

**2018 FOREST SURVEY RESULTS -
MARBLED MURRELETS IN THE SANTA CRUZ MOUNTAINS**

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Prepared for the California State Parks Department

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with a statistical evaluation of the data
provided by Emily Comfort*

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SUMMARY OF KEY FINDINGS

There has been a statistically significant increase in Murrelet detections at Big Basin State Park from 2007 to 2018. 2007 was the year in which efforts to control corvid numbers began in the park.

Simultaneous A-V surveys were conducted at the Butano, Gazos (Gazos Camp), and Big Basin survey stations on 5 days in July 2018 using the PSG Forest Survey protocol. Data from these stations were compared with existing prior year data. A statistical analysis of the data was performed to assess: (1) trends in detection numbers over time for all three stations combined, (2) differences in detection numbers for all types of detections, and (3) differences over time at each individual station over both short term and long term study periods for all types of detections.

As in previous years, all three stations had numerous observations of those types of detections that are associated with active nesting nearby. However, occupied behavior detections and below-one-canopy detections at Gazos were down to about half of what was detected in 2017, and were slightly lower at Butano. In contrast, both types of detections experienced a moderate increase in Big Basin in 2018.

The number of total detections for all three stations combined in 2018 was about 20% less than in 2017, and also lower than 2016 or 2015. This parameter should be watched closely in the future as a possible indicator of overall population decline (see Table 3). Numbers of most detection types were lower at Gazos and Butano in 2018 than 2017, while numbers at Big Basin were higher. The number of mean daily total detections at Big Basin (50.4) was the highest value recorded there in the last 15 years. Although most types of detections at Butano were down in 2018, that station did record the highest ever mean value for murrelet wing sounds (12.8) and an all-time high single day value of 27 wing sounds on July 19.

Over the 2014 – 2018 period, the results from all three stations combined did not show any significant trend. However, over this same short-term period, total detections numbers at Butano and at Gazos have declined. In contrast, total detection numbers at Big Basin have increased.

Over the longer term at Big Basin, from 2007 (when raven control efforts began) to 2018 there has been a statistically significant increase in murrelet detection numbers. No such increase was detected at either Gazos (1998-2018) or Butano (2003-2018).

INTRODUCTION

This report discusses the results of 2018 Marbled Murrelet audio-visual (A-V) surveys at three breeding areas in the Santa Cruz Mountains (see map in Appendix 2). The three stations are (1) Big Basin, which is located at the Redwood Meadow in Big Basin State Park; (2) Gazos, also known as Gazos Mountain Camp, which is located inside Butano State Park, and (3) Butano, which is also known as Butano Service Road or Little Butano, and is located on a service road in Butano State Park. All three stations are located in different watersheds. In 2018, results were not available from two stations that were surveyed in previous years – Pescadero Creek County Park and Portola State Park.

This effort is the continuation, on a reduced scale, of a long term inland murrelet monitoring program that was administered by the California State Parks Department that began in 2003 and ended in 2011. That effort included 11 stations and 3 – 5 surveys at each station. Results of that effort can be found in Shaw (2011) and Singer (2017). Other long-term murrelet A-V surveys in Zone 6 are the Gazos Mountain Camp study which began in 1998, and, consisted of 7 surveys per year at one station (Singer, 2017; Singer 2013), and is now merged into this study; surveys at Upper Pilarcitos Creek on land belonging to the San Francisco Public Utilities Commission; surveys in Pescadero Creek County Park by the San Mateo County Parks Department; and surveys by the Midpeninsula Regional Open Space District on several of their preserves. A complete review of the history and extent of inland marbled murrelet monitoring efforts in the Santa Cruz Mountains through 2017 can be found in the Marbled Murrelet Management Plan for Zone 6 (Halbert and Singer 2017).

There are several different types of murrelet detections that are reported in these A-V surveys. The meaning of these is discussed below.

Total Detections – These are any detection of a murrelet by either sight or sound and can include audio detections of murrelet vocalizations that are more than 400 meters away from the observer. These detection numbers have limited value for determining trend in activity levels at any one station due to high day-to-day variability of detections and the small number of surveys per station. However they do give an indication of the difference in murrelet activity levels between stations.

Occupied Behaviors and Below-canopy Detections – “Occupied behaviors” are observations of murrelets seen circling overhead at a height between one canopy and two canopy or flying below one-canopy height. This definition is slightly different than that used in the protocol, in Shaw (2011), and in Singer (2013), but the resulting values are very similar and the raw data from Shaw were not available.

“Below-canopy” detections are observations of murrelets flying below the tree top level. Since the vast majority of occupied behaviors are made by below-canopy birds, these two types of detections can be considered together, being very similar. Studies have shown that below-canopy detections are made by birds that either currently have or had earlier in the season a nest in the near vicinity (Plissner et al. 2015).

Single Silent Birds Below Canopy (SSBBC) Detections – These are observations of non-vocalizing solitary murrelets flying below one canopy. They are an even stronger indicator of nesting activity. “Early Single Silent Birds Below Canopy” are those observed 8 minutes or more prior to sunrise. These are strong evidence of an active nest. Although the cutoff time of 8 minutes is somewhat arbitrary, it does

represent the approximate cut-off time for the earliest nest visits as made during studies of active nests in California and Oregon (Nelson and Peck 1995, Singer et al. 1995). These individuals are most likely visiting the nest to make an incubation exchange or to provide the first feeding of the day to a nestling.

Wing Sound Detections – These are non-vocal sounds made by murrelets and believed to be agnostic in nature. They are usually made by birds flying below canopy and often are made by birds flying behind the observer so are not actually seen. We include wing sound detections of birds not seen as below-canopy detections. They are believed to be strong indicators of nesting nearby.

METHODS

Audio-visual (A-V) Survey Methodology

Survey procedures followed the 1994 Pacific Seabird Group (PSG) protocol for forest surveys (Evans et al. 2003), starting 45 minutes before sunrise and lasting for a minimum of two hours, or 15 minutes from the last detection. Audible wing sounds from murrelets not seen were considered to be below-canopy flights by single birds.

As in 2017, A-V surveys at all sites in 2018 were done simultaneously. Surveys were done at Big Basin, Butano, and Gazos on these dates: July 3, July 10, July 16, July 19, and July 26. A map showing survey station locations appears in Appendix 2. Surveys were primarily done by Bryan Mori, Mike Duffy, Alex Rinkert, and Portia Halbert.

In 2011 and prior years A-V surveys were not conducted simultaneously and the number of surveys per season (normally 3) was different at some stations. Memorial County Park and Portola State Park were part of the original survey effort but have since been dropped. Surveys at Portola ended in 2016 and at Memorial they ended in 2014. No surveys were done at Gazos in 2005, and no surveys were done at any of the other sites in 2012 and 2013.

Observations were recorded live into tape or digital recorders and later transcribed onto standard forest survey forms.

The maximum number of Common Ravens detected simultaneously (seen or heard) and the maximum number of Steller's Jays detected simultaneously (seen or heard) were also recorded. It should be noted that corvid detections can't be collected in the same manner as murrelet detections. This is because a single raven or jay, unlike a murrelet, can perch on a branch nearby and make intermittent calls all morning long. Corvid sampling was more comprehensive in 2011 and prior years, and a summary of those efforts can be found in Halbert and Singer (2017). In 2018, as in 2016 and 2017, the maximum number of murrelets seen in the sky at the same time was also recorded.

A statistical analysis of the data was prepared for this report by Emily Comfort. The details of that review and the methodology used can be found in Comfort (2018). Highlights from her findings are included in this report.

RESULTS AND DISCUSSION

All Three Survey Stations Combined

The number of total detections for all three stations combined (Big Basin, Gazos, and Butano) is shown in Table 1 and Graph 1 (Note: all tables and graphs can be found in Appendix A). The 2018 value was about 20% less than in 2017, and also lower than in 2016 or 2015. This parameter should be watched closely in the future as a possible indicator of overall population decline.

From 2017 to 2018, occupied behavior, below-one-canopy detections, and visual detections were roughly similar for all 3 sites combined (Table 4).

Over the 2015 – 2018 time period, the results from all three stations combined did not show any statistically significant trend for total detections (Graph 4) or for occupied behaviors. Note the high daily variation evident in the data points shown in Graph 4. It is this high daily variation that makes it challenging to find results that are statistically significant.

No significant trends in total detections were found at Gazos or Butano over this same period. However, numbers have declined at Butano and Gazos between 2014 and 2018 (Graph 5).

Occupied Behavior and Other Behaviors Indicative of Active Nesting Nearby

From 2017 to 2018 mean occupied behaviors increased at Big Basin (25 to 32.2), decreased dramatically at Gazos (10.8 to 5.8), and decreased slightly at Butano (19.6 to 17.6) (Table 2, Graph 3). During this same period, mean SSBBC detections, which are a better indicator of active nesting, remained nearly the same at Big Basin (14 to 13) and Gazos (3.2 to 2.2), but showed a large decrease at Butano (7 to 2) (Table 5, Graph 7).

Below-one-canopy, SSBBC, and Early SSBBC detections also showed a significant increase over time at Big Basin. In a statistical analysis of the data using an ordinary least squares linear regression model to test for an increase or decrease in average detections over time, Comfort (2018) found occupied behaviors had a statistically significant increase over the 2014 to 2018 period in Big Basin (Graph 8).

Supporting evidence for an increase in murrelet nesting activity at Big Basin include: (1) the ratio of occupied behaviors to total detections has increased in recent years (Table 6); (2) the number of SSBBC detections increased dramatically from 2016 to 2017 and have stayed at the higher level (Graph 7); and (3) two branch landings were observed there in 2018. These findings add support to the hypothesis that increased murrelet detections at Big Basin are not merely the result of prospecting or socializing birds, but that active nesting is occurring.

Occupied behaviors have declined at Butano and Gazos over the 2014 – 2018 period (Table 2, Graph 6). Below-one-canopy detections, which are very similar to occupied behavior detections have also declined at both stations over this period, especially at Gazos. This is also true for SSBBC detections (Graph 7) and Early SSBBC detections (details in Comfort 2018).

These occupied behavior flight behaviors are just some of the indications that there is an active or inactive nest nearby. In order of decreasing strength of prediction, the full complement of indicators are (1) grounded fledgling or chick found, (2) eggshell fragments found, (3) branch landing heard or seen on a potentially suitable nest tree, (4) Jet plane sound heard, (5) SSBBC detections early during the survey period, (6) wing sounds, (7) Other SSBBC detections, and (8) below-one-canopy occupied behaviors (Evans et al 2003, Nelson and Peck 1995, and Singer et al 1995). It should be noted that only the first two items are proof certain. A branch landing might be a nest or it might just be a bird practicing tree landings. Information not widely publicized but made available in Plissner (2015) disclosed the fact that below-one-canopy flights may be made by a nesting pair at a site throughout the breeding season even when the nest is no longer active.

Wing sounds are strongly indicative of nesting activity. Numbers in 2018 at both Big Basin and Gazos were similar to the 2017 values (Table 5). In contrast, Butano had more than double the number of wing sounds recorded in 2017, with a 2018 mean value of 12.8. Butano also had the highest number of wing sounds recorded on any one day – 27 on July 19 (Table 5). This is the highest value every recorded at any station for the duration of record, which goes back to 2014.

Other evidence that nesting occurred in the Santa Cruz Mountains in 2018 was also found. A grounded fledgling murrelet was found at Big Basin on August 5 and two attempted branch landings were observed in Big Basin on July 16.

Total Detections at Individual Survey Stations

Big Basin

Total detection numbers and occupied behavior detection numbers have increased at Big Basin in 2018 over 2017 (Table 1, Graph 2, and Graph 3).

In a statistical analysis of the data using an ordinary least squares linear regression model to test for an increase or decrease in average detections over time, Comfort (2018) found that both total detections and occupied behavior detections have shown a statistically significant increase over the 2014 to 2018 period (Graph 8). Below-one-canopy, SSBBC, and Early SSBBC detections also showed a significant increase over time at Big Basin (see Comfort (2018) for details).

Over a longer period of record (2007 – 2018), Comfort (2018) found there to be a statistically significant upward trend for total detections at Big Basin (Graph 9). It was in 2007 that efforts to control corvid numbers in Big Basin were instituted. This is likely a cause and effect relationship, although no surveys of corvid numbers in Big Basin were conducted in 2018.

Butano

Between 2017 and 2018, total detections were slightly up (Table 1, Graph 2).

Over the short term (2014 to 2018), total detections were down, but a statistics review using a linear regression model with fixed and interaction effects to test the hypothesis that stations were different and have become more similar over time, found no significant trend (Graph 5).

Audio-visual surveys began at Butano in 2003, and over the 2003 to 2018 period a statistical evaluation of the data using an ordinary least squares linear regression model to test for increases or decreases in mean total detections, found no significant trend (see Comfort 2018 for details).

Gazos

From 2017 to 2018, total detections dropped dramatically from a mean of 55.2 to a mean of 22.8 (Table 1, Graph 2).

Over the short term (2014 to 2018) total detections numbers also decreased, but a statistical review using a linear regression model with fixed and interaction effects found no significant trend (see Comfort 2018, Graph 5).

A-V surveys began at Gazos in 1998. A statistical evaluation of the data to date using a linear regression model with fixed and interaction effects found no significant trend (see Comfort 2018 for details).

Heard-only Detections

When looking at the combined detection numbers from all 3 stations over the 2014 – 2018 period, there was no statistically significant trend for any type of detection including heard-only detections.

When looking at individual stations over this time period, there was a significant increase in almost all detection types at Big Basin. The one type of detection that did not mirror the others was heard-only detections. A review of the raw data for Big Basin (Singer, 2018) revealed that the percent of total detections that are heard-only detections over the last three years has decreased from 75% to 34%. Thus changes in heard-only detections moved in the opposite direction as total detections at Big Basin.

Looking at data from the 2014 to 2018 period, a linear regression model with fixed and interaction effects was used to test for a trend in heard-only detections at Big Basin. No significant trend was found (see Comfort 2018 for details).

Common Raven and Steller's Jay Numbers in 2018

Although individual raven or jay detections were not recorded, the maximum number of ravens and jays detected at any one moment (seen and/or heard) was recorded. The greatest simultaneous number of ravens was 3 at Big Basin on July 3. At least one raven was recorded on every survey day at
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Big Basin. In contrast, at Gazos, no ravens were detected on any survey day, which was also the case in 2017. Butano had ravens present on three of the five days.

Jays were detected at every station and on every survey day. The maximum number of jays detected at any one moment was five at Big Basin on July 16.

RECOMMENDATIONS

1. If permission can be obtained, do a season long Acoustic Recording Unit (ARU) survey at the Hidden Gulch Stand in the Pescadero Unit of the Big Creek Lumber property.
2. Continue to do season long ARU surveys at Big Basin and Gazos. Work with Conservation Metrics to devise a monitoring scheme that utilizes both ARU and A-V surveys to produce results with greater statistical power.
3. Continue to do A-V surveys at the three existing survey sites and expand the network to do surveys at Portola State Park as well.
4. Work with all agencies doing A-V surveys in the Santa Cruz Mountains to standardize methodologies and survey dates, and strongly encourage them to archive their full data spreadsheets with the State Parks Department in the developing Zone 6 data archive site.

ACKNOWLEDGEMENTS

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APPENDIX I – Tables and Graphs

Table 1. Mean Number of Total Detections 2003 - 2018

Mean Number of Murrelet Total Detections 2003 – 2018 (Empty boxes are years where no surveys were done or results were not available)						
Year	Big Basin	Portola	Gazos Mtn. Camp	Butano	Memorial	3 Sites Combined (Big Basin, Gazos, and Butano)
2003	16.3	33.2	59.7	34	4.3	110
2004	17	35.6	44.7	68.3	1	130
2005	14	18		26.7	1.3	
2006	18.3	18.6	79.7	48	4.7	146
2007	16.3	30.6	31.2	46.3	0.7	93.8
2008	12	19	71.8	20.7	0.7	104.5
2009	1.7	5.4	6.8	17.7	0.7	26.2
2010	15.3	33	66	62	11	143.3
2011	22	55	44.3	32	4.7	98.3
2012			53.1			
2013			28.1			
2014	8.3	27.7	37	78	10.3	123.3
2015	18	27.8	62.2	62.6		142.8
2016	36.4	74.2	61.2	48.2		145.8
2017	38		55.2	54.8		148
2018	50.4		22.8	46.6		119.8

Table 2. Mean Number of Occupied Behavior Detections 2003 -2018

Mean Number of Murrelet Occupied Behavior Detections 2003 – 2018 (Empty boxes are years where no surveys were done or results were not available)						
Year	Big Basin	Portola	Gazos Mtn. Camp	Butano	Memorial	3 Sites Combined (Big Basin, Gazos, and Butano)
2003	1.3	6	9.7	6	0	17
2004	2.3	4.4	9.5	22	0	33.8
2005	1.3	0.2		4	0	
2006	9	2.4	19.8	4.3	0.3	33.1
2007	2.7	0.8	9.2	5.7	0	17.6
2008	0	0.6	27.2	3	0	30.2
2009	0	0	0.8	2	0	2.8
2010	3	5.8	25.7	19.7	1	48.4
2011	3	16.7	7.4	6.7	0.3	17.1
2012			15.1			
2013			2.1			
2014	1.33	2.33	8	28.7	7.7	38
2015	2.4	5.6	20.4	21.6		44.4
2016	6.4	13.4	29.8	10.8		47
2017	25		10.8	19.6		55.4
2018	32.2		5.8	17.6		55.6

Table 3 below provides the number of total detections and below-one-canopy detections (which are shown in parentheses) on every 2018 survey at all three sites and provides the Standard Deviation (STDEV) and Coefficient of Variation (CV) for each site. 2017 values are included on bottom line for comparison.

Table 3. 2018 Total Detections and Below-one-canopy Detections

Date	Big Basin	Butano	Gazos Camp	3 Sites Combined*
July 3	60 (20)	23 (6)	40 (4)	123 (30)
July 10	43 (36)	28 (14)	13 (5)	84 (55)
July 16	55 (43)	75 (32)	28 (3)	158 (78)
July 19	62 (35)	73 (34)	16 (3)	151 (72)
July 26	32 (17)	34 (2)	30 (3)	83 (19)
2018 TOTAL	252 (151)	233 (88)	114 (15)	599 (254)
MEAN	50.4 (30.2)	46.6 (17.6)	22.8 (3)	119.8 (50.8)
STDEV	12.66 (11.17)	25.32 (14.72)	11.17 (1.87)	35.63 (25.74)
CV	0.25 (0.37)	0.54 (0.84)	0.49 (1.87)	0.3 (0.51)
2017 TOTAL	190 (112)	274 (95)	276 (32)	740 (239)

Table 4. Frequency of Detection Types in 2018 and 2017 – Three Stations Combined

Type of Detection	Total 2018 Daily Mean Per Site (of 15 survey-days)	Total 2017 Daily Mean Per Site (of 15 survey-days)
Total Detections	39.9	49.3
Total Visual Detections	18.9	18.9
Below 1 Canopy Detections	16.9	15.9
Single Silent Birds Below 1-Canopy	5.7	8.1

Table 5. 2018, 2017 and 2016 Single Silent Birds Below-one-canopy (SSBBC) and Wing Sound (W) Detections. Wing sound detections are shown in parentheses. C.V. stands for Coefficient of Variation. Note that SSBBC excludes vocalizing birds but includes single birds making a wing sound, but not a pair of birds making a wing sound. SSBBC and W detections are believed to be associated with a current season active nesting effort nearby. The 2017 total is included at the bottom for comparison with 2018.

Date	Big Basin 2018	Butano 2018	Gazos Camp 2018	2018 3 Sites Combined	2017 3 Sites Combined	2016 3 Sites Combined
Day 1	15 (1)	0 (5)	3 (0)	18 (6)	26 (5)	7 (7)
Day 2	10 (1)	3 (7)	4 (3)	17 (11)	35 (11)	14 (2)
Day 3	20 (5)	2 (23)	1 (0)	23 (28)	13 (7)	22 (3)
Day 4	12 (11)	5 (27)	3 (1)	20 (39)	44 (22)	9 (5)
Day 5	8 (2)	0 (2)	0 (0)	8 (4)	3 (5)	12 (3)
2018 TOTAL	65 (20)	10 (64)	11 (4)	86 (88)	121 (50)	64 (20)
MEAN	13.0 (4.0)	2.0 (12.8)	2.2 (0.8)	17.2 (17.6)	24.2 (10)	12.8 (4)
STDEV	4.69 (3.79)	2.12 (11.37)	1.64 (1.30)	5.63 (15.24)	16.5 (7.1)	5.6 (1.3)
CV	0.36 (0.95)	1.06 (0.89)	0.75 (1.63)	0.33 (0.87)	0.6 (0.71)	0.43 (0.31)
2017 TOTAL	70 (22)	35 (28)	16 (0)	--	--	--

Table 6. Ratio of Occupied Behaviors to Total Detections (OB/TD)

Survey Station	2014	2015	2016	2017	2018
Big Basin	0.16 (1.33/8.33)	0.13 (2.4/18.0)	0.18 (6.4/36.4)	0.65 (24.6/38.0)	0.64 (32.2/50.4)
Gazos	0.45 (1.33/8.33)	0.33 (20.4/62.2)	0.49 (30.0/61.2)	0.20 (10.8/55.2)	0.25 (5.8/22.8)
Butano	0.37 (28.7/78.0)	0.34 (21.6/62.6)	0.22 (10.6/48.2)	0.36 (19.6/54.8)	0.39 (18.0/46.6)

Table 7. Comparison of Murrelet Activity Levels at Each Park for All Data Years. Values from 2011 and prior years are from Shaw (2011) or Singer (2013, 2010). The multiple park monitoring program began in 2003, but two stations had earlier data that is included here.

Only the Gazos Camp station was surveyed in 2012 and 2013.

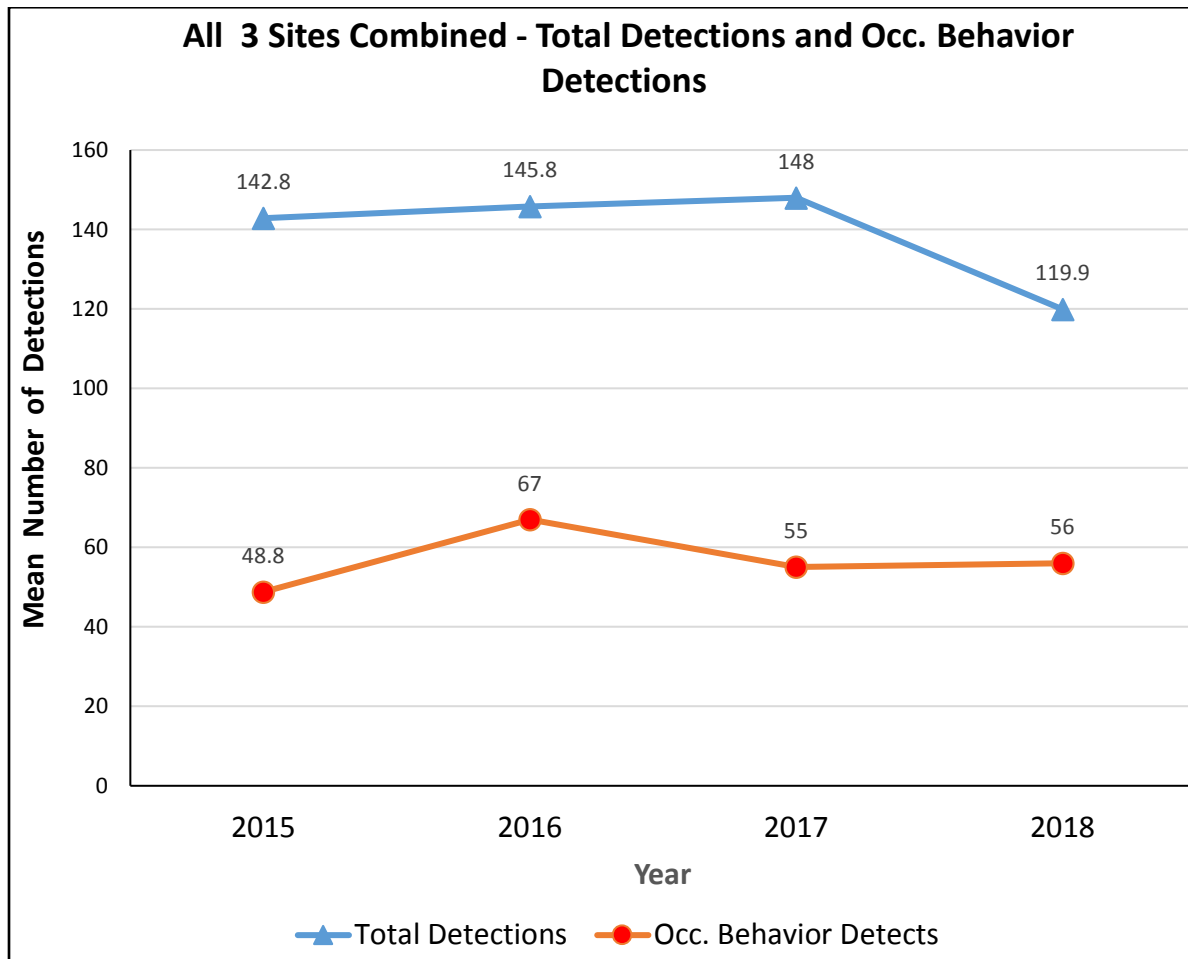
Note that only since 2014 were different stations surveyed on the same day.

Station	Year	N	Average Total Detections	Average Occupied Beh. Detections
Big Basin – Redwood Meadow	1995	4	177.0	64.0
“ “	1996	4	97.0	27.5
“ “	1998	4	92.3	33.5
“ “	2001	3	86.3	8.0
“ “	2002	3	18.7	1.3
“ “	2003	3	16.3	1.3
“ “	2004	3	17.0	2.3
“ “	2005	3	14.0	1.3
“ “	2006	3	18.3	9.0
“ “	2007	3	16.3	2.7
“ “	2008	3	12.0	0.0
“ “	2009	3	1.7	0.0
“ “	2010	3	15.3	3.0
“ “	2011	3	22.0	3.0
“ “	2014	3	8.3	0.3
“ “	2015	5	18.0	2.4
“ “	2016	5	36.4	6.4
“ “	2017	5	38.0	24.6
	2018	5	50.4	32.2
Portola – Peters Creek Bridge	2003	5	33.2	6.0
“ “	2004	5	35.6	4.4
“ “	2005	5	18.0	0.2
“ “	2006	5	18.6	2.4
“ “	2007	5	30.6	0.8
“ “	2008	5	19.0	0.6
“ “	2009	5	5.4	0.0
“ “	2010	5	33.0	5.8
“ “	2011	5	55.0	16.7
“ “	2014	3	27.7	2.3
“ “ – near Peters Creek Bridge	2015	5	27.8	5.6
“ “ – near Peters Creek Bridge	2016	5	74.2	13.4

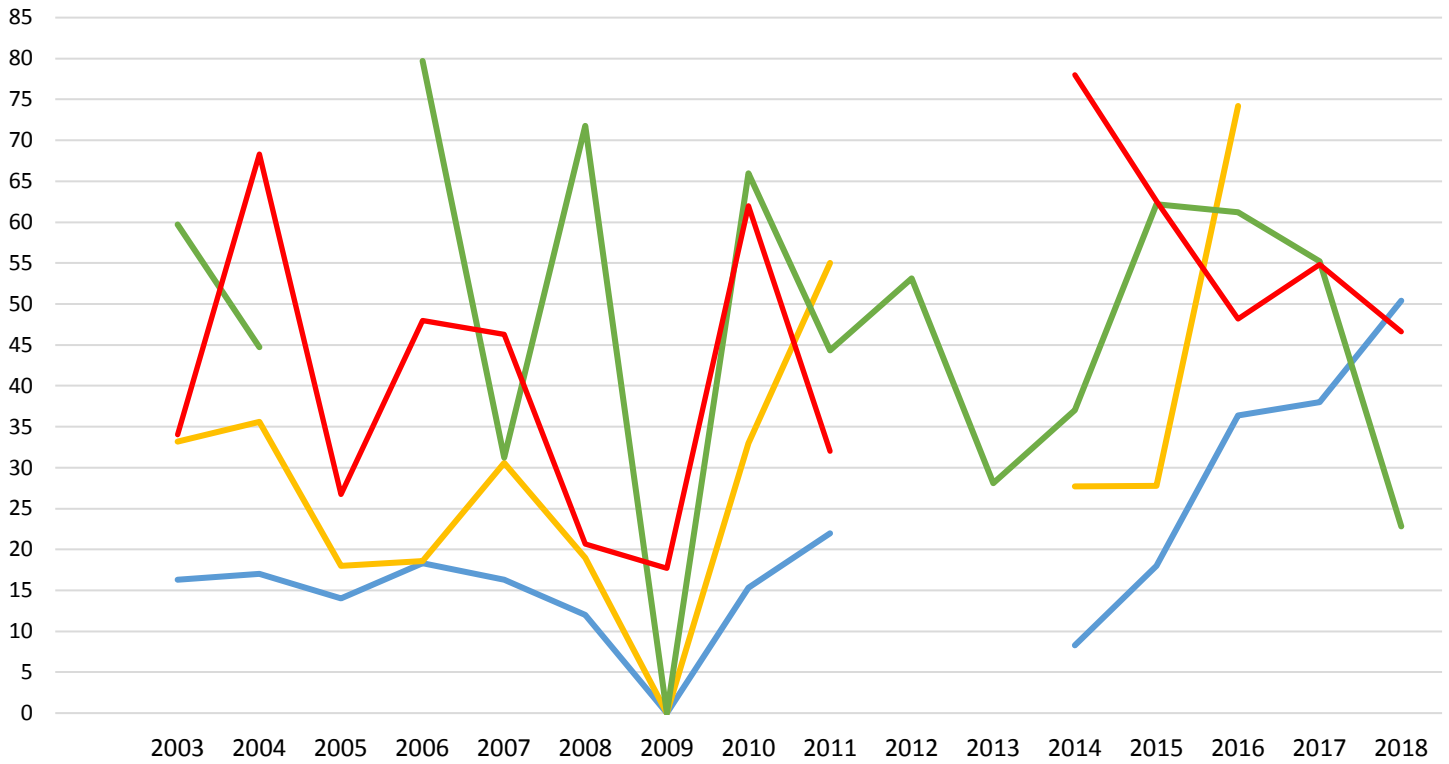
Station	Year	N	Average Total Detections	Average Occupied Beh. Detections
Butano – Little Butano Creek	2003	3	34.0	6.0
“ “	2004	3	68.3	22.0
“ “	2005	3	26.7	4.0
“ “	2006	3	48.0	4.3
“ “	2007	3	46.3	5.7
“ “	2008	3	20.7	3.0
“ “	2009	3	17.7	2.0
“ “	2010	3	62.0	19.7
“ “	2011	3	32.0	6.7
“ “	2014	3	78.0	27.7
“ “	2015	5	62.6	21.6
“ “	2016	5	48.2	10.6
“ “	2017	5	54.8	19.6
	2018	5	46.6	18.0
Memorial – Memorial	2003	3	4.3	0.0
“ “	2004	3	1.0	0.0
“ “	2005	3	1.3	0.0
“ “	2006	3	4.7	0.3
“ “	2007	3	0.7	0.0
“ “	2008	3	0.7	0.0
“ “	2009	3	0.7	0.0
“ “	2010	3	11.0	1.0
“ “	2011	3	4.7	0.3
“ “	2014	3	10.3	7.7
Gazos – Gazos Mtn. Camp	1998	6	36.0	10.7
“ “	2000	6	57.3	15.0
“ “	2001	6	64.7	17.8
“ “	2002	6	52.0	9.2
“ “	2003	6	59.7	9.7
“ “	2004	6	44.7	9.5
“ “	2006	6	79.7	19.8
“ “	2007	6	31.2	9.2
“ “	2008	6	71.8	27.2
“ “	2009	6	6.8	0.8
“ “	2010	6	66.0	25.7
“ “	2011	7	44.3	7.4
“ “	2012	7	53.1	15.1

Station	Year	N	Average Total Detections	Average Occupied Beh. Detections
" "	2013	7	28.1	2.1
" "	2014	3	37.0	3.3
" "	2015	5	62.2	20.4
" "	2016	5	61.2	30.0
" "	2017	5	55.2	10.8
" "	2018	5	22.8	5.8

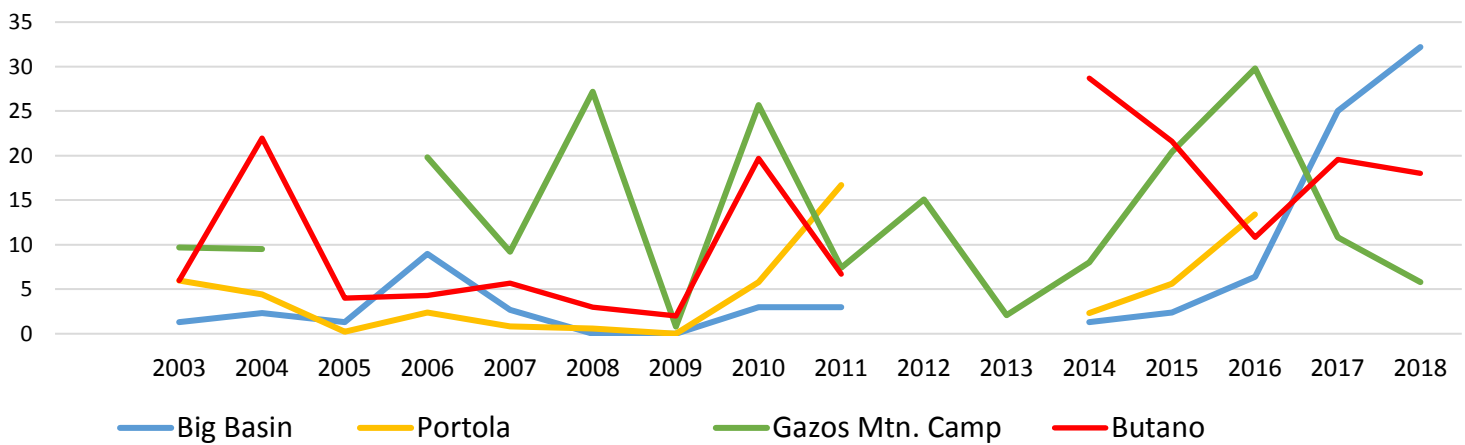
Graph 1. Total Detections and Occupied Behavior Detections at All 3 Sites Combined 2015 -2018



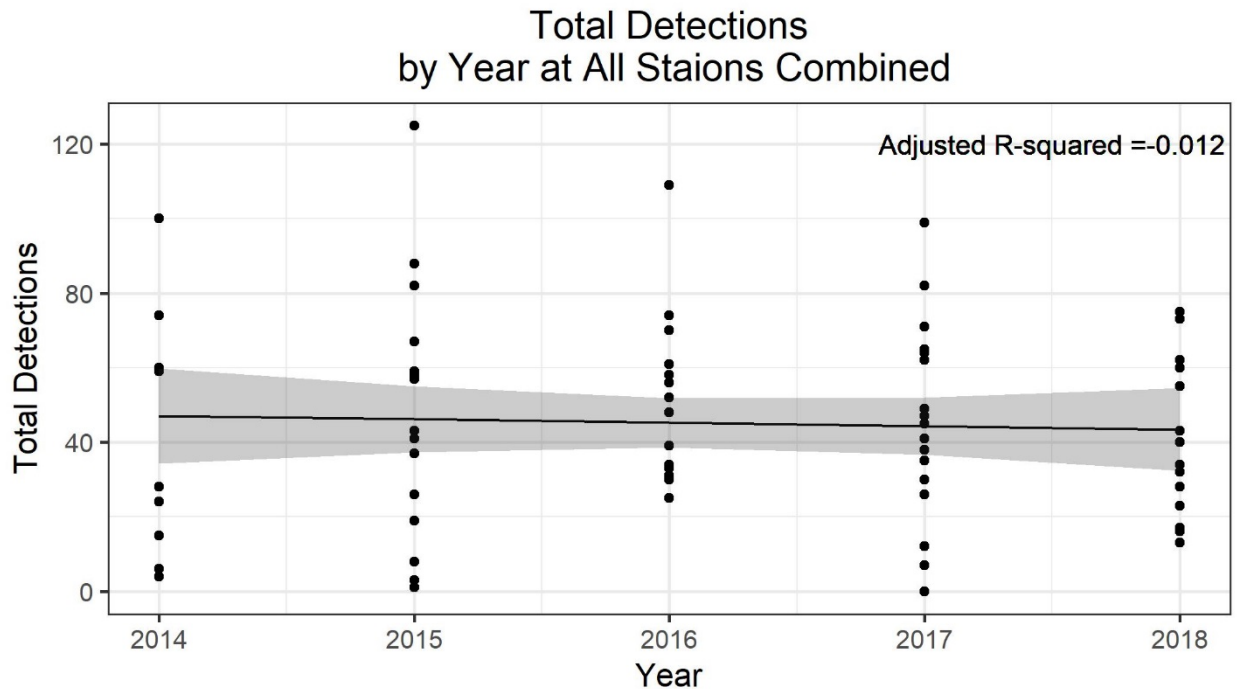
Graph 2 - 2003 - 2018 Mean Total Detections



Graph 3 - 2003 - 2018 Mean Occupied Behavior Detections



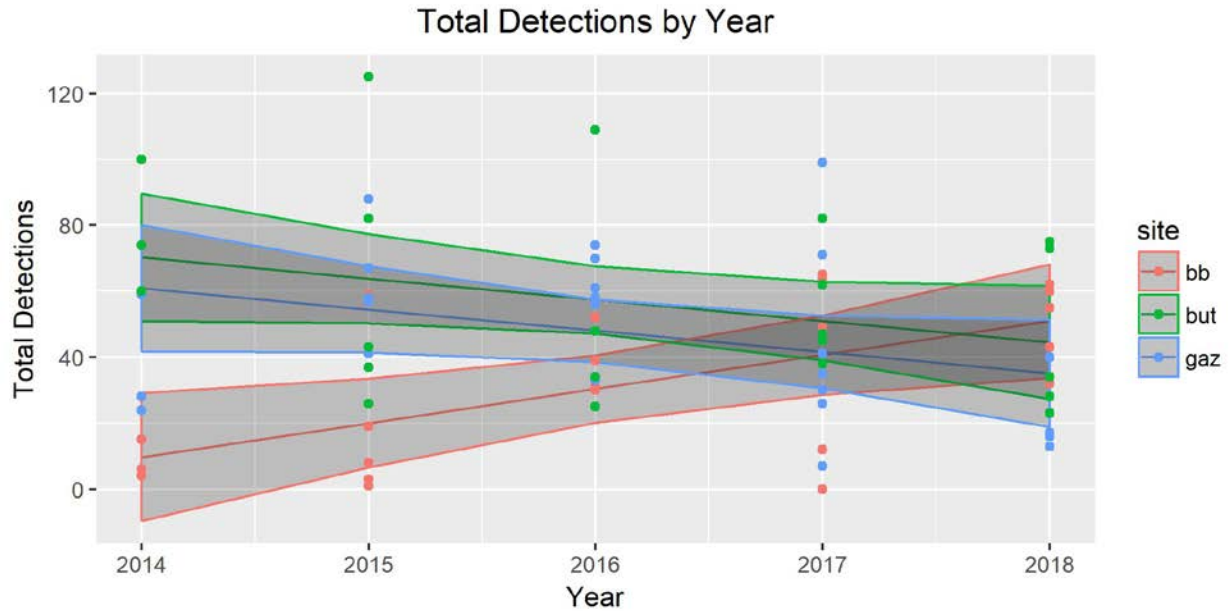
Graph 4. Linear Regression – Mean Total Detections By Year for All Stations Combined (2014 – 2018)



Graph 4. Plot shows observed total daily detections ($n=15$) per year (dots) at all stations from 2014-2018. The black line is the linear model that describes the trend of total detections combined for all stations and the grey area is the 95% confidence interval of the actual trend. (From Comfort 2018).

Comment by Emily Comfort: There is no statistical evidence that total detections are changing across the three sites between 2014 and 2018 ($F_{1,71}=0.1$, $p=.706$). On average, total detections decreased by 0.9 detections per year across the three sites, but the 95% confidence of the true mean is from 5.6 fewer detections per year to an increase of 3.8 detections (Graph 4). The linear model used to describe this trend accounts for about 0.1% of the variation in observed total detections.

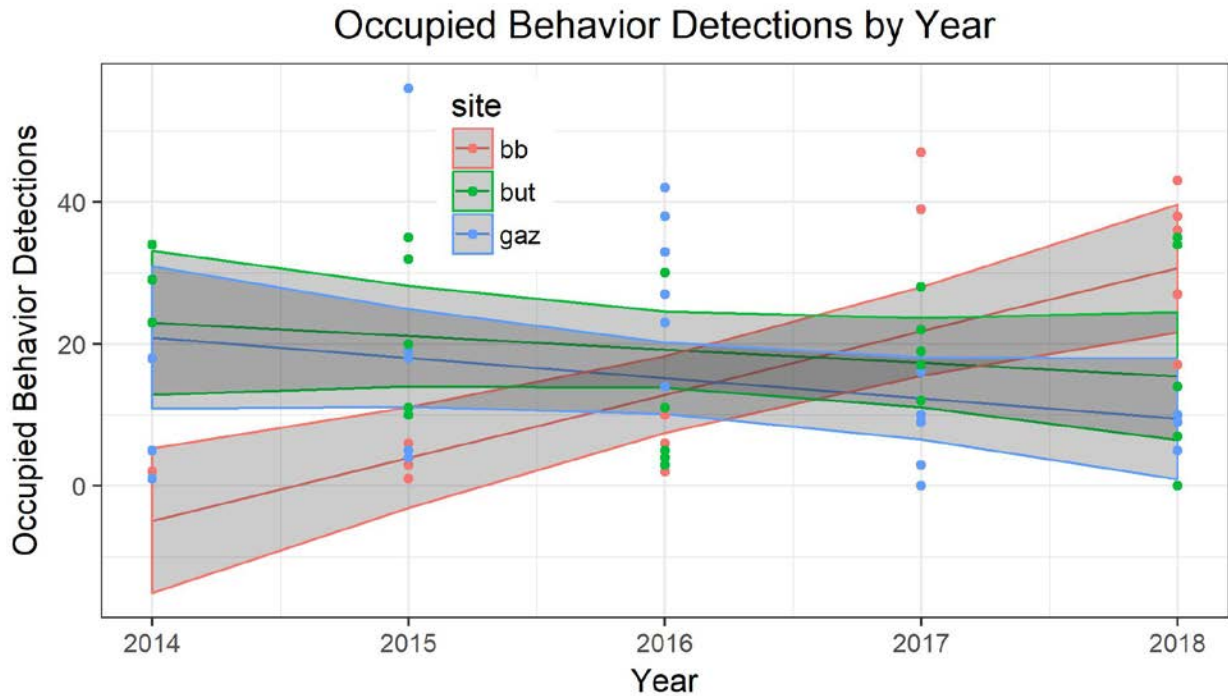
Graph 5. Linear Regression – Differences in Mean Total Detections Between Stations and Trends Over Time, if Any (2014 – 2018)



Graph 5. Regression lines (colored lines), 95% confidence limits (shadowed areas) for average total detections between 2014 and 2018 at 3 sites. Big Basin (bb) is red, Butano (but) is green, and Gazos (gaz) is blue. The circles are observed values of total detections colored by site. (From Comfort 2018)

Comment from Emily Comfort: There is strong statistical evidence that the average number of total detections was initially lower at Big Basin in 2014 than at Butano ($t_{67}= 4.6$, $p<0.001$) or Gazos ($t_{67}= 3.9$, $p<0.001$). Although Butano and Gazos were similar in 2014 (overlapping 95% confidence interval of intercept). On average, there has been an increase of 10.3 total detections at Big Basin per year (95% CI: 3.1 to 17.5, $t_{67}= 2.8$, $p=0.006$). There is strong evidence there is a different trend in total detections at Butano (on average -16.7 fewer detections per year 95% CI: -26.9 to -6.6, $t_{67}= -3.2$, $p=0.002$) and Gazos (on average 16.8 fewer detections per year 95 % CI: -26.8 to -6.7, $t_{67}= -3.2$, $p=0.002$, Figure 7). Because the 95%CI intervals of the differences in trend between Big Basin and Butano/ Gazos overlap, the difference in trends between Butano and Gazos are not statistically different.

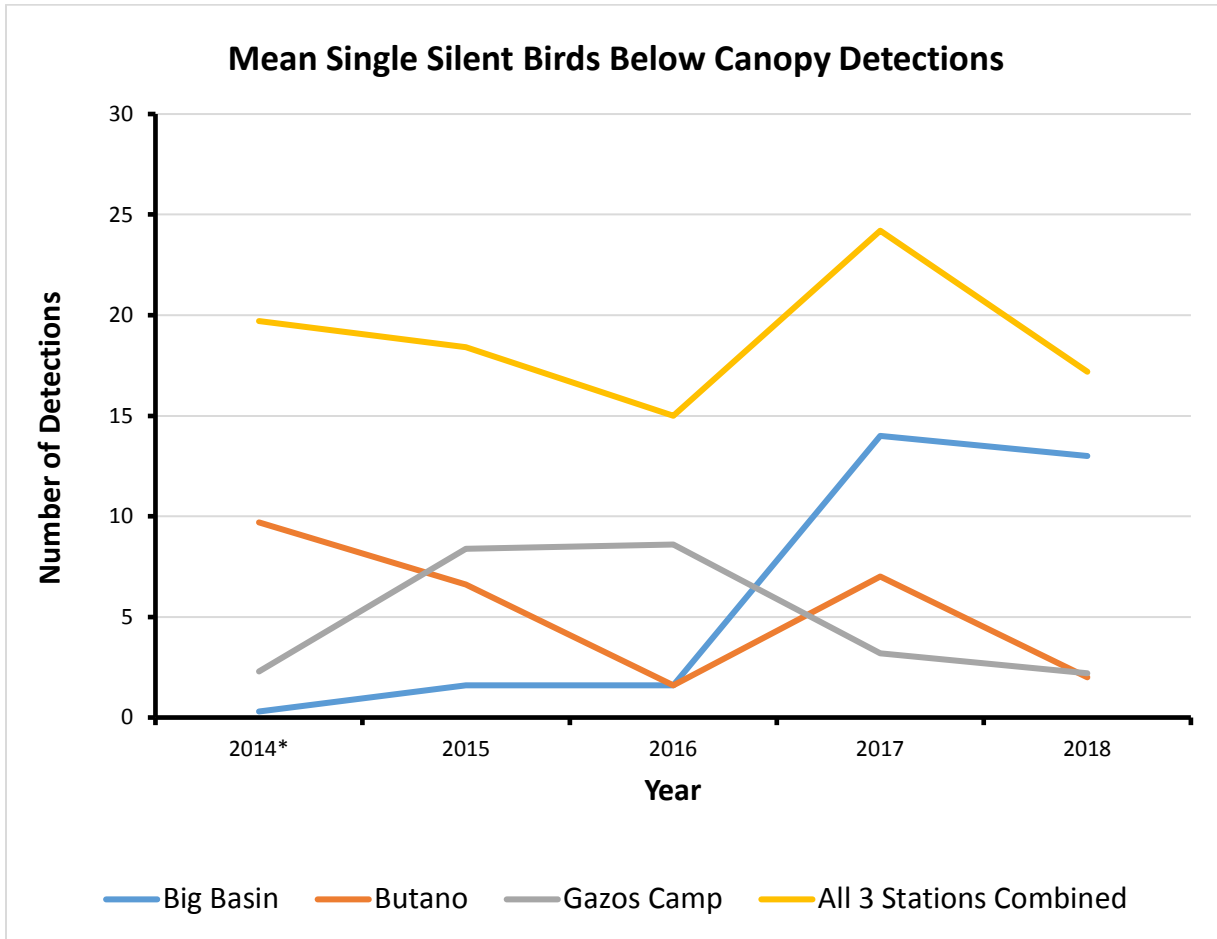
Graph 6. Linear Regression – Differences in Mean Occupied Behavior Between Stations, and Trend, if Any (2014 – 2018)



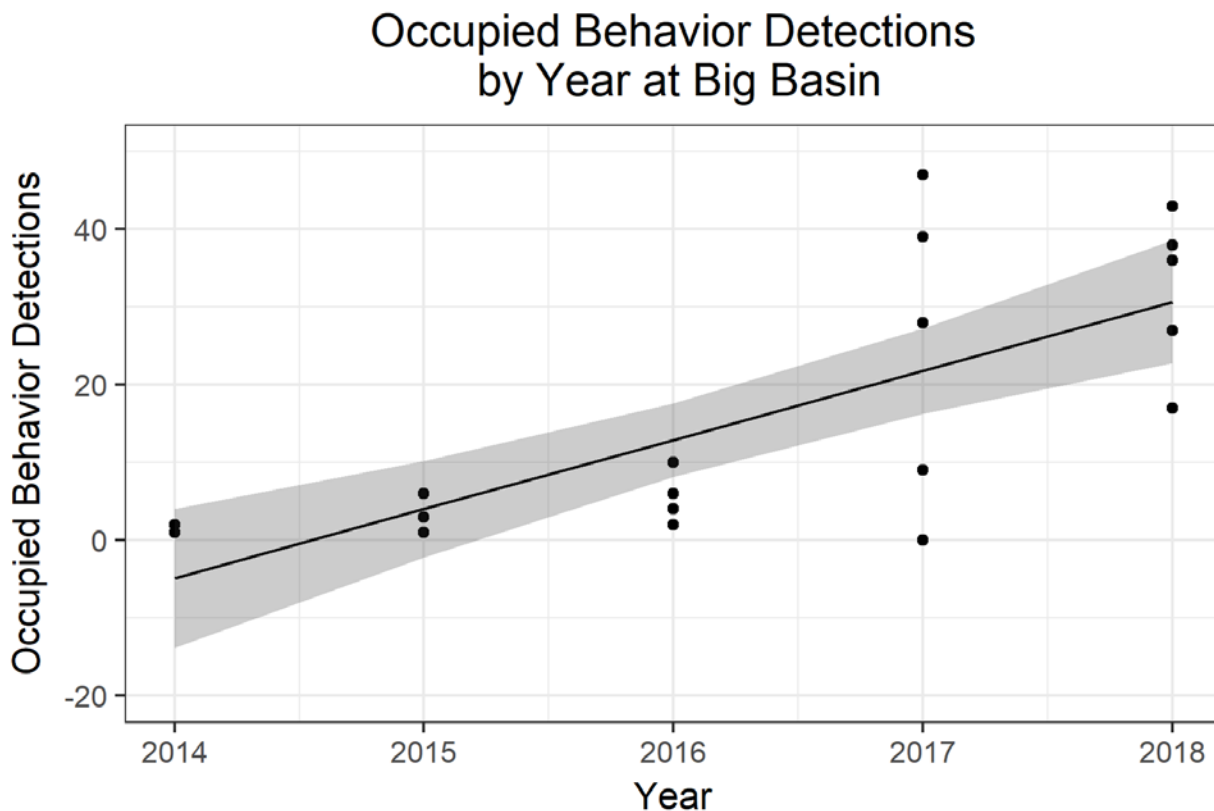
Graph 6. Regression lines (colored) and 95% confidence limits (shaded areas) for mean occupied behavior detections between 2014 and 2018 at 3 sites. Big Basin (bb) is red, Butano (but) is green, and Gazos (gaz) is blue. The circles are individual survey results (n=15, except for 2014) colored by site. (From Comfort 2018).

Comment from Emily Comfort: There is strong statistical evidence that the average number of occupied behavior detections was initially lower at Big Basin in 2014 than at Butano ($t_{67} = 4.0$, $p < 0.001$) or Gazos ($t_{67} = 3.8$, $p < 0.001$). Although Butano and Gazos were similar in 2014 (overlapping 95% confidence interval of intercept). There has been an increasing trend over the five years of observations at Big Basin of, on average, 8.9 more occupied behavior detections per year (95%CI: 5.1-12.7, $t_{67} = 4.6$, $p < 0.001$). There is strong statistical evidence that there has been a different trend in occupied behavior detections per year at Butano (10.8 fewer detections per year than at Big Basin, 95% CI -16.1 to -5.5, $t_{67} = -5.5$, $p < 0.001$) and Gazos (11.8 fewer detection per year than at Big Basin, 95% CI: -17 to -6.5, $t_{67} = -6.5$, $p < 0.001$, Graph 6). Because the 95% CI intervals of the difference in trend between Big Basin and Butano/ Gazos overlap, the difference in trends between Butano and Gazos are not statistically different.

**Graph 7. Mean Number of Detections – Single Silent Birds Below Canopy (SSBBC)
2014 – 2018**



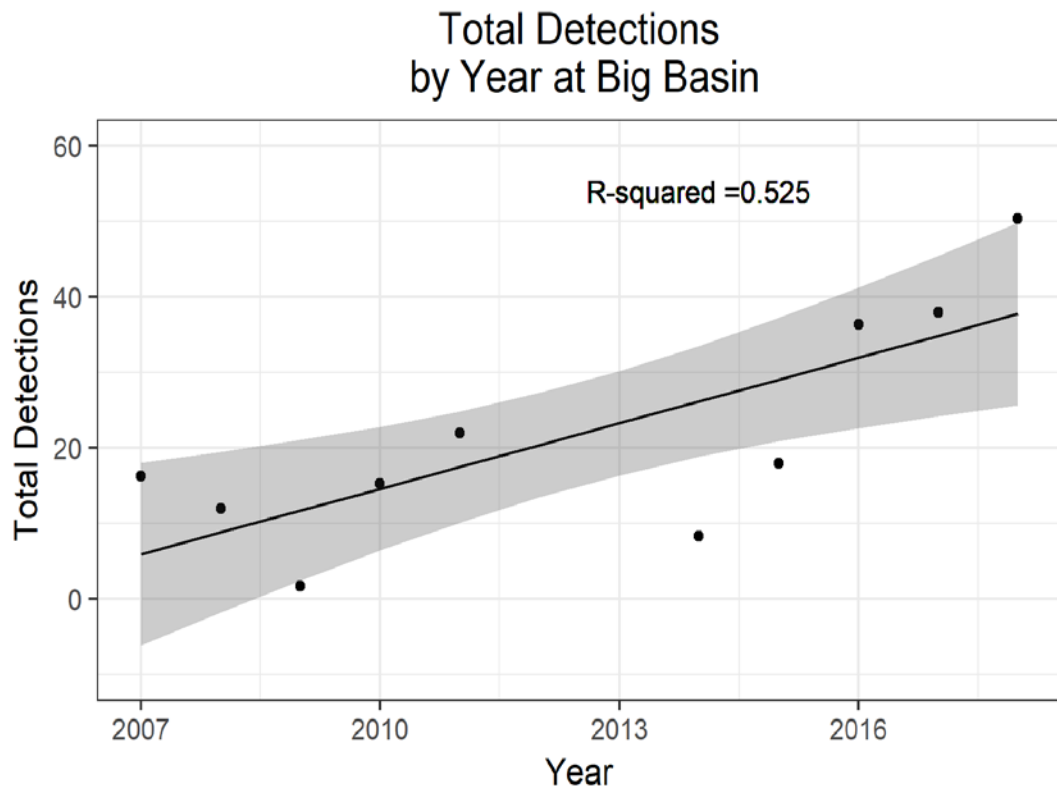
**Graph 8. Linear Regression – Mean Occupied Behaviors at Big Basin Over Time
2014 - 2018**



Graph 8. The linear relationship between average number of occupied behavior detections and year from 2014 to 2018 at Big Basin. The black line is the linear model for the true mean, the gray shaded area is the 98% confidence interval for the linear relationship, and the black dots are the individual survey values of occupied behavior detections (n=5, except for 2014). (From Comfort 2018).

Comment from Emily Comfort: Average occupied behavior detections at Big Basin increased each year from 2014 to 2018. The linear models that describes these detections was statistically significant (full model p-value ≤ 0.05) and had statistically significant slope estimates that were greater than 0 (see full report), providing evidence that these detections are increasing over time. However, the linear models that describe increase in these detection types over time only account for between 29 and 55% of the variability in the data (Adjusted r-square values). On average, occupied behavior detections have increased by 8.9 detections per year.

**Graph 9. Linear Regression – Mean Total Detections at Big Basin Over Time
2007 - 2018**



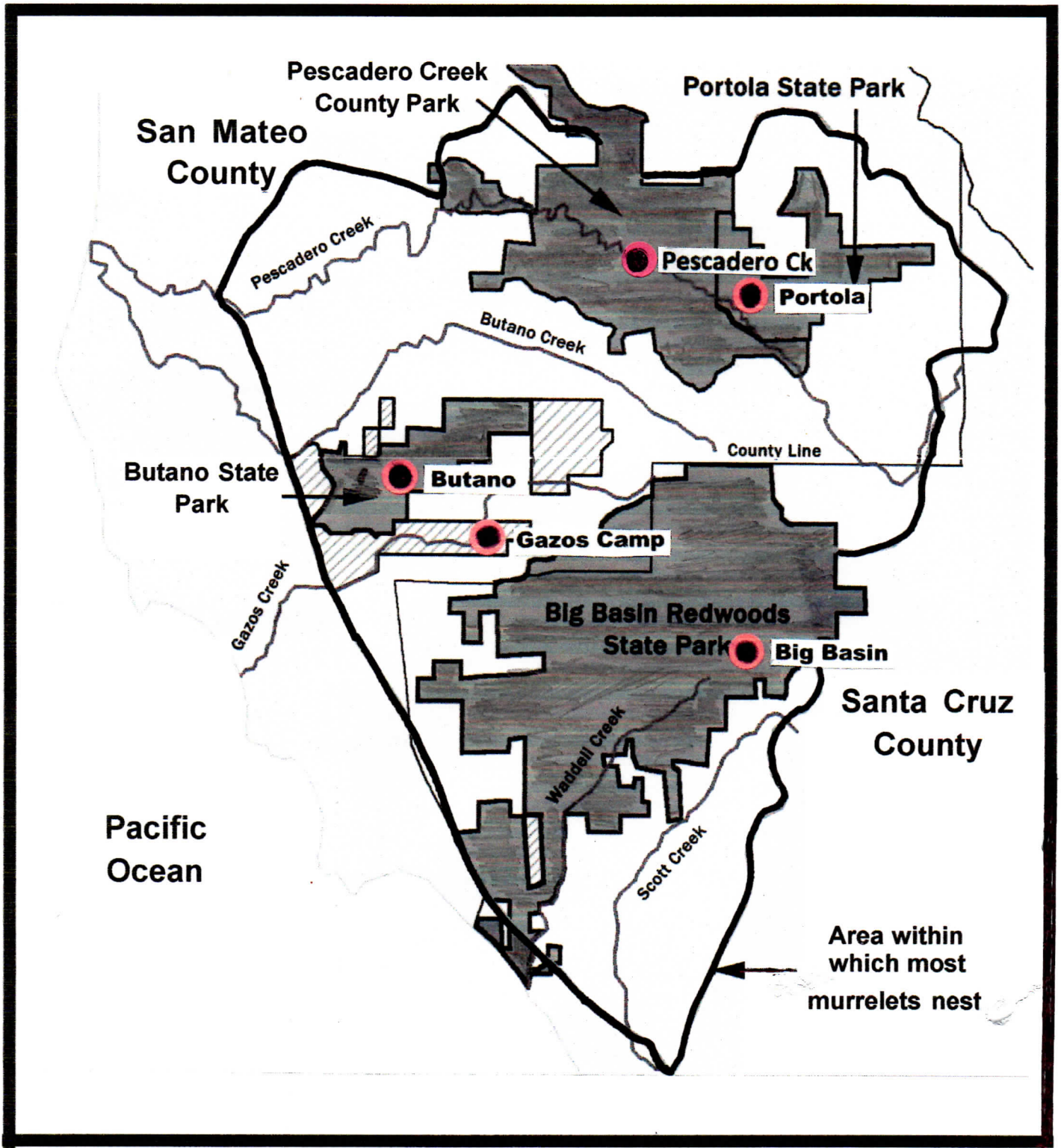
Graph 9. Plot shows observed average annual total detections (dots) at Big Basin. The black line is the linear model that describes the trend and the grey area is the 95% confidence interval of the actual trend. (From Comfort 2018).

Comment from Emily Comfort: There was evidence for a linear relationship between year and mean yearly total detection between 2007 and 2018 at Big Basin ($F_{1,8} = 15.62$, $p = 0.011$). On average, total detections increased by 2.9 detections each year from 2007 to 2018 ($p=0.011$). The 95% confidence interval for the actual trend is an increase of 0.9 detections to an increase of 4.9 detections (Graph 9). The model used to estimate these parameters explained about 53% of the variability in the observed total detection values.

APPENDIX 2 – Station Location Map
(on following page)

*[Note: The map shows the location of Big Basin, Butano, and Gazos stations
as well as two stations used in previous years]*

Map 1. Location of Marbled Murrelet Audio-Visual Survey Stations



Map by L. Robinson, modified by S. Singer