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Overview of North Pacific blue whale distribution, and the need for an assessment of the western and central Pacific

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INTERNATIONAL WHALING COMMISSION

Overview of North Pacific blue whale distribution, and the need for an assessment of the western and central Pacific

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ABSTRACT

An overview is provided of catches, sighting surveys, acoustic detections, satellite tagging and abundance estimates for blue whales in the North Pacific. There are at least two populations: the eastern North Pacific population from the Gulf of Alaska to Mexico, and the western North Pacific population that extends from Japan through to the Gulf of Alaska, including the central North Pacific. While population models estimate that the ENP population is at relatively high abundance compared to pre-whaling levels, much less is known about WNP blue whales. However catches in the WNP were nearly twice as high, and recent sighting rates are much lower, compared to the ENP. In addition, the JSV data suggest that a subpopulation or population off Japan was seriously depleted or even extirpated by whaling in the past, and blue whales have only recently been sighted there again. Recent POWER and JARPN line-transect surveys provide an opportunity to obtain abundance estimates for the WNP region, which when combined with new catch time series for the WNP region, would allow for a population model to assess the status of WNP blue whales in the near future. This assessment should be a priority given the likelihood that the status of WNP and ENP blue whales differs substantially.

INTRODUCTION

At least two populations of blue whales occur in the North Pacific, and possibly more. The eastern North Pacific (ENP) population is heavily studied, with an extensive photo-identification catalogue, surveys, satellite tracking, genetics, abundance estimates, and studies of feeding behaviour (e.g. Calambokidis et al. 2009, 2015; Irvine et al. 2014, Goldbogen et al. 2013). The major concern for the ENP population is ship strikes (e.g. Redfern et al. 2013). Until recently no assessment of any blue whale population in the North Pacific had been conducted, mainly because catches were known to be under-estimated due to Soviet misreporting (e.g. Yablokov 1994), and because catches had not been split among the component populations. In 2014, however, a complete North Pacific time series of catches, accounting for Soviet misreporting, was pieced together from Russian archives (Ivashchenko et al. 2013; Ivashchenko & Clapham 2014). This time series of catches was then split among the ENP population and the western North Pacific (WNP) using differences in song types across areas (Monnahan et al. 2014, Table 1). These catches were then used to conduct the first assessment of population status (Monnahan et al. 2015), revealing that despite continued ship strikes, the ENP population has recovered to a median of 97% (95% interval 62–99%) of pre-whaling levels (Fig. 1). Furthermore, these results are robust to a variety of levels of ship strikes, prior distributions, and structural assumptions about the models used (Monnahan et al. 2015, Monnahan & Branch 2015).

Although the status of the ENP population is well known, it is unclear how many additional populations of blue whales there might be in the North Pacific, nor what their status is. For simplicity in the methods and results, we will refer to all of the blue whales in the western North Pacific as if they were a single WNP population, and then revisit this assumption in the discussion. Given the increasing number and variety of data now available for WNP blue whales, we argue it would be timely to conduct an assessment of blue whales in this region. Here, we outline a few of the major data series that are available to delineate population structure in the North Pacific, propose a complete collation of all available data, outline the steps needed to conduct an assessment, and present plausible scenarios for stock status in the western North Pacific.

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METHODS AND RESULTS

Catches in the North Pacific (1905-1971)

Catches were reported from 1905 to 1971 in the North Pacific; the data now include all Soviet catches during the period of misreporting (Ivashchenko et al. 2013, Monnahan et al. 2014). Not all blue whale catches in the North Pacific have exact locations recorded. Of those that do (Fig. 2b), most are relatively close to the coastline compared to the more widespread catches of other similar species (Fig. 2b, fin, sei, and minke whales). For the many catches without exact catch locations, a general catch area is often known. In Fig. 3, all individual catches are plotted, with locations drawn from the catch area, following the patterns of blue, fin, sei, and mink whale catches. However, it should be noted that some of these inferred catch locations are probably outside the likely range of blue whale catches (notably those in the Bering Sea).

Of key interest, once catches are separated between ENP and WNP populations, is that most of the historical catches came from the WNP population (median total 6362) and not the ENP population (median total 3411), although there remains substantial uncertainty in separating the catch time series (Table 1). Thus it is possible that even though the ENP population is largely recovered (Monnahan et al. 2015), the WNP population may be seriously depleted.

JSV sightings and effort (1965-1987)

The Japanese Scouting Vessel (JSV) dataset includes extensive sightings from 1965 to 1987, mostly after the end of whaling on blue whales. Despite extensive search effort around Japan, no sightings were recorded. Instead, sightings extended from 155°E to 125°W, with substantial sightings much further south than reported in catches with exact locations. There are also no sightings in the Bering Sea and substantial sightings in the Gulf of Alaska.

JARPN and JARPNII data (1994-2014)

After the JSV data ends, sightings of blue whales were recorded from 1994–2014 during the JARPN and JARPNII cruises. In these more recent years, blue whales have again been sighted in waters fairly close to Japan (Fig. 5).

IWC-POWER surveys (2010-2016)

The IWC Pacific Ocean Whale and Ecosystem Research (IWC-POWER) surveys are designed to cover the region 170°E to 135°W and north of 20°N over the period 2010–2016 (Fig. 6). To the end of 2014, all waters north of 30°N had been surveyed once. No blue whales were sighted in 2013 or 2015, but blue whales were sighted in 2010 (n=5) (Matsuoka et al. 2011) (n=10) (Matsuoka et al. 2012), 2012 (n=4) (Matsuoka et al. 2013) and 2014 (n=1, emaciated calf) (Matsuoka et al. 2015b). Sightings were spread through the survey area, much farther afield than the known-location catches in Fig. 1, with none close to land (Fig. 6) and most sightings falling in regions identified as inhabited by WNP blue whales by acoustic call types (Monnahan et al. 2014).

Acoustic detections (1992-2004)

Two distinctive blue whale call types have been recorded in the North Pacific, the ENP and the WNP call type. Assuming that each population has a distinct call type (e.g. McDonald et al. 2006), these provide the strongest evidence for only two populations in the North Pacific. The WNP call types are heard in the Aleutians through Gulf of Alaska, and the central North Pacific to locations approaching the California coast (Fig. 7, red). The ENP call type is heard from the Gulf of Alaska down to California, close to the coast, and as far south as the Tropical Eastern Pacific (Fig. 7, blue). Overlap between the two call types is mostly in the Gulf of Alaska.

Satellite tags (1999-2009)

Nearly all of the satellite tags have been placed in California, and reveal that blue whales in this region spend most of their time in the California Current (California, and to a less extent Oregon and Washington), and Mexico, especially the offshore coast and the Gulf of California, and frequent the Costa Rica Dome (Fig. 8). More rarely, tagged blue whales venture far offshore and towards the Gulf of Alaska.

Abundance estimates

For the ENP population, abundance estimates have been obtained from photo-id mark-recapture, showing no consistent trend over time with different methods of analysis (e.g. Monnahan et al. 2014). Typical estimates are around 1500-2500 individuals (e.g. Calambokidis et al. 2004). In addition, line-transect surveys in the California Current have also yielded abundance estimates, but these were high initially (2936 in 1996) before falling to low values (878–1496) in 2001 to 2014 (Barlow 2016). In explaining this discrepancy, the assumption is made that the mark-recapture estimates more reliably capture the whole population, while the line-transect estimates only capture the portion of the ENP population that happens to be within the survey area at the time of the survey. The reasoning goes that ENP blue whales pursue patches of krill wherever they might be, shifting distribution fluidly and substantially among years, instead of following the stereotypical baleen whale migration seen in humpback whales (Calambokidis et al. 2009).

Unlike for the ENP population, synoptic abundance estimates do not exist for WNP blue whales. The POWER line-transect surveys cover the central part of their distribution (170°E to 135°W), and are scheduled for completion in 2016. At that time, an abundance estimate should be possible for WNP blue whales. Genetic samples collected during the POWER survey should also be analysed to detect if these blue whales are indeed WNP or if some belong to the ENP population. Similarly, photographs collected during POWER are being matched to the extensive Cascadia photo-id collection (J. Calambokidis) and if ENP blue whales are in the POWER survey area, there should be multiple matches. Given the geographic pattern in acoustic call types, it is expected that the POWER surveys contain only WNP blue whales, and would therefore provide a reliable estimate of the central portion of the WNP population.

Additional abundance estimates for the westernmost portion of the WNP population have been obtained from the JARPNII line-transect surveys (Hakamada & Matsuoka 2015). These estimates are based on small numbers of sightings, resulting in highly variable abundance estimates: 958 (2008), 38 (2009), and 161 (2011-12). Time trends are not possible from the line-transect portion of these cruises, because the 2008 survey was conducted later in the year (2 July–29 Aug) than the other surveys (within 5 May–29 June), and the 2009 survey did not cover the area north of 45°S.

DISCUSSION & CONCLUSIONS

Population structure

This overview of the available data for North Pacific blue whales reveals substantial gaps in knowledge, particularly for the western North Pacific (WNP) region. Since genetic analysis has only been conducted on the ENP population, it is not possible to definitely conclude that there is a single "WNP" population in the western and central Pacific. The main line of evidence supporting two populations is that only two call types have been recorded in the North Pacific, and the "ENP" call type corresponds closely to the ENP population while the WNP call type corresponds with historical catches and sightings across a broad area. In addition, there is a distinct difference in catch lengths of sexually mature female whales in areas with ENP call types and those in areas with WNP call types (Monnahan et al. 2014). As the probability increases that a catch was ENP, length declines, with the WNP catches of sexually mature females being on average 0.91 m longer (95% interval 0.76-1.03 m) than the ENP catches (Monnahan et al. 2014).

The above data all support a division between ENP and WNP. But could there be a more complex population structure? Notably, blue whale catches were taken from Japanese whaling stations, but the JSV data in the 1960s to 1980s found zero blue whale sightings anywhere near Japan. It is possible that a distinct "Japan" population was extirpated (as has previously been suggested by R. Brownell). If this is true, the JARPNII data in recent decades showing blue whales again coming close to Japan, in areas of absence in the JSV data, would suggest expansion of blue whales into the area of extirpation. Alternatively, there have been shifts in blue whale distribution over decadal time periods, and a single WNP population of blue whales has shifted northward and eastward before shifting back again in recent years.

Population status

ENP blue whales have recovered to near pre-whaling levels. Their population status is now well-established, and unlikely to change unless ship strikes increase dramatically, catch time series are greatly altered, or new and revised abundance estimates are small and declining (Monnahan et al. 2015).

The population status of WNP blue whales is much less certain. First, catches were nearly twice as high in the WNP than in the ENP. Second, current sightings are sparse in the WNP compared to sighting rates off California that are high enough to support whale-watching operations, suggesting a much lower population size. Third, there is suggestive evidence of serious population decline or extirpation near Japan after whaling ended, with re-expansion in this region only occurring in recent years. In combination, these factors suggest that WNP blue whales could be substantially depleted compared to ENP blue whales. At a minimum, an assessment should be conducted as soon as

POWER abundance estimates are available, to see if WNP blue whales warrant a different conservation status than ENP blue whales.

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

Year	ENP		WNP		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
Total	3411	(2593-4114)	6362	(5659-7180)	9773

Table 2. Base case estimated median abundance (and 95% credibility interval) of eastern North Pacific blue whales from a Bayesian assessment (Monnahan et al. 2015). For this scenario, a uniform prior is assumed for the population rate of increase, and ship strikes were assumed to be proportional to the number of ships and the number of whales, fitted to an estimated 10 ship strike deaths in 2013. Source: Monnahan et al. (2015).

Year	ENP abundance	
1905	2204	(1819-3695)
1906	2203	(1818-3693)
1907	2149	(1766-3638)
1908	2116	(1733-3594)
1909	2051	(1668-3512)
1910	2024	(1643-3463)
1911	1966	(1585-3382)
1912	1842	(1459-3222)
1913	1741	(1353-3081)
1914	1760	(1372-3055)
1915	1666	(1275-2922)
1916	1706	(1314-2914)
1917	1740	(1345-2905)
1918	1755	(1357-2881)
1919	1773	(1375-2860)
1920	1785	(1386-2838)
1921	1801	(1400-2822)
1922	1853	(1453-2841)
1923	1880	(1483-2842)
1924	1869	(1475-2810)
1925	1860	(1466-2776)
1926	1724	(1331-2617)
1927	1532	(1137-2391)
1928	1431	(1024-2255)
1929	1166	(742-1956)
1930	964	(513-1726)
1931	952	(464-1707)
1932	1017	(495-1777)
1933	1058	(498-1838)
1934	1117	(520-1909)
1935	1172	(538-1971)
1936	1172	(494-1977)
1937	1227	(509-2039)
1938	1273	(514-2091)
1939	1338	(538-2154)
1940	1407	(569-2213)
1941	1475	(600-2265)
1942	1537	(630-2308)
1943	1599	(665-2346)
1944	1658	(701-2382)
1945	1713	(740-2410)
1946	1762	(778-2436)
1947	1805	(815-2456)
1948	1844	(856-2469)
1949	1878	(898-2480)
1950	1905	(939-2490)
1951	1925	(975-2496)
1952	1940	(1009-2498)
1953	1948	(1037-2493)
1954	1960	(1072-2498)
1955	1964	(1099-2493)
1956	1970	(1129-2493)
1957	1972	(1159-2489)
1958	1976	(1187-2486)
1959	1964	(1201-2471)
1960	1958	(1215-2458)
1961	1971	(1247-2468)
1962	1977	(1276-2468)
1963	1957	(1278-2447)
1964	1724	(1054-2216)
1965	1645	(961-2146)
1966	1595	(887-2106)
1967	1641	(908-2154)
1968	1670	(913-2187)
1969	1714	(939-2229)
1970	1750	(961-2265)
1971	1792	(993-2306)
1972	1834	(1033-2344)
1973	1872	(1070-2375)
1974	1905	(1105-2403)
1975	1933	(1142-2426)
1976	1957	(1182-2445)
1977	1977	(1220-2460)
1978	1993	(1256-2472)
1979	2007	(1293-2482)
1980	2020	(1330-2490)
1981	2031	(1369-2497)
1982	2039	(1405-2502)
1983	2047	(1439-2507)
1984	2055	(1471-2512)
1985	2061	(1504-2517)
1986	2067	(1538-2522)
1987	2072	(1568-2524)
1988	2076	(1598-2526)
1989	2080	(1621-2528)
1990	2084	(1647-2530)
1991	2088	(1668-2533)
1992	2091	(1688-2534)
1993	2095	(1704-2535)
1994	2098	(1719-2537)
1995	2101	(1729-2539)
1996	2104	(1737-2542)
1997	2107	(1744-2543)
1998	2111	(1753-2545)
1999	2114	(1760-2546)
2000	2117	(1767-2547)
2001	2120	(1771-2548)
2002	2122	(1773-2550)
2003	2124	(1774-2552)
2004	2127	(1776-2554)
2005	2128	(1776-2559)
2006	2130	(1776-2561)
2007	2132	(1776-2563)
2008	2134	(1776-2567)
2009	2135	(1775-2570)
2010	2137	(1774-2576)
2011	2138	(1774-2581)
2012	2138	(1773-2588)
2013	2139	(1773-2591)
2014	2140	(1773-2597)

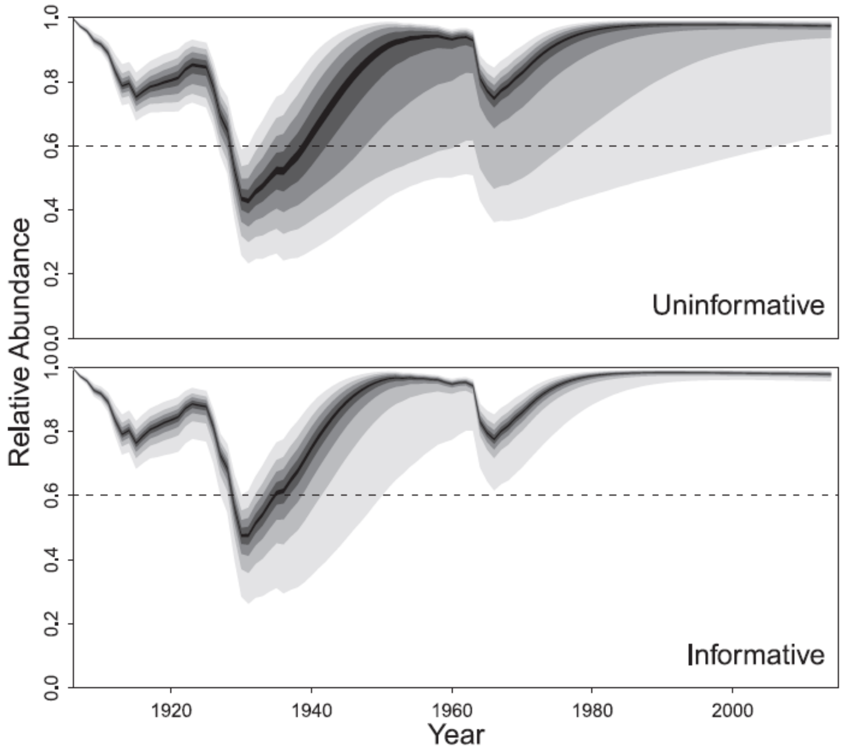

Figure 1. Base case abundance trajectories (relative to pre-whaling levels) of eastern North Pacific blue whales from a Bayesian population model, assuming either that the rate of increase has a uniform prior (top), or an informative prior from meta-analysis (bottom). Source: Monnahan et al. (2015).

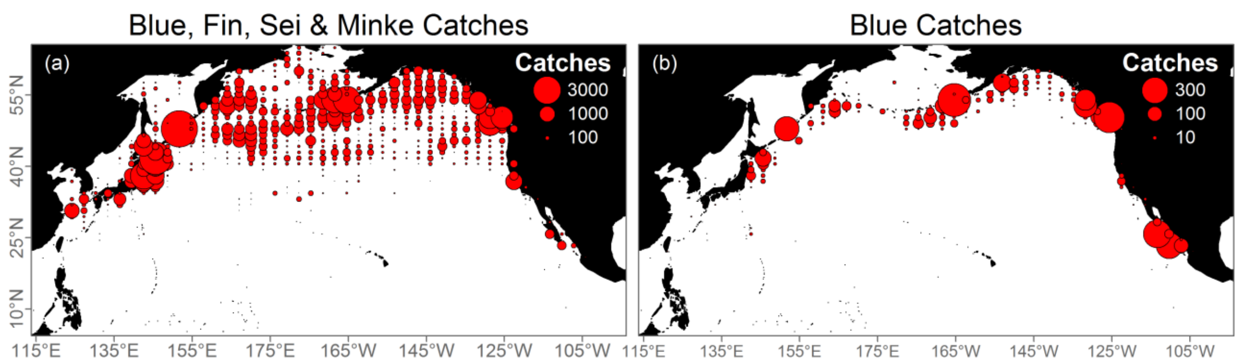

Figure 2. Catches with known locations of (a) combined blue, fin, sei, and minke whales; and (b) blue whales alone, during years when these species were targeted together (1905-1971). The comparison of (a) and (b) reveals where blue whales were encountered (Aleutian Islands, Gulf of Alaska, Japan) and were absent (Bering Sea).

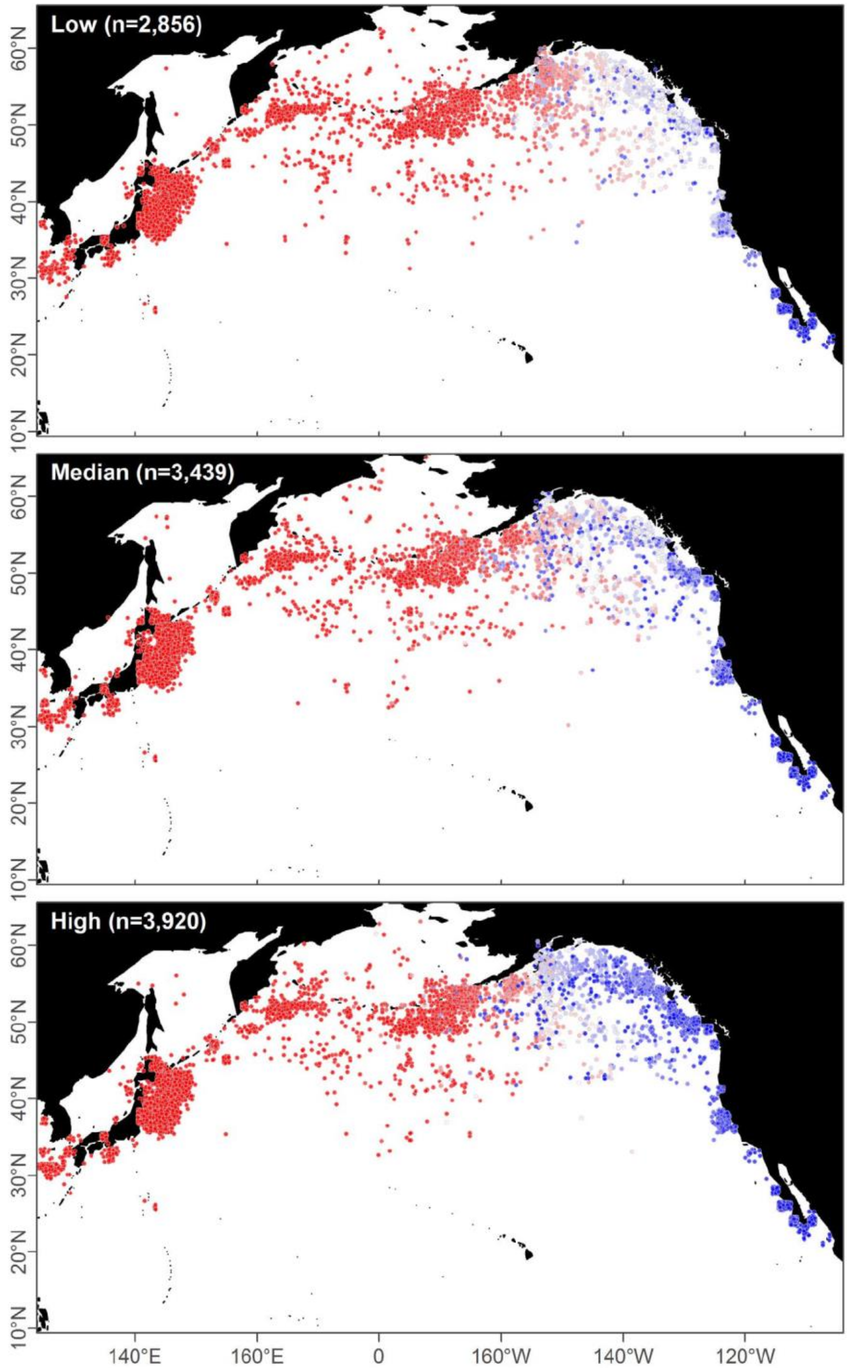

Figure 3. Inferred locations of all catches of eastern North Pacific (ENP, blue) and western North Pacific (WNP, red) blue whales. Population separation is based on the differences in acoustic song type as shown in Fig. 4, with the 3 plotted scenarios (out of 1000) representing a low, median, and high 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. In addition, 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).

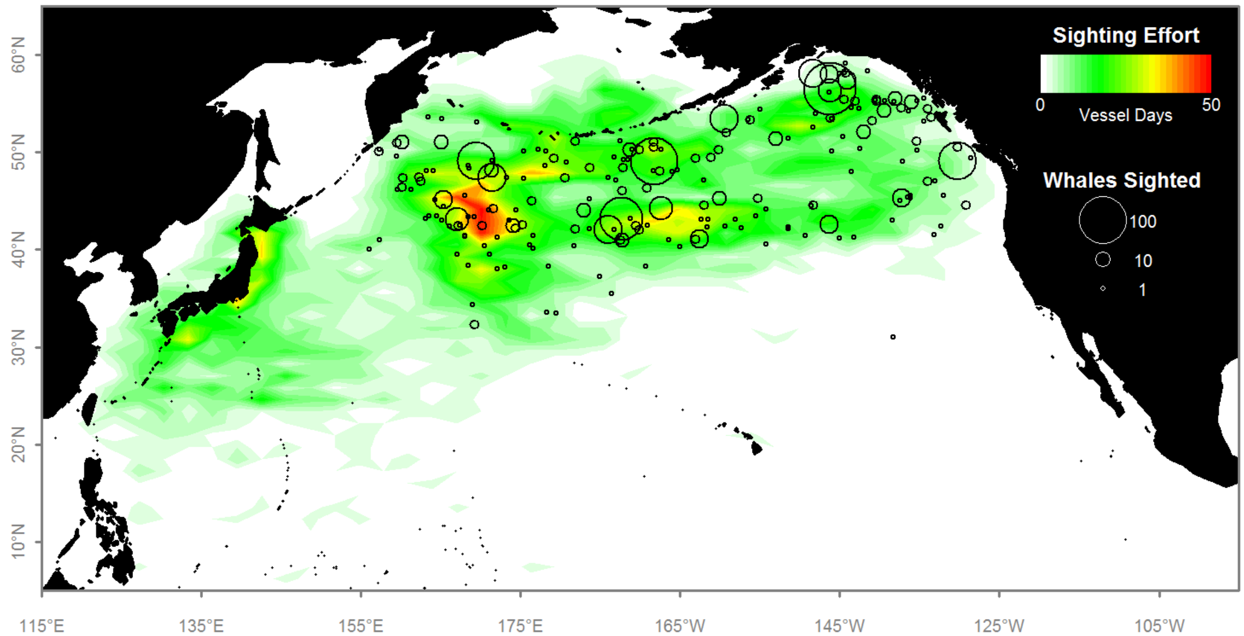

Figure 4. Blue whale sightings (circles) and search effort (color) in the Japanese Scouting Vessels (JSV) dataset, 1965–1987. Blue whales were sighted throughout Alaskan waters but are completely absent west of 155E in areas where they were formerly caught. Data: T. Miyashita.

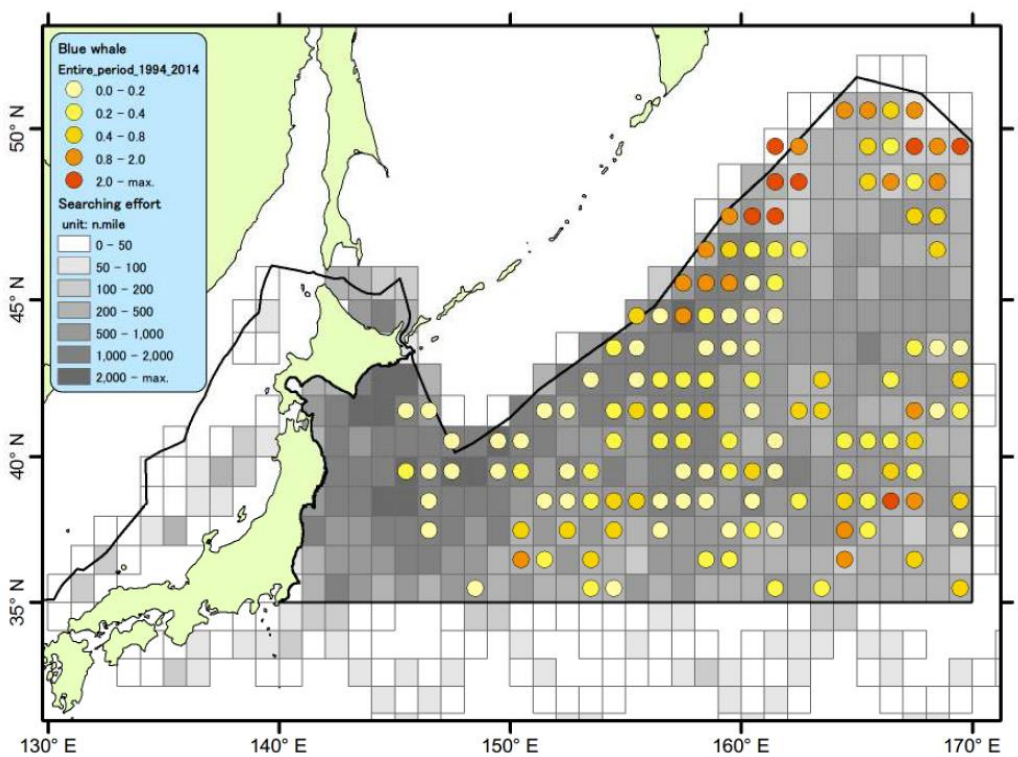

Figure 5. Blue whale sighting rate in individuals per 100 nmi (filled circles) and search effort (gray shading in 1°×1° grid cells) in the JARPN and JARPNII data, 1994–2014. Blue whales were rarely encountered close to the Japanese coast, but were encountered in areas where they were absent in the 1965–1987 JSV dataset. Reprinted from Figure 1a in Matsuoka et al. (2015a), with permission.

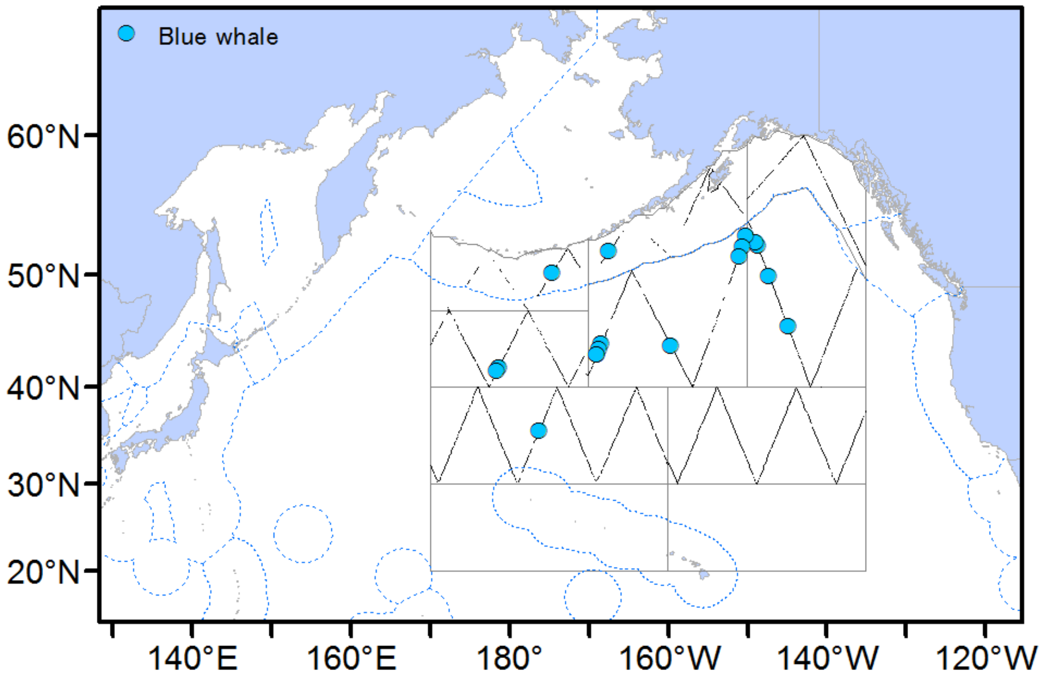

Figure 6. Survey strata, cruise tracklines, and blue whale sightings during the IWC-POWER surveys, 2010–2014. In 2015 (south-westernmost stratum) there were no blue whale sightings. Figure provided by Koji Matsuoka.

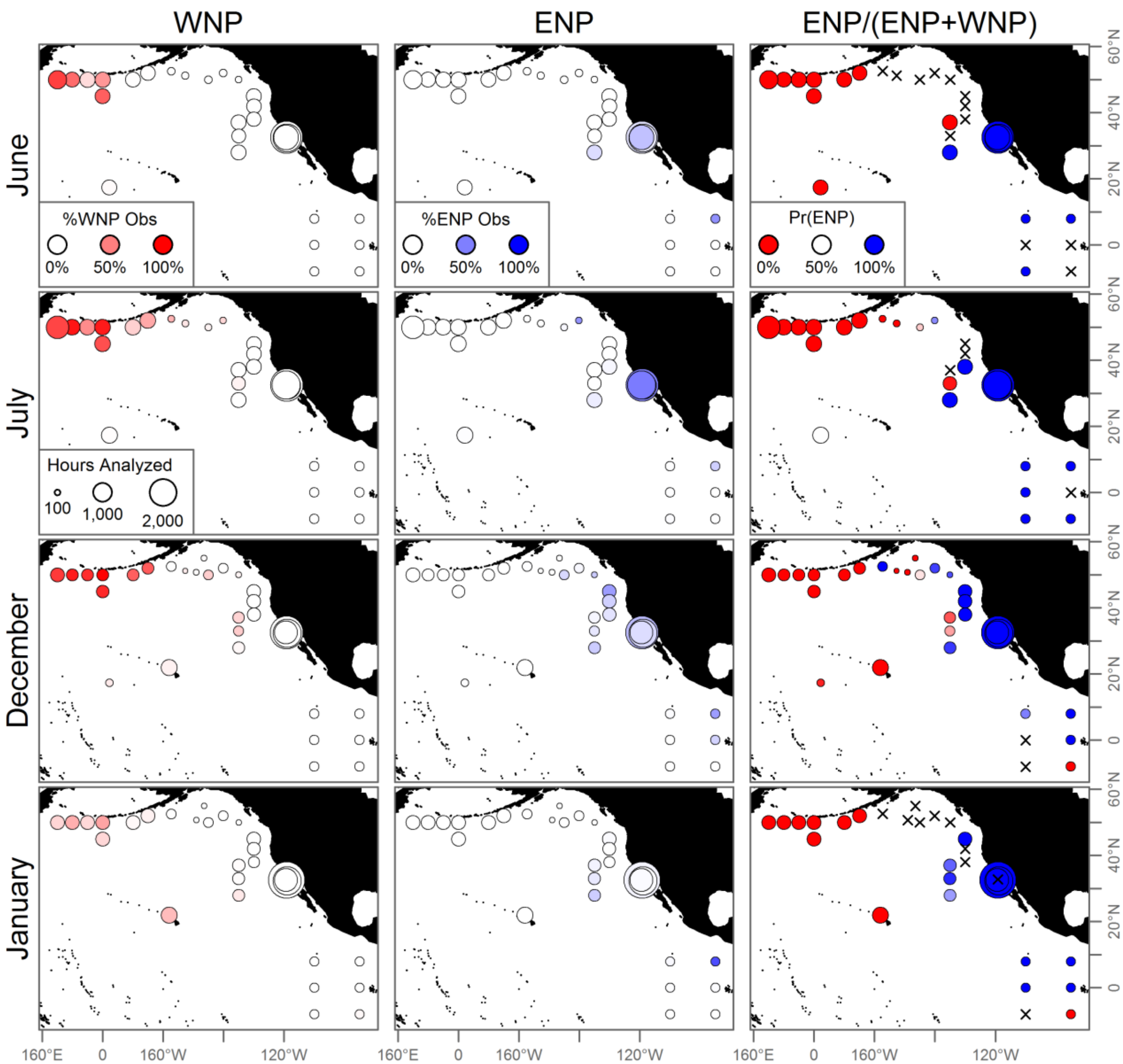

Figure 7. Acoustic detections of the western (left) and eastern (middle) North Pacific blue whale song type, and the proportion of eastern to western calls (right). Data for summer months (June-July) and winter months (December-January) excerpted from year-round data in Monnahan et al. (2014).

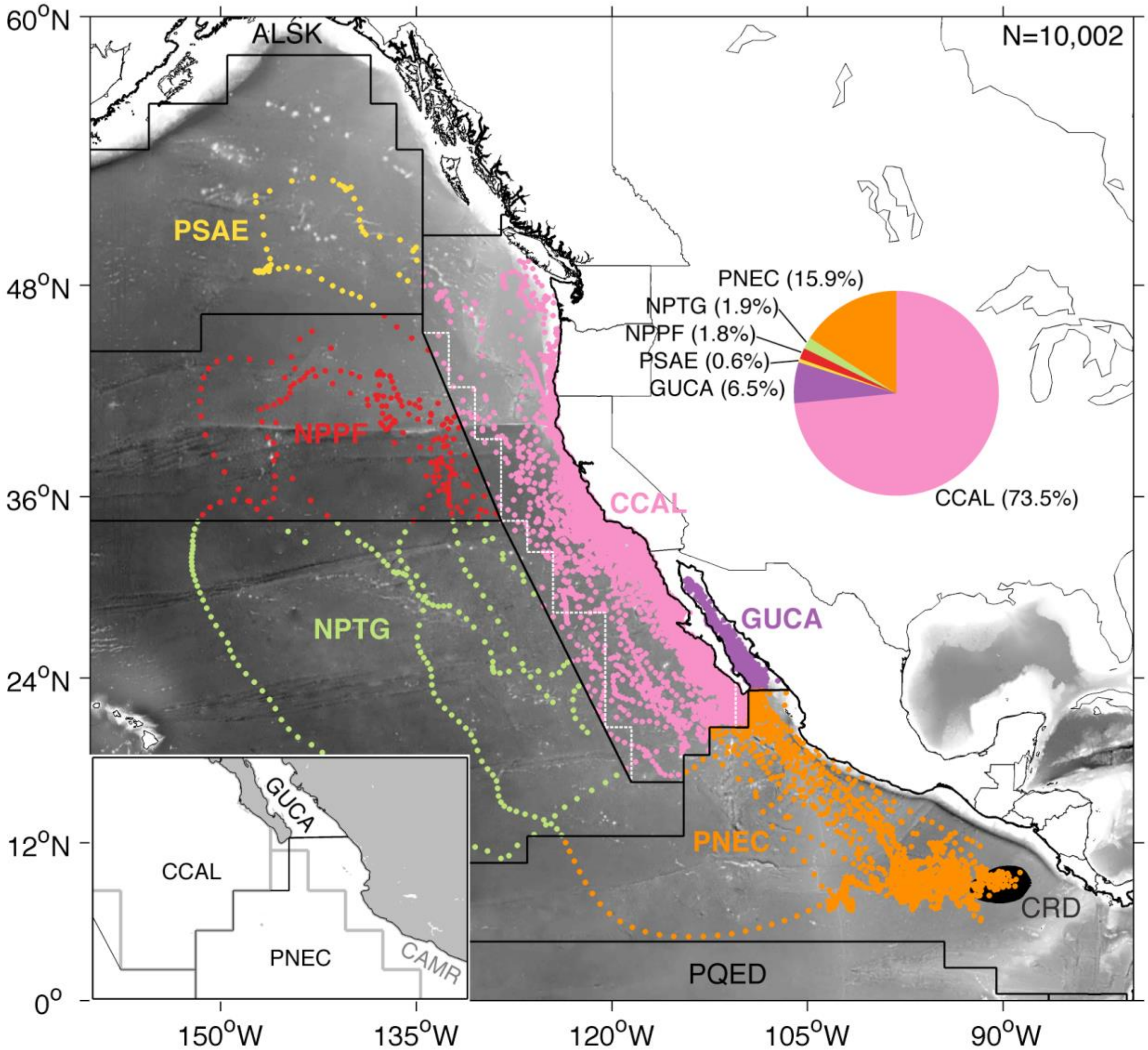

Figure 8. Tracks from satellite tags (1999-2009) on 87 eastern North Pacific blue whales, demonstrating that most blue whales in Alaskan waters are not from the eastern population, but are from the far more endangered western North Pacific blue whale population. Source: D. Palacios.