UPDATED ABUNDANCE ESTIMATES OF BLUE AND HUMPBACK WHALES OFF THE US WEST COAST INCORPORATING PHOTO-IDENTIFICATIONS FROM 2010 AND 2011

Final Report for contract AB133F-10-RP-0106

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Introduction

Cascadia Research has conducted photographic identification efforts for humpback and blue whales off the US West Coast since 1986 and these have served as the primary basis for examining the movement, population structure, abundance, and trends of these populations (Calambokidis et al. 1990, 2001, 2008, 2009, Calambokidis and Barlow 2004). Here we report updated abundance estimates and trends from past data (including any corrections or late additions to our catalog) as well as incorporating field effort from 2010 and 2011 funded under a contract from SWFSC with support from the Navy's N45 research program.

Humpback whales in the North Pacific utilize distinct feeding areas with little interchange among them based on both photo-ID information (Calambokidis et al. 2008) and genetics (Baker et al. 2008). The humpback whales that feed off the US West Coast appear to be part of two feeding aggregations, one that ranges from California north roughly through Oregon and a second one that extends from Washington through southern British Columbia Calambokidis et al. 1996, 2004, 2008).

Methods

Photographic identification was conducted as described in previous reports and publications (Calambokidis and Barlow 2004, Calambokidis 2009). Photographic identifications were obtained from the following primary sources:

- Dedicated photo-ID surveys conducted using day trips from shore in 5.9 m RHIBs along the US West Coast.
- Incidental to other Cascadia survey effort including for SOCAL-Behavioral Response Study (Southern California Bight), SCORE work around San Clemente Island, and ship-strike related work in southern and Central California.
- Opportunistic photo-ID provided from programs working from whale watch operations, primarily the Channel Islands Naturalist Corps (trips out of Santa Barbara and Ventura) and the Aquarium of the Pacific (out of Long Beach) but also from other whale watch operations out of San Francisco, Monterey Bay, Dana Point, and San Diego.
- Collaborating researchers/naturalists who provided identification photographs obtained as a part of their research including for 2010-11 Jeff Jacobsen, Dawn Goley, SWFSC researchers, Casey Clark (as part of his thesis work for MLML), Izzy Szczepaniak, Brian Gisborne, Peggy Stapp, Michael Fishback and others.
- Occasional opportunistic photographs from members of the public and boaters.

Results

Trends in abundance of humpback whales

Abundance estimates of humpback whales off California-Oregon using our normal inter-year Petersen estimates showed a dramatic reversal in the trend in recent years (Table 1, Figure 1). Abundance estimates for humpback whales through the late 2000s had shown a steady 7-8% annual increase (Calambokidis and Barlow 2004, Calambokidis 2009). While there had been some periods not showing growth, these were generally fairly brief and likely the result of sampling variation, none were as long or consistent as those from recent years. One change in our recent sampling that may have contributed somewhat to the recent decrease is the increased focus of research and identifications from the Southern California Bight starting in 2010. This has been the result of more associated funded research activities in that region as part of the SOCAL-BRS and ship strike research Cascadia has been conducting and less dedicated photo-ID in central and northern California. Additionally opportunistic identifications from whale watch vessels have grown in southern California in relation to participation in northern California. This would have the potential to bias estimates downward due to greater heterogeneity of capture probabilities created by the increased chances of resighting one segment of the population in multiple years.

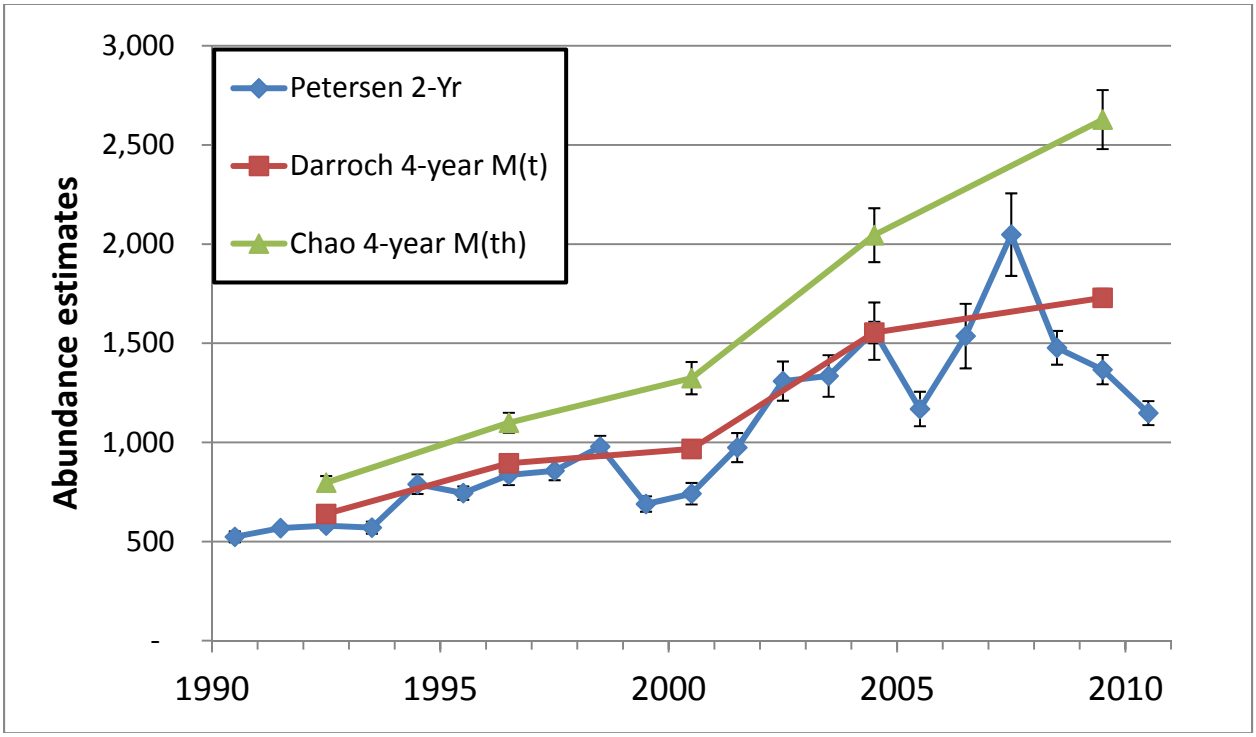

Figure 1. Estimates of abundance of humpback whales using closed mark-recapture models and multi-year sampling intervals for California to Oregon. Bars show Standard Errors. Darroch and Chao models use four consecutive sample years in non-overlapping periods except for the final estimate which uses the four most recent years (2008-11 instead of 2007-10).

Table 1. Abundance estimates of humpback whales from California to Oregon based on intern-year Petersen mark-recapture estimates, n1 and n2 are the number of unique individuals in each of the two adjacent years and m is the number of matches.

Year	n1	n2	m	Pop	CV	SE
1990-91	205	269	105	**524**	0.05	28
1991-92	269	397	188	**568**	0.03	16
1992-93	397	253	173	**580**	0.03	18
1993-94	253	244	108	**570**	0.05	31
1994-95	244	328	101	**789**	0.06	49
1995-96	328	332	146	**744**	0.05	34
1996-97	332	268	106	**836**	0.06	52
1997-98	268	385	120	**857**	0.06	48
1998-99	385	329	129	**979**	0.06	54
1999-2000	329	227	108	**689**	0.06	39
2000-01	227	266	81	**741**	0.07	54
2001-02	266	313	85	**974**	0.08	73
2002-03	313	387	92	**1,309**	0.08	99
2003-04	387	302	87	**1,335**	0.08	105
2004-05	302	365	70	**1,561**	0.09	145
2005-06	365	293	91	**1,169**	0.07	87
2006-07	293	297	56	**1,536**	0.11	163
2007-08	297	439	63	**2,048**	0.10	208
2008-09	439	476	141	**1,477**	0.06	85
2009-10	476	432	150	**1,367**	0.05	74
20010-11	432	389	146	**1,148**	0.05	61

To further examine trends and also test the potential contribution of heterogeneity we conducted additional estimates using two closed population abundance models based on 4-year periods of annual samples (Table 2, Figure 1). The Darroch estimate (model Mt in Mark with time varying capture probability) shows good agreement with the inter-year Petersen though generally slightly higher consistent with the fact these 4-year periods do involve a greater violation of population closure. The Darroch estimates do show a decline in recent years but this is fairly slight in part because with 4-year sample periods it still includes the peak abundance period. The Chao estimate (model Mth with time heterogeneity and time varying capture probability), shows a higher estimate throughout the period indicating it is adjusting for some level of sample heterogeneity. It does not show the same recent decline as the Darroch estimate indicating perhaps greater heterogeneity is occurring in recent years as suggested above.

Table 2. Estimates of abundance based on 4-year periods (annual samples) using two closed population abundance: Darroch model Mt in Mark with time varying capture probability and Chao model Mth with time heterogeneity and time varying capture probability.

Time	Darroch			Chao Mth		
Period	N	SE	CV(N)	N	SE	CV(N)
1991-1994	639	9.1	0.014	797	33.1	0.042
1995-1998	895	17.4	0.019	1099	50.3	0.046
1999-2002	967	26.6	0.028	1324	81.4	0.061
2003-2006	1554	54.4	0.035	2045	136	0.067
2008-2011	1729	45.4	0.026	2628	148.9	0.057

To examine the trend in humpback whale abundance using two-year sample periods but without the potential impact of heterogeneity from recent higher effort in Southern California, we conducted our usual Petersen estimates for California-Oregon but excluding the southern California Bight (Figure 2). This shows a similar trend as the Petersen with the full data although with not quite as dramatic a recent decline.

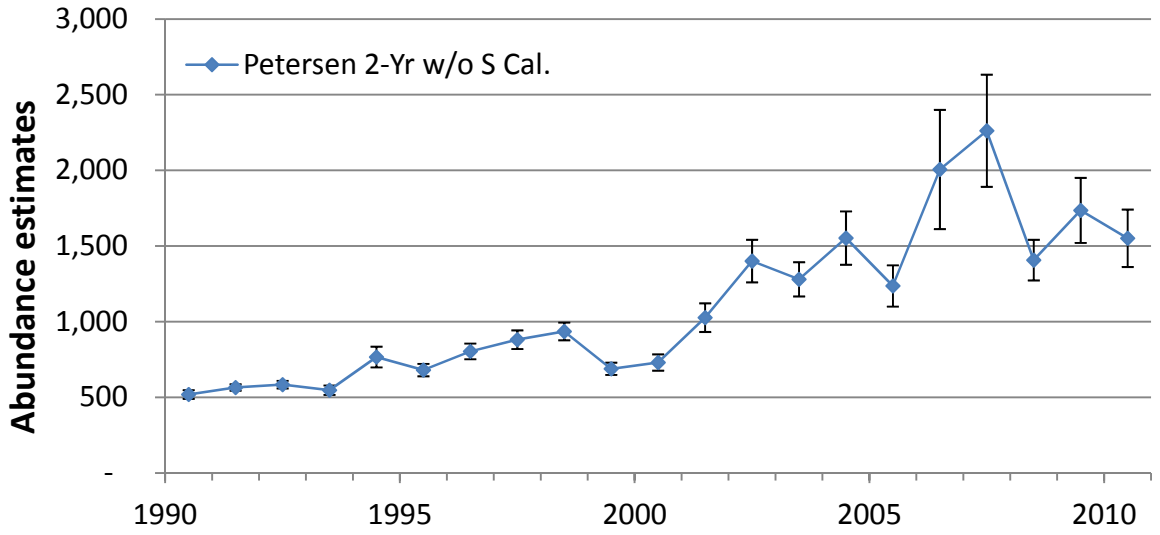

Figure 2. Humpback whale abundance using Petersen 2-year sample estimates for CA-OR but excluding identifications from the southern California Bight. Bars show Standard Errors.

Our conclusion is that there is strong evidence that the humpback whale population growth off the US West Coast has tapered off either stabilizing or possibly declining. It may take some a couple of more years of effort to allow adequate testing of this change fully accounting for heterogeneity which appears to be a contributing factor to the decline in the shorter term 2-year estimates.

Our estimates encompass the animals that feed off California and Oregon and excluded Washington where our sample size is not adequate for estimating separately but based on past estimates (Calambokidis et al. 2004) represent a much smaller number of animals than for California-Oregon.

Blue whale abundance estimates

Blue whale mark-recapture abundance estimates have been more problematic than for humpback whales because of their greater range and use of offshore waters outside the reach of most of the photo-identification effort. Past estimates have relied on Petersen mark-recapture estimates using one small but unbiased identification sample from the systematic surveys SWFSC conducts periodically for line transects and a second larger sample from the coastal photo-IDs for the time period surrounding the systematic sample (Calambokidis and Barlow 2004, Calambokidis 2009). Blue whales appear to have shifted aspects of their distribution in the eastern North Pacific in the last 10 years (Calambokidis et al. 2009) and this has resulted in changes in estimated densities of blue whales from line-transect surveys (Barlow 2009, Barlow and Forney 2007, Forney 2007).

Here we report revised abundance estimates using this same approach incorporating a larger geographic range (west coast Baja to British Columbia) since these have now been shown to be part of the feeding range of this population , and an updated database that includes some additional contributions, quality screenings, and internal reconciliations (Table 3). Because the last systematic survey was conducted in 2008 and additional surveys may be less frequent in the future, we also conduct some analysis and comparisons using the Chao 4-year model that includes heterogeneity and time varying capture probability (Table 4).

Table 3. Estimates of blue whale abundance based on Petersen mark-recapture using n1 sample from identifications obtained on systematic surveys (with SWFSC) and n2 using all other identifications from US West Coast (including some IDs from west coast of Baja and British Columbia). This includes new and updated identifications and matches from those reported previously (Calambokidis and Barlow 2004, Calambokidis 2009).

Periods	**Left sides**					**Right sides**					**Mean**
	n1	**n2**	**m**	**Est.**	**CV**	**n1**	**n2**	**m**	**Est.**	**CV**	
1991-93 (Syst. effort in 91 and 93)	84	279	13	**1,699**	0.23	83	277	12	**1,795**	0.24	**1,747**
1995-97 (Syst. effort in 96)	48	342	11	**1,400**	0.24	39	354	11	**1,182**	0.23	**1,291**
2000-2002 (Syst. effort in 01)	20	439	5	**1,539**	0.32	24	458	5	**1,912**	0.33	**1,725**
2005-2008 (Syst. effort in 05 & 08)	50	537	10	**2,493**	0.25	48	538	11	**2,200**	0.24	**2,347**

Table 4. Estimates of blue whale abundance based on 4-year periods (annual samples) using two closed population abundance: Darroch model Mt in Mark with time varying capture probability and Chao model Mth with time heterogeneity and time varying capture probability. Identifications are from West Coast including west Baja and British Columbia.

Years	**Method**					
	Darroch M(t)			**Chao M(th)**		
	N	**SE**	**CV**	**N**	**SE**	**CV**
1992-1995	1133	57.7	0.051	1553	144.5	0.093
1996-1999	863	39.2	0.045	1339	124.7	0.093
2000-2003	1189	46.0	0.039	1363	93.6	0.069
2004-2007	1143	48.4	0.042	1459	114.2	0.078
2008-2011	1053	33.4	0.032	1647	116.7	0.071

Revised estimates of blue whale abundance still show no signs of increase in the last 20 years (Figure 3) unlike humpback whales. Estimates based on the systematic surveys were revised slightly downward compared to the estimates previously reported (Calambokidis and Barlow 2004), with the most dramatic change for the 1995-97 estimates (Table 3). While the last estimate (for 2005-2008) is slightly higher than the earlier, this difference was well within the margin of error.

Estimates from the Chao models were extremely promising and yielded similar estimates to those based on the systematic surveys but with much lower confidence limits (Table 4, Figure 3). These showed a near constant abundance of right around 1,500 blue whales. While these estimates may not fully account for downward biases due to heterogeneity they provide a very consistent estimate of abundance especially for trend analysis.

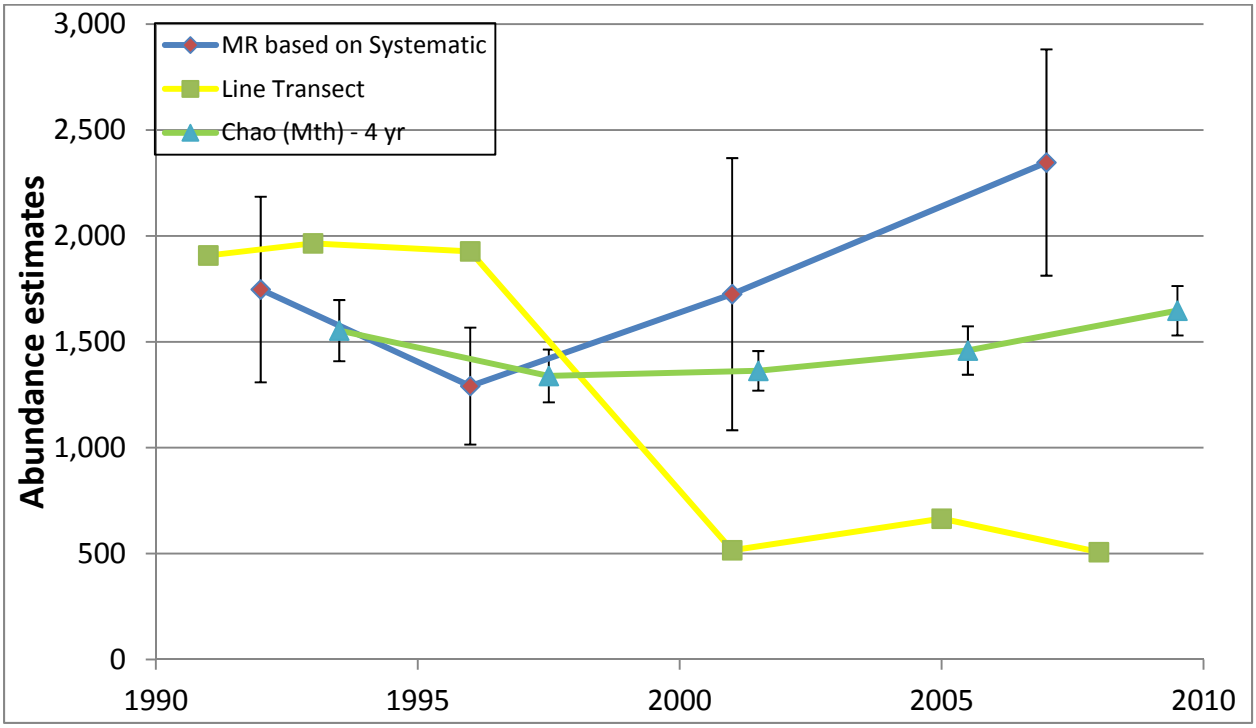

Figure 3. Blue whale abundance estimates based on mark recapture from photo-identification in comparison with estimates from SWFSC line transects (Barlow 2009, Barlow and Forney 2007, Forney 2007).

New insights into movements

From 26 March to 2 April 2011, Cascadia participated in a research expedition from San Diego down the Baja coast to Isla Cedros and back (Calambokidis et al. 2011). On 1 April, at least 9 humpback whales were spotted off Punta Baja apparently feeding just as the fog was closing in, three of these were photo-identified and a fourth animal was identified the next day further north also apparently feeding. This is an area where do not have previous identifications so is of special interest. Two of the four whales identified were known from our historical catalog as whales documented from California. One (10957) had been documented 17 times in our database with earliest identifications were from Baja and mainland Mexico in 1988 and 1989 (from UABCS) and this know male (from a biopsy in 2002) has been documented 7 years from 1996 through 2011 in the Santa Barbara Channel, southern California. The other individual (15276) had been seen only once before in the Santa Barbara Channel in June 2010. The finding of two known California whales feeding in early spring off the west coast of northern Baja suggests that this may be a transitional feeding area for humpback whales as they shift from their breeding areas in Mexico to feeding off California.

We only have records of three other humpback whales identified off the west coast of northern Baja. Of two individuals identified from 18-20 October 2006 (13774 13778) and one whale identified on 18 May 2008 (12466) none had have been documented off the US West Coast.

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