RESTORATION AND MONITORING OF COMMON MURRE COLONIES IN CENTRAL CALIFORNIA: ANNUAL REPORT 2018

REPORT TO THE *LUCKENBACH* TRUSTEE COUNCIL

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U.S. Fish and Wildlife Service
San Francisco Bay National Wildlife Refuge Complex
1 Marshlands Road, Fremont, CA 94555 USA

and

Humboldt State University
Department of Wildlife
1 Harpst St., Arcata, CA 95521

FINAL REPORT March 2020

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[1]U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, 1 Marshlands Road, Fremont, CA 94555 USA
[2]Humboldt State University, Department of Wildlife, Arcata, CA 95521 USA
[3]Mailing Address: U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, 1 Marshlands Road, Fremont, CA 94555 USA
[4] Institute of Marine Sciences, University of California, 115 McAllister Way, Santa Cruz, California 95060 USA

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Cover photo: Aerial photograph of Devil's Slide Rock, 4 June 2018 by C.M. Bednar

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PROJECT ADMINISTRATION

Project Staff

Project Manager: Gerard J. McChesney
Co-Principal Investigator: Richard T. Golightly
Wildlife Biologist: Cassie M. Bednar
Wildlife Biologist (Point Reyes Headlands): Zofia M. Burr
Wildlife Biologist (Devil's Slide): Justin A. Windsor
Wildlife Biologist (Castle-Hurricane): Amy C. Wilson
Wildlife Technician (Point Reyes Headlands): Emily K. Schmidt
Wildlife Technician (Devil's Slide): Jonah F. Kuwahara-Hu

Luckenbach Trustee Council

U.S. Department of the Interior

Representative: Carolyn Marn (U.S. Fish and Wildlife Service, Bay Delta Field Office, Sacramento, CA)
Alternate: Dave Press (U.S. National Park Service, Point Reyes National Seashore, Point Reyes Station, CA)
Solicitor: Lisa Stevens (Office of the Solicitor, Washington, DC)

California Department of Fish and Wildlife

Representative: Laird Henkel (Office of Spill Prevention and Response, Monterey, C)
Attorney: Kathy Verrue-Slater (Office of Spill Prevention and Response, Sacramento, CA)

National Oceanic and Atmospheric Administration

Representative: Jennifer Boyce (NOAA Restoration Center, Long Beach, CA)
Attorney: Ericka Hailstocke-Johnson (NOAA Restoration Center, Long Beach, CA)

ABBREVIATIONS USED

BM227X = Bench Mark-227X

CCS = California Current System

CDFW = California Department of Fish and Wildlife

CHCC = Castle-Hurricane Colony Complex (includes Bench Mark-227X, Castle Rocks and Mainland, and Hurricane Point Rocks)

CMRP = Common Murre Restoration Project

CRM = Castle Rocks and Mainland

DBCC = Drakes Bay Colony Complex (includes Point Resistance, Millers Point, and Double Point)

DPR = Double Point Rocks

DSCC = Devil's Slide Colony Complex (includes Devil's Slide Rock & Mainland, and San Pedro Rock)

DSM = Devil's Slide Mainland

DSR = Devil's Slide Rock

DSRM = Devil's Slide Rock and Mainland

GFNMS = Greater Farallones National Marine Sanctuary

HPR = Hurricane Point Rocks

LHR = Lighthouse Rock

MPR = Millers Point Rocks

NOAA = National Oceanic and Atmospheric Administration

NPFC = National Pollution Funds Center

NPS = National Park Service

OSLTL = Oil Spill Trust Liability Fund

PRH = Point Reyes Headlands

PRNS = Point Reyes National Seashore

PRS = Point Resistance

SPN = Seabird Protection Network

SPR = San Pedro Rock

USCG = U.S. Coast Guard

USFWS = U.S. Fish and Wildlife Service

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In 2018, the *Luckenbach* Oil Spill Trustee Council, comprised of California Department of Fish and Wildlife (CDFW), National Oceanic and Atmospheric Administration (NOAA), and Department of the Interior through U.S. Fish and Wildlife Service (USFWS) and National Park Service, provided funding and oversight.

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We conducted monitoring in collaboration with Seabird Protection Network outreach and education efforts by the staff of the Greater Farallones National Marine Sanctuary, including Paul Hobi, Wendy Kordesh and Karen Reyna. We conducted research at the Devil's Slide Trail County Park with assistance and permit support from Ramona Arechiga, Matt Del Carlo, Mark Rogers and Darrick Emil (San Mateo County Parks). We conducted research at Point Reyes National Seashore under Permit No. PORE-2018-SCI-0001, with assistance from Ben Becker. We owe special thanks to our committed volunteer, Linda Schmid, for conducting surveys of Bird Island.

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EXECUTIVE SUMMARY

Efforts in 2018 were the 23rd year of restoration and associated monitoring of central California seabird colonies by the Common Murre Restoration Project. This project was initiated in 1996 with the goal to restore breeding colonies of seabirds, especially those of Common Murres (*Uria aalge*), that were harmed by the 1986 *Apex Houston* oil spill, as well as by gill net fishing and other impacts. Subsequent to the original *Apex Houston* settlement, funds from the 1998 *Command* and extended *Luckenbach* oil spills have supported the project. From 1995 to 2005, the primary goals were to restore the previously extirpated Devil's Slide Rock (DSR) colony using social attraction techniques, and to assess restoration needs at additional central California colonies. Since 2005, we have incorporated standardized procedures for the surveillance and assessment of human disturbance at central California Common Murre colonies into daily survey methods. Additionally, we continue to monitor the outcome of initial recolonization efforts at DSR and recovery of other central California murre colonies. The human disturbance assessments were used to inform outreach, education and regulatory efforts by the Seabird Protection Network (SPN; coordinated by the Greater Farallones National Marine Sanctuary; GFNMS) and allow for evaluation of the success of those efforts. The goal of the SPN is to protect central California seabird breeding colonies primarily through reduction of human disturbance, which also enhances the restoration of previously injured colonies.

We conducted monitoring of human disturbance (mainly aircraft and watercraft), non-anthropogenic disturbance, seabird productivity, seabird attendance patterns and relative population sizes at three Common Murre colony complexes. In addition, a volunteer conducted less intensive monitoring of Common Murre attendance at Bird Island. In 2018, at Point Reyes Headlands (PRH) we recorded the highest rate of disturbance events since dedicated monitoring began in 2005. In 2018, the majority (88%) of disturbance events at PRH were aircraft that caused agitation. For watercraft, analysis of long-term data (2005-2018) showed significant declines in the annual change of both watercraft detections and watercraft disturbances. Devil's Slide Rock and Mainland (DSRM) continued to have greater combined aircraft and watercraft disturbance rates (0.09 disturbance events/hour) than PRH and the Castle-Hurricane Colony Complex (CHCC). Of the 40 disturbance events at DSRM, 14 (35%) included flushing. Examination of long-term (2005-2018) trends in the annual rate of aircraft and watercraft disturbance rates at DSRM showed significant declining trends of plane and helicopter detections as well as watercraft disturbances. In 2018, CHCC had lower total disturbance rate (0.01 disturbances/hour) than PRH or DSRM. There were three disturbance events at CHCC, and for the first time since monitoring began, drones caused two seabird disturbances. Analysis of the annual change of aircraft and watercraft disturbance rates from 2005-2018 did not show any significant trends across years at CHCC.

General aviation (e.g., private or charter) planes were the most commonly observed aircraft, and caused 42% of aircraft disturbances at all monitored colonies. The second most observed aircraft was general aviation helicopters, which caused 5% of aircraft disturbances. U.S. Coast Guard helicopters caused the second most disturbances (14% of aircraft disturbances). Private recreational fishing boats and charter fishing boats accounted for 97% of watercraft observed, but caused no disturbances. Only one watercraft caused a disturbance in 2018; a Search and

Rescue boat caused flushing of Brandt's Cormorants at DSRM. One private recreational fishing boat entered the Special Closure at PRH but caused no disturbance. We observed 12 watercraft within the Special Closure at DSR, but they did not cause any disturbances.

Seasonal attendance at PRH Lighthouse Rock (LHR) plots (PRH-03-B Dugout, Edge and Ledge) was similar to the long-term average. PRH plots Boulder (PRH-05-BP) and Cone (PRH-13-CP) were both lower than the long-term average during the pre-lay period but in May attendance patterns became more typical. At DSR in 2018, seasonal attendance during the pre-lay period was variable but was above average during most counts. Disturbance events in May and June caused several large changes in attendance. Seasonal attendance was near or below average at Castle Rocks and Mainland (CRM) plots (CRM-04, 04-P) but was greater than the average at HPR-02 throughout the season.

Aerial photograph counts of Common Murres were greater in 2018 than in 2016, although we did not conduct aerial surveys at PRH in 2017. Within the Drake's Bay Colony Complex, murre counts were greater in 2018 than 2017 at both Point Resistance and Double Point Rocks, but lower at Miller's Point Rocks. At DSRM, murre counts in 2018 were similar to 2017. Within the CHCC, murre counts were lower in 2018 than in 2017 at CRM and Hurricane Point Rocks, but greater at Bench Mark-227X.

Common Murre productivity (chicks fledge per pair) at PRH plots was greater than the long-term average in 2018, and the highest recorded since 2010. Murre productivity was also greater than the long-term average at DSR but similar to the long-term mean at CHCC.

During focused non-anthropogenic disturbance surveys ("Avian Disturbance Surveys"), we recorded the greatest disturbance rate at PRH. There, Common Ravens (*Corvus corax*) caused the greatest number of disturbance events but Brown Pelicans (*Pelecanus occidentalis*), Peregrine Falcons (*Falco peregrinus*), Turkey Vultures (*Cathartes aura*) and waves disturbed more murres, overall, during events. Similar to 2017, at DSR, Common Ravens caused the greatest rate of disturbance and the most events that included displacement and flushing of murres. The total non-anthropogenic disturbance rate during avian disturbance surveys at CHCC was greater than at DSR and Western Gulls (*Larus occidentalis*) caused the greatest rates of disturbance.

In 2018, Brandt's Cormorant (*Phalacrocorax penicillatus*) nests counted from land-based monitoring were greater at PRH and DSRM than were counted in 2017. At CHCC, we counted similar numbers of Brandt's Cormorant nests in 2018 and 2017. Brandt's Cormorant productivity in 2018 was near the long-term average at PRH but below the long-term average at DSRM and CHCC. We monitored productivity of Pelagic Cormorants (*P. pelagicus*), Western Gulls and Black Oystercatchers (*Haematopus bachmani*) at both DSRM and CHCC. Productivity of Pelagic Cormorants at DSRM was near average and the highest recorded since 2013. At CHCC, Pelagic Cormorant productivity was greater than average. Western Gull productivity was greater than average and the highest recorded since 2006 at both DSRM and CHCC. Three Black Oystercatcher chicks successfully fledged at CHCC.

INTRODUCTION

In central California, Common Murre (*Uria aalge,* hereafter referred to as murre) breeding colonies occur on nearshore rocks and adjacent mainland cliffs between Marin and Monterey counties as well as on the North and South Farallon Islands, which are 20 to 40 km offshore of San Francisco (Carter et al. 1992, 2001). A steep decline in the central California population occurred between 1980 and 1986 and was attributed primarily to mortality associated with gill-nets and oil spills, including the 1986 *Apex Houston* oil spill (Page et al. 1990; Takekawa et al. 1990; Carter et al. 2001, 2003). Between 1982 and 1986, a colony of about 3,000 breeding murres on Devil's Slide Rock (DSR) in northern San Mateo County was extirpated. Since 1995, the Common Murre Restoration Project (CMRP) has sought to restore DSR and other central California colonies using several techniques, including social attraction. Social attraction techniques were utilized at DSR between 1996 and 2005 (McChesney et al. 2006; Parker et al. 2007), and were discontinued after the colony appeared to be restored and self-sustaining. Restoration efforts at other murre colonies in central California have focused on documenting the impacts of human disturbance, gill-net mortality, and other threats to colonies, as well as working with government agencies and the public to reduce these impacts.

Since the early 1990s, the central California murre population has shown an increasing trend due to implementation of restrictions on gill-net fishing, favorable prey conditions, and other factors (Carter et al. 2001; USFWS, unpublished data). However, anthropogenic impacts to murres continue to occur and may continue to affect the population. Gill-net mortality continued until the California Department of Fish and Wildlife (CDFW) enacted an emergency closure of the gill-net fishery in September 2000, followed by a permanent closure in September 2002 in waters less than 110 meters deep (60 fathoms) from Point Reyes to Point Arguello (Forney et al. 2001). Extensive oil pollution (e.g., 1998 *Command* oil spill and a series of oil releases from the sunken vessel *S.S. Jacob Luckenbach* from the early 1990s to the early 2000s) continued to kill thousands of murres in central California (Carter 2003; Carter and Golightly 2003; Hampton et al. 2003; Roletto et al. 2003). Disturbances from aircraft and watercraft have affected colonies as well (Rojek et al. 2007, Fuller et al. 2018; USFWS, unpublished data).

Beginning in 1995, restoration and associated monitoring of murre colonies in central California have been funded largely through oil spill restoration plans and associated trustee councils, including the *Apex Houston* (1995-2009), T/V *Command* (2005-2009), and, beginning in 2010, the *Jacob Luckenbach*. On 14 July 1953, the *S.S. Jacob Luckenbach* collided with the freighter *Hawaiian Pilot* and sank in 55 meters of water approximately 27 kilometers southwest of San Francisco. The *S.S. Jacob Luckenbach* was loaded with 457,000 gallons of bunker fuel, which subsequently leaked periodically during winter storms. Using chemical analysis, oil that was associated with several mystery spills was linked to this vessel, including the Point Reyes tar ball incidents of winter 1997-1998 and the San Mateo Mystery Spill of 2001-2002. In the summer of 2002, the U.S. Coast Guard (USCG) and the *Luckenbach* trustees removed much of the oil from the vessel and sealed the remaining oil inside (Hampton et al. 2003). An estimated 51,569 seabirds were killed between 1990 and 2003 from Bodega Bay to Monterey Bay, including 31,806 murres (*Luckenbach* Trustee Council 2006).

The USCG National Pollution Funds Center (NPFC) awarded $22.7 million to implement 14 restoration projects. The award was a result of a claim filed by the *Luckenbach* trustees in 2006 for funding from the Oil Spill Liability Trust Fund (OSLTF), as the company responsible for the *Luckenbach* no longer existed. The OSLTF pays for oil spill cleanup and restoration of impacted natural resources when there is no responsible party. Fees from the oil industry sustain the fund and the NPFC manages it.

The Central California Seabird Colony Protection Project, now called the Seabird Protection Network (SPN), was initiated by the *Command* Oil Spill Restoration Fund (Command Trustee Council 2004) in 2005 and was extended in 2010 with *Luckenbach* funds. The Greater Farallones National Marine Sanctuary (GFNMS) and CMRP implements the SPN in coordination with the CMRP, to restore seabird colonies harmed by these oil spills primarily through reducing human disturbance. The GFNMS focuses on the outreach, education and regulatory components, while the CMRP conducts the colony surveillance and monitoring component of the program. Surveillance and monitoring data from these colonies guide education and outreach efforts and are used to assess the success of those efforts.

Colony surveillance and monitoring efforts have focused on three colonies or colony complexes established as murre restoration or reference sites in 1996: Point Reyes Headlands (PRH), Devil's Slide Colony Complex (DSCC), and Castle-Hurricane Colony Complex (CHCC). From 2005-2016, less intensive surveys were conducted at three additional colonies in the Drakes Bay Colony Complex (DBCC): Point Resistance (PRS), Millers Point Rocks (MPR), and Double Point Rocks (DPR). Colony count surveys to document potential murre attendance and breeding were also conducted once per week at Bird Island (near Point Bonita) in Marin County.

Here we summarize colony surveillance and monitoring efforts conducted at central California nearshore murre colonies in 2018. As in past years, we recorded and categorized aircraft, watercraft and other disturbances to seabirds; murre seasonal attendance patterns; and productivity (or reproductive success). We also recorded Brandt's Cormorant relative breeding population sizes and productivity, as well as relative breeding population sizes and/or productivity of Pelagic Cormorants, Black Oystercatchers, Western Gulls), and Pigeon Guillemots (*Cepphus columba*). We reported counts from aerial photographic surveys for colonies between Point Reyes and Hurricane Point.

METHODS

Study Sites

We monitored three colony complexes, PRH, DSCC and CHCC, for productivity, disturbance and attendance of seabirds in 2018 (Figure 1). Volunteers monitored only seabird attendance at Bird Island. PRH, (Figure 2) is located within the Point Reyes National Seashore, Marin County. Bird Island is located near the mouth of the Golden Gate within Golden Gate National Recreation Area, Marin County. DSCC, located in San Mateo County, consists of the colonies at Devil's Slide Rock and Mainland (DSRM) and San Pedro Rock (SPR; Figures 3, 4). CHCC in

Monterey County consists of the colonies Bench Mark-227X (BM227X), Castle Rocks & Mainland (CRM), and Hurricane Point Rocks (HPR; Figure 5). The offshore rocks of DSCC and CHCC are within the California Coastal National Monument. Mainland portions of DSCC are either part of the Devil's Slide Trail County Park or are privately owned. Mainland portions of CHCC are either privately, state or county-owned. At each colony, individual rocks and mainland cliffs with nesting seabirds were identified by their recognized subcolony number, subcolony name, or subarea. In this report, colonies are ordered north to south within each section.

Monitoring Effort

To track monitoring effort, observers recorded a start time to the nearest minute upon arrival at a field vantage point and an end time when departing the vantage point. From these data, observation hours were totaled irrespective of the number of observers (i.e., *not* a calculation of person-hours). For calculating the total observation hours for a colony or colony complex, we combined observation hours from all vantage points. When multiple observers were present at multiple vantage points simultaneously, the total hours of observation were calculated as hours on site regardless of the number of people observing (i.e., hours were not double counted). In addition, time transiting between vantage points was not included in observation hours.

Disturbance

Anthropogenic Disturbance Events

Anthropogenic disturbance affecting murres or other seabirds was recorded at each study colony. These included any instances in which adult birds were alarmed or agitated (e.g., head-bobbing in murres, raised head or wing-flapping in cormorants), displaced (i.e., birds moved from breeding or roosting site but did not fly away) or flushed (i.e., birds left the colony or roost) as a result of human activity. Numbers of disturbed seabirds within each disturbance category, for each disturbance event, were recorded. Numbers of eggs or chicks exposed, displaced, or depredated or otherwise lost (taken) were also recorded. When seabirds were disturbed by a human source (e.g., helicopter with recorded tail number), a SPN wildlife disturbance report was filed. These reports included pertinent information on the event and photos (when available).

We calculated monitoring effort for each colony and colony complex (except for Bird Island). In order to compare disturbance among colonies and among years, we calculated disturbance rates. We calculated anthropogenic disturbance rates during the breeding season as the number of disturbance events per hour of observation at each colony complex. We used Generalized Linear Model with a Poisson distribution (or Quasi-poisson in cases of "overdispersion"; R Core Team, 2018) to examine long-term trends in anthropogenic disturbance and to predict trends in annual changes in detection and disturbance rates for aircraft and watercraft during 2005-2018. We reported percent annual changes in detection and disturbance rate, confidence intervals and p-values.

For the annual Pacific Coast Dream Machines event that took place 29 April 2018 at the Half Moon Bay Airport, observers monitored potential disturbance events at Devil's Slide Rock (DSR). This event included an aircraft fly-in and air tours, which in some years have caused high rates of seabird disturbance. In 2009, the SPN began conducting outreach specifically directed toward pilots attending this event and has continued to do so each year since.

In addition to disturbance events, all aircraft flying at or below an estimated 1,000 ft (305 m) above sea level and 1,500 ft (460 m) horizontal distance, as well as all watercraft within an estimated 1,500 ft (460 m), of the nearest seabird breeding or roosting area were recorded to identify use patterns of potential sources of anthropogenic disturbance. We calculated detection rates as the number of aircraft or watercraft observed within these given zones per observation hour, using monitoring effort for each colony complex. We recorded and reported all watercraft entering the Egg Rock/Devil's Slide Rock and PRH Special Closure areas to Cal-TIP ("Californians Turn in Poachers") or to California Department of Fish and Wildlife (CDFW) wardens directly as well as to the SPN. Special Closures are no-entry zones designated by CDFW under the California Marine Life Protection Act to protect important seabird and marine mammal colonies from disturbance.

Non-anthropogenic Disturbance Events

In 2018, non-anthropogenic disturbance events (e.g., avian, other wildlife, etc.) were recorded during focused "Avian Disturbance Surveys" surveys. We based the protocol for this survey on surveys that were conducted by the CMRP in 1999-2001 and were re-initiated in 2017 to more efficiently and randomly capture non-anthropogenic disturbances at PRH, DSRM and CHCC. We conducted avian disturbance surveys in two-hour time segments between 0600-1800 h at murre productivity monitoring overlooks. We monitored each two-hour time segment between 0600-1800 h within a two-week period. Observers recorded all non-anthropogenic disturbance events including the species and number of individuals causing disturbance, the types of behaviors exhibited by the disturbance source (Table 1), as well as the species, numbers of individuals, and behaviors of birds disturbed.

We recorded monitoring effort during avian disturbance surveys to calculate rates. At DSRM events that caused agitation only were not recorded until 14 June, so the sum of total disturbance events should be considered a minimum. We also recorded any anthropogenic disturbances observed during avian disturbance surveys. We separately recorded major incidental non-anthropogenic disturbance events that occurred outside avian disturbance surveys. These disturbance events are reported separately.

Common Murre Seasonal Attendance Patterns

We monitored seasonal attendance of murres at each colony from standardized mainland observation points using 65-130X or 15-60X spotting scopes. Attending murres were counted at each colony, subcolony, or index plot. We made three consecutive counts and averaged those counts for most surveys. Seasonal attendance data were collected regularly at most PRH, DSCC and CHCC nesting areas throughout the field season, until all chicks fledged and adult attendance ceased. We conducted breeding season counts during a standardized period between 1000-1400 h. At productivity plots and a subset of subcolonies and subareas, we compared murre counts to weekly long-term mean patterns (2008-2017) and 95% confidence intervals. Results are reported as above or below average if they fell outside of the 95% confidence interval surrounding the long-term mean.

Point Reyes Headlands

We recorded seasonal attendance at PRH at all murre subcolonies visible from mainland observation points (Figure 2) once per week from 13 April to 14 August. Attendance was recorded at established Type II index plots (see Birkhead and Nettleship 1980) on Lighthouse Rock (LHR; Ledge, Edge, and Dugout plots), Boulder, Flattop, Middle, Beach, and Cone Rocks. Counts of index plots were counted three times per survey and calculated the average. We counted all other visible areas of subcolonies once per survey.

Bird Island

Murres were first recorded attending Bird Island among nesting Brandt's Cormorants in 2007 (McChesney et al. 2008), and breeding was first confirmed in 2008 (McChesney et al. 2009). In 2018, monitoring of this recent colonization continued and observations were conducted by trained volunteers once per week in April and June, however volunteer availability was limited and counts could not be conducted in May and the beginning of June. Counts were conducted during late afternoon (after 1500 h) from the north (the bluff above the north end of Rodeo Beach).

Devil's Slide Rock & Mainland, San Pedro Rock

We counted murres on DSR every other day from 16 April to 13 August from the Traditional Pullout (Figure 3). We used a Canon EOS 80D camera with a 300 mm telephoto lens to photograph DSR. We counted birds using digital photo count software. On Devil's Slide Mainland (DSM), we monitored attendance patterns once per week wherever we could view murres (see map, Figures 3, 4). Access to the best observation point for viewing Lower Mainland South (DSRM-05-A Lower) and Turtlehead Boulder was limited to short periods of time in order to minimize disturbance to nearby nesting Peregrine Falcons (*Falco peregrinus*). At SPR, we conducted bird counts once per week throughout the breeding season from Pipe Pullout (Figure 3).

Castle-Hurricane Colony Complex

We monitored seasonal attendance of murres for all active subcolonies visible from accessible, standardized mainland observation points (Figure 5). We conducted counts twice per week during the breeding season from 17 April to 27 July. At four subcolonies, separate subarea counts were also conducted: CRM-04 (productivity plot and entire rock), CRM-03B (south and east sides), CRM-06-B (also called CRM-06-South; south side only), CRM-06-A (also called

CRM-06-North; north side only), and HPR-02 (Ledge and Hump plots). Subarea CRM-06-A was observed from the Castle Pullout (Figure 5).

Common Murre Productivity

As in previous years, productivity (chicks fledged per pair) of murres was monitored at PRH, DSRM and CRM daily or near daily, from standardized mainland observation points using either 65-130x or 15-60x spotting scopes. At the PRH LRH plots, we mapped and numbered all followed sites using digiscoped photographs of the colony and updated photographs from 2017. At DSR, we mapped and numbered all followed sites using digiscoped photographs of the 2018 colony and updated photographs from the 2017 breeding season, as well as 2017 aerial photographs. At CRM-04-P, locations of returning or new breeding and territorial sites were identified using maps and photographs updated from the 2017 breeding season. We did not follow productivity at CRM-03-B for the 2018 season due to time restrictions, because murres do not nest there every year, and because murres have unusually poor breeding success there.

We defined a breeding site as a site where an egg was observed or inferred based on adult behaviors. A territorial site was defined as a location with attendance greater than or equal to 15% of monitored days but where an egg was not observed or inferred based on adult behaviors. Some territorial sites were likely breeding sites where eggs were lost at the time of laying, or shortly after but without our detection. We defined a sporadic site as a location attended for at least two days but for less than 15% of monitored days. Chicks were considered to have fledged if they survived at least 15 days. We compared results from 2018 to previous long-term means: PRH, 1996-2002, 2005-2015, 2017 (n=19 years) DSR and CRM, 1996-2017 (n=22 years).

Point Reyes Headlands

We monitored murre productivity at PRH within two established Type II plots on LRH. Ledge Plot and Edge Plot were located in the interior and edge of the colony, respectively.

Devil's Slide Rock and Mainland

Due to widespread colony growth and the increasing difficulty of monitoring the entire colony, three Type I plots (A, B and C, see Birkhead and Nettleship 1980) were established on DSR in 2006 (McChesney et al. 2006; Figure 6). Since 2006, as plots continued to fill in with increased numbers of murres, we have adjusted plot boundaries based on the visibility of sites. In 2014, we dropped Plot C entirely due to poor viewing conditions and in 2015 we added Plot D to continue monitoring the edge effects previously captured in Plot C (Figure 6). In addition, we have dropped individual sites within current plot boundaries if productivity data could not consistently be obtained due to poor viewing conditions. We have added new sites within current boundaries (Figure 7) as new birds have established territorial or breeding sites.

In 2018, we monitored 201 sites within the DSR plots (Figure 7). At DSM, breeding was confirmed and monitored only in subarea DSRM-05-A. We monitored all active sites in plots and subareas beginning 16 April.

Castle-Hurricane Colony Complex

We monitored 105 active murre breeding and territorial sites within a standardized plot on CRM-04 (established in 1996) beginning 17 April.

Nest Surveys

To assess locations of nesting areas, relative breeding population sizes, and potential impacts from disturbance, we conducted nest and bird surveys of non-murre seabird species at each colony in conjunction with murre colony attendance surveys. Surveys were conducted weekly at PRH, DSRM and semi-weekly at CHCC between mid-April and 10 July. Brandt's Cormorant nests and territorial sites were classified into five groups that described nesting stages: territorial site, poorly built nest, fairly built nest, well-built nest, and nests with brooded chicks. In addition, large, wandering ("creching") cormorant chicks were counted. See McChesney et al. (2007) for more detailed descriptions of nest categories. For other species, we only counted well-built nests (i.e., those beyond the poorly built stage). Nest counts reported were the sum of seasonal peak counts of well-built nests (including nests with chicks) at each subcolony or subarea.

Brandt's Cormorant Productivity

We monitored breeding phenology and reproductive success (clutch sizes, brood sizes and chicks fledged per pair) of Brandt's Cormorants at PRH, DSRM and CHCC wherever vantage points provided adequate viewing. At PRH in 2018, we monitored Brandt's Cormorants on the East half of Hooves (PRH-07-A), Face Rock (PRH-11-B), Wishbone Point (PRH-11-E), Cone Shoulder (PRH-13-CS), Cone Upper (PRH-13-CU), West Cone (PRH-13-WC), an unnamed section of Cone (PRH-13) and PRH-14-E. At DSRM, we monitored at DSR (DSRM-01), Lower Mainland South (DSRM-05-A Lower), April's Finger (DSRM-05-AF) and Turtlehead (DSRM-05-B). At CHCC, we conducted monitoring at CRM-06-AN and CRM-07.

We checked monitored nests every one to seven days from mainland observation points using binoculars and spotting scopes. We considered chicks fledged if they survived to at least 30 days of age. After that age, chicks typically begin to wander from their nests and become impossible to associate with specific nests without marking (Carter and Hobson 1988, McChesney 1997). Results from 2018 were compared to prior long-term means for PRH (1997-2001, 2006-2015, 2017; n=16 years), DSRM (1997-2007, 2009-2017; n=20 years), and CHCC (1997-2001, 2006-2017; n=17 years).

Pelagic Cormorant, Black Oystercatcher, and Western Gull Productivity

We monitored productivity of Western Gulls and Black Oystercatchers at select subcolonies or subareas that were easily visible from mainland observation points at DSRM and CHCC. We also monitored productivity of Pelagic Cormorants at DSRM and CHCC. We checked nests at least once per week. We considered chicks fledged if they survived to at least 30 days. We used feathering status as a proxy for chick age if precise age was not known (i.e., chicks that were greater than 75% feathered were considered to have fledged). We compared results to long-term averages for DSRM (2006-2017; n=12 years) and CHCC (2006-2011, 2016-2017; n=8 years).

Pigeon Guillemot Surveys

To assess relative population sizes and seasonal attendance patterns, we conducted standardized counts from mid-April to late June for birds rafting on the water and roosting on land (intertidal and nesting areas) at PRH, DSCC and CHCC. We conducted surveys at all colonies between 30 minutes after sunrise and 0830 h and in Beaufort states <4. From mid-April to 5 May, when numbers often peak, we conducted surveys twice per week (weather permitting) and about once per week thereafter. At PRH, the area to the north and south of Point Reyes (PRH-01, 02, 03 and 04; Figure 2) was surveyed. On two occasions, we conducted counts at PRH in weather conditions (Beaufort 5) above protocol standard (Beaufort 3) because of consistently poor weather conditions. At DSCC, we surveyed the entire area from the south side of San Pedro Rock to the South Bunker (DSRM-04; Figures 3, 4).

Common Murre and Brandt's Cormorant Breeding Population Sizes

The University of California, Santa Cruz and CDFW conducted aerial photographic surveys of central California Common Murre, Brandt's Cormorant and Double-crested Cormorant colonies on 4, 5 and 7 June. Two photographers with digital SLR cameras photographed active colonies at the Farallon Islands and nearshore colonies between Point Reyes and Point Sur, from a Partenavia aircraft. We selected photographs to provide the most complete colony coverage with high quality imagery. We obtained counts from murre and Brandt's Cormorant colonies using Image Pro Plus software (Media Cybernetics, 2007). We individually counted all visible murres from each subcolony or subarea; these counts were summed to provide whole-colony counts. For further information on aerial photographic survey methods, see McChesney and Carter (1999), Carter et al. (2001), and Capitolo et al. (2014). To obtain murre breeding population size estimates, we applied a correction factor to the raw aerial photograph counts to account for breeding birds not present and non-breeding birds present at the time of the survey. We used the correction factor of 1.73 derived for murres in 2018 at nearby Southeast Farallon Island (Johns and Warzybok et al. 2019). It is not clear how appropriate the Farallon correction factor is for other colonies, but we believe it provides a reasonable estimate of breeding population sizes at most colonies and assists in making standardized comparisons.

For examining long-term patterns in breeding population sizes over time, we applied correction factors to past years counts from annual Southeast Farallon Island values provided by Point Blue Conservation Science (1985-2018) or from other sources for earlier years (e.g., Sowls et al. 1980, Briggs et al. 1983). Exceptions were for DSR in 1996-2007 when breeding population size estimates were derived from murre productivity monitoring at the colony (USFWS, unpubl. data).

For Brandt's Cormorants, we obtained whole-colony nest counts from aerial photographs of all monitored colonies as well as other nearshore colonies between Point Reyes and Año Nuevo

Island. Counts included territorial sites, poorly built nests, active well-built nests, nests with brooded chicks, abandoned nests (well-built nest with no birds present), and empty nests (well-built nest with no adult present). For further description of counting protocol and nest categories used for aerial photograph counting, see McChesney and Carter (1999) and Capitolo et al. (2014).

To examine long-term population trends, we plotted and fitted annual murre population estimates and cormorant nest counts at each colony (or colony complex) dating back to 1979 with a LOESS curve (R Core Team, 2018) and 95% confidence intervals. We determined linear trends for estimates from the 1999-2018 period using Generalized Linear Model with a Poisson distribution (or Quasi-poisson in cases of overdispersion; R Core Team, 2018). These years correspond to the period following the very strong 1997-98 El Niño and the shift to a colder water regime that persisted until the mid-2010s. Following several years of warm water conditions associated with the "blob" (2014-2016), cooler sea surface temperatures have returned in recent years.

To provide more complete breeding population estimates of Brandt's Cormorants, we compared peak subcolony and subarea counts from land-based surveys with aerial photograph counts. We then combined the higher counts between methods for each area to provide a combined population estimate (total number of nesting pairs).

RESULTS

Anthropogenic Disturbance

During the 2018 field season, monitoring effort across PRH, DSCC and CHCC totaled 1381.3 on-site hours (Table 2). There were 111 aircraft observed (detection and disturbance events combined) within our monitoring areas at PRH, DSRM and CHCC combined; these included 64 planes, 38 helicopters, 8 drones and one unknown aircraft (Tables 3, 4). Overall, 59 of these overflights resulted in disturbance to seabirds (e.g. agitation, displacement or flushing). A total of 35 planes, 21 helicopters, two drones and one unknown aircraft caused disturbance. Twelve helicopters and four planes caused displacement and/or flushing of murres. The most frequently detected aircraft categories were general aviation planes (also referred to as private recreational) and general aviation helicopters (or private recreational), while most disturbances were caused by general aviation planes, USCG helicopters, and general aviation helicopters (Figure 8; Appendix 1). Two drones caused agitation disturbances at CHCC; this was the first time we have observed drones causing a disturbance at any of the three monitored colonies. At PRH from 2005-2018, there were no significant trends in detection or disturbance rates of aircraft; however, there was a significant declining trend in the long-term annual change of detection rates of all sources (plane, helicopter, drone, unknown, and watercraft) combined (Table 3). There were significant declining trends in the change of annual plane and helicopter detection rates between 2005-2018 at DSRM but no significant trends in annual aircraft detections or disturbance rates at CHCC (Table 3 and 4).

There were 41 total watercraft observed within 1,500 feet of monitored colonies, including 35 recreational fishing boats, two Search and Rescue boats, and four charter boats (Appendix 2). The only watercraft that caused a disturbance was a Search and Rescue vessel, which caused flushing of Brandt's Cormorants at DSCC (Figure 9, Appendix 2). There were significant declining trends in the annual change of watercraft detection rates at PRH and in the change of annual watercraft disturbance rates at PRH and DSRM (Table 3). There were no significant trends in annual watercraft detection or disturbance rates at CHCC (Table 4). After the 2018 field season, it was discovered DSRM field staff during the 2015-2018 period may not have been recording all watercraft within our typical 1,500-ft detection zone, although they were recording all observed watercraft estimated to be within the Devil's Slide Rock Special Closure and all watercraft disturbances. Due to these inconsistencies in data recording, results of watercraft detections at DSRM should be considered a minimum estimate and comparisons to previous years should be considered with caution.

A total of 51 Wildlife Disturbance Reports were submitted to the SPN in 2018 (ten from PRH, 38 from DSCC and three at CHCC). This included 17 reports of flushing and/or displacement and 34 reports of agitation. Fifty of the reports involved aircraft disturbance, and one involved watercraft disturbance.

We recorded 13 watercraft that were estimated to have entered Special Closures in 2018. Twelve of these occurred at DSR and one occurred at PRH, but no disturbance was caused during any of these events. We reported all Special Closure violations to the SPN and CDFW.

Point Reyes Headlands

We detected 36 aircraft and 12 watercraft at PRH in 2018 (Table 3; Figures 10, 11). There were 17 events that caused disturbances to murres (two flushing events and 15 agitation events), all of which were caused by aircraft. The 2018 combined aircraft disturbance rate was 0.03 disturbances/hr, the second highest rate recorded since monitoring began in 2005. There were no watercraft disturbances at PRH in 2018. There was a significant declining trend in the annual change in the detection rate of watercraft (-18.5% annual change, $P=0.003$) and in the detection rate of all sources combined (-10.2% annual change, $P=0.03$). There was also a significant declining trend in the annual change of the disturbance rate of watercraft at PRH (-21.7% annual change, $P<0.001$; Table 3 Appendix 3).

Devil's Slide Rock and Mainland

In 2018 at DSRM, 39 overflights resulted in disturbance to seabirds (Table 3; Figures 10, 11). Twenty-three planes and 16 helicopters caused disturbances. The rate of disturbance events involving displacement and/or flushing of seabirds (0.03 disturbances/hr) was higher than in 2017, but analysis of long-term trends showed a significant declining trend in annual change in the rate of detection of helicopters (-6.7% annual change, $P=0.03$) and planes (-12.0% annual change, $P=0.05$; Table 3). There were 13 total flushing events caused by aircraft, including five general aviation helicopters, three law enforcement helicopters, two general aviation planes, one military helicopter, one USCG helicopter and one charter plane (Appendix 1). The largest disturbance event was on the second day of field crew training when a general aviation helicopter caused 1800 murres to be agitated and 40 murres to flush (Table 5). The only watercraft disturbance occurred on the first day of field crew training when a Search and Rescue watercraft flushed Brandt's Cormorant's from DSM. We detected twenty-eight other watercraft within 1500 ft of the colony; however, as noted above, this total should be considered a low estimate because of observer inconsistencies data recording. There was also a significant declining trend in the annual change of disturbance rates for watercraft at DSRM (-25.3% annual change, P=0.004, Table 3, Appendix 5).

The annual Pacific Coast Dream Machines event took place on 29 April 2018 at the Half Moon Bay Airport. Weather conditions were overcast with a high cloud ceiling [>1000 ft (304.7 m)] and calm throughout the day. We stationed observers at the observation point for DSR from 0755 h to 1600 h to record overflights and disturbance events. Two prop planes and one helicopter caused flushing of murres and ten additional planes caused agitation. One additional plane entered the detection zone [1000 ft (304.7 m) above sea level, 1500 ft (457.2) horizontal distance] but did not cause a disturbance. We observed fifty-two additional aircraft outside the detection zone. Since dedicated observation during the Dream Machines event began (2005) there has been a significant declining trend in annual change of aircraft detection rates (-14.2% annual change; P=0.04) but no significant trend in annual change of disturbance rates. As in previous years, SPN staff located at the Half Moon Bay airport provided outreach to pilots during the event.

Castle-Hurricane Colony Complex

In 2018, we observed five drones, eleven helicopters, six planes, and one watercraft within the detection zones at CHCC with disturbance to seabirds occurring during three aircraft events. The rate of disturbance events involving displacement and/or flushing of seabirds (0.003 disturbances/hr) was significantly higher than in 2017 (Table 4; Figures 10, 11). A pair of military helicopters caused the only observed flushing event (Appendix 1). This was the largest disturbance event at CHCC and flushed 35 murres while agitating 200 other murres (Table 6). The first drone disturbance observed by the CMRP occurred at CHCC on 25 April and caused agitation of 350 murres. The same drone caused a second, smaller disturbance on the same day. Members of the public launched drones from Highway 1 pullouts. There was no significant trend found for the annual change in detection or disturbance rates for aircraft or watercraft detections and disturbances rates observed at CHCC (2005-2018; Table 4).

Non-Anthropogenic Disturbance

Point Reyes Headlands

Avian Disturbance Surveys

We conducted avian disturbance surveys at LHR (PRH-03-B) for 98.9 hours. The non-anthropogenic disturbance rate during this period was 8.4 disturbance events per hour, with an average of 16.0 disturbance events per survey. This was the greatest disturbance rate in 2018 among PRH, DSRM and CHCC. Western Gulls caused the greatest number of disturbances at PRH, followed by Common Ravens (*Corvus corax*) and Turkey Vultures (*Cathartes aura*) (Table 7). During surveys, flying over the colony by these species was the most common cause of agitation behaviors in murres. Also, Western Gulls and Common Ravens depredated twelve murre eggs and three chicks during avian disturbance surveys (Table 7, Figure 12).

Incidental Non-Anthropogenic Disturbance

We recorded incidental non-anthropogenic disturbance from all observation overlooks including LHR (PRH-03-B). The largest incidental non-anthropogenic events occurred on 9 May and 15 May and were the result of Brown Pelicans (*Perecanus occidentalis*) landing on LHR. Combined, these events resulted in 37 eggs exposed, one egg displaced, and 19 depredated eggs. The numbers of murres flushed or displaced during each event ranged from 800 to 2700.

Devil's Slide Rock and Mainland

Avian Disturbance Surveys

At DSR, we conducted avian disturbance surveys for 90.9 hours. The non-anthropogenic disturbance rate during these observations was 0.6 disturbance events per hour. Common Ravens caused the highest rate of disturbance events and accounted for 63% of all the events during the season (Figure 12). Ravens also depredated or directly caused the loss of five murre eggs during. Brown Pelicans and Western Gulls caused additional disturbance events (Table 8). Also, a Northern Gannet (*Morus bassanus*) was observed displacing Brandt's Cormorants on two occasions.

Incidental Non-Anthropogenic Disturbance

We recorded incidental non-anthropogenic disturbance from all DSRM overlooks. Brown Pelicans were responsible for all of the recorded incidental non-anthropogenic disturbance events, the largest of which occurred on 10 May when 100 murres were displaced and 300 murres were flushed. We suspect that the Northern Gannet that was observed displacing Brandt's Cormorants on DSR also caused disturbance to nesting Brandt's Cormorants on DSM and caused the abandonment of several nests. Although we did not observe a direct disturbance, we observed the gannet scavenging Brandt's Cormorant chicks from abandoned nests on DSM.

Castle-Hurricane Colony Complex

Avian Disturbance Surveys

At Castle Rocks (CRM-04), we conducted 45 avian disturbance surveys for 86.8 hours. The non-anthropogenic disturbance rate during this period was 0.6 disturbance events per hour. Western Gulls caused the greatest number of disturbance events and were responsible for 52% of all events. Brown Pelicans flying over caused the second highest number of disturbance events (33% of all events). Thirty-two of the 54 disturbance events observed were characterized as flushing or displacement events (Figure 12). The largest event was a Peregrine Falcon flying over that occurred on 2 July and caused agitation of 500 murres. During avian disturbance surveys, no eggs or chicks were observed exposed, displaced or taken (Table 8).

Incidental Non-Anthropogenic Disturbance

At CHCC in 2018, there were no major incidental, non-anthropogenic disturbance events that were recorded. We did not observe any eggs or chicks exposed or taken during the 2018 season.

Common Murre Seasonal Attendance Patterns

Point Reyes Headlands

In 2018, we confirmed all well-established murre nesting areas that had active breeding at PRH. The date of peak counts at subcolonies ranged from 17 April to 15 July. All count plots on LHR (PRH-03-B) and Cone Rock (PRH-14-CP) had peak attendance counts prior to the first egg lay date from our monitored plots on LHR (11 May). All active count areas in PRH-10 and PRH-11 had later peak counts, ranging from 18 June to 15 July. Of the active subcolonies, 79% were no longer attended by the last colony count on 12 August, and the first observations of unattended subcolonies ranged from 22 July to 14 August. (Figures 13-17).

Seasonal attendance at PRH-03-B plots Dugout, Edge, and Ledge as well as Cone (PRH-13-CP) plots reflected long-term patterns. However, we did not observe murre attendance at Boulder Plot (PRH-05-BP) until 7 May, well outside the confidence interval for early season attendance although earlier attendance may have gone undetected; departure from Boulder at the end of breeding season was consistent with the long-term pattern.

Bird Island

Surveys were conducted at Bird Island from 14-26 April and 14 June to 13 August 2018, based on volunteer availability. Murres were observed on 43% of observation days. The average number of murres observed on days when they were present was four (range = 2-7, n = 7 days). Murres continued to use the small area under the last remains of a former U.S. Navy Compass House, on the far western end of the rock. Overall, fewer murres were counted in 2018 compared to 2017. No eggs or chicks were observed at Bird Island in 2018.

Devil's Slide Rock, Mainland and San Pedro Rock

Devil's Slide Rock

We observed murres on all count days between 16 April and 13 August 2018. Murres were completely absent from the rock on 14 August following the end of breeding activity (Figure 18). The maximum count of 1,575 murres occurred on 18 April during the pre-egg-laying period (first egg observed on 16 May) and was 9% more than the 2017 peak count of 1,438 murres. During the pre-lay period, murres often departed DSR in large numbers in the afternoon. Brown Pelicans caused several disturbances in the pre-lay and early incubation periods that caused several low attendance counts. On 10 May, we observed four pelicans that caused 300 murres to flush before the count and at least partly resulted in the lowest count. Attendance patterns became more consistent from 4 June through the incubation and early chick periods. From 4 June to 20 July counts maintained an average of 1,119 (range: 885-1,297) murres and by 28 July numbers started to steadily decrease as chicks fledged. Seasonal attendance was relatively similar to long term patterns (2008-2017) except that counts were consistently greater in 2018 (Figure 18); this reflects both increased colony size over earlier years and perhaps a change in count methodology in 2018 from real-time counts through spotting scopes to counts from photographs. Counts from photographs appear to be much less variable than counts using a spotting scope.

Devil's Slide Mainland and San Pedro Rock

We observed murres attending Lower Mainland South (DSRM-05-A Lower) and intermittently amongst nesting Brandt's Cormorants at other Mainland South subareas (DSRM-05-A Roost, DSRM-05-A Upper, DSRM-05-AF and DSRM-05-C). An average of 43 murres attended at DSRM-05-A Lower from 2 May until 6 August. Seasonal attendance at mainland subcolonies in 2018 reflected long-term patterns (2008-2017), with relatively high attendance in May and lower attendance later in the season. One breeding pair successfully fledged a chick, and was the first successful breeding attempt on DSM since 2015. We did not observe murres on San Pedro Rock in 2018.

Castle/Hurricane Colony Complex

Attendance counts at CHCC subcolonies began on 17-18 April. Murre attendance across subcolonies was variable. At some areas, attendance in 2018 reflected long-term patterns with minor deviations (Figure 19) such as earlier than normal departure from CRM-04 Plot that resulted from early chick fledging. Peak counts at several subcolonies between late June and late July likely reflected visitation by sub-adult prospecting birds; high attendance in late July at CRM-02 and CRM-05 was later than the typical peak in other years (Figures 20, 21). At CRM-03B, early season attendance followed by abandonment in mid-June was typical of recent years at this subcolony.

Common Murre Productivity

Point Reyes Headlands

We monitored a combined 190 sites in Ledge (n = 109) and Edge plots (n = 81) on LHR, of which 145 were breeding sites, 38 were territories, and seven were dropped due to poor viewing conditions. The first egg we observed was outside of monitored plots on 9 May. The mean egg-laying date (exclusive of replacement eggs) for Edge and Ledge plots combined was 22 May (range = 11 May – 18 June; n = 123; Table 9), which was five days earlier (outside two standard errors) than the long-term mean (27 May ± 1.9 days). We observed 28 replacement eggs in Edge and Ledge Plots. Overall productivity was 0.74 chicks fledged per pair, which was above average) and the greatest recorded since 2010 and (1996-2017; Figure 22). Productivity was influenced by both high hatching (72.7%) and fledging (95.5%) success. Chicks fledged at an average age of 24 ± 0.8 days (n = 107), and the last chick was observed on 13 August.

Devil's Slide Rock and Mainland

Of 201 sites documented within DSR plots, 189 (94%) were breeding, eight (4%) were territorial, and four (2%) were sporadic. We observed the first murre eggs on 16 May, in productivity plots A and B. At all sites combined, the mean egg-laying date (exclusive of replacement eggs) was 26 May ± 0.3 days (range = 16 May – 16 June, n = 189; Table 10), which is consistent with (within two standard errors) the long-term average (26 May ± 1.8 days). We recorded 191 eggs laid, including four replacement eggs. Overall productivity of 0.82 chicks fledged per pair was above the long-term mean (0.66 ± 0.05; Table 10, Figure 22). High productivity was influenced by 85% hatching success and 96% fledging success. Chicks that fledged remained on DSR for an average of 24 ± 4.3 days (n = 155), and the last chick was seen on 29 July.

Fifteen egg laying sites were monitored on DSM; however, only one egg hatched and successfully fledged. We observed the chick for 23 days and last saw it on 24 July.

Castle-Hurricane Colony Complex

Of 105 total monitored sites in the CRM-04 plot in 2018, 96 (91.4%) were breeding and nine (8.5%) were territorial. We observed the first egg on 11 May. The mean egg-laying date was 20 May ± 0.75 days (range = 11 May – 20 June; n = 93), five days later than the long-term mean of 15 May ± 2.2 days (Table 9). No replacement eggs were observed. Overall productivity at CRM-04 was 0.53 chicks per pair, similar to the long-term mean (Figure 22). Chicks that fledged remained for an average of 22 ± 3.07 days (n = 51) after hatching, and the last chick was seen on 13 July Table 9).

In 2018, we did not monitor productivity at subcolony CRM-03-B. We confirmed breeding, but did not observe chicks.

Brandt's Cormorant Nest Surveys and Productivity

We reported seasonal peak nest counts of Brandt's Cormorants obtained from weekly land surveys and aerial surveys in Table 10. In most cases, not all nests were visible from our observation points, so nest counts should be considered a minimum. Consequently, comparisons to previous years should also be considered with caution. Aerial counts tend to be more complete than other methods where views could be obscured.

Point Reyes Headlands

Nest surveys

Well-built nests were recorded at Hooves (PRH-07-A), on the mainland of PRH-08, Chip Rock (PRH-11-A), Face Rock (PRH-11-B), Wishbone Point (PRH-11-E), several subareas of Cone Rock (Cone Shoulder, , Cone Upper, West Cone, and an unnamed section), Border Rock (PRH-14-C) and PRH-14-E. The single-day count of nests for all subcolonies combined was 156 nests on 15 July; however, aerial surveys indicated that a high number of breeding sites were out of view from mainland observation points. The sum of the seasonal peak counts from land based surveys for each subcolony was 179 nests, 27% lower than in 2017 (245 nests; Table 10). From photographs obtained during aerial surveys on 5 June, we counted 328 Brandt's Cormorant nests, which was 43% higher than the 230 nests counted in 2016. Comparisons between aerial surveys and land-based surveys resulted in a total count of 346 Brandt's Cormorant nests at PRH (Table 10).

Productivity

At PRH, we monitored 122 nests at eight subareas, all of each were egg-laying sites (Table 11). We began monitoring after nest initiation at the following colonies: Hooves (PRH-07-A) began on 30 April; Face Rock (PRH-11-B) on 27 May, Wishbone Point (PRH-11-E) on 21 May, Cone Shoulder (PRH-13-CS) on 25 April, Cone Upper (PRH-13-CU) on 4 May, West Cone (PRH-13-WC) on 17 May, an unnamed section of Cone (PRH-13) on 25 April and PRH-14-E on 23 April. For all subareas combined, the average clutch initiation date was 18 May ± 1.4 (range = 24 April – 30 June, n = 115; Table 10). The first chick hatched on 29 May. Overall productivity of 1.96 chicks fledged per pair (subarea range = 0 – 3.0) was near average (1.80 ± 0.2; Figure 23). Breeding success (nests that fledged at last one chick) per nest was 86% (subarea range = 0 – 1.0, Table 11). There were three replacement clutches.

Bird Island

Surveys were conducted at Bird Island from 14-26 April and from 14 June to 13 August 2018. Roosting Brandt's Cormorants were present predominately during the middle and end of the season (14 June–13 August), with counts ranging from 0 to 209 roosting birds. No Brandt's Cormorant nests were established on Bird Island and we suspect no breeding occurred in 2018.

Devil's Slide Rock and Mainland

Nest surveys

We counted nests and territorial sites between 16 April and 3 July. The first well-built nests were recorded on 23 April. The peak count of nests on DSR was 19 nests on 29 May. On the mainland, nesting occurred on Mainland North (DSRM-02-MN; peak count of five nests), April's Finger (DSRM-05-AF; peak count of one nest), Lower Mainland South (DSRM-05-A-Lower; peak count of 41 nests), Mainland South Roost (DSRM-05-A-Roost; peak count of four nests); Upper Mainland South (DSRM-05-A-Upper; peak count of three nests), Turtlehead (DSRM-05-B; peak count of nine nests), and South of Turtlehead Cliffs (DSRM-05-C; peak count of two nests).

The peak single day count for DSRM combined was 45 nests on 25 June, 59% less than the 2017 peak count (105 nests). The sum of the seasonal peak counts at each nesting area was 86 nests (Table 10), 27% less than the 2017 seasonal peak count sum of 118 nests.

From aerial surveys, 159 Brandt's Cormorant nests were counted. Of these, 92 nests could not be seen from mainland vantage points. Thus, by combining aerial and land-based surveys we obtained a total count of 174 nests at DSRM (Table 10).

Productivity

We monitored 95 breeding sites at DSRM in 2018, including nests on DSR (DSRM-01), Lower Mainland South (DSRM-05-A Lower), April's Finger (DSRM-05-A-AF) and Turtlehead (DSRM-05-B; Table 10). We observed the first egg on Turtlehead on 8 May. For all subareas combined, the mean clutch initiation date was 12 May ± 2.7 days (range = 8 April to 19 July). Overall productivity of 1.3 chicks fledged per pair (subarea range = 0–3; n = 90) was below average (Figure 23). There were nine replacement clutches.

Castle-Hurricane Colony Complex

Nest surveys

We conducted Brandt's Cormorant nest surveys from 17 April to 10 July. Subcolonies or subareas with confirmed breeding in 2018 were CRM-03-A, CRM-06-AN, CRM-06-BS, CRM-07, BM227X-02, and BM227X-03. We observed the first well-built nests on 17 April at CRM-03-A, BM227X-02 and BM227X-03. At all CHCC subcolonies combined, we recorded the peak single nest count survey of 112 nests on 31 May, which was 48% lower than the 2017 peak count of 214. The sum of the seasonal peak subcolony counts was 148 nests, 36% fewer than the 2017 count of 231 nests.

From aerial photographic surveys, 334 nests were counted (Table 9). Of these, it was determined that 191 nests could not be seen from mainland vantage points. By combining aerial and land-based counts, we for a complete count of 339 nests. In 2018, we counted no Brandt's Cormorant nests at HPR, unlike 2017 when we counted 82 nests.

Productivity

We monitored Brandt's Cormorant productivity on CRM-06-AN and CRM-07 (Table 12). The mean clutch initiation date was 21 May ± 2.0. We observed the first chick on 3 June. The overall productivity at CRM of 0.48 chicks fledged per pair (subcolony range = 0–3.0; n = 27) was less than the long-term average of 1.8 ± 0.2 (Figure 23). Breeding success per nest of 0.19 reflected a high rate of nest abandonment (Table 12).

Pelagic Cormorant, Black Oystercatcher, Western Gull, and Pigeon Guillemot

Nest and bird surveys

We summarized seasonal peak counts of nests (Pelagic Cormorant, Western Gull, and Black Oystercatcher) or birds (Pigeon Guillemot) from land-based observations and aerial surveys in Table 10. Pelagic Cormorant nesting areas typically vary from year to year and often nests are not be visible from land-based vantage points. Because of this, nest counts should be considered a minimum estimate and comparisons to previous years should be considered with caution. For Pelagic Cormorants, we were also able to record some nests at DSRM and CHCC from aerial photographs that could not be seen from mainland vantage points. By comparing aerial and land-based counts, we obtained total counts of 16 nests and 21 Pelagic Cormorant nests at DSRM and CHCC, respectively.

For Pigeon Guillemots, the 2018 peak standardized count at PRH was 145 birds on 18 April. The 2018 peak standardized count at DSRM was 192 guillemots on 26 April, which was 4% more than the 2017 count. At CHCC, the peak standardized count was 67 guillemots on 18 April, which was 116% higher than we observed in 2017 (Table 9).

Productivity

We conducted productivity monitoring for Western Gulls, Black Oystercatchers and Pelagic Cormorants at DSRM and CHCC.

Pelagic Cormorant

At DSRM, we monitored Pelagic Cormorant productivity at DSRM-05-D and DSRM-05 Lower. The first egg was recorded on 15 May. Overall productivity of 1.57 chicks fledged per pair was similar to the long-term mean (1.5 ± 0.2; Figure 24). At CHCC, we monitored Pelagic Cormorant productivity on CRM-04 and CRM-07 and we observed the first egg on 5 May. Productivity at CHCC was 1.0 chicks fledged per pair (n=4) which was higher than the long-term mean (0.63 ±0.17; Figure 24) and was the highest productivity recorded since 2011.

Western Gull

Gull productivity at both DSRM and CHCC was 1.5 chicks fledged per pair, although sample sizes were small (n = 2, DSRM; n = 6, CHCC). Productivity values at both colonies were above long-term means (DSRM, 0.64 ±0.1; CHCC, 0.55 ±0.11; Figure 25) and were the highest since monitoring began in 2006.

Black Oystercatcher

CHCC was the only colony with followed nests in 2018. Productivity at CHCC was monitored at all five nests discovered. Two nests hatched and fledged chicks and one pair had two separate breeding attempts, neither of which hatched any young. Overall productivity was 0.6 chicks fledged per pair (n = 5).

Breeding Population Sizes

We obtained counts from aerial photographs from all nearshore murre and Brandt's Cormorant colonies within the Gulf of the Farallones region, as well as CHCC farther south. Because of their greater completeness in comparison to land-based surveys, we use aerial photographic surveys for standardized estimates of breeding population sizes and trends of these species in the California Current System (CCS).

Common Murre

Raw bird counts of Common Murres were obtained from aerial survey photographs. To estimate breeding population sizes, a correction factor of 1.73 was applied to all 2019 counts (see Methods). Long-term patterns of population sizes for the period 1979-2018, using population estimates, are presented in Figures 25-27. Nearly all colonies have shown recovery since the large declines of the mid-1980s, including significant increases since 1999.

Point Reyes Headlands

From photographs obtained on aerial surveys conducted at PRH on 5 June, we counted 37,459 murres. Applying the correction factor yielded an estimated breeding population size 64,804 birds (Table 10), or about 32,402 breeding pairs. Aerial surveys were not conducted at PRH in 2017 but count estimates in 2018 were 12% higher than the most recent estimate from 2016 (57,150 murres). PRH has shown a significant increasing trend in breeding population size since 1999 (Figure 26) and numbers of murres have been fairly stable since 2011.

Drakes Bay Colony Complex

Aerial surveys were conducted at three Drake's Bay colonies on 5 June (Table 9). Numbers at PRS and DPR have been relatively stable since about 2011. MPR was the only colony in the region that showed decline. Only one bird was recorded from the aerial survey. An opportunistic land-based count on 14 July 2018 found 27 murres on MPR North Rock (MPR-01 among nesting Brandt's Cormorants) these murres may have been late season prospectors. Likely, the correction factor applied to estimate breeding population size provides an overestimate for the MPR colony. Land-based monitoring of MPR in 2005-2015 showed that murre attendance was highly variable from year to year and even seasonally; most birds did not breed and often abandoned the colony early in the breeding season.

Bird Island

We did not conduct aerial surveys of Bird Island in 2018.

Devil's Slide Colony Complex

From photographs obtained during the aerial survey on 4 June, 1,676 murres were counted on DSR (Table 10). Applying the correction factor to the aerial survey count yielded an estimate of 2,899 breeding murres, or about 1,450 breeding pairs (Figure 27). This estimate is nearly identical to the estimate calculated in 2017 (2,906 murres). Since 2012, aerial counts of DSR have been similar to the historic estimates of 2,300-2,923 breeding birds in 1979-1982 prior to colony extirpation (Sowls et al. 1980, Briggs et al. 1983, Carter et al. 2001). DSR has shown a significant increasing trend in breeding population size since 1999 (Figure 27). During the aerial surveys, we counted an additional 56 murres on DSM and none on SPR.

Castle-Hurricane Colony Complex

From photographs obtained during the aerial survey on 6 June (Table 10), we counted 4,624 murres within CHCC. Applying the correction factor to this count yielded 8000 breeding murres, including 2,062 at HPR and 5,937 at CRM. Both colonies within CHCC show significant increasing trends for the 1999-2018 period and have largely recovered from declines in the mid-1980s (Figure 28).

Brandt's Cormorant

Breeding population trends of Brandt's Cormorants at four colony complexes based on aerial photographic surveys are shown in Figure 29. Breeding population sizes have varied considerably since monitoring began in 1979 (Capitolo et al. 2014). Over the last two decades, cormorant numbers first increased dramatically during the 2000-2007 period, then declined rapidly in relation to a decline in the prey base (Ainley et al. 2018). In recent years, Brandt's Cormorant numbers have largely recovered to about average long-term values at most colonies.

DISCUSSION

Anthropogenic Disturbance

As has been typical in most years of our study, DSRM experienced higher anthropogenic detection rates and disturbance rates than either PRH or CHCC. Although aircraft detection and disturbance rates may have been slightly greater in 2018 than the last few years, rates are lower than earlier years (2005-2012) of the project, with declining trends in plane, helicopter, and all aircraft (combined) detection rates. Graphically (see Figures 10, 11), patterns appear similar for disturbance rates at DSRM but sample sizes may be too small to detect a significant trend. Disturbance and detection rates during the Pacific Coast Dream Machines event were higher in 2018 than we have observed since 2015; however, there continues to be a significant declining trend in the annual change of detection rates during the event. The increased detection and disturbance rates we observed in 2018 indicate the continuing need for the GFNMS SPN outreach staff presence during the event.

At PRH, plane and helicopter detection and disturbance rates were the highest observed in several years, contrary to the trend of declining annual change in overall detection rates at PRH. However, detection and disturbance rates at PRH were still considerably lower than at DSRM. Unlike PRH and DSRM, helicopters surpassed planes as the main contributor to detection and disturbance rates at CHCC. In 2017, somewhat higher rates of helicopter detections were attributed to the Highway 1 road closure (Bednar et al. 2018); however, helicopter activity in 2018 appeared to be similar to 2017. The increasing use of drones by the public launched from Highway 1 pullouts adjacent to CHCC should be monitored; further increases could lead to disturbance issues in the future.

Although 13 Special Closure entries by watercraft were recorded in 2018, including 12 at DSR, there was only one disturbance event from watercraft observed across all three colonies. At both PRH and DSRM there continues to be significant declining trends in the annual change of watercraft disturbance rates. No watercraft disturbances have been recorded at CHCC since 2015. Although these patterns suggest that boaters are increasingly aware of Special Closures and appropriate behavior around sensitive seabird nesting colonies, the fairly high number of Special Closure entries at DSR in 2018 indicates that outreach efforts are still needed. Continued communication between field staff and CDFW wardens and prompt enforcement of Special Closures, as well as continue GFNMS SPN outreach will hopefully reduce the numbers of future violations and associated disturbances.

Non-Anthropogenic Disturbance

Results from avian disturbance surveys varied widely between PRH, DSRM and CHCC. Disturbance rates at PRH were over 15 times greater than at either DSRM or CHCC. Although Western Gulls caused the large majority of avian disturbance events PRH, Brown Pelicans, Common Ravens, and Turkey Vultures also contributed relatively large numbers of disturbance events. Incidentally, recorded disturbances by Brown Pelicans resulted in at least 20 lost murre eggs. Common Ravens also caused relatively high numbers of disturbance events at both PRH and DSRM, with multiple egg predation events at each colony.

At DSR, the large majority of avian disturbances were from Common Ravens, including several eggs taken. Raven disturbance and predation at DSR appears to be from one pair of birds that are suspected to be nesting somewhere nearby. However, despite high predation rates at both PRH and DSR, murre productivity was greater than the long-term average in 2018.

Attendance and Reproductive Success

Common Murre seasonal attendance, colony extent, and breeding population estimate (based on aerial photographs) at DSR shows relatively stable numbers over the last six years following 15 years of substantial growth. Colony growth resulted from social attraction efforts that led to the recolonization of this formerly extirpated colony (Parker et al. 2007). The stabilizing of the colony at breeding numbers similar to the 1979-1982 period may indicate colony saturation, although some apparently suitable habitat remains on the north side of the rock. Numbers at most other Gulf of the Farallones murre colonies have similarly leveled off in recent years, although murre numbers at CHCC may still be growing. Annual Brandt's Cormorant breeding population sizes and even colony locations tend to be more variable than for murres. Based on aerial photographic surveys, most central California colonies have largely recovered to near "normal" numbers following a dramatic decline in 2008-2010.

In 2018, murre breeding was earlier than average at PRH, consistent with the average at DSR, and later than average at CHCC. Late breeding often is associated with low breeding success (Boekelheide et al. 1990). Although CHCC breeding was later than average, productivity was consistent with the long-term average; productivity at CHCC is generally lower than at PRH or DSR. Productivity at both PRH and DSR were above the long-term average. For PRH, murre productivity was the highest we have recorded since 2000; at Edge Plot, productivity was the highest ever recorded during our study. For DSR, 2018 continued a long-standing pattern of high breeding success for murres.

Similar to murres, Pelagic Cormorants and Western Gulls had high breeding success in 2018. However, Brandt's Cormorant breeding success was near average (PRH) compared to below average at our monitored colonies (DSRM, CHCC). In comparison to our nearshore colonies, monitoring at the nearby but offshore South Farallon Islands found that productivity for murres was near average, Brandt's Cormorants were above average, and Pelagic Cormorants were below average (Johns and Warzybok 2018).

Overall, high and near average productivity of most species in 2018 is consistent with observations in 2017 following the shift to El Niño neutral conditions and the dissipation of the "blob" (McClatchie et al. 2016). Conditions in the CCS were classified as neutral or weak El Nino (Harvey et al. 2019) in 2018. At the offshore Farallon Islands, the mean seasonal SST (March-August) was near or below average in 2018 (Johns and Warzybok 2018).

Similar to 2017, central California fisheries data in 2018 indicated abundant anchovy, juvenile sardine, and market squid, but low abundance of adult sardine (Harvey et al. 2019). Juvenile rockfish, although more abundant than in the mid-2000s, were less abundant then recorded from 2013-2017 (Harvey et al. 2019). Murres and Brandt's Cormorants at the Farallon Islands primarily fed anchovies to their chicks, and there was a decline in the frequency of juvenile rockfish observed compared to 2017 (Johns and Warzybok, 2018). Prey use among Gulf of the Farallones colonies likely overlaped to some extent but differences in foraging ecology between nearshore and Farallon Islands colonies has not been investigated. Such information would be highly insightful for describing differences among colonies.

Recommendations for Future Management, Monitoring and Research

• Outreach and education efforts targeting aircraft and watercraft user groups should be continued and adapted to changing sources and characteristics of disturbance.

• The Devil's Slide pedestrian trail was completed in March of 2014, and the 2018 field season marked the fifth year of pedestrian access to the span of road above DSM. While no pedestrian-related disturbances were recorded, monitoring should be continued to detect any new or different types of potential disturbance. The presence of thousands of visitors throughout the seabird season provided a great opportunity for outreach.

• Annual aerial photographic surveys are the best means to monitor breeding population trends of Common Murres, Brandt's Cormorants and Double-crested Cormorants. While surveys of central California murre and Brandt's Cormorant colonies continued in 2018 in cooperation with University of California, Santa Cruz, USFWS Migratory Birds, and CDFW, sustained funding is not currently available and the continuation of this long and valuable dataset is at risk. A steady source of funds should be found so that these surveys are continued annually.

• As the numbers and densities of murres on monitored breeding colonies increase, continued evaluation of monitoring methods for productivity (especially at DSR) will be necessary. This will include adjustments to plot boundaries and elimination of sites that are difficult to view.

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Table 1. Behavior categories used to record disturbances in standardized non-anthropogenic disturbance surveys. Each behavior is described as either occurring in the air or on land and as either an active or passive action.

Behavior	Behavior Description
Presence	Causing a disturbance to the colony just by presence, not actively harassing (Land, Passive)
Ground harass	Walking through the colony in a threatening manner (Land, Active)
Lunge	Lunging at COMU with beak (Land, Active)
Pull	Pulling a COMU by the wing, foot or beak (Land, Active)
Snatch	Snatching an unattended or poorly guarded egg or chick without driving the parent off the site (Land, Active)
Easy picking	Taking unattended eggs or chicks following a flushing event (Land, Active)
Scavenging	Consuming an abandoned egg, dead chick, or dropped fish (Land, Passive)
Flyover	Flying over a colony without pause (only recorded if it causes a disturbance) (Air, Passive)
Air lunge	A flying predator lunges at a COMU on the ground (Air, Active)
Air hovering	Hovering over a colony (Air, Passive)
On the wing	Taking a flying adult COMU from the air (Air, Active)
Air attack	Chasing a flying adult COMU from air (Air, Active)

Table 2. Monitoring effort of study colonies or colony complexes, April 2018 to August 2018.

Colony/Colony Complex	Start date	End date	Observation Days	Total hours
Point Reyes Headlands	4/13/2018	8/14/2018	115	606
San Pedro Rock	4/17/2017	8/17/2018	10	1.4
Devil's Slide Rock & Mainland	4/11/2018	8/17/2018	119	456
Castle-Hurricane Colony Complex	4/17/2018	7/27/2018	77	318

Table 3a. Total detected watercraft and aircraft, and resulting disturbances to all seabirds (Common Murres, Brandt's Cormorants, and Brown Pelicans) at Point Reyes Headlands (PRH) and Devil's Slide Rock and Mainland (DSRM), 2018. Disturbances are number of alert, displaced, and flushed birds. Detection and disturbance rates reported as numbers per observation hour.

Disturbance Source	Total Detections	Detections/hr.	# Alert Birds	# Displaced Birds	# Flushed Birds	Total Disturbed/hr.[1]	Total Flushed or Displaced/hr.
Plane (PRH)	25	0.04	11	0	1	0.02	0.002
Helicopter (PRH)	9	0.02	3	0	1	0.01	0.002
Drones (PRH)	1	0.002	0	0	0	0	0
Unknown (PRH)	1	0.002	1	0	0	0.002	0
Aircraft Total (PRH)	36	0.06	15	0	2	0.03	0.003
Watercraft (PRH)	12	0.02	0	0	0	0	0
PRH Total	**48**	**0.08**	**15**	**0**	**2**	**0.03**	**0.003**
Plane (DSRM)	25	0.04	11	0	1	0.02	0.002
Helicopter (DSRM)	9	0.02	3	0	1	0.01	0.002
Drones (DSRM)	1	0.002	0	0	0	0	0
Unknown (DSRM)	1	0.002	1	0	0	0.002	0
Aircraft Total (DSRM)	36	0.06	15	0	2	0.03	0.003
Watercraft (DSRM)	12	0.02	0	0	0	0	0
DSRM Total	**48**	**0.08**	**15**	**0**	**2**	**0.03**	**0.003**

Table 3b.The percent annual change, 95% confidence intervals, and p-values results from Poisson or quasi-poisson regression statistics for annual change **in detection rates** (2005-2018) for Point Reyes Headlands (PRH) and Devil's Slide Rock Mainland (DSRM). No test for watercraft detection rate was completed at DSRM because of inconsistent data recording from 2005-2018. Only significant values shown.

Disturbance Source	Percent Annual Change	95% Confidence Interval	P-value
Watercraft (PRH)	-18.5%	(-27.3%) – (-9.9%)	0.003
PRH Total	-10.2%	(-18.0%) – (-2.4%)	0.03
Plane (DSRM)	-12.0%	(-22.2%) – (-1.5%)	0.05
Helicopter (DSRM)	-6.7%	(-10.4%) – (-2.9%)	0.03
Aircraft Total (DSRM)	-10.9%	(-19.5%) – (-2.0%)	0.04
DSRM Total	-10.9%	(-18.7%) – (-2.8%)	0.03

Table 3c.The percent annual change, 95% confidence intervals, and p-values results from Poisoon or quasi-poisoon regression statistics for annual change in **disturbance rates** (2005-2018) for Point Reyes Headlands (PRH) and Devil's Slide Rock Mainland (DSRM) watercraft. Only significant values shown.

Disturbance Source	Percent Annual Change	95% Confidence Interval	P-value
Watercraft (PRH)	-21.7%	(-33.0%) – (-10.7%)	<0.001
Watercraft (DSRM)	-25.3%	(-37.5%) – (-13.5%)	0.004

Table 4. Total detected watercraft and aircraft, and resulting disturbances to all seabirds (Common Murres, Brandt's Cormorants, and Brown Pelicans) at Castle-Hurricane Colony Complex (CHCC), 2018. Detection and disturbance rates reported as numbers per observation hour. Quasi-poisson regressions were run to access the annual change in detections and disturbance rates from 2005-2018. Percent annual change were not reported due to lack of significant trends.

Disturbance Source	Total Detections	Detections/hr.	# Alert Birds	# Displaced Birds	# Flushed Birds	Total Disturbed/hr.[1]	Total Flushed or Displaced/hr.
Plane (CHCC)	6	0.02	0	0	0	0	0
Helicopter (CHCC)	11	0.04	0	0	1	0.003	0.003
Drones (CHCC)	5	0.02	2	0	0	0.01	0
Aircraft Total (CHCC)	22	0.07	2	0	1	0.01	0.003
Watercraft (CHCC)	1	0.003	0	0	0	0	0
CHCC Total	**23**	**0.07**	**2**	**0**	**1**	**0.01**	**0.003**

Table 5. Number of disturbance events from anthropogenic sources and mean numbers (range) of Common Murres, Brandt's Cormorants, and all seabirds combined (as applicable) disturbed (agitated, displaced and/or flushed) and displaced/flushed at Point Reyes Headlands and Devil's Slide Rock and Mainland, 2018.

Species and Colony		Plane	Helicopter	Unknown Aircraft	Total
Common Murre (PRH)	Number of Disturbance Events	11	5	0	**16**
Common Murre (PRH)	Mean Number Birds Disturbed	2686 (500-5000)	2270 (500-4050)	0	**2556 (500-5000)**
Common Murre (PRH)	Number of Displaced/Flushed Events	1	1	0	**2**
Common Murre (PRH)	Mean Number of Birds Displaced/Flushed	300 (300-300)	300 (300-300_	0	**300 (300-300)**
Common Murre (DSRM)	Number of Disturbance Events	23	16	1	**40**
Common Murre (DSRM)	Mean Number Birds Disturbed	394 (80-100)	716 (200-1840)	30	**514 (30-1840)**
Common Murre (DSRM)	Number of Displaced/Flushed Events	3	10	1	**14**
Common Murre (DSRM)	Mean Number of Birds Displaced/Flushed	62 (5-150)	51 (10-120)	30	**52 (5-150)**
Brandt's Cormorant (DSRM)	Number of Disturbance Events	1	1	1	**3**
Brandt's Cormorant (DSRM)	Mean Number Birds Disturbed	6	17	150	**5 (6-150)**
Brandt's Cormorant (DSRM)	Number of Displaced/Flushed Events	1	1	1	**3**
Brandt's Cormorant (DSRM)	Mean Number of Birds Displaced/Flushed	6	17	150	**58**
Total DSRM Seabirds	**Mean Number Seabirds Disturbed**	**394 (80-1000)**	**718 (200-1857)**	**180**	**518 (80-1857)**
Total DSRM Seabirds	**Mean Number Seabirds Displaced/Flushed**	**64 (11-150)**	**53 (10-120)**	**180**	**64 (10-180)**

Table 6. Number of disturbance events and mean numbers (range) of Common Murres disturbed (agitated, displaced and/or flushed) and displaced/flushed at Castle-Hurricane Colony Complex, 2018.

Species and Colony		Plane	Helicopter	Watercraft	Drone	Total
Common Murre (CHCC	Number of Disturbance Events	0	1	0	2	**3**
Common Murre (CHCC)	Mean Number Birds Disturbed	0	235	0	200 (50-350)	**200 (50-350)**
Common Murre (CHCC)	Number of Displaced/Flushed Events	0	1	0	0	**1**
Common Murre (CHCC)	Mean Number of Birds Displaced/Flushed	0	35	0	0	**35**

Table 7. Number of disturbance events and mean numbers (range) of bird species disturbed (agitated, displaced and/or flushed) and displaced/flushed during avian disturbance surveys at Point Reyes Headlands, 2018. Brandt's Cormorant (BRAC), Brown Pelican (BRPE), Pelagic Cormorant (PECO), Peregrine Falcon (PEFA), Common Raven (CORA), Turkey Vulture (TUVU), Unknown Gull (GULL), Western Gull (WEGU).

	Brandt's Cormorant	Brown Pelican	Pelagic Cormorant	Peregrine Falcon	Common Raven	Turkey Vulture	Unidentified Gull	Wave	Western Gull	Total
Number of Disturbance Events	5	21	2	160	72	2	2	2	558	**824**
Mean Number Birds Disturbed	464 (5-2000)	1869 (200-5000)	260 (20-500)	1650 (800-2500)	866 (1-3750)	2428 (8-5000)	500 (500-500)	2500 (750-4250)	617 (1-4000)	**860 (1-5000)**
Number of Displaced/Flushed Events	3	2	0	0	41	23	0	0	76	**145**
Mean Number of Birds Displaced/Flushed	4 (3-5)	575 (350-800)	0	0	37 (1-755)	78 (3-290)	0	0	3 (1-21)	**33 (1-800)**
Number Eggs Exposed or Taken	0/0	0/0	0/0	0/0	0/6	0/0	0/0	0/0	0/6	**0/12**
Number Chicks Exposed or Taken	0/0	0/0	0/0	0/0	0/1	0/0	0/0	0/0	0/2	**0/3**

Table 8. Number of disturbance events and mean numbers (range) of Common Murres, disturbed (agitated, displaced and/or flushed; Dist.) and displaced/flushed during avian disturbance surveys at Devil's Slide Rock and Castle-Hurricane Colony Complex, 2018.

Disturbance at Devil's Side Rock Mainland	Brown Pelican	Common Raven	Western Gull	**Total**
Number of Disturbance Events	6	20	6	**32**
Mean # Birds Disturbed	503 (3-1000)	286 (28-752)	312 (2-800)	**332 (2-1000)**
Number of Displaced/Flushed Events	3	20	1	**24**
Mean Number of Birds Displaced/Flushed	106 (3-300)	38 (1-81)	1 (1-1)	**45 (1-300)**
Number of Eggs Exposed or Taken	0/0	0/5	0/0	**0/5**
Number of Chicks Exposed or Taken	0/0	0/0	0/0	**0/0**

Disturbance at Castle-Hurricane Complex	Brandt's Cormorant	Brown Pelican	Great Blue Heron	Pelagic Cormorant	Peregrine Falcon	Western Gull	**Total**
Number of Disturbance Events	5	18	1	1	1	28	**54**
Mean # Birds Disturbed	16 (3-38)	61 (2-340)	35 (35-35)	25 (25-25)	500 (500-500)	43 (1-300)	**54 (1-500)**
Number of Displaced/Flushed Events	5	18	1	0	0	8	**32**
Mean Number of Birds Displaced/Flushed	10 (3-30)	40 (2-60)	5 (5-5)	0	0	2 (1-1)	**10 (1-60)**
Number of Eggs Exposed or Taken	0/0	0/0	0/0	0/0	0/0	0/0	**0/0**
Number of Chicks Exposed or Taken	0/0	0/0	0/0	0/0	0/0	0/0	**0/0**

Table 9. Common Murre breeding phenology and reproductive success at Point Reyes Lighthouse Rock (PRH-03-B, 2 plots and combined), Devil's Slide Rock & Mainland (DSR, 3 plots and combined; DSM), and Castle Rocks & Mainland (1 plots), 2018. Means are accompanied by ranges and n in parenthesis. [1] Calculated using first eggs only; i.e., does not include replacement clutches. [2] Hatching success is defined as the number of eggs hatched per eggs laid (includes both first and replacement clutches).[3] Fledging success is defined as the number of chicks fledged per eggs hatched (includes both first and replacement clutches).

Point Reyes Headlands	PRH-03-B-Edge	PRH-03-B-Ledge	**PRH Combined**
Number Sites Monitored	81	109	**190**
Number Egg Lay Sites	57	88	**145**
Mean Lay Date[1]	18 May (5/11-6/12; 47)	23 May (5/11-6/18; 76)	**22 May (5/11-6/18; 123)**
Number Eggs Laid	61	98	**159**
Mean Hatch Date	22 June (6/13-7/29; 63)	28 June (6/13-7/29; 63)	**26 June (6/13-7/29; 101)**
Hatching Success[2]	76% (58)	71% (96)	**72.7% (154)**
Mean Fledge Date	16 July (7/4-8/5; 42)	22 July (7/7-8/14; 65)	**19 July (7/4-8/14; 107)**
Fledging Success[3]	96% (68)	96% (44)	**95.5% (112)**
Chicks Fledged per Pair	0.75 (53)	0.74 (88)	**0.74 (141)**

Devil's Slide Rock	DSR-01-A	DSR-01-B	DSR-01-D	**DSR-01 Combined**	DSRM-05-A Lower
Number Sites Monitored	101	74	26	**201**	15
15Number Egg Lay Sites	94	71	24	**189**	15
Mean Lay Date[1]	26 May (5/16-6/16; 92)	24 May (5/16-6/4; 68)	26 May (5/18-6/12; 25)	**26 May (5/16-6/16; 184)**	01 June (5/28-6/8;15)
Number Eggs Laid	95 (94)	71 (71)	25 (24)	**191 (189)**	15 (15)
Mean Hatch Date	27 June (6/18-7/18; 84)	25 June (6/15-7/7; 59)	28 June (6/21-7/13; 19)	**27 June (6/15-7/18; 162)**	02 July (7/2-7/2; 1)
Hatching Success[2]	88.4% (95)	83.1% (71)	76% (25)	**84.8% (191)**	6.7% (15)
Mean Fledge Date	21 July (7/7-7/31; 80)	20 July (7/11-7/28; 58)	19 July (7/11-7/24; 17)	**20 July (7/7-7/31; 155)**	25 July (7/25-7/25; 1)
Fledging Success[3]	95.2% (84)	98.3% (59)	89.5% (19)	**95.7% (162)**	100% (1)
Chicks Fledged per Pair	0.85 (94)	0.82 (71)	0.71 (24)	**0.82 (189)**	0.07 (15)

Castle Rock and Mainland	CRM - 04
Number Sites Monitored	105
Number Egg Lay Sites	96
Mean Lay Date[1]	20 May (5/11-6/20; 96)
Number Eggs Laid	96
Mean Hatch Date	20 June (6/10-7/9; 70)
Hatching Success[2]	74% (96)
Mean Fledge Date	11 July (7/3-7/15; 51)
Fledging Success[3]	71.8% (70)
Chicks Fledged per Pair	0.53 (96)

Table 10. High counts of nests and breeding birds from aerial (conducted on 4 and 5 June 2018) and land surveys of nests for Common Murres, Brandt's Cormorants, Pelagic Cormorants, Western Gulls, and Black Oystercatchers, 2018. Pigeon Guillemots counts reported are for bird (not nest) peak counts only. A dash indicates no survey was conducted. [1] Sum of high season nest (Brandt's and Pelagic Cormorants, Western Gull and Black Oystercatcher) and bird (Common Murre and Pigeon Guillemot) counts during land-based surveys. [2] For combined counts, land-based and aerial counts were compared. Nests accounted from the aerial survey were combined with the land-based count. [3] Aerial counts are not reported for nests of WEGU and BLOY due to incomplete aerial photograph coverage.[4] Miller's Point Rocks was opportunistically counted once on 14 July. Reported murre and land-based cormorant counts are from that survey.

Type of Survey and Colony location	Common Murre[1,2]	Brandt's Cormorant[2,3]	Pelagic Cormorant[2,3,4]	Western Gull[2,4]	Black Oystercatcher[2,4]	Pigeon Guillemot[2,4]
Land – Point Reyes	-	179	19	64	2	165
Aerial – Point Reyes	37,459	328	33	-	-	-
Total – Point Reyes	-	346	53	-	-	-
Land – Point Resistance	-	-	-	-	-	-
Aerial –Point Resistance	5,760	0	0	-	-	-
Total –Point Resistance	-	-	-	-	-	-
Land – Miller's Point Rocks	-	70[4]	-	-	-	-
Aerial–Miller's Point Rocks	27[4]	178	0	-	-	-
Total – Miller's Point Rocks	-	178	-	-	-	-
Land – Double Point Rocks	-	-	-	-	-	-
Aerial – Double Point Rocks	12,108	130	8	-	-	-
Total –Double Point Rocks	-	-	-	-	-	-
Land – Bird Island	-	4	-	10	-	-
Aerial –Bird Island	-	-	-	-	-	-
Total – Bird Island	-	4	-	-	-	-
Land – Devil's Slide Rock & Mainland	-	85	10	7	0	194
Aerial –Devil's Slide Rock & Mainland	1,732	159	8	-	-	-
Total –Devil's Slide Rock & Mainland	-	174	16	-	-	-
Land – Gray Whale Cove	-	0	12	0	0	0
Aerial –Gray Whale Cove	0	-	-	-	-	-
Total –Gray Whale Cove	-	-	-	-	-	-
Land – San Pedro Rock	-	0	0	0	0	30
Aerial –San Pedro Rock	0	0	0	-	-	-
Total –San Pedro Rock		0	0	-	-	-
Land – Bench Mark-227X	-	54	1	6	0	17
Aerial – Bench Mark-227X	290	70	0	-	-	-
Total – Bench Mark-227X	-	74	1	-	-	-
Land – Castle Rock & Mainland	-	94	13	9	3	-29

Aerial – Castle Rock & Mainland	3,432	264	9	-	-	-
Total – Castle Rock & Mainland	-	265	13	-	-	-
Land – Hurricane Point Rocks	-	0	7	5	2	-35
Aerial – Hurricane Point Rocks	1,192	0	5	-	-	-
Total – Hurricane Point Rocks	-	0	7	-	-	-

Table 11. Brandt's Cormorant breeding phenology and reproductive success at Point Reyes Headlands, 2018. Reported are means (range; n).[1] Includes first clutches only. [2] Includes replacement clutches. See text for details. [3] Breeding success per nest is defined as the proportion of egg-laying nests that fledged at least one chick.

Colony or Sub colony	Number. Breeding Sites	Clutch Initiation Date[1]	Clutch Size[1]	Breeding Success[2]	Number. Chicks Fledged/Pair[2]	Breeding Success/ Nest[3]
Hooves (PRH-07-A)	6	17 May (5/7-5/24; 5)	1.4	0% (11)	0 (0-0; 6)	0 (6)
Face Rock (PRH-11-E)	8	07 June (5/28-6/29; 7)	2.9	77% (23)	2.14 (0-3; 7)	0.86 (7)
Wishbone Point (PRH-11-E)	6	30 May (5/24-6/23; 6)	3.0	92% (18)	2.80 (0-3; 7)	0.86 (7)
PRH-13 Area (PRH-13-CS)	3	17 May (5/12-5/24; 3)	3.5	83% (7)	3.00 (2-4; 3)	1 (3)
Cone Shoulder (PRH-13-CS)	36	11 May (4/30-5/26; 34)	3.1	61% (106)	1.85 (0-3; 34)	0.88 (34)
Cone Upper (PRH-13-CU)	8	17 May (5/8-6/4; 15)	3.1	76% (44)	2.38 (2-3; 13)	1.0 (13)
West Cone (PRH-13-WC)	26	28 May (5/18-6/30; 23)	3.0	67% (57)	1.95 (0-3; 22)	0.91 (22)
Mainland (PRH-14-E)	22	8 May (4/24-5/22; 22)	3.2	67% (68)	2.05 (0-3; 19)	0.89 (19)
Point Reyes Headlands Total	**122**	**18 May (4/24-6/30; 115)**	**3.0**	63% (334)	**1.96 (0-4; 109)**	**0.86 (109)**

Table 12. Brandt's Cormorant breeding phenology and reproductive success at Devil's Slide Rock & Mainland and Castle Rocks & Mainland, 2018. Reported are means (range; n). [1] Includes first clutches only. [2] Includes replacement clutches. See text for details. [3] Breeding success per nest is defined as the proportion of egg-laying nests that fledged at least one chick.

Colony or Subcolony	Number Breeding Sites	Clutch Initiation Date[1]	Clutch Size[1]	Breeding Success[2]	Number Chicks Fledged/Pair[2]	Breeding Success/ Nest[3]
Devil's Slide Rock (DSRM-01)	17	11 May (5/02-5/23; 16)	3.3	58.8% (56)	2.08 (0-3; 13)	0.77 (13)
Mainland South (DSRM-05-A Lower)	61	15 May (4/18-6/19; 59)	3.2	37.9% (204)	1.37 (0-3; 60)	0.55 (60)
April's Finger (DSRM-05-AF)	2	11 May (5/08-5/14; 2)	2.5	0% (5)	0 (0-0; 2)	0 (2)
Turtlehead (DSRM-05-B)	15	02 May (4/08-6/6; 15)	2.8	9.2% (54)	0.4 (0-3; 15)	0.2 (15)
Devil's Slide Rock & Mainland Total	**95**	**12 May (4/08-6/19; 92)**	**3.1**	**35% (319)**	**1.28 (0-3; 90)**	**0.51 (90)**
CRM-06-AN	26	23 May (5/5-6/2; 13)	3.0	28.2% (39)	.42 (0-3; 26)	0.15 (26)
CRM-07	1	1 May (5/1-5/1;1)	-	-	2 (2-2; 1)	1 (1)
Castle Rocks & Mainland Total	127	**21 May (5/1-6/2; 14)**	3.0	**28.2% (39)**	**0.48 (0-3; 27)**	**0.19 (27)**

Table 13. Productivity of Pelagic Cormorants, Black Oystercatchers, and Western Gulls at Point Reyes Headlands, Devil's Slide Rock and Mainland, and Castle Rocks & Mainland, 2018. Means (range; n) or (n) are reported. [1] Breeding success per nest is defined as the proportion of egg-laying nests that fledged at least one chick.

Productivity at Colony	Pelagic Cormorant	Black Oyster Catcher	Western Gull
Number Breeding Sites (DSRM)	7	0	2
Number Chicks Fledged (DSRM)	11	-	3
Number of Chicks Fledged/Pair (Productivity) (DSRM)	1.57 (0-3; 7)	-	1.5 (1-2; 2)
Breeding Success/Nest[1](DSRM)	0.86 (7)	-	1 (2)
Number Breeding Sites (CHCC)	5	5	6
Number Chicks Fledged (CHCC)	4	3	9
Number of Chicks Fledged/Pair (Productivity) (CHCC)	1 (0-2; 4)	0.60 (0-2; 5)	1.5 (0-3; 6)
Breeding Success/Nest[1](CHCC)	0.75	0.40 (5)	0.66 (6)

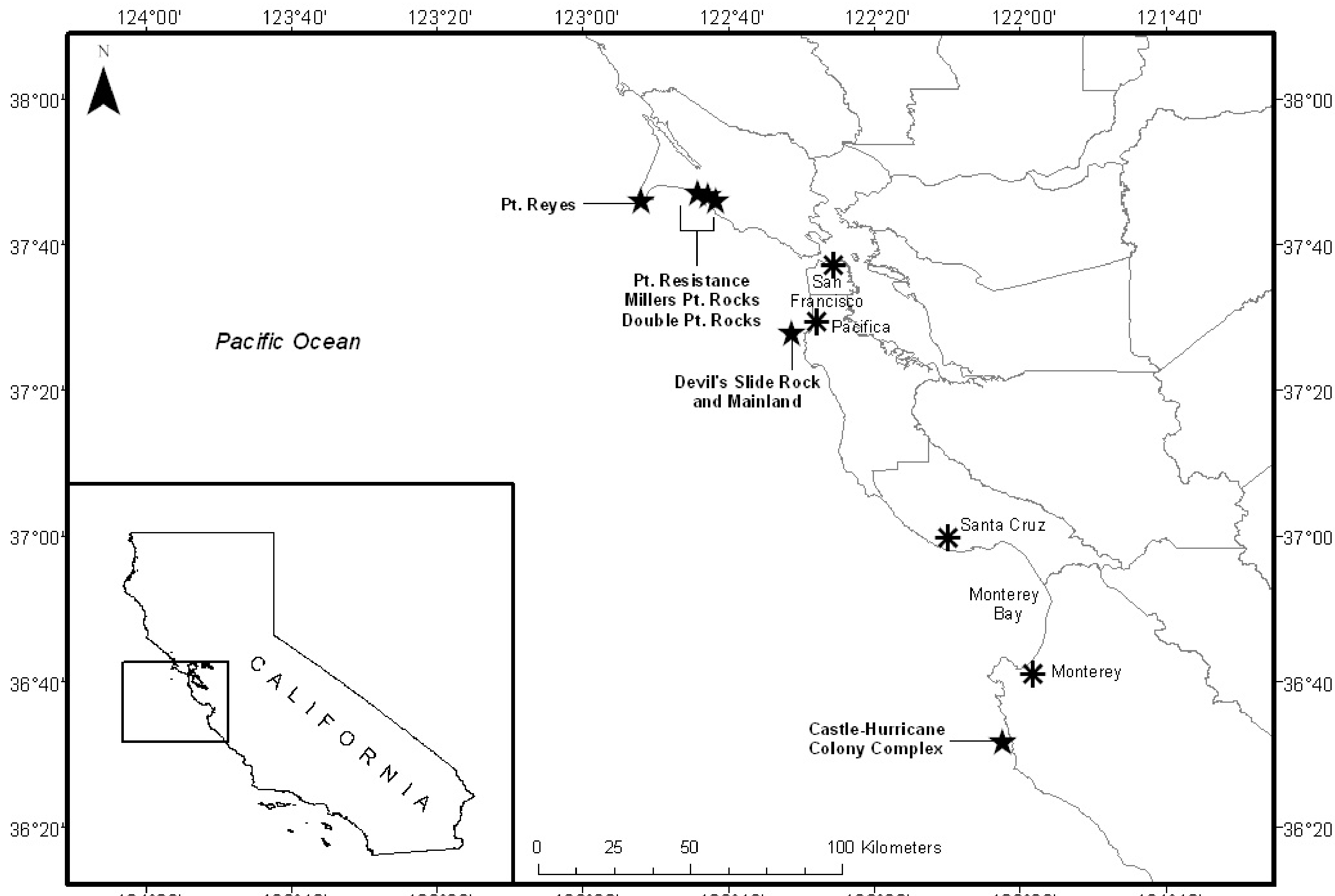


Figure 1. Study area, showing locations of study colonies or colony complexes along the Central California coast where we monitored seabird disturbance, attendance and breeding biology. Pt. Resistance, Miller's Pt. and Double Pt. were not monitored in 2018.

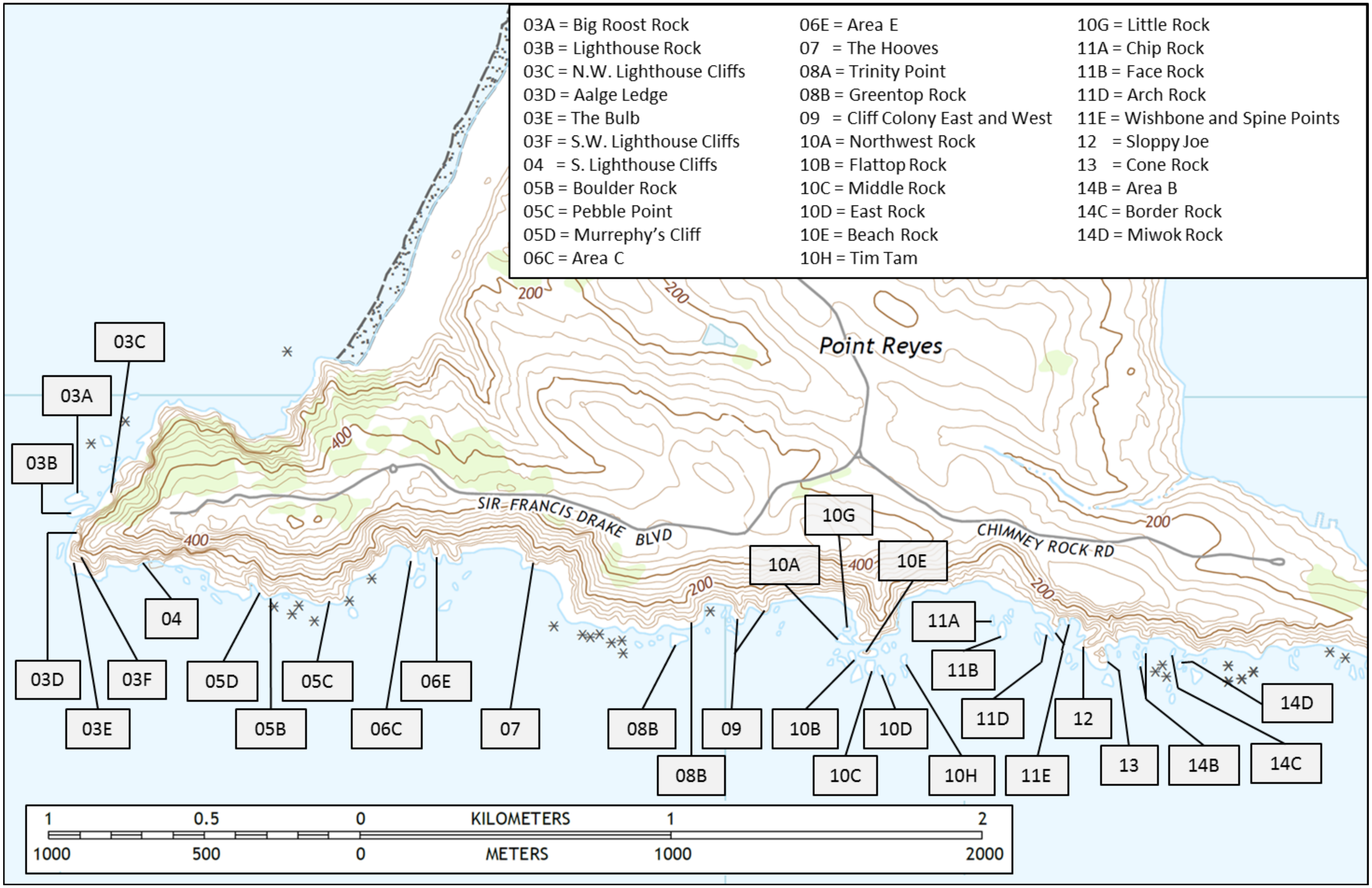


Figure 2. Point Reyes Headlands, including subcolonies 03A through 14D.

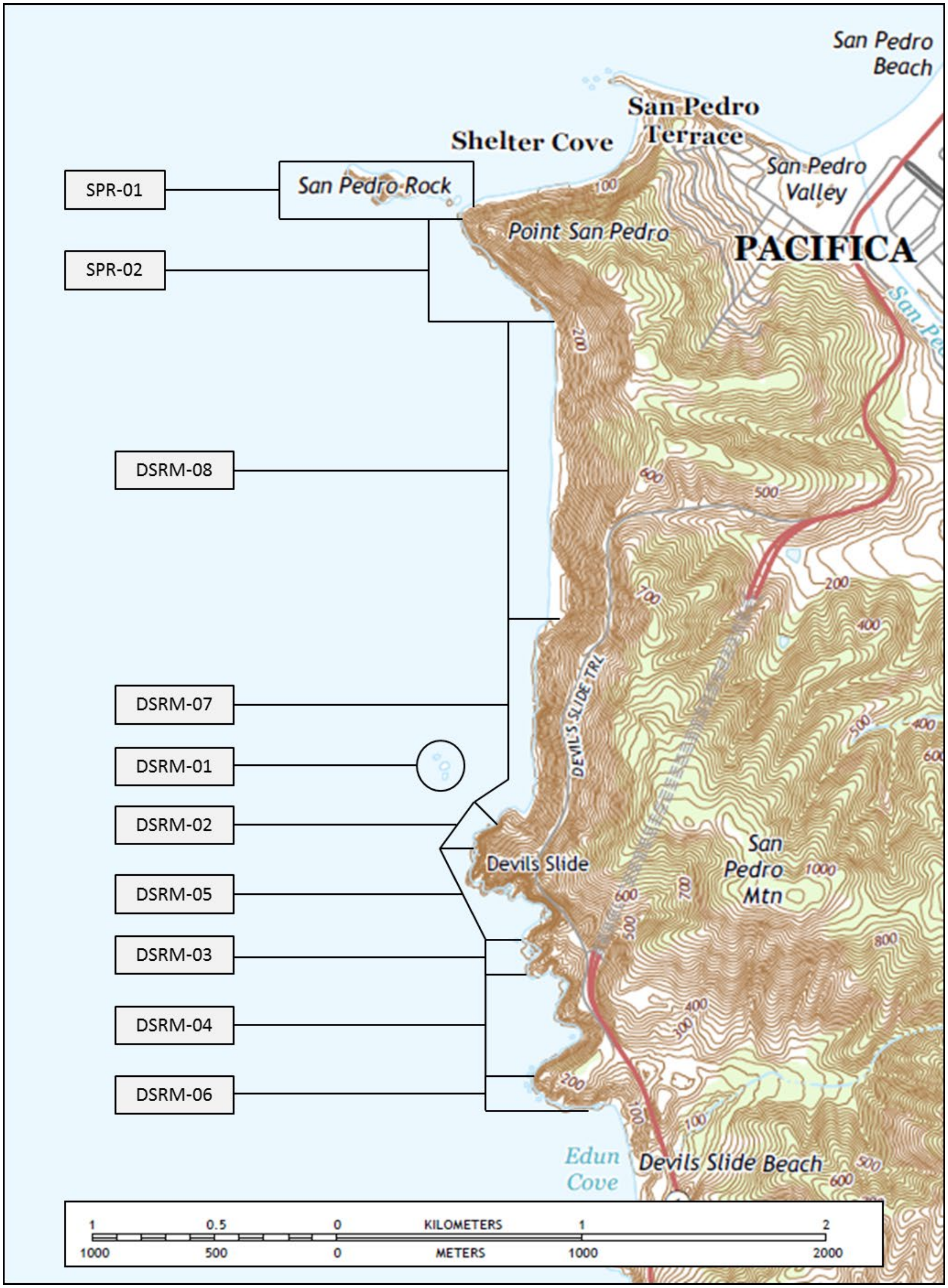


Figure 3. Devil's Slide Colony Complex, including San Pedro Rock and Devil's Slide Rock & Mainland colonies and subcolonies.

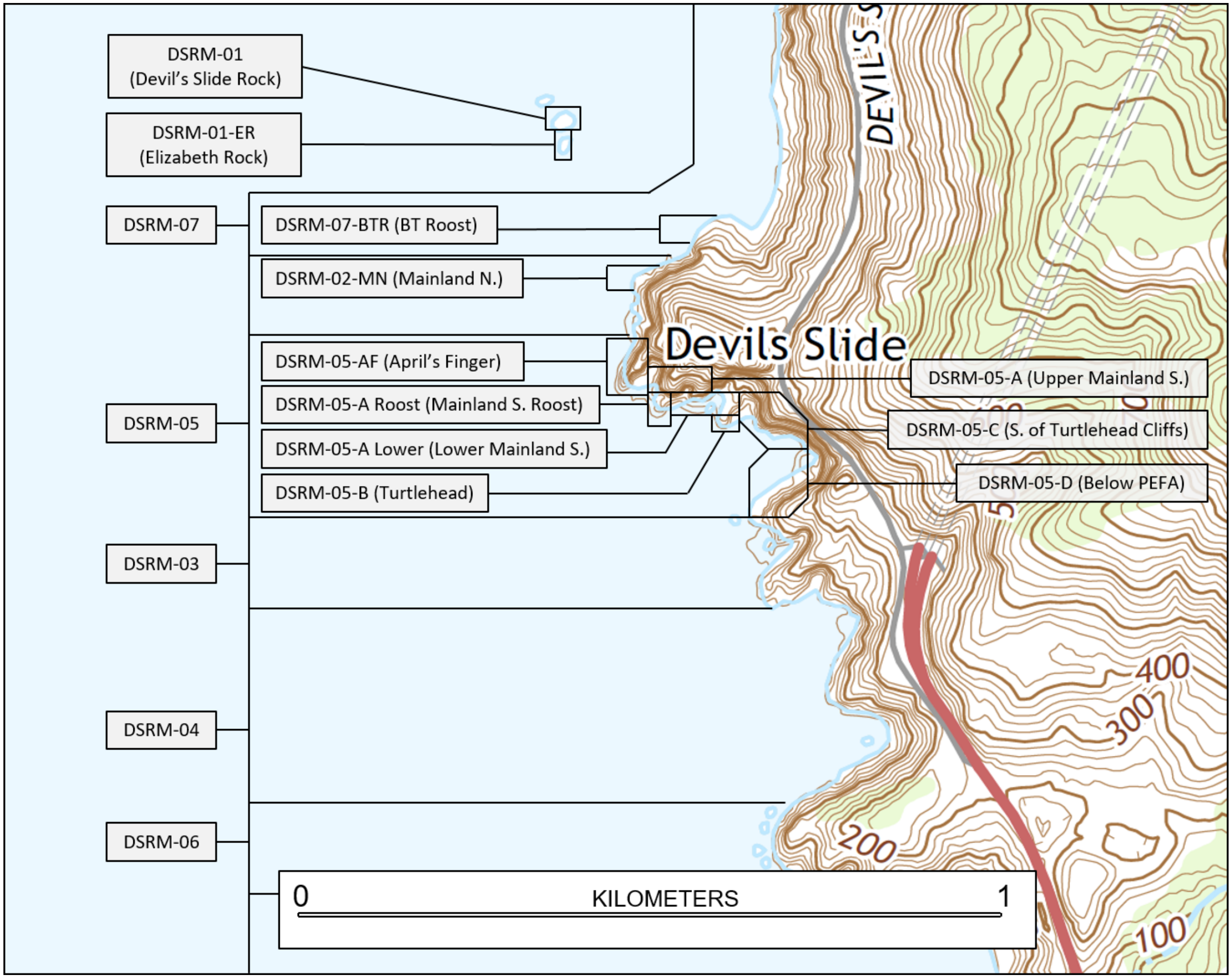


Figure 4. Devil's Slide Colony close-up, showing all subcolonies within DSRM-01, 07, 02 and 05.

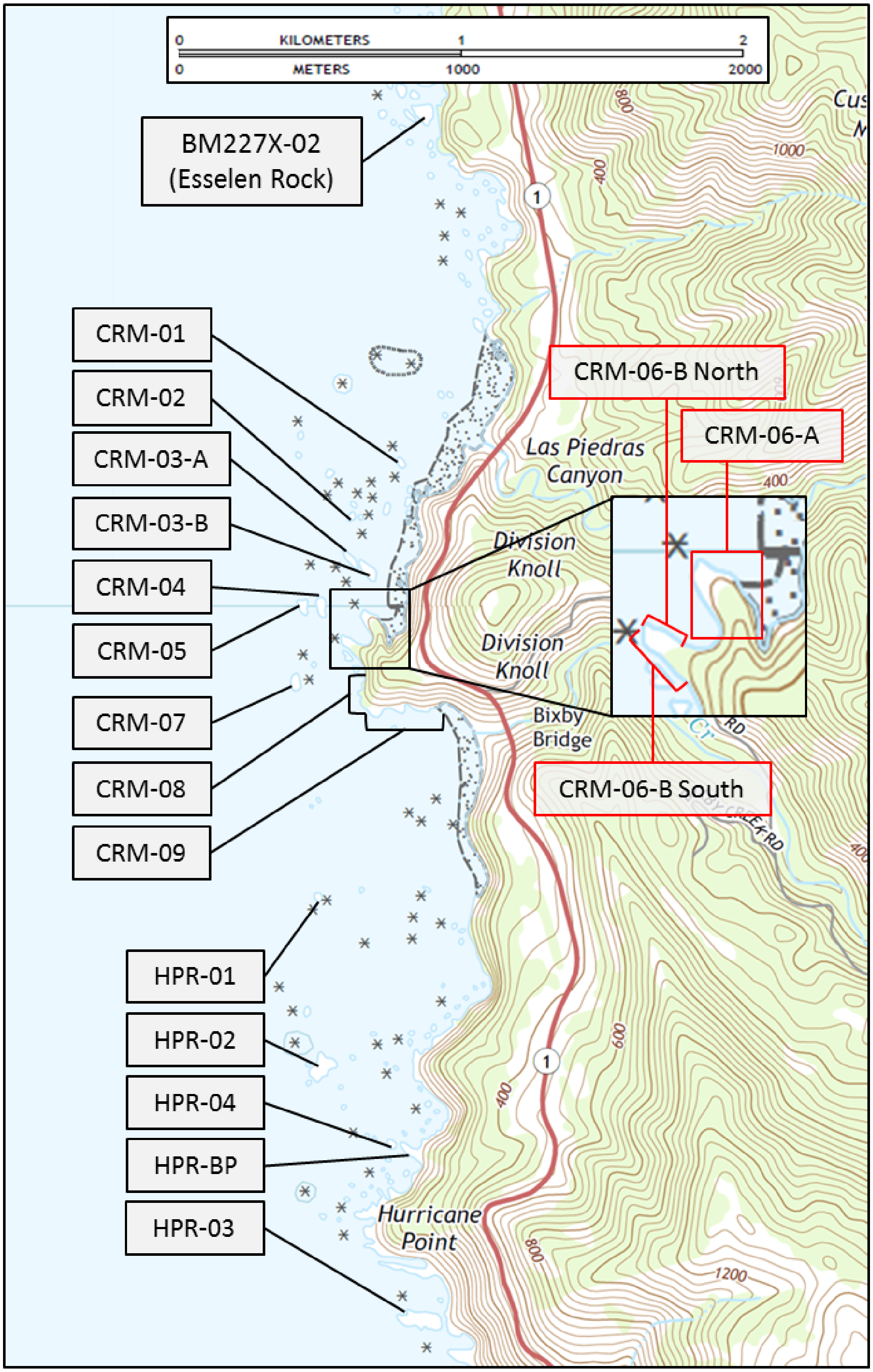


Figure 5. Castle-Hurricane Colony Complex, including Bench Mark-227X (BM227X), Castle Rocks and Mainland (CRM), and Hurricane Point Rocks (Hurricane) colonies and subcolonies.

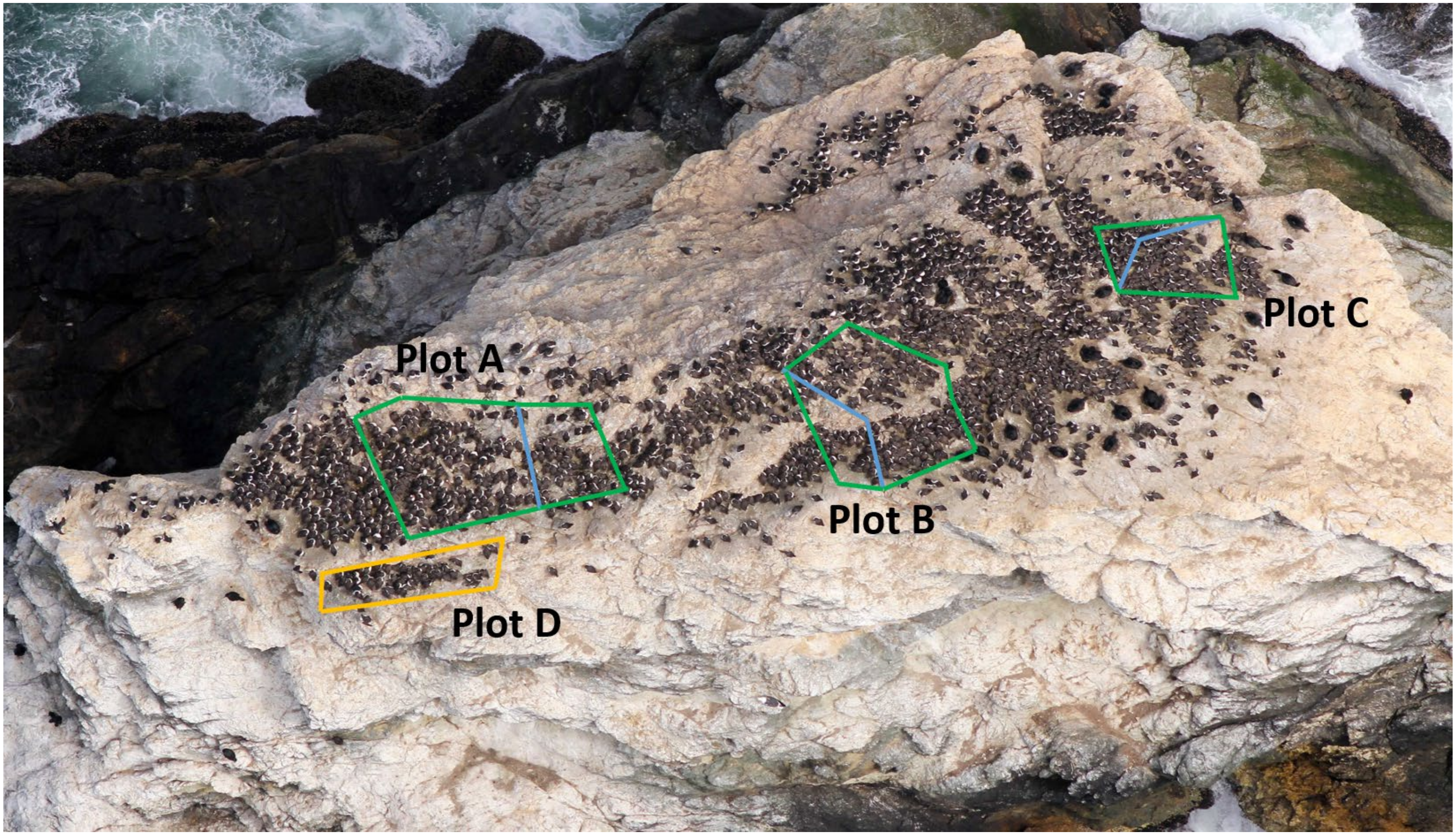


Figure 6. Common Murre Plot boundaries on Devil's Slide Rock from 2006-2018 (view from the south). Green boundaries show plot boundaries for the 2006 season, blue boundaries show adjustments made to Plots A, B and C for 2007 and subsequent seasons (productivity was followed in remaining larger sections only). Plot C was no longer followed beginning in 2014 and Plot D was added for the 2015 season.

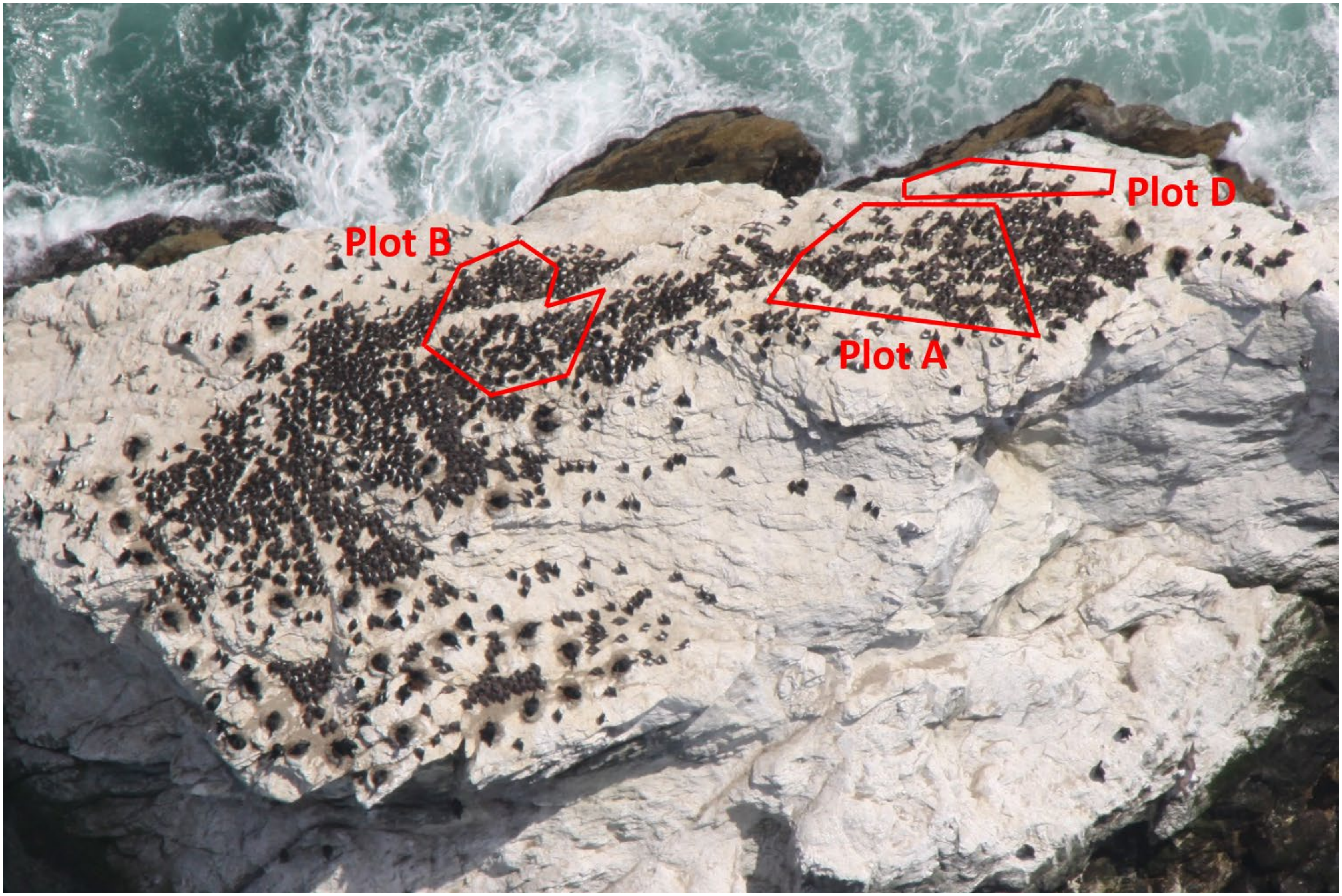


Figure 7. Aerial photograph of Devil's Slide Rock, 4 June 2018, showing the distribution of the Common Murre and Brandt's Cormorant breeding colony and current boundaries of murre productivity plots. View is from the north.

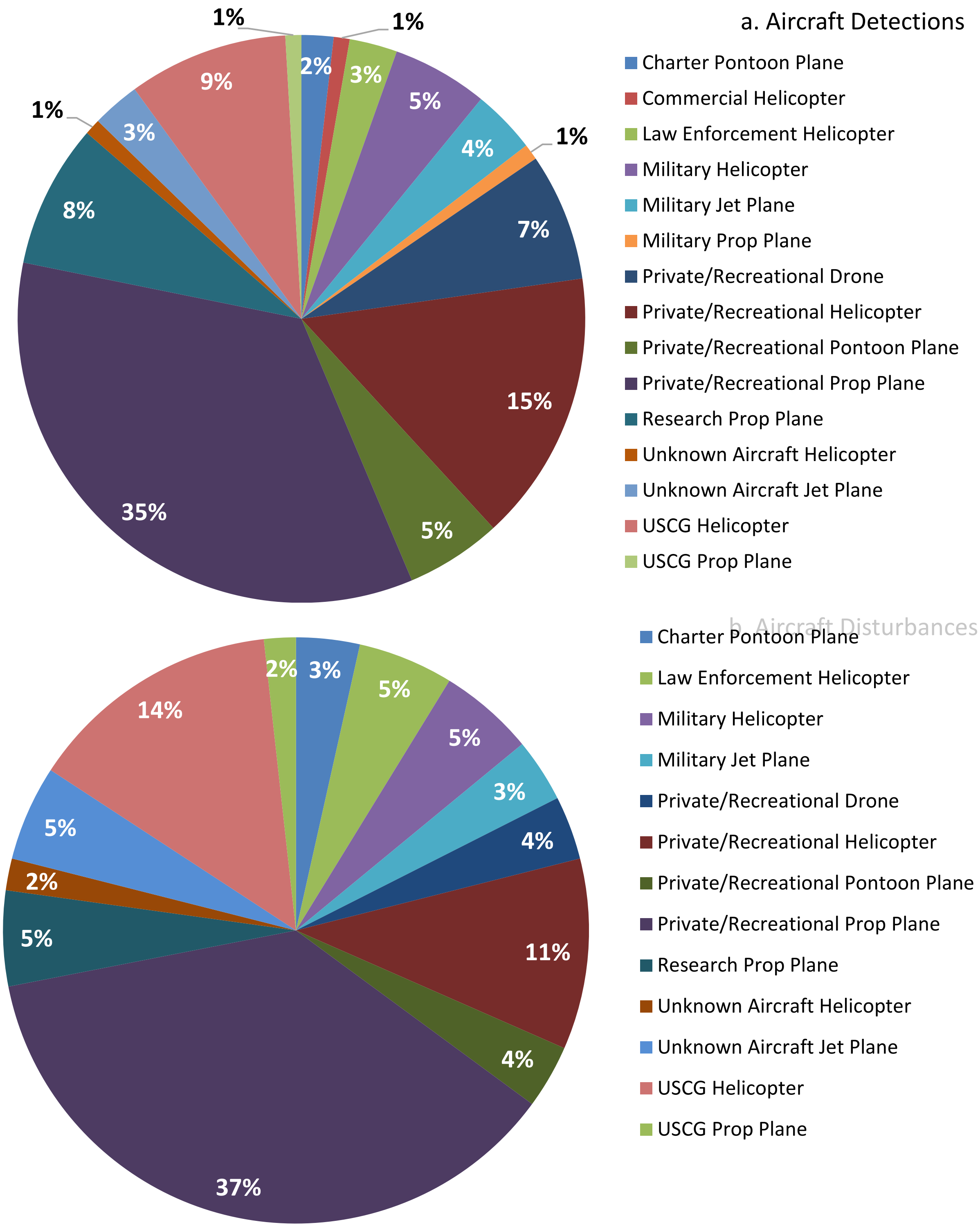


Figure 8. a. Aircraft detections (n = 111) and b. aircraft disturbances (n = 49) at Point Reyes Headlands, Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex combined in 2018, categorized by type.

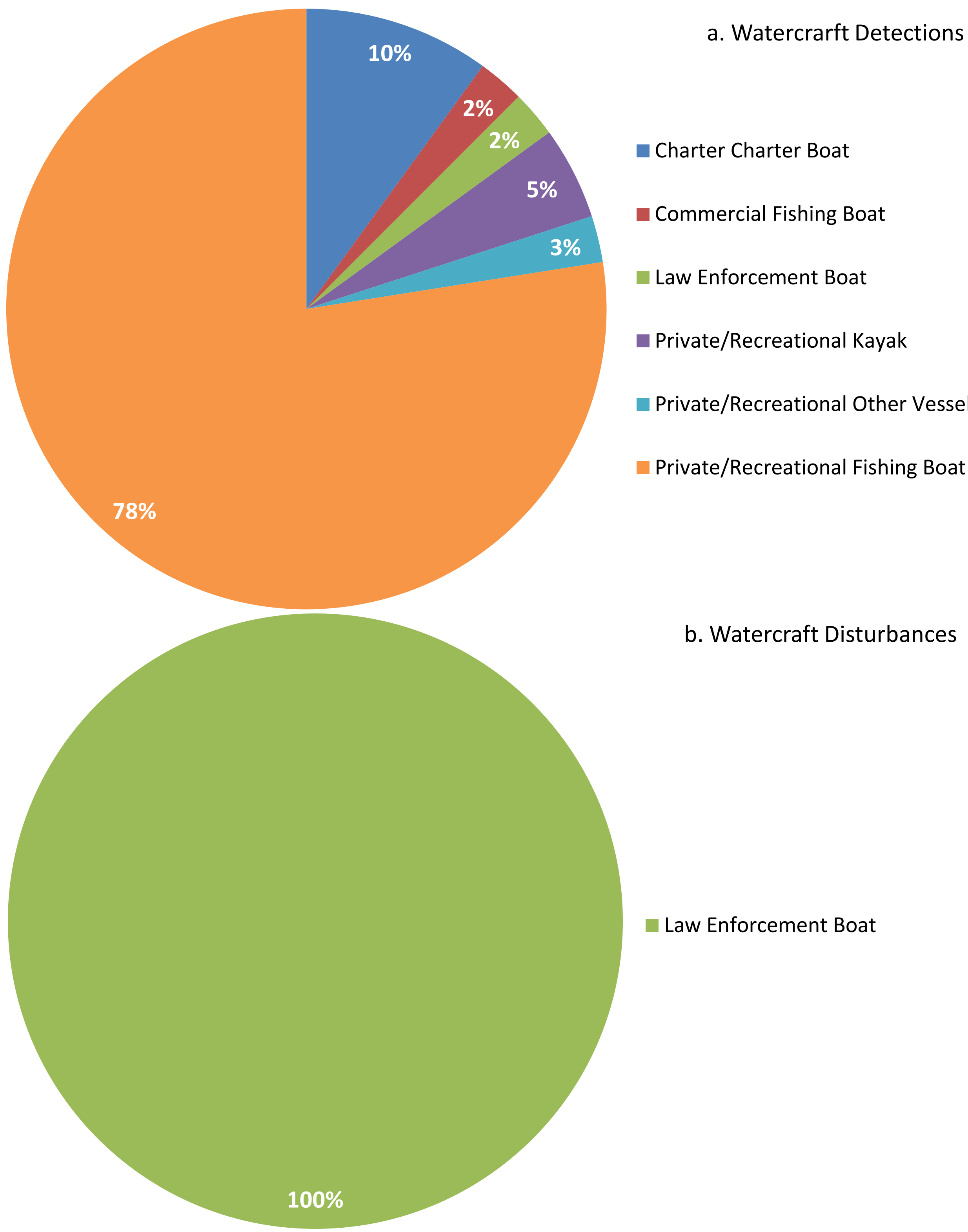


Figure 9. a. Watercraft detections (n = 40) and b. watercraft disturbances (n = 1) at Point Reyes Headlands, Devil's Slide Rock and Mainland and Castle Hurricane Colony Complex combined in 2018, categorized by type.

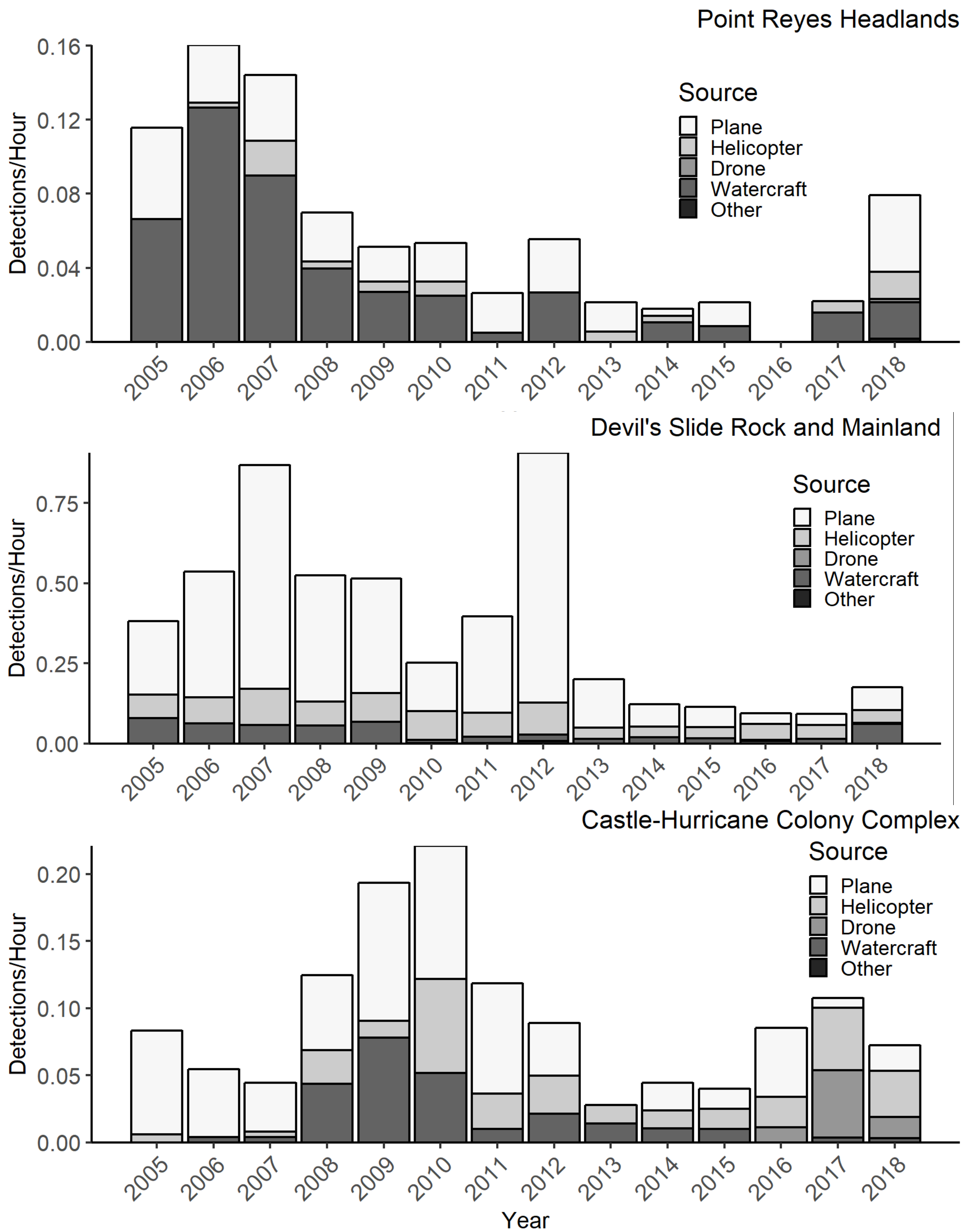


Figure 10. Detection rates (number of detections per observation hour) of watercraft, helicopters, planes, drones and other anthropogenic sources at Point Reyes Headlands, Devil's Slide Rock and Mainland, and Castle-Hurricane Colony Complex from 2001 to 2018. Note different scales between graphs. Point Reyes Headlands was not monitored in 2016. At Devil's Slide Rock and Mainland, watercraft detection rates in 2016-2018 may be underestimated since some detections may not have been recorded; see text for more information.

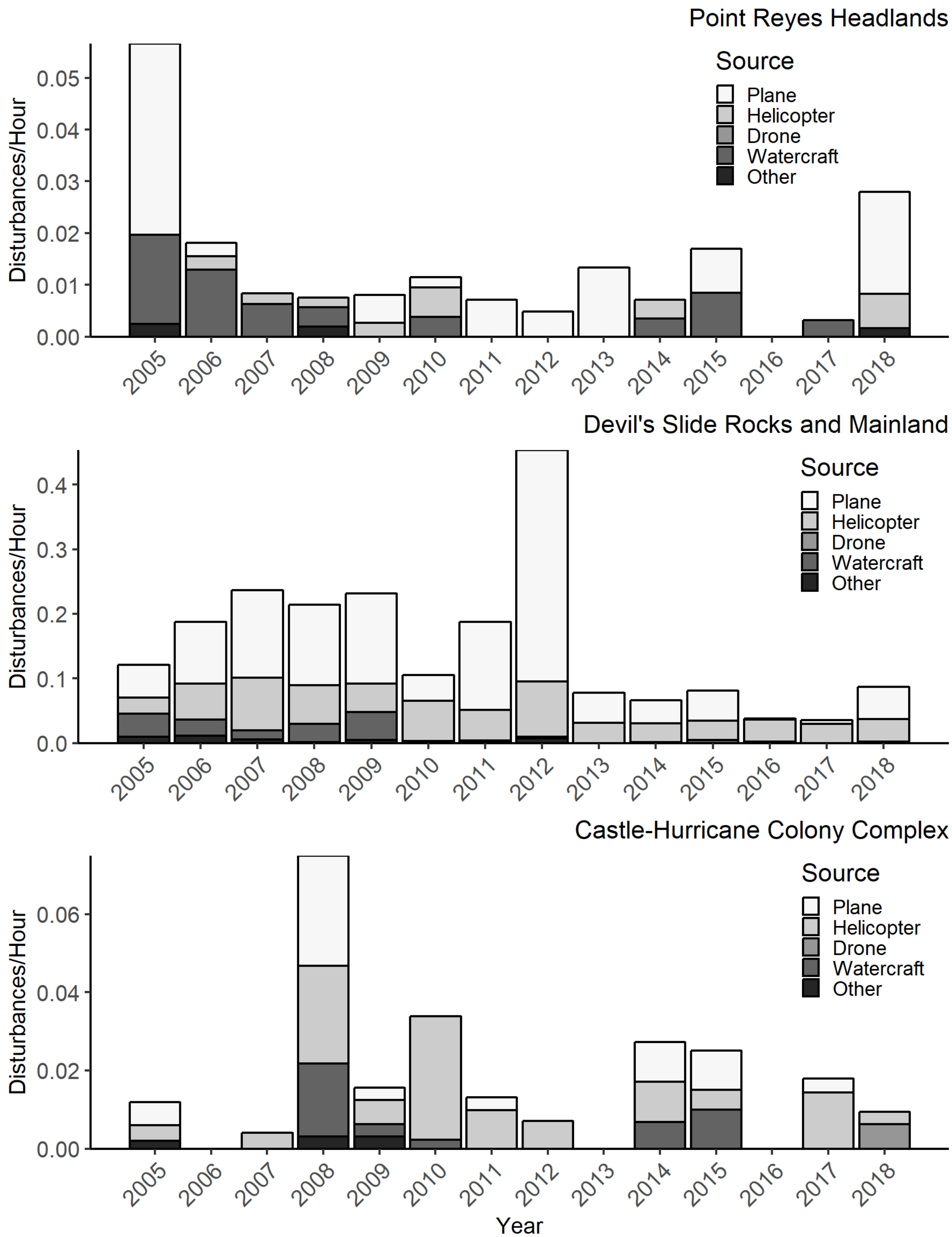
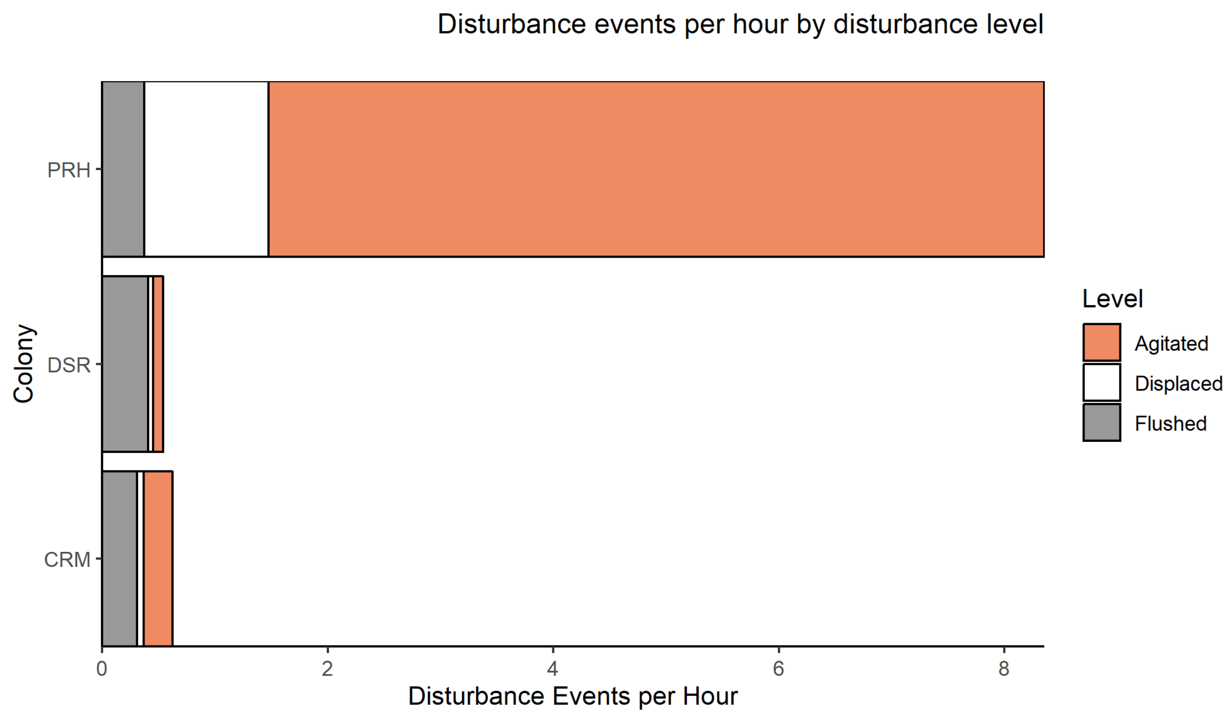


Figure 11. Disturbance rates (number of disturbances per observation hour) of watercraft, helicopters, planes, drones and other anthropogenic sources at Point Reyes Headlands, Devil's Slide Rock and Mainland, and Castle-Hurricane Colony Complex from 2001 to 2018. Note different scales between graphs. Point Reyes Headlands was not monitored in 2016.



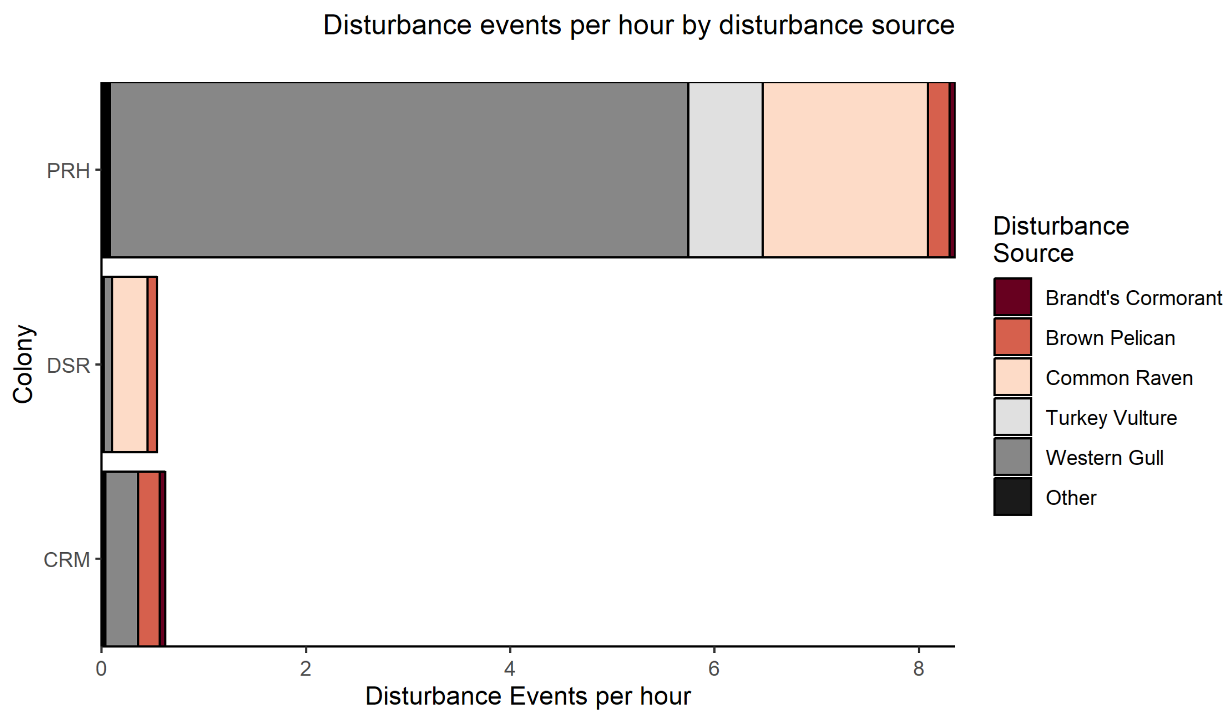


Figure 12. Disturbance events per hour during avian disturbance surveys, by disturbance level and disturbance source. Species included in "Other" caused less than five disturbance events and included Great Blue Heron, Peregrine Falcon, Northern Gannet, Pelagic Cormorant, unknown gull and ocean waves.

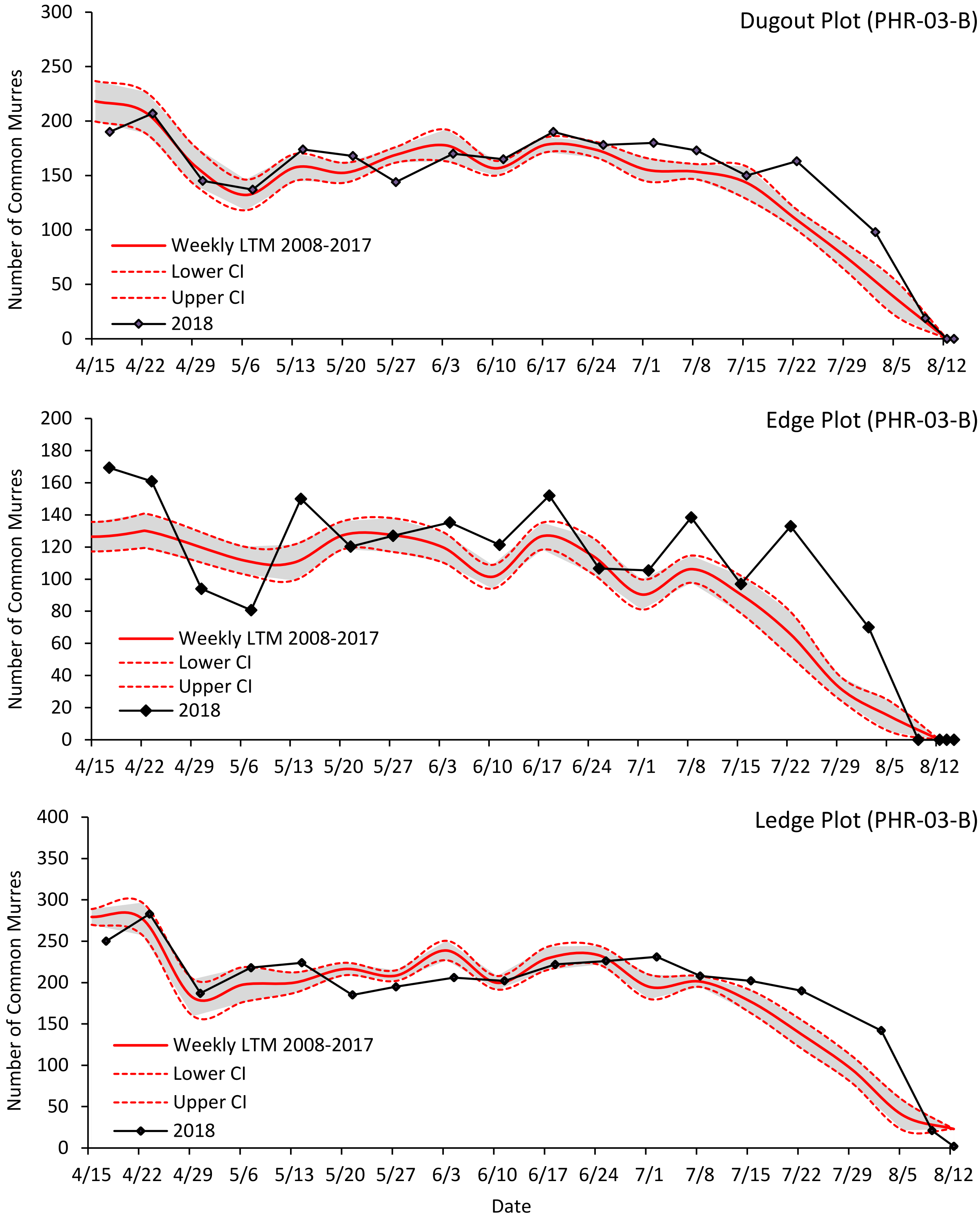
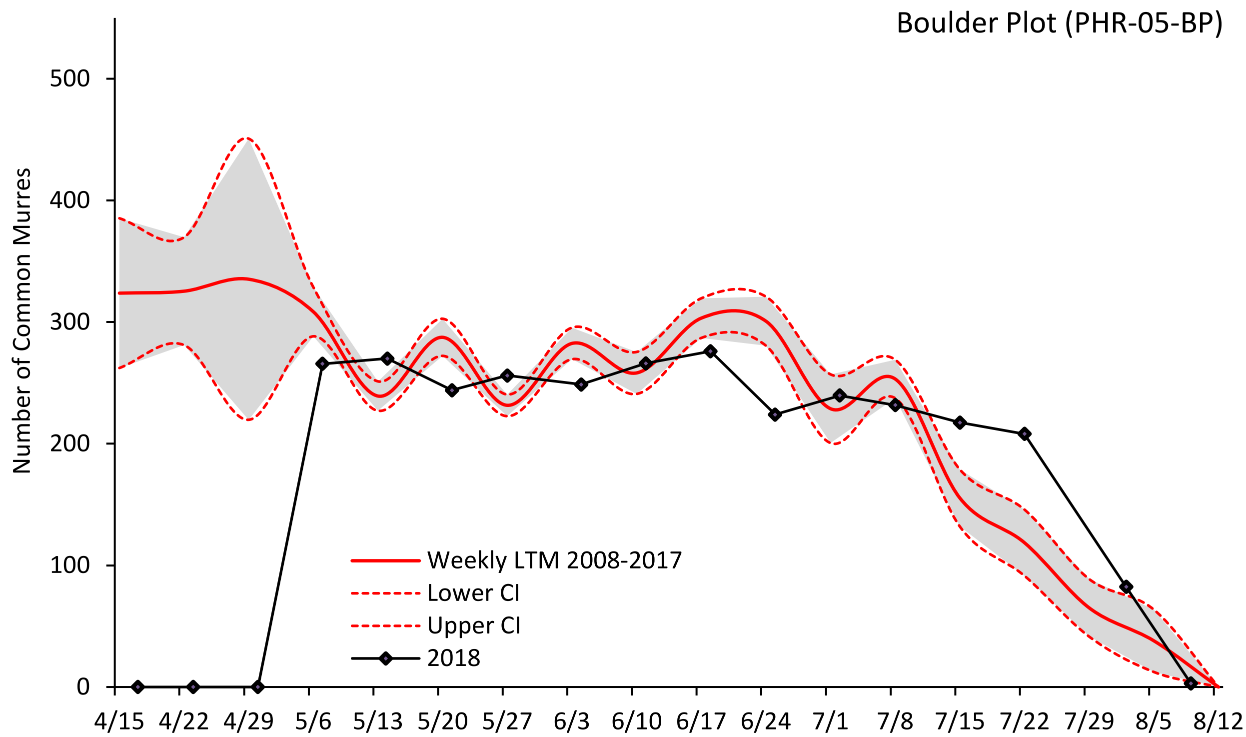


Figure 13. Seasonal attendance of Common Murres at Point Reyes Headlands Lighthouse Rock plots (three plots; PRH-03-B) in 2018 compared to long-term patterns (LTM, 2008-2017).



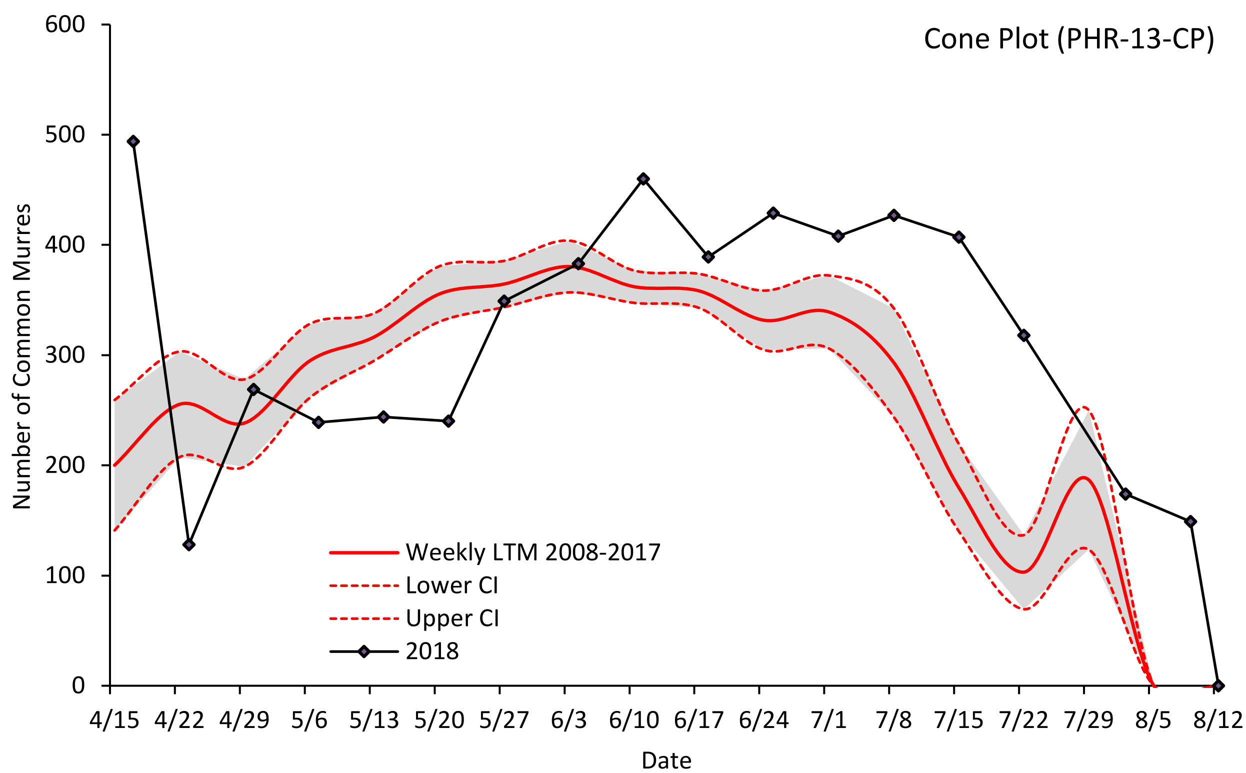


Figure 14. Seasonal attendance of Common Murres at Point Reyes Headlands (subcolonies: PRH-05-BP and PRH-13-CP) in 2018 compared to long-term patterns (LTM, 2008-2017).

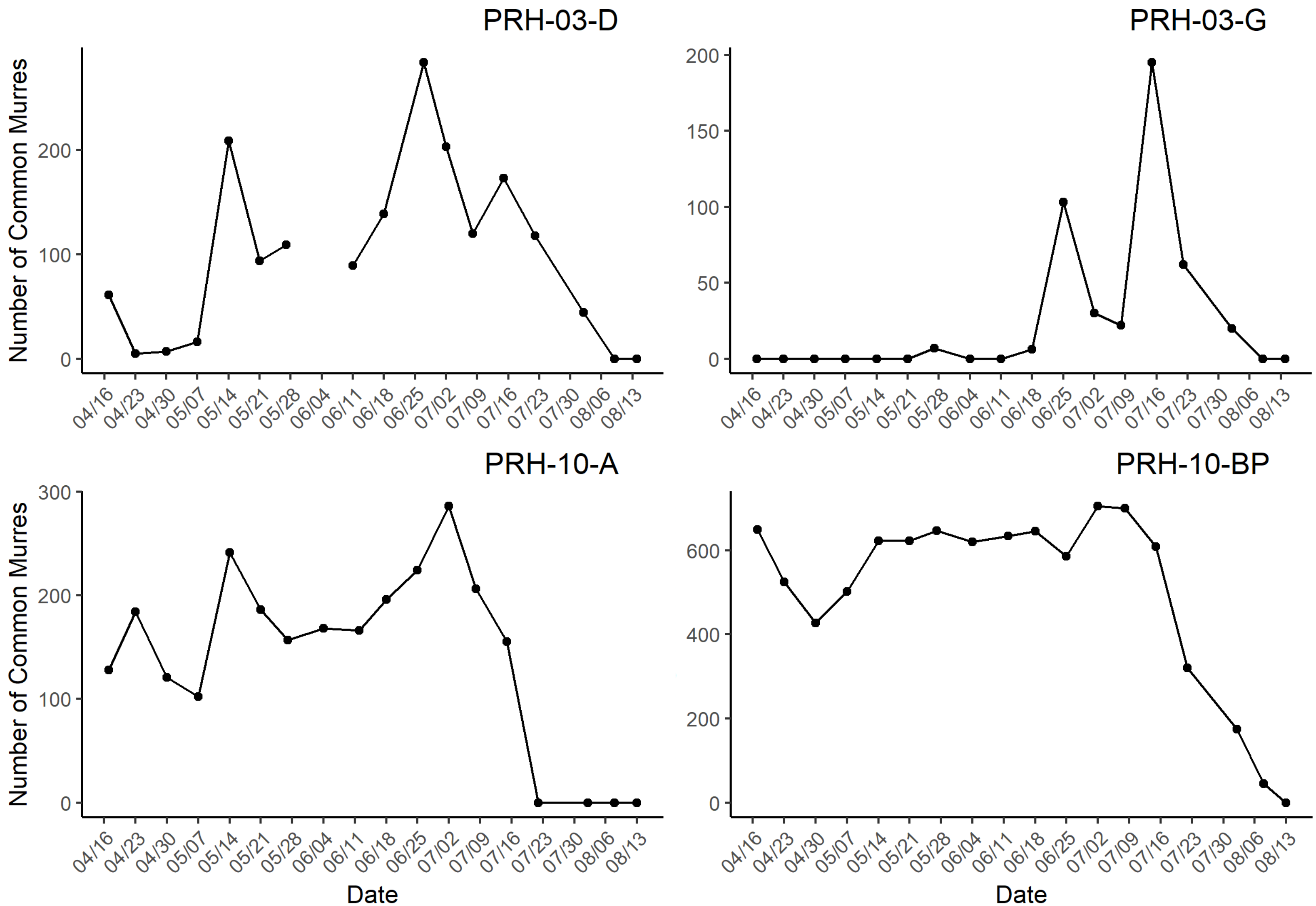


Figure 15. Seasonal attendance of Common Murres at Point Reyes Headlands (subcolonies: PRH-03-D (Aalge Ledge), 03-G (Levin's Rock), 10-A (Northwest Rock) and 10-BP (Flatop Plot)) from 16 April to 13 August, 2018.

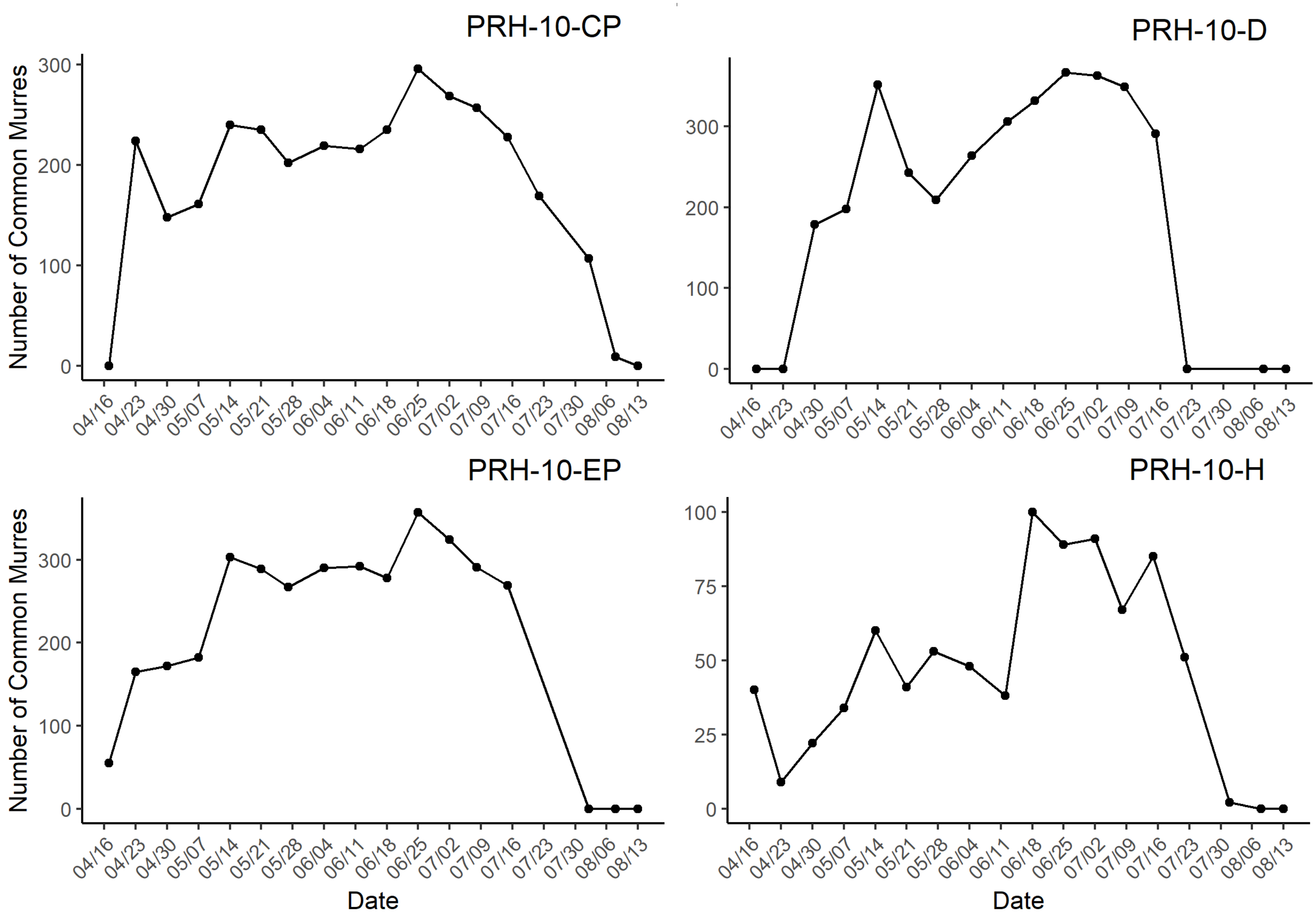


Figure 16. Seasonal attendance of Common Murres at Point Reyes Headlands (subcolonies: PRH-10-CP (Middle Rock Plot), 10-EP (Beach Rock Plot), 10-D (East Rock) and 10-H (Tim Tam)) from 16 April to 13 August, 2018.

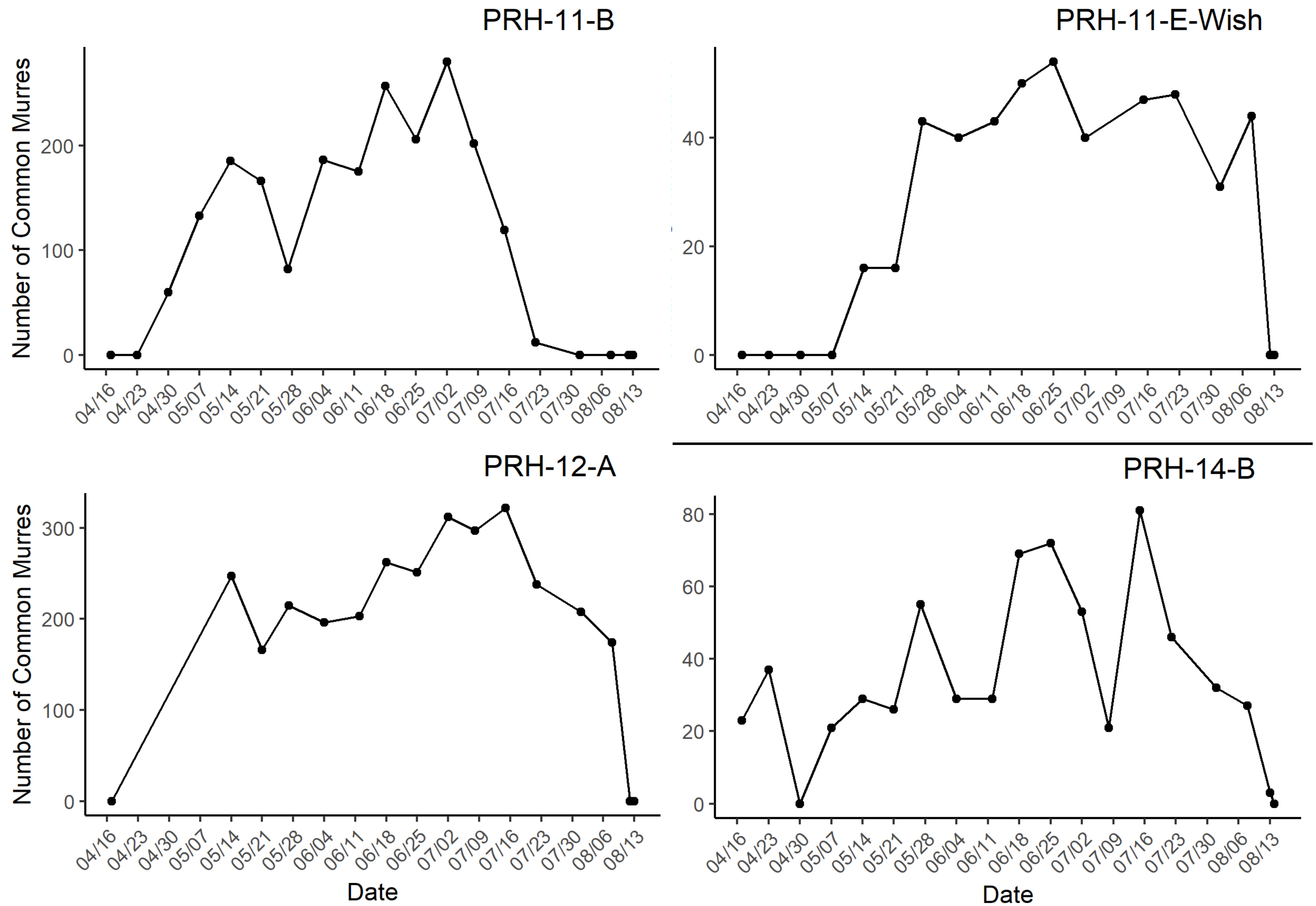
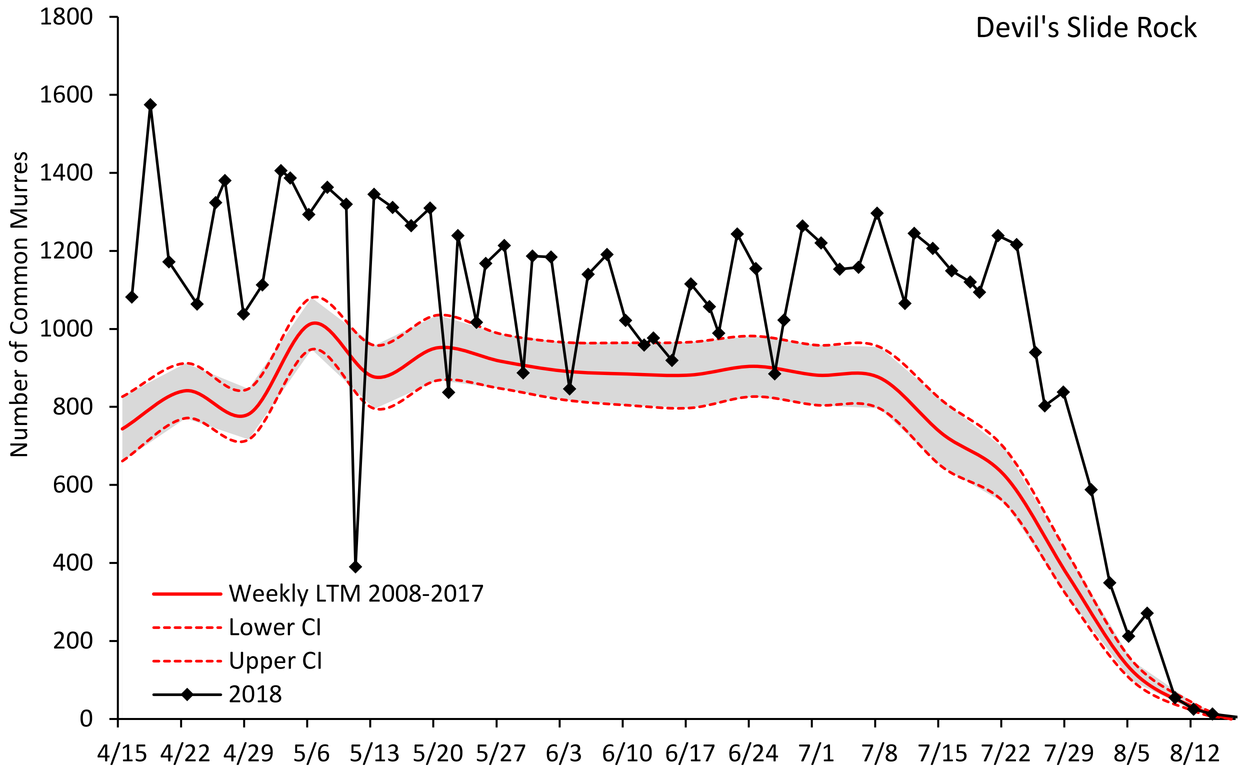


Figure 17. Seasonal attendance of Common Murres at Point Reyes Headlands (subcolonies: PRH-11-B (Face Rock), 11-E-Wish (Wishbone Point), 12-A (Sloppy Joe) and 14-B (Area B)) from 16 April to 13 August, 2018.



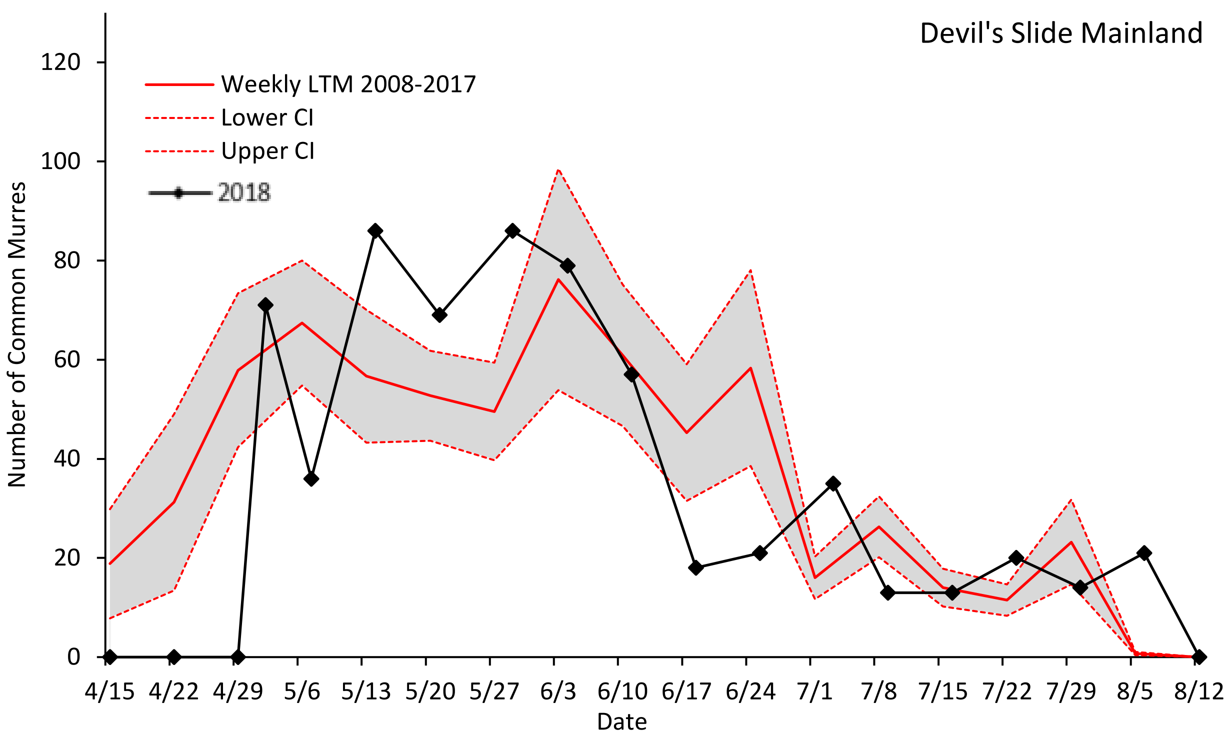


Figure 18. Seasonal attendance of Common Murres at Devil's Slide Rock (DSRM-01) and Devil's Slide Mainland (DSM) colonies in 2018 compared to long-term patterns (LTM, 2008-2017).

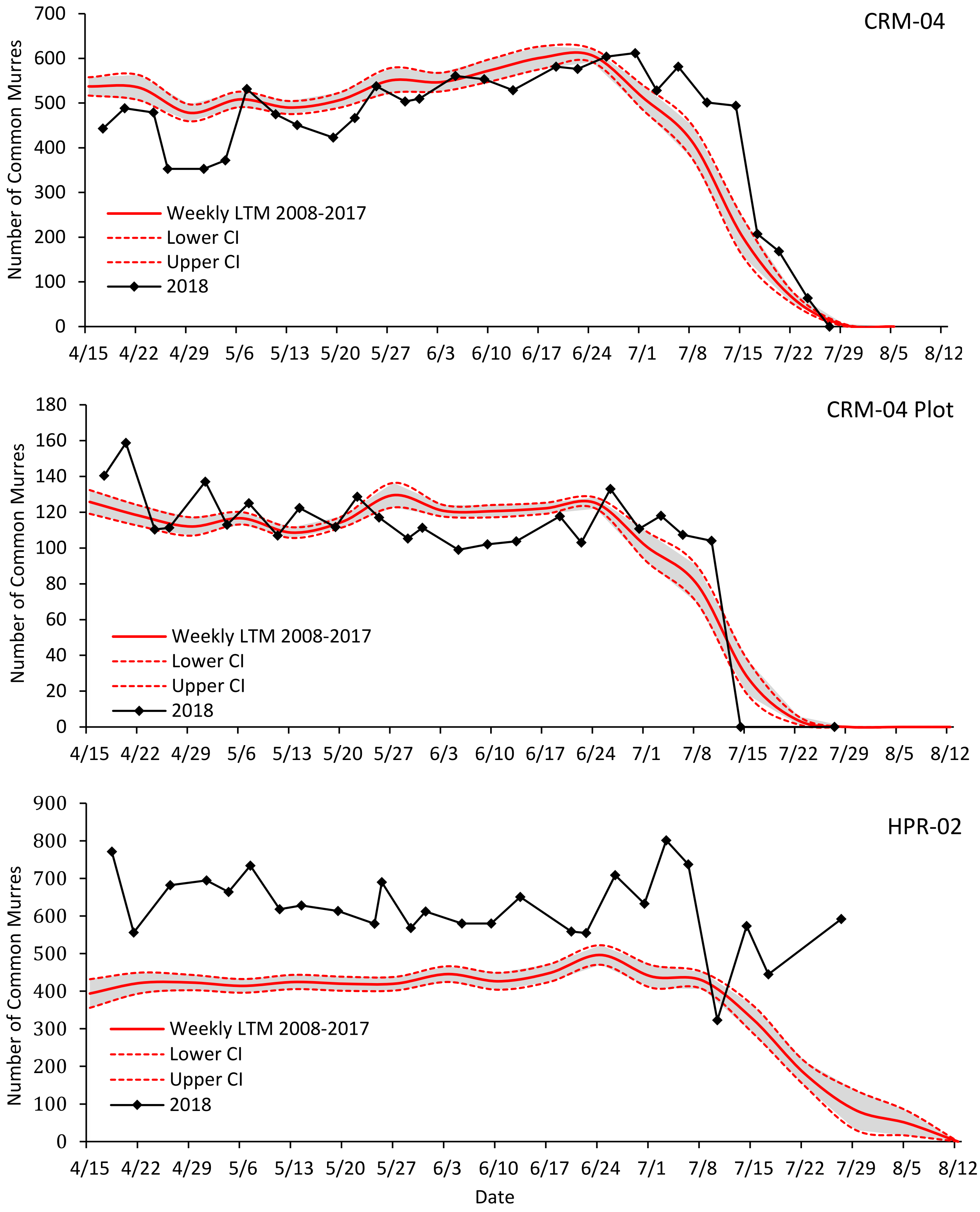


Figure 19. Seasonal attendance of Common Murres at Castle Rocks (CRM-04) and Castle Rock plot (CRM-04-P) and Hurricane Rocks colony HPR-02 in 2018 compared to long-term patterns (LTM, 2008-2017).

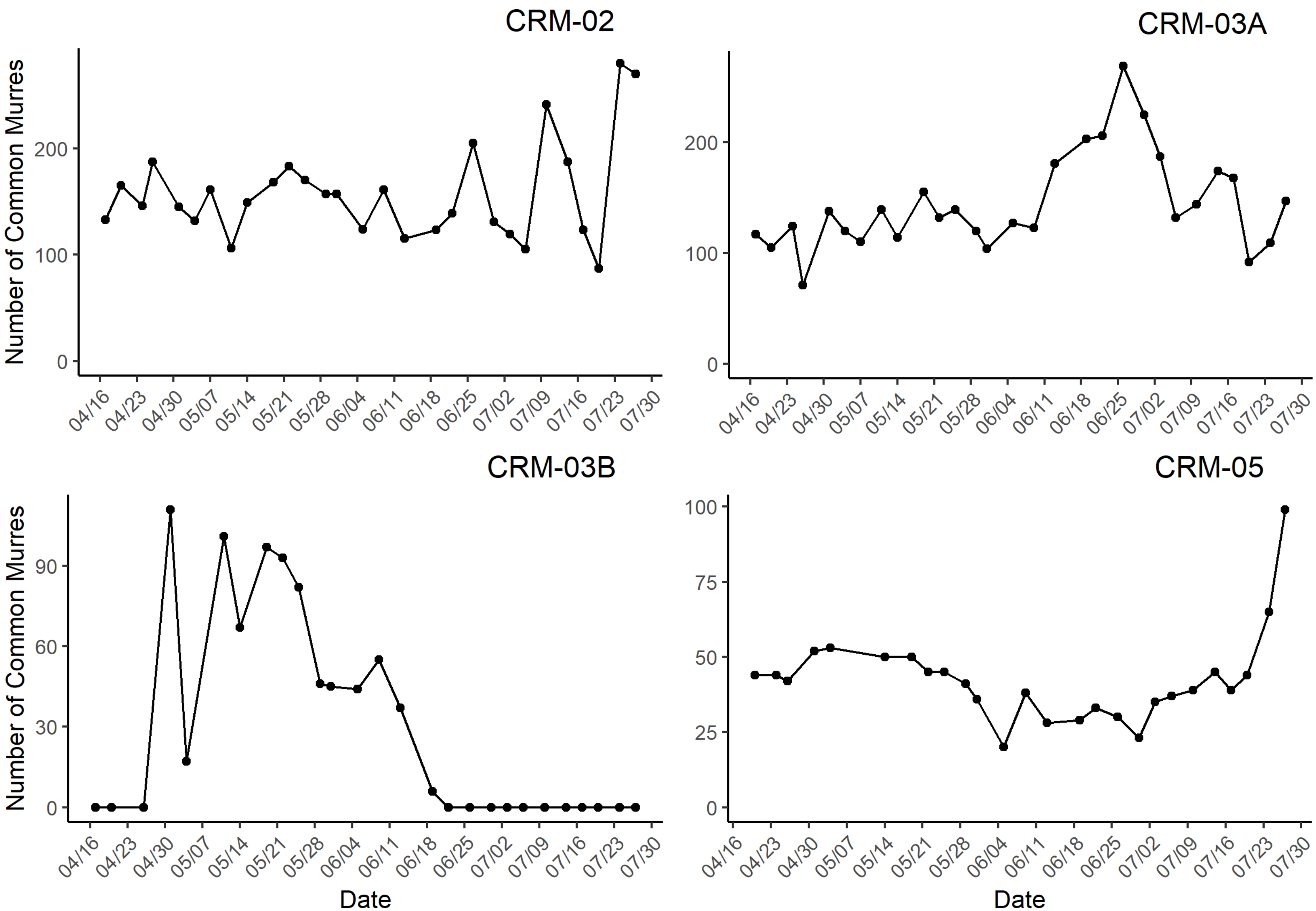


Figure 20. Seasonal attendance of Common Murres at Castle-Hurricane Colony Complex (subcolonies: CRM-02, 03-A, 03-B and 05) from 16 April to 27 July, 2018.

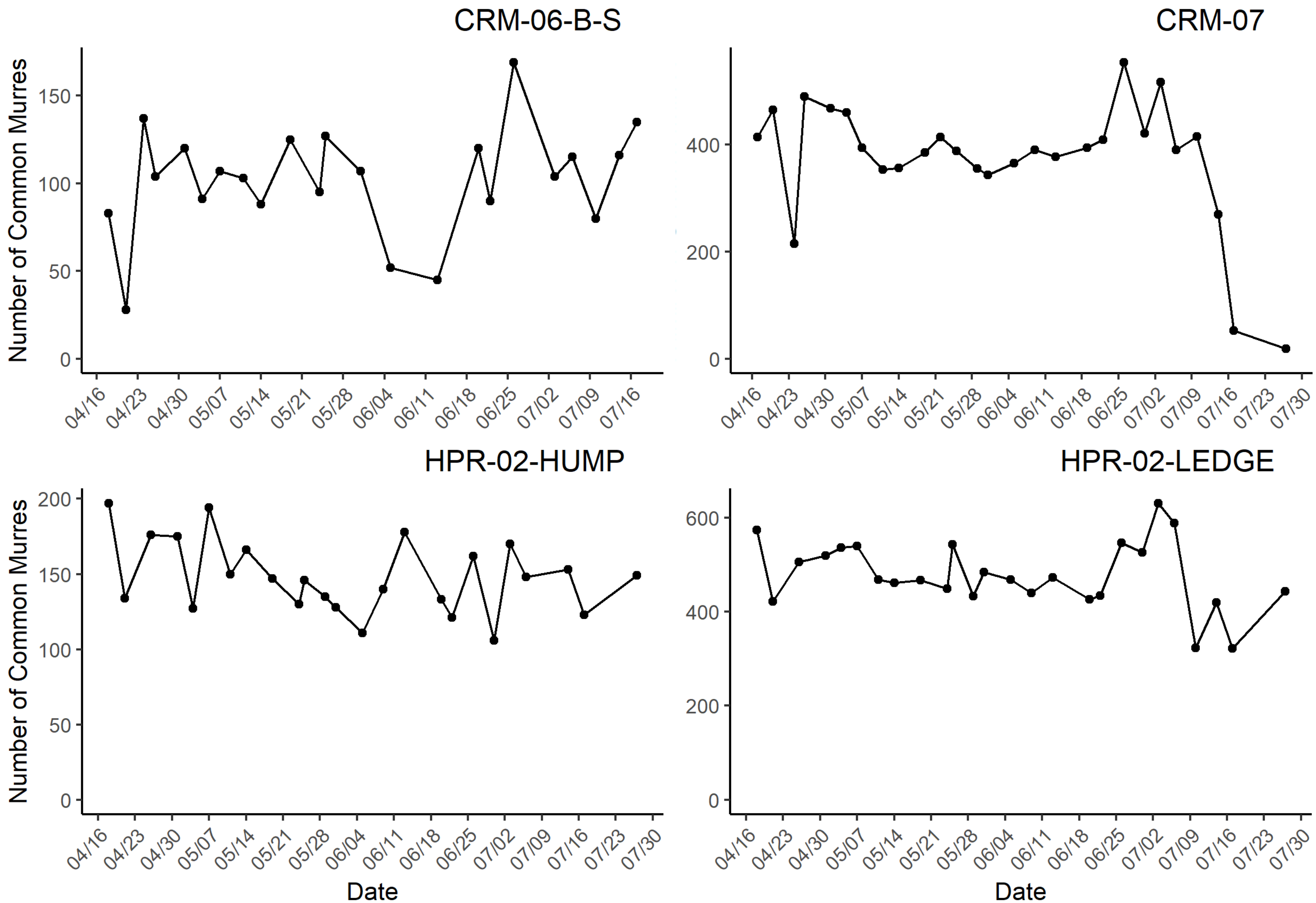


Figure 21. Seasonal attendance of Common Murres at Castle-Hurricane Colony Complex (subcolonies: CRM-06-B-S, 07, HPR-02-Hump and 02-Ledge) from 16 April to 27 July, 2018.

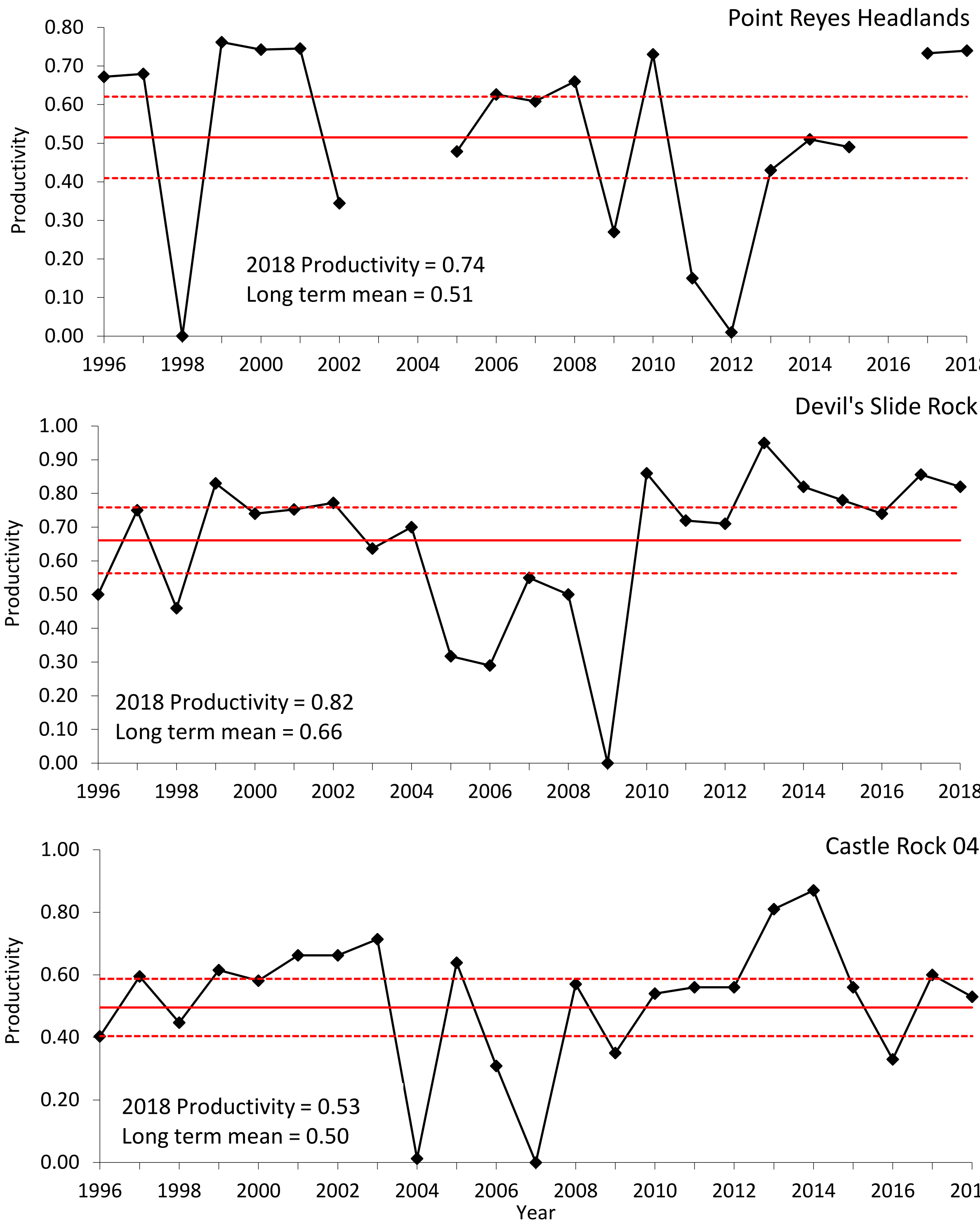


Figure 22. Productivity (chicks fledged per pair) of Common Murres at Point Reyes Headlands, Devil's Slide Rock and Castle Rock -04 from 1996-2018. The solid horizontal line indicates the long-term weighted mean (1996-2017) and the dashed lines represent the 95% confidence interval.

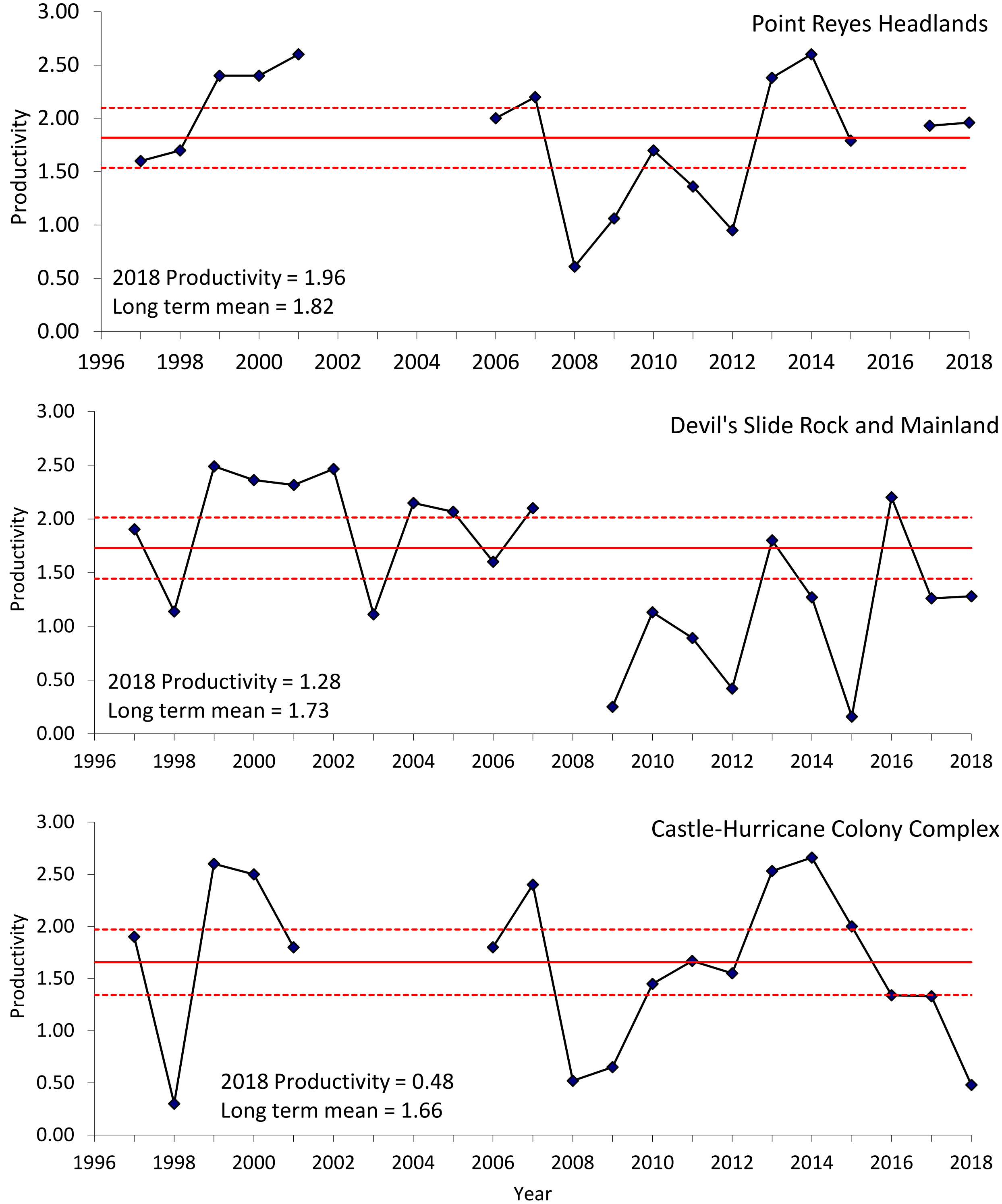


Figure 23. Productivity (chicks fledged per pair) of Brandt's Cormorants at Point Reyes Headlands, Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex from 1997-2018. The solid horizontal line indicates the long-term weighted mean (1996-2016) and the dashed lines represent the 95% confidence interval.

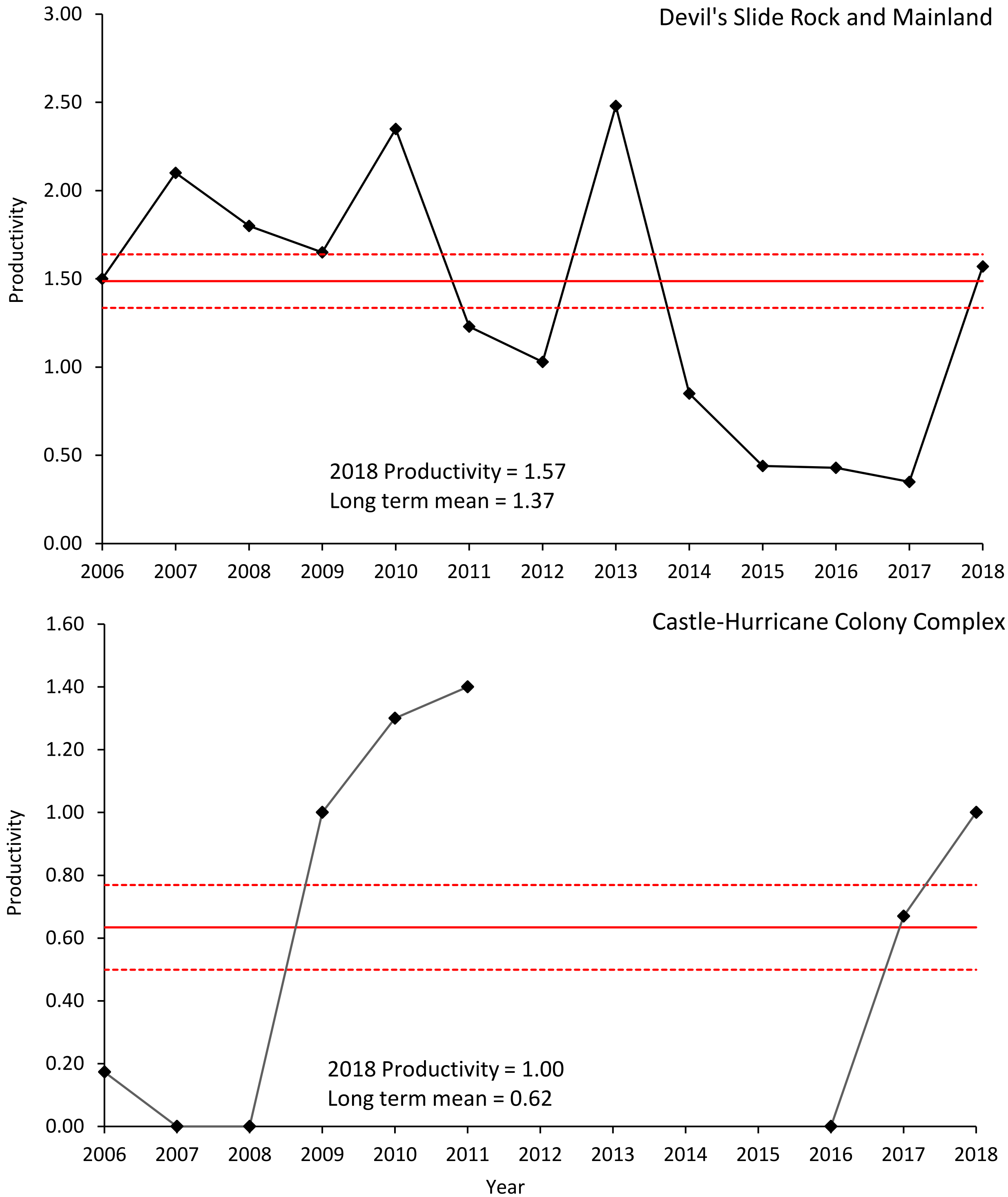
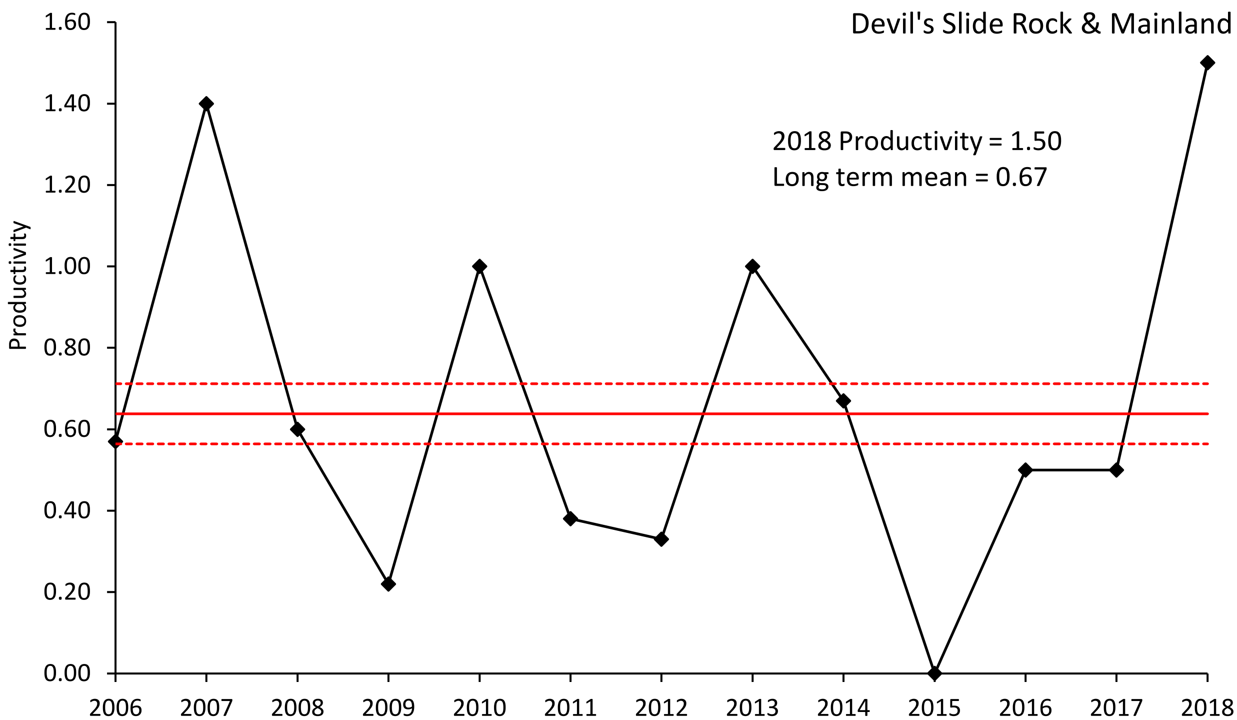


Figure 24.Productivity (chicks fledged per pair) of Pelagic Cormorants at Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex from 2006-2018. The solid horizontal line indicates the long-term weighted mean (2006-2017) and the dashed lines represent the 95% confidence interval. Data was not collected at CHCC for Pelagic Cormorants between 2012 - 2015.



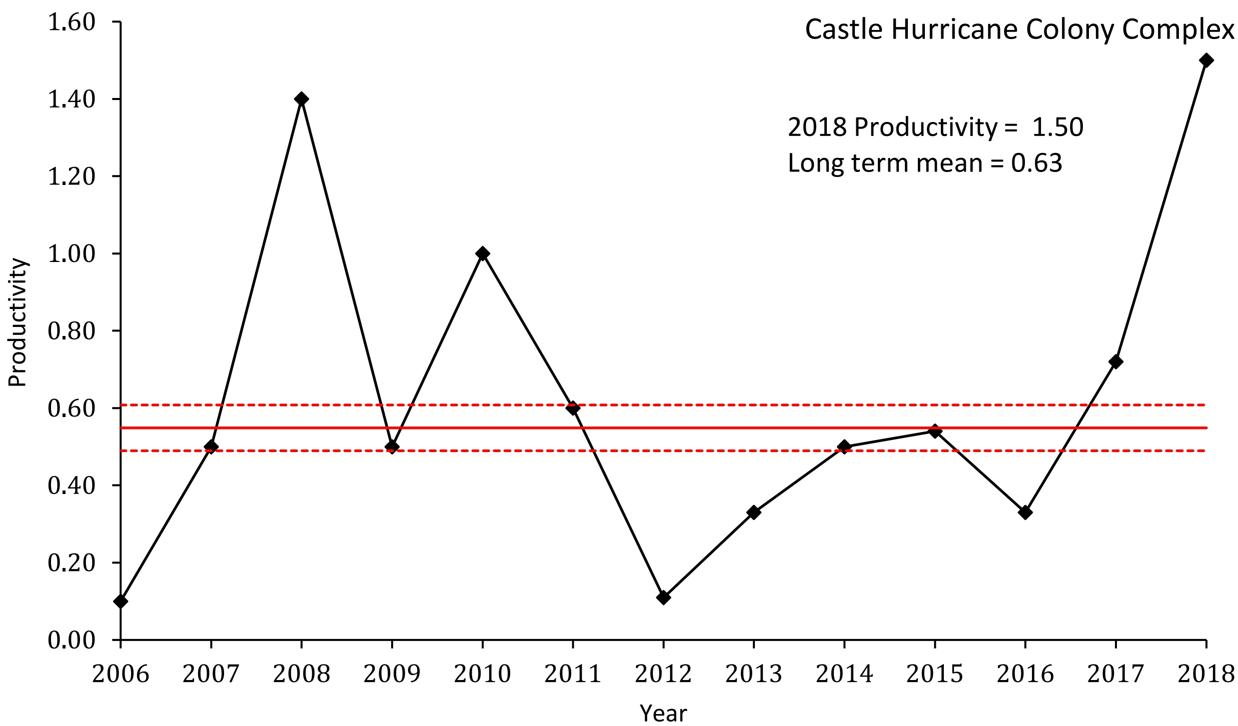


Figure 25. Productivity (chicks fledged per pair) of Western Gulls at Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex from 2006-2018. The solid horizontal line indicates the long-term weighted mean (2006-2017) and the dashed lines represent the 95% confidence interval.

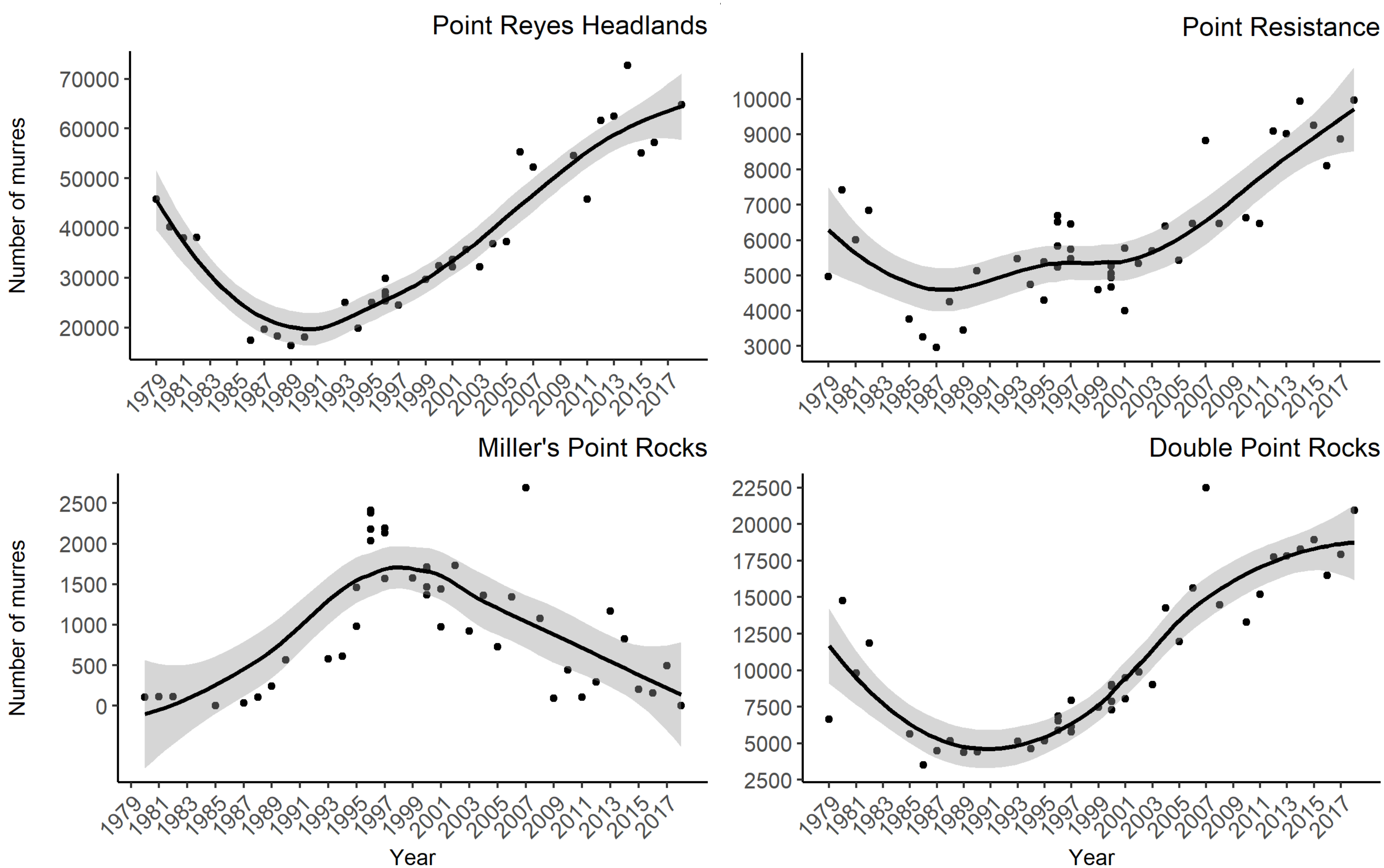


Figure 26.Common Murre breeding population trends at Point Reyes Headlands, Point Resistance, Millers Point Rocks and Double Point Rocks, 1979-2018. Data points are raw counts from aerial photographic surveys multiplied by correction factors (see Methods). LOESS curves (R Core Team, 2013) are shown with 95% confidence intervals. Note different scales between graphs.

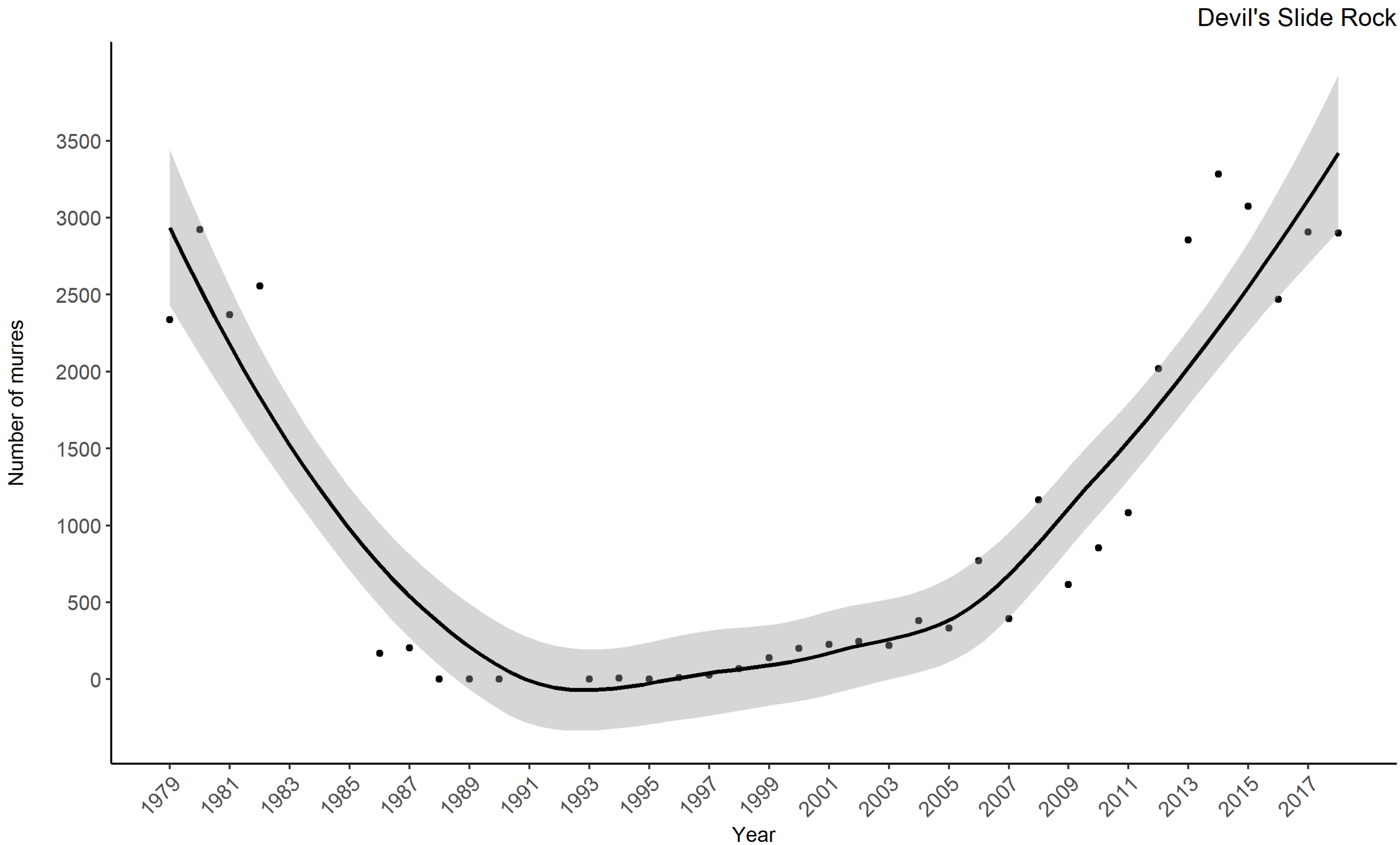


Figure 27. Common Murre breeding population trends at Devil's Slide Rock, 1979-2018. Data points are number of breeding birds from colony monitoring (1996-2007) or raw counts from aerial photographic surveys multiplied by correction factors (all other years; see Methods). LOESS curve is shown with 95% confidence intervals (R Core Team, 2013).

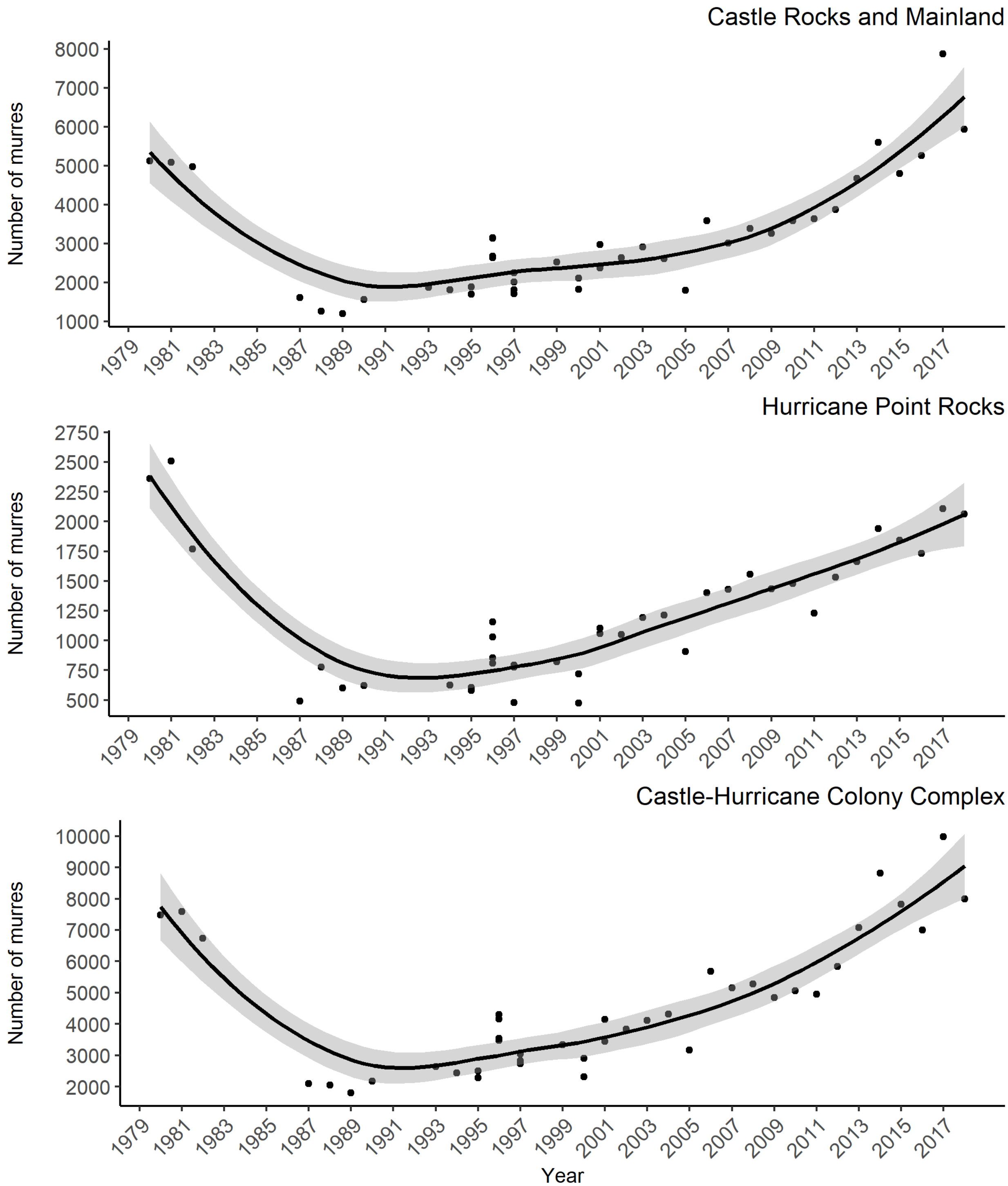


Figure 28. Common Murre breeding population trends at the Castle Rocks & Mainland and Hurricane Point Rocks colonies as well as the combined Castle-Hurricane Colony Complex, 1979-2018. Data points are raw counts from aerial photographic surveys multiplied by correction factors (see Methods). LOESS curves are shown with 95% confidence intervals (R Core Team, 2013). Note different scales between graphs.

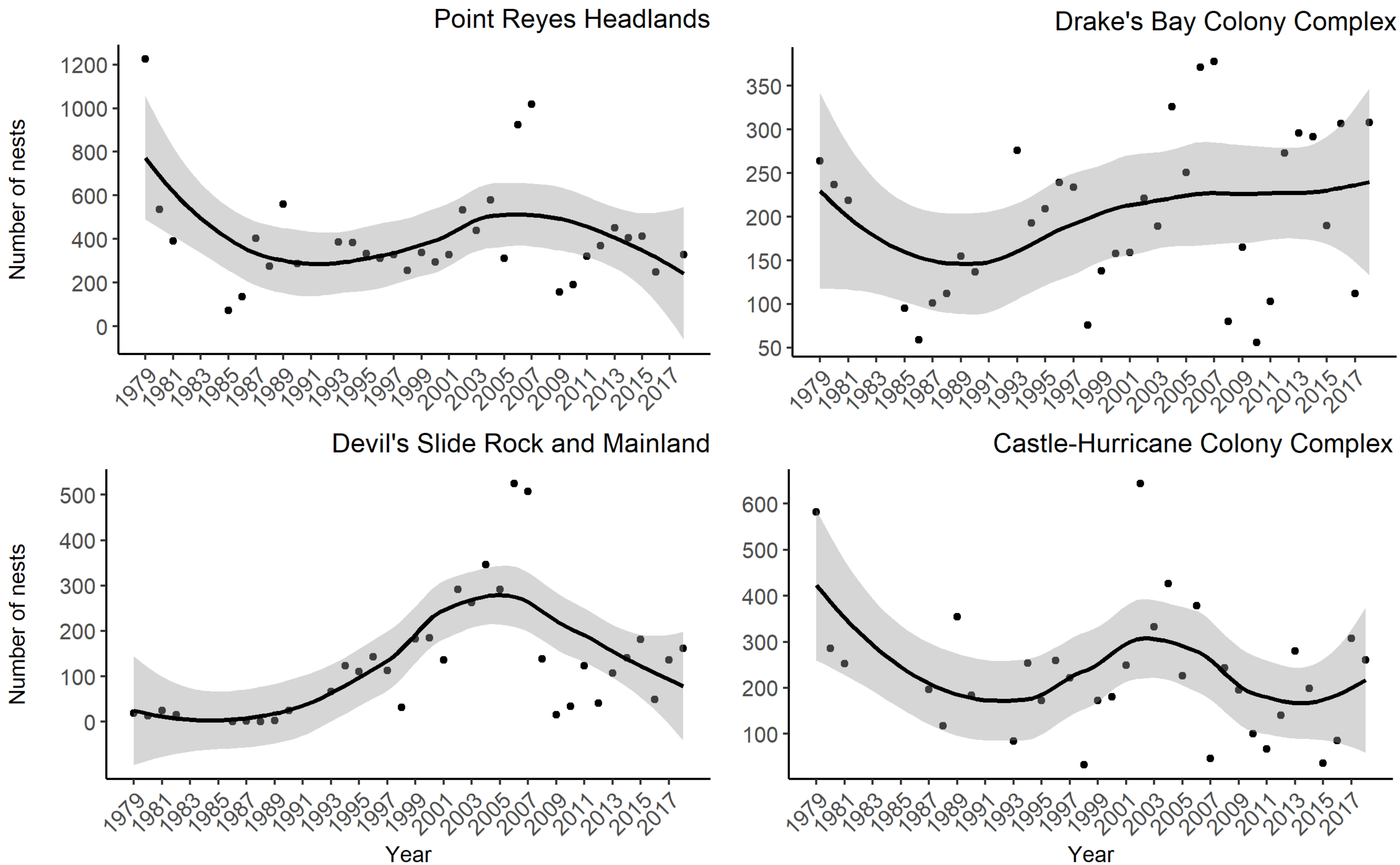


Figure 29. Brandt's Cormorant nest count trends from aerial photographic surveys for Point Reyes Headlands, Drake's Bay Colony Complex, Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex, 1979-2018. LOESS curves are shown with 95% confidence intervals (R Core Team, 2018). Note different scales between graphs.