NOAA Technical Memorandum NMFS

SEPTEMBER 2012

CRUISE REPORT FOR THE VAQUITA EXPEDITION IN 2008 CONDUCTED ABOARD NOAA SHIP *DAVID STARR JORDAN, R/V KOIPAI YÚ-XÁ* AND THE *VAQUITA EXPRESS*

Annette Henry, Barbara Taylor, Lorenzo Rojas-Bracho, Shannon Rankin, Armando Jaramillo-Legoretta, Tom Akamatsu, Jay Barlow, Tim Gerrodette, Candice Hall, Alan Jackson, Jessica Redfern, Rene Swift and Nick Tregenza

NOAA-TM-NMFS-SWFSC-495

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

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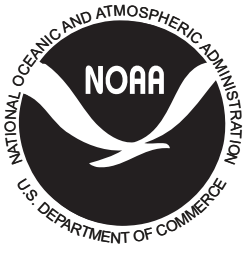

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U.S. DEPARTMENT OF COMMERCE
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National Marine Fisheries Service
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Table of Contents

LIST OF TABLES

LIST OF FIGURES

CRUISE REPORT FOR THE VAQUITA EXPEDITION 2008 CONDUCTED ABOARD NOAA SHIP DAVID STARR JORDAN, R/V KOIPAI YÚ-XÁ, AND THE VAQUITA EXPRESS

The Vaquita Expedition 2008 was a three-ship survey as follows:

Chief Scientists:

United States: Barbara L. Taylor
Mexico: Lorenzo Rojas-Bracho

Vessel Platforms:

Platform One: NOAA Ship *David Starr Jordan*
Cruise Numbers: DS-08-06, SWFSC Cruise Number 1637
Cruise Dates: 01 October through 04 December 2008 (survey dates: 6 October through 25 November 2008)

Platform Two: *Koipai Yú-Xá*
Cruise Dates: 6 October through 25 November 2008

Platform Three: *Vaquita Express* (chartered Corsair 24 trimaran)
Cruise Dates: 15 September through 25 November 2008

Sponsoring Institutions:

United States: NOAA-National Marine Fisheries Service:
Southwest Fisheries Science Center
8604 La Jolla Shores Drive, La Jolla, CA 92037

Mexico: Instituto Nacional de Ecología (INE)
Investigación y Conservación de Mamíferos Marinos
Km. 107 Carretera Ensenada-Tijuana Ensenada, BC 2286

Mission Statement

A small porpoise (*Phocoena sinus*) found only in the upper Gulf of California is called vaquita and is the most endangered species of marine mammal in the world. A rough projection using the last abundance estimate in 1997 and mortality in gillnets resulted in an estimate of only about 150 vaquitas remaining prior to the 2008 survey. With so few vaquitas remaining, the visual and acoustic methods used to monitor trends in vaquita abundance in the past were too imprecise to determine whether the species is continuing to decline. The primary objective of the cruise was to develop the ability to monitor trends in abundance for vaquitas using acoustic monitoring equipment (autonomous devices and towed hydrophones). Autonomous acoustic devices should increase precision because they can record for long periods of time; however, such devices were yet to be tested in the noisy vaquita habitat.

To characterize the abilities of the autonomous acoustic devices to detect vaquitas, the initial research required visual validation of porpoise densities that could best be attained with a large ship equipped with high power binoculars. There was also the question of how many devices would be needed and where they should be placed. This required a better description of current vaquita distribution. A secondary objective was to obtain a new abundance estimate from a combination of visual sighting survey and towed hydrophone survey. Specifically, the cruise was designed to:

- Describe the current distribution of the vaquita
- Locate vaquitas for the purposes of testing autonomous acoustic equipment

- Gather data allowing choice of acoustic equipment that will be deployed and maintained from the R/V *Koipai-Yú-X*á.
- Gather data that can be compared through time for a minimum of 10 years
- Calibrate any new methods for acoustic monitoring to the methods that have been used over the past decade to allow a time series that extends over a longer period
- Cover a sufficient part of the range to reliably detect trends in abundance with the objective of being able to detect a 4% per year increase as "positive growth" within a 10-year period
- Conduct a visual survey for vaquitas to obtain an abundance estimate comparable to the 1997 survey.

Vaquita Expedition 2008 was a collaborative international cruise with United States and Mexican scientists together with expert acousticians from Great Britain, the United States and Japan. This cruise was a research and development project that required methods and operations to be tested, refined, and revised as necessary while at sea. The research cruise used three research vessels: NOAA Ship *David Starr Jordan*, the R/V *Koipai Yú-Xá*, and a chartered Corsair 24 trimaran, the *Vaquita Express*.

Itineraries

NOAA Ship *David Starr Jordan*

Transit:
Departure: 01 October, San Diego, CA Arrival: 06 October, Guaymas, MX
Leg 1:
Departure: 08 October, Guaymas, MX Arrival: 09 October, San Felipe, MX

Leg 1a: 10-20 October, San Felipe, MX
Leg 1b: 21-30 October, San Felipe, MX
Scientific personnel transferred off ship on 30 October
Departure: 30 October, San Felipe, MX Arrival: 01 November, Guaymas, MX

Leg 2:
Departure: 04 November, Guaymas, MX
Leg 2a: 05-16 November, San Felipe, MX
Leg 2b: 17-25 November, San Felipe, MX
Scientific Personnel transferred off ship on 25 November
Transit:
Departure: 29 November, Guaymas, MX Arrival: 04 December, San Diego, CA

R/V *Koipai Yú-Xá*
Leg 1: 6-27 October, San Felipe, MX
Leg 2: 6-25 November, San Felipe, MX

Corsair 24 trimaran, *Vaquita Express*
15 September – 23 November, San Felipe, MX

Study Area

The survey area was the upper Gulf of California waters, including San Felipe Bay, the Upper Gulf of California and Colorado River Delta Biosphere, the Vaquita Refuge Area and their surrounding waters (Fig. 1). The vast majority of the survey took place in the Biosphere and Vaquita Refuge Area, from 30.5 N to 31.5 N and from 113.5 W to 114.5 W.

The entire survey was done in a very small area in the northern portion of the Gulf of California, and the order of trackline coverage was weather dependent. Most tracklines were conducted in a northerly direction to avoid direct glare that negatively affects the

detection of cetaceans by the visual observers.

Scientific Operations

The three platforms conducted three separate research operations. This report covers operations carried out by NOAA Ship *David Starr Jordan* and R/V *Koipai Yú-Xá* (MX, hereafter called *Koipai*). A detailed account of the operations conducted by the *Vaquita Express* is available in NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-439 (Rankin *et al.*, 2009).

In addition to the three platforms, three inventors of the primary acoustic devices being tested joined Vaquita Expedition 2008. Jonathan Gordon (Sea Mammal Research Unit, University of St. Andrews, United Kingdom) is an expert in the equipment used for the past decade on the *Koipai Yú-Xá* called the "Porpoise Box" and the newer incarnation that was towed from the *Vaquita Express* called "RainbowClick." Tomonari (Tom) Akamatsu (Fisheries Research Agency, Japan) is the inventor of the A-tag. His student, Satoko Kimura, accompanied him on the expedition. Nick Tregenza, an independent researcher from the United Kingdom, is the inventor of two commercially available porpoise detectors called the T-POD and the C-POD that were tested on the survey. All participants in Vaquita Expedition 2008 are listed in Table 1.

NOAA Ship David Starr Jordan

Cetacean research

Visual operations.-- Line-transect survey methods were used to collect cetacean abundance data. A daily watch for cetaceans was maintained on the flying bridge during daylight hours (approximately 0600 to 1900) by seven mammal observers. Each observer worked in 2-hr rotations, manning each of the following four stations on the flying bridge for 40 minutes: a port side 25x150 binocular station, a center-line data recorder position, a starboard 25x150 binocular station, and the inside 25x150 binocular station. Observers alternated 2-hr on duty and 2-hr off duty.

Daily search effort began on the trackline with the ship traveling at 6 kts (through the water) along the designated trackline. The cruise was conducted in passing mode to match the 1997 survey (Jaramillo-Legorreta *et al.*, 1999); additionally, vaquitas average only two to a group, making it unnecessary to leave the trackline to estimate group size. The observer sighting the vaquitas would tell the recorder their best, high, and low estimates of group size. If diversion from the established trackline during regular effort was necessary due to glare or adverse sea conditions, the ship was allowed to divert up to 30 degrees from the established course. This deviation might continue until the ship was 5nm from the trackline, at which point the ship should have turned back toward the trackline. Deviations from the planned trackline also occurred to avoid artisanal fishing boats and their nets.

During Vaquita Expedition 2008, 1,631 km of trackline were surveyed (Table 2) during the 42 survey days. The vast majority (75.5%) of survey effort occurred in sea

conditions of Beaufort 2 or less. Survey effort was similar to that in the 1997 survey; however, survey effort at Beaufort 2 or less (necessary for vaquita sightings) almost doubled in 2008 as compared with 1997 (1231 km vs. 680 km respectively). There were 313 cetacean sightings during the survey (Table 3) that included 211 sightings to the species level. Vaquitas were sighted on 121 separate occasions (Fig. 2). Other cetacean species sighted included long-beaked common dolphin (*Delphinus capensis*, Fig. 3), bottlenose dolphin (*Tursiops truncatus*, Fig. 4), killer whale (*Orcinus orca*), false killer whale (*Pseudorca crassidens*, Fig. 5), fin whale (*Balaenoptera physalus*, Fig. 6), Bryde's whale (*Balaenoptera edeni*), sei whale (*Balaenoptera borealis*, Fig. 7), blue whale (*Balaenoptera musculus*) and humpback whale (*Megaptera novaeangliae*, Fig. 8.).

Photography.-- Photographs of marine mammals, specifically vaquitas (Fig. 9), were taken on an opportunistic basis. Photographs of vaquitas taken from NOAA ship *David Starr Jordan*, *Koipai* and *Vaquita Express* as well as photos taken as part of a separate project led by T. Jefferson (Jefferson *et al.*, 2009) are being used to study social behavior and movement patterns of identified individuals.

Biopsy.-- No biopsy samples were collected during Vaquita Expedition 2008.

Autonomous Vaquita Recording Experiments.-- Static acoustic monitoring devices (C-POD, T-POD and A-tag) were placed on four buoys. The buoys were anchored on the ocean bottom at depths of up to 30m; buoys were positioned at eight locations (Fig. 10) during the expedition.

The buoys had a dumbbell shape with a steel rod below with large links attached to

increase stability (Fig. 11). A separate metal unit was developed to attach the three separate pieces of acoustic equipment. This was deployed mid-water between the buoy and the anchor. A synthetic line was used to attach the buoy to the acoustic package and then to the anchor (railroad wheel with 9m chain; weight ~800 lbs.).

Three types of static acoustic monitoring devices were placed on the buoys: C-PODs, T-PODs, and A-tags (Fig. 11, inset photo). All are event loggers designed to detect porpoise-like sounds and record data that are analyzed later for acoustic properties of vaquitas. Event loggers can be deployed for several months, retrieved and the data downloaded.

Prior to buoy launching, an experiment was conducted to determine the sensitivity of various porpoise click detectors to find and classify simulated vaquita clicks in a noisy environment near San Felipe. Series of simulated porpoise clicks were generated and broadcast from a small boat at varying distances from an instrument cluster with five types of porpoise click detectors (the 3 static acoustic monitoring devices mentioned above and the two porpoise detectors used on the *Koipai* and *Vaquita Express*). Impulsive sounds from snapping shrimp resulted in a high level of ambient noise. In general, the detection distances for C-PODs, T-PODs, and the porpoise detectors used on the *Koipai* and *Vaquita Express* were approximately 200m. Individual clicks were received at greater distances, but it is not clear if the single clicks would have been classified as from porpoises. The A-tag was less sensitive, with a detection distance of approximately 60m.

The results from the simulated click experiment were similar to results from the

detectors placed on the buoys. The C-POD out-performed the now obsolete T-POD, so we report only C-POD results. 109 days of C-POD logging from buoys yielded 171 minutes with vaquita detections. Half the sites had no detections. 21,928 clicks were logged in 328 groups of clicks detected automatically and visually screened.

A-tags were deployed at buoys A, B, E, and F during October to November 2008. Many biosonar signals were detected at buoys B, E, and F, but no detections were made at buoy A. Most detections were at night. Vaquita sounds have energy at a high frequency range above 120kHz, whereas bottlenose dolphin sounds have a broadband spectrum. This was used to discriminate species. Employing strict criteria, all of the detections were categorized as dolphins. Based on less strict criteria, four detections at buoy B and F were categorized as vaquitas. The detection rates were 0.36 and 0.16 detections/day/buoy, for buoy B and E, respectively. It is important to exclude false positives caused by bottlenose dolphins and other noise sources in future applications of acoustic monitoring of vaquitas.

Vaquita group size varied; the A-tag successfully detected group size. Discriminating the independent traces of sound sources using bearing angles identified each animal. A group of dolphins observed acoustically at buoy E on 01 November was calculated to comprise eight individuals. The visual observers on the research vessel confirmed this detection and group size. Still, most detections consisted of one or two animals at the same time.

Periodic change of noise contamination was observed by the A-tag. Noise

contamination was greatest when the tidal current was weak, corresponding with the periods of highest and lowest tides. Snapping shrimp are the most likely source of the noise contamination that could cause the false positive detection of vaquitas. A noise map would be helpful to exclude inappropriate areas for the acoustic survey.

Ecosystem Sampling

Oceanography.-- Chronological records of sampling in Coordinated Universal Time (UTC) were kept in the ship's Marine Operations Log. The ship provided an electronic copy of its operation logs, including the weather log and other meteorological data, to the Chief Scientist upon completion of the cruise.

Thermosalinograph Sampling.-- Ship personnel provided and maintained a calibrated Sea-Bird Electronics (SBE) thermosalinograph (TSG, Model SBE-21). The intake for the TSG was located on the bow of the ship approximately 3m below the surface. The TSG was used to measure temperature and conductivity and derive salinity of surface seawater at approximately 30-second intervals. The ship's Scientific Computing System (SCS) recorded these data. The oceanographer provided the ship's Operations Officer and electronics technician with detailed SCS acquisition information. All SCS and raw data were provided to the oceanographer.

Surface Water Samples.-- Discrete bucket surface temperatures and chlorophyll samples were collected at the start and end of effort and two points in between, resulting in a sampling frequency of approximately every 4 hr (Fig. 12). Water samples of 265ml

were filtered through Whatman 25mm GF/F (glass fiber) filters, which retain particles of 0.7µm and greater; filters were immersed in 10ml of 90% acetone for extraction. Immersed filters were refrigerated for a minimum of 24 hr and a maximum of 36 hr. Surface water samples were collected during Legs 1 and 2. Temperature and salinity data from the TSG (see above section) were also logged at those times.

Shipboard chlorophyll *a* and phaeophytin analysis (detailed in Holm-Hansen *et al*. 1965) was conducted using a Turner Designs Model 10-AU fluorometer; results were recorded using FLog, version 0804 (author: Jim Wilkinson, Scripps Institution of Oceanography, 2008). The fluorometer was calibrated with chlorophyll *a* liquid standards prior to the research cruise.

CTD.-- Conductivity, temperature, and depth (CTD) casts were made using a Sea-Bird Electronics 911*plus* CTD unit on leg 2 (Fig. 13). The CTD was deployed off the portside using the J-frame and lowered via a conducting cable to within 4m of the bottom. Wetlabs 25cm C_Star Transmissometer and Sea-Bird Electronics temperature, conductivity, and pressure sensors were used on all casts. A General Oceanics rosette system with Micro7-washed Niskin bottles was used to collect chlorophyll and suspended particulate matter (SPM) samples at 5m intervals. Niskin bottles were retrofitted with silicone rubber o-rings in the valves and end-caps. Silicone rubber tubing was used as the bottle closing mechanism. Sediment samples were filtered through GF/F filters before freezing; sediment samples were weighed, post-cruise, at SWFSC. A deck pressure test was conducted at the beginning of the leg to calculate the offset of the SBE 911plus

pressure sensor. The test was performed by the Oceanographer, with the CTD on deck.

Focal site CTD sampling - Sampling occurred at night through a semidiurnal tidal cycle between slack tides. Two locations were sampled: one where vaquitas were seen and one where they were not (buoy deployment sites E and B, respectively). At each location, sampling occurred once during a neap tide cycle and once during a spring tide cycle. Water column chlorophyll and SPM samples were collected.

Transect CTD sampling -This sampling closely followed the type of transect analysis done in Alvarez and Jones 2004. Sampling was conducted between the lines formed by buoys C-H and B-E, approximately once every 5 nm. The exact sampling locations were determined by cast time, which was selected to ensure transect completion between 1 hr before and 1 hr after slack tide. Water column chlorophyll and SPM samples were collected at 5m intervals.

When neither focal site nor transect sampling was scheduled, CTDs casts were conducted at night in areas where high vaquita densities had been observed during the day. CTD deployments occurred every 2 hr throughout the semidiurnal tide cycle to collect chlorophyll and SPM samples at 5m depth intervals.

Acoustic Backscatter.-- Acoustic backscatter data were collected at 200kHz using a Simrad EK500 transceiver system and the Simrad Echolog 500 software program. A transmitted pulse of 1.024 milliseconds (i.e., the pulse duration of an individual ping transmitted by the transducer), a ping interval of two seconds, and a maximum depth of 500m were used throughout the survey. Data were recorded on a computer's internal hard

drive and backed up on an external hard drive.

Underway pCO2 System.-- The Pacific Marine Environmental Laboratory's (PMEL) underway pCO_2 system continuously measured the partial pressure of CO_2 in the air and surface water during the cruise. The pCO_2 values, along with wind, temperature, and salinity data were used to calculate the flux of CO_2 at the air-sea interface. The system uses 3 liters of seawater per minute and determines CO_2 content with a Licor infrared detector. For more information, contact the PMEL Carbon Group, http://www.pmel.noaa.gov/co2/uwpco2/.

End of Daily Operations

When scientific operations were completed for the night, the ship would proceed to the next day's starting point. The Chief Scientist coordinated the *Jordan's* movement with the other two vessels. In some instances, the Commanding Officer chose to anchor for the night.

R/V Koipai Yú-Xá

Testing Acoustic Equipment

In June 2008, the *Koipai* sailed to San Felipe to begin testing three of the four new types of acoustic equipment to be used in Vaquita Expedition 2008. Equipment trials were performed with the A-tag, T-POD, and C-POD. During these trials, the *Koipai* anchored for 24 hr in the area with the highest number of vaquita detections over the past

10 years (the vaquita "hotspot") and both the A-tag and the C-POD had vaquita acoustic detections.

The fourth type of equipment was the Rainbow Click system assembled by Jonathan Gordon from the University of St. Andrews and EcoLogic in the United Kingdom. The Rainbow Click system is able to detect vaquitas in real time as compared to the other three and would be used by the *Koipai* during the Vaquita Expedition.

In October 2008, the *Koipai* and *Vaquita Express* deployed acoustic detectors in an area of intense background environmental noise both biological (snapping shrimp) and anthropogenic. These conditions tested the performance of the equipment under severe acoustic conditions and assessed the correct acoustic identification of vaquitas' clicks. Because vaquitas are rare, simulated acoustic pulses, similar to those generated by vaquitas, were used for the testing. Simulated clicks were emitted from different distances, through a system designed by Jay Barlow, Southwest Fisheries Science Center. The information obtained during this experiment allowed all participants to adjust the parameters of each equipment type according to the acoustic environment of the Upper Gulf of California.

Acoustic Survey

R/V *Koipai* acoustically surveyed for vaquitas using Rainbow Click and Porpoise Detector. Porpoise Detector, designed by International Fund for Animal Welfare, has been used aboard the *Koipai* for many years. Rainbow Click was tested concomitantly with the Porpoise Detector for data comparison at all stations. At stations 6 through 8, the

C-POD and T-POD were added to the complement of acoustic devices.

As was done during the previous 10 years, the *Koipai* set anchor at different locations (Leg 1: Fig. 14; Leg 2: Fig. 15) in the study area to begin a minimum 12-hr listening period using the acoustic devices. Once the *Koipai* was successfully anchored, the ship's engine was turned off and the electric generator used only as needed to charge the batteries needed to run the scientific equipment. Not all acoustic equipment was used at every station.

Recordings

High frequency recordings consume a considerable amount of disk storage space. In order to conserve space, high frequency recordings were made during the first 15 minutes of each hour and opportunistically when vaquitas were sighted and in the presence of boats. Boats were recorded in order to characterize vessels using the same habitat as vaquitas. Table 4 lists date, location, and effort for each listening station by leg.

CTD

During Leg 2, a CTD (IBRD SBE 37-IF) was used starting with station 4 through 8 (Table 4). The CTD was deployed to a depth of 2m above the ocean bottom and measurements were collected an average of 10 times per minute. The CTD was raised and lowered through the water column at a rate of 1/3 m sec^{-1}. Vertical profiles were compared with tidal changes to evaluate the tidal force in the upper gulf region. These vertical profiles quantified the movement of the CTD in addition to the movement of the

hydrophones used by Rainbow Click. Because the depth of station 5 exceeded the cable length, vertical profile data were not collected. Since information generated at the other stations indicated that the water column was well mixed with regards to temperature and salinity, the sampling scheme was varied for stations 7 and 8. The water at these stations was approximately 30m deep and measurements were collected at 3 depths (5, 15 and 25m) to elucidate the variations between layers that compose the water column. The CTD was left at each of these depths for 1 hr throughout the station duration (minimum 12 hr). Oceanographic measurements were collected by the *Koipai* and the *Jordan* near buoys B and E, and were in agreement.

Visual Observations

Koipai scientists observed vaquitas during Legs 1 and 2. These observations provided opportunities for photographs and verification that vaquitas are reproducing in the upper Gulf of California. Encounters are described.

21 October: a group of five vaquitas were observed one nautical mile southeast of Station 5. This sighting lasted 50 min and porpoises were as close of 30m to the boat. Vaquitas were diving repeatedly in a relatively small area apparently feeding; a fish school was detected in the same vicinity, reinforcing this assumption. The boat did not disturb the porpoises and observations ended due to sunset. The group included a cow/calf pair.

26 October: During the transit to Station 6, a group of three vaquitas was seen near bottlenose dolphins (*Tursiops truncatus*). A distance of 100m was maintained from the

animals and they were observed for 30 min.

Leg 2 (21 November 2008): A group of three animals, including a cow/calf pair were first observed about 500m from the boat at 1450; these animals swam as close as 50 to 100m of the boat. As they moved away from the *Koipai*, a panga was launched to continue observing them and obtain additional photographs and video. The panga successfully stayed with this group for 90 min, an unprecedented amount of time. Similar to the observation on 21 October, both groups were feeding, which may explain why the animals were more tolerant of the boat. On the other hand, vaquitas were not recorded acoustically during these two sightings (recording equipment would have recorded echolocation pulses if they were being produced).

S/V Vaquita Express

The *Vaquita Express*, an 8-m trimaran sailing vessel, was chartered to survey areas that are inaccessible to large ships due to shallow waters and high density of gillnets. The purpose of this survey was to 1) obtain absolute abundance estimate for these areas and 2) test the feasibility of implementing towed hydrophone surveys to monitor abundance. The Vaquita Refuge was surveyed concomitantly with the *Jordan* in order to calibrate the two survey platforms.

A two-element hydrophone array and A-tag were towed 25 – 50 m behind the boat to detect vaquita echolocation clicks. Digital recordings were made to a computer hard drive using a National Instruments data acquisition card (NI-DAQ 6251), sampling at 480 kHz,

with a 20 kHz high pass filter. Twelve-volt power was supplied to the vessel by a bank of deep cycle batteries, which were recharged by a flexible solar panel or recharged nightly. The International Fund for Animal Welfare's (IFAW) Rainbow Click and Logger software (www.ifaw.org/sotw) provided a real-time click detector, broadband recordings, positional information, and environmental data.

Nearly half of the 1484 km trackline covered by the Vaquita Express was considered *on effort*, providing data for abundance estimation (Fig. 16). There were 36 detections of "vaquita events" and 101 detections of individual echolocation clicks attributed to vaquitas (Table 5). Vaquita Events were defined as click trains with ≥ 5 clicks and consistent change in direction. Single clicks were defined as click trains of < 5 clicks, typically consisting of a single click with the waveform and power spectra of a vaquita click. It is very likely that some single clicks were vaquitas while others were false triggers.

A detailed account of the operations conducted by the *Vaquita Express* is available in NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-439 (Rankin *et al.*, 2009).

Summary

Vaquita Expedition 2008 was highly successful, as all goals were accomplished. In addition to providing data to calculate an abundance estimate for vaquita, autonomous acoustic methods were successfully evaluated. Working together, the three vessels collected data to:

- Characterize the abilities of the autonomous acoustic devices to detect vaquitas
- Validate porpoise densities using a large ship equipped with high power binoculars for comparison with acoustic devices
- Describe the distribution of the vaquita in order to answer the question of where autonomous acoustic devices should be placed as well as the number of devices necessary to reliably detect trends in abundance with the objective of being able to detect a 4% per year increase as "positive growth" within a 10-year period
- Test the feasibility of towing acoustic arrays behind a sailing vessel as a monitoring tool

In conclusion, autonomous acoustics were shown to be a viable tool to detect vaquitas, and data collected will allow the scientists to design a scheme to monitor vaquitas for changes in abundance.

Disposition of Data

The data collected aboard NOAA Ship *David Starr Jordan* and Corsair trimaran *Vaquita Express*, as part of Vaquita Expedition 2008, have been archived as follows:

Marine Mammal Sightings:

Barbara Taylor, NOAA Fisheries – SWFSC; Barbara.Taylor@noaa.gov

Acoustic Backscatter:

Jessica Redfern NOAA Fisheries – SWFSC; Jessica.Redfern@noaa.gov

Oceanographic Samples and Data:

Jessica Redfern, NOAA Fisheries – SWFSC; Jessica.Redfern@noaa.gov

NOAA Passive Acoustic Recordings:

Jay Barlow, NOAA Fisheries – SWFSC; Jay.Barlow@noaa.gov

Acknowledgments

This project owes its success to many, and we thank the many people who sailed on the three platforms: aboard the *Vaquita Express*: acoustician Denise Risch and Captains Rodrigo Olson and Steve Brown; aboard R/V *Koipai Yú-Xá*: Biologist Gustavo Cardenas, Captain Juan Osuna and José Arce; aboard NOAA Ship *David Starr Jordan*: officers and crew, observers, particularly Robert Pitman. Tom Jefferson and his scientific team in San Felipe. Acoustician Jonathan Gordon assisted with design of equipment for the *Vaquita Express*; Paul Harvey, Scripps Institution of Oceanography provided insight regarding buoy design for the survey area and loaned equipment to the project; Terry Henry further assisted with buoy design and fabricated the buoys and deployment gear; Satoko Kimura assisted with A-tag acoustics. Lynn Evans assisted with travel arrangements. Edwyna Nieto and Paloma

Ladrón, both with the Instituto Nacional de Ecología, helped with logistics. Pacific Life Foundation provided funding. The Intercultural Center for the Study of Deserts and Oceans (CEDO) provided logistical support. This research was conducted using software Logger/RainbowClick developed by the International Fund for Animal Welfare (IFAW) to promote benign and non-invasive research. Benjamin Neal, Scripps Photobiology Group, Scripps Institution of Oceanography lent us the transmissometer. This project was completed with the assistance and cooperation of the Mexican Government (permit SGPA/DGVS/03276/08) and the Upper Gulf of California and Colorado River Delta Biosphere Reserve.

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Table 1. Scientists participating on Vaquita Expedition 2008 including nationality and affiliation. Chief scientists are bolded.

First	Last	Nationality	Affiliation
Barbara	**Taylor**	**United States**	**NOAA Fisheries**
Lorenzo	**Rojas**	**Mexico**	**Instituto Nacional de Ecología**
Tomonari	Akamatsu	Japan	National Research Institute of Fisheries
Jay	Barlow	United States	NOAA Fisheries
Robert	Bistodeau	United States	NOAA Fisheries
Dawn	Breese	United States	NOAA Fisheries (contractor)
Steve	Brown	United States	NOAA Fisheries (contractor)
Gustavo	Cardenas Hinojosa	Mexico	Instituto Nacional de Ecología
Fleming	Alyson	United States	Scripps Institution of Oceanography
Tim	Gerrodette	United States	NOAA Fisheries
Jonathan	Gordon	United Kingdom	University of Scotland, St. Andrews
Julian	Guardido	Mexico	Instituto Nacional de Pesca
Anna	Hall	Canada	NOAA Fisheries (contractor)
Candice	Hall	United Kingdom	Ocean Associates
Chris	Hall	United States	NOAA Fisheries (contractor)
Armando	Jaramillo-Legoretta	Mexico	Instituto Nacional de Ecología
Chris	Johnson	Australia	EarthOcean
Satoko	Kimura	Japan	National Research Institute of Fisheries
Virginia	Leal	Mexico	Instituto Nacional de Pesca
Sarah	Mesnick	United States	NOAA Fisheries
Cornelia	Oedekoven	Germany	Ocean Associates
Rodrigo	Olson	Mexico	NOAA Fisheries (contractor)
Aurora	Paniagua	Mexico	Instituto Nacional de Ecología
Robert	Pitman	United States	NOAA Fisheries
Todd	Pusser	United States	NOAA Fisheries (contractor)
Tracey	Regan	Australia	NRC
Shannon	Rankin	United States	NOAA Fisheries
Denise	Risch	Germany	NOAA Fisheries (contractor)
Brenda	Rone	United States	NOAA Fisheries
Greg	Silber	United States	NOAA Fisheries
René	Swift	United Kingdom	NOAA Fisheries (contractor)
Nick	Tregenza	United Kingdom	Chelonia, Ltd.
Ernesto	Vazquez	Mexico	NOAA Fisheries (contractor)
Omar	Vidal	Colombia	World Wildlife Federation
Tara	Whitty	Ireland	Scripps Institution of Oceanography

Table 2. Line-transect survey effort (nm) for the 2008 survey conducted by NOAA Ship *David Starr Jordan*; survey data for 1997 is included for comparison. Effort (nm) for the 2008 survey; effort for 1997 is included for comparison.

Beaufort	2008	1997
0	78	51
1	579	223
2	574	406
3	211	429
4	117	401
5	72	148
Total	1631	1658

Table 3. Number of sightings by species observed from NOAA Ship *David Starr Jordan* during the Vaquita Expedition 2008.

Species	Common name	No. of sightings
Phocoena sinus	Vaquita	121
Delphinus sp.	Common dolphin	26
Delphinus capensis	Long-beaked common dolphin	9
Tursiops truncatus	Bottlenose dolphin	55
Pseudorca crassidens	False killer whale	1
Orcinus orca	Killer whale	2
Unidentified small delphinid	Unidentified small delphinid	7
Unidentified medium delphinid	Unidentified medium delphinid	4
Unidentified large delphinid	Unidentified large delphinid	2
Unidentified dolphin	Unidentified dolphin	25
Balaenoptera musculus	Blue whale	1
Balaenoptera physalus	Fin whale	10
Balaenoptera edeni	Bryde's whale	10
Balaenoptera borealis/edeni	Sei/Bryde's whale	8
Balaenoptera sp.	Unidentified baleen whale	24
Megaptera novaeangliae	Humpback whale	2
Unidentified large whale	Unidentified large whale	4
Unidentified cetacean	Unidentified cetacean	2
Total		313

Table 4. Description of effort by the R/V *Koipai* during Legs 1 and 2.

Station	Date	Lat	Lon	Effort (hr)	Equipment*	Detections
Leg 1, Station 1	18-Oct-08	31°07.10’	114° 38.00’	19.6		2 probable
Leg 1, Station 2	19-Oct-08	31°14.57’	114° 35.20’	14.6		
Leg 1, Station 3	20-Oct-08	30°51.05’	114° 30.00’	16.1		
Leg 1, Station 4	21-Oct-08	30°57.95’	114° 38.20’	4.4		
Leg 1, Station 5	21-Oct-08	31°07.33’	114° 31.60’	11.6		3 verified; 2 probable
Leg 1, Station 6	24-Oct-08	31°14.85’	114° 30.20’	20.5		1 probable
Leg 1, Station 7	25-Oct-08	31°18.83’	114° 37.30’	19.8		
Leg 1, Station 8	26-Oct-08	31°02.14’	114° 39.80’	11.5		
Leg 2, Station 1	8-Nov-08	31°06.25’	114° 31.60’	12.0	t, c, r	1 verified
Leg 2, Station 2	10-Nov-08	30°58.96’	114° 34.60’	13.8	p, r	
Leg 2, Station 3	18-Nov-08	31°19.07’	114°37.40’	13.5	p, r	
Leg 2, Station 4	18-Nov-08	31°05.43’	114°43.5’	20.01	r, ctd	
Leg 2, Station 5	19-Nov-08	31°06.22’	114°31.6’	25.04	r, ctd-1	1 verified
Leg 2, Station 6	20-Nov-08	31°17.86’	114°25.0’	23.58	r, ctd-1	1 verified
Leg 2, Station 7	22-Nov-08	30°50.84’	114°31.1’	24.31	r, ctd-2	
Leg 2, Station 8	23-Nov-08	31°05.78’	114°34.9’	19.85	r, ctd-2	

* r: rainbow click recording; t: T-Pod; c: C-Pod; ctd: CTD with one package of hydrophones; ctd-1: CTD with separate package of hydrophones used in series of vertical profiles lasting 3 hr each; ctd-2: CTD with separate package of hydrophones used at 1 hr interim sampling at depth.

Table 5. Survey effort and location of vaquita detections by the *Vaquita Express*..

Survey area	Effort (km)	Vaquita events[1]	Single clicks[2]	Total
Vaquita Reserve	551	14	37	51
North shallow	231	3	13	16
West shallow	630	19	50	69
Other	72	0	1	1
Total	1484	36	101	137

[1.] Vaquita events: Click train with ≥ 5 clicks and consistent change in direction
[2.] Single clicks: One click with waveform and power spectra of a vaquita click

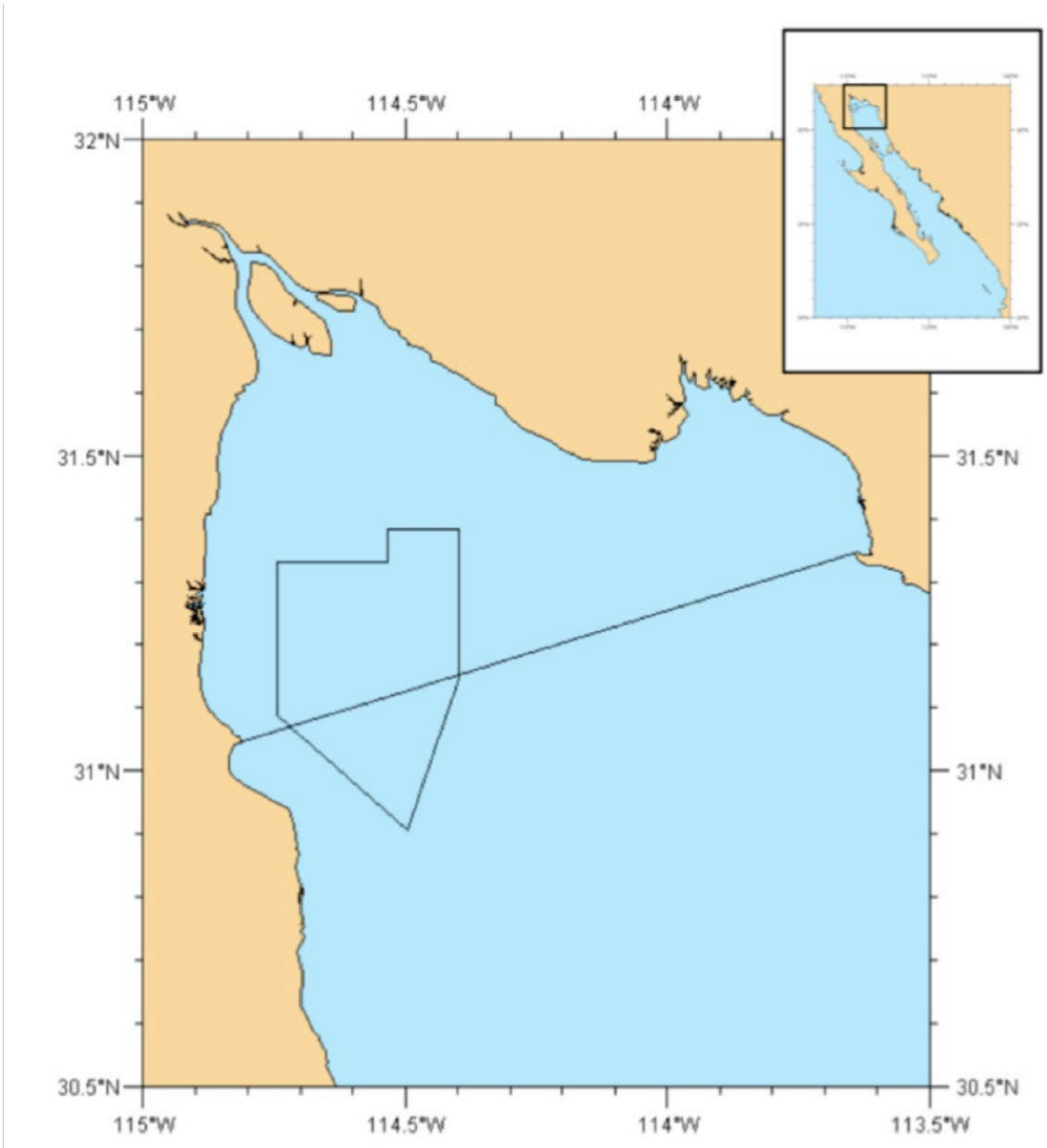

Figure 1. Study area in the Gulf of California. Polygon denotes Vaquita Refuge Area; solid black line is the lower boundary of the Upper Gulf of California and Colorado River Delta Biosphere.

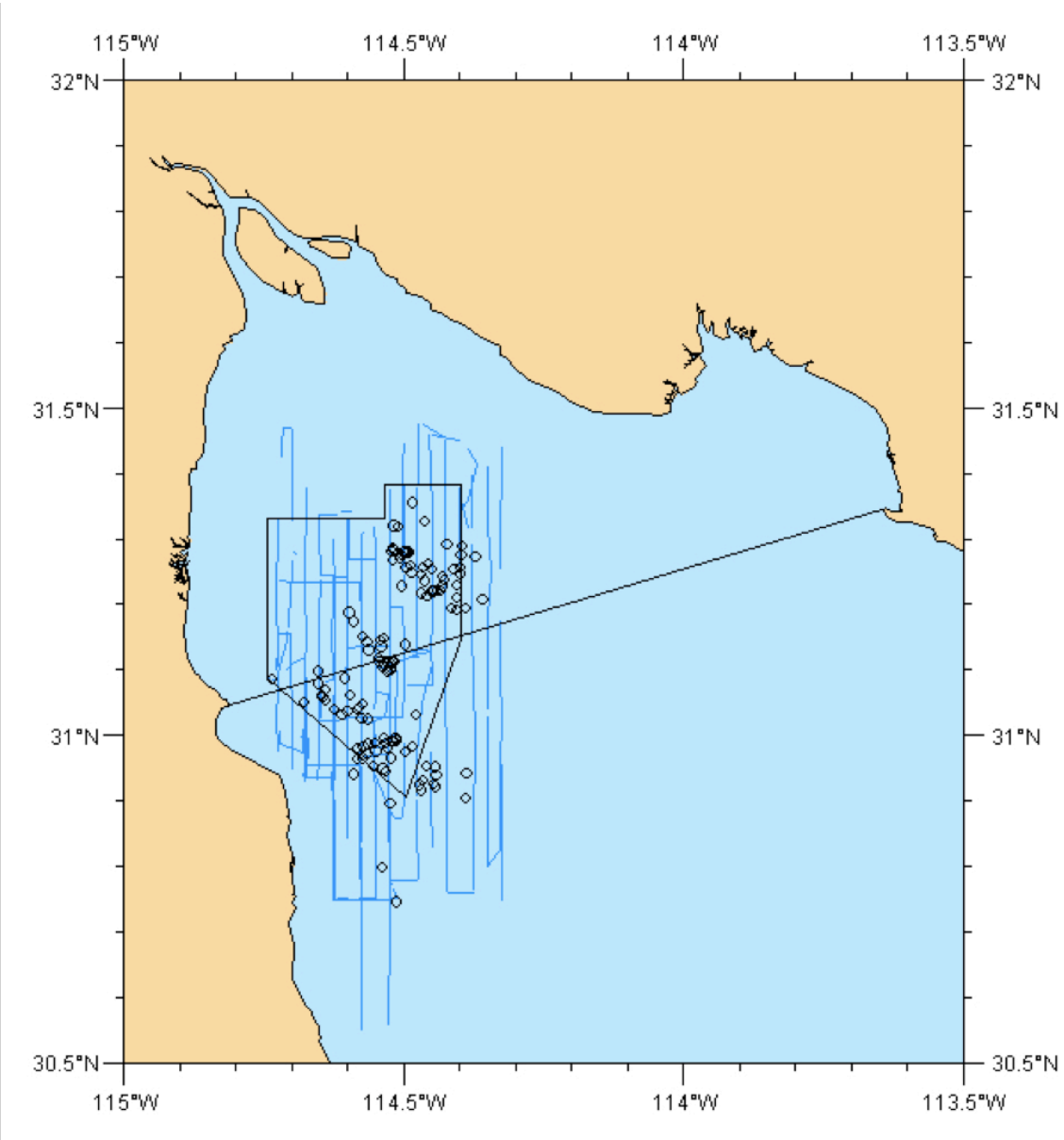

Figure 2. Vaquita (*Phocoena sinus*) sightings overlaid on survey tracklines for NOAA Ship *David* Star Jordan during Vaquita Expedition 2008.

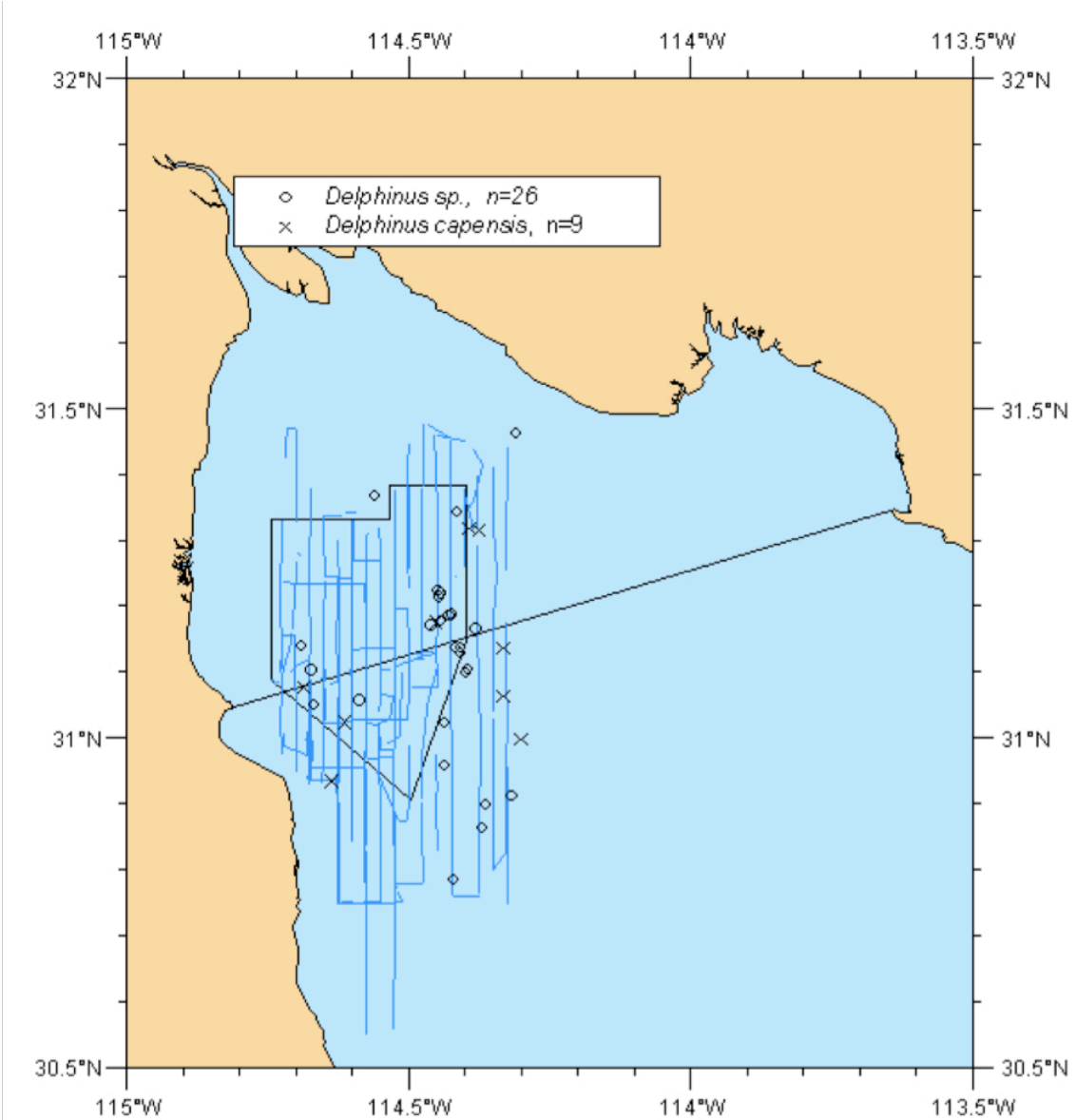

Figure 3. Long-beaked common dolphin (*Delphinus capensis*) and *Delphinus* sp. sightings overlaid on trackline accomplished by NOAA Ship *David Starr Jordan* during Vaquita Expedition 2008.

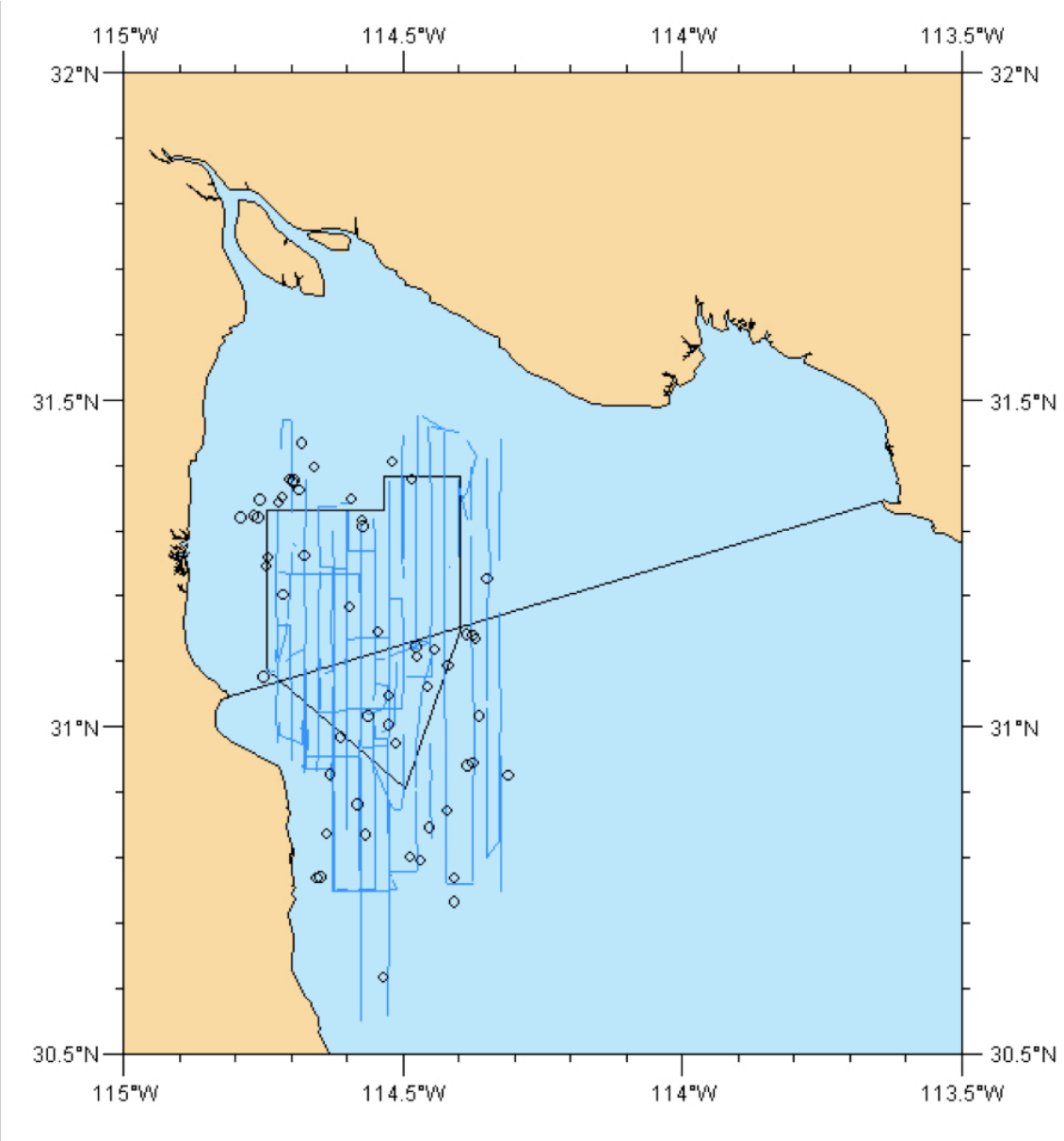

Figure 4. Bottlenose dolphin (*Tursiops truncatus*) sightings overlaid on trackline accomplished by NOAA Ship *David Starr Jordan* during Vaquita Expedition 2008.

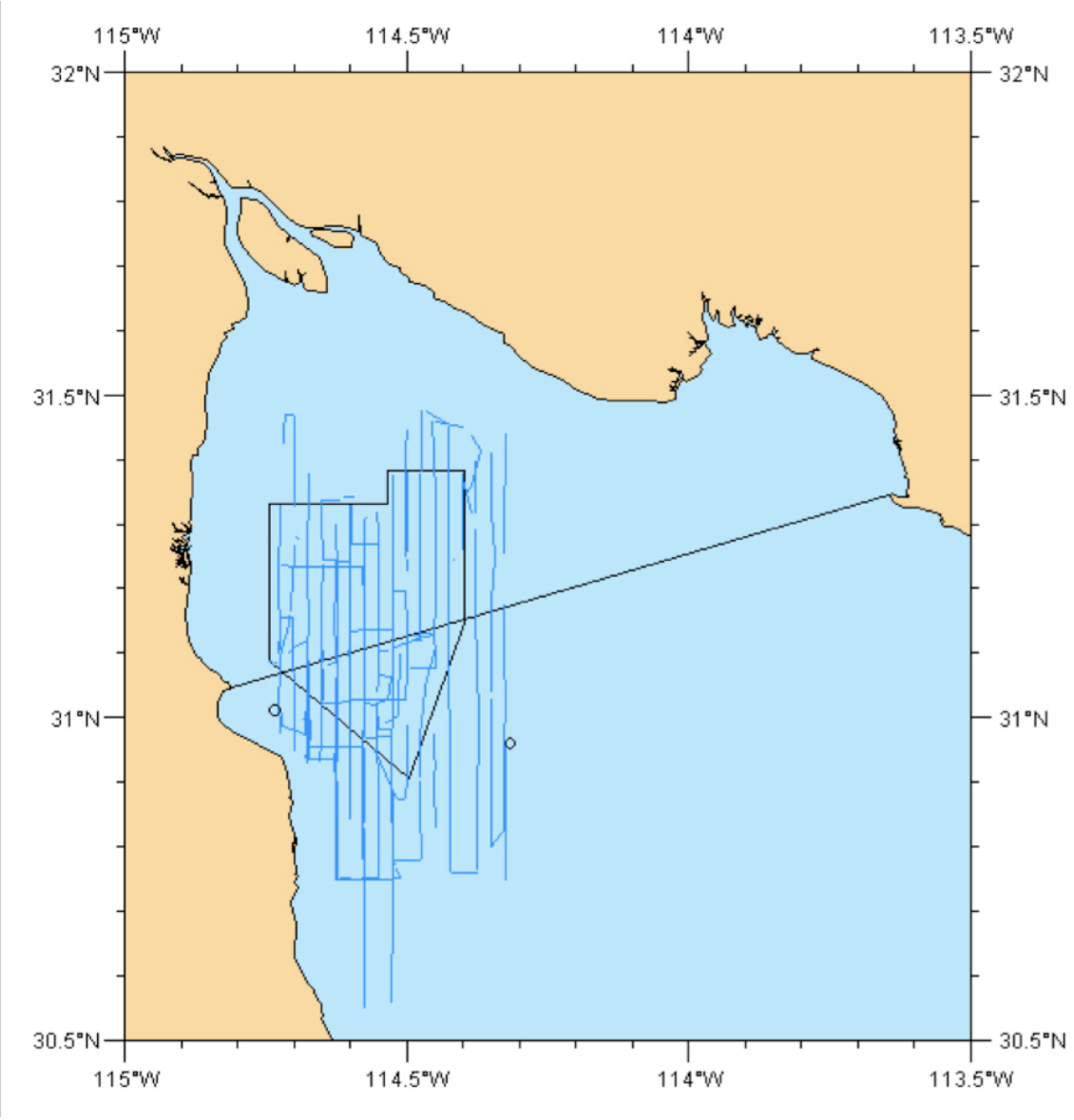

Figure 5. Killer whale (*Orcinus orca*) and false killer whale (*Pseudorca crassidens*) sightings overlaid on trackline accomplished by NOAA Ship *David Starr Jordan* during Vaquita Expedition 2008.

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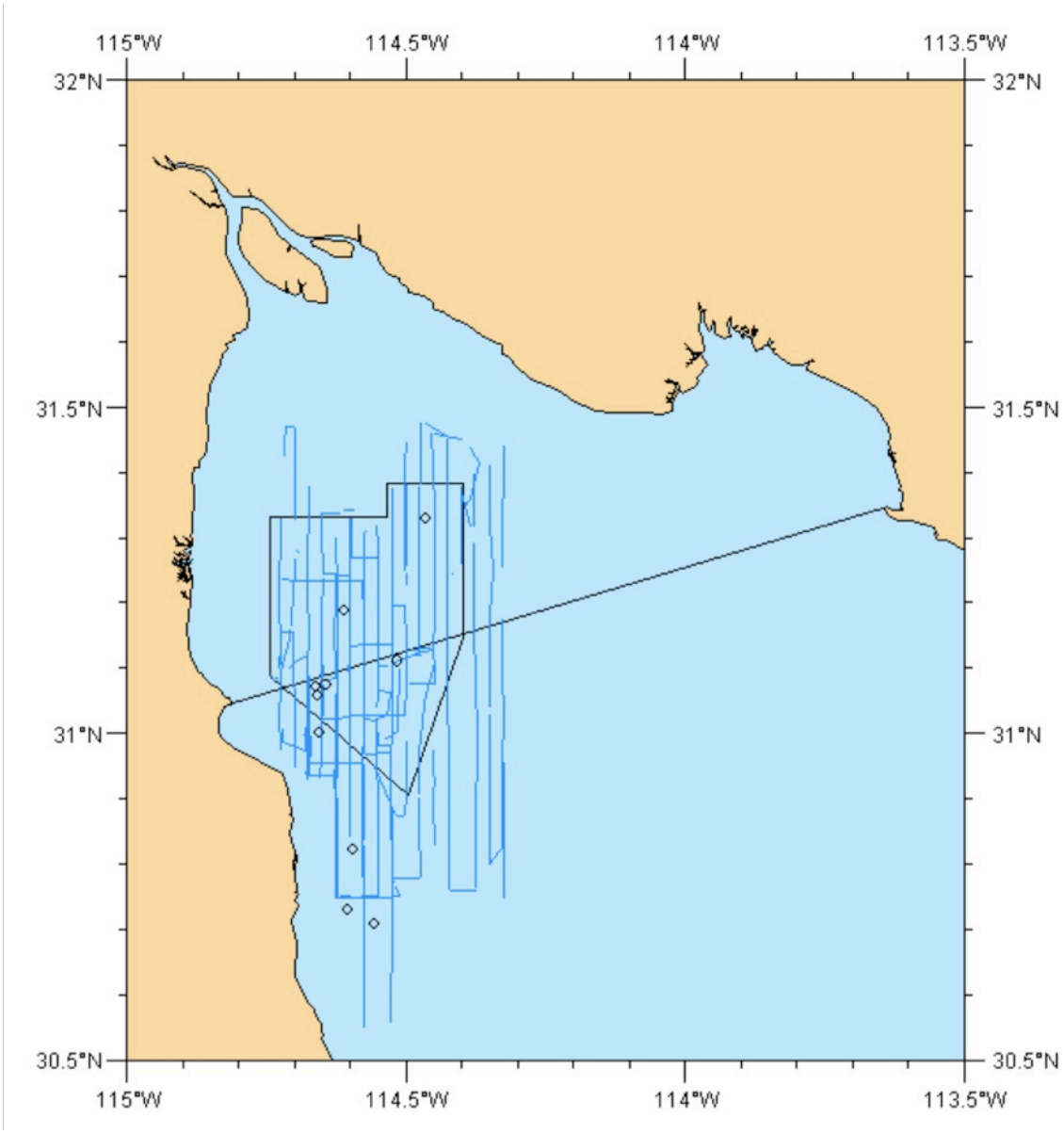

Figure 6. Fin whale (*Balaenoptera physalus*) sightings overlaid on trackline accomplished by NOAA Ship *David Starr Jordan* during Vaquita Expedition 2008.

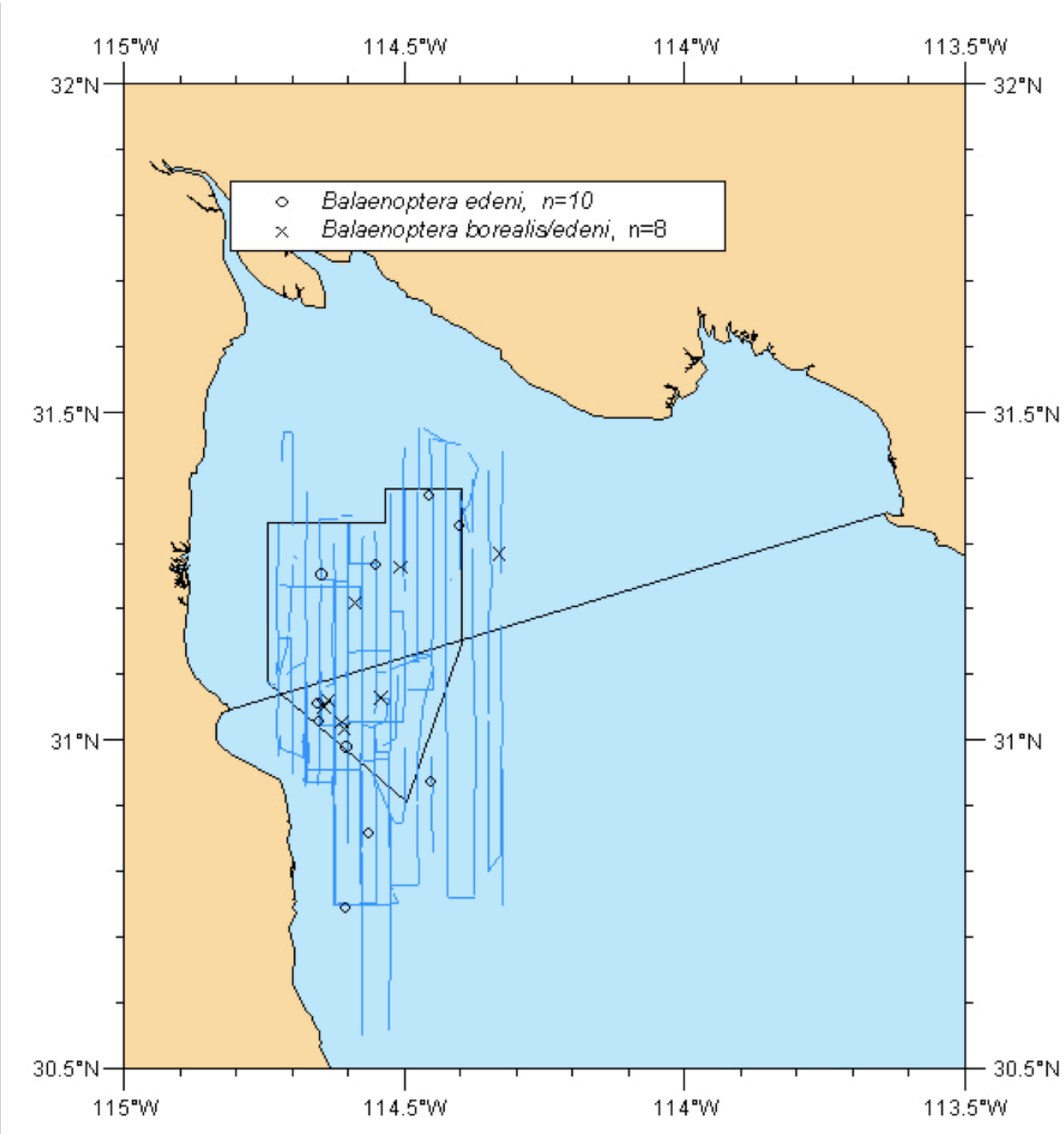

Figure 7. Bryde's whale (*Balaenoptera edeni*) and sei whale (*B. borealis*) sightings overlaid on trackline accomplished by NOAA Ship *David Starr Jordan* during Vaquita Expedition 2008.

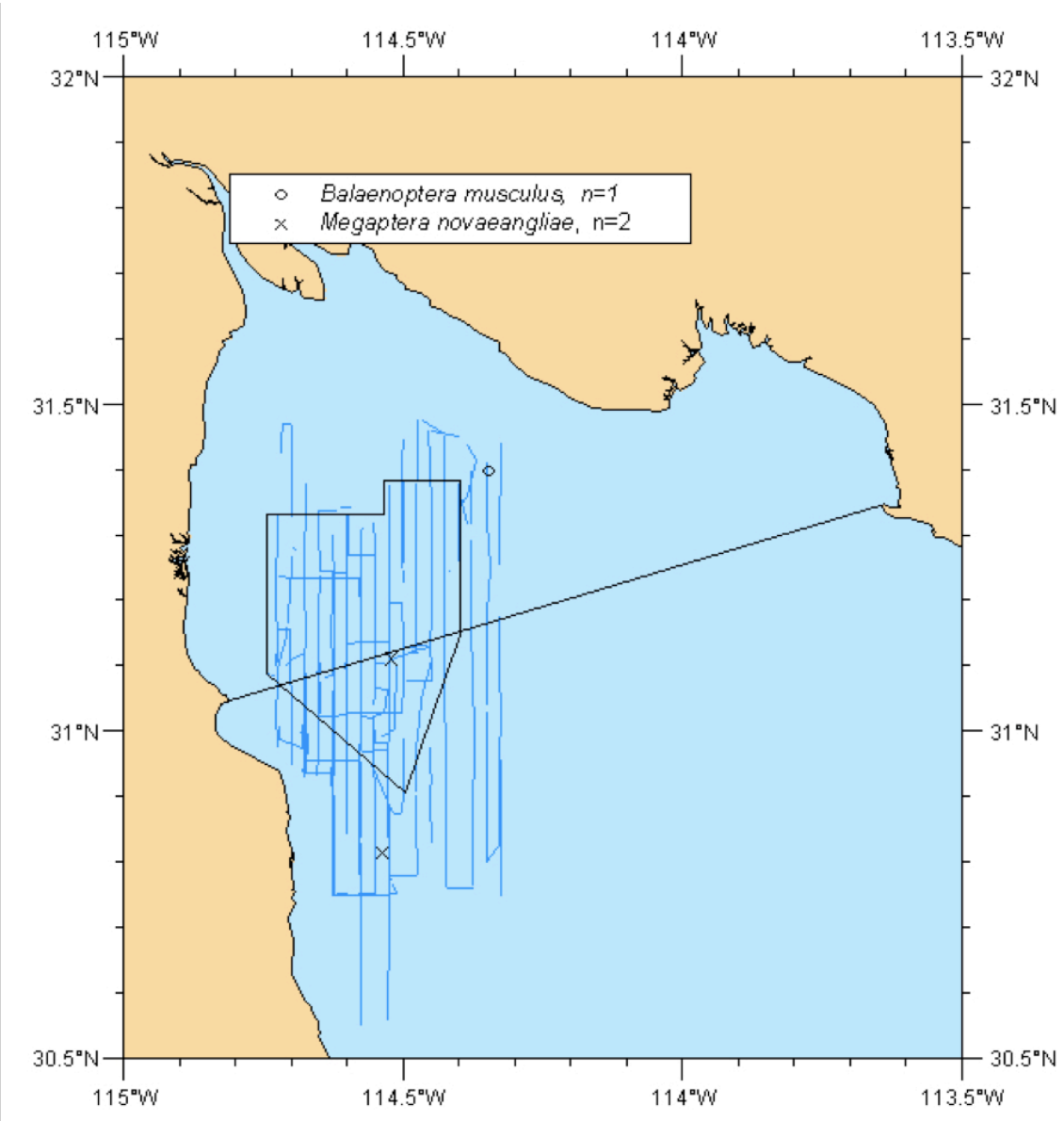

Figure 8. Blue whale (*Balaenoptera musculus*) and humpback whale (*Megaptera novaeangliae*) sightings overlaid on trackline accomplished by NOAA Ship *David Starr Jordan* during Vaquita Expedition 2008.

Figure 9. Photograph of vaquita (*Phocoena sinus*) taken by T. Jefferson; photos taken under permit Oficio No. DR/488/08 from the Comisión de Áreas Naturales Protegidas (CONANP) y Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT), within a natural protected area subject to special management and decreed as such by the Mexican Government. This work was made possible thanks to the collaboration and support of the Coordinador de Investigación y Conservación de Mamíferos Marinos at the Instituto Nacional de Ecología (INE).

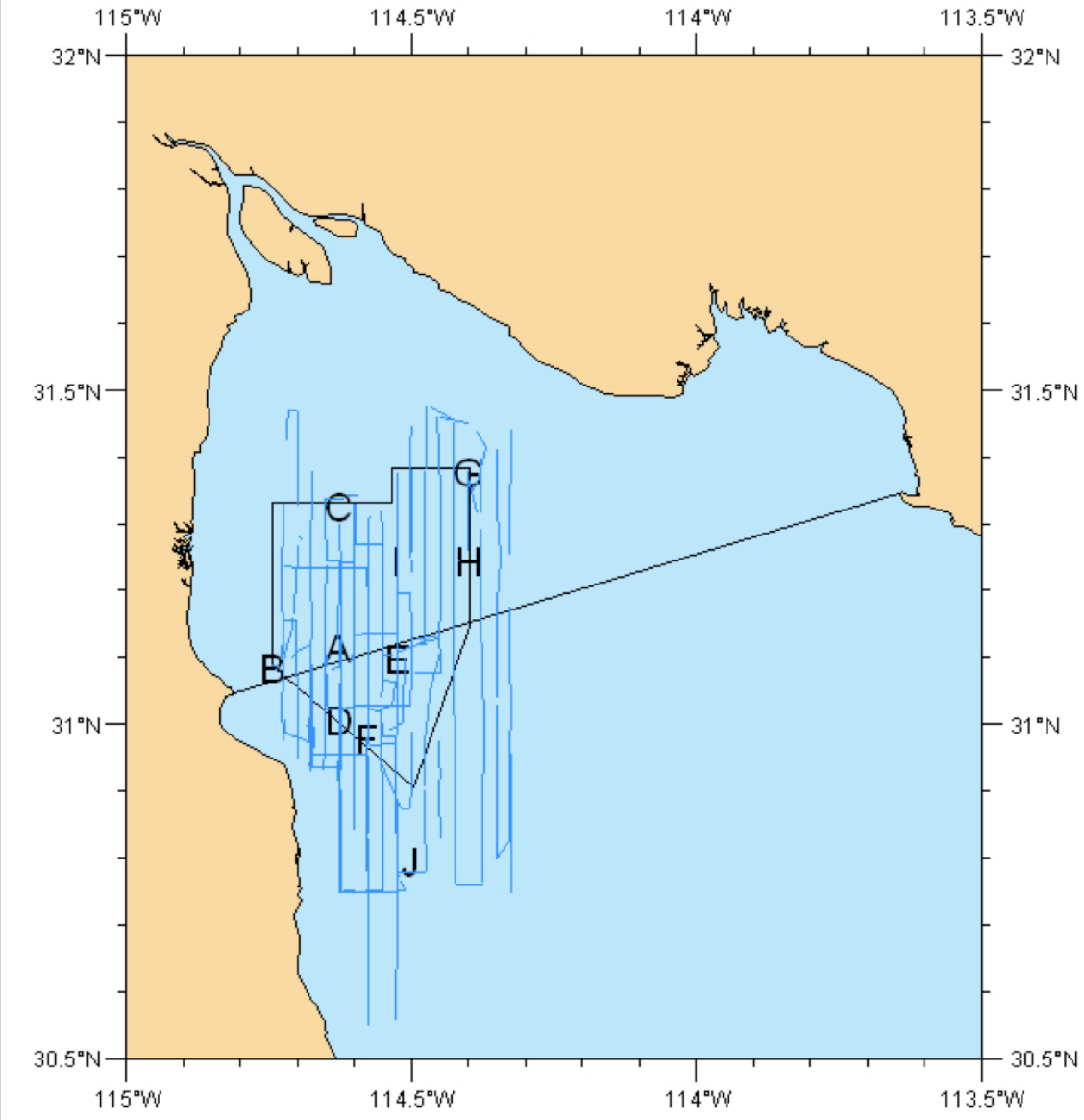

Figure 10. Buoy deployment locations overlaid on trackline accomplished by NOAA Ship *David Starr Jordan* during Vaquita Expedition 2008.

Figure 11.A stationary buoy is launched into the ocean. Various acoustic devices (C-POD, T-POD, and A-tag) were mounted together and suspended in the middle of the water column under the buoy at a series of locations for times ranging from one week to two

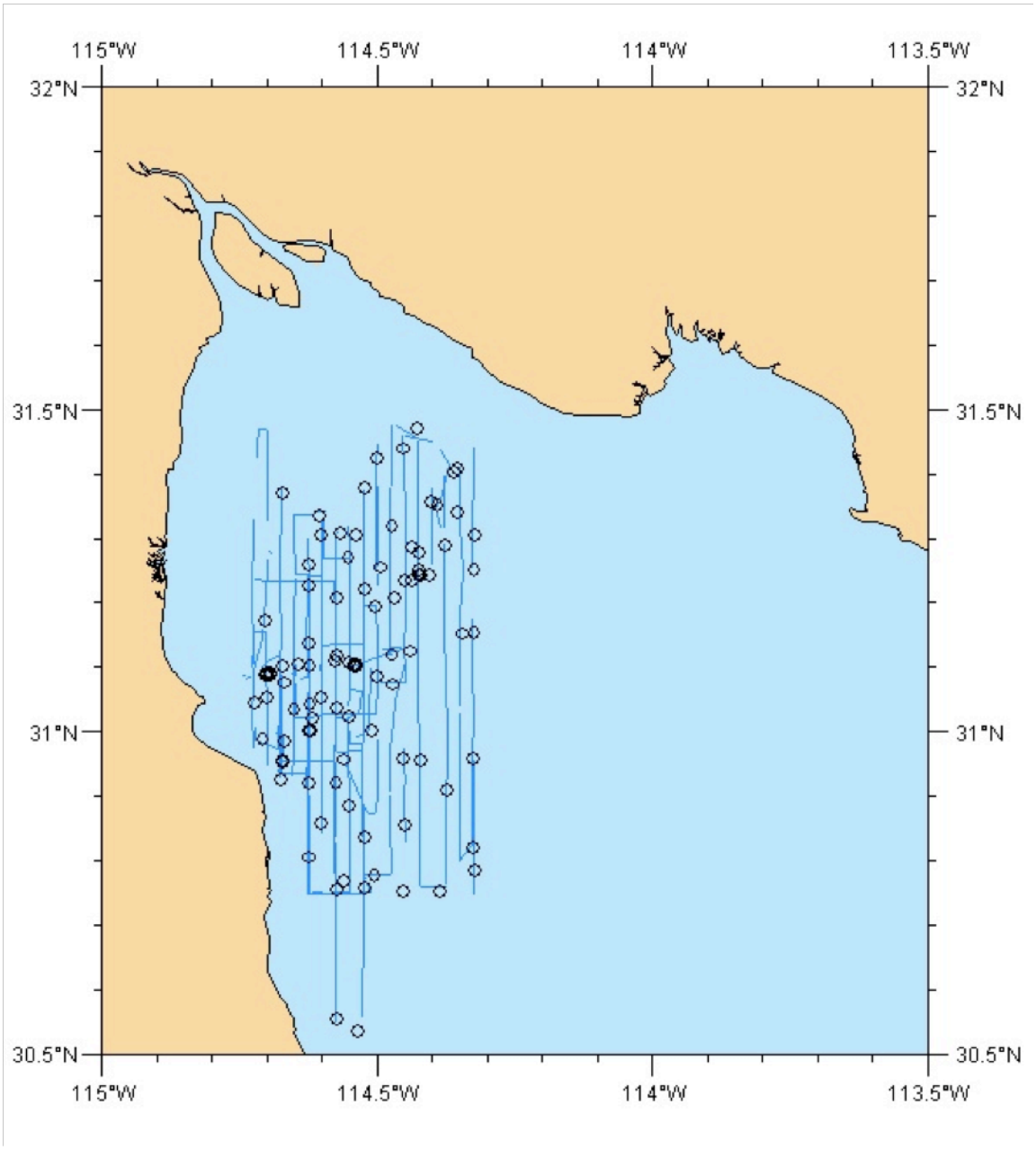

Figure 12. Chlorophyll sampling stations conducted and overlaid on trackline accomplished by NOAA Ship *David Starr Jordan* during Vaquita Expedition 2008.

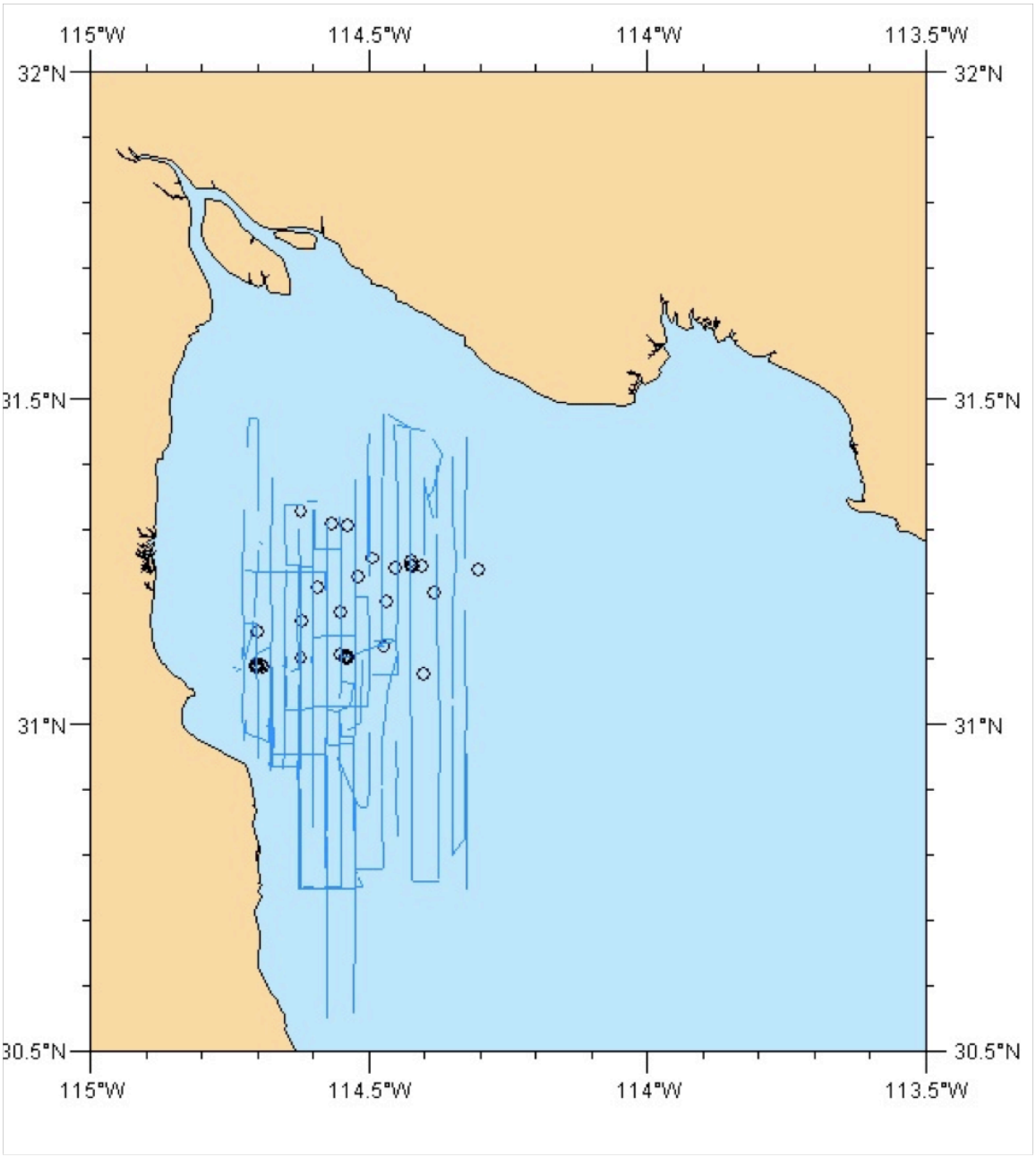

Figure 13. CTD sampling stations conducted and overlaid on trackline accomplished by NOAA Ship *David Starr Jordan* during Vaquita Expedition 2008.

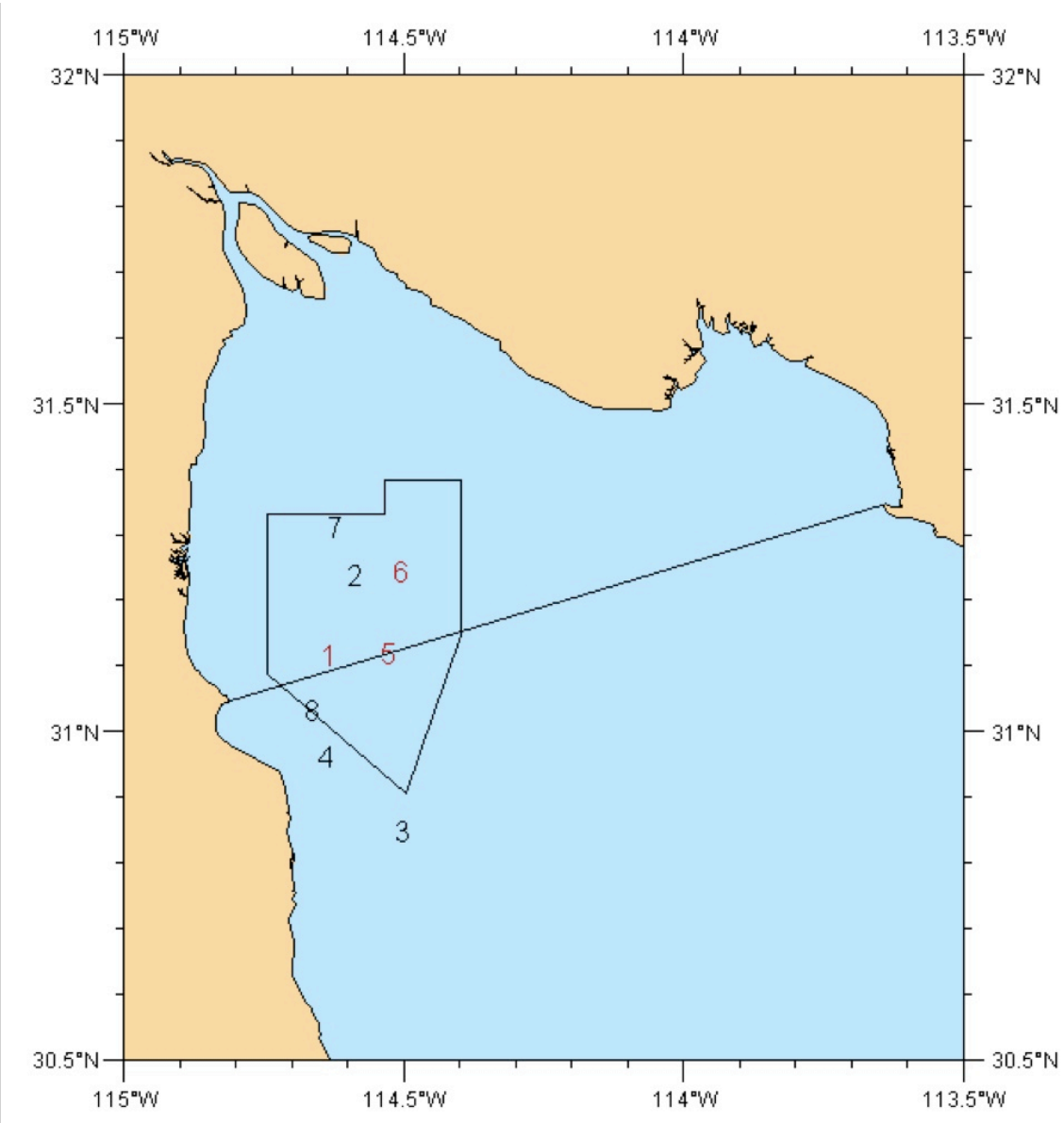

Figure 14. R/V *Koipai* sampling stations (1 through 8) accomplished during Leg 1; the numbers correspond to those in Table 4. The stations in red are where vaquita were detected.

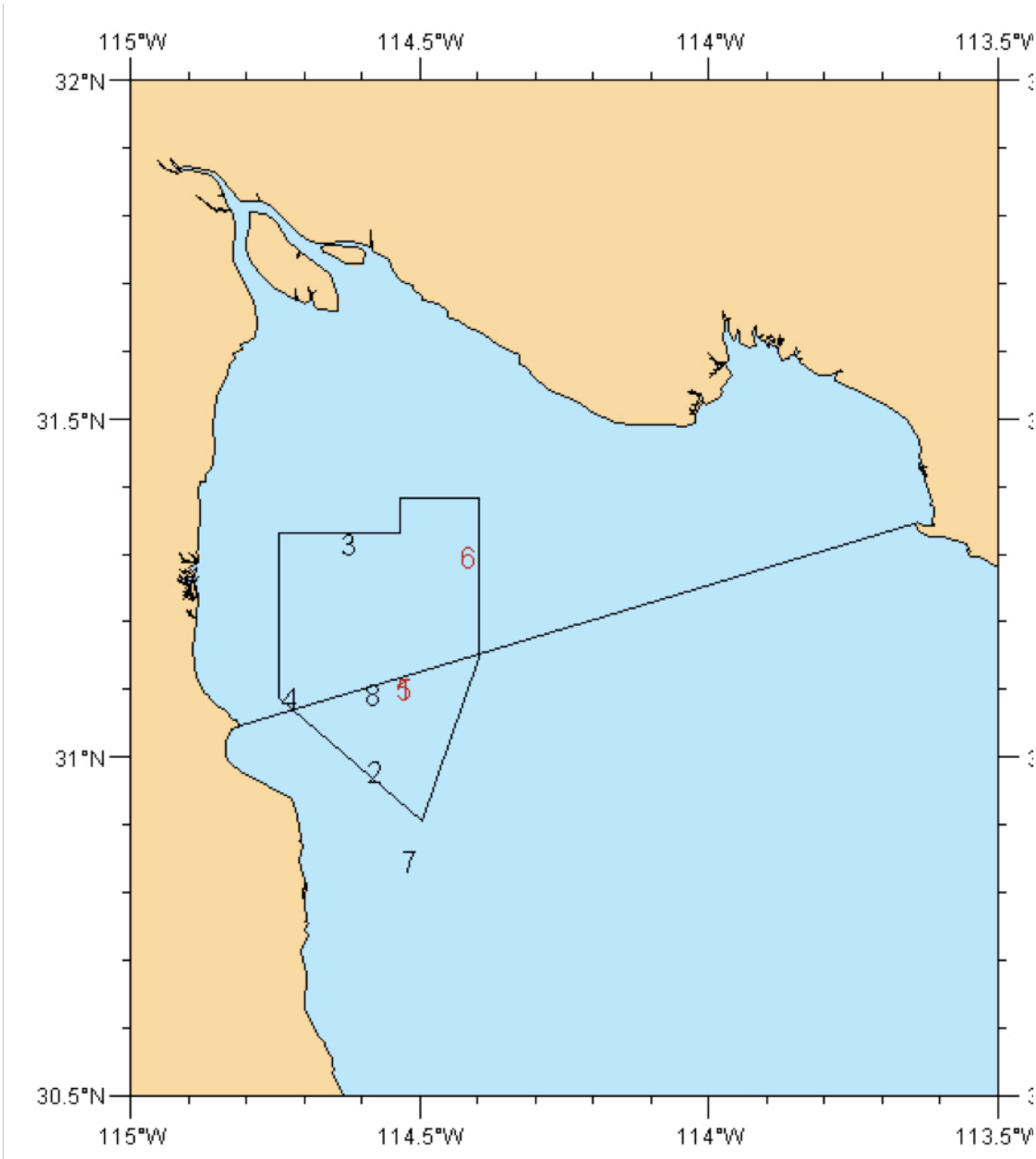

Figure 15. R/V *Koipai* sampling stations (1 through 8) accomplished during Leg 2; the numbers correspond to those in Table 4. The stations in red are where vaquita were detected.

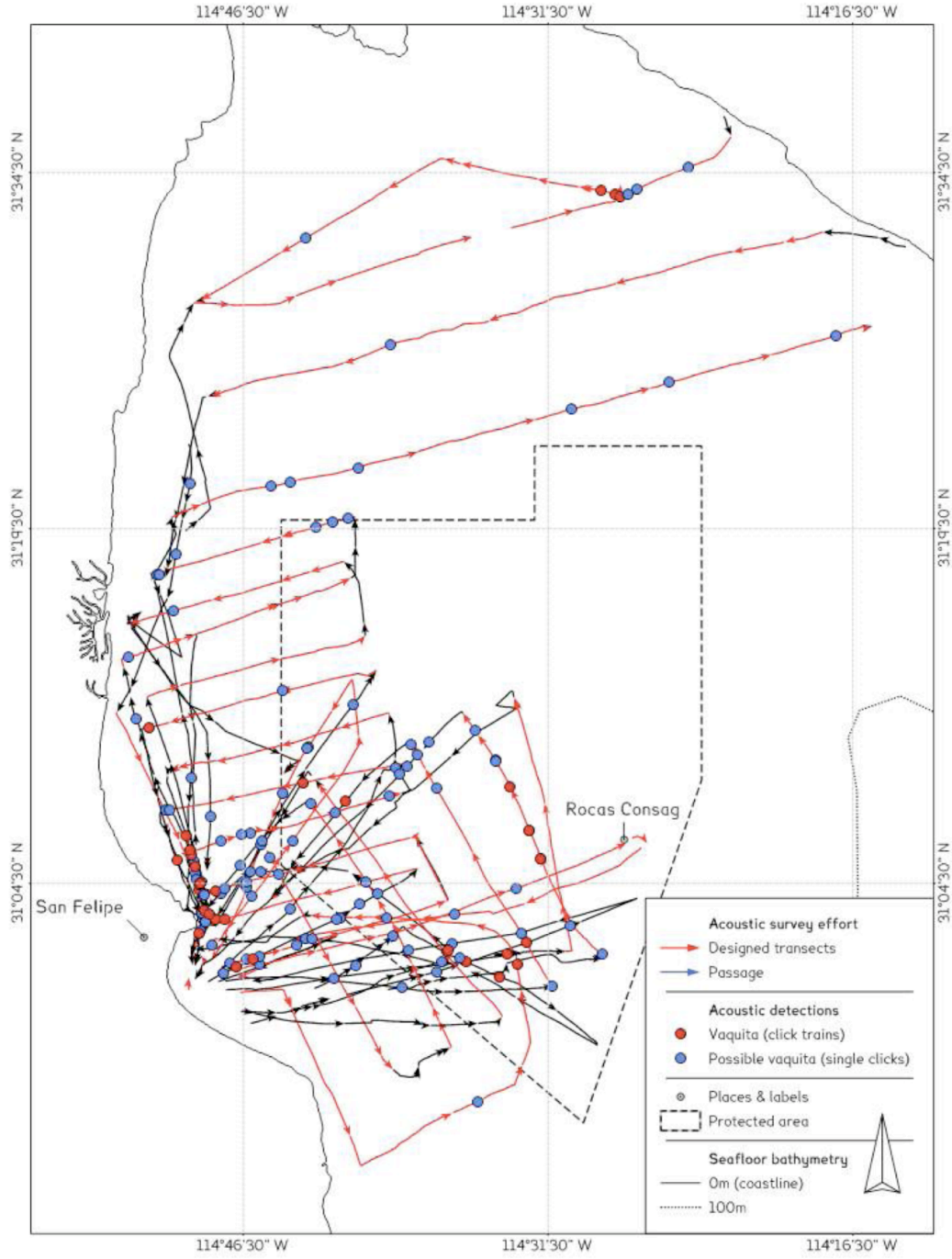

Figure 16. Diagram of acoustic effort and detections by *Vaquita Express*. Cartographer: René Swift.

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