Marbled Murrelet Effectiveness Monitoring, Northwest Forest Plan

2018 Summary Report

Northwest Forest Plan Interagency Regional Monitoring Program

Adult marbled murrelet holding a fish (likely, sandlance). National Park Service, Alaska.

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Marbled Murrelet Effectiveness Monitoring Team

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Adult marbled murrelet on nest. Photo credit: Nick Hatch, U.S. Forest Service

SUMMARY OF 2018 RESULTS

Here, we report the 2018 monitoring results from the Northwest Forest Plan Effectiveness Monitoring Program for the Marbled Murrelet (*Brachyramphus marmoratus*; hereafter, murrelet), and provide a brief description of our methods and a discussion of our findings. The purpose of the murrelet program is to assess status and trends of: 1) at-sea murrelet populations during the nesting season in coastal waters adjacent to the Northwest Forest Plan area (Figure 1); and 2) murrelet nesting habitat throughout the listed range of the species. Here, we only report population monitoring results from at-sea surveys. Habitat monitoring work was not conducted in 2018, and therefore is not presented in this report. More in-depth evaluations of population and habitat monitoring will be reported in our "25-year report," with an expected publication date in 2020. Please refer to the 20-year report and past publications for more details on the program and methods (Madsen *et al*. 1999; Huff *et al.* 2006; Raphael *et al.* 2007; Raphael *et al.* 2011; Miller *et al.* 2012; Falxa *et al*. 2014; Falxa and Raphael 2016).

The population monitoring strategy was designed (see Raphael *et al*. 2007) to estimate at-sea population size and trend during the breeding season in five of the six murrelet Conservation Zones, which extend from the United States border with British Columbia, Canada, south to San Francisco Bay, California, as identified in the Recovery Plan for the Marbled Murrelet (U.S. Fish and Wildlife Service 1997; Figure 1). We present detailed results through 2018 (where available) in the tables and figures below. We conducted annual surveys in Conservation Zones 1-4 in years 2000-2013. Beginning in 2014, we implemented a reduced-sampling effort design, where Conservation Zones 1 and 3 are sampled in even years (e.g., 2014, 2016, etc.), Conservation Zones 2 and 4 are sampled in odd years, and Conservation Zone 5 is sampled every fourth year, in conjunction with Conservation Zone 4.

Due to the reduced sampling effort, we are not able to provide a Plan-wide area ("All-Zones") population size estimate for 2018. We are, however, able to provide an All-Zone estimate for 2017, which is approximately 23,000 murrelets (95% Confidence interval "CI" [rounded] = 18,500-27,600) (Table 1). In 2018, we sampled Conservation Zone 1 (Puget Sound and Strait of Juan de Fuca, Washington) and Conservation Zone 3 (mouth of Columbia River south to Coos Bay, Oregon). At the Conservation Zone scale, the 2018 population estimates were approximately 3,800 murrelets (CI = 1,900-7,000) in Conservation Zone 1, and approximately 8,400 murrelets (CI = 5,900-12,000) in Conservation Zone 3.

The All-zone trend for years 2001-2017 indicates no evidence of a trend (0.34% increase per year; 95% CI: -0.9 to 1.6%). At the Conservation Zone scale, Zone 1 shows a significant negative slope (-4.9%; 95%CI: -7.3% to -2.4%), for years 2001 through 2018. Conservation Zone 3 shows no trend for years 2001 through 2018 (1.4% increase per year; 95% CI: -0.4% to 3.3%). These results are summarized in Table 2 and Figure 2. We do not provide trends through 2018 for Zones 2, 4 and 5 because they were not surveyed in 2018.

At the state scale, Washington exhibited a significant declining trend between 2001 and 2017 (-3.9% decrease per year; 95% CI: -5.8% to -2.0%) while Oregon and California (each state, years 2000-2017) showed significant positive trends (OR = 2.0% increase per year; 95% CI: 0.5% to 3.6%; CA = 4.5% increase per year; 95% CI: 2.2% to 6.9%) (Table 2).

The abundance and distribution of murrelets in the marine environment during the nesting season appears to be influenced by both marine and terrestrial factors (Raphael *et al*. 2015). We are observing local decreases in murrelet density in Zone 1 and some increases in the zones to the south, especially since 2012. We don't know if these changes are the result of birds moving among zones (or at even larger spatial scales, e.g., from Alaska or British Columbia), and to what degree local reproduction and survival influence these apparent trends. Even though the marine distribution and abundance derived from our monitoring efforts correlate with the amount and extent of adjacent murrelet nesting habitat (see Yen *et al*. 2004, Lorenz *et*

al. 2016, Raphael *et al*. 2015, 2016b), the degree to which our at-sea numbers reflect the local population of birds actually breeding in a given season is unknown. As a result, our population estimates may include locally breeding birds, non-breeders and transients and, the ratio of these different "groups" of birds likely changes among years. In addition, large-scale ecosystem drivers like the recent Pacific marine heatwave (Di Lorenzo and Mantua 2016) can result in severe disruption of energy transfer from lower trophic levels to predators (Biela *et al*. 2019) and can result in population level effects to seabirds (Jones *et al*. 2018). We will continue to examine the various factors driving these apparent population trends in the 25-year report and in on-going and future research.

We recommend continued monitoring to track these population changes because: (1) trend increases in Oregon and California and trend decreases in Washington may be related to a combination of marine and terrestrial factors or movements among zones; (2) an apparent transition from negative to positive trends in the southern portion of the murrelet's range is relatively recent (since 2012) and these changes are occurring differently across different time-periods and Zones; (3) with a reduced sampling effort, there is reduced statistical power to detect trends and consequently it will likely require more time to detect trend or change in trend; and finally (4) we emphasize that these are the only data available for assessing murrelet recovery and response to the Northwest Forest Plan.

Due to the nature of sampling a seabird that is sparsely and patchily distributed, and our level of survey effort, some of our population and trend estimates have wide confidence intervals. We repeat here information from the 20-year report (Falxa *et al*. 2016) on our criteria for evaluating for evidence of a trend:

> "For the purposes of evaluating the evidence for a linear trend, we considered: (1) the magnitude of the annual trend estimate, particularly in relation to zero, where zero represents a stable population, and (2) the width and location of the 95 percent confidence intervals surrounding that trend estimate, also in relation to zero. The evidence for a population trend, versus a stable population, is stronger when the trend estimate and its 95 percent confidence interval do not overlap zero, and when the trend estimate is farther from zero. When the confidence interval of a trend estimate is tight around zero, then we would conclude that there is no evidence of a trend. Finally, when the confidence interval of a trend estimate broadly overlaps zero and the trend estimate is not close to zero, this indicates evidence that is not conclusive for or against a non-zero trend. Confidence intervals that are mainly above or below zero, but slightly overlap zero, can provide some evidence of a trend. "

Publications that include recent detailed population and habitat monitoring results include the three chapters in the 20-year murrelet report: 1) population (Falxa *et al*. 2016), 2) nesting habitat (Raphael *et al*. (2016a), and 3) an integrative chapter (Raphael *et al*., 2016b). In addition, Raphael *et al*. (2015) examined the relative influence of terrestrial and marine factors on at-sea distribution and abundance.
All of these reports and others relevant to the Marbled Murrelet Effectiveness Monitoring Program can be found at http://www.fs.fed.us/r6/reo/monitoring/murrelet/.

Additional Notes on 2018 surveys

Conservation Zone 1. A team from Washington Department of Fish and Wildlife conducted these surveys. There were no significant survey issues to report for 2018.

Conservation Zone 3. A team from Crescent Coastal Research conducted these surveys. There were no significant survey issues to report for 2018.

Conservation Zones 2, 4 and 5. These zones were not surveyed in 2018, and will be surveyed in 2019 (except for Conservation Zone 5, which will be surveyed in 2021).

Adjustments to Trend Analysis Method to Account for Reduced Effort Sampling Design

Prior to implementing the reduced-effort sampling design, the program was able to generate population trend estimates annually for inference units (individual Conservation Zones, All-Zones, and states). Now, with Conservation Zones 1-4 sampled only every-other year, and Conservation Zone 5 sampled every fourth year, trend analyses must account for years without population estimates. In 2015, the population monitoring team developed the following adjustments to the trend analyses method to take into account this new population data structure. These methods are reflected in the estimates provided in the Tables and Figures.

1. At the Conservation zone scale, population trend estimates will be generated through the most recent year of surveys.
2. At the All-Zones and state scales, trend estimates will be generated through the most recent year with either (a) population surveys and density estimates, or (b) an interpolated value, for the input density components from Conservation Zones 1 through 4. Extrapolations will not be used for components from these Zones. This means that All-Zones and state-scale estimates will be one year "behind" (except for the California estimate; see below).
    - For example, the 2016 All-Zones estimate uses the actual 2016 density estimates for Conservation Zones 1 and 3 and interpolated 2016 values for Conservation Zones 2 and 4 (which were all surveyed in 2015 and 2017).
3. Interpolations will only be used to generate zone density estimates for the last year of a trend analysis period, and only for generating All-Zones and state-scale trend estimates, as described above.
4. For California, trend estimates will be generated only through the most recent year with population surveys and density estimates for Conservation Zone 4 (which provides the primary component to the California estimate).
5. For the Zone 5 component of the California and All-Zones trend estimates, we will use the density estimate from the most recent year with Zone 5 surveys. With Conservation Zone 5 scheduled to be surveyed only every fourth year, this extrapolation of Conservation Zone 5 data allows updating of the California and All-Zone trend estimates more frequently than every fourth year. Prior to 2017 (see Pearson *et al*. 2018), Conservation Zone 5 has typically contained few birds, and this extrapolation has a negligible effect on these trend estimates. In the "25-year report," we will evaluate the 2017 results from Zone 5 on trend and rate of change in California.

Habitat Monitoring: For the nest habitat monitoring component of the Marbled Murrelet Effectiveness Monitoring Program, habitat trends (years 1994-2017) will be reported in the NWFP's "25-year report," which is currently being drafted, with an anticipated publication date (Forest Service General Technical Report) of early 2020.

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Web Site: Additional information, reports, publications, and program updates relevant to the Marbled Murrelet Effectiveness Monitoring Program (as well all other modules from the Interagency Regional Monitoring Program) can be found at https://www.fs.fed.us/r6/reo/.

RECOMMENDED CITATION:

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TABLES AND FIGURES

Table 1. Summary of 2001-2017 marbled murrelet density and population size estimates (rounded to nearest 100 birds) for all Conservation Zones combined. Numbers in some years may differ slightly from those in previous summary reports (as indicated by an asterisk [*], as a result of additional data quality reviews performed in 2019. Note that the most recent range-wide estimate is always one year behind the current sampling year because it takes two years to derive estimates when sampling units every other year.

Year	Density (birds/km^2)	Bootstrap Standard Error (birds/km^2)	Coefficient of Variation of Density (%)	Birds	Birds Lower 95% CL	Birds Upper 95% CL
2001*	2.53	0.25	9.8%	22,300	18,000	26,600
2002*	2.58	0.30	11.8%	22,700	17,400	27,900
2003*	2.53	0.23	9.1%	22,200	18,300	26,200
2004	2.46	0.26	10.5%	21,600	17,100	26,000
2005	2.30	0.25	10.7%	20,200	16,000	24,400
2006	2.09	0.17	8.2%	18,300	15,400	21,300
2007	1.97	0.27	13.7%	17,300	12,700	22,000
2008	2.06	0.18	8.9%	18,100	15,000	21,300
2009	1.96	0.21	10.6%	17,200	13,700	20,800
2010	1.89	0.21	11.1%	16,600	13,000	20,200
2011	2.50	0.31	12.6%	22,000	16,600	27,400
2012	2.40	0.27	11.3%	21,100	16,400	25,800
2013	2.24	0.25	11.1%	19,700	15,400	23,900
2014*	2.42	0.22	9.2%	21,300	17,500	25,100
2015	2.75	0.26	9.5%	24,100	19,700	28,600
2016	2.58	0.26	10.0%	22,600	18,200	27,100
2017	2.62	0.26	10.0%	23,000	18,500	27,600

Table 2. Estimates of average annual rate of marbled murrelet population change based on at-sea population surveys. Confidence limits are for the estimates of percent annual change. The *P*-value is based on a 2-tailed test for whether the annual rate of change is less than zero, significant values are shaded in gray. Based on updated population estimates reported in Tables 1 and 3. For guidance on interpretation of rates of change and confidence intervals, please refer to Falxa *et al*. (2016), and the excerpt from that report in the summary text above. Numbers in some years may differ slightly from those in previous summary reports, as a result of additional data quality reviews performed in 2019. Please note that the period of analysis extends to either 2017 or 2018 depending on which year sampling units were last surveyed.

Zone or State	Period of Analysis	Annual Rate of Change (%)	95% Conf. Limits		Adjusted R^2	*P*-value
			Lower	Upper		
Zone 1[a]	2001-2018	-4.9	-7.3	-2.4	0.503	<0.001
Zone 2	2001-2017	-3.0	-6.8	0.9	0.105	0.119
Zone 3[a]	2000-2018	1.4	-0.4	3.3	0.104	0.111
Zone 4	2000-2017	3.7	1.4	6.1	0.425	0.004
Zone 5	2000-2017	7.3	−4.4	20.3	0.085	0.199
WA	2001-2017	-3.9	-5.8	-2.0	0.523	<0.001
OR	2000-2017	2.0	0.5	3.6	0.279	0.014
CA	2000-2017	4.5	2.2	6.9	0.487	<0.001
All-Zones	2001-2017	0.34	−0.9	1.6	0.000	0.569

Footnotes – [a] Surveyed in 2018

Table 3. Marbled murrelet population estimates for Conservation Zones and sampling strata within Zones, 2000-2017, with parameter values (right 3 columns) used in the Distance Sampling method used to estimate population size. Based on at-sea surveys. The Zone 5 and "All Zone" estimates use interpolated values in years when Zone 5 was not surveyed. Numbers in some years may differ slightly from those in previous summary reports, as a result of additional data quality reviews performed in 2019. See text for details on use of interpolated or extrapolated values for estimates.

Year	Zone	Stratum	Density	CV	Birds	Lower 95% CI	Upper 95% CI	Area	f(0)	*E(s)*	Truncation Distance (m)
2000	3	All	4.129	18.6%	6,587	3,987	8,756	1,595	0.0165	1.623	100
2000	3	1	1.336	32.2%	883	357	1,350	661			
2000	3	2	6.104	19.6%	5,704	3,296	7,608	935			
2000	4	All	4.216	30.9%	4,887	3,417	9,398	1,159	0.0097	1.730	180
2000	4	1	6.024	34.0%	4,420	2,931	8,784	734			
2000	4	2	1.097	32.1%	467	297	881	425			
2000	5	All	0.090	80.6%	79		260	883			
2000	5	1	0.179	80.6%	79		260	441			
2000	5	2	0.000					441			
2001	All	All	2.531	9.8%	22,337	18,038	26,635	8,826			
2001	1	All	2.553	18.0%	8,936	5,740	11,896	3,501	0.0133	1.594	142
2001	1	1	4.506	23.1%	3,809	2,432	5,689	845			
2001	1	2	1.764	21.4%	2,111	948	2,816	1,196			
2001	1	3	2.067	37.2%	3,016	404	5,003	1,459			
2001	2	All	1.241	35.3%	2,094	791	3,555	1,688	0.0147	1.447	85
2001	2	1	1.976	36.4%	1,436	424	2,416	727			
2001	2	2	0.685	75.7%	658	131	1,674	961			
2001	3	All	4.636	13.2%	7,396	5,230	9,075	1,595	0.0166	1.735	140
2001	3	1	1.724	23.0%	1,140	657	1,700	661			
2001	3	2	6.695	14.1%	6,257	4,241	7,814	935			
2001	4	All	3.286	22.1%	3,809	3,020	6,238	1,159	0.0101	1.749	170
2001	4	1	4.570	24.9%	3,353	2,497	5,781	734			
2001	4	2	1.072	7.4%	456	320	896	425			
2001	5	All	0.115	39.5%	102	11	177	883			
2001	5	1	0.198	173.1%	87		147	441			
2001	5	2	0.032	129.1%	14		57	441			
2002	All	All	2.581	11.8%	22,683	17,440	27,926	8,788			
2002	1	All	2.788	21.5%	9,758	5,954	14,149	3,501	0.0103	1.761	194
2002	1	1	7.207	32.8%	6,092	2,716	9,782	845			
2002	1	2	1.879	26.9%	2,248	909	3,309	1,196			
2002	1	3	0.972	34.7%	1,419	580	2,515	1,459			
2002	2	All	1.329	25.6%	2,193	828	2,978	1,650	0.0197	1.434	70
2002	2	1	2.660	27.6%	1,927	688	2,705	724			
2002	2	2	0.288	39.6%	267		436	926			
2002	3	All	3.583	24.1%	5,716	3,674	9,563	1,595	0.0118	1.892	150
2002	3	1	0.696	34.1%	460	258	886	661			
2002	3	2	5.624	24.7%	5,256	3,301	8,732	935			
2002	4	All	4.112	15.1%	4,766	3,272	6,106	1,159	0.0108	1.724	175
2002	4	1	5.186	15.9%	3,805	2,501	4,892	734			
2002	4	2	2.260	33.1%	961	437	1,665	425			
2002	5	All	0.282	42.3%	249	27	400	883			
2002	5	1	0.510	46.1%	225	8	371	441			
2002	5	2	0.054	71.1%	24		54	441			

Table 3. (continued)

Year	Zone	Stratum	Density	CV	Birds	Lower 95% CI	Upper 95% CI	Area	f(0)	*E(s)*	Truncation Distance (m)
2003	All	All	2.531	9.1%	22,234	18,275	26,194	8,786			
2003	1	All	2.428	16.6%	8,495	5,795	11,211	3,498	0.0087	1.817	300
2003	1	1	6.644	22.1%	5,617	3,372	7,795	845			
2003	1	2	1.441	32.9%	1,721	911	2,794	1,195			
2003	1	3	0.793	32.8%	1,156	252	1,912	1,458			
2003	2	All	2.059	23.0%	3,399	2,032	5,157	1,650	0.0171	1.398	80
2003	2	1	2.679	25.4%	1,941	1,110	3,013	724			
2003	2	2	1.574	39.4%	1,458	568	2,567	926			
2003	3	All	3.686	16.1%	5,881	3,992	7,542	1,595	0.0132	1.664	130
2003	3	1	1.192	23.8%	788	499	1,212	661			
2003	3	2	5.450	17.8%	5,093	3,244	6,680	935			
2003	4	All	3.806	17.3%	4,412	3,488	6,495	1,159	0.0086	1.704	180
2003	4	1	4.960	19.7%	3,640	2,622	5,392	734			
2003	4	2	1.816	27.2%	773	557	1,424	425			
2003	5	All	0.055	61.1%	48		85	883			
2003	5	1	0.109	61.1%	48		85	441			
2003	5	2	0.000					441			
2004	All	All	2.455	10.5%	21,572	17,144	26,000	8,786			
2004	1	All	1.562	22.0%	5,465	2,921	7,527	3,498	0.0108	1.789	280
2004	1	1	3.833	30.0%	3,241	1,365	4,845	845			
2004	1	2	1.513	25.4%	1,807	1,042	2,777	1,195			
2004	1	3	0.286	60.0%	417		727	1,458			
2004	2	All	1.823	27.0%	3,009	1,669	4,634	1,650	0.0115	1.411	115
2004	2	1	3.373	33.4%	2,444	1,217	4,093	724			
2004	2	2	0.611	25.0%	565	314	841	926			
2004	3	All	5.051	13.7%	8,058	5,369	9,819	1,595	0.0141	1.697	110
2004	3	1	1.721	20.7%	1,137	707	1,732	661			
2004	3	2	7.405	15.1%	6,921	4,278	8,564	935			
2004	4	All	4.272	26.9%	4,952	3,791	9,021	1,159	0.0093	1.700	200
2004	4	1	5.331	32.2%	3,911	2,729	7,732	734			
2004	4	2	2.447	43.5%	1,041	608	2,421	425			
2004	5	All	0.099	60.5%	88	18	214	883			
2004	5	1	0.091	64.5%	40		104	441			
2004	5	2	0.107	93.6%	47		137	441			
2005	All	All	2.300	10.7%	20,209	15,976	24,442	8,785			
2005	1	All	2.275	20.5%	7,956	4,900	11,288	3,497	0.0156	1.758	150
2005	1	1	2.501	37.7%	2,114	698	3,661	845			
2005	1	2	2.426	25.4%	2,895	1,186	4,210	1,194			
2005	1	3	2.021	30.1%	2,947	1,198	5,019	1,458			
2005	2	All	1.561	20.4%	2,576	1,675	3,729	1,650	0.0136	1.418	130
2005	2	1	2.785	19.1%	2,018	1,233	2,764	724			
2005	2	2	0.603	56.7%	558	166	1,461	926			
2005	3	All	3.669	16.9%	5,854	3,580	7,447	1,595	0.0127	1.841	150
2005	3	1	0.808	32.2%	534	269	962	661			
2005	3	2	5.693	17.8%	5,320	3,156	6,760	935			
2005	4	All	3.169	23.6%	3,673	2,740	6,095	1,159	0.0108	1.518	170
2005	4	1	4.487	25.5%	3,292	2,329	5,562	734			

Table 3. (continued)

Year	Zone	Stratum	Density	CV	Birds	Lower 95% CI	Upper 95% CI	Area	f(0)	*E(s)*	Truncation Distance (m)
2005	4	2	0.895	42.1%	381	243	901	425			
2005	5	All	0.169	31.8%	149	69	251	883			
2005	5	1	0.141	48.1%	62	8	121	441			
2005	5	2	0.197	39.7%	87	36	156	441			
2006	All	All	2.087	8.2%	18,335	15,395	21,275	8,785			
2006	1	All	1.687	18.1%	5,899	4,211	8,242	3,497	0.0138	1.765	139
2006	1	1	2.760	16.3%	2,333	1,628	3,182	845			
2006	1	2	1.418	24.9%	1,693	777	2,551	1,194			
2006	1	3	1.284	40.4%	1,873	595	3,440	1,458			
2006	2	All	1.443	18.0%	2,381	1,702	3,433	1,650	0.0130	1.567	107
2006	2	1	2.261	19.9%	1,638	1,038	2,372	724			
2006	2	2	0.802	34.0%	743	380	1,344	926			
2006	3	All	3.731	12.7%	5,953	4,546	7,617	1,595	0.0114	1.814	145
2006	3	1	1.034	29.6%	684	352	1,070	661			
2006	3	2	5.638	14.1%	5,269	3,886	6,827	935			
2006	4	All	3.410	14.9%	3,953	3,164	5,525	1,159	0.0106	1.622	150
2006	4	1	4.821	15.5%	3,538	2,698	4,894	734			
2006	4	2	0.977	47.8%	416	209	981	425			
2006	5	*Not surveyed. Interpolated estimate used for All Zone calculation.*									
2007	All	All	1.971	13.7%	17,317	12,654	21,980	8,785			
2007	1	All	1.997	24.2%	6,985	4,148	10,639	3,497	0.0117	1.642	378
2007	1	1	3.445	27.6%	2,912	1,025	4,392	845			
2007	1	2	1.218	21.9%	1,453	708	1,993	1,194			
2007	1	3	1.796	51.3%	2,620	206	5,629	1,458			
2007	2	All	1.536	26.7%	2,535	1,318	3,867	1,650	0.0135	1.496	126
2007	2	1	2.851	32.0%	2,065	964	3,336	724			
2007	2	2	0.508	25.5%	470	234	666	926			
2007	3	All	2.518	19.8%	4,018	2,730	5,782	1,595	0.0106	1.653	150
2007	3	1	0.526	58.5%	348	26	744	661			
2007	3	2	3.927	20.4%	3,670	2,525	5,378	935			
2007	4	All	3.234	34.8%	3,749	2,659	7,400	1,159	0.0106	1.607	180
2007	4	1	4.730	37.5%	3,470	2,329	7,025	734			
2007	4	2	0.655	36.9%	279	146	549	425			
2007	5	All	0.033	37.7%	30		49	883			
2007	5	1	0.067	37.7%	30		49	441			
2007	5	2	0.000					441			
2008	All	All	2.064	8.9%	18,134	14,983	21,284	8,785			
2008	1	All	1.344	17.6%	4,699	3,000	6,314	3,497	0.0109	1.739	206
2008	1	1	3.572	25.1%	3,019	1,439	4,472	845			
2008	1	2	0.899	27.6%	1,073	580	1,640	1,194			
2008	1	3	0.416	30.8%	607	288	970	1,458			
2008	2	All	1.169	22.1%	1,929	1,164	2,868	1,650	0.0112	1.535	187
2008	2	1	2.584	22.4%	1,872	1,132	2,801	724			
2008	2	2	0.062	49.1%	57		116	926			
2008	3	All	3.857	14.7%	6,153	4,485	8,066	1,595	0.0113	1.750	130
2008	3	1	0.337	28.4%	223	107	353	661			
2008	3	2	6.345	15.3%	5,930	4,233	7,816	935			
2008	4	All	4.560	17.9%	5,285	3,809	7,503	1,159	0.0100	1.705	200
2008	4	1	6.386	19.5%	4,685	3,167	6,687	734			
2008	4	2	1.410	39.0%	600	302	1,195	425			
2008	5	All	0.076	48.1%	67	9	132	883			

Table 3. (continued)

Year	Zone	Stratum	Density	CV	Birds	Lower 95% CI	Upper 95% CI	Area	f(0)	*E(s)*	Truncation Distance (m)
2008	5	1	0.065	60.1%	29		81	441			
2008	5	2	0.087	70.3%	38		68	441			
2009	All	All	1.963	10.6%	17,246	13,656	20,836	8,785			
2009	1	All	1.608	21.2%	5,623	3,786	8,497	3,497	0.0094	1.694	254
2009	1	1	3.811	27.7%	3,221	1,777	5,107	845			
2009	1	2	0.689	26.3%	822	489	1,302	1,194			
2009	1	3	1.083	42.9%	1,580	410	3,299	1,458			
2009	2	All	0.770	21.7%	1,271	800	1,902	1,650	0.0092	1.469	191
2009	2	1	1.621	23.7%	1,175	695	1,796	724			
2009	2	2	0.105	61.7%	97		206	926			
2009	3	All	3.696	17.7%	5,896	3,898	7,794	1,595	0.0131	1.696	120
2009	3	1	0.650	42.5%	430	187	893	661			
2009	3	2	5.849	19.0%	5,467	3,339	7,250	935			
2009	4	All	3.786	19.9%	4,388	3,599	6,952	1,159	0.0100	1.661	150
2009	4	1	5.304	20.9%	3,892	3,031	6,170	734			
2009	4	2	1.167	67.3%	497	244	1,390	425			
2009	5	*Not surveyed. Interpolated estimate used for All Zone calculation.*									
2010	All	All	1.889	11.1%	16,595	12,969	20,220	8,785			
2010	1	All	1.256	20.0%	4,393	2,719	6,207	3,497	0.0100	1.717	200
2010	1	1	2.004	26.8%	1,694	957	2,712	845			
2010	1	2	1.783	23.6%	2,128	1,021	3,052	1,194			
2010	1	3	0.391	43.1%	571	62	1,142	1,458			
2010	2	All	0.779	25.5%	1,286	688	1,961	1,650	0.0114	1.582	145
2010	2	1	1.336	23.8%	968	552	1,439	724			
2010	2	2	0.343	71.9%	318		784	926			
2010	3	All	4.503	16.7%	7,184	4,453	9,425	1,595	0.0138	1.770	160
2010	3	1	1.071	50.1%	708	239	1,354	661			
2010	3	2	6.930	17.7%	6,476	3,691	8,468	935			
2010	4	All	3.162	28.5%	3,665	2,248	6,309	1,159	0.0120	1.624	165
2010	4	1	3.774	34.3%	2,769	1,463	5,087	734			
2010	4	2	2.106	36.3%	896	431	1,700	425			
2010	5	*Not surveyed. Interpolated estimate used for All Zone calculation.*									
2011	All	All	2.501	12.6%	21,972	16,566	27,378	8,785			
2011	1	All	2.055	17.4%	7,187	4,807	9,595	3,497	0.0089	1.666	289
2011	1	1	5.580	20.3%	4,717	2,621	6,399	845			
2011	1	2	1.243	23.7%	1,484	790	2,147	1,194			
2011	1	3	0.676	65.8%	986	206	2,384	1,458			
2011	2	All	0.721	33.4%	1,189	571	2,106	1,650	0.0110	1.496	161
2011	2	1	1.314	30.8%	952	400	1,572	724			
2011	2	2	0.256	102.0%	237	38	772	926			
2011	3	All	4.661	16.3%	7,436	5,067	9,746	1,595	0.0126	1.678	120
2011	3	1	0.980	38.6%	648	343	1,455	661			
2011	3	2	7.264	17.4%	6,788	4,304	9,054	935			
2011	4	All	5.196	34.9%	6,023	2,782	10,263	1,159	0.0122	1.644	145
2011	4	1	6.724	42.2%	4,933	1,643	8,767	734			
2011	4	2	2.561	47.3%	1,090	592	2,472	425			
2011	5	All	0.155	53.0%	137	16	295	883			
2011	5	1	0.243	64.8%	107	5	259	441			
2011	5	2	0.068	78.8%	30		66	441			
2012	All	All	2.400	11.3%	21,086	16,401	25,770	8,785			
2012	1	All	2.414	20.7%	8,442	5,090	12,006	3,497	0.0109	1.847	164

Table 3. (continued)

Year	Zone	Stratum	Density	CV	Birds	Lower 95% CI	Upper 95% CI	Area	f(0)	*E(s)*	Truncation Distance (m)
2012	1	1	7.166	24.4%	6,056	3,289	8,823	845			
2012	1	2	1.507	30.4%	1,799	812	2,892	1,194			
2012	1	3	0.402	48.1%	587	168	1,227	1,458			
2012	2	All	0.719	33.5%	1,186	564	2,360	1,650	0.0131	1.485	106
2012	2	1	1.178	29.2%	853	325	1,289	724			
2012	2	2	0.360	89.9%	333		1,459	926			
2012	3	All	3.986	15.5%	6,359	4,136	8,058	1,595	0.0112	1.765	186
2012	3	1	0.895	34.9%	591	227	1,042	661			
2012	3	2	6.172	15.9%	5,768	3,775	7,330	935			
2012	4	All	4.279	24.9%	4,960	3,414	8,011	1,159	0.0107	1.652	140
2012	4	1	6.050	27.6%	4,439	2,916	7,497	734			
2012	4	2	1.225	39.6%	521	166	940	425			
2012	5	*Not surveyed. Interpolated estimate used for All Zone calculation.*									
2013	All	All	2.236	11.1%	19,643	15,377	23,909	8,785			
2013	1	All	1.257	27.9%	4,395	2,298	6,954	3,497	0.0109	1.695	137
2013	1	1	2.379	31.4%	2,010	861	3,253	845			
2013	1	2	0.657	20.1%	784	508	1,124	1,194			
2013	1	3	1.097	64.4%	1,600	381	3,717	1,458			
2013	2	All	0.758	19.3%	1,251	889	1,796	1,650	0.0117	1.569	132
2013	2	1	1.604	19.8%	1,162	843	1,728	724			
2013	2	2	0.096	58.3%	89		189	926			
2013	3	All	4.939	16.3%	7,880	5,450	10,361	1,595	0.0112	1.637	160
2013	3	1	0.991	43.8%	655	151	1,226	661			
2013	3	2	7.731	17.8%	7,225	4,707	9,667	935			
2013	4	All	5.216	20.5%	6,046	4,531	9,282	1,159	0.0128	1.607	146
2013	4	1	7.384	21.8%	5,418	3,939	8,516	734			
2013	4	2	1.477	36.7%	629	279	1,184	425			
2013	5	All	0.080	45.4%	71	5	118	883			
2013	5	1	0.160	45.4%	71	5	118	441			
2013	5	2	0.000					441			
2014	All	All	2.423	9.2%	21,283	17,452	25,114	8,785			
2014	1	All	0.801	20.6%	2,801	1,598	3,876	3,497	0.0102	1.664	172
2014	1	1	1.235	28.0%	1,044	558	1,643	845			
2014	1	2	1.274	27.2%	1,521	600	2,219	1,194			
2014	1	3	0.162	70.9%	236		541	1,458			
2014	2	All	1.318	30.7%	2,176	1,038	3,574	1,650	0.0131	1.508	122
2014	2	1	2.879	31.5%	2,086	925	3,466	724			
2014	2	2	0.098	65.6%	90		214	926			
2014	3	All	5.541	12.4%	8,841	6,819	11,276	1,595	0.0108	1.720	140
2014	3	1	1.477	34.1%	976	286	1,587	661			
2014	3	2	8.415	13.1%	7,864	6,156	10,240	935			
2014	4	*Not surveyed. Interpolated value used for All Zone calculation.*									
2014	5	*Not surveyed. Extrapolated value used for All Zone calculation.*									
2015	All	All	2.747	9.5%	24,134	19,658	28,610	8,785			
2015	1	All	1.227	24.1%	4,290	2,640	6,565	3,497	0.0111	1.786	191
2015	1	1	2.218	35.8%	1,875	829	3,383	845			
2015	1	2	1.945	29.9%	2,321	1,148	3,863	1,194			
2015	1	3	0.064	92.6%	94		267	1,458			
2015	2	All	1.941	30.4%	3,204	1,883	5,609	1,650	0.0093	1.866	175
2015	2	1	2.849	27.9%	2,064	1,176	3,316	724			
2015	2	2	1.231	71.2%	1,140	144	3,290	926			

Table 3. (continued)

Year	Zone	Stratum	Density	CV	Birds	Lower 95% CI	Upper 95% CI	Area	f(0)	*E(s)*	Truncation Distance (m)
2015	3	*Not surveyed. Average of 2014 and 2016 estimates used for All-Zones estimate.*									
2015	4	All	7.542	16.8%	8,743	7,409	13,125	1,159	0.0118	1.701	159
2015	4	1	9.897	17.3%	7,262	5,906	10,692	734			
2015	4	2	3.480	48.9%	1,481	859	3,713	425			
2015	5	*Not surveyed. Extrapolated value used for All Zone estimate.*									
2016	All	All	2.577	10.0%	22,638	18,204	27,071	8,785			
2016	1	All	1.319	30.0%	4,614	2,298	7,571	3,497	0.0112	1.675	224
2016	1	1	2.693	36.6%	2,276	969	4,062	845			
2016	1	2	1.655	51.7%	1,975	617	4,075	1,194			
2016	1	3	0.249	37.7%	362	106	621	1,458			
2016	2	*Not surveyed. Extrapolated value used for All-Zones estimate.*									
2016	3	All	4.271	13.8%	6,813	5,389	8,821	1,595	0.0116	1.661	130
2016	3	1	0.862	27.9%	570	346	944	661			
2016	3	2	6.681	14.8%	6,244	4,760	8,195	935			
2016	4	*Not surveyed. Extrapolated value used for All-Zones estimate.*									
2016	5	*Not surveyed.*									
2017	All	All	2.623	10.0%	23,040	18,527	27,552	8,785			
2017	2	All	1.065	23.2%	1,758	1,041	2,623	1,650	0.0097	1.648	154
2017	2	1	2.127	25.8%	1,541	820	2,353	724			
2017	2	2	0.235	36.5%	218	56	363	926			
2017	3	*Not surveyed.*									
2017	4	All	7.397	14.5%	8,574	6,358	11,155	1,159	0.0118	1.658	170
2017	4	1	9.147	15.1%	6,711	4,654	8,700	734			
2017	4	2	4.378	11.3%	1,863	968	3,313	425			
2017	5	All	0.983	39.7%	868	457	1,768	883			
2017	5	1	0.765	190.2%	337	63	765	441			
2017	5	2	1.202	48.8%	531	301	1,179	441			
2018	All	*Will have 2018 estimate in 2019.*									
2018	1	All	1.097	34.7%	3,837	1,911	6,956	3,497	0.0080	1.739	242
2018	1	1	1.375	42.6%	1,162	297	2,158	845			
2018	1	2	1.044	29.0%	1,246	595	1,976	1,194			
2018	1	3	0.980	86.7%	1,428		4,177	1,458			
2018	2	*Not surveyed.*									
2018	3	All	5.274	19.2%	8,414	5,866	12,183	1,595	0.0123	1.640	120
2018	3	1	1.026	46.3%	678	290	1,533	661			
2018	3	2	8.277	20.3%	7,736	5,203	11,195	935			
2018	4	*Not surveyed.*									
2018	5	*Not surveyed.*									

Table 4. Summary of 2000 to 2017 marbled murrelet density and population size estimates at the State scale. Numbers in some years may differ slightly from those in previous summary reports, as a result of additional data quality reviews performed in 2019.

Year	State	Density (murrelets per km2)	Murrelets	Murrelets 95% CL Lower	Murrelets 95% CL Upper	Area (km2)
2001	WA	2.13	11,030	7,554	14,505	5,188
2002	WA	2.32	11,951	7,687	16,216	5,151
2003	WA	2.31	11,894	8,729	15,058	5,149
2004	WA	1.65	8,474	5,625	11,322	5,149
2005	WA	2.05	10,533	7,179	13,887	5,148
2006	WA	1.61	8,280	6,024	10,536	5,148
2007	WA	1.85	9,520	5,946	13,095	5,148
2008	WA	1.29	6,628	4,808	8,448	5,148
2009	WA	1.34	6,894	4,495	9,294	5,148
2010	WA	1.10	5,679	3,840	7,518	5,148
2011	WA	1.63	8,376	5,802	10,950	5,148
2012	WA	1.87	9,629	6,116	13,142	5,148
2013	WA	1.10	5,646	3,195	8,097	5,148
2014	WA	0.97	4,977	3,248	6,706	5,148
2015	WA	1.46	7,494	4,711	10,276	5,148
2016	WA	1.38	7,095	4,060	10,130	5,148
2017	WA	1.16	5,984	3,204	8,764	5,148
2000	OR	3.85	7,983	4,992	10,974	2,071
2001	OR	4.43	9,168	6,654	11,682	2,071
2002	OR	3.64	7,530	4,727	10,332	2,071
2003	OR	3.56	7,380	5,370	9,390	2,075
2004	OR	4.40	9,112	6,833	11,391	2,071
2005	OR	3.36	6,966	4,812	9,121	2,071
2006	OR	3.68	7,617	5,916	9,318	2,071
2007	OR	2.59	5,357	3,332	7,381	2,071
2008	OR	3.64	7,541	5,682	9,400	2,071
2009	OR	3.58	7,423	5,208	9,638	2,071
2010	OR	3.95	8,182	5,743	10,622	2,071
2011	OR	4.05	8,379	5,943	10,816	2,071
2012	OR	3.76	7,780	5,605	9,956	2,071
2013	OR	4.74	9,819	7,195	12,443	2,071
2014	OR	5.50	11,384	8,839	13,930	2,071
2015	OR	5.30	10,975	8,188	13,762	2,071
2016	OR	4.85	10,053	7,527	12,580	2,071
2017	OR	5.28	10,945	8,018	13,872	2,071
2000	CA	2.28	3,571	1,884	5,258	1,566
2001	CA	1.31	2,049	600	3,497	1,566
2002	CA	2.04	3,202	2,181	4,224	1,566
2003	CA	1.90	2,985	1,753	4,217	1,567

Year	State	Density (murrelets per km2)	Murrelets	Murrelets 95% CL Lower	Murrelets 95% CL Upper	Area (km2)
2004	CA	2.55	3,986	2,197	5,775	1,566
2005	CA	1.73	2,710	1,896	3,523	1,566
2006	CA	1.56	2,438	1,727	3,149	1,566
2007	CA	1.56	2,440	1,465	3,415	1,566
2008	CA	2.53	3,964	2,802	5,126	1,566
2009	CA	1.87	2,928	1,589	4,268	1,566
2010	CA	1.69	2,644	1,098	4,191	1,566
2011	CA	3.33	5,217	1,962	8,472	1,566
2012	CA	2.24	3,514	1,812	5,216	1,566
2013	CA	2.67	4,178	2,662	5,694	1,566
2014	CA	3.14	4,922	3,410	6,433	1,566
2015	CA	3.62	5,666	3,970	7,361	1,566
2016	CA	3.51	5,489	3,995	6,984	1,566
2017	CA	3.90	6,111	4,473	7,749	1,566

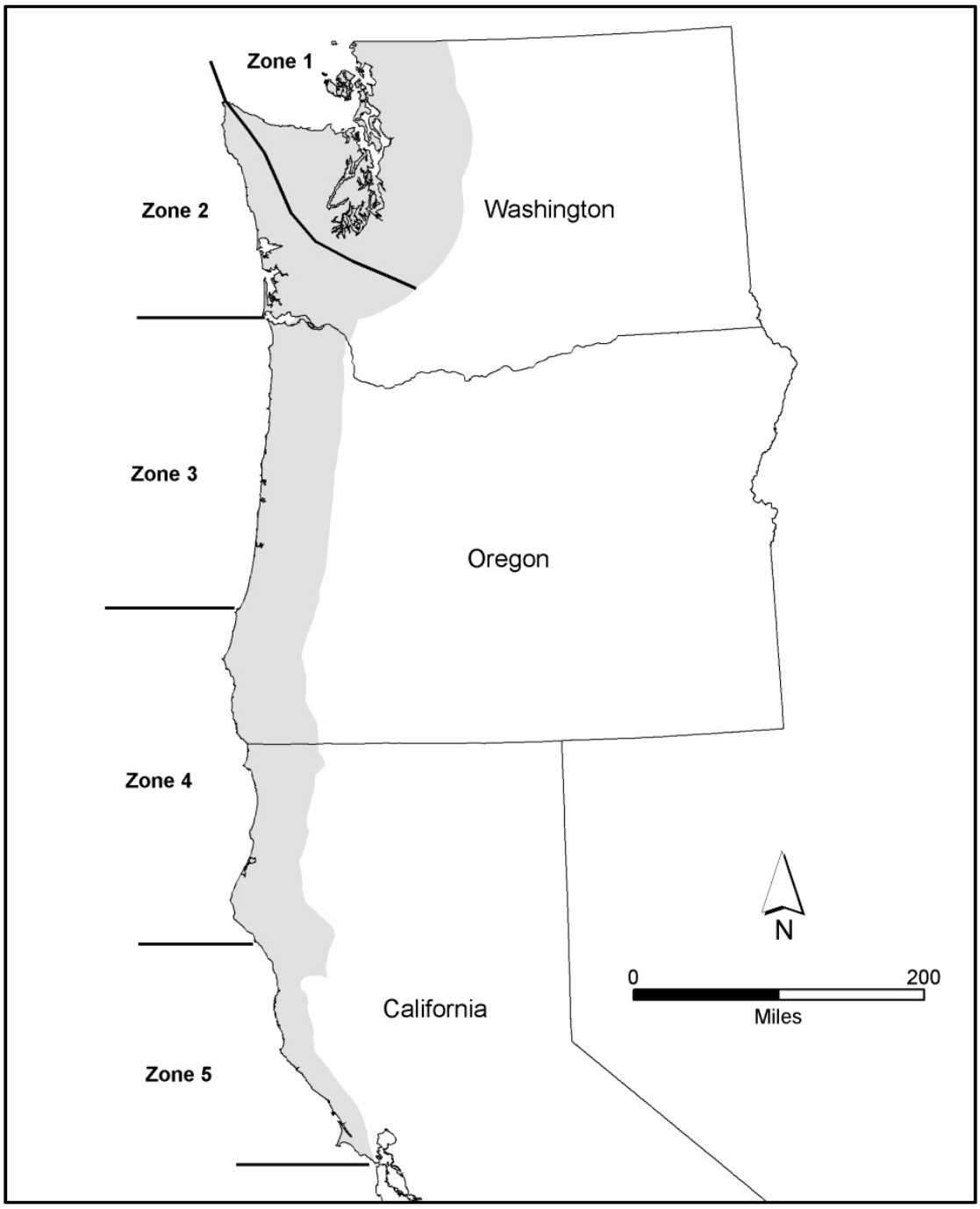

Figure 1. The five at-sea marbled murrelet Conservation Zones adjacent to the Northwest Forest Plan area. Approximate inland breeding distribution is shaded (adapted from U.S. Fish and Wildlife Service 1997).

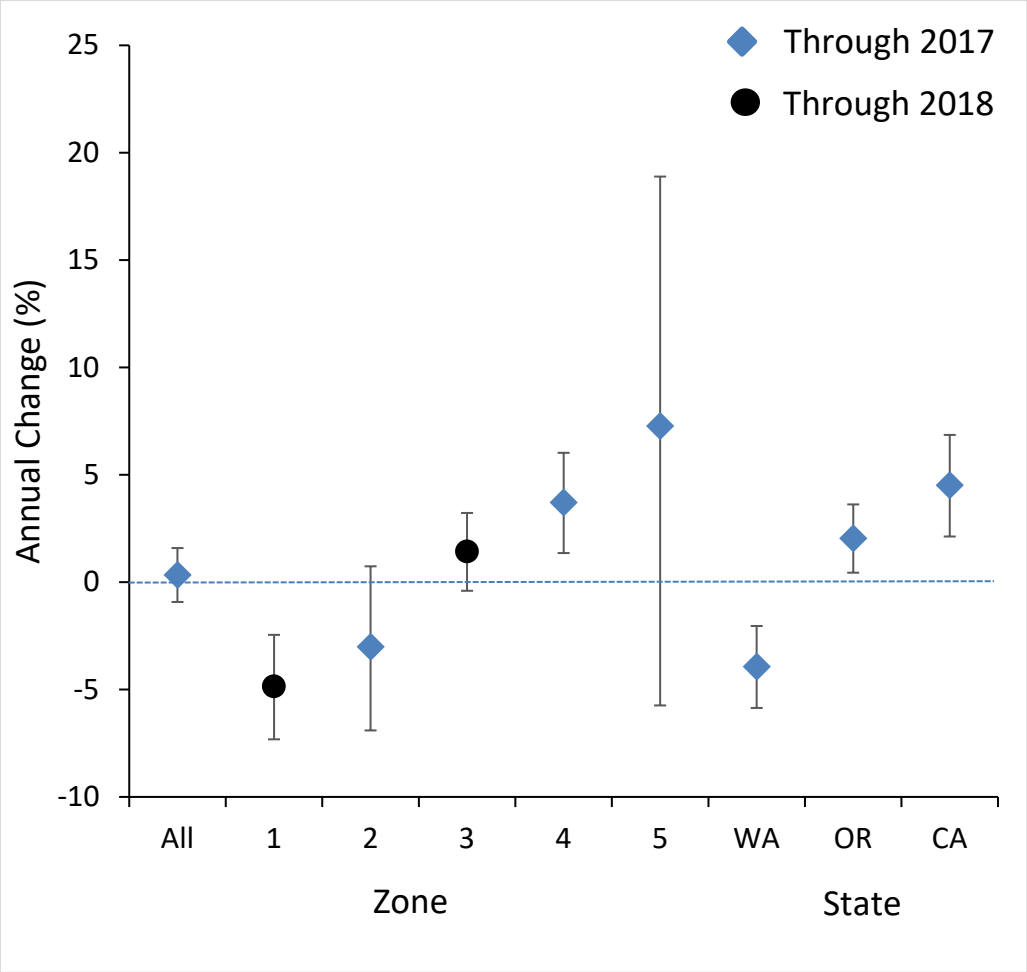

Figure 2. Percent annual change (95% Confidence interval) by Conservation Zone, "All"-Zones combined and by State. Trends are through 2017 for the blue squares and through 2018 for the black circles. If the confidence intervals do not overlap zero, then there is support for either a positive (e.g., Zone 4) or a negative (e.g., Zone 1) trend. Note that these results are provided in a tabular form in Table 2.

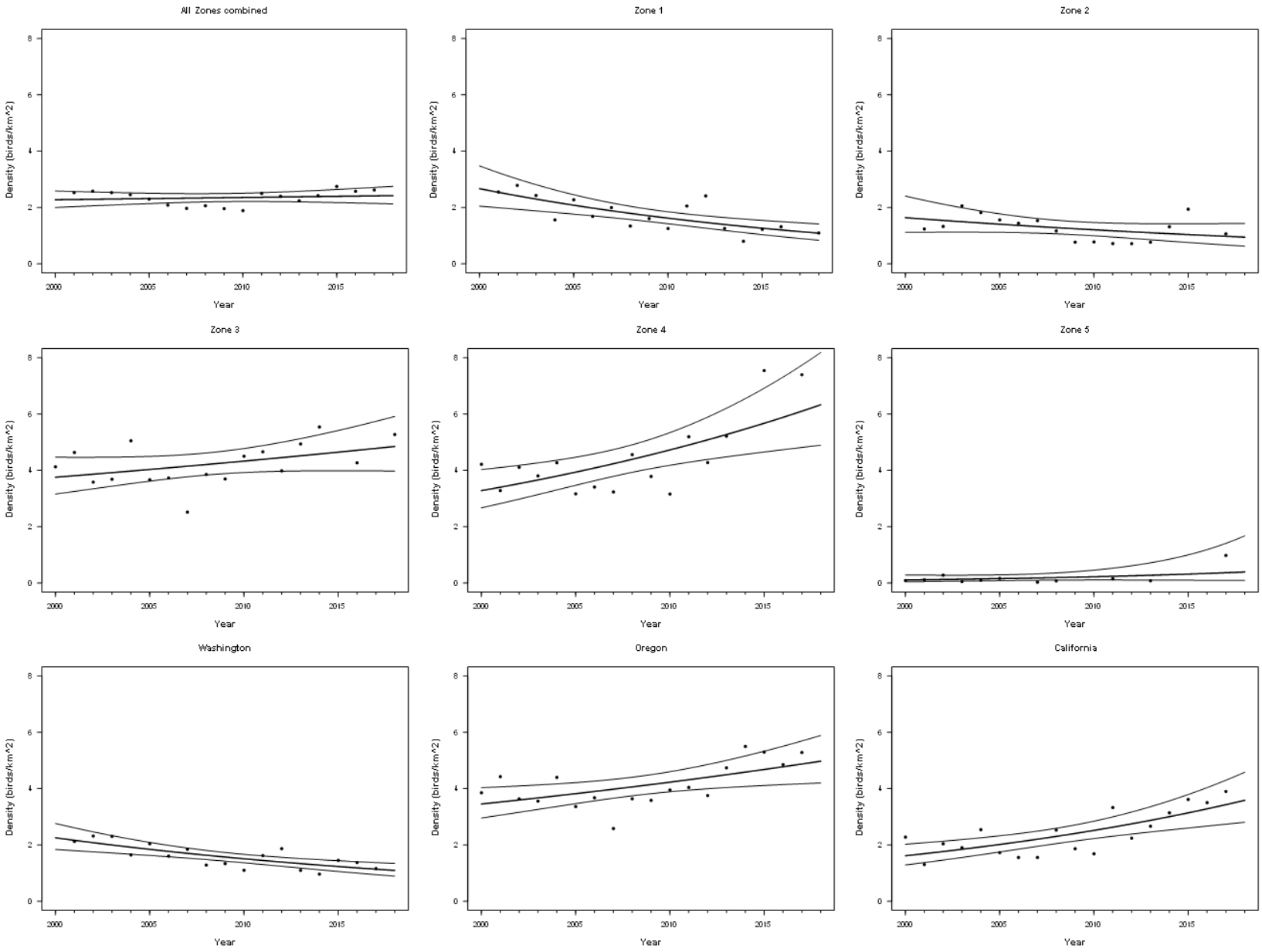

Figure 3. Marbled murrelet population trend analyses for All-Zones, individual Conservation Zones, and State scales. Graphs show fitted regression lives through the annual population estimates for the period of analysis (through 2017 for Zones 2, 4, and 5 only), with 95 percent confidence limits.

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Program products are available at: http://www.fs.fed.us/r6/reo/monitoring/murrelet/

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