Report on abundance estimates of blue and humpback whales along the US West Coast extended to 2022 to 2024

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This report updates abundance estimates for blue and humpback whales through 2024 and summarizes the survey and photo-ID effort for 2022 to 2024 that generated the data for these most recent estimates. This work was conducted with support from a number of sources:

1. a subaward from WDFW under the NOAA Section 6 program to conduct small boat surveys, photographic identifications, sample collections, and tag deployments on endangered large whales to inform risks from entanglements and ship strikes,
2. a project to inform decisions on the California commercial Dungeness crab fishery funded by the Pacific States Marine Fisheries Commission and the California Ocean Protection Council,
3. work off Oregon and northern California supported through a subaward from Oregon State University to inform offshore alternative energy development, and
4. support from Southwest Fisheries Science Center to estimate blue whale abundance using new data and models.

We summarize some of the work and results in the sections that follow but additional detail can be found in more than 40 publications in scientific journals that have come out during the project period that are based at least in part on some of the work conducted under this project (see full list of these is included at the end of this report).

Small boat surveys along the US West Coast

We conducted small boat surveys from 2022 to 2024 for a number of related studies mentioned above. These covered the US West Coast with 423 days of surveys representing 2,962 of effort across the three years and spread among the three states (Table1, Figure 1). These surveys found 2,212 sightings of 5,952 humpback whales (Table 2) and 554 sightings of 1,150 blue whales across all years and regions (Table 2). The locations of these sightings were generally distributed throughout the areas of survey coverage but for blue whales there no sightings in any of the effort north of southern Oregon (Figures 1 and 2). This was consistent with past work that has also shown blue whale occurrence relatively rare of northern Oregon and Washington.

Table 1. Summary of number of surveys and hours of effort conducted along the US West Coast for 2022 to 2024.

	2022		2023		2024		Total 2022-2024	
State	**Days**	**Hours**	**Days**	**Hours**	**Days**	**Hours**	**Days**	**Hours**
Washington	29	181	44	236	44	278	117	695
Oregon	5	31	19	146	5	34	29	211
California	59	436	91	667	127	953	277	2056
Totals	93	648	154	1049	176	1265	423	2962

The number of boat surveys we were able to conduct (423) reflects our being able to include the effort funded through multiple sources that still contributed to some of the overall objectives of that work. This allowed more thorough coverage of the entire US West Coast and more representative and larger number of sightings than would have been possible otherwise.

Table 2. Summary of humpback and blue whale sightings and individuals seen during Cascadia small boat surveys by state and year.

	2022		2023		2024	
State	**Sightings**	**Animals**	**Sightings**	**Animals**	**Sightings**	**Animals**
Humpback whales						
Washington	100	234	111	448	97	688
Oregon	27	59	87	212	55	144
California	561	1293	642	1364	532	1500
Total humpback	688	1586	840	2024	684	2332
Blue whales						
Oregon	1	1	92	172	7	8
California	46	76	86	169	322	724
Total blue whales	47	77	178	341	329	732

Abundance estimates of humpback whales from photo-ID data

The total identifications available for analysis of calculations like the mark-recapture abundance estimates, includes additional identifications available from other collaborating researchers and opportunistic sources such as naturalists or citizen scientists going out on whale watch boats including those contributed to Happywhale. We also utilized identifications from long-term collaborators Monterey Bay Whale Watch, Marine Life Studies, Channel Islands Naturalist Corps, and Aquarium of the Pacific. Along with the identifications from Cascadia surveys, these provided almost 25,000 identifications across the three years and represented 5,087 unique individuals (Table 3). The contributed photos provide an important source of added data but are disproportionally from areas where there is regular whale watch activity such as Monterey Bay, the S California Bight and the Salish Sea.

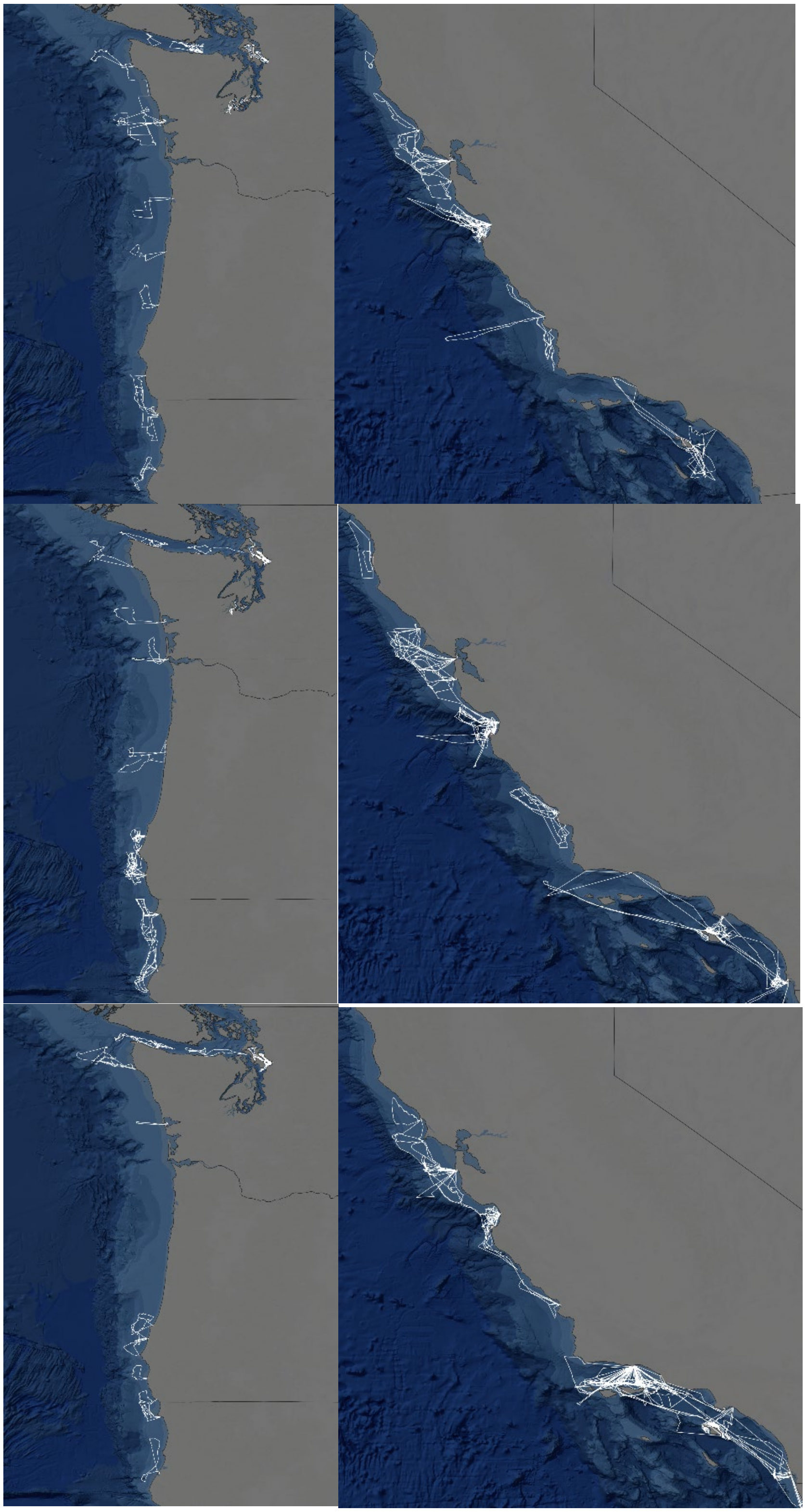

Figure 1. Cascadia small boat survey track lines by year for 2022 (top), 2023(middle), and 2024 (bottom).

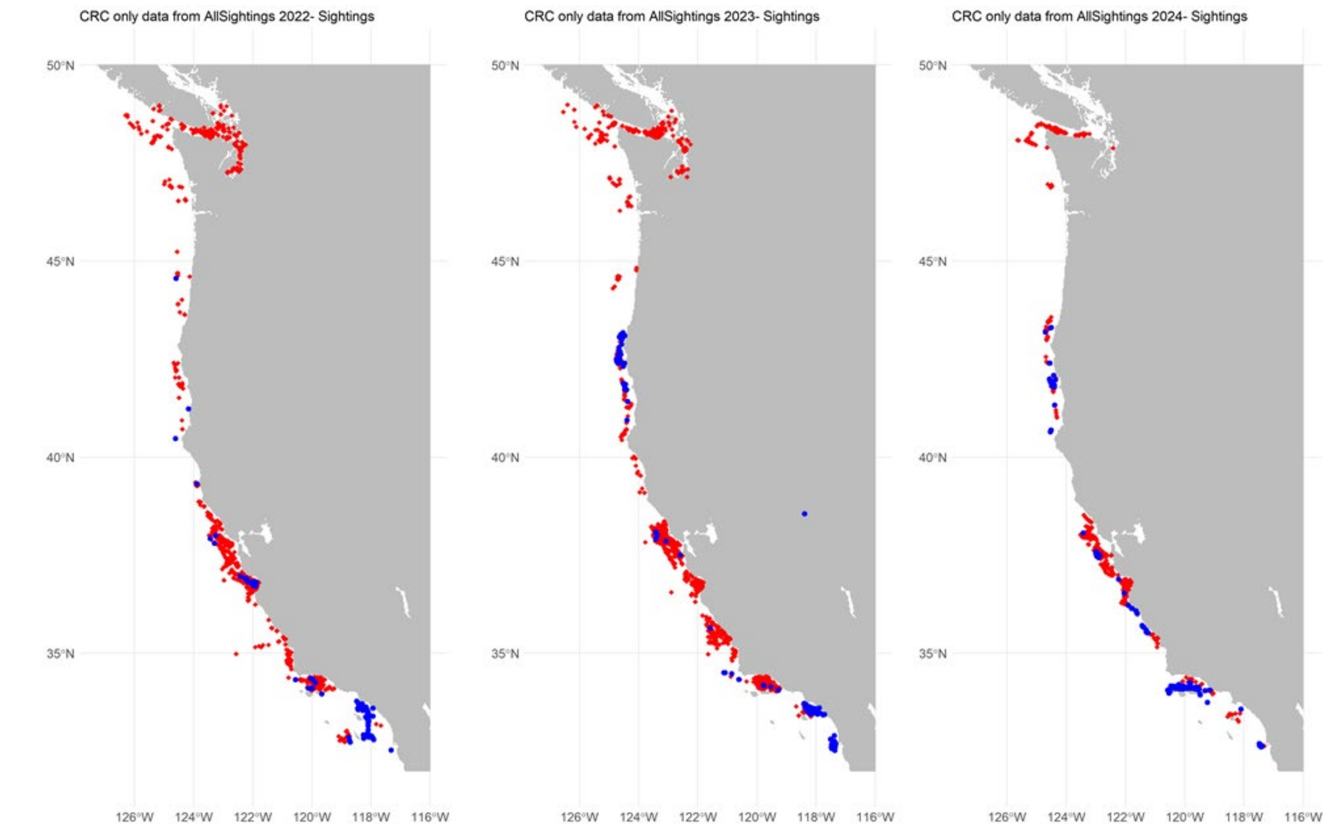

Figure 2. Locations of sightings of humpback (red) and blue (blue) whales from Cascadia small boat effort by year for 2022 (left), 2023 (middle), and 2024 (right).

Table 3. Total identification photographs of humpback whales from all sources by year and region for 2022 to 2024.

	2022		2023		2024	
State	**Ident.**	**Unique**	**Ident.**	**Unique**	**Ident.**	**Unique**
Wash. (incl S BC to 49N)	2216	654	1652	546	1529	509
Oregon	127	75	365	226	369	196
California	7494	1887	5336	1812	5697	2111
Along US WC	9837	2594	7353	2559	7595	2788

Past mark-recapture estimates of humpback whales along the US West Coast were reported by Calambokidis and Barlow (2020) and used in the NOAA Stock Assessment reports which included separate calculations for California-Oregon and Washington-S British Columbia (separate feeding areas recognized in the SPLASH study and most analyses since). The new humpback whale abundance estimates through 2024 were conducted for both feeding areas using the same basic approach as some of the past time series estimates (Calambokidis and Barlow 2004, 2013, 2017, 2020, Calambokidis et al. 2009) but with a few modifications based on insights in recent years including:

1. Restricting the seasonality of the identifications used in the mark-recapture calculations to the period from May through October where largest numbers of identifications come from anyway. We also found that outside that period, there were an increased proportion of humpback whales sighted that had been identified in feeding areas farther north including Alaska that were likely

whales migrating from those areas and either caught in migration or because they had stopped to feed on migration (Figure 4).

2. We added a new quality restriction to the photos and matches reported in Happywhale after we discovered that some matches reported in Happywhale involved flukes of poor quality that we did not have confidence in. Some of this was revealed when we tested for migration speed and saw that many of those with unrealistic movement speeds between sightings involved these low confidence matches. To apply these evenly for all whales we removed from consideration in the mark-recapture calculations encounters that were represented by images in the two lowest Happywhale quality categories (0 and 1).

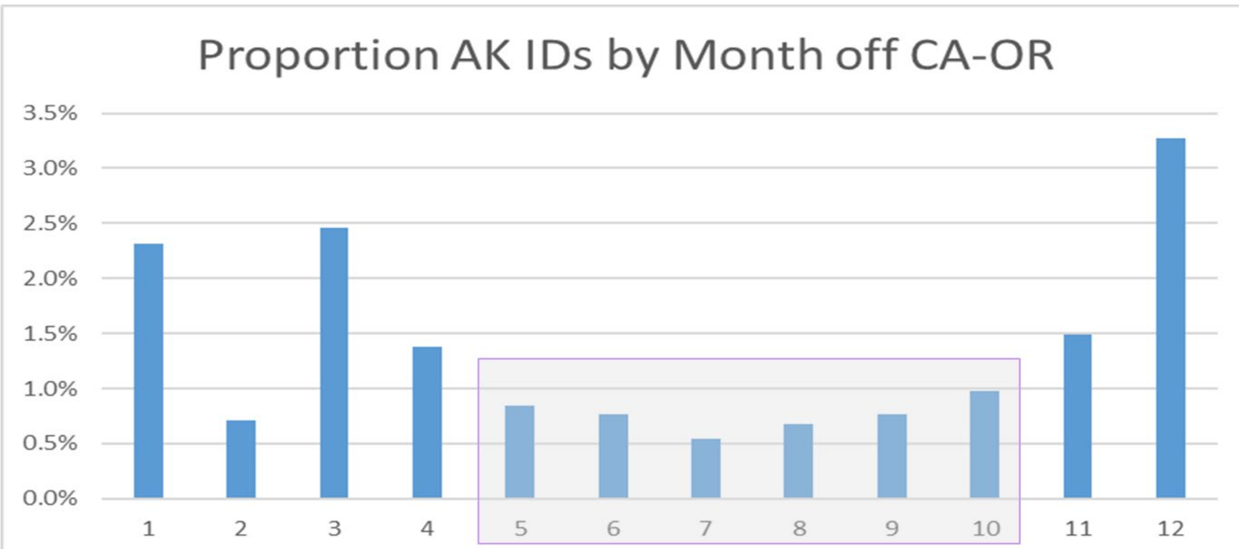

Figure 4. Proportion of humpback whales seen off California-Oregon that had known matches to Alaska feeding areas as of Cascadia dataset on 11 March 2024 that includes CRC and HW 2023 data but not all contributors.

Even though the proportion of humpback whales identified off California-Oregon was small, there was an apparent increase in the proportion of these whales matching Alaska in 2015-19 (Figure 5). This was during the period that the whales in SE Alaska and likely other areas were experiencing a sharp decrease apparently due to environmental factors (Cheeseman et al. 2024). This response appeared to continue into the more recent period as well (Figure 5). The very low proportion of whales seen off California-Oregon that had also been seen in Alaska indicates that while this was an apparent response to the challenges humpback whales were facing on the Alaska feeding grounds, it does not come close to accounting for the number of whales that went missing in Alaska.

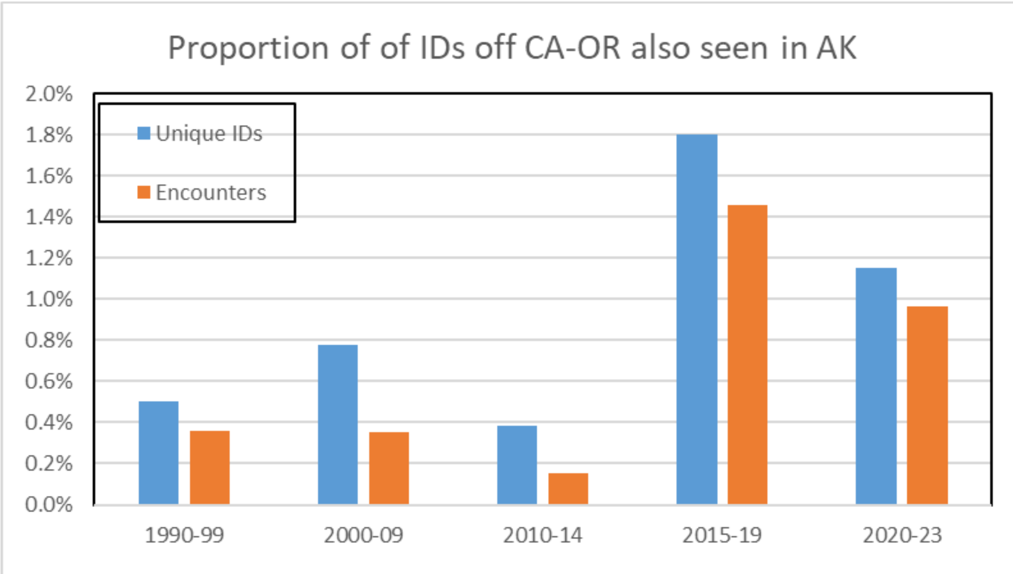

Figure 5. Proportion of humpback whales (IDs and encounters) seen off California-Oregon that had known matches to Alaska feeding areas as of Cascadia dataset (11 March 2024 which includes CRC and HW 2023 data but not all contributors) by years.

New abundance estimates were calculated using the Darroch (Mt) and Chao (Mth) models and 4-year sample periods (similar to Calambokidis and Barlow 2020) but now restricted to months May to October and extended through 2024 (Figure 6). The new estimates through 2024 show a continued increase in the abundance estimates of humpback whales through 2024 with the most recent Chao estimate now being just over 7,000. These estimates for earlier years were similar to past estimates though with some modest changes. In particular, the Chao estimates for the periods ending 2015 and 2016 were revised downward more than other years because of the season restriction. The ratio of the Chao and Darroch estimates helps show the degree to which the Chao estimate is correcting for heterogeneity in capture probability. That proportional difference showed the highest level in any year (1.74 compared to generally below 1.4 previously) for the 2013-2016 period that is when the big increase in abundance occurred. While it is subtle, the rapid increase in the Chao estimates in the mid to late 2010s is in part the result of that model correcting for higher perceived levels of heterogeneity in the data with the Darroch estimates increasing at a more moderate rate. One possible explanation for this is that the habitat compression during this period combined with a greater proportion of IDs from MB including from HW, resulting in the Chao model calculating a much higher level of heterogeneity and therefore an exaggerated correction for it. While the Chao better accounts for heterogeneity so overall are likely more accurate, the Darroch may capture the true rate of increase in that one anomalous period (mid to late 2010s) better.

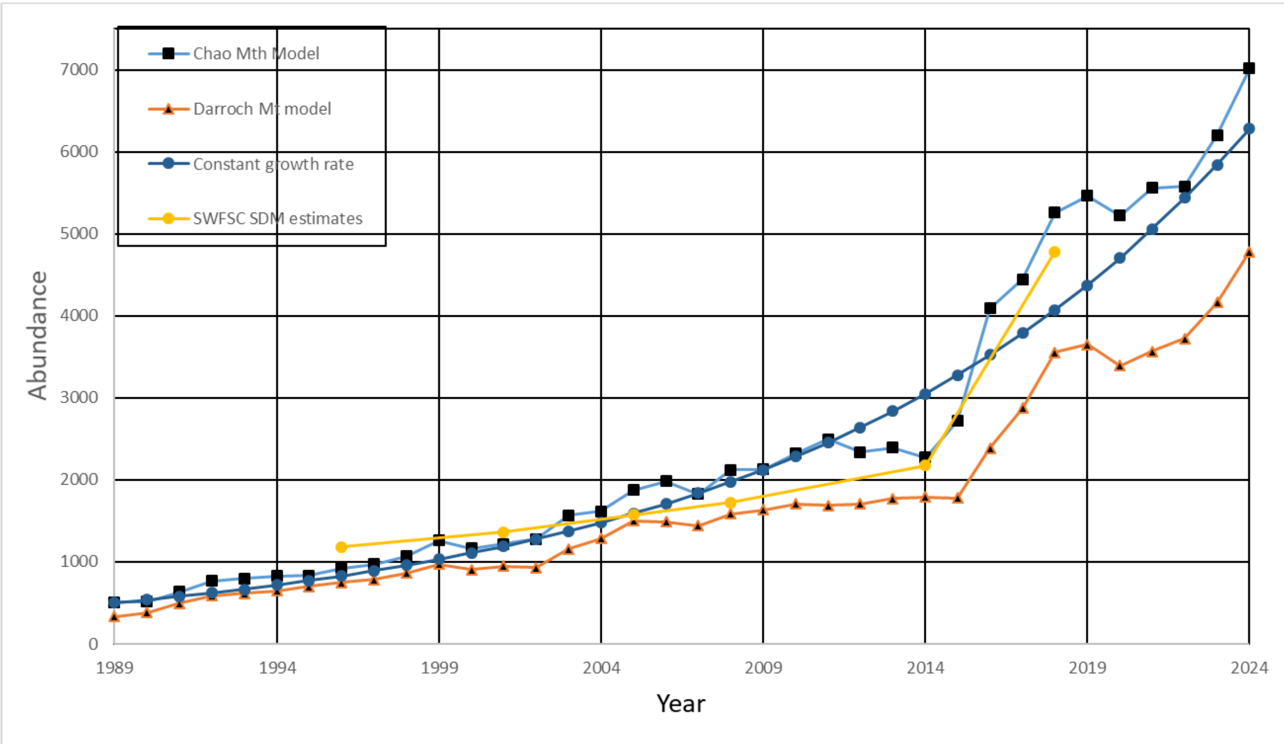

Figure 6. New estimates of humpback whale abundance for California-Oregon from Darroch (Mt) and Chao (Mth) models using photo-identification results through 2024. These were conducted similarly to those described in Calambokidis and Barlow (2020) but now are restricted to May to October only and new quality screening of IDs from Happywhale. Also shown are the SDM estimates from the SWFSC line-transect surveys as reported in Becker et al. (2020).

New abundance estimates were calculated for the Washington to Southern British Columbia feeding area using similar methods as described for California and Oregon and included:

1. Abundance estimates were updated through 2024 with available data. The 2024 data included all Cascadia data and those from close collaborators including OSU and those available in Happywhale but excluding some identifications from past contributors that were not yet available.
2. We applied the same month restriction of May to October for the capture histories based on the results discussed above for California-Oregon and keeps things consistent between the two regions.
3. We also restricted identifications to 49.5 N latitude south to the Oregon-Washington border. This northern boundary is roughly half way up Vancouver Island and is a slightly more restrictive border than has been applied in the past.

The new estimates from both the Darroch and Chao models and are shown in Figure 7 along with the previous calculated estimates that did not include some of the restrictions above. The new estimates only varied slightly form those calculated previously indicating the new updated data, and the restrictions to only months May-October and the tighter northern boundary did not alter things very much. As with the previous estimates show an increasing abundance that appeared to plateau somewhat in the 2010s before increasing again in the late 2010s. The growth rate during the earliest period from the mid-1990s to early 2000s exceeds typical growth rates and may have been impacted by the lower sample size and more limited spatial coverage during those periods. Since the early 2000s, however, the growth rate based on the Chao estimates has been fairly consistent with a very reasonable 7.5% growth rate (Figure 7), similar to what has been seen for California-Oregon.

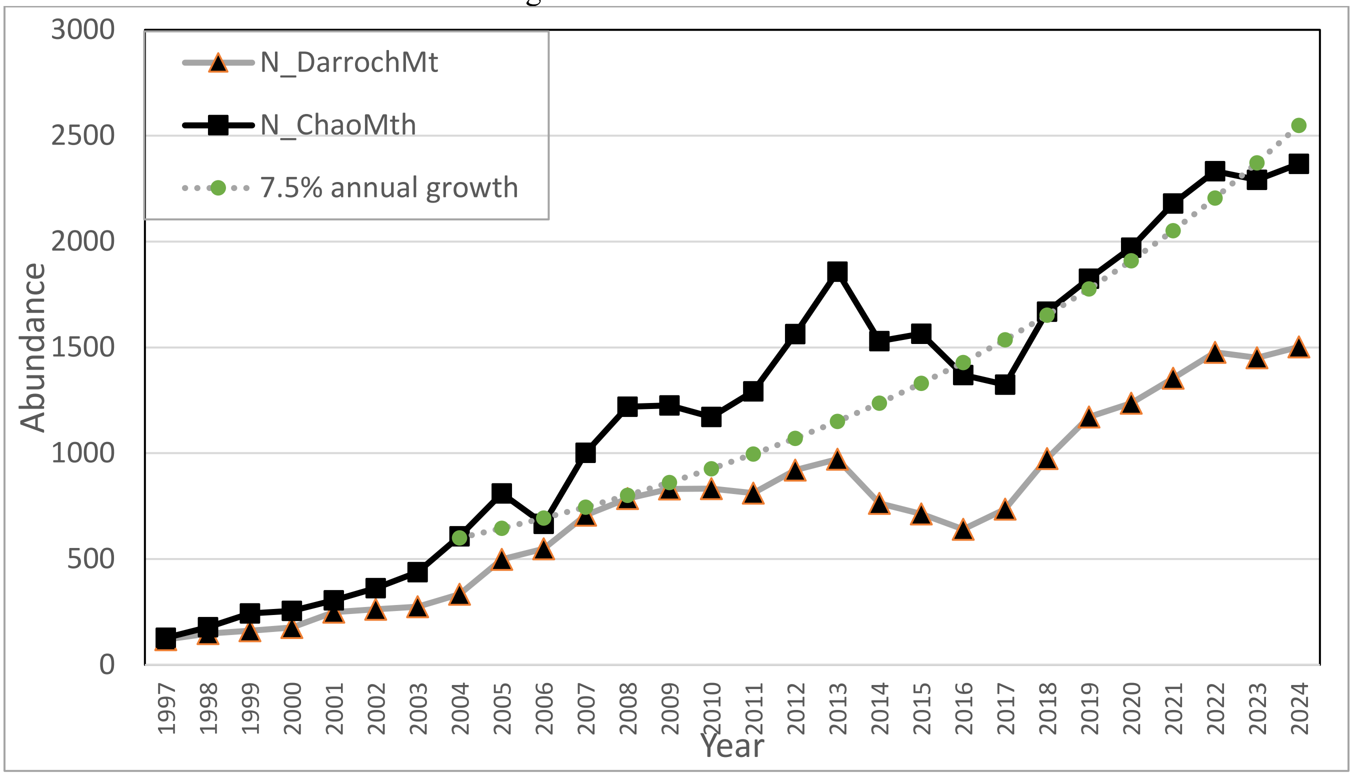

Figure 7. Summary of the new abundance estimates through 2024 calculated with updated data and restricted for Washington to S British Columbia (S of 49.5 N) with comparison to 7.5% growth rate starting in 2004 when surveys more thoroughly covered the study area.

Updated mark-recapture abundance estimates for humpback whales are calculated for both California-Oregon and Washington-Southern British Columbia. The mark-recapture estimates for California-Regon mirror the SDM line-transect estimates from the SWFSC cruises (also shown in Figure 6) fairly well. A couple of considerations in this comparison is that the SDM estimates are from Becker et al. (2020) and are for the entire West Coast while the mark recapture estimates are for the California-Oregon feeding area. While we calculate separate mark-recapture estimates Washington-S British Columbia, we did not add those to comparison to the SDM estimates would be problematic since they include southern BC waters not included in the SDM estimates.

Our results show that humpback whale abundance continues to increase off the US West Coast even though populations in other feeding areas of the North Pacific, especially southeast Alaska, have decreased in the same period (Cheeseman et al. 2024). Despite the apparent limits and stresses placed on populations feeding in these other areas, they have only resulted in a small increase in the number of humpback whales shifting from those other areas to the US West Coast. This suggests humpback whales have a high level of site fidelity and loyalty to specific feeding areas, though they do show ability to make smaller shifts within these areas.

Blue whale abundance estimates

We developed new abundance estimates for blue whales with data going through 2024, updating past reports that only went through 2021. We did not make as extensive an evaluation of new models as we did with humpback whales, but this will be a part of a more extensive evaluation of blue whale abundance being conducted by Georgie Whittome, PhD student at University of St. Andrews, collaborating with us. Her dissertation work will include not only development of new mark-recapture models but also examining data from line-transect and satellite tag data to better understand how blue whale use of the US West Coast has changed in recent decades. A major part of the motivation for this is the puzzling disagreement between the abundance and trends from the mark-recapture data and the line transect data (Figure 8).

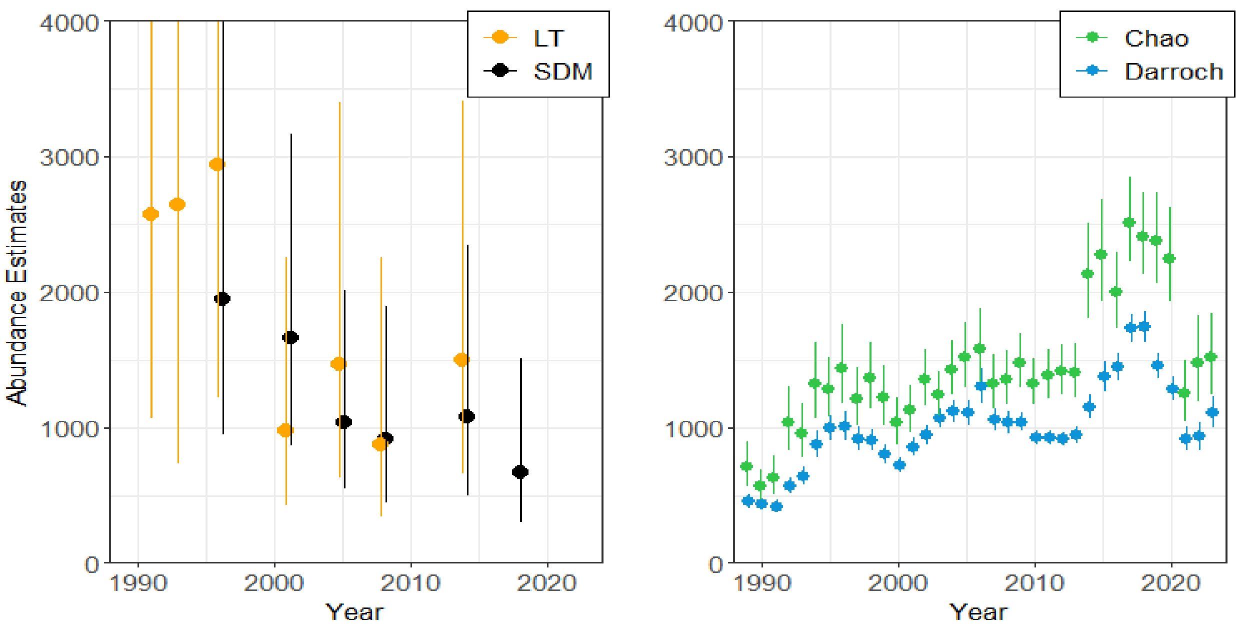

Figure 8. Estimates of abundance of blue whales off the US West Coast based on different methods.

The above trends in blue whale abundance by the two methods results in a growing discrepancy between the methods in both recent abundance and direction of the trend (Figure 8). If blue whale abundance is declining to the degree indicated by the line-transect estimates, going from 2,000 to 3,000 in the 1990s to under 1,000 more recently this would be a major concern.

These two methodologies measure different things and that has suggested a potential insight to what has changed. Line-transect surveys estimated the average density of blue whales and hence the abundance represents the average number of animals in the region during the survey period. Mark-recapture from photo-identification estimates the total population size being sampled. This means differences in the line-transect estimates may be the result of fewer whales feeding off the U.S. West Coast and instead using other parts of their range (Calambokidis and Barlow 2004, Calambokidis et al, 2009). Verifying whether this explanation is true and the reason for it is critically needed.

We generated new estimates of blue whale abundance updated through 2024 using the models we have reported previously and used with both blue and humpback whales (Calambokidis and Barlow 2020). These benefited from a record year of identifications obtained in 2024 when we successfully obtained

1,432 identifications of blue whales overall for the US West Coast and Baja California, Mexico. We decided to restrict our analysis to only identifications from 30 degrees N (northern Baja) up through US West Coast waters. This limited the number of identifications to 1,249 of 459 individuals. The results of our new estimates are summarized in Figure 9 comparing the Chao and Darroch models and using either 4-year or 5-year sample periods.

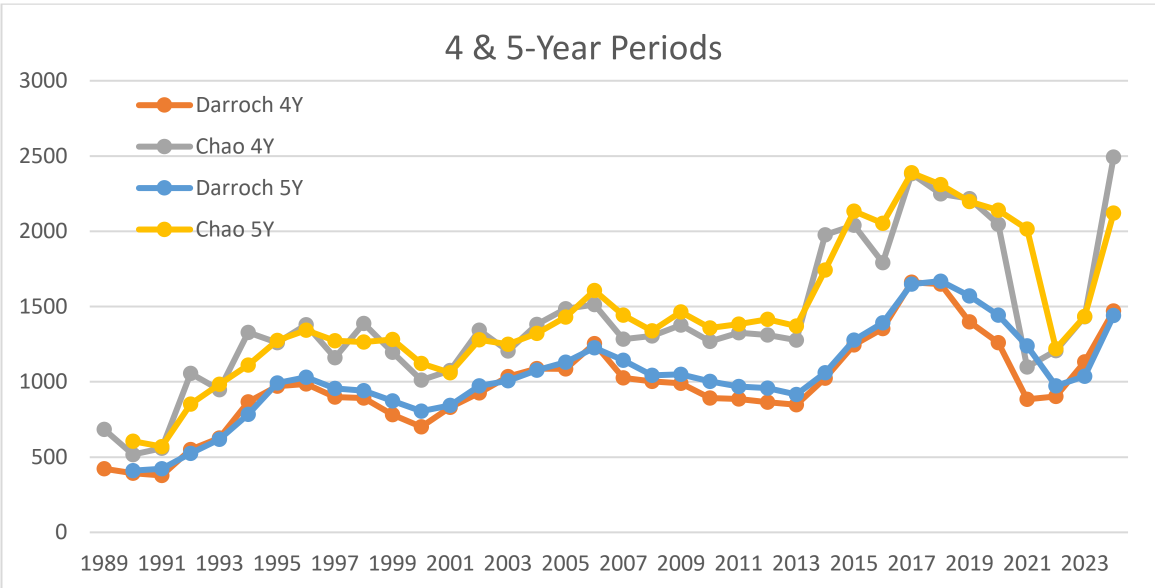

Figure 9. Estimates of blue whales in the eastern North Pacific based on 4 and 5-year sample periods using Darroch and Chao mark-recapture closed models restricted to latitudes from 30 degrees N (northern Baja) through US West Coast waters.

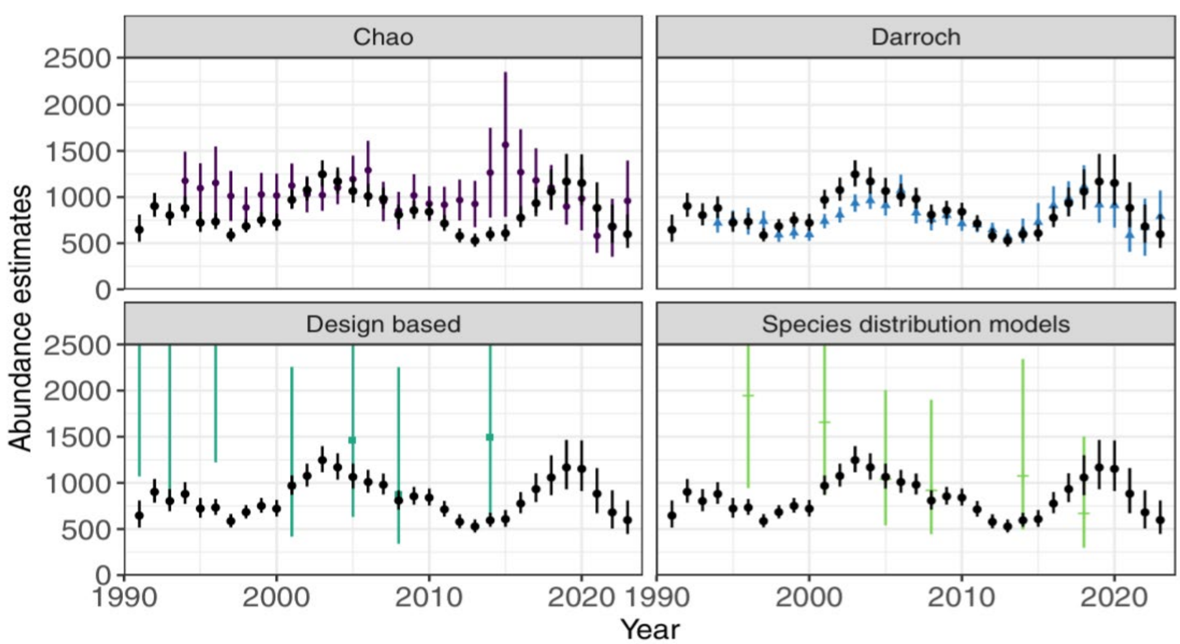

Figure 10. Comparison of blue whale abundance through 2023 based on different models including new Spatial Mark-Recapture model reported in Whittome et al. (2025).

Recent estimates of blue whale abundance have provided insight but not fully resolved some of puzzling questions about how blue whales in the eastern North Pacific are doing. Mark-recapture estimates through the late 2010s especially from the Chao model had suggested an increasing blue whale abundance, which was in contrast to the declines seen in the line-transect based estimates, but the addition of more recent data has shown these mark-recapture estimates to be more variable. They declined after the late 2010s and increased again recently. High mark-recapture estimates appear to be associated with periods that include years where we identified unusually large numbers of blue whales off the US West Coast. During two years, 2017 and 2024, we identified the largest numbers of unique blue whales in our study area (496 and 459, respectively) compared to any other year. The five periods that included either 2017 or 2024, represent the periods with the five highest Chao estimates across our entire study period (based on 4-year sample periods). We suspect that in these two years, ENP blue whales that perhaps do not traditionally use US West Coast waters, were more present in areas we were able to identify them. The presence of these animals along with whales that more typically used the US West Coast resulted in the Chao model detecting a higher rate of heterogeneity in capture probabilities in the multi-year sample and consequently adjusting the abundance estimate upwards.

Overall, our new estimates combined with results from other models (Whittome et al. 2025) and the line transect results from the years SWFSC conducts their systematic surveys (Becker et al. 2020), suggest there is an overall ENP blue whale population using waters from the Costa Rica Dome north into the Gulf of Alaska (and including the US West Coast) that appears to number 2,000 to 2,500 animals but only a portion of that population, 500-1,000, regularly uses the US West Coast with environmental conditions impacting krill abundance in this larger range altering this proportion. The marine heat wave in the eastern North Pacific in the mid-2010s resulted in habitat compression of humpback whales along the California coast (Santora et al. 2020) and appeared to be responsible for a major decline in humpback whales feeding in Alaskan waters (Cheeseman et al. 2024). This may also have played a role in shifts in blue whale distribution. The body condition of blue whales feeding off the US West Coast from 1993 to 2023 varied significantly by year with 2017 being one of only to years where a majority of blue whales were judged to be in poor body condition (Wachtendonk et al. 2022, Meyers et al. Submitted). These periods of high blue whale occurrence off the US West Coast therefore may not represent particularly good periods in that area but perhaps poor conditions elsewhere.

Publications

The following scientific publications in scientific journals that have come out since 2022 based in part on data from Cascadia Research US West Coast work:

Cade, D.E., Kahane-Rapport, S.R., Gough, W.T., Bierlich, K.C., Linsky, J.M., Calambokidis, J., Johnston, D.W., Goldbogen, J.A. and Friedlaender, A.S., 2023. Minke whale feeding rate limitations suggest constraints on the minimum body size for engulfment filtration feeding. Nature Ecology & Evolution, pp.1-12.

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Cheeseman, T., J. Barlow, J.M. Acebes, K. Audley, L. Bejder, C. Birdsall, O.S. Bracamontes, A.L. Bradford, J. Byington, J. Calambokidis, et al. 2024. Bellwethers of Change: Population Modelling of North Pacific Humpback Whales from 2002 through 2021 Reveals Shift from Recovery to Climate Response. Royal Society Open Science 11(2): 231462. doi: 10.1098/rsos.231462

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Corsi, E., J. Calambokidis, K.R. Flynn, and G.H. Steiger. 2022. Killer Whale Predatory Scarring on Mysticetes: A Comparison of Rake Marks Among Blue, Humpback, and Gray Whales in the Eastern North Pacific. Marine Mammal Science 38(1): 223-234. doi: 10.1111/mms.12863

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Appendix Table 1. Abundance estimates for humpback whales off California and Oregon using only photo-identifications from May to October and excluding HW IDs of lower quality (0-1).

Year	Period used	IDs	N Darroch Mt	Se N Darroch Mt	N Chao Mth	seN Chao Mth	7.5% growth
1986		91					
1987		149					
1988		209					
1989	1986_1989	93	336	8.2	506	40.6	500
1990	1987_1990	148	381	9.6	517	36.6	538
1991	1988_1991	253	498	13.4	636	42.4	578
1992	1989_1992	368	587	12.8	766	45.5	621
1993	1990_1993	261	617	10.7	800	39.4	668
1994	1991_1994	242	644	10.2	830	37.7	718
1995	1992_1995	269	701	12.5	834	36.5	772
1996	1993_1996	293	752	17.1	922	47.8	830
1997	1994_1997	257	788	19.1	974	52.9	892
1998	1995_1998	379	861	18.8	1,068	53.7	959
1999	1996_1999	313	975	23.3	1,263	68.1	1,031
2000	1997_2000	202	908	22.5	1,166	65.4	1,108
2001	1998_2001	258	948	24.8	1,220	70.5	1,191
2002	1999_2002	291	928	27.1	1,277	82.5	1,280
2003	2000_2003	386	1,160	38.4	1,566	106.3	1,376
2004	2001_2004	291	1,287	42.2	1,618	102.9	1,479
2005	2002_2005	351	1,504	51.4	1,878	120.0	1,590
2006	2003_2006	270	1,489	51.6	1,985	132.6	1,710
2007	2004_2007	213	1,441	59.0	1,826	135.4	1,838
2008	2005_2008	395	1,585	62.4	2,123	155.2	1,976
2009	2006_2009	414	1,635	61.8	2,131	148.0	2,124
2010	2007_2010	477	1,704	54.4	2,324	145.1	2,283
2011	2008_2011	372	1,686	46.3	2,495	144.6	2,454
2012	2009_2012	501	1,708	43.2	2,340	123.9	2,639
2013	2010_2013	527	1,772	42.4	2,394	120.2	2,836
2014	2011_2014	555	1,789	40.6	2,270	105.7	3,049
2015	2012_2015	599	1,779	33.7	2,718	124.2	3,278
2016	2013_2016	1120	2,387	41.3	4,091	182.3	3,524
2017	2014_2017	1066	2,876	46.3	4,444	171.6	3,788
2018	2015_2018	1425	3,555	49.9	5,261	174.6	4,072
2019	2016_2019	982	3,654	46.4	5,462	168.4	4,377
2020	2017_2020	972	3,393	41.5	5,226	162.9	4,706
2021	2018_2021	1051	3,568	46.7	5,558	179.5	5,059
2022	2019_2022	1502	3,727	49.7	5,577	177.8	5,438
2023	2020_2023	1700	4,164	49.2	6,208	179.6	5,846
2024	2021_2024	1960	4,786	49.9	7,021	181.5	6,284