MARBLED MURRELET PRODUCTIVITY MEASURES

AT SEA IN NORTHERN CALIFORNIA DURING 2011

AN ASSESSMENT RELATIVE TO REDWOOD NATIONAL AND STATE PARK LANDS

Final annual report
22 February 2012

By Crescent Coastal Research (CCR) and the U.S. Fish and Wildlife Service (USFWS) Arcata Field Office

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INTRODUCTION

Marbled Murrelets (*Brachyramphus marmoratus*) are a federally threatened seabird species that is dependent on mature forest stands for nesting habitat on the west coast of the United States (Nelson 1997). With evidence of poor productivity (McShane et al. 2005), declining populations (Falxa et al. 2010), and a strong relationship between distribution and remaining mature coastal forest habitat (Raphael et al. 2011), there is a need to improve and manage remaining nesting habitat to meet recovery goals. Monitoring population trend of the Marbled Murrelet is a component of the Northwest Forest Plan Effectiveness Monitoring Program (Madsen et al. 1999) and has been carried out along the west coast for the past 12 years (Falxa et al. 2010, Strong 2011), but the only consistent long term effort to assess productivity of the species is in the San Juan Islands (M. Raphael pers. comm.). We conducted vessel-based surveys designed to estimate productivity of the species in coastal waters adjacent to some of the last large stands of habitat in California contained in the Redwood National and State Parks (RNSP) of Humboldt and Del Norte Counties. This effort was supported by *Kure* and *Stuyvesant* oil spill settlement funds to assist in the assessment of the effectiveness of marbled murrelet predator management on RNSP lands. It is anticipated that predator management will result in improved marbled murrelet reproductive success. Complementary to this project is an effort, funded by the USFWS Arcata Field Office, to assemble and analyze existing productivity data for Conservation Zone 4 from 2000 to 2010 to assess the statistical power of these sampling techniques in detecting a signal of improved productivity, such as might be attributable to Park management activities; that effort will be reported on separately. Data on other seabirds and marine mammals are collected concurrently with the murrelet data, and can also be used in event of future oil spills and with respect to management of marine protected areas.

METHODS

Survey Protocol

Vessel surveys were made from 7 m boats equipped with marine radio, compass, GPS, and sonar depth finder, which also relayed sea surface temperature. Other equipment included binoculars, digital watches, and micro tape recorders for each person, maps covering planned transect lines, and a laser range finder. The deck of the boat is about level with the waterline; so standing observer viewing height was about 2 m above water. The GPS was loaded with the randomly selected transect routes prior to each survey. Two observers and a vessel driver were on board for all transects. Each observer scanned a 90^{o} arc between the bow and the beam continuously, only using binoculars to confirm identification or to observe plumage or behavior of murrelets. Search effort was directed primarily towards the bow quarters and within 50 m of the vessel, so that densities based on the transect line and narrow strip transects (used for seabirds other than murrelets) were more accurate (Buckland et al. 1993). All seabirds within 50 m of the boat and on the water were recorded. Only murrelets and aerial foragers (pelicans, terns, and osprey) were also recorded when flying. All Marbled Murrelet detections at any distance were recorded with information on group size and estimated perpendicular distance from the transect line, behavior, age (as After-hatch-year = 'AHY', or as Hatch-year = 'HY', representing birds that fledged during the survey year), and molt class. Marine mammals and boats were also recorded using line transect methods. Environmental parameters and observing conditions were monitored on all surveys. Data were recorded on cassette tapes and later transcribed and entered on computer. The vessel driver maintained a speed of 10 knots following the transect route, watched for navigational hazards, and paused transects to navigate strategically around birds requiring age determination. The driver participated in searching for murrelets when not otherwise occupied.

Transect layout was the same as used by the NWFP population monitoring effort (see Miller et al. 2006, Raphael et al. 2007). In short, contiguous 20 km coastal sections extending 3 km out to sea are Primary Sampling Units (PSU). PSU are divided into inshore (300 to 2000 m) and offshore (2000 to 3000 m out to sea) subunits. Inshore subunits are sampled for the entire 20-km length of the PSU, and offshore subunits are sampled by a 6 Km transect angling across the offshore subunit. The inshore subunit was further divided into four 5 km. long segments which are each surveyed at different distances offshore, such that all habitats (relative to shore) are sampled. At 10 knots, a PSU survey typically takes about 3 hours.

Age determination techniques will follow the basic methods of Strong (1998a). Briefly, plumage is categorized into 4 stages of prebasic molt of after-hatch-year (AHY) birds or as hatch-year (HY) plumage. When black and white murrelets are detected, the transect survey is paused and close observation of plumage and behavior are recorded until an age determination can be made (see Strong 1998a and Appendix A).

Geographic and Temporal Coverage

Inland nesting habitat contained in Redwood National Park in northern Humboldt County is the management area of interest, adjacent to PSUs 12, 13 and 14 (Fig 1). We surveyed PSU's 11

through 15 to account for bird movement at-sea and to sample within a range of shoreline and benthic habitats. Where the shorelines in PSU 13 and 14 are fairly uniformly sandy beach, adjacent PSUs to the north and south have partially to wholly rocky shore, kelp, and embayments, which may be preferred marine habitat by HY murrelets (Kuletz and Piatt 1999, Strong 1998b).

Sampling was conducted within four 10 day sample intervals from 14 July to 22 August following the productivity sampling intervals used by the US Forest Service-Redwood Sciences Laboratories (see Long et al. 2010). This period matches the season when most HY fledge in northern California, and ended early enough to avoid confusion of advanced prebasic molt AHY with HY. The study goal was to obtain 6 replicate samples of each of the 5 target PSU, including one replicate for each of the first two 10-day periods and 2 replicates per PSU for each of the two August sampling periods (3-12 August and 13-22 August), when peak numbers of HY were expected based on fledging dates.

Analysis

Productivity was measured as a ratio of known-age HY: AHY as well as the detection rate of HY birds per km of survey at sea (the latter provides a measure of hatch-year bird abundance independent of AHY abundance). Peery et al. (2007) developed a regression-based technique to estimate the proportion of HY fledged to sea by date during the main fledging period, and the method was modified by M. Raphael (USFS PNW Res. Sta.) for use in the Pacific Northwest. This technique generates a date-adjusted estimate of HY based on local nesting chronology, and can provide a confidence interval around HY:AHY point estimates by treating surveys within 10 day time intervals as samples.

RESULTS

Effort

CCR completed 28 PSU samples of the 5 PSU within the 40 day period 14 July to 22 August 2011 (Table 1). One sample on 24 July (PSU 14) was removed due to poor observing conditions. Mechanical failure with the vessels in early August also prevented reaching the target of 30 PSU samples, and sampling was clustered in the last 10 day period (Tables 1, 2a). Geographic sampling was distributed evenly over the 5 PSU, except for missing replicates in PSU 14 and 15 for reasons noted above. In addition to the PSU sample transects, we conducted several supplementary transects when moving to and from PSU transects in order to get a larger overall sample and to cover more of the very near-shore, where murrelets sometimes concentrate at the end of the nesting season. These extra survey data are not included in this report, but are included in the accompanying databases.

Productivity indices

Age determination between advanced molt AHY and HY was relatively easy through the season until the last day (22 August) when large groups of advanced molt AHY were encountered and the first fully basic plumage AHY were seen. The file PPMAMU11.XLSX contains detail on

how each bird was aged in the AGEn and NOTES fields.

The overall unadjusted HY /AHY counts in the sampling area after 13 July were 48:2098 (ratio = 0.023 or 2.24% HY). The date-adjusted HY:AHY ratio was 61:2098 (ratio =0.029). While the direct ratio showed an increase at the end of the study period when divided into 10 day intervals, the date-adjusted ratio was steady except for the 3-12 August period (Table 2a). There was a geographic pattern in which higher ratios and detection rates were found at the north and south ends of the study area (Table 2b). It may be relevant that the areas with higher ratios were off the rocky and convoluted shores near Crescent City and Trinidad.

Detection rate (or encounter rate, the number of HY per km of survey) correlated fairly well with age ratios, both by 10 day time period (r = 0.764) and by PSU sample (r = 0.787, data from Tables 2a and 2b). Detection rates showed a temporal peak at the end of the sampling period, and highest rates at either end of the study area, off rocky and complex shorelines.

Comparison with Prior Years

CCR conducted all Zone 4 surveys during 2010 and 2011, including the additional productivity surveys for this project in 2011. From 2000 to 2009 Zone 4 surveys were completed cooperatively with the USFS' Redwood Sciences Laboratories (RSL). Tables 3a and 3b show the data from both efforts combined for 2000-2011, for the focal period of this study (14 July through 22 August). Table 3a reports result for the entire Zone 4, and Table 3b for PSUs 11-15 only. The adjusted productivity indices for 2000-2010 in Table 3b show 2011 to be slightly lower-than average, in terms of the adjusted HY:AHY ratio for the 5-PSU study area, while the HY detection rate (HY per km) in 2011 was above the mean (Table 3b). This indicates a slightly higher-than-average density of HY birds in 2011, but also a higher density of AHY birds in that year, resulting in the lower HY:AHY ratio. In comparison with 2010, 2011 had lower ratios than 2010 for both the study area and all of Zone 4, although the HY detection rate was slightly higher in 2011 than in 2010 in the 5-PSU study area (Tables 3a, b).

The additional sampling effort permitted by the Kure-Stuyvesant spill funding resulted in much larger samples of murrelets compared to previous years, with 2,098 AHY murrelets detected in 2011 in the study area, compared to an annual mean of 334 birds for 2000-2010 (Table 3b). Similarly, 48 HY birds were recorded in 2011 compared to a mean of 8.0 for 2000-2010.

The additional sampling effort in 2011 also provided better sampling distribution in space and time over the study area, compared to prior years. The 28 PSU samples provided 5 to 6 replicates for each PSU in the study area, and 4 to 14 replicates for each 10-day time periods (Tables 2a, b). More sampling effort occurred during the latter periods, when typically more HY birds are on the water due to the cumulative effects of ongoing fledging. In comparison with 2011, a mean of about 6.6 PSU samples were collected for the same area and time period during 2000-2010 (range 1-10 PSU samples; convert kilometers sampled [Table 3b] to number of PSU samples by dividing by 26 km, the standard length of one PSU sample).

Data Products

Companion products with this report are two electronic database versions of the data collected, which are being provided separately. These files are:

PP11SEGT.XLSX (1,264 records): Detection for all marine species summed by each transect segment during transects for this study.

PPMAMU11.XLSX (1,281 records): All individual Marbled Murrelet records from the field work for this study in 2011

Appendix A reiterates field methods, and includes metadata documentation for the databases.

DISCUSSION

The first result from this pilot study is that the field methods and sampling regime were feasible and achievable. Productivity data on other Alcid species (Common Murre and Pigeon Guillemot) can provide a 'check' in attributing variation in indices to marine conditions or terrestrial habitat management (other species data are not summarized here, but are contained in the file PP11SEGT).

The date-adjusted HY number and HY:AHY ratio was remarkably steady over the four 10 day periods (Table 2a), suggesting that the regression used in this formula is appropriate for this region. Further years are needed to confirm or qualify this.

Though there is a strong relation between HY:AHY ratios and the HY detection rate in Tables 2a and 2b, detection rate can provide additional information on murrelet productivity since it is independent of AHY distribution. If the two age classes show different habitat preference, then age ratios would be skewed more than detection rates. An example of this is in PSU 15, where the ratio was 1.5 times higher than the next highest ratio (PSU 11) due to relatively few AHY, but the HY detection rate was slightly lower (Table 2b). Date-adjusted ratios should give an even stronger correlation with detection rate (an autocorrelation actually), since that method relies on the ratio of encounter rates rather than simple sum numbers.

There is evidence of HY habitat preference in the high numbers (and ratios) encountered off the convoluted and rocky shores at either end of the study area. Strong (1998a) speculated on a HY preference for this type of habitat in Oregon, and also noted certain semi-protected areas where AHY in advanced molt would concentrate. The region from Sisters Rocks (segment D of PSU 11) to north of the Klamath (segment C of PSU 12) and Trinidad Bay (segment D of PSU 15) are such places within this studies surveyed area.

RSL and CCR data will be combined for years 2000 through 2011 in a separate, forthcoming power analysis of the productivity methods used in this report. That analysis should provide statistical information on the sensitivity of the sampling method and metrics of this study to detect differences, such as between years, in murrelet reproductive success. This can inform both the feasibility and value of continuing Marbled Murrelet productivity monitoring in the future,

and the likelihood of the method detecting an effect of RNSP habitat management on murrelet reproductive success. While it is premature to speculate on the statistical power achievable by this study's approach, the sample sizes provided by this study, with its additional, focused sampling effort, far exceeds those of previous years. Larger sample sizes in general enhance statistical power to detect changes or effects. At the least, the relatively large number of HY murrelets observed (48), combined with improved spatial and temporal distribution of sampling effort, provide a more robust measure of the hatch-year bird abundance, compared to most previous years, when typically less than 10 and sometimes only 1 or 2 PSU samples were collected in the study area. Ratios and estimates of abundance based on such small sample sizes tend to be unreliable, because of the effect of 1 or 2 observations on those estimates.

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Report preparation by Craig Strong, Crescent Coastal Research, with improvements by Gary Falxa, USFWS.

CITED REFERENCES

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L. Laake. 1993. Distance sampling, estimating abundance of biological populations. Chapman Hall, New York. 446 pp.

Falxa, G, J. Baldwin, M. Lance, S.L. Miller, S.F. Pearson, M.G. Raphael and C.S. Strong. 2010. Status of the Marbled Murrelet in the Northwest Forest Plan area: Ten years of population monitoring. Pacific Seabird Group 31st annual meeting, Long Beach, CA. Abstract.

Herbert, P.N. and R.T. Golightly. 2008. At-sea distribution and movements of nesting and non-nesting Marbled Murrelets (*Brachyramphus marmoratus*) in northern California. Marine Ornithology36:99-105.

Kuletz, K.J, and J.F. Piatt. 1999. Juvenile Marbled Murrelet nurseries and the Productivity Index. Wilson Bull. 111:257-261.

Long, L.L., S.L. Miller, C.J. Ralph, and C.S. Strong 2010. Marbled Murrelet abundance, distribution and productivity along the coasts of northern California and southern Oregon, 2009. Redwood Sciences Laboratory, USFS, Arcata, CA Unpub. report. 35 p.

Madsen, S., D. Evans-Mack, T. Hamer, P. Henson, S. Miller, S.K. Nelson, D. Roby, and M. Stapanian. 1999. Marbled Murrelet effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-439. Portland, OR. USDA, Forest Service, Pacific Northwest Res. Sta. 51 p.

McShane, T, T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. Evaluation report for the 5-year Status Review of the Marbled Murrelet in Washington, Oregon, and California. Unpub. report. EDAW, Inc. Seattle WA.

Miller, S.L., C.J. Ralph, M.G. Raphael, C. Strong, C. Thompson, J. Baldwin, and M. H. Huff. 2006. At-sea monitoring of Marbled Murrelet population status and trend in the Northwest Forest Plan area. Chapter 3 *In* Northwest Forest Plan- The first 10 years (1994-2003): Status and trends of populations and nesting habitat for the Marbled Murrelet. Gen. Tech. Rep. PNW-GTR-650. 149 p

Nelson, S.K. 1997. Marbled Murrelet. In Poole, A. and F. Gill (eds.): The birds of North America, no. 276. The Birds of North America. Philadelphia, PA. 32 p.

Peery, Z.M, B.H. Becker, and S.R. Beissinger. 2007. Age rations as estimators of productivity: Testing assumptions on a threatened seabird, the Marbled Murrelet (*Brachyramphus marmoratus*). Auk 124:224-240.

Ralph, C.J. and L.L Long. 1995. Productivity of Marbled Murrelets in California from observations of young at sea. In: C.J. Ralph, G.L. Hunt, Jr., J.F. Piatt, and M.G. Raphael (eds.), Ecology and conservation of the marbled murrelet in North America: an interagency scientific evaluation. USDA Forest Service. PSW-GTR-152. p 371-380.

Raphael, Martin G. 2011. Personal communication. Research Scientist, U.S. Forest Service, PNW Research Station, 3625 93rd Avenue SW, Olympia, WA 98512

Raphael, M.G., J. Baldwin, G.A. Falxa, M.H. Huff, M. Lance, S.L. Miller, S.F. Pearson, C.J. Ralph, C. Strong, and C. Thompson. 2007. Regional population monitoring of the marbled murrelet: field and analytical methods. Gen. Tech. Rep. PNW-GTR-716. Portland, OR. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station. 70 p.

Raphael, M.G.; Falxa, G.A.; Dugger, K.M.; Galleher, B.M.; Lynch, D.; Miller, S.L.; Nelson, S.K.; and Young, R.D. 2011. Status and trend of nesting habitat for the marbled murrelet under the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-848. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 52 p.

Strong, C.S. 1998a. Marbled Murrelet distribution shifts between coastal habitats of northern California and Oregon. Pacific Seabird Group 25th annual meeting, Monterey, CA Abstract.

Strong, C.S. 1998b. Techniques for Marbled Murrelet age determination in the field. Pacific Seabirds 25:6-8.

Strong, C.S. 2011. Population monitoring and productivity estimates of Marbled Murrelets in Conservation Zones 3 and 4 during 2010. Crescent Coastal Research, Crescent City, CA Unpub. report to the U.S. Fish & Wildlife Service.

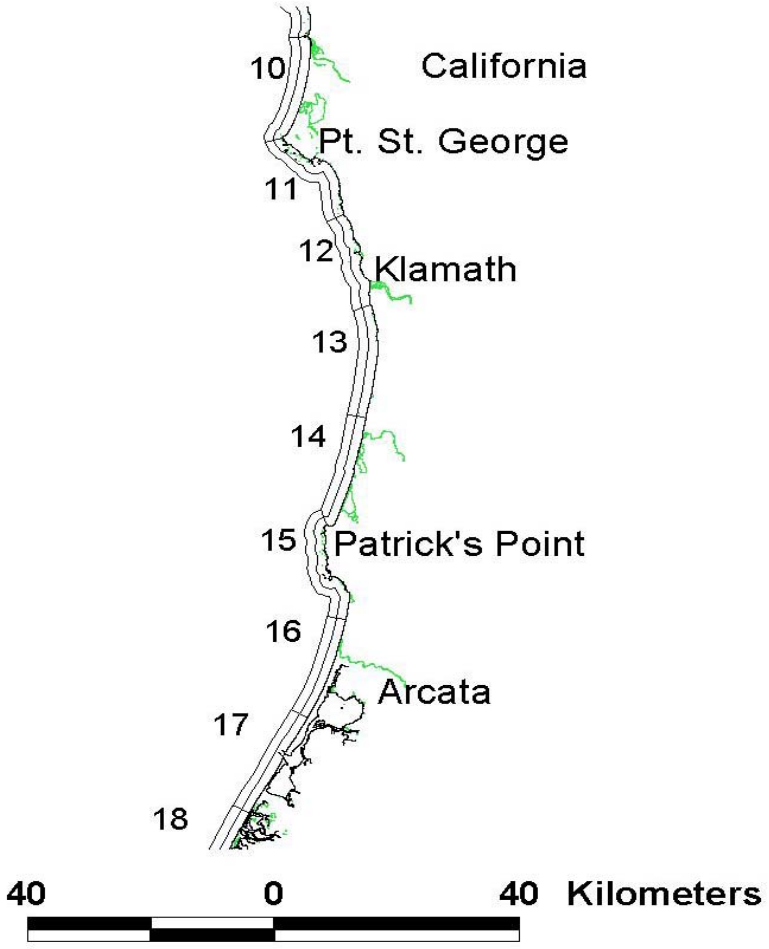

Figure 1. Northern California showing Primary Sampling Unit numbers within the study region (PSU 11 – 15).

Table 1. A daily summary of productivity survey results of PSU transects completed by CCR in 2011. Refer to Fig. 1 for PSU locations. Rep. is the replicate completed per PSU, Draw is the GIS route followed, period is 10 day interval for which date-adjusted ratios are calculated, and Inshore / Offshore refers to transects conducted inshore of 2 km and between 2 and 3 km from shore ('Offshore'). Effort is KM of transect, and HY/AHY are counts of HY and AHY.

						Inshore		Offshore	
DAY	**PORT**	**PSU**	**Rep.**	**Draw**	**Period**	**Effort (km)**	**HY/AHY**	**Effort (Km)**	**HY/AHY**
JULY									
14	Crescent City	13	1	2	1	20.0	3 /117	6.0	0 / 17
14	Crescent City	14	1	2	1	20	3 /185	5.7	0 / 14
17	Crescent City	11	1	2	1	19.9	0 / 49	6.2	0 / 3
17	Crescent City	12	1	2	1	19.7	0 / 7	6.0	0 / 0
18	Trinidad	15	1	2	1	20.2	0 / 36	6.0	0 / 4
24	Trinidad	13	2	1	2	19.5	0 / 78	5.5	0 / 3
25	Trinidad	15	2	3	2	21.2	1 / 16	6.2	0 / 0
AUG									
1	Crescent City	11	2	3	2	19.1	2 / 16	6.1	0 / 0
2	Crescent City	12	2	3	2	19.4	0 / 28	5.6	0 / 2
3	Crescent City	13	3	4	3	20.0	0 / 75	6.0	0 /102
3	Crescent City	14	2	4	3	19.9	0 / 35	3.1	0 / 0
9	Crescent City	11	3	4	3	18.7	1 / 64	6.1	0 / 21
9	Crescent City	12	3	4	3	18.9	0 / 31	5.9	0 / 12
10	Trinidad	15	3	4	3	18.6	4 / 68	6.0	0 / 2
13	Crescent City	11	4	6	4	21.0	3 / 61	6.0	3 / 67
13	Crescent City	12	4	6	4	18.8	0 / 39	6.0	2 / 14
14	CC to Trin.	13	4	6	4	20.0	1 /127	6.0	0 / 10
14	CC to Trin.	14	3	6	4	19.6	1 / 57	6.0	0 / 1
15	Trinidad	15	4	6	4	20.5	2 / 37	6.0	0 / 2
16	Crescent City	11	5	5	4	19.8	3 / 60	6.0	1 / 15
16	Crescent City	12	5	5	4	18.9	3 / 82	6.0	0 / 8
17	CC to Trin.	13	5	5	4	20.5	3 / 77	6.0	0 / 5
17	CC to Trin.	14	4	5	4	19.6	0 / 17	6.3	0 / 5
18	Trinidad	15	5	5	4	21.4	2 / 40	5.9	2 / 10
19	Crescent City	11	6	7	4	18.1	2 / 80	6.0	0 / 10
21	Trinidad	14	5	7	4	20.0	0 / 54	6.0	0 / 0
22	Crescent City	12	6	7	4	18.8	2 /131	5.9	2 / 60
22	Crescent City	13	6	7	4	20.0	2 / 44	6.0	0 / 0

TOTALS	19 days	552.1	38 / 1711	164.5	10 / 387

Table 2a. Marbled Murrelet HY: AHY ratios and detection rate divided by 10 day periods between 14 July and 22 August 2011.

	Time Period			
	14–23 July	24 July–2 August	3–12 August	13–22 August
Km effort	129.7	102.6	123.2	361.1
No samples	5	4	5	14
HY	6	3	5	34
AHY	432	143	410	1113
Ratio	0.014	0.021	0.012	0.031
Adjusted ratio	0.033	0.033	0.014	0.033
HY det./Km	0.0463	0.0292	0.0406	0.0942

Table 2b. Marbled Murrelet HY: AHY ratios by 20 Km long Primary Sampling Unit along the coast from 14 July to 22 August (see locations in Fig. 1)

	Primary Sampling Unit				
	11	12	13	14	15
Km effort	153.0	149.9	155.5	126.2	132.0
No samples	6	6	6	5	5
HY	15	9	9	4	11
AHY	446	414	655	368	215
Ratio	0.034	0.022	0.014	0.011	0.051
HY det./Km	0.0980	0.0600	0.0579	0.0317	0.0833

Table 3a. Productivity indices of Marbled Murrelets during the 14 July to 22 August study period in all of Zone 4, Coos Bay, OR, to Shelter Cove, CA. Includes data collected by both USFS-RSL and CCR sampling efforts. Indices use the date-adjusted number of HY birds to account for different sampling dates across years. Note that this table presents data for all of Zone 4, while Table 3b presents data only for PSUs 11-15 within Zone 4.

	Number of Murrelets			HY:AHY Ratio
YEAR	AHY	HY	Adj. HY	Adj. Ratio
2000	1727	75	109.7	0.064
2001	1142	49	71.4	0.062
2002	481	12	21.7	0.045
2003	1233	35	52.2	0.042
2004	601	13	14.8	0.025
2005	539	4	5.4	0.010
2006	173	2	4.7	0.027
2007	358	18	20.3	0.057
2008	825	55	82.3	0.100
2009	1133	27	37.7	0.033
2010	640	22	32.6	0.051
2011	2120	49	63.7	0.030
Mean 2000-2011				0.046

Table 3b. Productivity indices of Marbled Murrelets during the 14 July to 22 August study period in the study area region for this project; Pt. St. George to Clam Beach, CA (PSU 11-15). Includes data collected by both USFS-RSL and CCR sampling efforts. Indices use the date-adjusted number of HY birds to account for different sampling dates across years. Data from 2002 through 2004 surveys are not currently available. For 2000-2009, sampling effort was estimated by multiplying the number of PSU samples by 26 km, the standard sampling effort per PSU.

	Sampling Effort	Number of Murrelets			Indices	
YEAR	Km Sampled	AHY	HY	Adj. HY	Adj. Ratio	HY/ Km
2000	182	260	7	7.7	0.030	0.042
2001	182	167	9	10.2	0.061	0.056
2002	NA	NA	--	--	--	--
2003	NA	NA	--	--	--	--
2004	NA	NA	--	--	--	--
2005	208	438	2	3.2	0.007	0.015
2006	78	62	2	4.7	0.077	0.061
2007	52	101	2	3.2	0.031	0.061
2008	234	476	23	32.7	0.069	0.140
2009	260	804	11	13.1	0.016	0.050
2010	155	361	8	12.6	0.035	0.081
2011	717	2098	48	61.3	0.029	0.086
Mean 2000-2011:					0.039	0.066
Mean 2000-2010:	172.3	333.6	8.0	10.9	0.041	0.063

Appendix A.
DOCUMENTATION OF AT-SEA SURVEY PROTOCOL AND DATABASE USED BY CRESCENT COASTAL RESARCH FOR YEARS 2000 – PRESENT (2012) IN CONSERVATION ZONES 3, 4, AND 5. By Craig Strong, Crescent City, CA *cstrong.ccr@charter.net*

Vessel Protocol

Vessel surveys were made from 6 and 7 m boats equipped with marine radio, compass, Global Positioning System receiver (GPS), and sonar depth finder, which also relayed sea surface temperature. Other equipment included binoculars, digital watches, and micro tape recorders for each person, maps covering planned transect lines, and a laser range finder. The deck of the boat is about level with the waterline; so standing observer viewing height was about 2 m above water. The GPS was loaded with the randomly selected transect routes prior to each survey. Two observers and a vessel driver were on board for all transects. Each observer scanned a 90^{o} arc between the bow and the beam continuously, only using binoculars to confirm identification or to observe plumage or behavior of murrelets. Search effort was directed primarily towards the bow quarters and within 50 m of the vessel, so that densities based on line and narrow strip transects will be at their most accurate (Buckland et al. 1993). All seabirds within 50 m of the boat and on the water were recorded. Only pelicans, terns, Osprey (aerial foragers), and murrelets were also recorded when flying. All Marbled Murrelet detections at any distance were recorded with information on group size and estimated perpendicular distance from the transect line, behavior, age (as After-hatch='AHY' or Hatch-year='HY'), and molt class. Marine mammals and boats were also recorded with an estimate of perpendicular distance from the transect line. Distance estimates were calibrated by running 10 replicates of estimated distance to small floating targets within the launch port on each survey day. All observers would estimate distance to the target, and then one would use the rangefinder and record the actual distance when the vessel was perpendicular to the target, and observers would adjust their estimates if necessary. Environmental parameters and observing conditions were monitored on all surveys. Data were recorded on cassette tapes and later transcribed and entered on computer.

The vessel driver maintained a speed of 10 knots, followed the transect route, and watched for navigational hazards. The driver participated in searching for murrelets when not otherwise occupied. Transects were paused sometimes to rest, make observations, or for equipment reasons, and resumed at the same location where they left off. A break from duties was taken at least every 3 hours. Observers and driver rotated duties at irregular intervals through 2011, usually on completion of a PSU sample or between Inshore and Offshore subunits (see below).

Vessel Sampling Design

A thorough description of the population monitoring sampling design can be found in The Northwest Forest Plan - the First 10 Years (Miller et al. 2006) and in Raphael et al. (2007). In short, the coast was divided into 20 km long Primary Sampling Units (PSU) and a transect was conducted through each PSU following a randomized transect route between 350 and 5000 m offshore (350 to 3000 m offshore in Zones 4 and 5). The goal in population monitoring under the Northwest Forest Plan was to complete 30 PSU samples within each Conservation Zone

during the primary nesting period, from 15 May to 31 July. However, in Zone 5 the sampling effort was halved to 15 PSU because so few murrelets occurred there it was cost effective to devote survey effort to other Zones for the purpose of monitoring the overall population.

DATA DOCUMENTATION FOR CRESCENT COASTAL RESEARCH'S AT-SEA TRANSECTS: DATA AND DATABASE EXPLANATION

This document is dual purpose; both as metadata to accompany distributed data files, and to inform biologist observer crew of required observations and what is to be transcribed and entered on data sheets and files.
This documentation is for the raw data file(s). Summary data files have the same field names, but numeric fields containing counts/detections and molt classes are summed for the segment, PSU, or whatever compilation is being performed. Data were originally entered and proofed with Dbase, and may later be accessed in EXEL, MS Access, or other programs. Some data files, particularly summary files, do not have all of the fields listed below. This is because they are superfluous in proofed files, redundant (e.g.; DATE duplicates MO, DY, and YEAR information), or do not apply to summed data (e.g., behavioral description of individual birds).

Field names are CAPS UNDERLINED (alternate field name in parentheses). Fields may not be in the same order as shown here.

PSU Header information Duplicated each record until the next survey or change in sampling.

DATE Full date of survey
MO (Month)
DY (Day)
YEAR Year
ZONE Corresponds to Marbled Murrelet Conservation Zones. Zone 3 = from S. side Columbia River to Coos Bay, Zone 4 = from Coos Bay to the Mendocino Co. line (just s of Shelter Cove, and Zone 5 = from Humboldt Co. line to Pt. Bonita out from the Golden Gate.
STR Stratum geographic division within ZONE, placed at the inception of the NWFP to designate regions of different mean Marbled Murrelet densities, and also biogeographic junctures.
PSU Primary Sampling Unit number where the transect took place. PSU are arranged in contiguous 20 km long sections of coastline, numbered north to south, starting at each Conservation Zone boundary.
DRAW The random draw number for which GIS generated transect route was followed, from PSU map page.
INOFF Noted ‘IN’ for transects in the nearshore, ‘OF’ for transects in the offshore subunit.
TRANLENGTH This is generally the sum length of transects in the inshore (segments A, B, C, D) or offshore (segment Z) subunits. Not filled in for raw data in most cases (use SEGLENGTH for effort). Tranlength is also the sum of Extra surveys within a PSU (see SEG below).
LOC A couple words describing where survey took place, e.g. ‘Florence north’, or

'Brookings area' (this only need be filled in on 1st page, actually is a relic from prior methods).
HDG General direction of transect up or down coast, filled in as 360 (north) or 180 (south).
OBSERVER The observer initials and 'P' or 'S' for port or starboard.

Segment 'Header' data updated @ begin & end each segment or with conditions change, and duplicated subsequent records until change. This info. is also often updated when passing waypoints.

SEG. (Segment) Segments are approximately 5 km long portions of coastline within each PSU, designated A, B, C, D north to south and Z for transects in the offshore subunit. If the survey was in addition to and not a part of the official PSU survey, the segment is designated 'EX__', where __ is the segment letter designation where the EX (extra) survey took place. . Note that in Zone 3 the outer limit of the PSU (sampled waters) is 5 km offshore and has multiple Zig-Zags where conditions are updated on each waypoint, however the entire survey effort is designated one segment, 'Z'. In Zones 4 and 5 the offshore limit is 3 km offshore and the transect is just one 'Zig' angled line.
SEGLENGTH (Effort or Survey_Effort) Kilometers of transect within each segment (A, B, C, D) The offshore segment Z is combined as 1 segment with 1 SEGLENGTH even if the effort is split in different pieces.
WAYPT. Waypoint number from the GPS that the driver calls out when passing.
SHOREDIST (Shore_dist) Distance offshore where the transect is taking place, from the map page. For the offshore transect, SHOREDIST is only recorded at begin and end of the line (in Zone 3 it goes between 1500 and 5000 m, and Z 4 & 5 goes between 2000 and 3000 m).
ACTUALDIST Filled in only where the actual shore distance of the transect differed from that stated on the GIS map due to breaking swell risk or obstructions (kelp, rocks, islands). SHOREDIST retains the distance stated on the maps.
SWELL (SWELLHDP) Estimated swell size and period, and sometimes direction; e.g.: '3@8 s' = 3 feet at 8 second intervals.
SKY We are using 10th of cloud cover or % to nearest 10%, so write 4/10 or 40% for ex. For Clear write 'Clr'. Fog and rain notes are in NOTES field.
WIND Wind direction and force. Direction is direction wind is coming from, e.g., 'NW', and force is in knots, estimated.
BEAUFORT Beaufort sea state number, use chart for reference.
OBSCOND = Observing conditions Coded, E = excellent, VG = very good, G = good, F = fair FP = fair to poor, P = poor. This approximately follows the beaufort scale of 0-4.
DEPTH. In feet, at begin and end of every segment or on passing waypoints.
SST (H2OTMP) Sea Surface temperature, updated as DEPTH. Given in Fahrenheit, will convert later.
TIME Real 24 hour notation to minute.
SP AOU Species code or made up code for marine mammals, fish, boats, or other biota (see codes page). Code 'NOTE' is for all info for which there is no species specific observation, such as end/start of a segment or change in weather. If you don't know the species code, check the species code page AND write out the full name in NOTES. No ambiguity allowed for this data. See codes in Table A1.

SPNO An assigned number for each species or species group in approximate phylogenetic order.

SPECIES Spelled out species name.

NO (N, Number) Group size, number seen within a few meters and acting as a unit for Murrelets. Multiple observations of consecutive murres can be summed in NO (group size is only specifically tracked for murrelets and marine mammals).

AHY Number of After Hatch Year aged birds in group. This applies generally only to Alcids (Common Murre, Marbled Murrelet, Pigeon Guillemot, Rhinoceros Auklet), but may also be used for gulls & marine mammals where age is determined. For Brown Pelicans AHY = number of white-headed birds (After 2nd Year).

HY Number of Hatch Year fledglings in group for alcids. For pelicans and gulls, HY may also include immatures (brown-headed pelicans, before third year gulls). This is optional for gulls and other spp. but critical for MAMU and other alcids.

NOLT55 For MAMU only, = NO truncated for observations less than 55 m from the boat to use MAMU data comparably with strip transect densities of other seabirds. 54 and less meters was selected to compensate for the 'crowding the line' effect of observers tending to include seabirds close to the strip transect boundary and thus including some beyond it.

LINEDIST (Perp_Dist) Estimated distance off the transect line. Should be recorded for all MAMU, boats, marine mammals, and pelicans. If the recorder reports 'Zero' meters, write 1 meter to distinguish from missing data. If the recorder fails to report line distance, write that in NOTES: 'no distance given'. For flying-by MAMU, estimated distance should be from where it was first detected relative to the transect line. LINEDIST should be estimated when the detection (or identification) is first made, not delayed until the animal is perpendicular to the transect line (the estimate is generally made for birds ahead of the boat).

SIDE Side of vessel. S for starboard, P for port, and B for bow, only for those species we take line transect data on (MAMU, Marine mammals, boats). Occasionally an observer will report data from the opposite side of vessel, so do fill this out for the line transect species.

BEH Behavior categories for MAMU: S= stay on water surface during passing, F__= fly from surface assumed due to boat disturbance, where __= flight direction, D= dive in assumed response to the boat, FD= forage diving, and FB__= flyby (first detected in flight) with __= direction of flight. Rare behaviors are TO= Take off and LO= Land On for birds acting not in response to the boat. For boats, BEH = activity, such as JIG (bottom fishing), RUN (traveling), TROLL, CRAB, etc.

M1, M2, M3, M4 (C1, C2, C3, C4) For MAMU only, the stage of molt code 1, 2, 3, or 4, see Strong 1998. This should be the number of birds in a group of each molt class. This is only filled out when good views are obtained, often left blank. Age is determinate by molt classes 1, 2, or 3; the working definition of an M4 bird is basically black and white in appearance such that closer investigation and viewing is necessary to determine age.

AGE1 … AGE6 For MAMU only. A sequence of code letters of what plumage /behavior features were seen of class 4 (M4) birds that caused the age determination, for up to 6 birds in a group. See Table A2.

NOTES All other notes on birds, weather, start and end of segments or change in course on zig-zag offshore transects, vagaries and variations in transect route (pauses, going around rocks, etc.) and other relevant information that the observer chatters onto the voice record. Often some

editing is needed to catch the essential data from the recorder. Use extra data sheet lines as needed to clearly capture the essential NOTES.
FLAP. For age determination of MAMU only; a Y (yes) or N (no) if the bird flaps following the first dive
(an age-specific behavior)
VOC. If vocalizations are noted on subject bird, not recorded regularly.
SECOBS (SEC_OBS) For age determination of MAMU only. Second of duration of observation of MC4 birds during age determination. This has not been done in recent years.
COUNT A tally field, not in all databases. Usually used to tally number of each species detections in summarization.
MMDET A tally field like COUNT, usually used to tally number of MAMU detections in summarization.
VESSEL, ENTITY, SOURCE These fields may occur in some databases and are used to denote which boat or research entity was used in conducting the survey. For these surveys, CCR= Crescent Coastal Research conducted all surveys.

Table A1. List of species codes as used in the SP and SPECIES fields.

CODE	SPECIES	* COMMON
COLO	Common Loon	*
PALO	Pacific Loon	*
RTLO	Red-throated Loon	
LOON	Loon species	*
CLGR	Clarks Grebe	
WEGR	Western Grebe	*
RNGR	Red-necked Grebe	
EAGR	Eared Grebe	
GREB	Grebe species	*
BFAL	Black-footed Albatross	
NOFU	Northern Fulmar	
SOSH	Sooty Shearwater	*
MASH	Manx Shearwater	
FFSH	Flesh-footed Shearwater	
PFSH	Pink-footed Shearwater	
BUSH	Buller's Shearwater	
SHEA	Shearwater species	*
LHSP	Leach's Storm Petrel	
FTSP	Fork-tailed Storm Petr	
PETR	Storm Petrel species	
BRPE	Brown Pelican	*
DCCO	Double-crested Cormora	*
BRCO	Brandt's Cormorant	*
PECO	Pelagic Cormorant	*
CORM	Cormorant species	*
GREG	Great Egret	
GTBH	Great Blue Heron	
CAGO	Canada Goose	
WWSC	White-winged Scoter	*
SUSC	Surf Scoter	*
BLSC	Black Scoter	
SCOT	Scoter species	*
HARD	Harlequin Duck	
RBME	Red Breasted Merganser	*
BLOY	Black Oystercatcher	*
WHIM	Whimbrel	
RNPH	Red-necked (northern) Phalarope	*
REPH	Red Phalarope	*
PHAL	Phalarope species	*
PEEP	Sandpiper species	*
WESA	Western Sandpiper	
POJA	Pomarine Jaeger	
PAJA	Parasitic Jaeger	
LTJA	Long-tailed Jaeger	
JAEG	Jaeger species	
HEEG	Heermann's Gull	*
BOGU	Bonaparte's Gull	
RBGU	Ring-billed Gul	
MEGU	Mew Gull	
HERG	Herring Gull	
GLGU	Glaucous Gull	
CAGU	California Gull	*
WEGU	Western Gull	*
GWGU	Glaucous-winged Gull	*
SAGU	Sabine's Gull	
GULL	Gull species	*
BLKI	Black-legged Kittiwake	
ARTE	Arctic Tern	
FOTE	Forster's Tern	
COTE	Common Tern	
ELTE	Elegant Tern	
CATE	Caspian Tern	*
COMU	Common Murre	*
PIGU	Pigeon Guillemot	*
MAMU	Marbled Murrelet	*
XAMU	Xantus's Murrelet	
ANMU	Ancient Murrelet	
LBMU	Long-billed Murrelet	
SMAL	Small Alcid	*
CAAU	Cassin's Auklet	*
RHAU	Rhinoceros Auklet	*
HOPU	Horned Puffin	
TUPU	Tufted Puffin	*
ALCD	Alcid Species	*
OSPR	Osprey	*
PEFA	Peregrine Falcon	
BEKI	Belted Kingfisher	
BAEA	Bald Eagle	*
ELSE	Northern Elephant Seal	
HASE	Harbor Seal	*
SEAL	Seal species	*
STSE	Steller Sea Lion	*
CASE	California Sea Lion	*
SELI	Sea Lion species	*
PINN	Pinniped species	*
GRWH	Gray Whale	*
HUWH	Humpback Whale	*
MIWH	Minke Whale	*
WHAL	Whale species	*
HAPO	Harbor Porpoise	*
RIDO	Risso's Dolphin, Grampus	
RIOT	River Otter	
BLSH	Blue Shark	*
MOLA	Mola Mola ocean sunfish	*
FISH	Other fish, say who in	*
HELO	Helicopter	*
PLAN	Fixed wing plane	*
BOAT	Boat: note type & activity	**
NOTE:	Any non-species notes e.g., location, weather, logistics, waypoint	

Table A2. Codes and descriptions of age determination criteria used in the AGE1, AGE2, …AGE6 fields. Note that these codes are used only when molt class is C4 (M4, advanced molt AHY or juvenile).

The first 1-2 letters of the code is the age determination, designated:
J: Confirmed HY Juvenile
JU: Unconfirmed HY
A: Confirmed AHY
AU: Unconfirmed AHY
U: Unknown age bird

Following letters are code for criteria seen that allow the age determination. The first set of codes applies to HY as:
Z: Crisp, sharply delineated black and white overall appearance, or glossy even dark plumage on top
FW: Full wing outline, no molt apparent on wing
WB: White belly and chest, usually viewed when the bird dives
B: Behavioral indication of age or molt status. The actual information should be in the NOTES field, and includes (juvenile behaviors): Rapid or evasive diving or flight, lack of flapping upon coming to the surface, separation from pair or group members, or (AHY behaviors): reluctance to dive when first approached, immediate wing-flapping upon surfacing, strong pairing or synchronous diving with group members.
FF: Fine Flecking on breast, giving an even coloration pattern at a distance
ET: Egg tooth visible on dorsal tip of bill

And codes indicating AHY age:
R: Brown feathers visible on back or in the neck or breast, viewed in good front lighting
P, OP, or IP: Primary flight feathers missing (OP indicating outer primaries missing giving the wing outline a stubby appearance, or IP for inner primaries or secondaries missing), P is nonspecific flight feather molt.
DB: Dark belly visible when bird dives. Ventral feathers, usually immersed, are the last body feathers to molt and are an effective ageing criteria. Usually observed on the dive.
B: Behavior, see above.
2: Strong pairing behavior.