MARBLED MURRELET POPULATION MONITORING

AT SEA IN CONSERVATION ZONE 4 DURING 2019.

RESULTS FROM SOUTHERN OREGON AND NORTHERN CALIFORNIA

Photo C. Strong

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SUMMARY

Vessel transect surveys of seabirds in Marbled Murrelet Conservation Zone 4 were used to estimate populations of Marbled Murrelets during summer 2019. This is the 20th year of Marbled Murrelet population monitoring as a component of the Northwest Forest Plan (NWFP). Using a stratified-random sampling as designed by the NWFP, 36 Primary Sampling Unit (PSU) samples were completed from Coos Bay, Oregon to the Humboldt-Mendocino county line, California. In total, 927 km of sampling transects were completed within 3 km of shore in the 15 May to 31 July survey period. In this effort, 818 murrelet detections were made comprising 1,434 birds, as well as counts of other seabirds, marine mammals, and vessels.

Population estimates generated by the NWFP at-sea monitoring group using line transect methods were of 6,821 Marbled Murrelets in Zone 4, with 95% confidence intervals from 5,576 to 11,062 birds. This estimate was equal to the mean of estimates since 2010, and higher than the long term mean, consistent with the recent upward population trend described for Zone 4.

Marbled Murrelet abundance and distribution was comparable with other years, but productivity indices were roughly 1/3 of average. Other seabirds in Zone 4 experienced either complete failure (Common Murres) or very depressed nesting attempts and success (Brandt's and Pelagic Cormorants). There was no ready explanation for this exceptionally poor season for seabirds throughout Zone 4 other than lag effects from the 2014-2016 marine heat wave and continuing impacts of climate change in the California Current.

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INTRODUCTION

Background

The Marbled Murrelet (*Brachyramphus marmoratus*;) is a small diving seabird in the Alcid family which is on the Federally Threatened Species list, and is state listed as endangered in California and Oregon. Marbled Murrelets have adapted to nesting on large branches high in old growth forests, and it this unique nesting habitat that led to their decline and federal listing when most of the forests on the west coast were cut for timber in the latter 1800's and 1900's (Marshall 1988, Nelson 1977). As a component of the Northwest Forest Plan (NWFP; initiated by the Clinton administration in 1994), Marbled Murrelet population monitoring has been completed since 2000 as a means of testing the effectiveness of the NWFP in conserving remaining old-growth forest habitat on federal lands and maintaining populations of murrelets (Madsen et al. 1999, Miller et al. 2006). Because murrelet nests are disperse and difficult to locate high in trees of mature coastal forests, research on overall abundance is conducted at sea, where the birds are more easily seen and concentrated within a few km of shore on the open coast (Ralph and Miller 1995, Strong 2016). Murrelet population monitoring is structured using the Conservation Zones identified in the Marbled Murrelet Recovery Plan (USFWS 1997). The Effectiveness Monitoring component of the NWFP produced evidence of population decline from 2000 to 2010 throughout the 3 state region, with the greatest decline occurring in Washington (Miller et al. 2012). More recent estimates have been higher in some Zones, making it difficult to define an overall population trend during this century (Falxa et al. 2016, McIver et al. 2020). Surveys were completed in Zones 1 through 4 annually since 2000, but in 2014 the program has cut back to surveys of each Zone in alternating years; Zone 4 was not surveyed in 2014, 2016, or 2018. Zone 5 is now surveyed with lesser effort and only every 4 years due to the very low murrelet numbers typically observed in that region (Shelter Cove to San Francisco, CA)

Zone 4 extends from Coos Bay, Oregon, to the Mendocino County border, California (near Shelter Cove). This region is quite heterogeneous both geographically and oceanographically, and includes two major upwelling centers off Cape Blanco, Oregon, and Cape Mendocino, California. The majority of high quality nesting habitat for murrelets is contained in state and national parks in the middle of the Zone, though other patches of old growth forest habitat exists in southern Oregon (Fig. 1)

Crescent Coastal Research (CCR) has contributed to population monitoring in the Oregon portion of Conservation Zone 4 since 1992, before the inception of standardized NWFP monitoring in 2000, and has completed all population monitoring in this Zone since 2010. Redwood Sciences Laboratories (U.S.Forest Service, PSW Station, Arcata) completed earlier NWFP surveys (years 2000-2009) of the rest of Zone 4.

This report summarizes the 2019 survey results for Zone 4 and compares distribution and abundance patterns of Marbled Murrelets with prior years. Also included here are data summaries for some other nesting seabirds and assessments of marine conditions for seabirds in Zone 4 during 2019.

METHODS

Vessel Survey Methods

Vessel surveys were made from a 21 foot Boston Whaler 'revenge' fitted with a Global Positioning System receiver (GPS), and sonar depth finder, which also relayed sea surface temperature (SST). Other equipment included binoculars, and digital micro recorders for each observer, maps covering planned transect lines, and a laser range finder. The deck of the boat is level with the waterline; so standing observer viewing height was about 1.8 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, using binoculars only to confirm identification or to observe plumage or behavior of murrelets. Search effort was directed primarily towards the bow quarters and within 100m of the vessel, so that density estimates based on distance sampling from line transects will be at their most accurate (Buckland et al. 1993). Observers stood side by side and verbally checked each other that all detections were recorded and none were duplicated. All Marbled Murrelet detections were recorded with information on group size, side of vessel, estimated perpendicular distance from the transect line, behavior, molt class, and age. All seabirds within 50 m of the transect line and on the water were recorded (ie; using strip transect methods). Flying birds other than murrlets were not recorded except for the aerial foragers (pelicans, terns, Osprey). Marine mammals and boats were recorded using line transect methods, with an approximate 1.2 km truncation distance in reporting boats. Observer distance estimates were checked weekly and calibrated by running 5 to 30 replicates of estimated distance to small floating targets near the launch port. Observers would estimate the perpendicular distance from the transect line to the target, and if estimates differed from laser readings by over 15% the exercise was repeated until adequate precision was obtained. Weather, depth, SST were recorded on each survey segment. Observing conditions were quantified into 5 categories based on estimates of swell height and period, wind force and direction, Beaufort sea state, percent of obscuring glare, visibility restriction due to fog, reflection from shore, and other. Data were recorded on digital recorders and later transcribed to data forms and entered on computer using Visual dBase database software.

The vessel driver maintained a speed of 10 knots (11 knots in excellent conditions, and down to 7 knots in compromised conditions or at high bird densities), followed the transect route, and watched for navigational hazards. The driver participated in searching for murrelets when not otherwise occupied. Detections made by the driver that would otherwise have been missed by observers pointed out by the driver and were coded as 'driver detection'. 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 positions between subunits of each PSU (see below) and between PSU samples when more than one sample was done per day.

Personnel

The field team was led by Craig Strong, with primary crew members Darell Warnock and Danielle Devincezni. Darell has been on the CCR murrelet survey team for over two decades and is familiar with all aspects of the field work as well as being an excellent observer, boat operator, photographer, and maintenance master. Danielle is a recent UC Santa Cruz graduate with seabird experience from her thesis work at Año Nuevo State Reserve. She came to the team as an intern, but performed so well in detecting and identifying murrelets that she advanced to being a biological observer. Rob Fowler and Teresa Bird were backup observers. Rob surveyed murrelets with CCR in 2010 and 2012-2013 and is an expert birder. Teresa works for Audubon and has conducts inland surveys for murrelets using the Pacific Seabird Group protocol, she displayed good competence performing the at-sea work.

Training with the above personnel was completed in mid-May, and included discussion of methods, distance estimation trials, and one day of on-water practice in observing birds and conducting trial surveys. All crew members displayed competence in line transect distance estimation, detecting murrelets, identifying seabirds, recording data, and using the methodology correctly.

All 2019 surveys were conducted by Craig, Darell, and Danielle with the exception of two days when Teresa Bird filled in, and three days when Jeff Jacobsen acted as our vessel operator. Jeff is a cetologist and marine scientist who has participated in this project many times in the past 25 years. In addition to the above team, we were joined by the population monitoring team leader Bill McIver on 27 June. Bill audited our work and obtained first-hand experience of CCR methodology and operation in conducting density sampling.

Sampling Design

A thorough description of the population monitoring sampling design can be found in in Raphael et al. (2007). In short, the coast was divided into 20 km long Primary Sampling Units (PSU, see Fig. 1) and a transect was conducted through each PSU following a randomized transect route between 400 and 3,000 m out to sea. Each PSU sample included an inshore subunit made up of four 5 km long transect segments running parallel with the coast at 4 randomly-selected distances from shore, and an offshore subunit where transects were conducted on a diagonal relative to shore from the inshore boundary out to 3,000 m, with a randomized starting point. In Zone 4 the inshore/offshore subunit boundary was set at 2,000 m. A PSU density sample consisted of approximately 20 km of transect effort in the inshore subunit and 6 km of transect effort in the offshore subunit based on the lower density of murrelets in the offshore (see Raphael et al. 2007).

Strata within Zones were designated as regions with distinctly different murrelet abundance, and low abundance strata received less sampling effort in the overall design (Raphael et al. 2007). In Zone 4 the higher abundance stratum 1 went from Coos Bay to Patrick's Point (PSU 1 – 14, see Fig. 1).

The goal in population monitoring under the NWFP was to complete 30 PSU samples within each Conservation Zone during the middle of the Marbled Murrelet nesting season, between 15 May and 31 July (Hamer and Nelson 1995, Raphael et al. 2007). Population estimates for strata and Zones were generated by Jim Baldwin and Nels Johnson (USFS, PSW Research Sta., NWFP at-sea working group) using line transect distance sampling analysis with each PSU as a density sample (replicate samples of a PSU were averaged). Annual PSU densities were also provided in the R statistical program that Jim developed. Further analysis details for the NWFP population monitoring effort are contained in Raphael et al. (2007).

A thorough review of all data and analytical methods from 2000 to 2013 was performed by Jim Baldwin, Gary Falxa and field team leaders during 2014 (see Falxa et al. 2016). Additional data quality reviews were performed by members of the murrelet effectiveness monitoring team in 2019 (McIver et al. 2019) These reviews and minor changes to the source data resulted in slight changes of point estimates in some years and Zones, and revision to the standard error and confidence intervals such that reports and publications prior to 2014 have slightly different values from reporting thereafter.

Analysis

Marbled Murrelet population estimates, the Zone 4 population trend, and summary of the near-shore to far-shore murrelet densities were generated by NWFP statisticians Jim Baldwin and Nels Johnson. Data on all other species and on murrelet productivity that were collected during transects are contained in Crescent Coastal Research databases. Counts of Pelagic Cormorant (*Phalacrocorax pelagicus*) nests on Castle Rock National Wildlife Refuge (NWR) and observations of nesting seabirds at other islands were made opportunistically during breaks in surveys. Pelagic Cormorant productivity data were collected at two subcolony locations in Del Norte County using methods adapted from the Alaska Maritime National Wildlife Refuge's Wildlife Inventory Plan, as described in Appendix A.

RESULTS

Effort

We attempted at-sea sampling surveys on 24 days during the 15 May to 31 July study season, and were successful in completing surveys on 22 days. In that time we completed 36 PSU sampling surveys in Zone 4 which included 927 km of transects (Table 1). Sampling was fairly evenly distributed through time and geographically, but with gaps in sampling in at the start of the season and in mid-June due to northwest winds. By a combination of improved weather forecast models and local knowledge, we lost very little effort due to poor weather, and were only prevented from 1 survey (due to Coast Guard bar closure at the Chetco River on 17 June, Table 1). Two PSU samples were cut short due to poor weather (on 9 and 31 July, Table 1), but they still met the criteria of over 75% completed (see Falxa et al 2016) and were included in the population estimation data. The PSU south of Cape Mendocino (19 – 22) were only visited once due to the high logistic and weather challenges in accessing this 'lost coast' area.

We reached our 30 PSU sampling goal by mid July, but in order to maintain distribution of sampling through time and space, we continued coverage until the end of July during the few days of good sampling weather, thus ending with 36 PSU samples.

NWFP Population Estimates and trend

The population estimate for Zone 4 in 2019 was of 6,821 birds, with 95% confidence intervals from 5,576 to 11,062 (Table 2). Where recent past sampling in 2015 and 2017 had unusually high overall estimates, 2019 was close to the mean since 2011 but well above the mean for the entire period. The mean group size in 2019 was comparable to other years, and this parameter has shown little variability across years (Table 2). The detection rate (number of groups seen per km of transect) has generally been the main driver of population estimates.

No clear trend in population was seen from 2000 to 2010 in Zone 4 (Miller et al. 2012), but estimates since then have been much higher (Fig. 2). The trend for the entire 2000-2019 time series was positive with a significant slope ($p = 0.0014$). The 2019 estimate was below this time series trend line (Fig. 2), but the point estimate was essentially the same as the average since 2011 (6,821 in 2019 vs 6,864 mean since 2011, data in Table 2)

Distribution along the Coast

While on population sampling transects, we had 818 murrelet detections in Zone 4 (Table 1). Murrelet abundance was similar to prior years from a large scale, regional perspective as shown in Figure 1. The area offshore from the Redwood National and State Parks (PSU 10 - 14) has usually held the highest numbers of murrelets, and this was again the case in 2019. PSU 1, 11, and 13 had densities notably higher than the long term average. Where PSU 10 had exceptionally high numbers in 2017 (Strong 2018), abundance was very low there this year.

Distribution Relative to Shore

Comparing densities in the inshore versus offshore subunits of all PSU shows that the density in the inshore subunit was 6.1 times that of the offshore density (Table 3). The average density ratio of all years in Zone 4 was 4.8, but there has been high variability in this measure over the years (Table 3). Offshore densities were actually higher than the inshore in two PSU samples, on 28 May in PSU 11 and on 25 June in PSU 10.

Looking at the distribution of detections of murrelets in 200 m increments of distance from shore, the region between 800 to 1,200 m had the most detections, both in the longer term data and in 2019 (Fig. 3). Both the prior year's data and 2019 showed an irregular pattern of detections, in contrast with Conservation Zone 3 which had a very smooth curve of declining detections with greater distance offshore (Strong 2017). To remember in examining Figure 3, the far-shore subunit receives roughly 1/3 the sampling effort as the near-shore, and starts at 2,000 m offshore, thus the drop in detections at that distance probably reflects less sampling.

Productivity

While on PSU sampling transects a total of 6 fledgling (HY) Marbled Murrelets were seen in Zone 4, and 2 more were noted after 31 July (not on transect). A confirmed fledgling observed and photographed on 28 May represents the earliest known HY at sea in California to my knowledge (however several HY have been recorded earlier in May in Zone 3, Strong 2019). Using all aged murrelet data from transects after 13 July as an index of productivity, the ratio of HY to AHY was 4:461 (0.0087), or 0.86% HY. This is the lowest ratio value since we conducted all Zone 4 surveys starting in 2010, slightly less than in 2017 (Table 4).

The detection rate of HY at sea independent of adult numbers serves as a second index of productivity, and is not dependent on the assumption of equal distribution between HY and older birds. HY densities for both Common Murres (*Uria aalge*) and Marbled Murrelets were at their lowest for both species in 2019 (Table 4, when counting since full Zone 4 coverage began in 2010). Where Marbled Murrelet productivity indices were a quarter (ratio) or a third (density) of average indices since 2010, Common Murres were roughly one hundredth (ratio) or 1/180th (density) of the mean, as seen in Table 4. For Common Murres, 2017 was an exceptionally poor year, with productivity indices approximately 1/10th of other years, but 2019 was again another order of magnitude lower, in which a total of 3 fledglings were seen in over 300 km of surveys in the latter 3 weeks of July.

Nesting seabirds in general had low or no nesting success through all of Zone 4, but particularly south of Cape Blanco. Following are summaries of observations on other nesting species.

Common Murre

Common Murre nesting at Castle Rock NWR (41^0 40’ N, 124^0 18’ W) showed moderate colony attendance in May through mid-June, with colonies at ’80 to 90 % full' on six scans from 5 May to 25 June, according to my field notes. Then on 12 July the entire island was abandoned by murres. Subsequent checks showed from a few hundred to ‘40% full’ in 3 scans later in July. Where in early and successful years such an observation could correspond with fledging in early July, in 2019 this was a result of colony abandonment. This was confirmed by the lack of fledglings at sea as shown in Table 4.

Other murre colonies in Zone 4 south of Cape Blanco also failed in 2019; colonies with sparse attendance and with murres ‘standing at sites’ (not sitting in incubation) in June and early July included Redfish Rocks and Goat Island in Oregon, and False Klamath Rock, Trinidad Rocks (all of them) and False Cape Rock in California. A total of 5 fledglings (HY) were seen at sea, and 3 of these were north of Cape Blanco (two of those were off-transect and thus do not appear in the transect data or Table 4). Also north of Cape Blanco were the only fish seen being returned by adults to colonies at Bandon Rocks. At Yaquina Head in Zone 3 murres had one of their best seasons in years (Porquez et al. 2019)

There was no evidence of unusual adult murre mortality in Zone 4 during 2019, however a dieoff of adult murres was described near Fort Bragg (Zone 5) in May (Ft. Bragg Advocate-News, 24 May 2019). Biologists between Fort Bragg and Cape Mendocino also reported zero or very few murre chicks at sea over multiple days of observation (J. Jacobsen, pers. comm)

Pelagic Cormorants

Pelagic Cormorants had very poor productivity in 2019, although at least some chicks fledged from a few colonies. The Castle Rock nest count data for 2019 showed 33 productive nests on Castle Rock, where in more normal years around 180 nests are counted (Table 5). Though the number of nest attempts was very small, most of the nests counted in incubation stage on 25 June went on to produce chicks of fledging age (field notes).

Pelagic Cormorants failed entirely at two smaller colonies which have been monitored over the past 5 or more years. Nesting numbers and success at the Tolowa Rock colony (41.75671° N, 124.22144° W) have shown high variability over 18 years, but 2017 and 2019 ranked among the worst (Table 5). At Hunter Island (41.95423° N, 124.20839° W), a total of two nests were established in 2019, but both failed by late July with no young produced. By contrast, this colony did quite well in other years, including 2017 (Table 5).

To the south, Pelagic Cormorants had nearly complete failure at SE Farallon Island NWR (Tiets and John, 2019). Researchers in Mendocino County also reported very poor success for Pelagic Cormorants, with low number of nesting attempts and low success of those that tried (D. Forsell, pers. comm.). Two cormorant monitoring studies in central and northern Oregon described a below average year for pelagics, certainly better than that described here for Zone 4 (Porquez et al. 2019,.).

Brandt’s Cormorants

Brandt’s cormorant (*P. penicillatus*) nesting success was not quantified in the Del Norte County area, though colonies were monitored in the Trinidad Rocks area, (Humboldt County, California; D. Barton, pers. Comm.) and in Mendocino County (R. LeValley, pers. Comm.). What can be said of the Castle Rock NWR population is that low numbers of birds attended some subcolonies on the island through May. From 29 May to 17 June there was more colony attendance and a flurry of nestbuilding, though numbers were still very low. Then on or before 12 July essentially all nests were abandoned; only two nests were being incubated on the entire north side on 13 July. Other colonies in Zone 4 were seen to have much reduced numbers of nests. As with Pelagic Cormorants, Brandt's fared better in Zone 3, and had a 'boom year' at Yaquina head (Porquez et al. 2019), though there were large differences between colony locations (Liebezeit and O'Connor unpubl.).

Other Productivity Indicators

Both Brown Pelicans (*Pelecanus occidentalis*) and gray whales (*Eschrichtius robustus*) were remarkably sparse during our transects in Zone 4 in 2019. In most summers, we observe many pelicans flying by northwards and additionally see them roosting on rocks and foraging nearshore. 2019 is on record for the lowest pelican densities seen in the time series, and the lowest whale densities since Crescent Coastal Research began surveying the entire Zone in 2010 (Table 6). From Table 6 there appears to be a strong negative trend in pelican density since 2012, but gray whales showed some of the highest densities in this time. It should be noted that our transect effort was less prior to 2010 when the Forest Service conducted most of the transects in stratum 1 of Zone 4 (and all transects in stratum 2). In a related observation, sport salmon fishing throughout Zone 4 was very poor, such that few boats even attempted to fish. In central Oregon (Zone 3), fishermen reported good salmon fishing

A small commercial shore smelt fishery has persisted on beaches in the middle of Zone 4 for over 25 years (H.T. Harvey and Assoc. 2015). While commercial landings data from California Dept. of Fish and Wildlife are not adjusted for effort, the fishermen check for presence of both surf (*Hypomesus peretiosus*) and night (*Spirinchus starksi*) smelt through the season, and fish when they are present (S. Compton pers. comm). Annual landings varied by roughly a factor of 4 for each species from 2000 to 2015, and then surf smelt virtually dropped out of the catch in 2016 (Fig. 4). This corresponds closely with an unprecedented failure of Common Murre nesting at Castle Rock NWR in 2016 (Schneider 2018). In 2017 surf smelt landings were even lower, and Common Murre nesting was a complete failure at Castle Rock (Schneider 2018). 2018 commercial landing data showed that surf smelt continued to be absent (Fig. 4), but we have no murre productivity data for Zone 4 in that year. Our at-sea fledgling data for 2019 showed an even worse or more widespread Common Murre failure than 2016 or 2017 (Table 4), though fishery landings data are not yet available. Most interestingly, the night smelt fishery appears to have remained robust through these recent years (Fig. 4). Smelt were again the dominant prey species for murres at Yaquina Head in 2019, as has been the case for most years excepting 2018 (Porquez et al. 2019). We do not know the species of osmerid smelt at Yaquina Head, however.

As in 2017, there were reports of abundant Humpback whales (*Megaptera novaeangliea*), Brown Pelicans, and Common Murres foraging near-shore in the Gulf of the Farallons during summer 2019 (Johns andWarzybok 2019, B. O'Connor, P. Pyle, pers. comm). The common prey for these species was northern anchovy (*Engraulis mordax*).

Oceanographic conditions in 2019 and recent years

The strong warm water anomaly known as the Marine Heat Wave (DiLorenzo and Mantua 2016) waned in the first half of 2017 and disappeared abruptly with the onset of a very late spring transition and strong upwelling in June 2017 (Thompson et al. 2018). Since then there have been positive and negative anomalies in smaller regions of the California Current System and over shorter time spans, but presently with a massive warm anomaly in the North Pacific Gyre (Fig. 5). The 2018-2019 winter was technically labeled as El Nino conditions, but it was not strong and appeared to be mostly an equatorial effect (https://coastwatch.pfeg.noaa.gov/elnino/coastal_conditions.html). Review of SST images in https://www.nnvl.noaa.gov/view/globaldata.html show the northern California Current System to have a warm 2018-2019 winter until March, then near normal temperatures until the end of April, when a strong bout of upwelling indicated a physical spring transition. But then warm water anomalies resumed until June, when several bouts of northwesterly winds set off several upwelling pulses. Coastal waters in Zone 4 have since had strong warm anomalies into fall 2019, possibly associated with the monstrous warm anomaly shown in Fig. 5. Spring and summer 2019 had near average upwelling indices in the Zone 4 region overall, with associated concentrations of Chlorophyl a. Negative Pacific Decadal Oscillation indices were seen through spring, but became became strongly positive in July, and then returned to near neutral values (see https://coastwatch.pfeg.noaa.gov/elnino/coastal_conditions.html).

Other products

A companion product to this report is an electronic database summary for all species encountered on transects during 2019 with metadata documentation.

DISCUSSION

Population estimates

The Zone 4 Marbled Murrelet population estimate in 2019 was essentially equal to the average since 2010 (6,857 birds, data in Table 2) and higher than prior years. Where there was evidence for an immigration event in 2017 and possibly 2015 in Zone 4 (see Strong 2018), I have no information for or against an immigration event that could have affected our 2019 estimate. The lack of concurrent monitoring surveys in conservation Zone 3 to the north limits our understanding of marine conditions and the potential to quantify shifts in population distribution. It could be that the 2015 and 2017 estimates were elevated due to immigration from the north, and that the 2019 estimate is a better representation of the nesting population residing in Zone 4. Alternatively, we may have seen somewhat reduced numbers in 2019 if murrelets emigrated from Zone 4 to the south (but I consider this unlikely, and supporting observations in Zone 5 are lacking). In 2017, the best documented year for in-season murrelet migration, birds were presumed to have moved primarily from Zone 3 and redistributed to the southern portion of Zone 4 and Zone 5 and (Horton et al. 2018, Strong 2018). No such irregularities were seen in the 2019 distribution of murrelets (Fig 1).

Seabird and Marine Productivity

The hypothesized cause of Marbled Murrelet immigration in 2017 (which likely affected the high Zone 4 and 5 estimates of that year) was limited prey availability. The 2017 and 2019 murre failures were almost certainly due to lack of prey availability. During 2016 the few fish that were returned to Castle Rock early in the chick period had more anchovy and far fewer smelt than in earlier years (Schneider 2018), which co-occurred with a collapse in the small surf smelt fishery (Strong 2018). In 2019 there were no murre chicks on Castle Rock, and consequently no fish returned. Where Common Murres had large scale failure in both 2017 and 2019, murres fared worse in 2019, and cormorant nesting failure was much more widespread in the 2019 season, at least in Conservation Zone 4. The chronology of misfortune for murres was also different between the years; in 2017 a large portion of murres laid eggs on Castle Rock NWR, and many brought them to chick stage before a relatively sudden collapse in early July caused widescale abandonment of eggs and chicks (Schneider 2018). In 2019, few murres even got to the egg laying stage on Castle Rock (however, at Trinidad rocks, D. Barton reported murre eggs being abandoned in early June during a localized heat wave).

The characterization of the California Current in the Zone 4 region in spring and summer 2019, as seen by a review of the narrative at https://coastwatch.pfeg.noaa.gov/elnino/coastal_conditions.html, do not show obvious indications of adverse productivity for seabirds in the Zone 4 region, in contrast to our observations. However, the 2018-2019 winter conditions of positive Pacific Decadal Oscillation values and warm winter SST, and the warm SST episode in May, could have disrupted primary productivity or impacted survival of forage fish into the summer. Ecosystem disruption from the marine heat wave of 2014-2017 were profound and impacted the trophic food web throughout the Gulf of Alaska and the California Current System, and Common Murres were among the species most impacted (Piatt et al. 2020). This could have carry over 'lag' effects on forage fish prey for seabirds. 2018 however, showed indications of conditions returning to something like normal in the northern CCS (Porquez et al. 2018, Thompson et al. 2018, CalCOFI reports), and this was reflected in our 2018 surveys in Zone 3 (Strong 2019). I know of no data on murre productivity south of Cape Blanco in 2018, but if the birds were relying primarily on surf smelt, one would estimate that it was another poor season. It may be there are insufficient spawning adults remaining to recover the local surf smelt population. From the data north and south of Zone 4, it is clear that our findings are region specific. Different regional features are becoming more recognized in the California Current, such that 'good years' and 'bad years' do not apply to the entire CCS (Wells et al. 2017, Thompson et al. 2018). The looming heat anomaly currently filling most of the North Pacific (Fig 5) is unlikely to have already affected the very near-shore ecosystem, though it can be expected to have future impacts. Overall, we are seeing the predicted effects of global warming in the CCS via higher variability, overall less productivity, and certainly less predictability than has been seen in the past.

Marbled Murrelet had a low but not atypical numbers of fledglings detected in both 2017 and 2019, in sharp contrast to Common Murre failure in both years. This points to different foraging strategies between murres and murrelets. A collapse of surf smelt populations was indicated in 2017 (Schneider 2018, Strong 2018), and is indicated to have continued; we do not yet know the status of smelt prey in 2019. Based on the small scale distribution distributions of murres and murrelets at sea over many years, I hypothesize that murrelets forage more readily on individual or very small schools of fish, where murres tend to rely on larger schools. In poor years there may be no large schools, but there are still sufficient individual fishes for murrelets to find prey and reproduce. Also to note is that murrelets are approximately one fifth the weight of murres, with commensurately lower caloric requirements.

A final consideration regarding Marbled Murrelet productivity indices is that, because fledgling detections at-sea are such a rare event (zero to 14 per year, Table 4), simple stochastic events of where and when sampling occurs can have a large effect on chances of detection and overall numbers of fledglings detected. In all areas of the NWFP area, zero to very few young are typically detected in a given year. this has led to demographic projections of declining population and high likelihood of extinction (McShane et al. 2004, Peery et al. 2004), and yet we do not see declining trends in Zones 3 or 4. The most likely explanation for this is that many fledglings are simply not detected in our surveys.

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Table 1. A summary of survey effort and number of Marbled Murrelet groups detected in the inshore and offshore subunits of each PSU sample of Conservation Zone 4 during 2019. In parentheses are the number of HY (fledglings) seen.

Month and day	PSU	Inshore Effort	No. of Murrelet detections	Offshore Effort	No. of Murrelet detections	Notes
May 17	(9)	-		-		Good cond., USCG bar closure
27	3	20.2	24	6.0	0	Wind since the 17th
"	4	19.6	11	6.9	1	
28	11	20.5	22(1)	6.2	15	Confirmed fledgling seen
31	14	20.0	75	6.0	0	
June 1	17	21.3	3	5.9	0	Fair cond
5	1	20.7	18(1)	6.1	2	
"	2	15.9	16	6.2	0	
7	5	20.2	12	5.0	0	
"	6	20.4	8	6.0	0	
11	18	20.7	9	6.1	0	
"	19	20.7	0	6.0	0	
12	7	20.3	13	5.0	0	
"	8	20.6	1	6.0	0	
13	12	18.0	27	6.1	1	
"	13	21.0	112	6.0	3	
14-24	-					Heavy NW wind whole coast
25	9	19.1	13	7.0	2	
"	10	20.8	1	6.1	4	
27	15	22.3	31	6.0	0	
"	16	18.9	11	5.9	1	
30	12	17.9	28	6.0	0	Start replicate 2
July 1	2	19.2	16	6.0	0	
"	3	20.1	3	6.0	0	
6	14	19.2	36	5.9	6	
9	20	15.4	1	3.9	0	Segment A and offshore cut short due wind at Pt. Gorda
10	21	19.2	3	6.1	0	
"	22	18.6	5	6.0	0	
15	5	21.0	13(1)	6.1	0	
"	6	20.2	6	6.0	0	
16	1	20.8	67(3)	6.1	2	
17	11	20.5	82	6.1	0	
22	9	21.0	8	6.1	0	
"	10	20.3	30	5.9	0	
23	16	18.9	10	6.2	0	
"	17	20.9	8	6.2	1	
31	13	19.7	49	6.2	3	
"	15	16.6	6	6.0	0	Segment D removed poor cond.
Totals	**36**	**710.8**	**777(6)**	**215.3**	**41(0)**	

Table 2. Estimates of Marbled Murrelet density and population size in Conservation Zone 4 from 2000 to 2019 from the NWFP Program.

			Std. error	Avg.		Confidence intervals	
Year	Stratum	Density	density	group size	No. birds	Lower	Upper
2000	1	6.024	2.051		4,420	2,931	8,784
	2	1.097	0.352		467	297	881
	All Zone	**4.216**	**1.302**	**1.730**	**4,887**	**3,417**	**9,398**
2001	1	4.567	1.241		3,351	2,436	5,880
	2	1.072	0.323		456	313	854
	All Zone	**3.284**	**0.787**	**1.749**	**3,807**	**2,983**	**6,425**
2002	1	5.186	0.824		3,805	2,501	4,892
	2	2.260	0.749		961	437	1,665
	All Zone	**4.112**	**0.620**	**1.724**	**4,766**	**3,272**	**6,106**
2003	1	4.960	0.976		3,640	2,622	5,392
	2	1.816	0.494		773	557	1,424
	All Zone	**3.806**	**0.658**	**1.704**	**4,412**	**3,488**	**6,495**
2004	1	5.331	1.714		3,911	2,729	7,732
	2	2.447	1.064		1,041	608	2,421
	All Zone	**4.272**	**1.150**	**1.700**	**4,952**	**3,791**	**9,021**
2005	1	4.487	1.146		3,292	2,329	5,562
	2	0.895	0.377		381	243	901
	All Zone	**3.169**	**0.748**	**1.518**	**3,673**	**2,740**	**6,095**
2006	1	4.821	0.746		3,538	2,698	4,894
	2	0.977	0.467		416	209	981
	All Zone	**3.410**	**0.509**	**1.622**	**3,953**	**3,164**	**5,525**
2007	1	4.730	1.776		3,470	2,329	7,025
	2	0.655	0.242		279	146	549
	All Zone	**3.234**	**1.126**	**1.607**	**3,749**	**2,659**	**7,400**
2008	1	6.386	1.243		4,685	3,167	6,687
	2	1.410	0.550		600	302	1,195
	All Zone	**4.560**	**0.818**	**1.705**	**5,285**	**3,809**	**7,503**
2009	1	5.304	1.110		3,892	3,031	6,170
	2	1.167	0.786		497	244	1,390
	All Zone	**3.786**	**0.754**	**1.661**	**4,388**	**3,599**	**6,952**
2010	1	3.774	1.295		2,769	1,463	5,087
	2	2.106	0.764		896	431	1,700
	All Zone	**3.162**	**0.902**	**1.624**	**3,665**	**2,248**	**6,309**
2011	1	6.724	2.840		4,933	1,643	8,767
	2	2.561	1.213		1,090	592	2,472
	All Zone	**5.196**	**1.811**	**1.644**	**6,023**	**2,782**	**10,263**
2012	1	6.050	1.672		4,439	2,916	7,497
	2	1.225	0.485		521	166	940
	All Zone	**4.279**	**1.065**	**1.652**	**4,960**	**3,414**	**8,011**
2013	1	7.384	1.609		5,418	3,939	8,516
	2	1.477	0.542		629	279	1,184
	All Zone	**5.216**	**1.068**	**1.607**	**6,046**	**4,531**	**9,282**
2015	1	9.897	1.717		7,262	5,906	10,692
	2	3.480	1.703		1,481	859	3,713
	All Zone	**7.542**	**1.268**	**1.701**	**8,743**	**7,409**	**13,125**
2017	1	9.185	1.442		6,740	4,677	8,890
	2	4.248	0.500		1,807	813	3,223
	All Zone	**7.373**	**1.100**	**1.660**	**8,547**	6,277	11,330
2019	1	8.091	1.845		5,936	4,588	9,921
	2	2.081	0.98		885	481	2,076
	All Zone	**5.885**	**1.288**	**1.696**	**6,821**	**5,576**	**11,062**

Table 3. Densities of Marbled Murrelets in the near shore and far shore subunits of Conservation Zones 4 since 2000. The near shore subunit extended from 400 to 2,000m, and the outer limit was 3,000 m. Density data from the NWFP (J. Baldwin).

Year	Near Shore density	Far shore density	Density Ratio Near: Far
2000	5.7089	1.7207	3.3179
2001	4.5929	0.7362	6.2386
2002	5.8992	1.0739	5.4932
2003	5.6401	0.9290	6.0711
2004	6.3665	0.7506	8.4814
2005	5.0547	0.3224	15.6799
2006	4.7859	1.1371	4.2089
2007	4.2183	1.6205	2.6031
2008	5.6806	2.6771	2.1219
2009	5.4387	1.4310	3.8005
2010	4.0552	1.6964	2.3904
2011	7.0049	2.7837	2.5164
2012	5.2678	2.3816	2.2119
2013	6.4977	3.0997	2.0962
2014	no data		
2015	9.4181	4.5010	2.0925
2016	no data		
2017	11.3868	1.8480	6.1617
2018	no data		
2019	8.6214	1.4040	6.1406
Average	6.2140	1.7714	4.8015

Table 4. Age ratios (HY:AHY) and HY encounter rates (HY/Km effort) of Common Murres and Marbled Murrelets in the Conservation Zone 4 since 2000. Data are from NWFP sampling surveys between 10 and 31 July. Only portions of Stratum 1 were sampled prior to 2010.

		Common Murre		Marbled Murrelet			
Year	Effort (km)	Ratio	HY density	No. AHY	No. HY	Ratio	HY density
2000	131.2	0.2589	1.6006	83	7	0.0843	0.0534
2001	77.9	0.1757	2.2978	70	3	0.0429	0.0385
2002	52	0.2563	0.9808	71	2	0.0282	0.0385
2003	37.8	0.2561	0.5556	68	5	0.0735	0.1323
2004	58.7	0.1822	1.3969	38	0	0.0000	0.0000
2006	51.4	0.0909	0.2918	23	0	0.0000	0.0000
2007	54.1	0.1532	0.6285	64	1	0.0156	0.0185
2008	80.1	0.3030	4.0325	42	5	0.1190	0.0624
2009	209	0.1147	0.8230	232	12	0.0517	0.0574
2010	308.9	0.0428	0.1489	338	7	0.0207	0.0227
2011	388.9	0.0523	0.4243	630	8	0.0127	0.0206
2012	284.1	0.0588	0.7357	519	10	0.0193	0.0352
2013	336.1	0.2072	3.0794	303	14	0.0462	0.0417
2015	312.6	0.1210	1.4044	614	8	0.0130	0.0256
2017	231.6	0.0116	0.0432	556	6	0.0108	0.0259
2019	310.7	0.0013	0.0064	461	4	0.0087	0.0129
Total, Mean	2925	0.1429	1.153	4112	92	0.0342	0.0366

Table 5. Pelagic Cormorant nest counts and nesting success data at 3 colonies in Del Norte Co. 'WBN' = well-built productive nest, 'W/C' = nest with chicks, and 'Tot C' = total number of fledge-age chicks. 'C/WBN' is a measure of reproductive success.

	Tolowa Rock				Hunter Island				Castle Rock NWR	
Year	WBN	WBN W/C	Tot C	(C/WBN)	WBN	WBN W/C	Tot C	(C/WBN)	Count Date	WBN
1989										178
1996	19	16	29	1.53						
1997	24	18	38	1.58					16-Jun	186
1998	2	0	0	0					7-Jul	25
1999	14	13	20	1.43					28-May	143
2006	11	7	8	0.73						
2007	24	22	nd	nd						
2008	20	20	52*	2.6						
2009	19	15	35	1.84						
2010	9	7	17	1.89						
2011	0	Col. abandoned mid-June		0					12-Jul	88
2012	4	3	3	0.75					20 Aug*	26
2013	20	19	53	2.65					16-Jun	235
2014	25	24	71	2.84	31	29	66	2.13		
2015	17	11	27*	1.59	26	23	51	1.96		
2016	12	8	19	1.58	24	12	12	0.5		
2017	3	3	1	0.33	38	31	60	1.58	7-Jul	182
2018	17	15	32	1.88	52	45	107	2.06		
2019	2	2	1	0.5	2	0	0	0	25-Jun	33

* Too late for accurate nest count

Table 6. Brown Pelican and Gray Whale counts and detection rate in stratum 1 of Zone 4 based on population monitoring transects since 2000. Survey coverage was more limited prior to 2010.

	Effort	Brown Pelicans			Gray Whales	
Year	(km)	No. Obs	No. Birds	Birds / Km	No. whales	Whales / Km
2000	157.9	16	272	1.723	0	0.0000
2001	205.2	3	50	0.244	2	0.0097
2002	214.7	3	9	0.042	0	0.0000
2003	184	11	97	0.527	2	0.0109
2004	150.5	8	125	0.831	10	0.0664
2005	122.4	6	77	0.629	0	0.0000
2006	289.3	11	63	0.218	0	0.0000
2007	276.8	9	52	0.188	0	0.0000
2008	291.5	10	130	0.446	1	0.0034
2009	383.6	24	316	0.824	5	0.0130
2010	588.9	19	186	0.316	7	0.0119
2011	642.8	23	117	0.182	3	0.0047
2012	567.4	29	469	0.827	9	0.0159
2013	516.2	22	365	0.707	14	0.0271
2015	646.3	23	217	0.336	15	0.0232
2017	591.2	16	148	0.250	24	0.0406
2019	649.3	16	97	0.149	2	0.0031
Total / Mean	6478	249	2790	0.431	94	0.0145

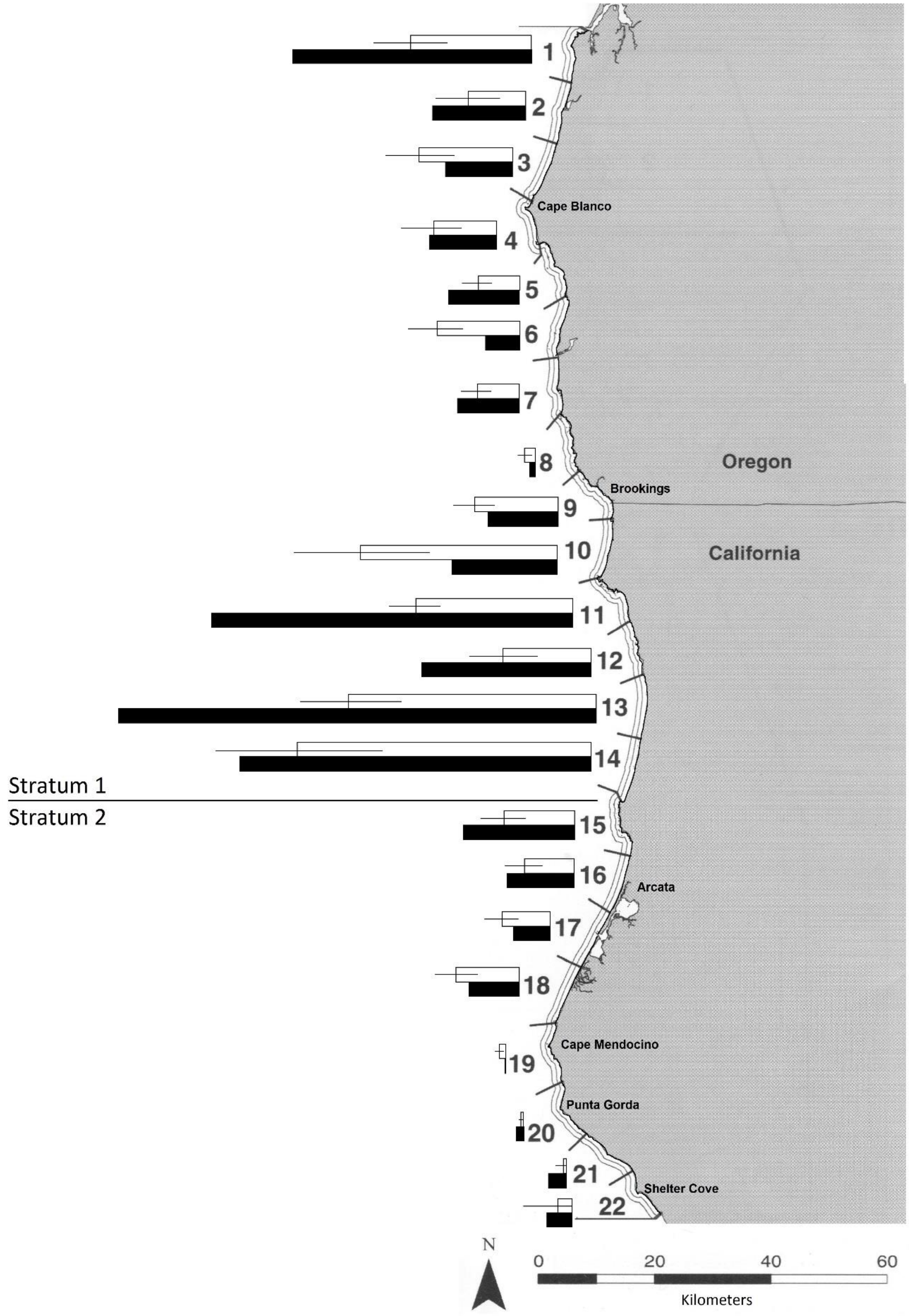

Figure 1. Conservation Zone 4 showing PSU locations (numbers along the coast), relative density of murrelets during the 2019 effort (filled bars) and the mean of 2000-2017 surveys (open bars). 'Whisker' lines are 1 Std. deviation of the 2000-2017 mean for each PSU

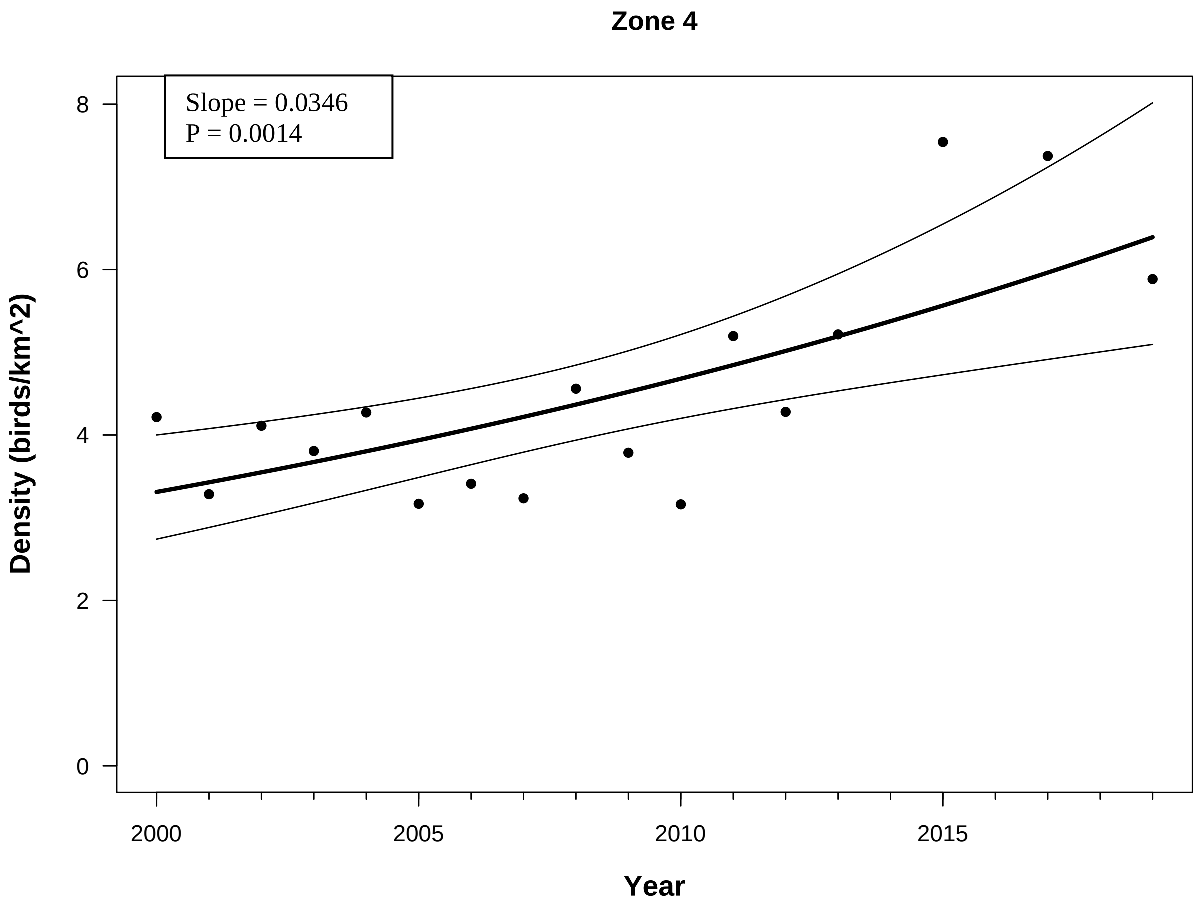

Figure 4. Linear regression of Marbled Murrelet population trend in Zone 4, 2000 to 2019. Data and statistics from Jim Baldwin, USFS PSW station for the NWFP at-sea working group.

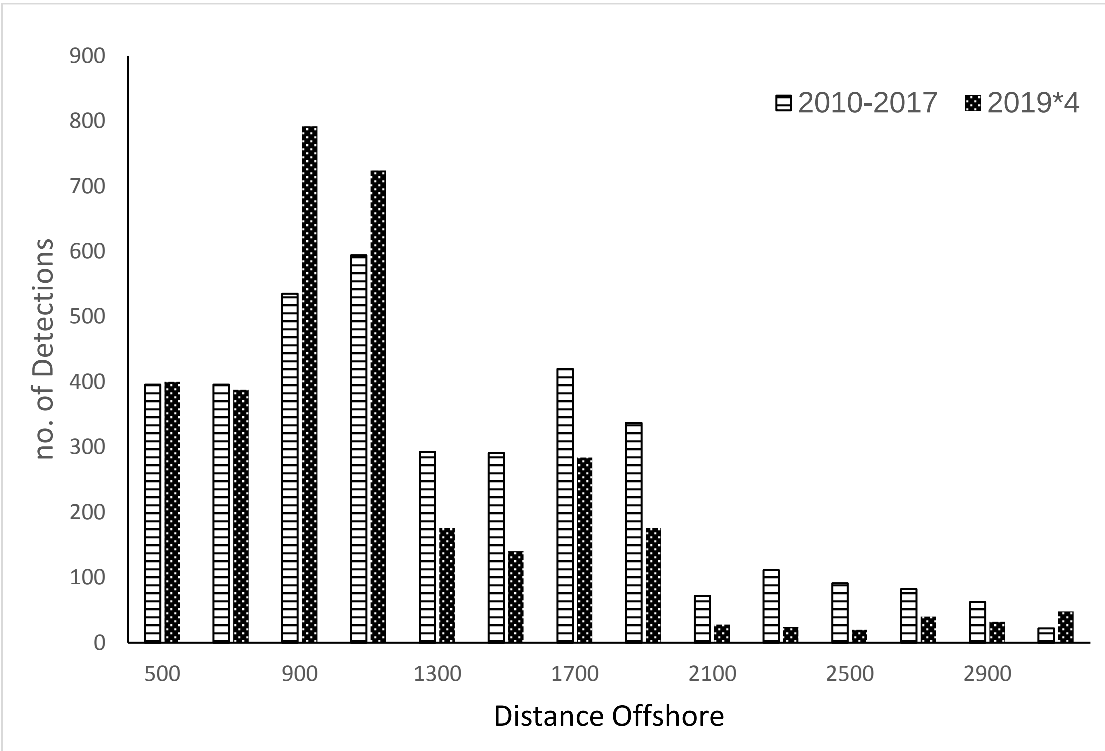

Figure 3. Number of Marbled Murrelet detections by 200 m increments of distance from shore in Conservations Zone 4 from 2010 to 2017 (Horizontal pattern) compared with 2019 (dark crosshatches).

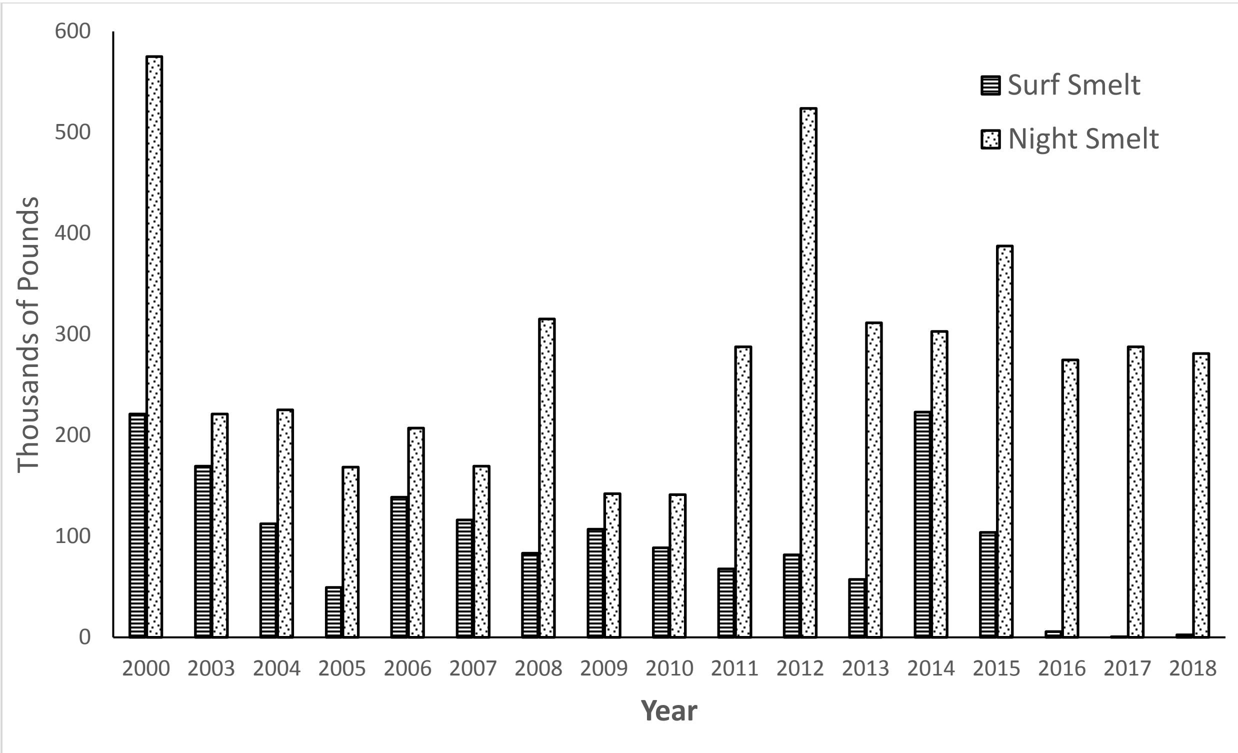

Figure 4. Commercial smelt fishery landings in the North Coast District (Eureka) reported to California Dept. of Fish and Wildlife. Source: https://wildlife.ca.gov/Fishing/Commercial/Landings#260041375-<year>

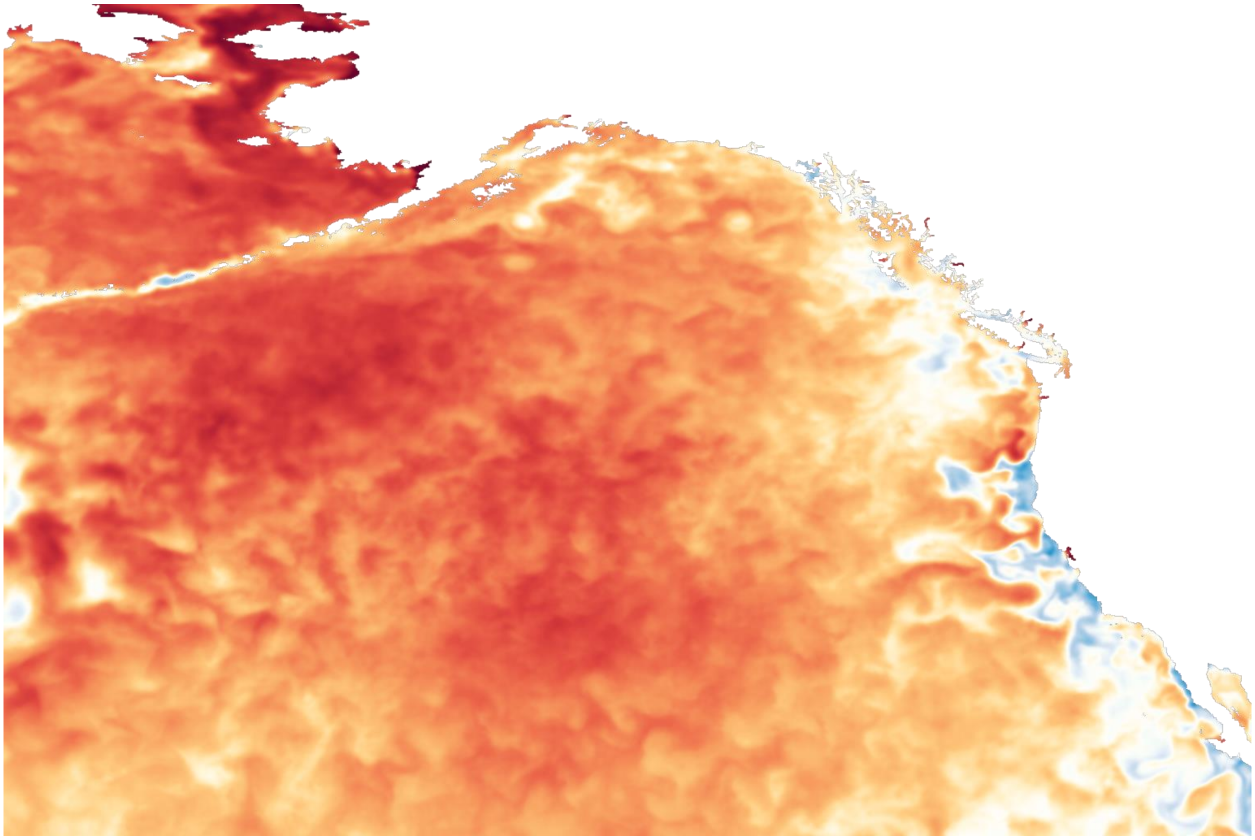

Figure 5. Sea surface temperature anomalies in mid-October, 2019 showing 'The Return of the Blob' (positive anomalies in red). Also visible are cold-water upwelling and plume anomalies in the California Current (negative anomalies in blue, neutral in white).
Data source: https://www.nnvl.noaa.gov/view/globaldata.html

Appendix A. A generalized description of cormorant productivity monitoring methods as used by Crescent Coastal Research.

Study Sites
Study colony locations were selected for their proximity to accessible viewpoints from shore.

The Tolowa Rock colony is located at the south end of Pebble Beach in Crescent City at 41.75671° N, 124.22144° W. the SE face of Tolowa Rock is approximately 280 m from the view point, which is easily accessed from Pebble Beach Drive.

The Hunter Island colony is located 500 m north of the Smith River mouth at 41.95423° N, 124.20839° W. The telescope viewpoint is 390m from the colony and is accessed from North Indian Road via a trail owned by the Smith River Rancheria. Immediately north of Hunter Island is the recently established Pyramid Point Marine Protected Area, where marine biota are protected from harvest except for that gathered by Smith River Rancheria (Tolowa) tribal members.

Only the eastern face of both the Tolowa Rock and Hunter Island sites are visible from shore, and additional Pelagic Cormorant nesting occurs on other sides of the islets. Larger Pelagic Cormorant colonies also occur on Castle Rock National Wildlife Refuge 1.7 km from Tolowa Rock, and on Prince Island, 800 m south of Hunter Island.

Survey Methods
Surveys were carried out with a 20-60 Zoom spotting scope in the morning hours at approximately weekly intervals. I usually surveyed close to 10 AM but the time varied between 0700 and 1200 hrs depending on logistics. Counts of all adults present, the number of paired birds at nesting sites, and total number of active nest sites were tallied at the start of every survey. Nest sites were considered 'active' when fresh nesting material and one adult or a pair of courting adults were present. Active sites were numbered on an 8x11" photo print of the colony so that the fate of individual sites could be tracked through the season. Sites were considered 'established' when a well built nest was complete and the site was continually attended by adults. Due to distance from the colonies and angle of view, no attempt was made to count eggs or young chicks. Other than brief views of nest contents on warm days or during parent nest duty exchanges, the incubation and early brood stages were inferred by parent behavior, where parents sit tight with very little movement when incubating eggs, and 'sit up' in a partial crouch with wings slightly open when incubating small chicks. Counts of the number of chicks in each nest were made when chicks were 3-4 weeks old; large enough to be easily seen but prior to wandering from the nest site. Summary descriptive statistics were used for comparison across years, and included 1) total number of established nests, 2) number of nests laying eggs, 3) number of nests with chicks, and 4) mean brood size of nests that hatched chicks.

Colony visits were initiated at the beginning of April. Colony visits ended when chick counts of all productive nests were completed, generally sometime in August.