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Data available for an assessment of North Pacific blue whales

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INTERNATIONAL WHALING COMMISSION

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North Pacific blue whale assessment, intersessional email group report.

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Abstract

Blue whales in the North Pacific comprise at least two populations, and possibly three, based largely on song type. The best studied is the eastern North Pacific population that has a reliable catch time series and previous assessment. For the less-studied central and western North Pacific population there are recent surveys and catch data, and many locations where their song type has been recorded including off Hokkaido. Assessments of the central and western population, will be possible once abundance estimates are obtained from the POWER and JARPN/JARPNII cruises. There is also a possible third Japanese population west of 145-155°E, and a unique third song type recorded off Hokkaido at 145°E. This area around Japan was the basis of substantial whaling, followed by a lack of sightings west of 155°E in JSV data in the 1960s to 1980s, and no catches for several decades, leading to the possibility of extirpation being raised. Blue whales have since been regularly sighted in the 145-155°E region during the JARPN/JARPNII cruises, forming a continuous distribution that spans from the site where the new song type was recorded eastwards into the area off Kamchatka. More hydrophones are needed in the region 130-155°E zone to determine the extent of whales making the new song type, to determine the extent and status of this possible Japanese population.

Background

North Pacific blue whales are at present divided into two populations: eastern North Pacific (ENP), and central and western North Pacific (CWNP). They are currently considered to be the same subspecies as blue whales in the North Atlantic, *Balaenoptera musculus musculus*, where blue whales were first described. However, due to their long isolation, it is likely that North Pacific and North Atlantic blue whales belong to different subspecies. An assessment of ENP blue whales was conducted by the SC in 2015 (Monnahan et al. 2014, Monnahan et al. 2015, Monnahan & Branch 2015), and concluded that ENP blue whales were close to recovery, at a median of 97% of carrying capacity (but with wide 95% intervals of 62–99%). However, no assessment has been conducted of CWNP blue whales, and it is possible that in this region, blue whales should be divided into multiple populations for assessment. Here we summarize available data, focusing on CWNP blue whales, building on previous overviews in 2016 and 2018.

Catch data

Sail-based whaling (1780-1920): American whalers during 1780-1920 recorded species of interest to them (sperm, right, bowhead, humpback, gray whales), which have been compiled by a variety of authors, including Smith et al. (2012). It is possible that some records of "sulphurbottom whales" (i.e. blue whales), exist in these data and could be useful for this effort. Notably, a new database (https://whalinghistory.org/participate/download/) includes sightings of blue whales during this era. Very few catches were attempted of blue whales before modern whaling (Tønnessen & Johnsen 1982). Dale Rice (unpubl.) describes several instances of blue whale catches before modern whaling, using a

modified darting gun and bomb lance: (1) in July 1858, Charles Scammon (1874) encountered blue whales off Isla Cedros (off Baja California, Mexico) and killed several; (2) in the summer of 1878, J.N. Fletcher and R.L. Suits used bomb lances to kill 35 whales off San Francisco Bay, including blue whales, fin whales and humpback whales.

Shore-based whaling off Japan: Shore-based whaling off Japan has a long history, and may include some catches of blue whales before modern whaling. A summary of modern catches is presented in Clapham et al. (2008):

> "Blue whales were taken by modern whaling methods off Japan and in nearby waters (including off the Korean Peninsula and in the Kuril Islands) beginning in about 1900. In all, sixteen shore stations were operating at various times between 1906 and 1949, with detailed records available from 1911 on (Kasahara 1950, Kasuya 2002). Although blue whales were killed at all sixteen stations (a total recorded take of 1,248 whales), the majority of catches (>1,000 animals) occurred at four stations along the Pacific coast of Honshu and off eastern Hokkaido (Kasahara 1950). To these figures must be added unrecorded catches between 1906 and 1910, as well as a minimum of forty-seven blue whales taken by net fisheries from 1698 to 1896 (Kasuya 2002). It is difficult to determine when this subpopulation became commercially extinct. Only small numbers of blue whales were taken off southern Honshu after about 1922, while catches off northeastern Honshu and eastern Hokkaido remained substantial until the late 1940s; for the purpose of this paper, we have somewhat arbitrarily taken 1948 as the point of terminal decline."

Clapham et al. (2008) concluded that the Japanese population was eventually extirpated based on the lack of sightings in the JSV database (Miyashita et al. 1995), although there have been more recent sightings during JARPN and JARPNII operations off eastern Hokkaido.

Modern whaling catches (1905-1971): catches are available from the IWC's annual catch database and individual catch database, and are summarized and analyzed in Monnahan et al. (2014), where they are separated between ENP and CWNP populations by assuming that recent acoustic records of the song types represent the regions occupied by each population (Table 1, Figures 1-2). An additional 17 catches have been uncovered since then, all from Soviet operations 178-1159 km off the coast of Washington and Oregon in July-September 1972 (Ivashchenko et al. 2017), which have been added to ENP in Table 1. It should be noted that the CWNP grouping may comprise more than one population, which would require further separation of the available catches.

Sources of mortality: ship strikes

A new paper (Rockwood et al. 2017) provides a best estimate of 18 blue whales per year being struck and killed by ships in the U.S. West Coast EEZ (federal waters off Washington, Oregon and California) for the 6 months from July to December. This result assumes moderate levels of avoidance behavior by whales and defines the vertical strike zone in the water column as equal to the draft of a ship. The predicted strikes are more than the 10 deaths per year in year 2013 used in Monnahan et al. (2015) as a base case, but less than the 35 per year tested in a sensitivity analysis in Table 3 of that paper. Rockwood et al. (2017) also ran an additional scenario of their model in which whales were assumed to 1) show no avoidance and 2) have a risk zone twice the draft of a vessel (following research in Silber et al. 2010). That model predicted 58 blue whale deaths per year. Monnahan et al. investigated the effects of annual ship strike mortality up to 100 per year (Fig S3 of Monnahan et al. 2015), allowing the estimates from Rockwood et al. to be taken from the paper. For the best estimate of 18 deaths,

abundance predicted by Monnahan et al. was 95% (90% CI 57–97%) of pre-whaling levels in 2013 and 93% (95% CI 61–96%) of pre-whaling levels in 2050 under assumptions about the growth in ship traffic over time. Assuming the higher estimate of 58 deaths, abundance was 85% (95% CI 43–90%) of pre-whaling levels in 2013 and 75% (95% CI 25–86%) of pre-whaling levels in 2050. Rockwood et al. note several caveats to their predictions which would proportionally increase both model predictions: 1) the model excludes some mortality which likely occurs at low levels in southern California during January to June and 2) it excludes strike deaths that occur outside the U.S. EEZ. In addition, the estimates of shipping traffic in Monnahan et al. (2015) could be further refined in future work.

Sources of mortality: strandings

A dead male blue whale calf washed ashore at Kamakura, Kanagawa Prefecture, measuring 10 m in length, in August 2018, with identification confirmed (Brownell pers. comm.). Reported genetic data was closely related to NEP blue whales (Sugimoto 2019).

Acoustic detections of song types

Acoustic detections of blue whales in the North Pacific were compiled by Monnahan et al. (2014) and used to separate catch data. Until recently, two main song types were thought to occur in the North Pacific (e.g. McDonald et al. 2006, Oleson et al. 2007, Stafford 2003, Stafford et al. 1999a, 2001, 2007, Širović et al. 2015), which were used to separate the ENP and CWNP populations. It should be noted that some of the positions of the recorders used in Monnahan et al. (2014) are highly uncertain, as they represent Navy SOSUS arrays and the positions are confidential. No acoustic recorders were available for Japan and much of the central and western North Pacific, with the most notable gap being off Japan, which is the most likely location for a population of blue whales separate from those in the central North Pacific, Aleutian Islands and Gulf of Alaska (Figure 3).

Analysis of acoustic data from Southern California, off Washington state, and Gulf of Alaska revealed variability in the NE Pacific blue whale song across sites, possibly indicating fine-scale structure in the NE Pacific population (Širović et al. 2016, Širović et al. 2017). Recordings from Hawaii (off Kona, Big Island of Hawaii), Wake, and Northern Marianas (Tinian) had rare occurrence of blue whale calls. These calls were different from the NE Pacific calls (Širović et al. 2016) and will be referred to as the central-western Pacific blue whale calls. An additional, new acoustic song type has been identified off Hokkaido, Japan, with limited range of occurrence and a peak in January and September (McDonald et al. 2017, Figure 4). Preliminary analysis of those data revealed that, in addition to the new, previously unreported song type, central-western Pacific song type was also present. Thus, based on acoustic data, at least three distinct blue whale song types are found in the North Pacific. However, further investigations are needed into the central-western Pacific song to identify whether fine-scale variability may also be present in this song type. It is possible that additional variants of the songs may imply as many as five distinct populations (Figure 4). Acoustic data have been recorded off Saipan and Tinian in the Northern Mariana Islands since 2010 and 2011, respectively, by NOAA's Pacific Islands Fisheries Science Center and could be analyzed more thoroughly for the presence of blue whale songs in recent years.

Morphometric data

There is good evidence that sexually mature female CWNP blue whales are 0.8-1.0 m longer than ENP blue whales (Monnahan et al. 2014, Figure 5). Similar differences were found in historical catches by Gilpatrick and Perryman (2008).

Ageing data

One source of age data for blue whales in the North Pacific were collected by Dale Rice from whaling stations around San Francisco (Rice 1963), and the resulting database is curated by Sally Mizroch. In brief, 20 blue whales were examined, 7 males, 13 females. Of these, ear plug growth layers were counted for 18 blue whales (range 6-46 ear plug layers), and are consistent with an age at maturity between 9 and 11 years (assuming one growth layer per year). Corpora data from the females are consistent with 0.46-0.50 corpora being added per year of age after the age at maturity (Rice 1963). In addition, a single stranded 21.2 m male blue whale from California was reported to have 24 ear plug layers and an age at maturity of 10 yr (Trumble et al. 2013). In addition, there were 8 blue whale ear plugs read by Japanese researchers in the North Pacific (Hikari Maeda, pers. comm.) that have been supplied to Branch. A joint paper is planned on all of these data.

Photo-id mark-recapture

Extensive photo-id catalogues containing around 2,000 individually identified blue whales are available for the ENP population from Cascadia Research Collective mostly off California to British Columbia (Calambokidis & Barlow 2004, Calambokidis et al. 1990, Calambokidis et al. 2009), with further identifications in the Gulf of California (e.g. Gendron et al. 2015, Sears et al. 2013) and the Costa Rica Dome (Olson & Gerrodette, SWFSC, unpubl.). Numerous resightings have been obtained from these catalogues, which have been used to estimate abundance (e.g. Calambokidis & Barlow 2004), examine distribution and movements (Calambokidis et al. 2009), and estimate population parameters such as survival and inter-calf intervals (Sears et al. 2013).

For the CWNP population, a photo-id catalogue is being developed by the Japanese Institute of Cetacean Research (ICR) based on JARPN/JARPNII surveys conducted during 1994-2016. Photographs were taken of 107 schools of blue whales during the surveys in 1994-2014.

The POWER cruise took photo-id for 15 individual blue whales during 2010–14, which have been matched to both the Cascadia catalog and the Gendron catalog, with no matches found (Anon 2017, p. 210). Photo-id for a further 6 blue whales were obtained in 2018 (45-50°N, 155-165°E) during transit (Matsuoka et al. 2019) but have not yet been matched to existing catalogs.

Discovery marks mark-recapture

Discovery marks (metal cylinders with unique identifying numbers) were fired in blue whales in the 1950s and 1960s. Although 16 recaptures were reported in the literature, precise recovery locations are available for only 15 recaptured during whaling operations (Omura & Ohsumi 1964, Ivashin & Rovnin 1967, Ohsumi & Masaki 1975), although Soviet researchers almost certainly did not report all of the marks that were recovered. All of these were placed by Japan or the USSR. The recaptures show movements from the Gulf of Alaska to the Sea of Okhotsk, and from British Columbia to south of Kodiak Island (Figure 6, Table 2). Recaptures also include length, sex, occasional ovary weights, and one age record of 34 years for a 23.3 m female marked and recaptured in the Gulf of Alaska. All marks placed close to Japan were recaptured off Japan. In addition, 113 marks were placed by the US during 1965-1969 off Mexico (Figure 7), but no recoveries were recorded.

These data are consistent with a population in the central and western North Pacific, although with the small sample sizes, movements between Japan and the remainder of the CWNP cannot be excluded.

Genetic studies and data

Substantial genetic samples have been obtained and several analyses conducted on the ENP population. Conway (2005) compared nuclear genetic variation among ENP, western North Atlantic, southern Indian Ocean, and Antarctic populations. LeDuc et al. (2017) compared microsatellite and mtDNA sequences from the ENP and Southern Hemisphere, showing that ENP blue whales are genetically differentiated from Chilean blue whales. Results of genetic analyses of samples collected from blue whales in the eastern Tropical Pacific (Torres-Florez et al. 2014, LeDuc et al. 2017) were consistent with acoustic and photo-identification data showing that ENP blue whales range at least as far south as the Costa Rica Dome (8-11°N), while Chilean blue whales use the waters off Peru, Ecuador and Chile (northward to 1-2°S) during the austral fall and winter (Stafford et al. 1999b, Chandler and Calambokidis 2004, Buchan et al. 2015, Torres-Florez et al. 2015). It should be noted that blue whales are present at the Costa Rica Dome year-round (Reilly and Thayer 1990), although the question of whether this is represented by the seasonal presence of alternating Southern and Northern Hemisphere populations and/or a resident population is yet to be resolved. Southwest Fisheries Science Center surveys conducted June to September between 1986 and 2006 in the eastern tropical Pacific (Figure 8, Branch et al. 2007, Hamilton et al. 2009) show a corresponding gap in sightings between these two regions. One individual has been documented to cross the equator (Douglas et al. 2015), and it is possible that some overlap of the two populations may occur between 1°S and 8°N.

For the CWNP region: One biopsy sample was collected as part of SPLASH south of the Aleutians, at a time when nearby acoustic recordings during the biopsy effort indicated that central-western Pacific blue whales were nearby (Rankin et al. 2006). Fifteen samples have been obtained from the IWC-POWER surveys (Table 5 in IWC 2017; Matsuoka et al. 2019); seven of these (collected up to 2012) have been included in an in-progress genetic study focused on evaluating subspecies taxonomy in blue whales (Lang, pers. comm.). Nine samples were obtained from JARPN and JARPNII cruises, but no genetic analyses have been conducted on these samples.

A high priority for the IWC should be a study comparing genetic variation in blue whales among regions in the North Pacific, particularly those close to Japan, in the central North Pacific, in the Gulf of Alaska where acoustic call types overlap, and in the coastal region from Mexico to British Columbia. This research should be a high priority for evaluating stock definition. However, the genetic data currently available are not sufficient to separate populations, and future sample collection efforts should, when possible, include simultaneous collection of acoustic data.

Satellite tagging data

Eastern North Pacific (1999-2009): satellite tags have been deployed on more than 100 blue whales resulting in usable tracks from 87 ENP blue whales (Figure 9). All of the tagged individuals remained in the eastern North Pacific, ranging from the eastern tropical Pacific to the Gulf of Alaska, and likely delineate the current range of the ENP population.

There are no known satellite tag deployments in the central and western North Pacific.

Sources for abundance estimates

Japanese Whale Research Program under Special Permit in the North Pacific, JARPN & JARPNII (1994-1999, 2000-present): sightings of blue whales during scientific whaling, with most effort and all sightings 140-170°E and 35-50°N (Figure 10a), with results reported in Matsuoka et al. (2015) and Hakamada and

Matsuoka (2016). Some of the individual sightings are close to the hydrophone that recorded a possible third blue whale call type (Figure 10b). Blue whales were mainly distributed north of 35°N and east of 157°E (374 schools and 508 individuals). Mean school size was 1.23 including 23 mother-and-calf pairs, with an apparent northward movement of whales between May and August. Annual abundance estimates ranged from 38 to 958 during 2008-2014 (Hakamada & Matsuoka 2016).

Soviet surveys: blue whale data were extracted from the digitization of Soviet sighting surveys and catches (Ivashchenko & Clapham 2018). These show a much broader distribution of blue whale sightings than was previously known, including some catches in the Bering Sea, and one north of the Bering Strait, in addition to blue whale sightings west of Hokkaido, scattered locations south of the hydrophone location, and catches and sightings around Hawaii and other low latitudes in the western and central North Pacific around 20-25°N (Figure 10c). Catches in the Sea of Japan and Sea of Okhotsk are also of interest.

IWC Pacific Ocean Whale and Ecosystem Research, POWER (2010-2018): designed to cover the region 170°E to 135°W, and 20°N northwards through to the Eastern Bering Sea (e.g. Matsuoka et al. 2018). There were 20 blue whales sighted 2010-2018 during 20,622.8 n.miles of primary search effort; of which none were north of the Aleutian Islands, and only one was south of 40°S (Figure 12). In addition, during transit in 2018, 8 schools (12 individuals) were sighted south-east and south of the Kamchatka Peninsula (45-50°N, 155-165°E).

Gulf of Alaska surveys (2009, 2013, 2015): blue whales were sighted in the Gulf of Alaska in 2015 during line transect surveys (Figure 12; Rone et al. 2017). Each year surveyed a somewhat overlapping region, with abundance estimates for blue whales of 0 in 2009, 63 (CV = 0.76) in 2013, and 59 (CV=0.58) in 2015 (Rone et al. 2017). These surveys provide more intensive search effort in an area lightly traversed by the IWC-POWER surveys.

Yushin-Maru No. 3 survey (2010): 35-40°N and 157°E-170°W (June-July), and 32-37°N and 145°E-180° (July-August). Saw and photographed 17 blue whale schools, taking 255 photographs (Matsuoka et al. 2011, Figure 13). Blue whales were recorded in greatest concentrations in the eastern portion of this survey.

Aleutian Islands surveys (1994, 2001, 2002, 2003): no sightings of blue whales on these surveys off the Aleutian Islands and Alaska Peninsula, despite surveys being in areas where blue whales were caught during the whaling era (Zerbini et al. 2006, Figure 14; Forney & Brownell unpubl. 1994). The paper also lists other surveys in the same region that also sighted no blue whales.

Japanese Scouting Vessel, JSV (1965-1987): there are extensive sightings and effort data from Japan to the Gulf of Alaska (Figure 15).

PIFSC surveys: a large number of surveys have been conducted in the EEZ of the Hawaiian Islands, Guam, Mariana Archipelago and other islands in the Pacific Ocean (Figure 16), similar to those described in Bradford et al. (2017), under the following names: HICEAS, PICEAS, PACES, MACS, American Samoa, Main Hawaiian Islands, and Hawaii to Guam. One blue whale was sighted in the Hawaiian Islands EEZ and an additional four blue whales were sighted between Hawaii and the US mainland off-effort or during transits, suggesting a very low density of blue whales in these regions during survey periods.

Acania cruise: in 1991 the diesel yacht *R/V Acania* cruised over much of the North Pacific, sighting blue whales on three occasions, two of which were mother-calf pairs (Hobbs 1991).

The JARPN, JARPNII and IWC-POWER surveys collectively cover nearly all of the region from 140°E-135°W and north of 20-35°N to the Aleutian Islands, and are supplemented by the Gulf of Alaska, Aleutian Islands, Yushin Maru No. 3 surveys, and those around the Hawaiian Islands. Abundance estimates could be obtained from these sources covering most of the historical range of CWNP blue whales. The JSV data and historical catches provide additional information that could be used to extrapolate abundance estimates to regions not covered by JARPN, JARPNII and IWC-POWER.

Priority items

1. Obtain abundance estimates from the IWC-POWER surveys.
2. Obtain abundance estimates from the JARPN and JARPNII surveys.
3. Analyze and compare genetic samples from ENP, IWC-POWER, and ICR biopsy samples to determine stock structure throughout the North Pacific.
4. Comparison of photo-id including new 2018 photos between POWER, Cascadia Research Collective and other ENP catalogues and JARPN/JARPNII catalogues (no matches between POWER and ENP catalogues)
5. Review new acoustic locations and information and conduct fine-scale analysis of song features for central Pacific blue whale calls, with particular focus on calls around Japan.
6. Obtain better life history parameters from the Sears and Gendron photo-ID dataset.
7. Mapping of older catches (prior to 1920) in Japanese waters, especially west of 145°E.

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Table 1. Estimated annual catches for eastern North Pacific (ENP) and central and western North Pacific (CWNP) blue whales. In gray are the 95% intervals taking into account uncertainty about catch location, month, and the split between ENP and CWNP. In all, 35% (95% 27-42%) of all North Pacific catches of blue whales came from the ENP. Source for 1905-1971 catches: Monnahan et al. (2014); for 1972 catches, Ivashchenko et al. (2017).

Year	ENP		CWNP		Total
1905	1	(1-1)	73	(73-73)	74
1906	54	(40-60)	129	(123-143)	183
1907	45	(33-51)	188	(182-200)	233
1908	82	(62-92)	231	(221-251)	313
1909	53	(42-59)	145	(139-156)	198
1910	90	(68-102)	162	(150-184)	252
1911	165	(123-189)	285	(261-327)	450
1912	155	(115-182)	364	(337-404)	519
1913	41	(30-51)	113	(103-124)	154
1914	153	(134-165)	172	(160-191)	325
1915	25	(17-33)	103	(95-111)	128
1916	27	(19-36)	130	(121-138)	157
1917	44	(27-61)	191	(174-208)	235
1918	39	(26-52)	98	(85-111)	137
1919	43	(31-55)	118	(106-130)	161
1920	38	(27-50)	108	(96-119)	146
1921	0	(0-0)	53	(53-53)	53
1922	18	(10-27)	100	(91-108)	118
1923	54	(39-64)	72	(62-87)	126
1924	54	(41-64)	81	(71-94)	135
1925	181	(172-187)	76	(70-85)	257
1926	251	(245-253)	51	(49-57)	302
1927	169	(162-175)	54	(48-61)	223
1928	339	(310-357)	89	(71-118)	428
1929	275	(254-288)	72	(59-93)	347
1930	79	(64-92)	134	(121-149)	213
1931	0	(0-0)	20	(20-20)	20
1932	25	(13-40)	70	(55-82)	95
1933	10	(8-11)	17	(16-19)	27
1934	15	(10-20)	67	(62-72)	82
1935	72	(62-85)	102	(89-112)	174
1936	16	(9-20)	40	(36-47)	56
1937	24	(16-34)	42	(32-50)	66
1938	5	(4-8)	36	(33-37)	41
1939	0	(0-1)	15	(14-15)	15
1940	2	(1-3)	50	(49-51)	52
1941	3	(1-6)	73	(70-75)	76
1942	1	(1-1)	14	(14-14)	15
1943	0	(0-0)	15	(15-15)	15
1944	0	(0-0)	2	(2-2)	2
1945	0	(0-0)	13	(13-13)	13
1946	0	(0-1)	10	(9-10)	10
1947	0	(0-1)	34	(33-34)	34
1948	0	(0-1)	53	(52-53)	53
1949	2	(1-2)	17	(17-18)	19
1950	3	(3-4)	15	(14-15)	18
1951	8	(5-9)	64	(63-67)	72
1952	14	(11-16)	108	(106-111)	122
1953	7	(6-10)	135	(132-136)	142
1954	15	(10-24)	192	(183-197)	207
1955	12	(9-17)	130	(125-133)	142
1956	17	(12-23)	134	(128-139)	151
1957	16	(13-20)	127	(123-130)	143
1958	30	(24-34)	95	(91-101)	125
1959	29	(22-33)	120	(116-127)	149
1960	9	(4-17)	77	(69-82)	86
1961	15	(8-22)	77	(70-84)	92
1962	40	(28-51)	109	(98-121)	149
1963	259	(179-330)	346	(275-426)	605
1964	132	(89-165)	119	(86-162)	251
1965	108	(79-134)	170	(144-199)	278
1966	15	(9-21)	45	(39-51)	60
1967	29	(19-38)	65	(56-75)	94
1968	12	(6-17)	44	(39-50)	56
1969	15	(10-21)	58	(52-63)	73
1970	4	(1-7)	15	(12-18)	19
1971	0	(0-0)	7	(7-7)	7
1972	17	(17-17)	0	(0-0)	17
Total	3428	(2610-4131)	6362	(5659-7180)	9790

Table 2. North Pacific blue whale mark-recovery data from the Discovery mark program. Source: Sally Mizroch.

Mark number	Longitude marked	Latitude marked	Longitude recovered	Latitude recovered	Date marked	Date recovered	Sex
JPN-4098	147.35	39.2667	145.8333	40.3333	7/13/1953	6/15/1964	F
JPN-7965	-175.0333	49.7833	-161.3167	50.8833	7/12/1959	7/16/1965	F
JPN-9041	-136.4167	56.8167	-137	57.2333	7/9/1963	7/10/1963	F
JPN-9243	-159.5833	52.9167	-151.9833	54.5833	6/16/1963	6/21/1964	F
USSR-635	153.1	50.2167	-147.2667	57.7	5/22/1958	6/5/1962	F
USSR-610841	-128.1	49.5	-152.35	56.0333	5/4/1963	6/21/1964	F
JPN-5920	-162.1	53.9833			7/9/1955	9/12/1956	
JPN-6892	-157.8	54.8333	-158	54.9667	7/11/1955	7/13/1960	M
JPN-6893	-157.8	54.8333	-164.8333	53.6833	7/11/1955	9/4/1956	F
JPN-6898	-156.4667	55.3167	-160.6333	53.75	7/11/1955	7/8/1960	F
JPN-7249	-156.7	55.15	-157.3667	54.7167	6/4/1957	7/12/1962	F
JPN-7982	-175.0333	49.8	-175.7667	49.7167	7/12/1959	7/24/1959	M
JPN-8022	-156.3833	55.6	-156.9333	55.6167	7/1/1960	7/10/1960	F
JPN-8118	-157	55.3	-156.35	55.35	7/1/1960	7/13/1960	F
JPN-3362	-168.95	52.35	-166.6667	53.2	8/7/1954	9/2/1956	M
JPN-3977	146.8	39.65	146.5	39.4167	7/11/1953	7/13/1953	F

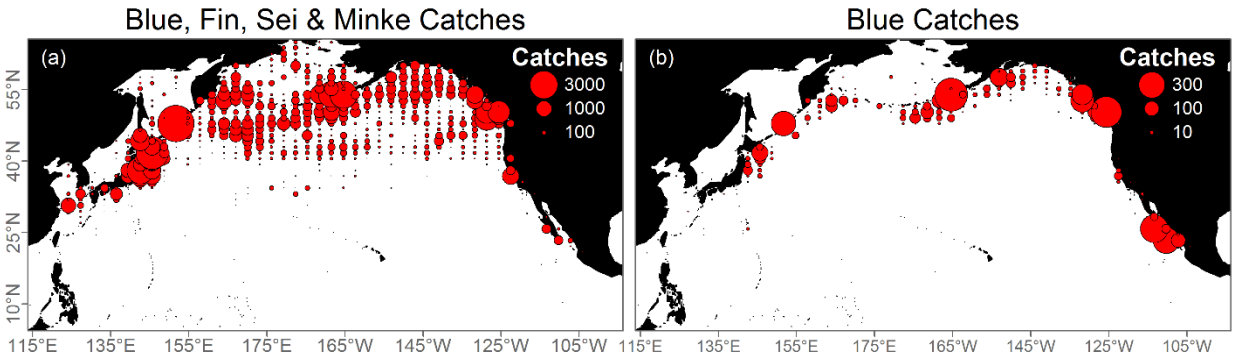

Figure 1. Catches with known locations of (a) combined blue, fin, sei, and minke whales; and (b) blue whales alone, during years when these species were targeted together (1905-1971). The comparison of (a) and (b) reveals where blue whales were encountered (Aleutian Islands, Gulf of Alaska, Japan) and were absent (Bering Sea). Source: Monnahan et al. (2015).

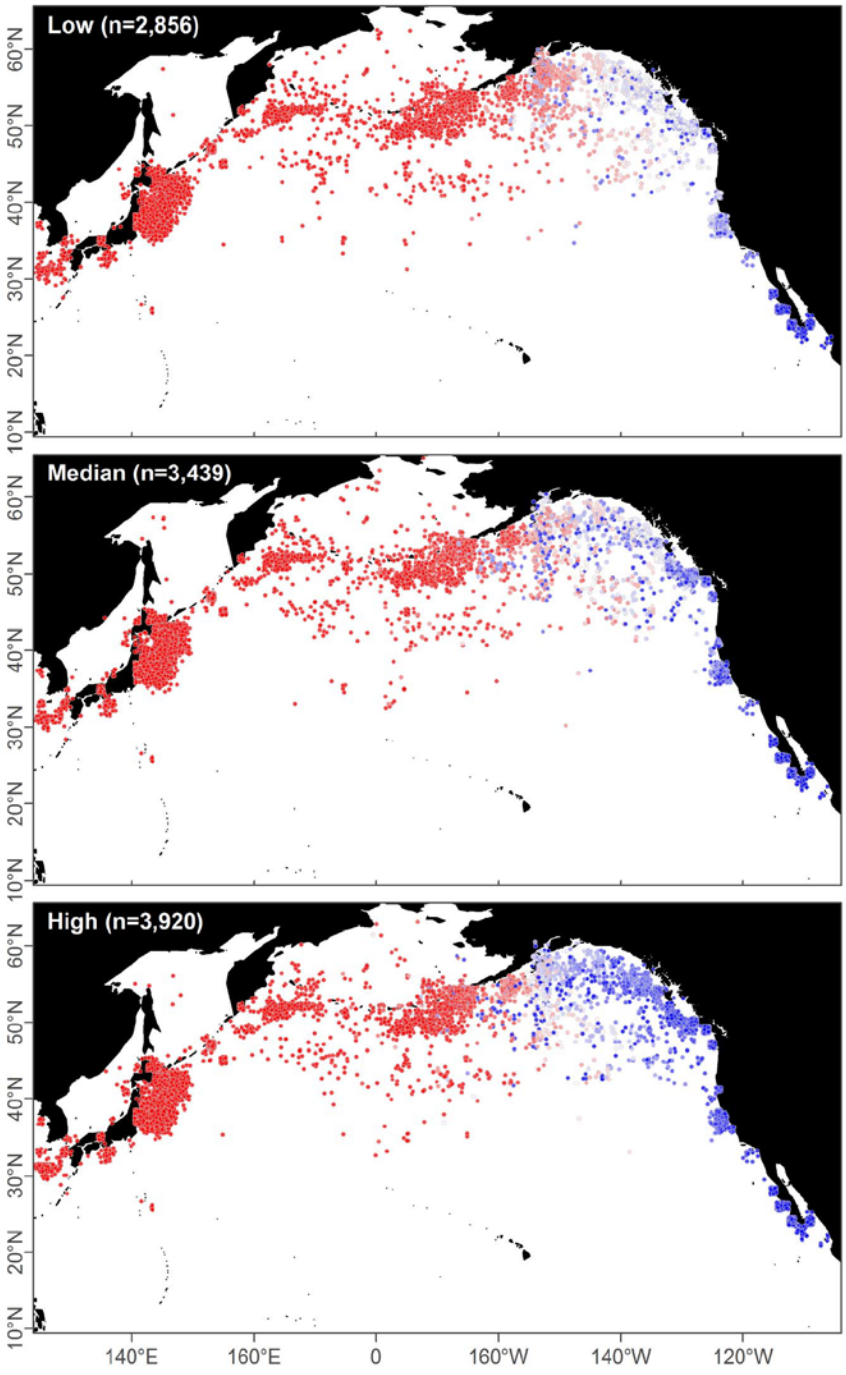

Figure 2. Inferred locations of all catches of eastern North Pacific (ENP, blue) and central and western North Pacific (CWNP, red) blue whales. Population separation is based on the differences in acoustic song type as shown in Fig. 4, with the 3 plotted scenarios (out of 1000) representing a low, median, and high proportion of catches assigned to the ENP population. Locations were randomly drawn from potential locations, and represent the uncertainty in catch location, catch month, and population identity. Where the exact locations were only identified to very large regions, locations of catches of other species (shown in Fig. 1a) were used to infer location, likely resulting catch locations being more spread out than in reality. Catch positions are plotted with a small amount of noise to prevent overplotting. Nearby catches can have different predictions (colors) because months are aggregated. Source: Monnahan et al. (2014).

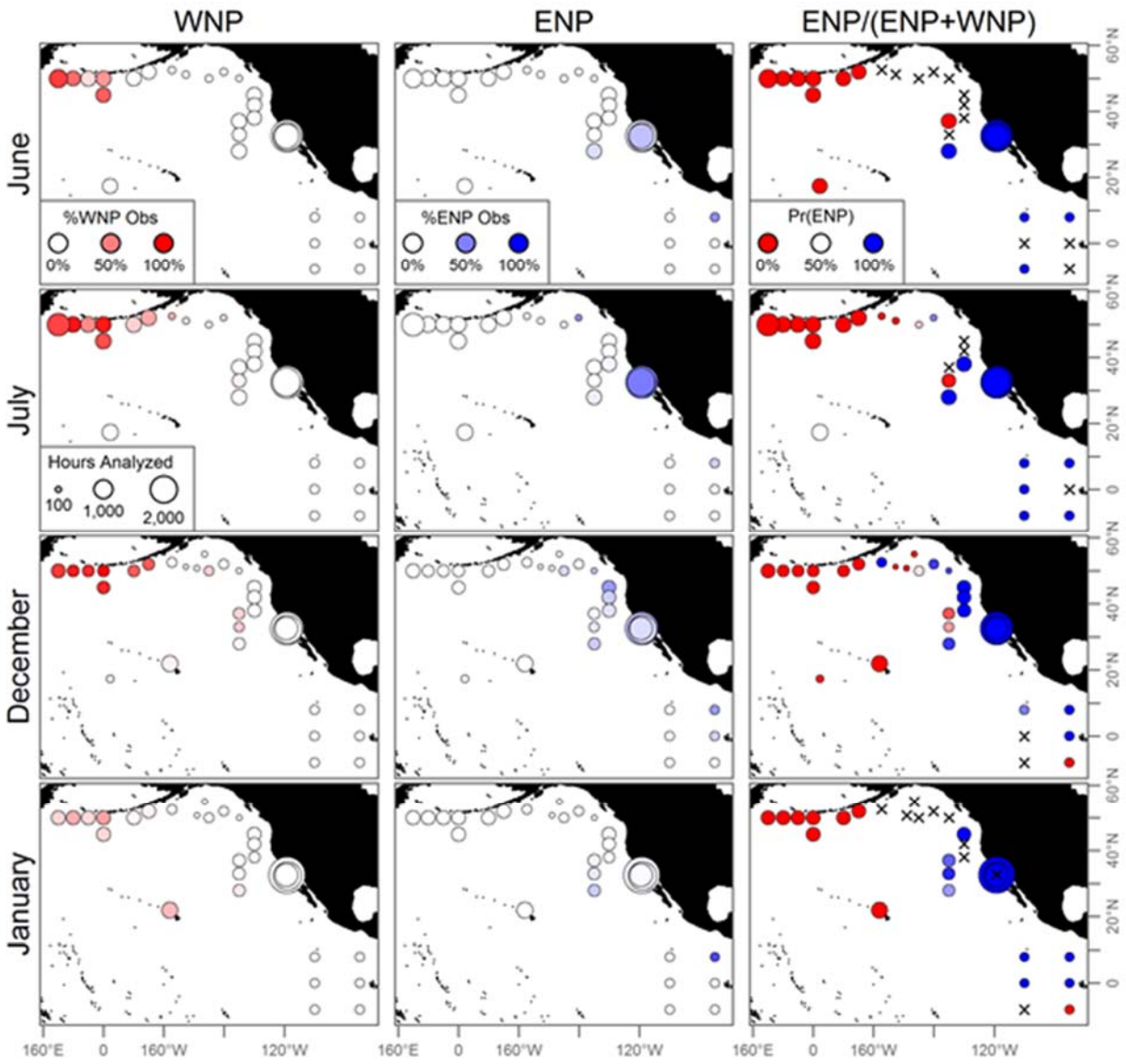

Figure 3. Acoustic detections of the western (left) and eastern (middle) North Pacific blue whale song type, and the proportion of eastern to western calls (right). Data for summer months (June-July) and winter months (December-January) excerpted from year-round data in Monnahan et al. (2014).

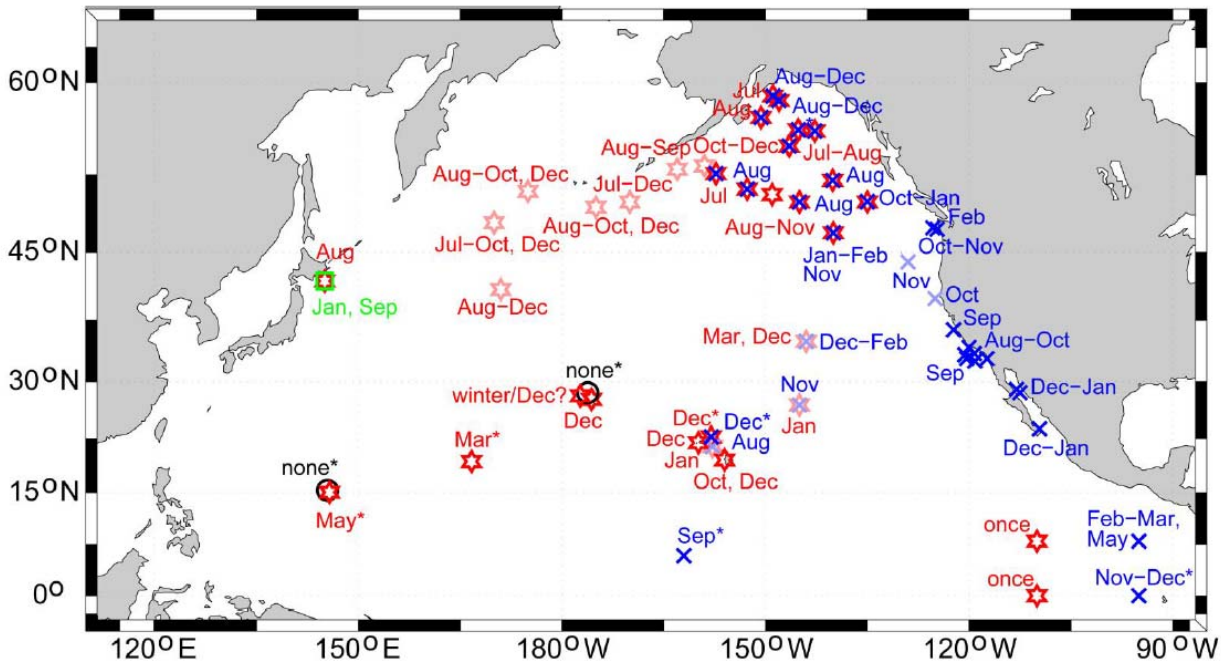

Figure 4. Figure and legend repeated from Širović et al. (2017). Locations of recorders with blue whale songs in the North Pacific. Blue X denotes location of Northeast Pacific (NEP), red hexagram Northwest Pacific (NWP), and green square Japan style (JAP) blue whale song. Months included for each site indicate peak months (>80% of maximum) of detection. Lighter color location markings indicate that the exact location of the recorder is not known, only its general area. In most cases year-round recordings were available. Black circles mark location where recordings exists but no blue whale songs were recorded. If three or more month of recording were missing per year, those peak months are marked with *.

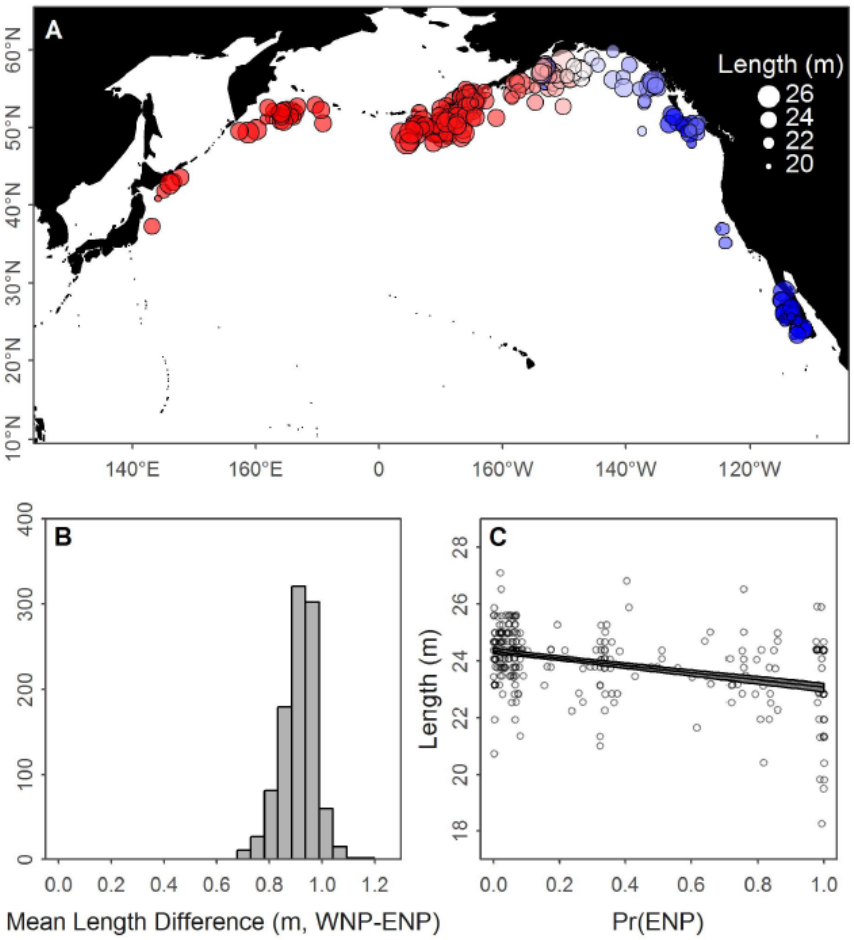

Figure 5. Lengths of sexually mature female blue whales caught in the North Pacific, separated into ENP and CWNP blue whales based on acoustic calls. (A) Locations, lengths, and median predicted population (color) for all years. (B) Distribution of mean length differences for all bootstrap iterations in the paper. (C) The 95% percentiles (gray polygon) and median line for all bootstrap linear models fit to the predicted population versus lengths. Source: Monnahan et al. (2014).

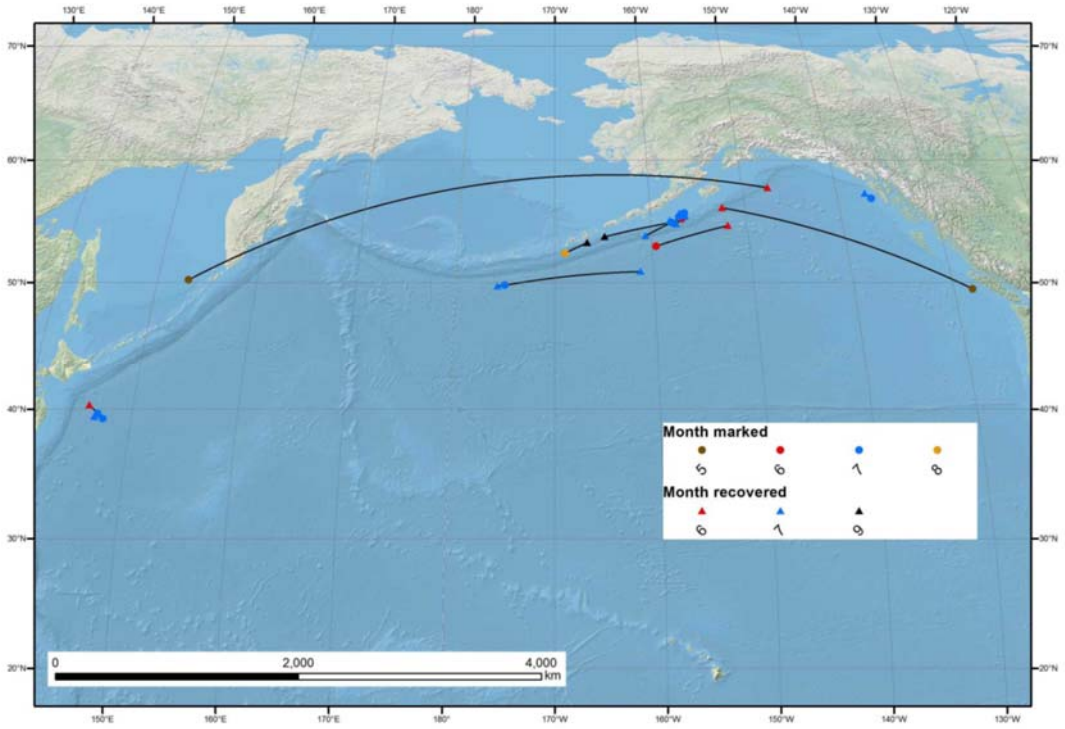

Figure 6. Blue whale Discovery marks that were recovered in the North Pacific. Source: Sally Mizroch, unpublished.

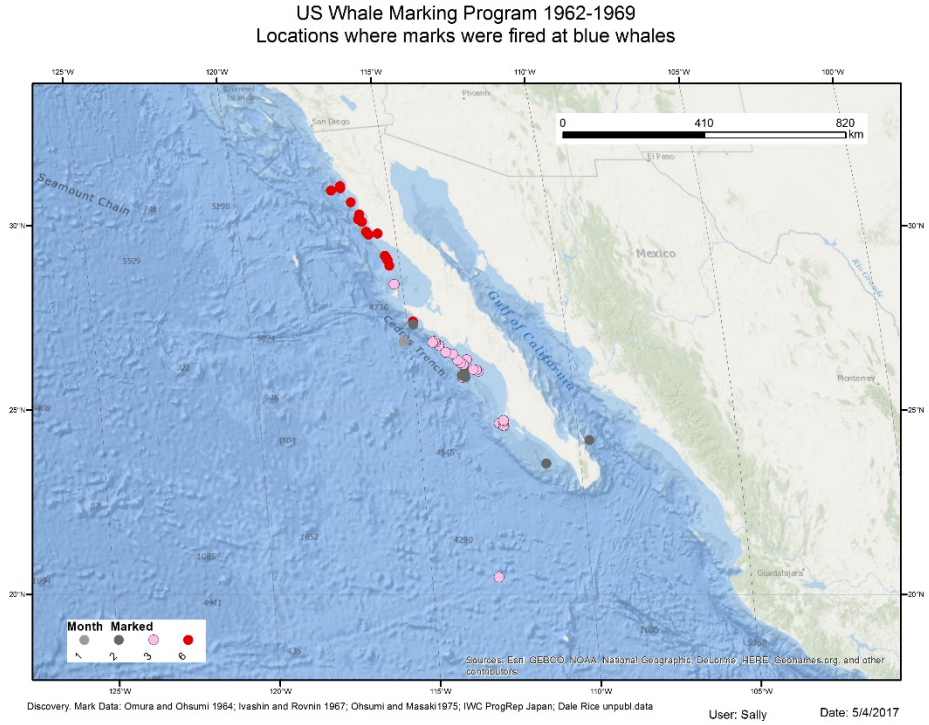

Figure 7. Blue whale Discovery marks placed by the US off Mexico; no recoveries have been reported of these marks. Source: Sally Mizroch, unpublished.

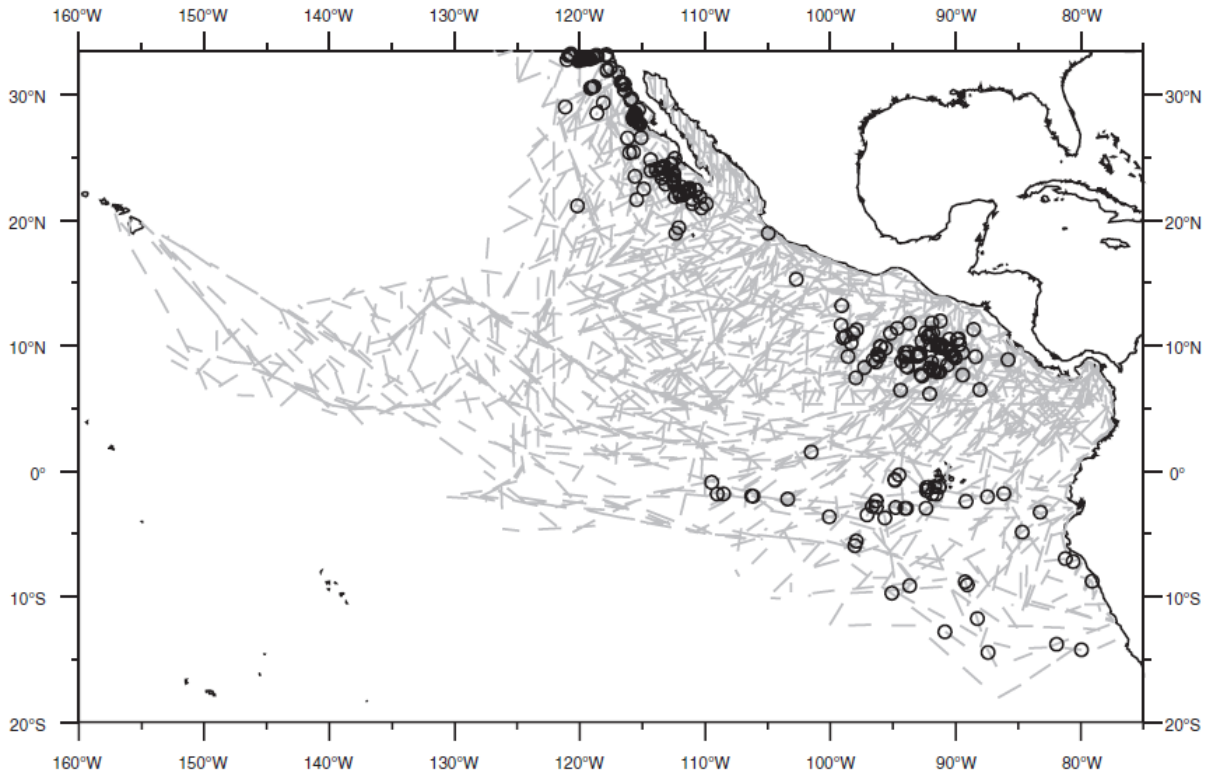

Figure 8. Southwest Fisheries Science Center surveys between 1986 and 2006 in the eastern tropical Pacific. Grey lines indicate primary search effort, while circles show both on-effort and off-effort sightings of blue whales. Source: Branch et al. (2007).

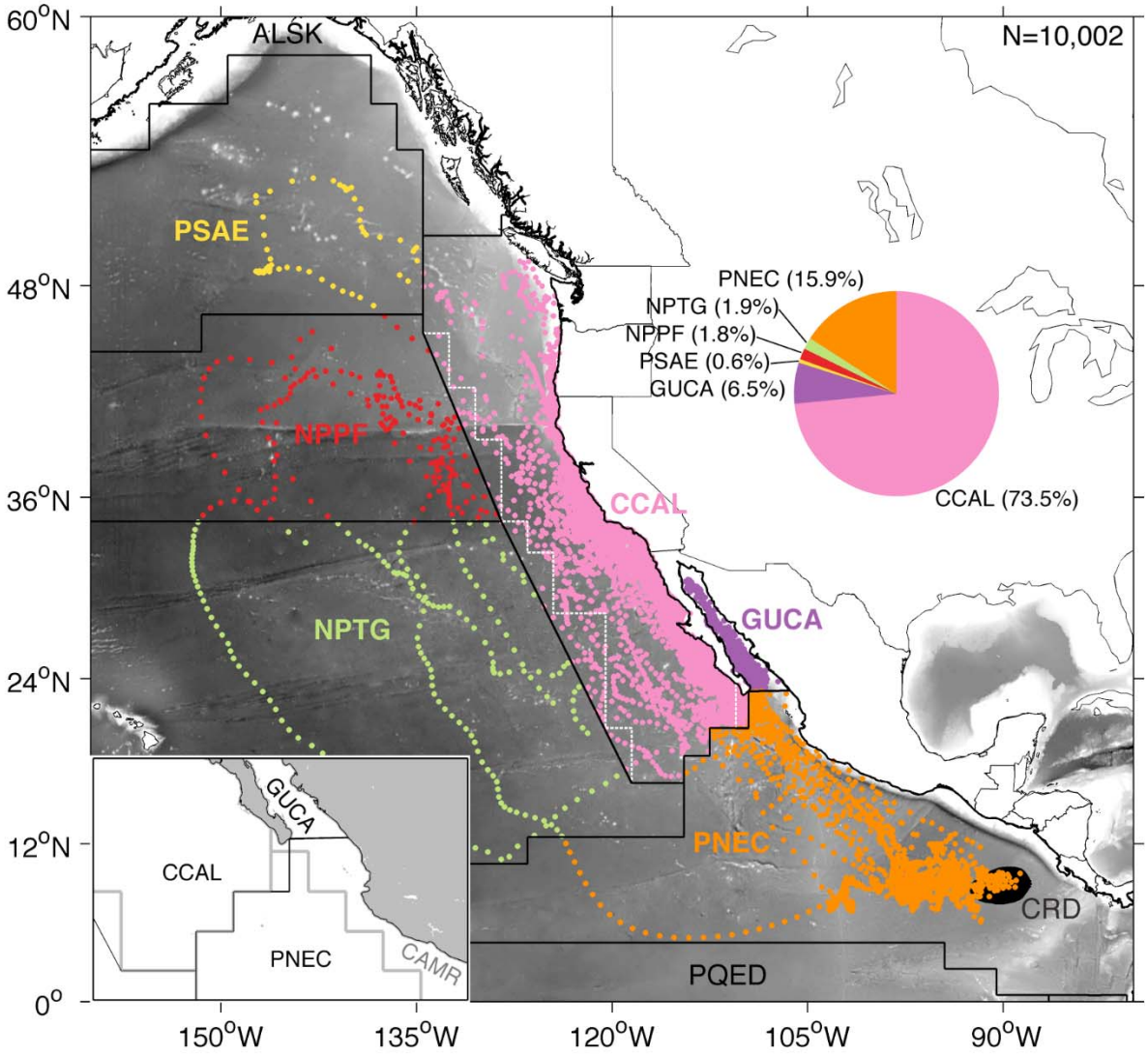

Figure 9. Tracks from satellite tags (1999-2009) on 87 eastern North Pacific blue whales. Source: D. Palacios.

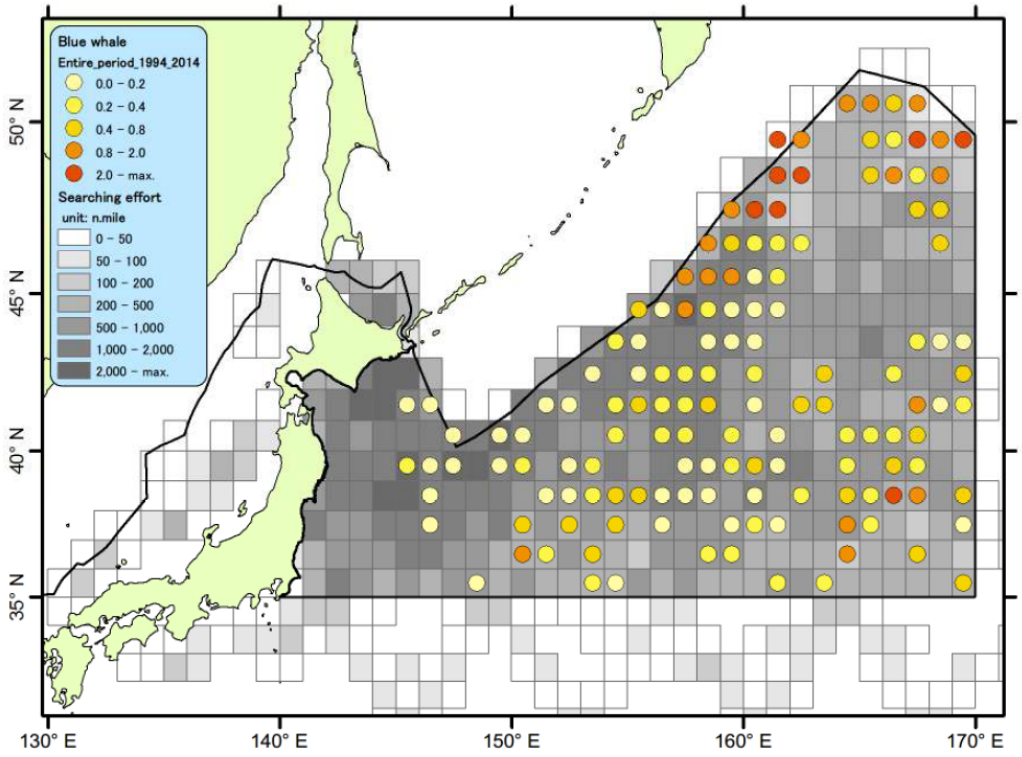

Figure 10a. Blue whale sighting rate in individuals per 100 nmi (filled circles) and search effort (gray shading in 1°×1° grid cells) in the JARPN and JARPNII data, 1994–2014. Reprinted from Figure 1a in Matsuoka et al. (2015a), with permission.

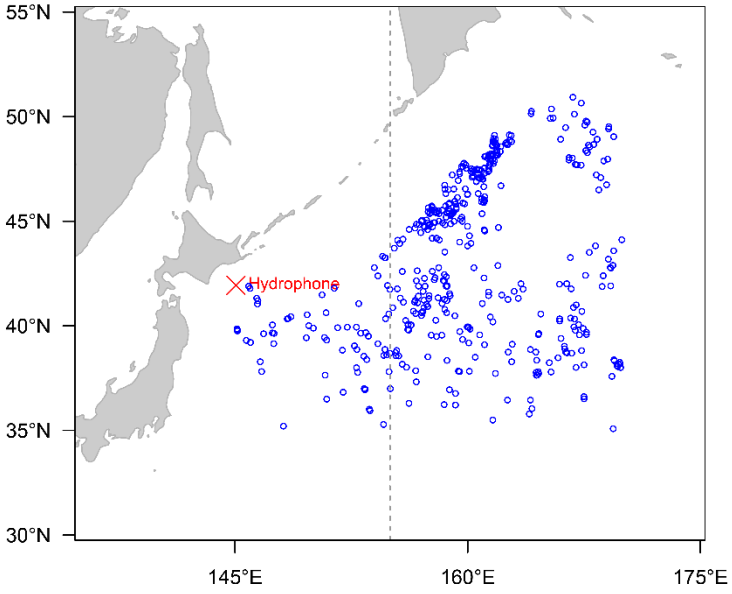

Figure 10b. Sightings of blue whales in the JARPN and JARPNII cruises, provided from the data presented in Matsuoka et al. (2015). The hydrophone location indicates the position where a possible third blue whale song type was recorded. The dashed gray line is at 155°E.

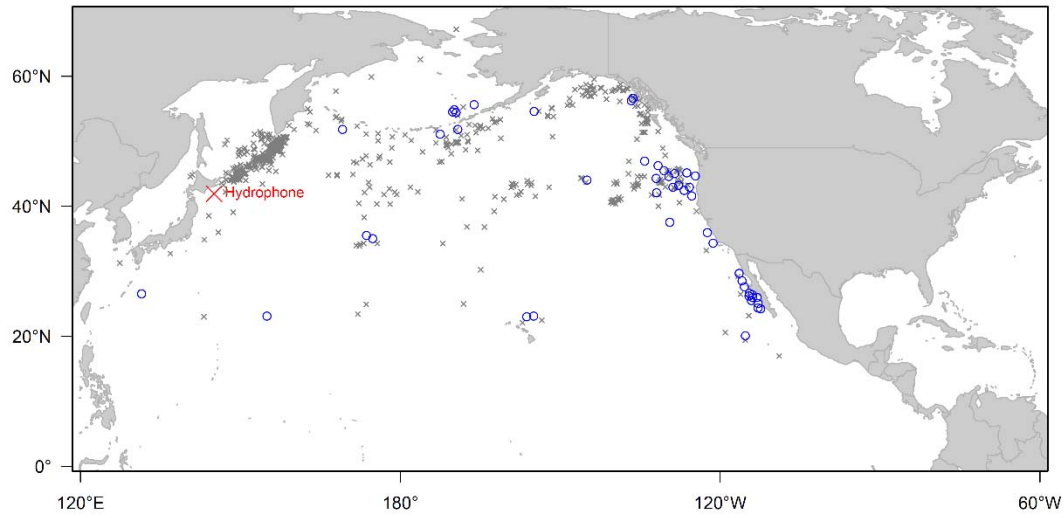

Fig. 10c. Locations of sightings (blue circles) and locations recorded as either catches or catches/sightings (gray x) from Soviet surveys. Source: Ivashchenko & Clapham (2018).

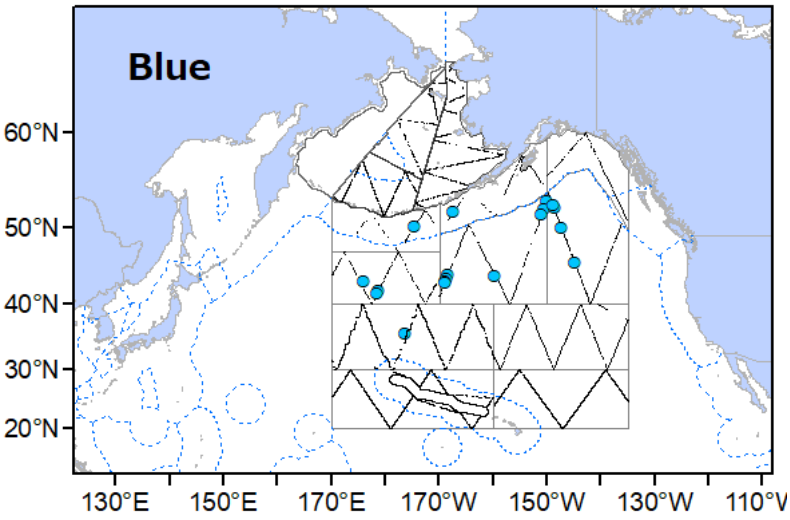

Figure 11. Survey strata, cruise tracklines, and blue whale sightings during the IWC-POWER surveys, 2010–2017. Figure provided by Koji Matsuoka.

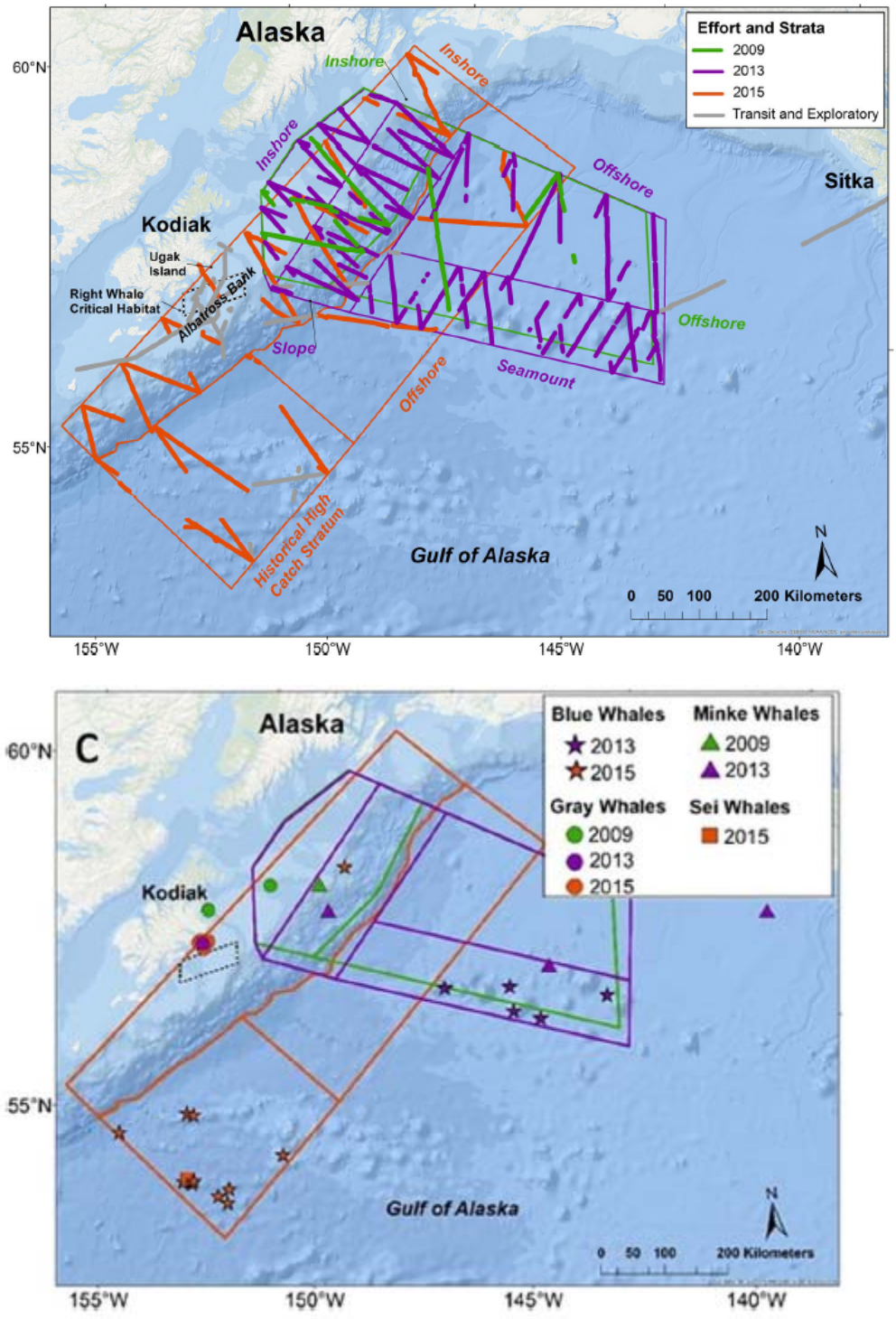

Figure 12. Effort (top panels) and blue whale sightings (bottom panel, stars) from the Gulf of Alaska surveys. Source: Rone et al. (2017).

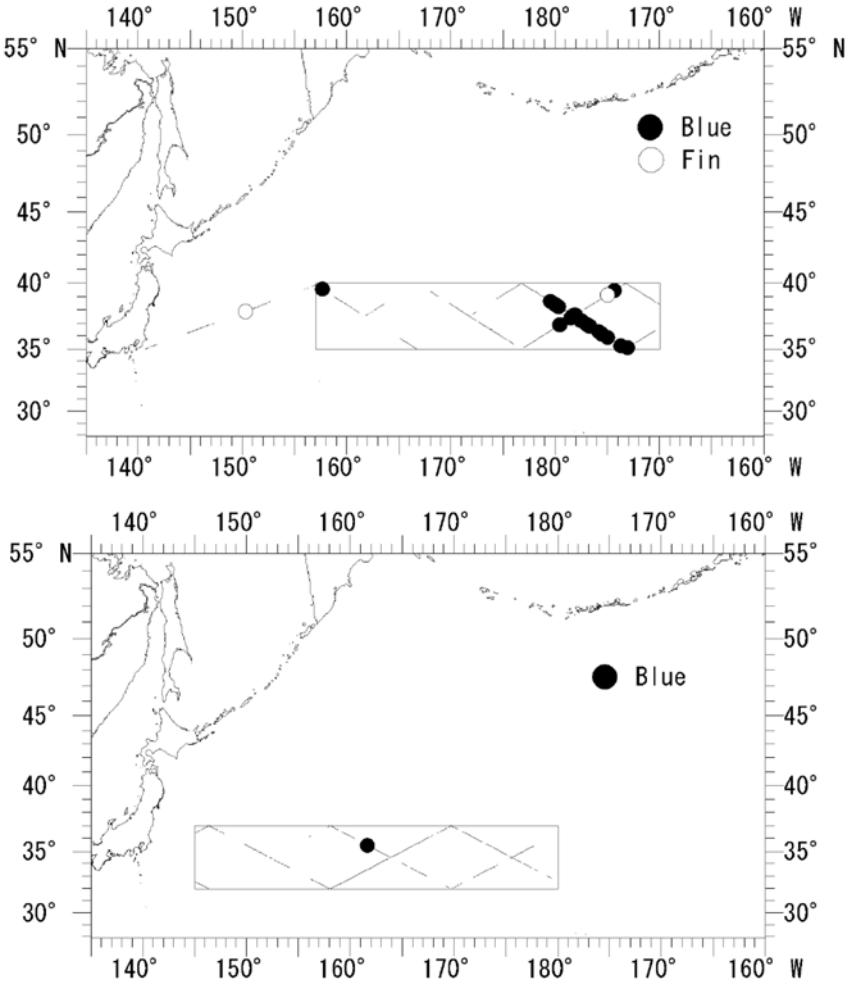

Figure 13. Survey effort and sightings by the RV Yushin-Maru No. 3 in two research cruises in 2010: top panel, first cruise June-July, bottom panel, second cruise July-August. Blue whale sightings are noted in black. Source: Matsuoka et al. (2011).

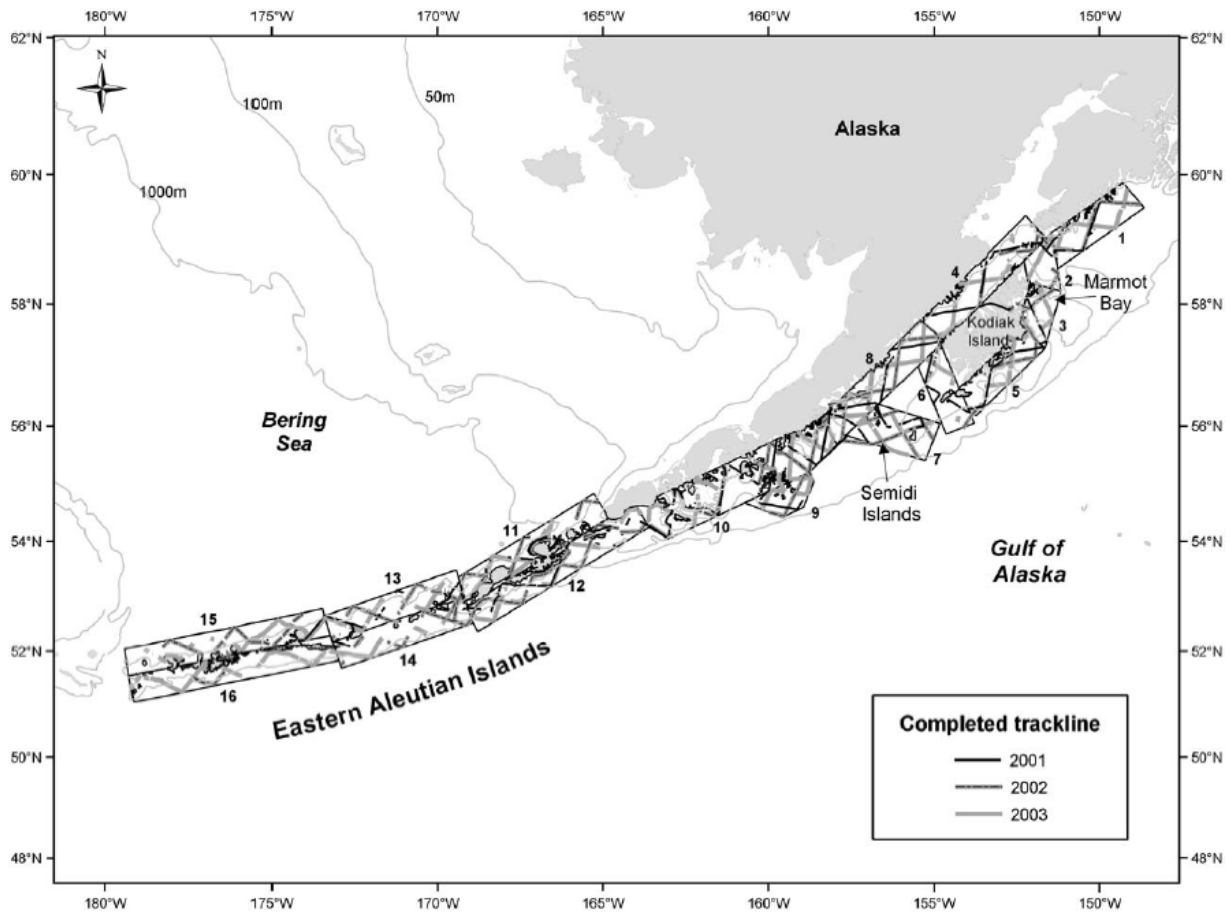

Figure 14. Completed transect legs during the three Aleutian Islands and Alaska Peninsula surveys in 2001-2003. No blue whales were sighted during these surveys. Source: Zerbini et al. (2006).

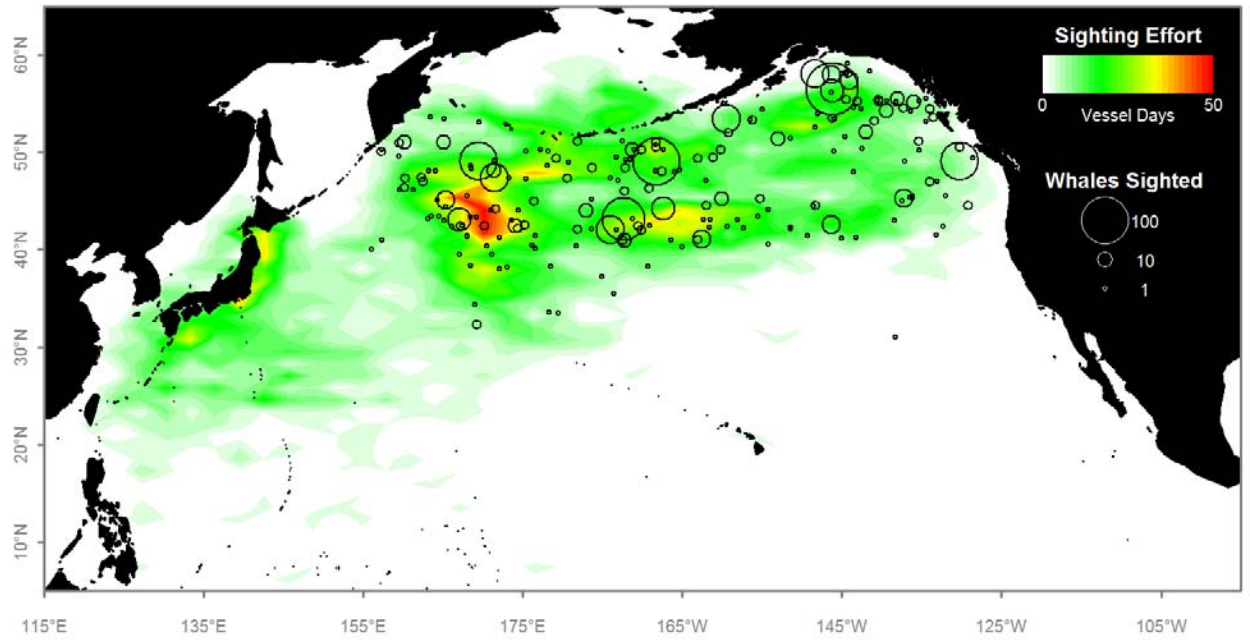

Figure 15. Blue whale sightings (circles) and search effort (color) in the Japanese Scouting Vessels (JSV) dataset, 1965–1987. Blue whales were sighted throughout Alaskan waters but are completely absent west of 155°E in areas where they were formerly caught. Data: T. Miyashita.

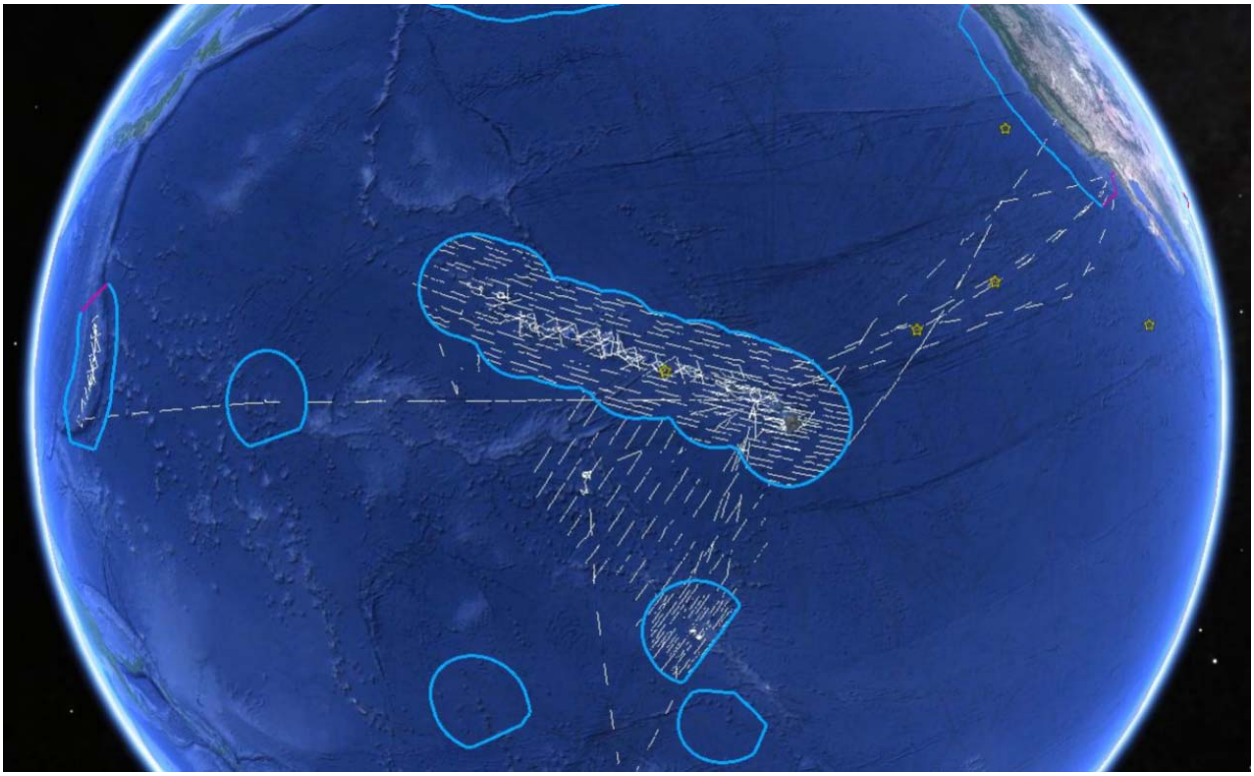

Figure 16. Cetacean surveys conducted by the US Pacific Islands Fisheries Center (PIFSC), with blue whale sightings denoted by stars. Only one blue whale has been sighted in the Hawaiian Islands EEZ on 27 November 2010 at 23.276°N 164.106°W. Data and figure from Amanda Bradford, PIFSC.