TB SSDs to ensure backup. However, in this mission archiving challenges arose as described below.

A question raised during all previous surveys is whether the location of the WG, receiving the sounds, is an accurate measure of the location of the singers. As stated in earlier papers (e.g., Darling et al., 2019a), the position of the WG did represent the approximate location of the calling whales with calculations "indicating detectable distance could range from 5.5–126 km (3-68 nm), the latter high distance only if acoustic propagation conditions supported a first or second convergence zone."

The only significant technical change over each of the four surveys was an increased separation and buffering of the recorder from mechanical components (float surface noise, rudder and wing assemblies, movements, and water flow), which led to decreasing self-noise from one survey to the next. By 2021, the need to filter out rudder noise was eliminated, which substantially improved the quality of recordings.

Survey route

The survey ran from Hawaii, the central Pacific humpback whale breeding ground, along the near-19°N latitude line until it reached Isla Clarión, Mexico, the westernmost location of the eastern Pacific humpback whale breeding ground, as shown in Figure 1. This choice of route was based on: 1) results of the initial 2018 survey; 2) objective of a full survey between the known winter grounds, and 3) generally, because the circa 20°N latitude band runs through humpback winter assemblies in Hawaii and Mexico (and most worldwide). Details are provided in Figure 1; Table 1, and Supplemental Figure 1.

Mid-survey modification of recording protocols

Recording and logging of data was continual 24/7 until a malfunction in the archiving of data from hydrophone to hard drives occurred on 26 January, 42 days, and 2,160 km into the mission. The problem was discovered during a routine download test

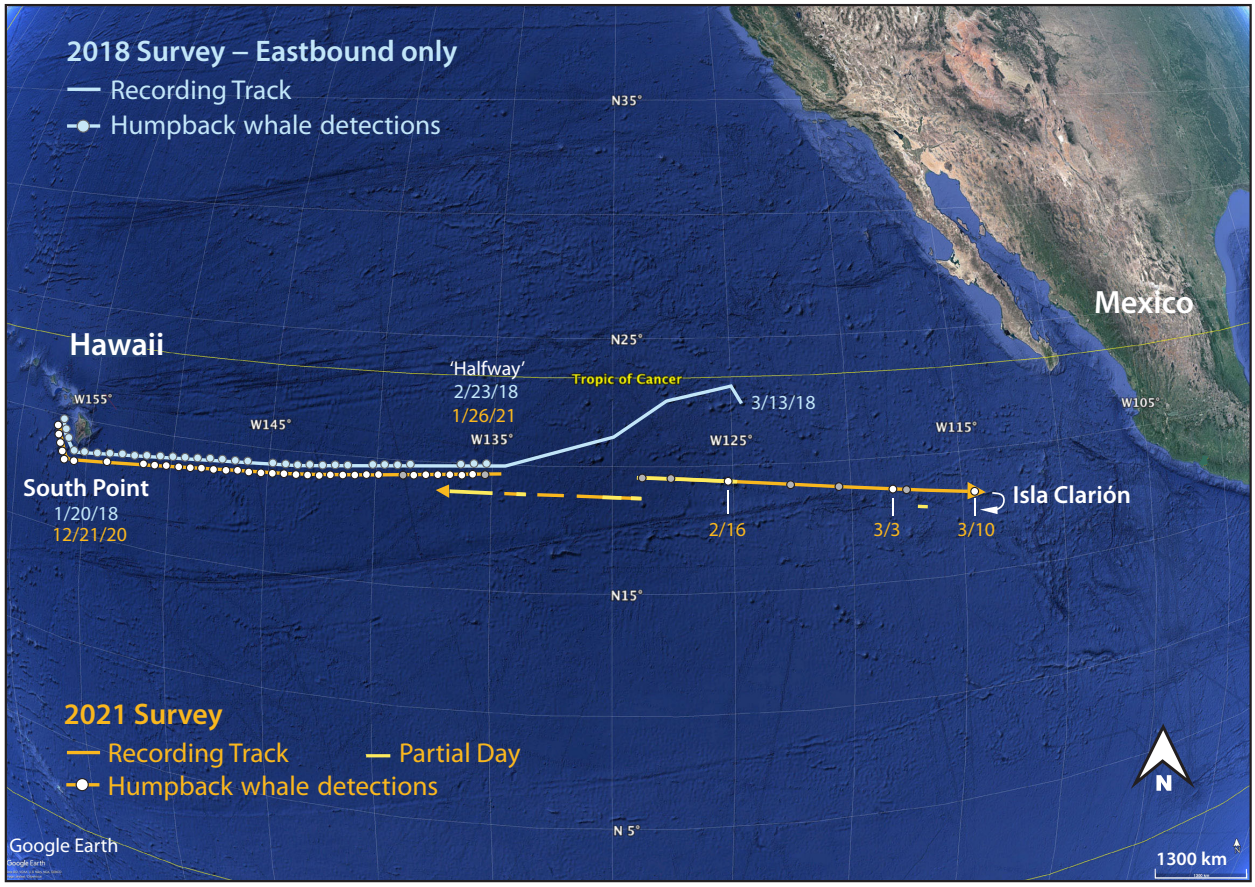

FIGURE 1
The 2021 (orange) and 2018 (blue) acoustic surveys, including tracks, benchmarks, and the location of humpback whale detections. The 2018 data is excerpted from Darling et al., 2019b; only the 2018 eastbound course is included. Where the 2018 and 2021 courses overlap significantly, they are illustrated in parallel on the map for clarity. The 'Halfway' designation is approximate, 2161 km from Hawaii, 2141 km to Clarión. The dots indicate days humpback whales were detected; the gray dots on the 2021 track indicate probable humpback detections.

via satellite that same day when only 1 hr 39 min of the 24-hour recording period was available. This led to two conditions which would impact the sampling for the remainder of the survey: 1) a 16-day period of no recording between 26 January to 10 February (from 19°C 32′ N, 135°C 51′ W to 19°C 8′ N, 127°C 42′ W) in the central NE Pacific basin, as troubleshooting and solutions were employed. On 11 February, recording started again, but was limited to 5–9 hours per day through to 16 February as reconfiguration continued. By 17 February (19°C N, 125°C 20′ W) recording returned to the near 24-hours-a-day until 10 March and the survey destination of Isla Clarión; 2) The system was reconfigured remotely to store recordings on the hydrophone directly rather than transfer them to the WG hard drives. Consequently, storage space on the hydrophone hard drive was limited to 30 days of recording from reconfiguration (with an estimated 85+ days then remaining in mission, including return). A decision was made to continue recording 24/7 on the eastbound course to Isla Clarión and then reduce recording times on the return trip, focusing on the region 'missed' on the outgoing route. (See Figure 1 and Supplemental Figure 1).

Analysis

All recordings were analyzed manually using Raven Pro 1.6. The audio files were filtered using a low-pass Chebyshev Type I Infinite Impulse Response (IIR) filter of order 8.

Spectrographs of the combined 1-minute files for each 24 hours were screened day-by-day; when any sounds were portrayed, each was listened to, selected for, and categorized.

All acoustic detections were logged. In addition to humpback whales, these included other readily identifiable cetaceans such as minke and sperm whales, a general category of odontocetes defined by odontocete-like whistles, calls, and echolocation clicks, and a category of unidentified cetaceans – where the signal was clearly a cetacean, but quantity/quality was not high enough to specify further. Other sounds recorded included WG mechanical sounds, passing ships, and a substantial number of unknowns.

Three screeners, two (BG and JDD) with decades of experience with humpback songs, including on the previous three WG missions, listened to and categorized potential humpback whale

TABLE 1 Survey benchmarks: Hawaii (South Point) to Mexico (Isla Clarión) and Return.

Totals	
Survey Distance, Days, Recording Hours	8,845 km (4,776 nm), 150 days, recording on 84 days for 1,715 hours
Eastbound: Hawaii (South Point) to Mexico (Isla Clarión)	4284 km (2,312 nm), 80 days, recording on 65 days for 1390:52 hours (WG latitude range 18°C 19′ N – 19°C 31′ N)
Westbound: Mexico (Isla Clarión) to Survey End	2492 km (1345 nm),38 days, recording on 14 days, for 204:56 hours (WG latitude range 18°C 20′ N – 19°C 21′ N)
Detail	
Start	16 Dec 2020, Puako, Kohala Coast, Big Island Hawaii
Eastbound	
Rounding South Point, Hawaii	21 Dec 2020
South Point to 'Halfway'	21 Dec 2020 – 26 Jan 2021, 37 days, 2,098 km (1133 nm)
Recording Hours South Point to 'Halfway'	947:19 hours
'Halfway' to Isla Clarión	27 Jan – 10 Mar 2021, 43 days, 2,142 km (1,157 nm)
Recording Hours 'Halfway' to Clarión	562:55 hours on 30 recording days
Turnaround Isla Clarión	10 Mar 2021
Westbound	
Leave Isla Clarión	11 Mar 2021
End Audio Survey	17 Apr 21 (19°C 2′ N, 138°C 30′ W), 1812 km (978 nm) from Hawaii and 2,492 km (1,346 nm) from Isla Clarión
Recording Hours Isla Clarión to Survey End.	Ranged from 0-24 hr. per day, total 204:56 hours on 14 days. On this segment recording was rationed due to memory space which was full by 17 Apr 2021
WG Return to Hawaii	14 May 2021 WG recovered (19°C N, 155°C 58′ W), ~ 22 km from Milolii, Hawaii

calls. All 1,715 hours of recordings were manually analyzed independently by BG and JDD, then the results compared and reviewed. Call detector programs were not used.

Humpback Whale Call Identification

Any, even moderately clear, sample of humpback whale song a few minutes in duration is distinctive at sea. The wide variety of loud sounds in a progression with repetitive patterns, most within a frequency range 100 Hz – 4 kHz, is unique, at least in tropical latitudes.

However, during these surveys, with the relative location of the whales and recorder entirely opportunistic, the sounds were often distant, and at a point, became unclear and difficult to identify with confidence. Hence, in the analysis we struck two levels of humpback whale detections: 1) *positive* humpback whales, and *2) probable* humpback whales. The determining factors for calls to be deemed probable rather than positive were few numbers and faintness. Further definition of these categories is provided in Supplemental Note 1; they are differentiated by color on Figure 1 and Supplemental Figure 1.

Humpback whale sounds recorded offshore were compared to humpback whale songs recorded in Hawaii in 2021, both from Maui (JDD) during the winter research season, and along the Kohala-Kona coastline of the island of Hawaii as the WG transited this region at the start of this survey.

Results

A survey overview, beginning as the WG rounded South Point, Hawaii (21 December 2020) and ending when the recording stopped (17 April 2021 at 19°C 2′ N, 138°C 30′ W), is provided in Supplemental Figure 1 This includes the hours per day recording occurred, all cetacean sounds identified and unidentified, and approximate distances from Hawaii and/or Mexico (Isla Clarión) on the day of detection.

Humpback whale calls were detected on 39 days (including seven days *probable* humpbacks) of the 84 days recording occurred; most of those days (31) were in the first half of the eastbound survey (Figure 1 and Supplemental Figure 1).

The results are presented in 24-hour periods. If humpback whale calls (song units) were detected at any time within a day's recording, the position of the WG at 1600 UTC that day was used as the detection's location (Figure 1). The number of calls identified per day ranged from 10s to 1000s as listed in Supplemental Table 1. The number of call detections do not equate with the numbers of whales present. (One whale may emit 100s of calls during a song session.)

After departure from the Kohala coast (west coast of Hawaii) on 16 December 2020 the WG took five days to round South Point Hawaii and begin the eastbound survey. As expected, humpback song was continual for these five days as the WG transited the Hawaii breeding ground. The formal survey began as of 21 December 2020 as the WG moved eastbound, away from well-known humpback whale presence.

The survey results are presented in three segments, two eastbound and one westbound (reasons described below) and illustrated in Figure 1.

Eastbound

Segment 1

Hawaii, South Point (18°C 44′ N, 155°C 34′ W) to 'Halfway' (19°C 32′ N, 135°C 11′ W) (Figure 1).

This is the first half of the eastbound survey from Hawaii (South Point) to the approximate halfway point, 2,161 km (1,140 nm) from Hawaii and 2,142 km (1,156 nm) from Isla Clarión. Following the same course as the 2018 survey, the 2021 WG took 37 days (21

December 2020 to 26 January 2021) to travel to this point. Sound recording was continual, 24/7, until 26 January when it was only 1 hr 39 min (as a malfunction occurred as explained above). Humpback whales were detected on 29 of those 37 days (with two additional days of *probable* humpbacks).

During the last week of this segment (on 19–20 January 2021), near the survey's halfway mark and most distant from Mexico and Hawaii, some of the most continual and clearest (closest to the WG) humpback whale sounds of the survey were recorded. For example, within one 24-hour period, 20 January 2021 (circa 19°C 29′ N, 138°C 15′ W), over 3,000 song units registered (see Supplemental Table 1**).** These included a series of overlapping units and phrases indicating more than one singer singing simultaneously. Examples of these offshore song units compared to contemporaneous Hawaii song units are shown in Figure 2, and an example of overlapping calls is provided in Supplemental Figure 2.

There are no seamounts on this survey track or in this region of the northeastern Pacific, depth ranged 1,829 m (21 December 2020) to 457 m (24 January 2021). Water temperature ranged from 26.23°C–22.17°C.

Segment 2

'Halfway' (19°C 32′ N, 135°C 11′ W) to Isla Clarión (18°C 20′ N, 114°C 51′ W).

The second eastbound segment, beginning approximately halfway from Hawaii to the destination of Isla Clarión, 2,142 km (1,157 nm) further to the east, was conducted over 43 days: 27 January to 10 March 2021. This segment differed from the first eastbound segment in two ways:

1) To this point, the 2021 route had followed the 2018 survey track; at the start of this segment it diverged, making it the first humpback whale acoustic survey on this line in the northeast Pacific (Figure 1).

2) While the recording in the first half of the eastbound survey was near continual, 24/7, in this second half, as described earlier, recording ranged from 0–24 hours a day. During this segment's 43 days eastbound recording occurred on 28 days with six of those partial days (approx. 8 hr/day). Hours recorded per day are illustrated in Supplemental Figure 1.

In this segment, and under these circumstances, humpback whale songs were detected on eight days (three positive and five probable) (Figure 1). The 'probable humpbacks' were heard on 8, 11, 21, 27 February and 5 March. The positive detections on 16 February, 3 and 10 March are described below.

Segment 2 *positive* humpback whale detections:

16 February 2021 – (19°C 2′N, 125°C 48′ W).

This day the WG was 3,122 km (1,686 nm) from Hawaii and 1,158 km (625 nm) from Isla Clarión (Figure 1). It was within the archival repair period, with only 9 hr 33 min of the 24 hours recorded. In addition, storage of the recorded data was intermittent, with minute-long files absent in between 1-minute files successfully saved.

Despite these limitations, two separated 1-min. files included humpback whale calls. The first included a sequence of song units,

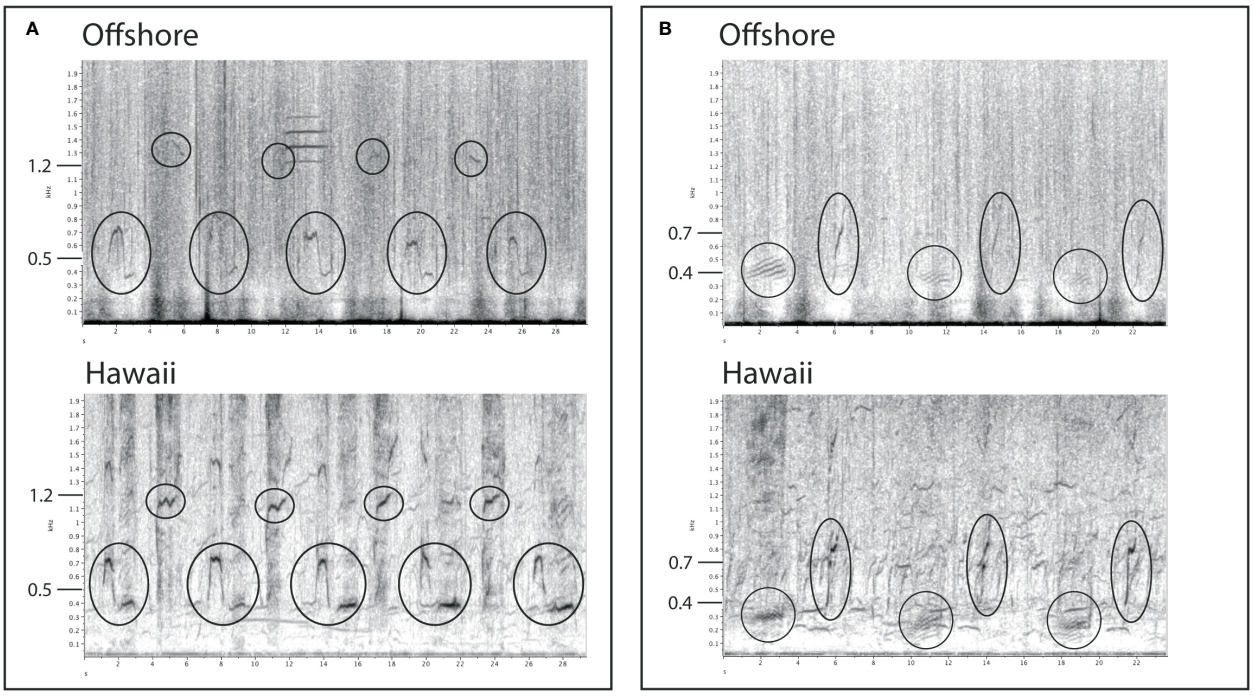

FIGURE 2
Examples **(A, B)** show the same song phrases recorded Offshore (mid-tropical North Pacific) and in Hawaii. Offshore examples were recorded on 20 January 2021 (1,841 km, 993 nm east of Hawaii, mid-ocean (19°C 29′ N, 138°C 15′ W); the Hawaii examples were recorded in Maui (23 January 2021). The horizontal parallel lines in Example **(A)** Offshore are a minke whale 'boing' occurring at the same time as the humpback whale song (Spectrographs Hann Window 50% overlap, FFT/DFT Example **(A)** Offshore 2048, Hawaii 8192; Example **(B)** Offshore 1,024, Hawaii 8,192.

then four minutes later (that is, four one-minute files not archived) the next available minute included a series of song units. Considering that the minute before the first song detection was also missing, the song sample may have been up to seven minutes long. The minute-long files of song separated by four minutes are included in Supplemental Figure 2.

Within these 1-min. files were two different phrases and a transition from one phrase to another, identifying it as uniquely humpback. Additionally, the calls (their acoustic parameters) and spacing were a close match to components of the 2021 Hawaii song. (Note the Hawaii and Mexico songs are often markedly similar (e.g., Darling et al., 2019a) as was the case in 2021).

There are no notable sea mounts in this region of the NE Pacific, depth 2,415 m. Water temperature average for this day was 22.23°C.

3 March 2021 – (18°C 38′ N, 118°C 53′ W).

This day the WG was 3,880 km (2,095 nm) from Hawaii and 444 km (240 nm) from Isla Clarión (Figure 1). It was also 204 km (110 nm) east of Seamount Alphecca (18°C 19′ N, 117°C 11′ W). This seamount is of interest as it is the shallowest offshore point on the survey route at 156 meters deep.

Recording was continual over the 24 hours and during that time, distant, yet convincing humpback calls were heard over 12 hr 30 min of those hours. Approximately 100 calls, including sequences of different sound units, occurred. An example is given in Supplementary Figure 3.

At this location the depth under the WG was 1,406 m. The sea temperature was 23.09°C.

10 March 2021 – Isla Clarión (18°C 20′ N, 114°C 51′ W).

The WG approached Isla Clarión to within 9.3 km (5 nm) on 10 March (Figure 1) with the recording continual for 23 of 24 hours. As expected, (as this is a known humpback winter ground) humpback calls were recorded through much of the day – heard in 18 hours 30 min of the 23 hours – with 292 calls counted. The calls were faint but audible and clear on the spectrograph. An example of the calls is provided in Supplemental Figure 4.

At the WGs closest point to Isla Clarión the depth was an estimated 1000-1500 m, up from the surrounding depths of approximately 3000 m. Sea temperature was 25.17°C.

Westbound

Segment 3

Return: Isla Clarión to Hawaii.

The decision to maximize recording time on the eastbound, outgoing trip meant the survey was left with eight days of recording space for the 65-day (10 March to 16 May)

return trip back to Hawaii. As the WG reversed course, the primary objective was to listen to the oceanic region 'missed' on the outgoing trip during the two-week period (26 January to 11 February) of archive repair (Figure 1).

Therefore, as illustrated in Figure 1, after recording on 14 March for approximately 12 hours as the WG retraced its route over the Alphecca Seamount the recording was stopped until 1 April. (Humpback whales were not detected at Alphecca; minke and unidentified odontocetes were, see Supplemental Figure 1). Between 1–17 April recording occurred for 14 days ranging from 24 hours to 4 hr 27 min on 13 of those days (one additional day was just four minutes recording time, but a minke whale was detected so it is included in the day total). No conclusive humpback whale detections were made in this period (Figure 1 and Supplemental Figure 1).

On all 13 of the extended recording days during this period, sounds designated as *unidentified cetaceans* could possibly have been humpback whales. Minke whales and many odontocete sounds, including sperm whales, were recorded during this time, but the potential humpback whales were too distant to make a confident determination and remain in the category of unidentified cetacean.

The available memory was full by 17 April 2021 at location 19°C 2′ N, 138°C 30′ W, 1,812 km (978 nm) from South Point Hawaii and 2,492 km (1346 nm) from Isla Clarión.

Discussion

Our understanding of the presence of humpback whales in deep tropical ocean between the known Mexico and Hawaii breeding grounds is at an early stage. Prior to the 2018 HUMPACS acoustic survey which detected humpback whales along this latitude into mid-ocean (Darling et al., 2019b), this occurrence had not been investigated. There were reasons for this: no shallows – a prime characteristic of humpback whale winter grounds (e.g., Rasmussen et al., 2007); migratory routes shown to be essentially straight lines between northern feeding grounds and Mexico or Hawaii (Mate et al., 1998; Lagerquist et al., 2008; Mate et al., 2020); and a prevailing notion of, at least, the seasonal separation, if not the biological distinction, of the populations (Baker et al., 2013; Federal Register, 2016).

The 2018 survey results were unexpected, so much so that one of the explanations considered was that this humpback whale presence was anomalous. This, among other questions, compelled the 2021 replication and expansion of the 2018 acoustic survey as reported here. Coincidently, in the same time frame as this 2021 HUMPACS acoustic survey was returning to Hawaii, new information came to light connecting the Mexico and Hawaii humpback whale populations (Darling et al., 2022).

Comparisons of humpback whale individual photo-identification collections in 2021 (by Happywhale[1]) uncovered an individual whale which had been identified off Guerrero, southern Mexico on 16 Feb 2018 and again in Maui 49 days later, on 6 April 2018 – that is, the whale travelled between Mexico and Hawaii in the same winter breeding season. Its straight-line course overlapped the time and route of the same year (2018) WG acoustic survey. This revived a single record of winter travel between Mexico and Hawaii in 1986 (Forestell and Urbán, 2007); and was soon followed by discovery of two further records of similar behavior, one occurring in 2006 (Darling et al., 2022) and another in 2022[2]. Whales were moving between Mexico and Hawaii within one breeding season; this was consistent with the survey's acoustic detections.

The 2021 survey confirmed the 2018 detections of near-continuous humpback whale presence from Hawaii eastward at

approximately 20°N to 2,161 km (over 1,100 nm) into the tropical mid-northeast Pacific (Darling et al., 2019b). On this same survey route in 2018, humpback whales were detected on 30 of 35 days: in this 2021 survey, 29 of 36 days. In both surveys, some of the highest number of call detections per day were in mid-ocean, the most distant region from both the Hawaii and Mexico breeding areas.

In the non-iterative segment of the 2021 survey, from the approximate mid-ocean ('Halfway') point to the westernmost Mexican breeding area, humpback whale detections were few but did occur periodically all the way to Isla Clarión. That is, we can report that humpback whales were detected in deep ocean across the eastern tropical North Pacific, over the 4,500 km from one known breeding ground to another in mid-breeding season – this now, not surprising considering the records of individual whales making this transit (Darling et al, 2022).

The fall-off in near-daily detections in both 2018 and 2021 surveys eastward of the mid-ocean mark is interesting. Also, neither survey detected clearly identifiable humpbacks on the return trip to Hawaii. There are several possible, and likely interconnected, explanations for this, even beyond the sampling lottery of a single audio recorder passing within 10 km of a singing whale in mid-ocean. These include a potential varying density of whales with 1) stage of winter season (early/late); 2) different and unknown pathways in different ocean regions; or, 3) social factors.

If we presume this variation in humpback whale detection reflects whale presence/absence (and not a sampling artifact) it indicates a non-uniform or patchy distribution across the tropical ocean basin. This suggests aggregations of whales, whether travelling or stationary, rather than a general scattering of individuals across this latitude band. The HUMPACS West survey, from Hawaii westward towards Asia in 2019, similarly detected a 'patch' of humpback whales in mid- ocean over a six-day period, with no detections for 23 days (and 1,408 km) prior and 14 days (937 km) after (Darling et al., 2020). This may be consistent with the idea that song plays a role in this social/spatial coherence, defining and/or maintaining the relatively tight group in vast ocean spaces (e.g., Clapham and Mattila, 1990; Darling et al., 2019a).

The numbers of whales, or portion of the population(s) using the tropical deep offshore between the familiar Hawaii or Mexico winter grounds is unknown; it cannot be deduced from these surveys. However, the near-daily detection of whales over two different month-long periods in two different surveys three years apart from Hawaii eastward to the mid-northeast Pacific, including records of multiple, simultaneous singers (all with a single WG listening station) suggest these are not just a few atypical whales.

This tropical offshore presence, whether it is all due to within season travel between coastal Mexico and Hawaii breeding grounds, is itself a breeding assembly, or has some other explanation, should be a factor in future discussion of population distinctiveness, abundance, behavior, and management.

Footnotes

[1] www.happywhale.com

[2] In 2022 a fourth record of an individual whale that travelled between Mexico and Hawaii in one winter was identified by the Happywhale computerized matching program (https://happywhale.com/individual/39898;enc=288934). This whale was photo-identified on 28 January 2022 off Cabo San Lucas, Mexico, and again 56 days and 4,774 km later on 25 March 2022 off West Maui Hawaii. The description of its social behavior in Hawaii suggests it was a male.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the study involving animals in accordance with the local legislation and institutional requirements because it involved passive listening with no approach to the animals.

Author contributions

JDD and BG were responsible for the conception and design of the study. BG was responsible for the customization of the Wave Glider, its operation during the survey, and the retrieval of the raw data. BG and JDD jointly analyzed and illustrated the survey data. JDD wrote the first draft of the manuscript, both authors contributed to the manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1223835/full#supplementary-material

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