

**RESTORATION AND MONITORING OF COMMON MURRE COLONIES IN
CENTRAL CALIFORNIA: ANNUAL REPORT 2016**

REPORT TO THE
LUCKENBACH TRUSTEE COUNCIL

Cassie M. Bednar, Gerard J. McChesney, Justin A. Windsor, Ryan J. Potter, Amy C. Wilson,
Allison R. Fuller, Phillip J. Capitolo, and Richard T. Golightly



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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
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ABBREVIATIONS USED

BM227X = Bench Mark-227X

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

MPR = Millers Point Rocks

NOAA = National Oceanic and Atmospheric Administration

NPFC = National Pollution Funds Center

NPS = National Park Service

OSPR = Office of Spill Prevention and Response

PRH = Point Reyes Headlands

PRNS = Point Reyes National Seashore

PRS = Point Resistance

SPN = Seabird Protection Network

SPR = San Pedro Rock

USFWS = U.S. Fish and Wildlife Service

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Observations of the Devil's Slide area colonies were conducted under a scientific collection permit from the County of San Mateo Parks Department. Aerial photographic surveys of seabird colonies within overflight regulation areas of the Greater Farallones and Monterey Bay National Marine Sanctuaries were conducted under NOAA permit GFNMS-2012-001-A1 (issued to University of California, Santa Cruz).

EXECUTIVE SUMMARY

Efforts in 2016 were the 21st year of restoration and associated monitoring of central California seabird colonies by the Common Murre Restoration Project (CMRP). 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, the project was supported by settlement funds from the 1998 *Command* and extended *Luckenbach* oil spills. 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, standardized procedures for the surveillance and assessment of human disturbance at central California Common Murre colonies have been incorporated into daily survey methods. Additionally, the outcome of initial recolonization efforts at DSR and recovery of other central California murre colonies continues to be monitored. 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) 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.

Monitoring of human disturbance (mainly aircraft and watercraft), seabird productivity, seabird attendance patterns and relative population sizes was conducted at two Common Murre colony complexes (with less intensive monitoring at two additional colonies with volunteers). In 2016, Devil's Slide Rock and Mainland (DSRM) continued to have the greatest combined aircraft and watercraft detection rate and disturbance rate of all monitored colonies. Aircraft and watercraft disturbance rates at DSRM during 2005-2016 did not have significant trends across years. Thirteen events resulted in flushing (72% of disturbance events) at DSRM and five events caused only agitation (28% of events). There were no recorded disturbance events at the Castle-Hurricane Colony Complex (CHCC) in 2016 and analysis of annual aircraft and watercraft disturbance rates from 2005-2016 did not show significant trends across years.

Military helicopters were the most commonly detected aircraft and caused 69% of disturbances at all monitored colonies, followed by general aviation (e.g., private or charter) helicopters, U.S. Coast Guard helicopters, law enforcement helicopters and media helicopters. Private recreational fishing boats accounted for three of four watercraft detections, but caused no disturbances. One group of two kayaks caused flushing at DSRM. All four of the watercraft detection events were recorded inside the recently established state Special Closure around DSR.

Although Common Murre attendance counts and productivity at Devil's Slide Rock continue to demonstrate recovery of this formerly extirpated colony, CHCC colonies had low productivity and lower peak attendance counts than observed in 2015. The 2016 aerial photograph count of 1,543 Common Murres on Devil's Slide Rock was 19% less than the 2015 count (1,895) but above the long-term average. Common Murre productivity (chicks fledged per pair) of 0.74 chicks per pair was greater than long-term average at DSR. Common Raven disturbance of

murres in the form of flushing, displacement and egg predation was higher than previously observed at DSR. However, most eggs were taken from outside our monitored plots and thus the impact of raven predation on our measurement of murre productivity was low. Of 25 known murre breeding sites on the Devil's Slide mainland, all failed before hatch. Common Murre productivity at CHCC of 0.33 chicks per pair was the lowest since 2007 and was less than the long-term average. Productivity monitoring was not conducted at PRH in 2016.

In 2016, there were fewer Brandt's Cormorant (*Phalacrocorax penicillatus*) nests counted at DSRM than in 2015 while at CHCC there were more nests than in 2015. Productivity measures above or below the 95% confidence interval of the mean were considered to be significant. Brandt's Cormorant productivity of 2.2 chicks per pair was greater than the long-term mean 95% confidence interval at DSRM. However, productivity of 0.66 chicks per pair was less than the long-term mean and 95% confidence interval at CHCC. Productivity of Pelagic Cormorants (*Phalacrocorax pelagicus*), Western Gulls (*Larus occidentalis*) and Black Oystercatchers (*Haematopus bachmani*) was monitored at both DSRM and CHCC. Productivity of Pelagic Cormorants at DSRM was less than and outside the 95% confidence interval of the long-term average and no monitored nests were successful at CHCC. Western Gull productivity was less than the 95% confidence interval at both CHCC and DSRM. Black Oystercatcher nests were monitored at CHCC; however they did not successfully breed.

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 murrelets on Devil's Slide Rock 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 murrelets continue to occur and may continue to impact 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 murrelets 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; 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 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 murrelets (*Luckenbach* Trustee Council, 2006).

The U. S. Coast Guard's 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 against the Oil Spill Liability Trust Fund, as the responsible party for the *Luckenbach* spills no longer existed. The Oil Spill Liability Trust Fund pays for oil spill cleanup and restoration of impacted natural resources when there is no responsible party. The fund is sustained by fees from the oil industry and managed by the NPFC.

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 SPN is implemented by Greater Farallones National Marine Sanctuary (GFNMS) and CMRP to restore seabird colonies harmed by these oil spills mainly by reducing human disturbance. 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 are utilized to guide education and outreach efforts and 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, Devil's Slide Colony Complex, and Castle-Hurricane Colony Complex. Since 2005, less intensive surveys have been conducted at three additional colonies in the Drakes Bay Colony Complex: Point Resistance (PRS), Millers Point Rocks (MPR), and Double Point Rocks (DPR). In 2016, limited monitoring was conducted at Point Reyes Headlands by National Park staff and monitoring at Drakes Bay Colony Complex was discontinued due to budgetary constraints. Colony count surveys to document potential murre attendance and breeding were conducted twice per week at Bird Island (near Point Bonita) in Marin County, which was colonized in 2007.

Here we summarize colony surveillance and monitoring efforts conducted at central California nearshore murre colonies in 2016. 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 (*Phalacrocorax penicillatus*) relative breeding population sizes and productivity, as well as relative breeding population sizes and/or productivity of Pelagic Cormorants (*P. pelagicus*), Black Oystercatchers (*Haematopus bachmani*), Western Gulls (*Larus occidentalis*), and Pigeon Guillemots (*Cepphus columba*). In addition, we reported data from aerial surveys for colonies between Point Reyes Headlands and Hurricane Point.

METHODS

Study Sites

Two colony complexes, Devil's Slide Colony Complex (DSCC) and Castle Hurricane Colony Complex (CHCC), were monitored for productivity, disturbance and attendance of seabirds in 2016 (Figure 1). Seabird attendance only was monitored by Point Reyes National Seashore staff

at PRH (PRH; Lighthouse Rock only) and by volunteers at Bird Island. 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 Devil's Slide Rock and Mainland (DSRM) and San Pedro Rock (SPR, Figure 2 and 3). CHCC in Monterey County consists of the colonies Bench Mark-227X (BM227X), Castle Rocks & Mainland (CRM), and Hurricane Point Rocks (HPR; Figure 4). 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 areas that 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. All means are reported as the mean plus or minus one standard error, unless otherwise noted.

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, observation hours from all vantage points were combined. 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., not double counted). Also, time transiting between vantage points was not included in observation hours.

Disturbance

Anthropogenic and non-anthropogenic disturbance affecting murrelets or other seabirds was recorded at each study colony. Disturbance events included any instances in which adult birds were alarmed or agitated (e.g., head-bobbing in murrelets, 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). 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 were also recorded. When seabirds were disturbed by a traceable 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).

Monitoring effort was calculated for each colony and colony complex except for PRH and Bird Island, where standardized disturbance monitoring was not conducted. In order to compare disturbance among colonies and among years, disturbance rates were calculated. Anthropogenic disturbance rates were calculated during the breeding season as the number of disturbance events per hour of observation at each colony complex. Long-term trends in detection rates and disturbance rates were analyzed using rates from 2005-2016. To examine long term trends in anthropogenic disturbance, Generalized Linear Model with a Poisson distribution (or Quasi-poisson in cases of overdispersion; R Core Team, 2013) was used to predict trends in annual

change of detection and disturbance rates for aircraft and watercraft during 2005-2016. Percent annual changes in rate, confidence intervals and p-values are reported.

For the annual Pacific Coast Dream Machines event that took place in late April at the Half Moon Bay Airport, observers were stationed most of the day to view potential disturbance events at Devil's Slide Rock. This event included an aircraft fly-in which in some years has 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. For non-anthropogenic disturbances, we reported the species that caused disturbance(s) and summarized major events.

In addition to disturbance events, all aircraft flying at or below an estimated 1,000 ft (305 m) above sea level and about 1,500 ft (460 m) horizontal distance, as well as all watercraft within about 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. Detection rates were calculated as the number of aircraft or watercraft observed within these given zones per observation hour, using monitoring effort for each colony complex. All watercraft entering the Egg Rock/Devil's Slide Rock Special Closure were recorded and reported to Cal-TIP ("Californians Turn in Poachers;" CDFW) or to 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 (MLPA) to protect important seabird and marine mammal colonies from disturbance.

Common Murre Seasonal Attendance Patterns and Breeding Population Sizes

Seasonal attendance of murre at each colony was monitored from standardized mainland observation points using 65-130X or 15-60X spotting scopes. Attending murre were counted at each colony, subcolony, or index plot. Three consecutive counts were made and counts were averaged for most surveys. Seasonal attendance data were collected regularly at all colonies throughout the field season, until all chicks fledged and adult attendance ceased. Breeding season counts were conducted during a standardized period between 1000-1400 h. Murre counts were compared to weekly long-term means (2008-2015) and to 95% confidence intervals.

Aerial photographic surveys of central California murre, Brandt's Cormorant and Double-crested Cormorant colonies were conducted on 15 and 16 June by University of California Santa Cruz and CDFW. Active colonies were photographed from a twin engine, fixed-wing Partenavia aircraft by two photographers with digital SLR cameras. Counts were obtained from all nearshore murre colonies between Point Reyes and Point Sur using Image Pro Plus software (Media Cybernetics, 2007). Photographs were selected to provide the most complete colony coverage with high quality imagery. All visible murre were individually counted 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, a correction factor was applied to the raw aerial photograph counts to account for breeding birds not present and non-breeding birds present at the time of the survey. For 2016, we used the correction factor of 1.60 derived for murre in 2016 at nearby Southeast Farallon Island

(Warzybok et al. 2016). 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 values provided by Point Blue Conservation Science (1985-2015) 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). Annual population estimates dating back to 1979 were plotted and fitted with a LOESS curve (R Core Team 2013) and 95% confidence intervals to show long-term patterns. Linear trends were determined for estimates from the 1999-2016 period using Generalized Linear Model with a Poisson distribution (or Quasi-poisson in cases of overdispersion; R Core Team 2013). This period corresponds to the period since the very strong 1997-98 El Niño and the shift to a colder water regime.

Point Reyes Headlands

No funds were available for paid monitoring staff in 2016, but limited murre seasonal attendance monitoring was conducted by trained personnel from Point Reyes National Seashore (PRNS) staff. Counts of three long-term plots on Lighthouse Rock, Ledge, Edge and Dugout, were conducted once per week.

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 2016, monitoring of this recent colonization continued and observations were conducted by trained volunteers, twice per week. From 18 April to 10 August, counts were conducted during two time periods; early morning (0700-0900 h) and late afternoon (after 1500 h), of both the north (from the bluff above the north end of Rodeo Beach) and south (from the Bird Island overlook) sides of Bird Island.

Devil's Slide Rock and Mainland, San Pedro Rock

Murres on DSR were counted every other day from 21 April to 16 August from the Traditional Pullout. On Devil's Slide Mainland (DSM), attendance patterns were monitored once per week wherever murres could be viewed (see map, Figure 2 and 3). 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 nesting Peregrine Falcons (*Falco peregrinus*). At SPR, bird counts were conducted once per week throughout the breeding season from Pipe Pullout.

Castle-Hurricane Colony Complex

Seasonal attendance of murres was monitored for all active subcolonies visible from accessible, standardized mainland observation points (Figure 4). Counts were conducted twice per week during the breeding season from 21 April to 30 July. At four subcolonies, separate subarea counts were also conducted: CRM-04 (productivity plot and entire rock), CRM-03-B (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). Area CRM-06-A was observed from the Castle Pullout.

Common Murre Productivity

As in previous years, productivity (chicks fledged per pair) of murres was monitored at DSRM and CRM daily (at least every two to three days; weather permitting) from standardized mainland observation points using either 65-130x or 15-60x spotting scopes. At CRM-04-P, locations of returning or new breeding and territorial sites were identified using maps and photographs updated from the 2015 breeding season. At CRM-03-B, a subset of breeding sites was followed, at the discretion of the on-site field biologist. At DSR, all followed sites were mapped and numbered using digiscoped photographs of the 2016 colony and photographs from the 2015 breeding season, as well as 2016 aerial photographs. A breeding site was defined 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 detection. A sporadic site was defined 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. Results from 2016 were compared to previous long-term means: DSR and CRM, 1996-2015 (n = 20 years).

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 5). Boundary adjustments were made to plots A and C in 2007, and difficult sites were dropped from plots B and C in 2012. These adjusted plots (A, B, and C) were utilized for monitoring in 2008-2013. Prior to the 2014 field season, difficult to observe sites were dropped from plot A and B, and more suitable sites were added. This resulted in 47 and 21 fewer sites followed compared to 2013 in plots A and B, respectively. Plot C was eliminated from monitoring entirely for the 2014 field season because of difficult viewing conditions (compared to 13 sites followed in 2013). In 2015, a new plot was added called Plot D, which was located on a ledge below Plot A (Figure 5). This plot was added in an effort to capture edge effects which were previously captured by following Plot C. In 2015, Plot D contained 31 sites but in 2016 there were only 25 sites. At DSM, visible sites were monitored at one active subarea: Lower Mainland South (DSRM-05-A Lower). All active sites in plots and subareas were monitored beginning 15 April.

Castle-Hurricane Colony Complex

All active murre breeding and territorial sites were monitored within a standardized plot on CRM-04 (established in 1996) beginning 21 April. A subset of active sites also was monitored on CRM-03-B.

Common Murre Co-attendance and Chick Provisioning

Murre co-attendance and chick provisioning observations, or time budget surveys, were not conducted in 2016.

Nest Surveys

To assess breeding population sizes, we used a combination of land-based and aerial photographic surveys. No boat surveys were conducted in 2016. Land-based nest and bird counts of non-murre seabirds were conducted weekly at DSRM and semiweekly at CHCC between mid-April to 10 July during the breeding season in order to assess relative breeding population sizes. Brandt's Cormorant nests and territorial sites were classified into five groups that described nesting stages: site with little or no nesting material, 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. Nest counts reported were the sum of seasonal peak counts of well-built nests (including nests with chicks) at each subcolony or subarea.

Whole-colony nest counts were obtained from aerial photographs of all monitored colonies as well as other nearshore Brandt's Cormorant colonies between Point Reyes and Año Nuevo (see Common Murre Seasonal Attendance Patterns and Breeding Population Sizes, above). Along with active well-built nests and nests with chicks, aerial photograph counts of "nests" also included poorly built nests, 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). Annual nest counts from aerial surveys dating back to 1979 were plotted and fitted with a LOESS curve (R Core Team 2013) and 95% confidence intervals to show long-term patterns. Linear trends were determined for estimates from the 1999-2016 period using Generalized Linear Model with a Poisson distribution (or Quasi-poisson in cases of overdispersion; R Core Team 2013). This period corresponds to the period since the very strong 1997-98 El Niño and the shift to a colder water regime.

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

Brandt's Cormorant Productivity

Breeding phenology and reproductive success (clutch sizes, brood sizes and chicks fledged per pair) of Brandt's Cormorants were monitored at DSRM and CHCC. At DSRM, monitoring was conducted at DSR (DSRM-01), Upper Mainland South (DSRM-05-A Upper), Lower Mainland South (DSRM-05-A Lower), and South of Turtlehead Cliffs (DSRM-05-C). At CHCC, monitoring was conducted at CRM-03-B.

Monitored nests were checked every one to seven days from mainland observation points using binoculars and spotting scopes. Chicks were considered to have 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 2016 were compared to prior long-term averages for DSRM (1997-2007, 2010-2015; n = 17 years), and CHCC (1997-2001, 2006-2015; n = 15 years).

Pelagic Cormorant, Black Oystercatcher, and Western Gull Productivity

Productivity of Western Gulls and Black Oystercatchers was monitored at select nests that were easily visible from mainland observation points at DSRM and CHCC. Productivity of Pelagic Cormorants was monitored at DSRM and CHCC. Productivity of Pelagic Cormorants had not been monitored at CHCC since 2011 due to low sample sizes and poor visibility of nests; however a small colony of easily monitored nests was found in May and added to regular monitoring in 2016. Therefore, monitoring of Pelagic Cormorants at CHCC began on 26 May after egg laying had already commenced. Nests were checked at least once per week. Chicks were considered to have fledged if they survived to at least 30 days. Feathering status was used 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). Results were compared to long-term averages for DSRM (2006-2015; n = 10) and CHCC (2006-2011; n = 6).

Pigeon Guillemot Surveys

To assess relative population size and seasonal attendance patterns, standardized counts were conducted from mid-April to late June of birds rafting on the water and roosting on land (intertidal and nesting areas) at DSCC and CHCC. Surveys at all colonies were conducted between 30 minutes after sunrise and 0830 h. From mid-April to 5 May, when numbers often peak, surveys were conducted twice per week (weather permitting) and about once per week thereafter. At DSCC, the entire area from the south side of San Pedro Rock to the South Bunker (DSRM-04; Figure 2) was surveyed. Access to the Turtlehead Overlook (DSRM-05; Figure 3) was restricted to short periods of time in order to reduce disturbance to nesting Peregrine Falcons (*Falco peregrinus*). At CHCC, the portion of the survey area between Rocky Point and Esselen Rock was dropped in 2014 due to access issues for certain vantage points, thus, comparisons to prior years must take into account the variation caused by changing vantage points.

RESULTS

Anthropogenic Disturbance

During the 2016 field season monitoring effort across DSCC and CHCC totaled 651.25 on-site hours (Table 1). There were 56 aircraft detections within our monitoring areas at DSRM and CHCC (Table 2) combined; these included 25 planes, 28 helicopters and 3 drones (Appendix 1). No significant change in detection rates of aircraft at DSRM or CHCC occurred during the 2005 to 2016 period (Table 2). Overall, 17 of these overflights resulted in disturbance to seabirds (e.g. agitation, displacement or flushing). One plane and 16 helicopters caused visible disturbance. Twelve helicopters caused displacement and/or flushing of murres. The most frequently detected aircraft categories were general aviation planes and research planes (one plane that made multiple passes; Figure 6). The research plane did not cause any disturbance. The third most observed aircraft type were military helicopters with eleven detections, of which ten caused disturbance (Figure 6). There were four total watercraft detections within 1,500 feet of monitored colonies, including three recreational fishing boats and one group of kayaks (Appendix 2). The group of kayaks flushed and displaced birds at DSRM (Figure 7).

A total of 19 Wildlife Disturbance Reports were completed and submitted to the SPN in 2016 (all from DSRM), including 18 aircraft disturbance events and one watercraft disturbance event.

Devil's Slide Rock and Mainland

In 2016, 17 (30%) overflights resulted in disturbance to seabirds. Disturbances were caused by one plane (2% of all overflights) and 16 helicopters (28% of all overflights). The rate of disturbance events involving displacement and/or flushing of seabirds (0.027 disturbances/hr) was lower than in 2015. Analysis did not reveal any significant long-term trends in aircraft detection or disturbance rates (Table 2); however visual inspection of long-term data (Figure 8 and 9) demonstrates an apparent pattern of reduced detections and disturbance since 2005. There were 13 total flushing events, including: six military helicopters, three general aviation helicopters, one U.S. Coast Guard helicopter, one California Highway Patrol helicopter, one media news helicopter and one group of two kayaks (Appendix 1 and 2). The largest flushing events were from one pair of military helicopters and one U.S. Coast Guard helicopter which each flushed about 500 murres (Table 3). There was no significant trend found for the annual detection or disturbance rates for aircraft between 2005-2016 at DSRM (Table 2) but long-term data indicates a significant declining trend in watercraft detections and disturbances (Table 2, $P < 0.001$ and $P = 0.01$ respectively, Figure 8 and 9). In addition, the rate of detections (0.03 detections/hr) and disturbances (0.002 disturbances/hr) from planes were the lowest rates recorded since dedicated disturbance monitoring began in 2005.

There were four watercraft recorded entering the Egg Rock/Devil's Slide Rock Special Closure, including the one kayak disturbance event. All watercraft observed inside Special Closures were reported to the SPN and CDFW, which resulted in several site visits by CDFW wardens as follow up on reports.

The annual Pacific Coast Dream Machines event took place on 24 April 2016 at the Half Moon Bay Airport. Weather conditions were clear but windy with a Beaufort wind force ranging from 5-7 throughout the day. Observers were stationed at the observation point for Devil's Slide Rock from 0754 h to 1604 h to record overflights and disturbance events. For the first time since disturbance monitoring began (2005) at DSR during the event, no disturbances were recorded during the event. Forty-five aircraft were observed flying over the area but none of these entered the detection zone (1000 ft above sea level, 1500 ft horizontal distance). There was no significant trend in annual change in aircraft detection or disturbance rates during the Dream Machines event. SPN staff located at the Half Moon Bay Airport provided outreach to pilots during the event.

Castle-Hurricane Colony Complex

Nine planes, four helicopters and two drones were observed flying within the detection zone at CHCC; however none of these aircraft caused visible disturbance to any species of seabird in 2016 (Table 2, Figure 8 and 9). There was no significant trend in annual aircraft detection or disturbance rates at CHCC. There was no watercraft disturbance observed and no significant long-term trends in the change of annual watercraft disturbance rates (2005-2016, Table 2).

Non-Anthropogenic Disturbance

Devil's Slide Rock and Mainland

In 2016, 274 flushing events and displacement events (730% more events than in 2015) were recorded at DSRM from non-anthropogenic sources. Brown Pelicans were responsible for 12% (n = 33), and Common Ravens for 86% (n = 236). Western Gulls accounted for the five other non-anthropogenic disturbances observed.

Ravens were first observed flushing murres from DSR on 19 April and continued until 30 June, after which ravens were no longer observed on the rock. The greatest number of birds disturbed in one raven disturbance event occurred on 20 April when a total of 519 murres flushed from DSR (Figure 10). Ravens were observed taking 98 murre eggs and three murre chicks. Three eggs were observed taken from monitored productivity plots and of these two were taken from the east side lower shelf of Plot B. Many eggs were also observed being taken from the north side of DSR which is mostly out of view and could only be seen once ravens flew away holding an egg. Some of these eggs were eaten on DSR and others were taken and eaten or cached at several locations along the mainland. These raven disturbances appeared to be from one pair of birds that often visited the rock together. No nest or other evidence of nesting by these birds was found in the area, although they appeared to be a territorial pair.

Brown Pelicans caused several disturbances to DSR throughout the 2016 season. The majority of events were the result of pelicans landing and roosting on DSR. On 28 July, fourteen pelicans landing and roosting on DSR resulted in 765 murres flushing from the DSR colony which was the largest non-anthropogenic disturbance event observed in 2016. On 19 May five pelicans walked into the nesting areas of Plot B and C which caused over 40 eggs to be exposed or

displaced. Although most were recovered, three exposed eggs were depredated by ravens and gulls and nine eggs rolled off DSR during the disturbance. Roosting Brown Pelicans also caused a disturbance on 6 June which was responsible for the exposure of 13 eggs over five separate disturbance events on the mainland (DSRM-05-A Lower) colony. We observed that four sites at DSM were abandoned or eggs were lost due to pelican disturbance and we suspect that subsequent disturbances from pelicans contributed to the eventual failure of murres breeding on the mainland.

Castle-Hurricane Colony Complex

In 2016, eight flushing events were recorded at CHCC from non-anthropogenic sources. Western Gulls were responsible for 62.5% ($n = 5$) of recorded disturbances along with one event each for Brown Pelicans, a Peregrine Falcon, and a Great Blue Heron. For all events, no eggs or chicks were observed to be taken. Events flushed an average of 27 (range = 10- 80) murres. The one documented Brown Pelican disturbance was three birds flying low over CRM-02 in late July resulting in 80 murres flushing from a group of non-breeding murres.

Common Murre Seasonal Attendance Patterns and Breeding Population Sizes

Point Reyes Headlands and Drake's Bay Colonies

Limited seasonal attendance monitoring was conducted by PRNS staff at Lighthouse Rock (PRH-03-B) for the Ledge, Edge and Dugout plots. Monitoring began on 5 May and murres were present at all plots until the last check on 11 August. Murre attendance at all plots was lower than long-term patterns (2008-2015) for the pre-egg and incubation periods but was above the long-term patterns in the chick rearing period (Figure 11).

At PRH and the three Drake's Bay colonies, aerial photographic surveys were conducted on 15 June (Table 5). Long-term patterns in breeding population sizes are shown in Figure 12. All colonies except Millers Point Rocks have shown recovery since the large declines of the mid-1980s, including significant linear increases since 1999. Our land-based monitoring of Millers Point Rocks in 2005-2015 showed that murre attendance is highly variable from year to year and even seasonally; most birds did not breed, and those that did breed had low breeding success based on attendance pattern (see 2005 to 2015 annual reports). The correction factor applied to estimate breeding population size likely provides an overestimate for the Millers Point Rocks colony.

Bird Island

Surveys were conducted at Bird Island from 18 April to 10 August 2016. Murres were observed on 46% of observation days but the first murre was not recorded until 31 May. The average number of murres counted on days when they were present was six (range = 3-11, $n = 21$ days between 31 May and 9 Aug). No murres were present on 10 Aug. 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. Eggs were never seen but at least one chick was seen on three separate observation

days. It is unclear if or how many of these chicks survived to fledging age. From the aerial survey on 16 June, nine murre were counted on Bird Island but more likely were hidden under the Compass House remains.

Devil's Slide Rock and Mainland, San Pedro Rock

Devil's Slide Rock

Murres were observed on all count days between 21 April and 10 August 2016. Murres were completely absent from the rock on 16 August following the end of breeding activity (Figure 13). The greatest counts were recorded during the pre-egg laying period and again during the hatching period. The maximum count of 1,707 murres on both 27 April and 12 July was 15% less than the 2015 peak count of 2,012 murres. During the pre-lay period, murres were observed leaving DSR in large numbers in the afternoon, sometimes in conjunction with Common Raven disturbance events. On 13 May, murre attendance was the lowest observed during the pre-lay period with only 45 murres remaining on DSR at the time of the count. Attendance counts were less variable from late May to early July through the egg-laying, incubation and early chick periods. By 18 July, numbers began to decline as murres started leaving the colony with fledging chicks. Generally, attendance at DSR was higher than the long-term mean throughout most of the season.

From photographs obtained during the annual aerial photographic survey on 15 June, 1,543 murres were counted on DSR, compared to the standardized land-based colony count of 1,171 murres from the same day. The greater aerial survey count reflects the more complete colony coverage provided by this method. Applying the correction factor to the aerial survey count of 1,543 birds yielded an estimate of 2,469 breeding birds, or about 1,235 breeding pairs. This estimate is 20% less than the estimate of 3,070 breeding birds in 2015 but is similar to 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 14).

Devil's Slide Mainland and San Pedro Rock

Murres attended the Devil's Slide Mainland cliffs in low numbers (mean = 27, range = 3-58, (Figure 15). Lower Mainland South (DSRM-05-A Lower) was the only mainland subarea with consistent attendance. After pelican disturbance events on 6 June, 18 June and 19 June resulted in the failure of many breeding sites, most attendance ceased. Attendance followed similar patterns to past years, with peak attendance in late April to mid-May followed by decline as breeding sites failed and murres abandoned the area.

From the 15 June aerial photographic survey, 16 murres were counted on the Devil's Slide Mainland cliffs.

No murres were observed on San Pedro Rock in 2016.

Castle-Hurricane Colony Complex

Attendance counts at all CHCC subcolonies began on 21 April. Similarities in attendance suggested relatively synchronous breeding at most active CHCC subcolonies, with fairly consistent, sharp declines between about 20 July and 30 July as chicks and adults departed the colony (Figure 16-19). Murres were gone completely from CHCC by 30 July. Comparisons of 2016 to past years showed similar seasonal attendance patterns but lower numbers of birds (Figure 16-19). It is unclear if this reduction reflected colony decline, reduced co-attendance by breeding pair members, or a combination of factors.

Despite apparent similarities in breeding phenology among established breeding areas, other subcolonies showed very different attendance patterns. Subcolony BM227X-02, or Esselen Rock, is an ephemeral subcolony with active breeding in some years and little to no attendance in others. In 2016, murres were in attendance at BM227X-02 at the start of the season but had abandoned the rock by 14 June (Figure 19) for unknown reasons. At CRM-03-B, attendance early in the season was mainly in the breeding area high on the rock. After breeding failure in late May (see Common Murre Productivity, below), small numbers of murres began regularly attending the lower portion of CRM-03-B among nesting Brandt's Cormorants, as well as a small area on the south side of the rock (Figure 17), but no breeding activity was observed. There were also relatively large groups of non-breeding murres attending the peripheries of breeding areas on CRM-02 and CRM-03-A.

Between mid-May and early June, a small group of murres attended a low, rocky mainland point in CRM-08 among a group of displaying Brandt's Cormorants (Figure 18). This was the first time we have recorded murres at that specific location. When the cormorants abandoned the site, murre attendance ceased. Later, it was revealed in aerial photographs that small numbers of murres were in attendance on 16 June among nesting Brandt's Cormorants on an adjacent cliff that was out of view from mainland vantage points.

Based on counts from an aerial photographic survey on 16 June (Table 5), a total breeding population estimate of 6,995 murres was estimated for all of CHCC, including 5,266 and 1,730 murres on CRM and HPR, respectively. All colonies, separately and combined, at CHCC show a significant increasing trend for the 1999-2016 period and have largely recovered from declines in the mid-1980s (Figure 20).

Common Murre Productivity

Devil's Slide Rock and Mainland

Of 203 sites documented within DSR plots, 181 (89%) were breeding, 21 (11%) were territorial, and one (0.4%) was sporadic. The first murre egg was observed on 4 May, outside of the productivity plots. At all sites combined in monitored plots, the mean egg-laying date (exclusive of replacement eggs) was 29 May \pm 1.1 days (\pm one standard error; range = 10 May – 30 June, n = 174; Table 4), which is four days later and (outside one standard error of the mean) than the long-term average (25 May \pm 1.9 days). A total of 206 eggs were laid, including 25 replacement

eggs. Overall productivity of 0.74 chicks fledged per pair was greater than the long-term average (0.64 ± 0.05 ; Figure 21) and near the upper 95% confidence interval. Hatching success was 72.7% and fledging success was 89.7%. Chicks that fledged remained on the rock for an average of 25 ± 0.4 days ($n = 126$), and the last chick was seen on 8 August (Table 4). Three eggs were observed taken from monitored plots, and of these, only one site relayed. It is unknown how many other eggs lost within plots were from raven depredation but it does not appear that raven depredation heavily impacted overall murre productivity within monitored plots in 2016. However, lower hatching and fledging success in Plot D could have been partially due to raven depredation.

Twenty-five breeding sites were followed on Lower Mainland South (DSRM-05-A Lower). Mean egg-lay date was 29 May ± 2.9 days (range = 14 May – 21 June, $n = 25$; Table 4). A total of 28 eggs were laid, including three replacement clutches, and all eggs were lost or abandoned. Brown Pelican disturbances caused the observed abandonment or loss of three eggs on 6 June and five more eggs on 18 and 19 June. The last replacement egg observed was laid on 21 June but no eggs were seen after 24 June.

Castle-Hurricane Colony Complex

Of 104 total monitored sites in the CRM-04 plot in 2016, 90 (87%) were breeding and 14 (13%) were territorial (Table 4). The first murre egg was observed on 6 May on CRM-04. The mean egg-laying date was 13 May ± 0.61 days (range = 6 May – 2 June; $n = 83$), two days later than the long-term average of 15 May ± 2.3 days. A total of four replacement eggs were observed. Overall productivity at CRM-04 was 0.33 chicks per pair, less than the long-term mean (0.53 ± 0.05 chicks per pair), and outside the 95% confidence interval (Figure 21). Chicks that fledged remained on the rock for an average of 22 ± 0.66 days ($n = 26$) after hatching, and the last chick was seen on 14 July.

For the eighth consecutive year, murrees bred and were monitored on the east side of CRM-03-B. Of 35 sites monitored, five (14%) were breeding and 30 (86%) were territories. The mean egg-laying date was 22 May ± 1.5 days (range = 18 May – 25 May; $n = 5$; Table 4), 12 days later (above one standard error) than the long-term average of 18 May ± 2.1 days. Replacement clutches were not observed. All breeding sites failed, with no replacement clutches, and all attending murrees abandoned the breeding area by 26 May. The long-term average for productivity at this subcolony was only 0.44 ± 0.08 chicks per pair (1999-2003, 2005, 2008-2014; $n = 13$ years) and breeding does not occur every year. In early June, small numbers of murrees began regularly attending the lower portion of the rock among nesting Brandt's Cormorants as well as a small area on the south side of the rock, but no breeding activity was observed there.

Brandt's Cormorant Nest Surveys and Productivity

Seasonal peak nest counts of Brandt's Cormorants obtained from weekly land surveys are reported (Table 5). 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. For 2016, we also included nest counts obtained from aerial photographic surveys. Aerial counts tend to be more complete than other methods.

Point Reyes Headlands and Drake's Bay Colony Complex

Based on aerial photographic surveys, Brandt's Cormorant nest counts were 40% lower at PRH but 62% greater at DBCC (three colonies combined) than in 2015 (Table 5, Figure 22). Nest counts have been highly variable over time and no significant linear trends were found for the 1999-2016 period.

Bird Island

Surveys were conducted from 18 April to 25 July. Roosting Brandt's Cormorants were present predominately during the beginning of the season (18 April – 16 May), with counts ranging 0-237 birds. No breeding activity was observed.

Devil's Slide Rock and Mainland

Nest surveys

Nests and territorial sites were counted between 25 April and 4 July. The first well-built nests were observed on 28 April. The peak count of nests on DSR was two nests. On the mainland, nesting occurred on Upper Mainland South (DSRM-05-A Upper; peak count of four nests), Lower Mainland South (DSRM-05-A Lower; peak count of four nests), and South of Turtlehead Cliffs (DSRM-05-C; peak count of 28 nests).

The peak single day count for DSRM combined was 36 nests on 20 June, 42% less than the 2015 peak count (62 nests). The sum of the seasonal peak counts was 38 nests (Table 5), 64% less than the 2015 seasonal peak count sum of 105 nests.

From the aerial photographic survey on 15 June, a total of 49 nests were counted, including nine on DSR and 40 on DSM (Table 5). Seven of nine nest counted on DSR were poorly-built nests and not easily visible from land-based survey overlooks. Consistent with land-based counts, the aerial count was much less than the 2015 aerial count and was among the lowest counts since 1999 (Figure 22). Numbers of nests at DSRM have fluctuated dramatically since 1999 and no significant linear trend was found.

Productivity

In 2016, Brandt's Cormorant breeding at DSRM was characterized by low numbers of nests initiated but high breeding success. A total of 45 breeding sites were monitored at DSRM in 2016, including sites on Upper Mainland South (DSRM-05-A Upper), Lower Mainland South (DSRM-05-A Lower), and South of Turtlehead Cliffs (DSRM-05-C; Table 6). While there was some evidence of nest building on DSRM-01, it is uncertain if any eggs were laid and no chicks were observed. The first egg was observed on DSM on 29 April. For all subareas combined, the mean clutch initiation date of 17 May \pm 1.5 days (range = 29 April to 12 June) was 10 days later (outside one standard error) than the long-term mean of 12 May \pm 2.7 days. There was one

replacement clutch. Overall productivity of 2.20 chicks fledged per pair (subarea range = 1.9 – 2.4; n = 45) was substantially greater (outside the upper 95% confidence interval) than the long-term average of 1.73 ± 0.2 (Figure 23). Relatively high breeding success per nest (0.95) reflected low nest abandonment.

Castle-Hurricane Colony Complex

Nest surveys

Brandt's Cormorant nest surveys were conducted from 21 April to 30 July. Subcolonies or subareas with confirmed breeding in 2016 were CRM-03-B and CRM-08. The first well-built nests were observed on 25 April at CRM-03-B. The 35 nest sites were established at CRM-08 but had all been abandoned by 29 May. At all CHCC subcolonies combined, the peak single survey nest count of 41 nests was recorded on 17 June; 52% less than the 2015 peak count of 86. The sum of the seasonal peak subcolony counts was 46 nests, 58% less than the 2015 count of 110 nests (Table 5).

From the aerial photographic survey on 16 June, 86 nests were counted for the entire CHCC, all on CRM (Table 5). The greater nest count from the aerial survey mainly reflected inclusion of nests not visible from land-based vantage points (e.g., at CRM-08). This count was 138% greater than the aerial count from 2015. Since 1999 this colony has shown a significant declining linear trend (Figure 22).

Productivity

Brandt's Cormorant productivity was monitored on CRM-03-B (Table 6). The mean clutch initiation date was 12 May ± 1.5 days, which was 7 days later (outside one standard error) than the long-term mean of 5 May ± 3.8 days. The first chick was observed on 29 May. Overall productivity of 1.34 chicks fledged per pair (n = 38) was less than the long-term average of 1.78 ± 0.2 , and outside the lower 95% confidence interval (Figure 23). Breeding success per nest of 0.66 reflected relatively high nest abandonment.

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

Nest and bird surveys

Seasonal peak counts of nests (Pelagic Cormorant, Western Gull, and Black Oystercatcher) or birds (Pigeon Guillemot) from land-based observations and aerial photographic surveys are summarized in Table 5. For these species, nesting areas typically vary from year to year and some nests were likely not visible from land-based observation points. Because of this, nest counts should be considered a minimum estimate and comparisons to previous years should be considered with caution.

Pelagic Cormorant

At DSRM, the first well-built nest was observed on 2 May and the first eggs were recorded on 17 May. Nest counts from mainland vantage points were 41% higher than in 2015. Counts from

aerial photographs showed at least six additional nests were present that were not visible from mainland vantage points. When land-based and aerial photographic counts were combined, a total of 45 nests were recorded in 2016 (Table 5). This includes nests counted by one method (land or aerial) but not the other.

At CHCC, the first well-built nests were observed on 29 April. The first eggs were recorded on 10 May. Nest counts from mainland vantage points were 62% lower than in 2015. However, counts from aerial photographs showed that up to twice the number of Pelagic Cormorant nests were present than were visible from mainland vantage points. When aerial and land counts were combined, a total of 22 nests were recorded at CHCC (Table 5).

Western Gull

At DSCC, the four Western Gull nests at DSRM and none at San Pedro Rock was low for these colonies but consistent with the pattern of recent years. Fifteen nests at CHCC were observed and monitored.

Black Oystercatcher

No Black Oystercatcher nests were found at DSRM although small numbers of birds were regularly observed. Four nests were found at CHCC.

Pigeon Guillemot

The 2016 peak standardized count at DSRM was 167 guillemots on 2 May; this was 2% less than the 2015 peak count. At CHCC, the peak standardized count was 37 guillemots on 5 May, 32% greater than the in 2015 peak count (Table 5).

Productivity

Productivity results for Pelagic Cormorants, Western Gulls, and Black Oystercatchers are summarized in Table 7.

Pelagic Cormorant

At DSRM, Pelagic Cormorant productivity was monitored at Mainland South (DSRM-05-A) and 0.43 chicks fledged per pair was well below (outside the lower 95% confidence interval) the long-term mean of 1.71 ± 0.2 chicks fledged per pair (2006 – 2015; Figure 24). In 2016 at CHCC, Pelagic Cormorant productivity was monitored from a sample of seven nests on CRM-03-B starting 26 May, after egg laying had already commenced. Hatching occurred at five nests but no chicks fledged (Figure 24).

Western Gull

At DSRM, all four nests discovered from mainland vantage points were monitored. Only two chicks fledged, both from the same nest. Low productivity of 0.50 chicks fledged per pair and outside the lower 95% confidence interval of the long-term mean (2006-2015; Figure 25). At CHCC, a more robust sample of 15 nests was monitored. Low productivity of 0.33 chicks

fledged per pair was outside the lower 95% confidence interval of the long-term mean (2006-2015, Figure 25).

Black Oystercatcher

At DSRM, no oystercatcher breeding sites were found to monitor in 2016. At CHCC, four nests were monitored and all nests failed.

DISCUSSION

Anthropogenic Disturbance

Consistent with past years, DSRM had greater rates of aircraft and watercraft disturbance than CHCC. But 2016 had some notable deviations from previous patterns. First, this was the first year since standardized detection monitoring began that more helicopters were detected than planes at DSRM. Second, detection and disturbance rates for planes at DSRM were among the lowest we have recorded, although statistical analysis for 2005-2016 does not yet detect a trend. Third, both aircraft (helicopters and planes combined) and total detection rates were similar between DSRM and CHCC. DSRM usually has considerably greater detection rates. Fourth, trends analyses detected significant declining trends in both watercraft detections and disturbances at DSRM. There is apparently declining activity of both planes and watercraft at DSRM, major goals of the SPN program. On the other hand, detection rates of aircraft, especially planes, appeared to be greater than the previous three years at CHCC, although no anthropogenic disturbances resulted from those aircraft.

Unlike past years, aircraft activity during the annual Pacific Coast Dream Machines event did not result in any observed detections or disturbances in 2016 at DSR. Like other recent years, monitoring efforts were coordinated with pilot outreach efforts conducted by SPN staff. Although relatively large numbers of aircraft were seen flying past the area, all were outside our standard aircraft detection zone and no visible disturbance was caused. Strong winds may have contributed to fewer low-flying aircraft in 2016.

Non-Anthropogenic Disturbance

At all colonies combined in 2016, Common Ravens caused 84% ($n = 236$) of recorded non-anthropogenic disturbance. All raven disturbances occurred at DSRM, including the depredation of 98 eggs and three chicks; we assume more were taken than were observed. Raven disturbance and depredation have become increasingly frequent on DSR since ravens were first observed on the rock in 2009. This is especially concerning at DSR because the colony is relatively small and potentially more vulnerable to persistent disturbance than much larger colonies (e.g. PRH).

Brown Pelicans and Western Gulls caused 12% and 4% of non-anthropogenic disturbances, respectively. Brown Pelicans (mainly immature birds) have caused large-scale disturbances at the murre colonies in the past, sometimes resulting in near to total breeding failure at affected colonies (e.g., Fuller et al. 2013). Similar pelican disturbance to murrees has been recorded

elsewhere (Horton and Suryan 2012). In 2016, disturbance events were characterized by groups of roosting pelicans, pelicans arriving at a rock, and pelicans walking through colonies, several of which caused substantial flushing of adults and egg losses. The Devil's Slide mainland murre subcolony was repeatedly disturbed and eventually failed, due largely to pelicans roosting near and within the nesting area.

Attendance and Reproductive Success

Murre attendance and estimated breeding population size at DSR continue to show a largely recovered colony, with numbers similar to the 1979-1982 period before the colony was extirpated. However, numbers of birds in 2016 were lower than in 2015. At DSM, small numbers of murres once again were in attendance, with peak attendance similar to other recent years but nearly double the number of breeding sites than in 2015. The colonization of the DSM cliffs is a probable consequence of the DSR re-colonization, but the DSM group has not grown in size since shortly after its inception in 2005. At CHCC, land-based counts showed lower attendance in 2016 compared to the previous eight-year mean pattern, although this conflicted with the aerial photograph count.

Results from aerial photographic surveys show the wide-scale murre declines in the early and mid-1980s due to gill-net fishing and oil spill mortality (Takekawa et al. 1990, Carter et al. 2001) followed by recovering numbers beginning in the mid-1990s (Carter et al. 2001). Since 1999, all colonies except Millers Point Rocks have increased significantly and have recovered to or beyond early 1980s levels. CMRP land-based counts of Millers Point Rocks in 2005-2015 found that numbers of murres varied substantially year to year and seasonally, and few bred successfully. Most attendance was in association with breeding Brandt's Cormorants. The reason for the reduced and erratic attendance by murres at Millers Point Rocks is not clear, but raven depredation was suspected of impacting the colony in the mid-2000s. Patterns at CHCC demonstrate recovery to early 1980s numbers only in the last few years, consistent with the trend observed in the 1985-1995 period (Carter et al. 2001), whereas most other colonies (except DSRM) showed recovery by the mid-2000s. It is unknown how large these colonies were prior to 19th century commercial eggging and early 20th century wide-scale oil pollution, when about one million murres bred at the nearby South Farallon Islands (Ainley and Lewis 1974, Carter et al. 2001). The Farallon colony has recovered to only about one-quarter of the historic estimate (Carter et al. 2001, Warzybok et al. 2016).

Murres continued to attend Bird Island in very low numbers but with confirmed breeding. Following initial prospecting in 2007 and the first confirmed breeding in 2008, murre attendance has been very low and sporadic with confirmed breeding in only two other years (2010 and 2012). Continued attendance at this colony by such small numbers of birds is highly unusual for murres, which typically need some sort of critical mass to incite breeding activity. Activity is confined to an area of only a few square meters underneath the remains of the former U.S. Navy Compass House, which seems to afford enough protection from predatory gulls to continue using the rock.

Murre breeding was later than average at all colonies in 2016 but was earlier compared to 2015. Murre productivity was slightly greater than the long-term mean at DSR but considerably less than the long-term mean at CRM-04. At CRM, productivity was among the five worst years since our monitoring began in 1996 and among the two worst for years when the colony was not impacted by major avian disturbances. At DSR, productivity was relatively high despite heavy egg depredation at the colony by Common Ravens. Although eggs were observed taken from monitored plots, most eggs were taken from non-monitored breeding sites, especially on the east side of the rock in the area of our former Plot C and from the northern side. Plot C was heavily impacted by some past disturbances, such as from roosting pelicans, but was dropped from productivity monitoring because of poor visibility. For comparison, murre breeding success at offshore Southeast Farallon Island of 0.45 chicks/pair was among the lowest of a 45 year time series (Warzybok et al. 2016).

The small numbers of murres ($N = 25$) that bred on DSM failed to hatch any chicks, largely because of Brown Pelican disturbance. This subcolony has been impacted in the past by pelican disturbance, which is likely a factor related to its failure to grow and frequent switching of nesting areas. In most years, murres on DSM breed alongside nesting Brandt's Cormorants, which frequently change nesting areas from year to year. Poor breeding success also occurred at CRM-03-B. Only five breeding sites were documented and all abandoned shortly after egg-laying. While breeding occurs in most years at this subcolony, its use is somewhat ephemeral and may not be of value for long-term monitoring.

Brandt's Cormorant nest numbers in 2016 were less than 2015 at most Gulf of the Farallones colonies. They were especially reduced at DSRM, where numbers of nests were among the lowest since 1999. After almost exponential increases between 1999 and 2007, the entire central California population declined dramatically in 2008-2010 (Capitolo et al. 2012, 2014; Bechaver et al. 2013; Schmidt et al. 2015; Warzybok et al. 2016; Ainley et al., 2017). Most Gulf of the Farallones colonies appear to have largely recovered and, with the exception of DSRM, numbers in 2016 were not dramatically different than long-term values. In contrast, Brandt's Cormorant productivity at DSRM was considerably greater than average and the highest value in a decade, while productivity at CRM was relatively low. In comparison, productivity at the nearby but offshore Farallon Islands colony was near average (Warzybok et al. 2016).

DSRM is our only colony with long-term monitoring of Pelagic Cormorants. For the third consecutive year, Pelagic Cormorants experienced high nest abandonment and low productivity. We re-instated nest monitoring for this species at CHCC in 2016; all followed nests were abandoned. Similarly, Pelagic Cormorants on the Farallon Islands experienced complete nest abandonment in July (Warzybok et al. 2016). Productivity for this species tends to be "boom or bust" depending on available prey resources (Boekelheide et al. 1990). Similar to previous years, Western Gulls had poor productivity at both DSRM and CHCC. Gull productivity at Southeast Farallon Island was slightly below average and estimated breeding population size was the lowest in a 45 year time series (Warzybok et al. 2016). Gull breeding success at the Farallones has also undergone a multi-decadal decline (Sydeman et al. 2001, Warzybok et al. 2016).

In the absence of major anthropogenic impacts or disturbance/predation from avian or mammalian predators, both the numbers of seabirds attempting to breed and seabird productivity are mainly influenced by ocean conditions and prey availability. The 2016 seabird breeding season was characterized by unusually warm ocean conditions throughout the Northeast Pacific Ocean. These conditions have largely persisted since a novel phenomenon known as the North Pacific Marine Heat Wave (*aka*, the warm water “Blob”) originated in the Gulf of Alaska in late 2013. This warm water mass subsequently spread throughout the region in 2014 and remained through much of 2015, creating very El Niño-like conditions (McClatchie et al. 2016). In late 2015, strong El Niño conditions developed and displaced the marine heat wave. Warm sea surface temperatures continued through May 2016 then moderate intensity La Niña conditions appeared in July and continued through the end of the breeding season (Wells et al. 2017). Impacts of the marine heat wave and El Niño showed similarities to past El Niño events. In general, marine conditions were characterized by warm sea surface temperatures, relatively low productivity, occurrences of many warm water species, low zooplankton abundance, and low abundances of forage fish like Pacific herring (*Clupea pallasii*) and Pacific sardine (*Sardinops sagax*). However, the impacts on the North Pacific ecosystem were not as consistent as many past warm water events, with marked differences regionally. For example, juvenile rockfish, which are generally thought of as preferring cooler water, were in high abundance off central California but in very low abundance off northern California (McClatchie et al. 2016, Wells et al. 2017). Despite low abundances as detected in fisheries data, northern anchovy (*Engraulis mordax*) were prevalent in Common Murre chick diets at Southeast Farallon Island in both 2015 and 2016 (McClatchie et al. 2016; Warzybok et al. 2015, 2016). Local observers in central California noted large numbers of humpback whales, California sea lions, and other predators feeding on huge schools of anchovy and other schooling fish through much of the spring and summers of 2015 and 2016 (G. McChesney, pers. obs.; many observers,). Anchovy egg enumeration and seabird diet data indicate that anchovy were in above average abundance in the nearshore environment (Wells et al. 2017).

Inconsistent responses of the El Niño conditions in 2016 appeared to be reflected in seabird breeding effort and breeding success. While numbers of Common Murres and Brandt’s Cormorants breeding at DSRM were lower than other recent years, breeding success was high. While we lack diet information for this colony, local observations and prey data from the Farallon Islands suggests that these birds were likely able to exploit surprisingly abundant local schooling prey such as anchovy and juvenile rockfish (Warzybok et al. 2016). Low productivity by CHCC murres and Brandt’s Cormorants suggests that prey resources were scarce near that colony. Low breeding success by Pelagic Cormorants at both DSRM and CHCC suggests that their preferred prey, small rocky reef fish and invertebrates (Boekelheide et al. 1990), were in short supply.

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.
- Depredation of Common Murre eggs by Common Ravens at DSR has become a very common occurrence, with nearly 100 eggs observed to be taken in 2016. If continued, raven predation could result in the abandonment of portions of the colony or perhaps even the entire colony. Management of ravens at Devil's Slide should be considered to protect the colony and better assure its long-term future. In addition, re-instituting avian predator surveys that were conducted in the late 1990s at all monitored colonies may help provide more standardized data collection and evaluation of the current impacts of ravens and other avian predators at the colonies.
- Annual aerial surveys of central California murre and Brandt's Cormorant colonies should be continued. These surveys are preferred for monitoring breeding populations of these species. These data are needed for monitoring the success of restoration efforts for these species as well as contributing to the overall understanding of coastal ecological systems. Further, aerial surveys provide more complete count than ground surveillance. At this time, no sustained funding source is currently available to assure that photographic surveys are conducted and to count nests and birds from the photographs.
- As the numbers and densities of murres on monitored breeding colonies increase, it will be necessary to continually evaluate productivity monitoring methods (especially at DSR). This will include adjustments to plot boundaries and elimination of sites that are difficult to view.
- The Devil's Slide pedestrian trail was completed in March of 2014, and the 2016 field season marked the third year of pedestrian access to the span of former road above DSM. No pedestrian-related disturbances were recorded which was likely aided by the fence that limits visitors from view of nesting birds. Monitoring should be continued so as to record any new or different types of potential disturbance from pedestrians. The presence of thousands of visitors throughout the seabird season provided a great opportunity for outreach. Increased outreach efforts should continue to be pursued, including coordination with San Mateo County Parks trail ambassadors.
- Communication with CDFW wardens should be continued to help enforce Special Closures. Our collaboration appears to be resulting in a successful reduction in watercraft disturbances at DSR.

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Table 1. Monitoring effort at study colonies (DSCC and CHCC) in the Common Murre Restoration Project, April 2016 to August 2016.

Colony/Colony Complex	Start date	End date	No. of Obs. Days	Total hours
San Pedro Rock	4/28/2016	6/25/2016	9	1.25
Devil's Slide Rock & Mainland	4/19/2016	8/18/2016	105	474
Castle-Hurricane Colony Complex	4/21/2016	7/30/2016	70	176

Table 2. Total detected watercraft and aircraft, and resulting disturbances to all seabirds (Common Murres, Brandt’s Cormorants, and Brown Pelicans) at Devil’s Slide Rock and Mainland (DSRM) and Castle-Hurricane Colony Complex (CHCC), 2016. Detection and disturbance rates reported as numbers per observation hour. Quasi-poisson regressions were run to assess the annual change in detections and disturbance rates from 2005-2016. Percent annual change is reported if significant trends were observed.

Colony	Source	Total Detections	Number Detections /hr.	Number of Disturbance Events ¹			Disturbance Rates: Events/hr.		Annual change in Detection Rates (2001-2016)			Annual change in Disturbance Rates (2001-2016)		
				A	D	F	Total/hr. ¹	Flush or Displace/hr.	% Annual Change ²	95% CI	P-value	% Annual Change ²	95% CI	P-value
DSRM	Plane	16	0.03	1	0	0	0.002	0.00	-	-	-	-	-	-
	Helicopter	24	0.05	4	0	12	0.04	0.03	-	-	-	-	-	-
	Drones	1	0.002	0	0	0	0.00	0.00	-	-	-	-	-	-
	Aircraft Total	41	0.09	5	0	12	0.04	0.03	-	-	-	-	-	-
	Watercraft	4	0.01	0	0	1	0.002	0.002	-18.2%	-23.8, -12.5	<0.001	-25.4	-39.3, -11.2	0.01
	DSRM Total	45	0.09	5	0	13	0.04	0.03	-	-	-	-	-	-
CHCC	Plane	9	0.05	0	0	0	0.00	0.00	-	-	-	-	-	-
	Helicopter	4	0.02	0	0	0	0.00	0.00	-	-	-	-	-	-
	Drones	2	0.01	0	0	0	0.00	0.00	-	-	-	-	-	-
	Aircraft Total	15	0.08	0	0	0	0.00	0.00	-	-	-	-	-	-
	Watercraft	0	0.0	0	0	0	0.00	0.00	-	-	-	-	-	-
	CHCC Total	15	0.08	0	0	0	0.00	0.00	-	-	-	-	-	-

¹ Events during which birds exhibited agitation or alert behaviors (A), flushing (F), or displacement (D).

² Only significant values shown.

Table 3. Number of disturbance events and mean numbers (range) of Common Murres (COMU), Brandt's Cormorants (BRCO) and Brown Pelicans (BRPE) disturbed (agitated, displaced and/or flushed; Dist.) and displaced/flushed (D/F) at Devil's Slide Rock and Mainland, 2016.

Source	COMU Disturbance						BRCO Disturbance					BRPE Disturbance		
	Mean Number Seabirds Disturbed	Mean Number Seabirds D/F	No. Dist. Events	Mean No. Birds Dist.	No. of D/F Events	Mean No. Birds D/F	No. Dist. Events	Mean No. Birds Dist.	No. of D/F Events	Mean No. Birds D/F	No. Dist. Events	Mean No. Birds Dist.	No. of D/F Events	Mean No. Birds D/F
Plane	860	-	1	860	-	-	-	-	-	-	-	-	-	-
Helicopter	794 (50-1503)	181 (5-650)	16	776 (50-1500)	12	158 (5-500)	8	33 (2-150)	8	33 (2-150)	1	15	1	15
Watercraft	165	165	-	-	-	-	1	150	1	150	1	15	1	15
Total	762 (50-1503)	180 (5-650)	17	781 (50-1500)	12	158 (5-500)	9	46 (2-150)	9	46 (2-150)	2	15	2	15

Table 4. Common Murre breeding phenology and reproductive success at Devil's Slide Rock & Mainland (DSR, 3 plots and combined; DSM), and Castle Rocks & Mainland (2 plots), 2016. Means (range; n) are reported.

Colony/Plot	No. Sites Monitored	No. Egg Laying Sites	Mean Lay Date ¹	No. Eggs Laid	Mean Hatch Date	Hatching Success ²	Mean Fledge Date	Fledging Success ³	Chicks Fledged per Pair
Devil's Slide Rock and Mainland (DSRM)									
DSR-A	105	90	28 May (5/10-6/28; 85)	105	30 June (6/17-7/16; 73)	73.1% (104)	24 July (7/8-8/8; 73)	96.1% (76)	0.81 (90)
DSR-B	78	68	28 May (5/13-6/23; 67)	73	1 July (6/14-7/13; 57)	80.5% (72)	25 July (7/11-8/4; 49)	87.9% (53)	0.76 (67)
DSR-D	31	23	1 June (5/12-6/30; 22)	28	8 July (6/27-7/26; 12)	50.0% (26)	28 July (7/23-8/2; 7)	58.3% (12)	0.35 (20)
DSR (combined)	203	181	29 May (5/12-6/27; 174)	206	1 July (6/14-7/26; 142)	72.7% (202)	25 July (7/8-8/8; 129)	89.7% (146)	0.74 (177)
DSM (DSRM-05 A Lower)	30	25	29 May (5/14-6/21; 25)	28	-	0.0% (28)	-	-	0.0 (25)
Castle Rocks and Mainland (CRM)									
CRM-04	104	90	13 May (5/6-6/2; 83)	94	14 June (6/5-6/28; 55)	67.8% (90)	6 July (6/25-7/15; 30)	49.2% (61)	0.33 (90)
CRM-03-B	35	5	22 May (5/18-5/25; 5)	5	--	0.0% (5)	-	-	0.0 (5)

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).

Table 5. Seasonal high counts of nests for Brandt's Cormorants (BRCO), Pelagic Cormorants (PECO), Western Gulls (WEGU) and Black Oystercatchers (BLOY), and birds for Common Murres (COMU) and Pigeon Guillemots (PIGU) from aerial and land surveys in 2016. A dash indicates no data.

Complex	Colony	COMU	BRCO			PECO			WEGU ⁴	BLOY ⁴	PIGU ⁴
		Aerial ¹	Land ²	Aerial ¹	Combined ³	Land ²	Aerial ¹	Combined ³	Land ²	Land ²	Land/ Water ²
PRH	Point Reyes	35,719	-	149	149	-	-	-	-	-	-
DBCC	Point Resistance	5,069	-	0	0	-	0	0	-	-	-
	Millers Point Rocks	96	-	197	197	-	-	-	-	-	-
	Double Point Rocks	10,303	-	110	110	-	0	0	-	-	-
	DBCC combined	15,468	-	307	307	-	0	0	-	-	-
	Bird Island	9	0	0	0	0	0	0	6	0	0
DSCC	DSRM	1,543	38	49	49	39	45	45	4	0	-
	San Pedro Rock	0	0	0	0	0	0	0	0	0	-
	DSCC combined	1,543	38	49	49	39	45	45	4	0	167
CHCC	Bench Mark-227X	0	0	0	0	0	0	0	13	1	-
	CRM	3,291	46	86	93	8	16	17	11	1	-
	HPR	1,091	0	0	0	5	0	5	22	2	-
	CHCC combined	4,382	46	86	93	13	16	22	46	4	37

¹Nests and birds counted from aerial photographic surveys.

²Sum of high seasonal nest (BRCO and PECO) and bird (COMU, WEGU, BLOY and PIGU) counts during land-based surveys at each complex and subcolony.

³For combined counts, land-based and aerial counts were compared. Nests accounted from the aerial survey were combined with the land-based high count.

⁴Aerial counts are not reported for nests of WEGU, BLOY and PIGU due to incomplete aerial photograph coverage.

Table 6. Brandt's Cormorant breeding phenology and reproductive success at Point Reyes, Devil's Slide Rock & Mainland, and Castle Rocks & Mainland, 2016. Reported are means (range; n).

Colony/ Subcolony	No. Breeding Sites	Clutch Initiation Date ¹	Clutch Size ¹	Breeding Success ²	No. Chicks Fledged/Pair ²	Breeding Success/ Nest ³
Devil's Slide Rock and Mainland (DSRM)						
South of Turtlehead Cliffs (DSR-05-C)	24	5/12 (4/29-5/29; 24)	3.2	85.2% (61)	2.4 (0-3; 24)	0.96 (23)
Mainland South (DSR-05-A)	21	5/23 (5/9-6/12; 21)	3.1	83.1% (77)	1.9 (0-3; 21)	0.95 (21)
DSRM Total	45	5/17 (4/29-6/12; 45)	3.1	84.1% 138	2.2 (0-3; 45)	0.95 (44)
Castle Hurricane Colony Complex (CHCC)						
CRM-03-B	38	12 May (4/29-5/30; 37)	3.0 (112)	45.5% (112)	1.34 (0-3; 38)	0.66 (38)

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

Table 7. Productivity of Pelagic Cormorants, Black Oystercatchers, and Western Gulls at Devil’s Slide Rock and Mainland, and Castle Rocks & Mainland, 2016. Means (range; n) or (n) are reported.

Colony	Pelagic Cormorant				Black Oystercatcher				Western Gull			
	Number of Breeding Sites	Number of Chicks Fledged	Number of Chicks Fledged/Pair (Productivity)	Breeding Success/Nest ¹	Number of Breeding Sites	Number of Chicks Fledged	Number of Chicks Fledged/Pair (Productivity)	Breeding Success/Nest ¹	Number of Breeding Sites	Number of Chicks Fledged	Number of Chicks Fledged/Pair (Productivity)	Breeding Success/Nest ¹
DSRM	21	9	0.43 (1-2; 21)	0.23 (21)	-	-	-	-	4	2	0.50 (0-2; 4)	0.25 (4)
CHCC	7	0	0.00 (0; 7)	0.00 (7)	4	0	0.00 (0; 4)	0.00 (4)	15	5	0.33 (0-2; 15)	0.14 (15)

¹ Breeding success per nest is defined as the proportion of egg-laying nests that fledged at least one chick.

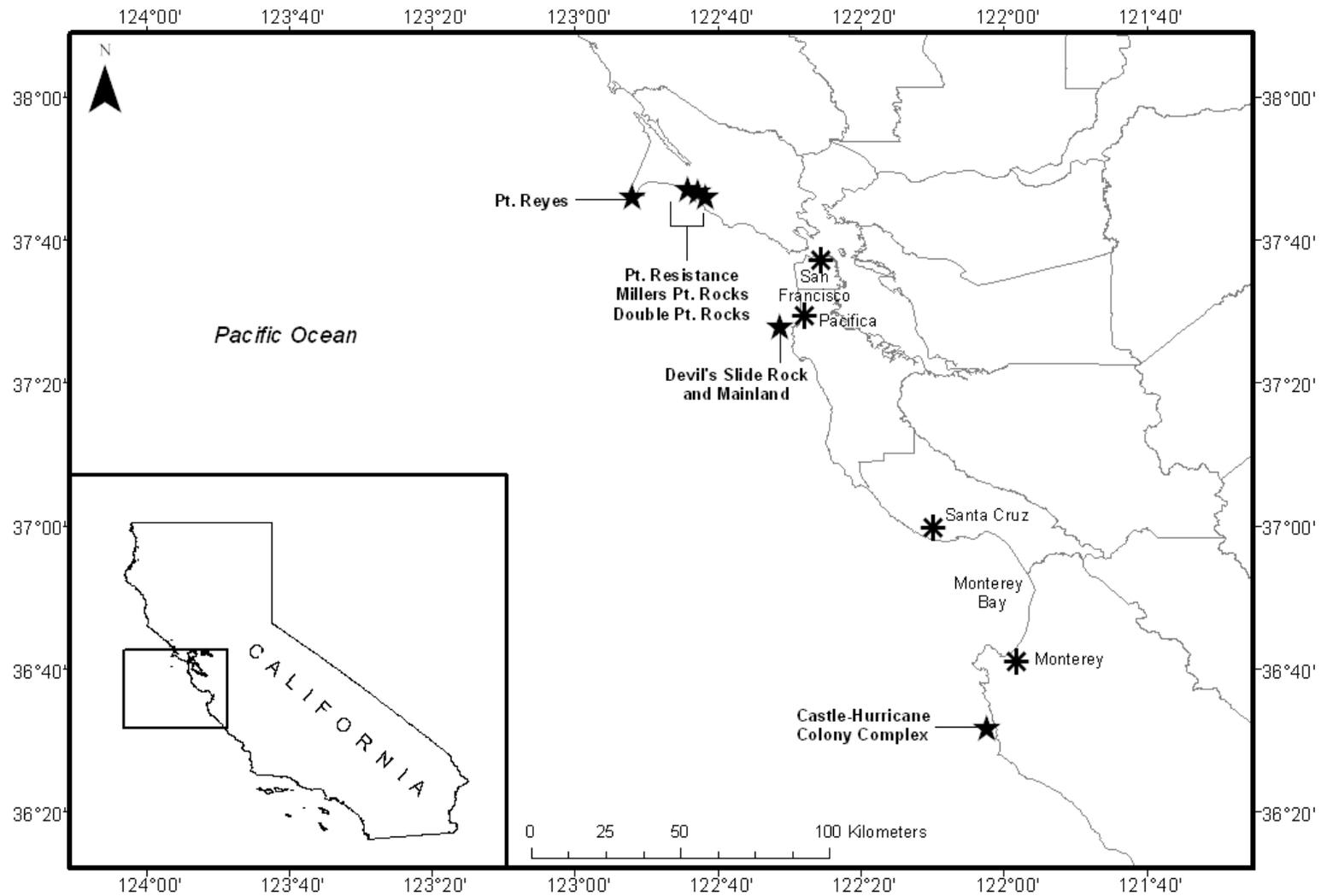


Figure 1. Study area showing locations of study colonies or colony complexes along the Central California coast where seabird disturbance, attendance and breeding biology are monitored. Point Reyes, Pt. Resistance, Miller's Pt. and Double Pt. were not monitored in 2016.

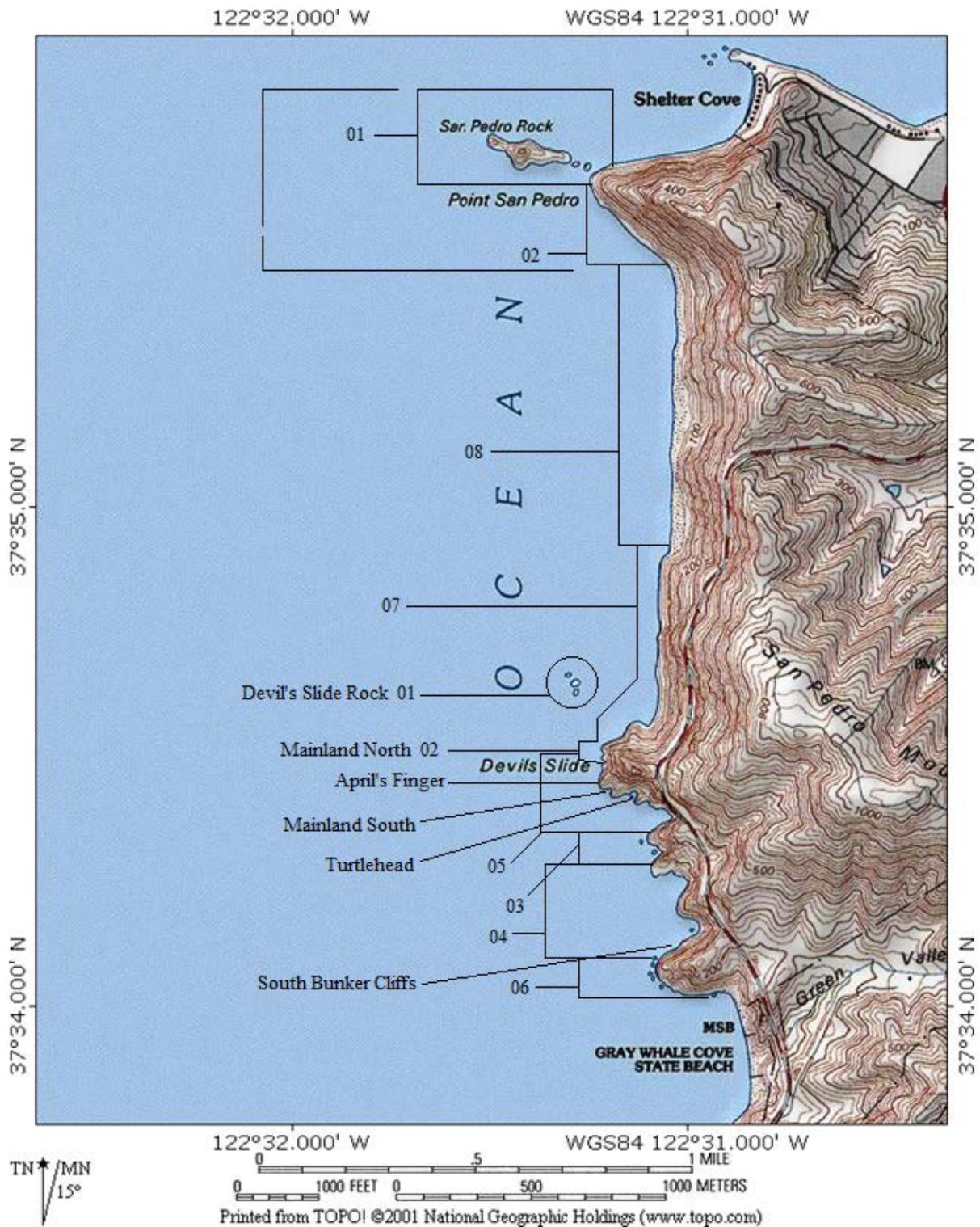


Figure 2. Devil's Slide Colony Complex, including San Pedro Rock and Devil's Slide Rock & Mainland colonies and subcolonies.

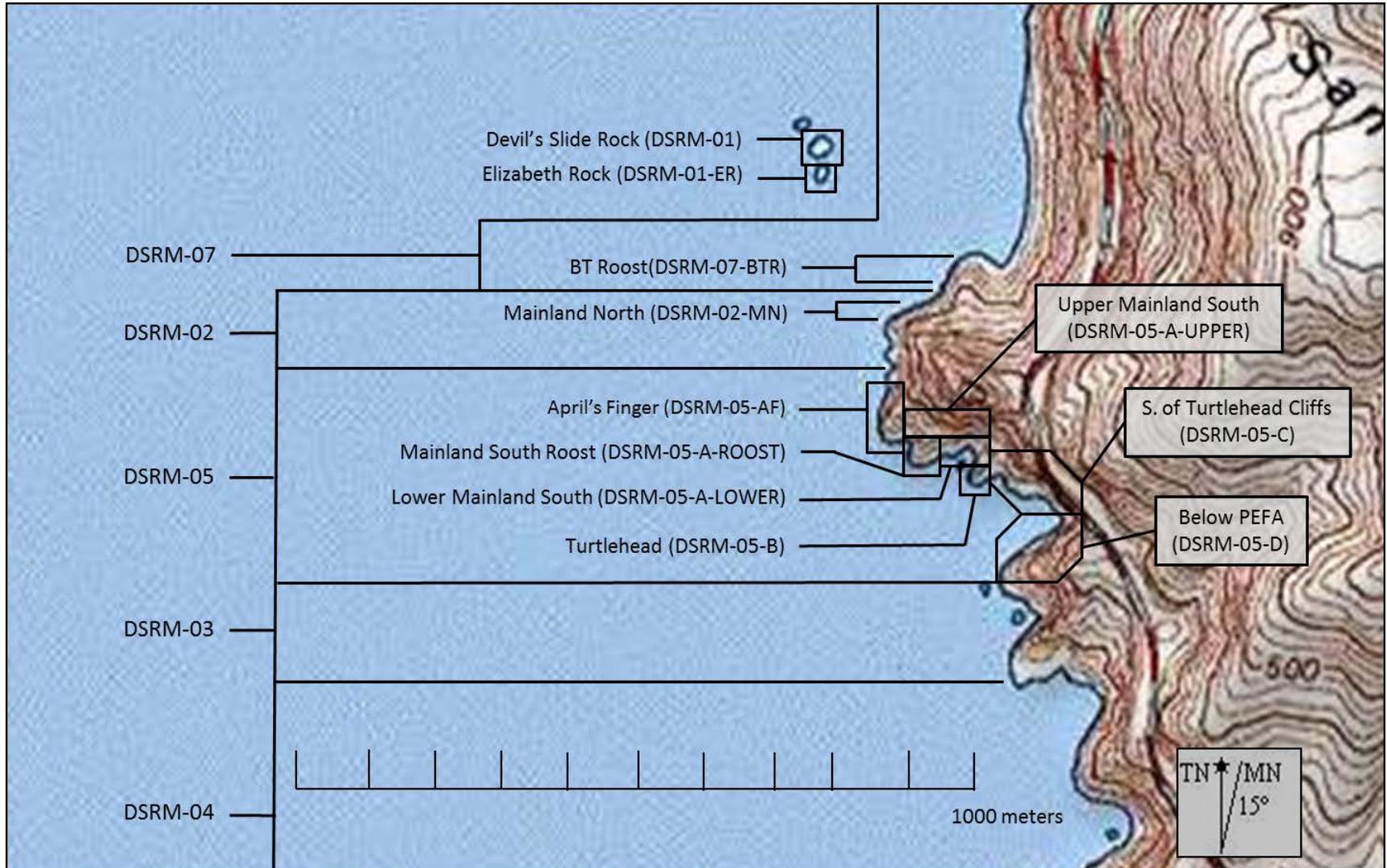


Figure 3. Devil's Slide Rock and Mainland close-up map, showing all identified subareas.

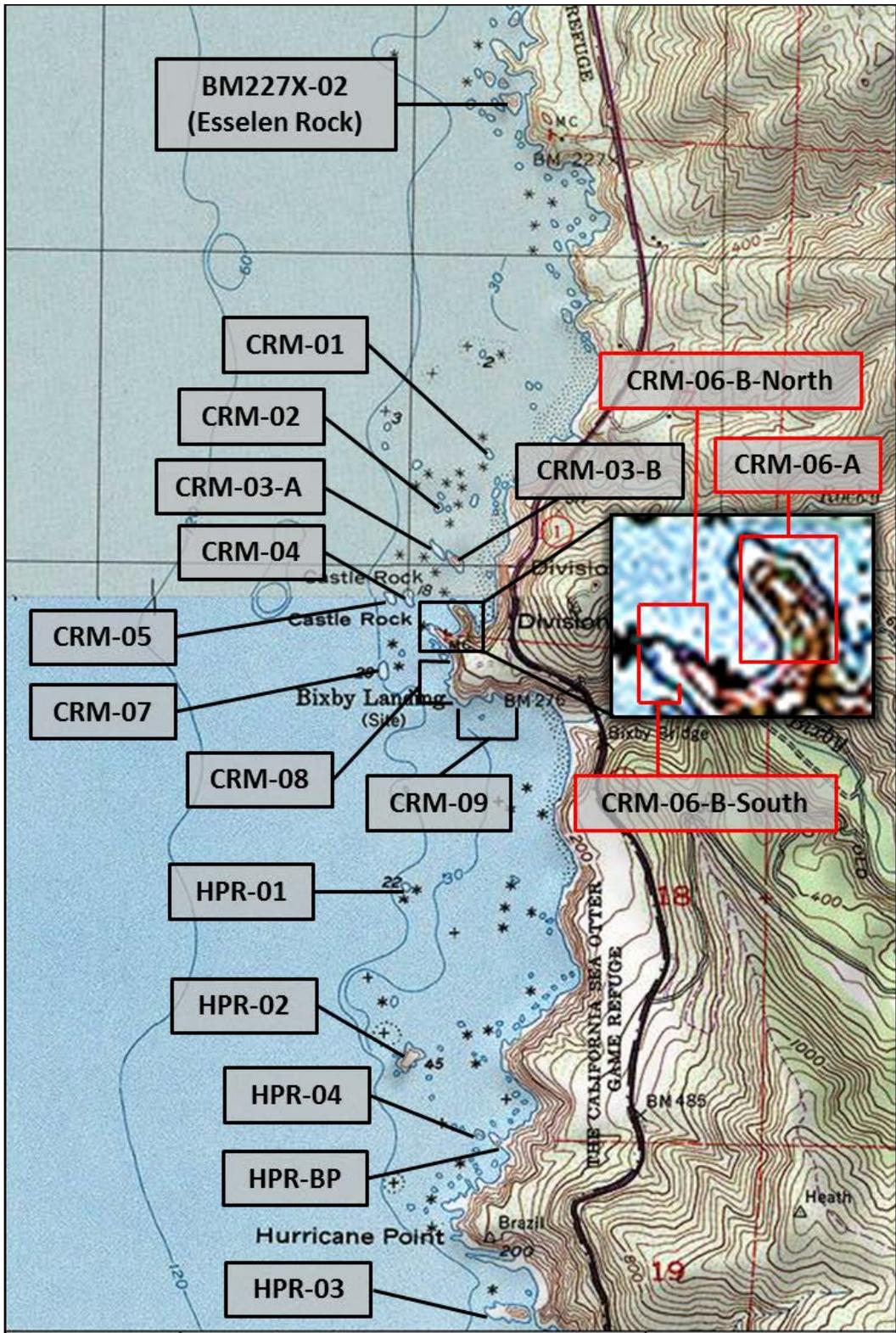


Figure 4. Castle-Hurricane Colony Complex, including Bench Mark-227X (BM227X), Castle Rocks and Mainland (CRM), and Hurricane Point Rocks (Hurricane) colonies and subcolonies.

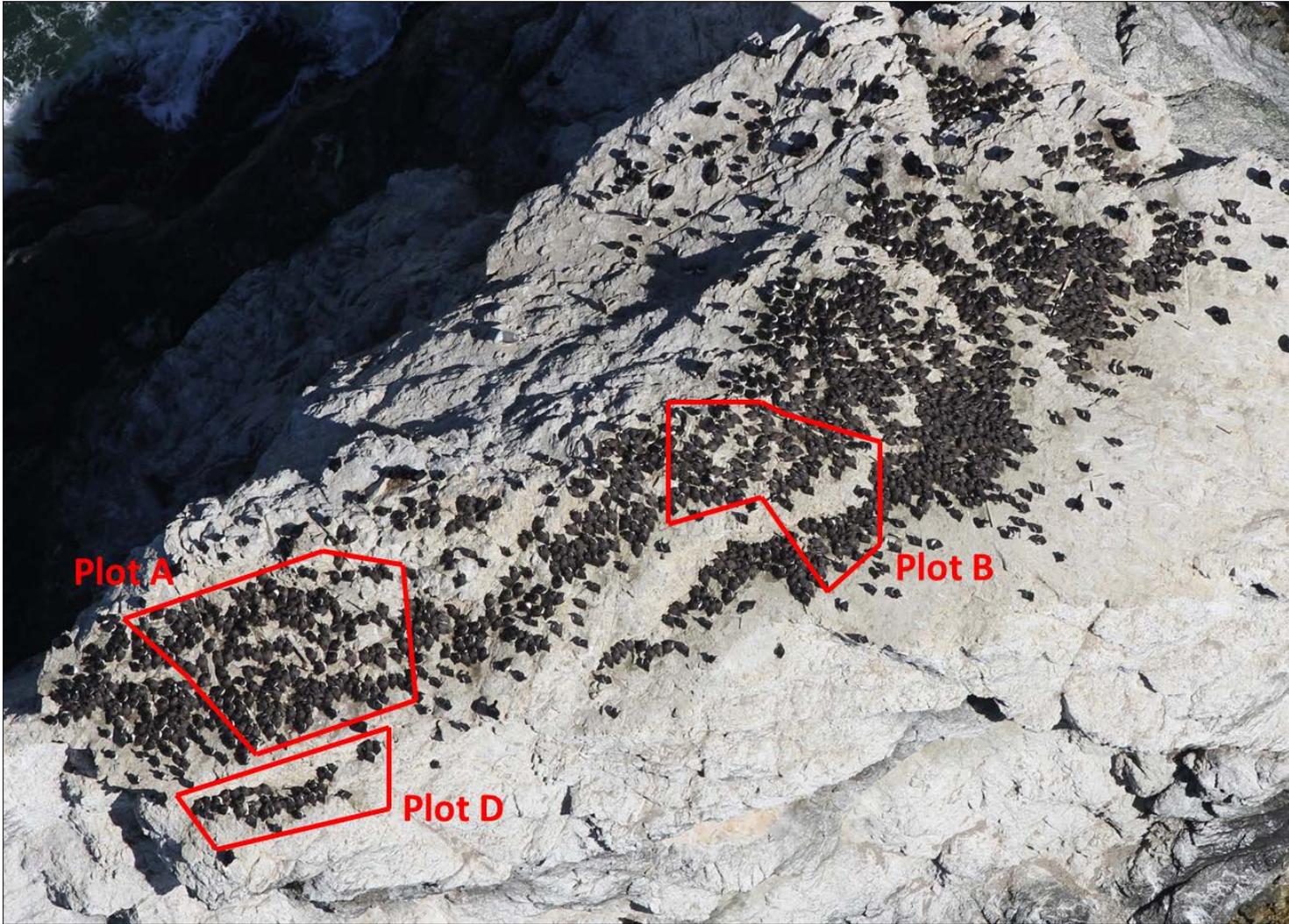


Figure 5. Aerial photograph of Devil's Slide Rock, 15 June 2016, showing the distribution of the Common Murre and Brandt's Cormorant breeding colony and boundaries of murre productivity plots. Photo by Phillip Capitolo.

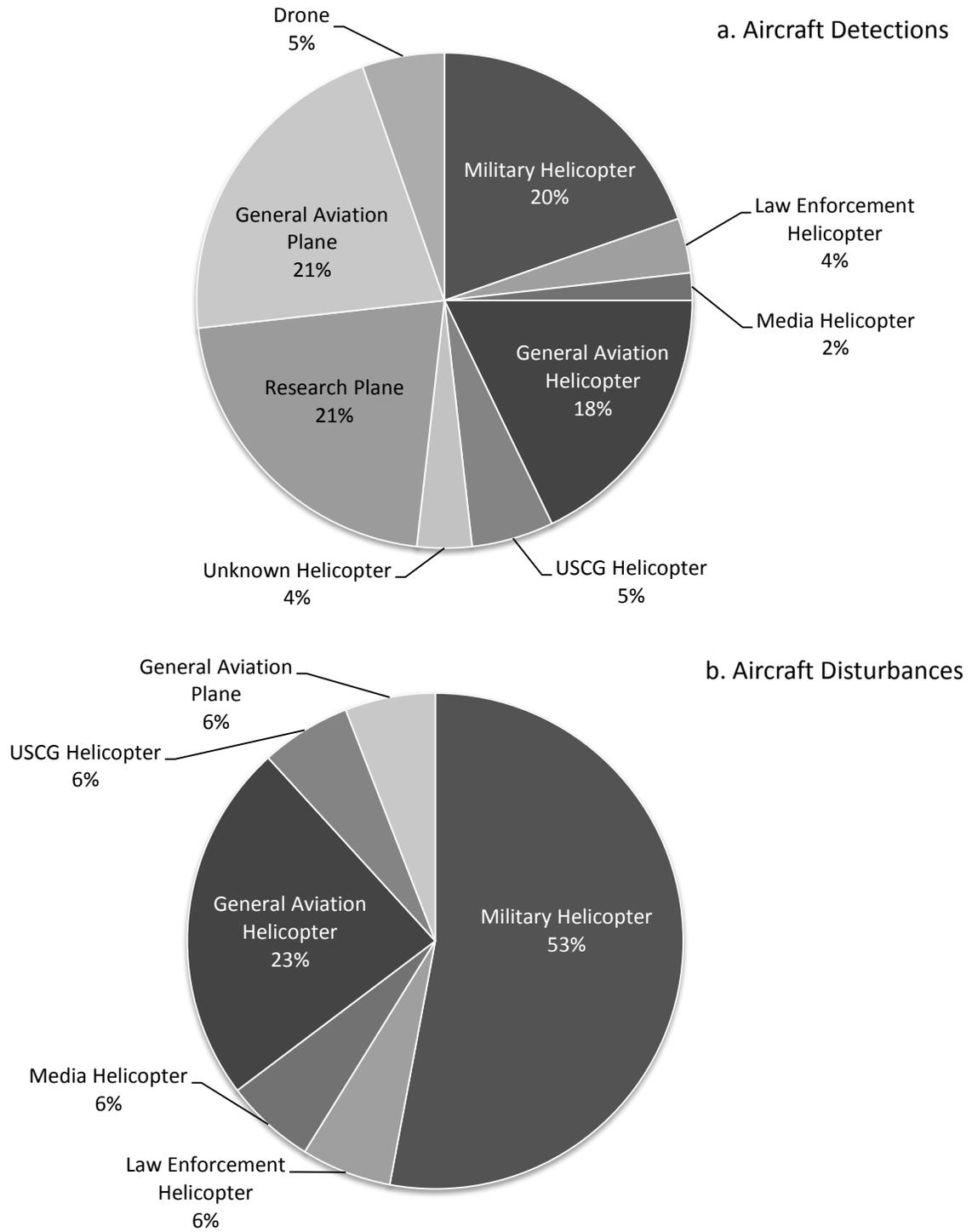
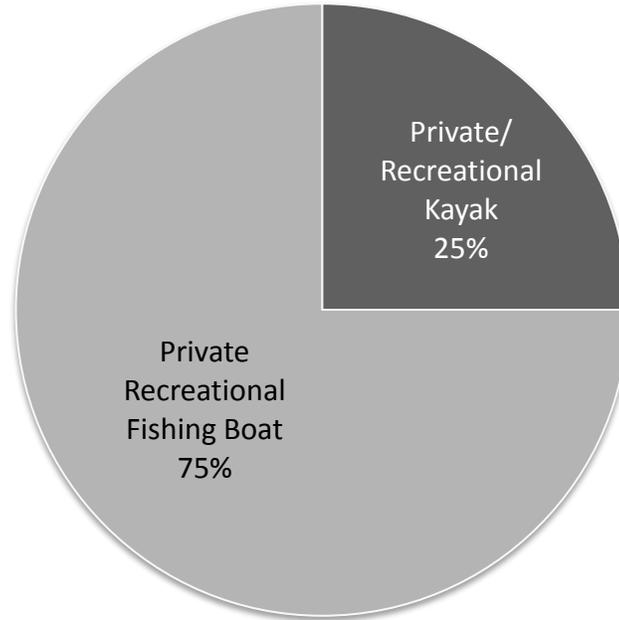


Figure 6. a. Aircraft detections (n = 76) and b. aircraft disturbances (n = 18) at Devil’s Slide Rock and Mainland and Castle-Hurricane Colony Complex combined in 2016, categorized by type.

a. Watercraft Detections



b. Watercraft Disturbance

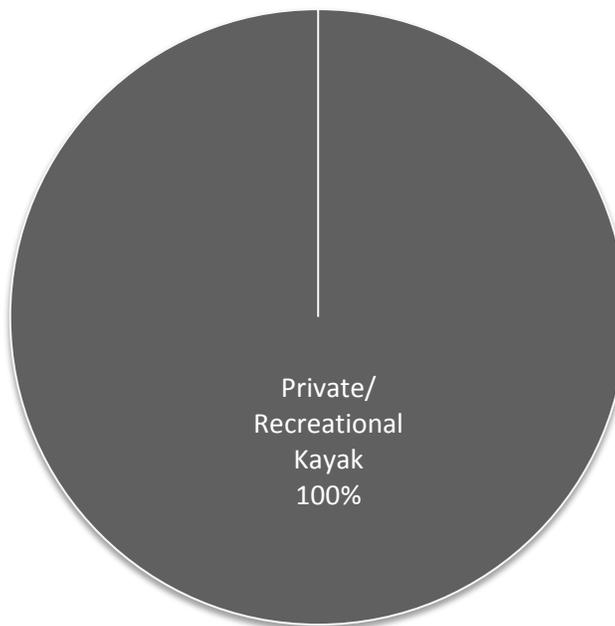


Figure 7. a. Watercraft detections (n = 4) and b. watercraft disturbances (n = 1) at Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex combined in 2016, categorized by type.

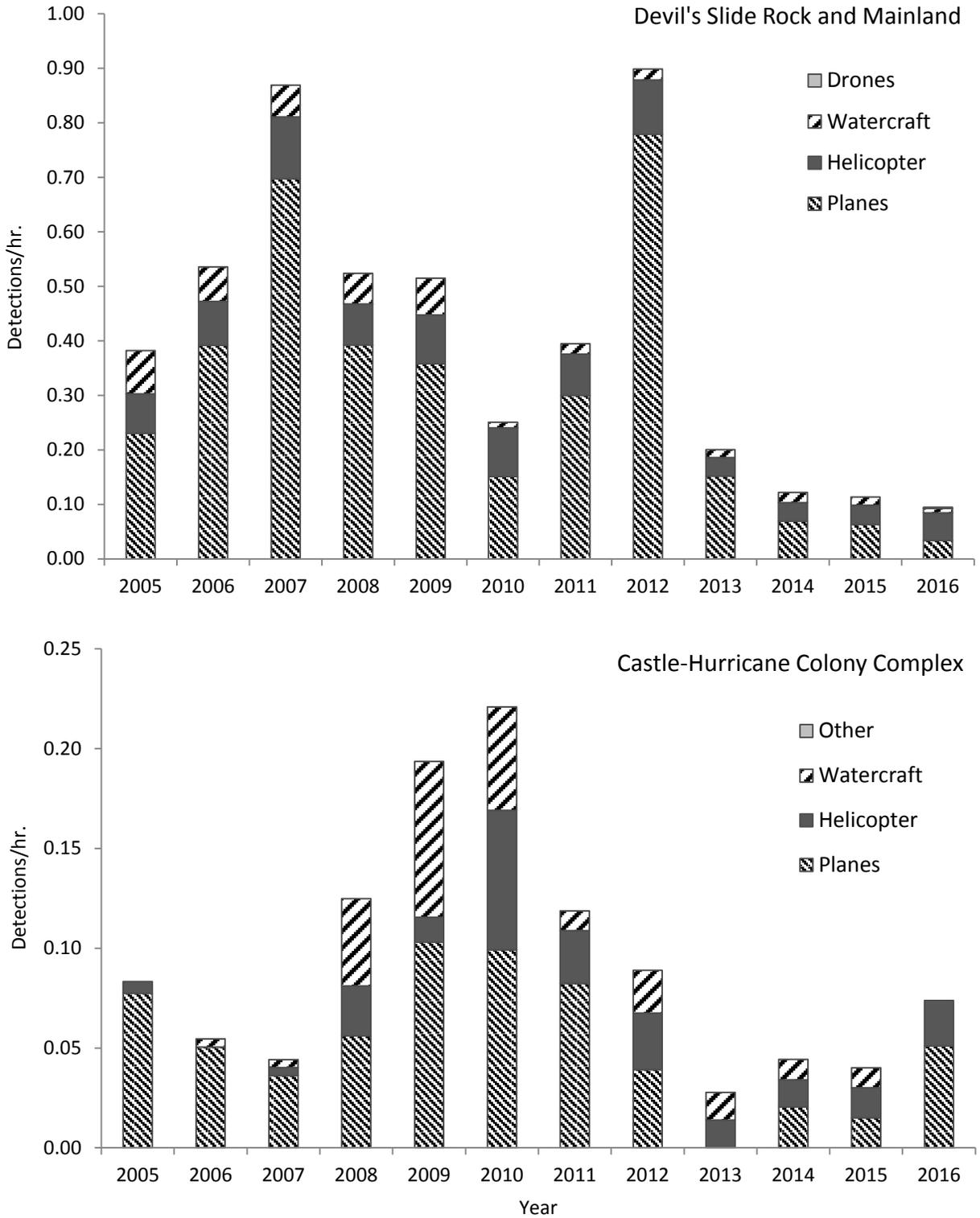


Figure 8. Detection rates (number of detections per observation hour) of watercraft, helicopters, planes and drones at Devil's Slide Rock and Mainland, and Castle-Hurricane Colony Complex, 2001 to 2016. Note the different scales between graphs.

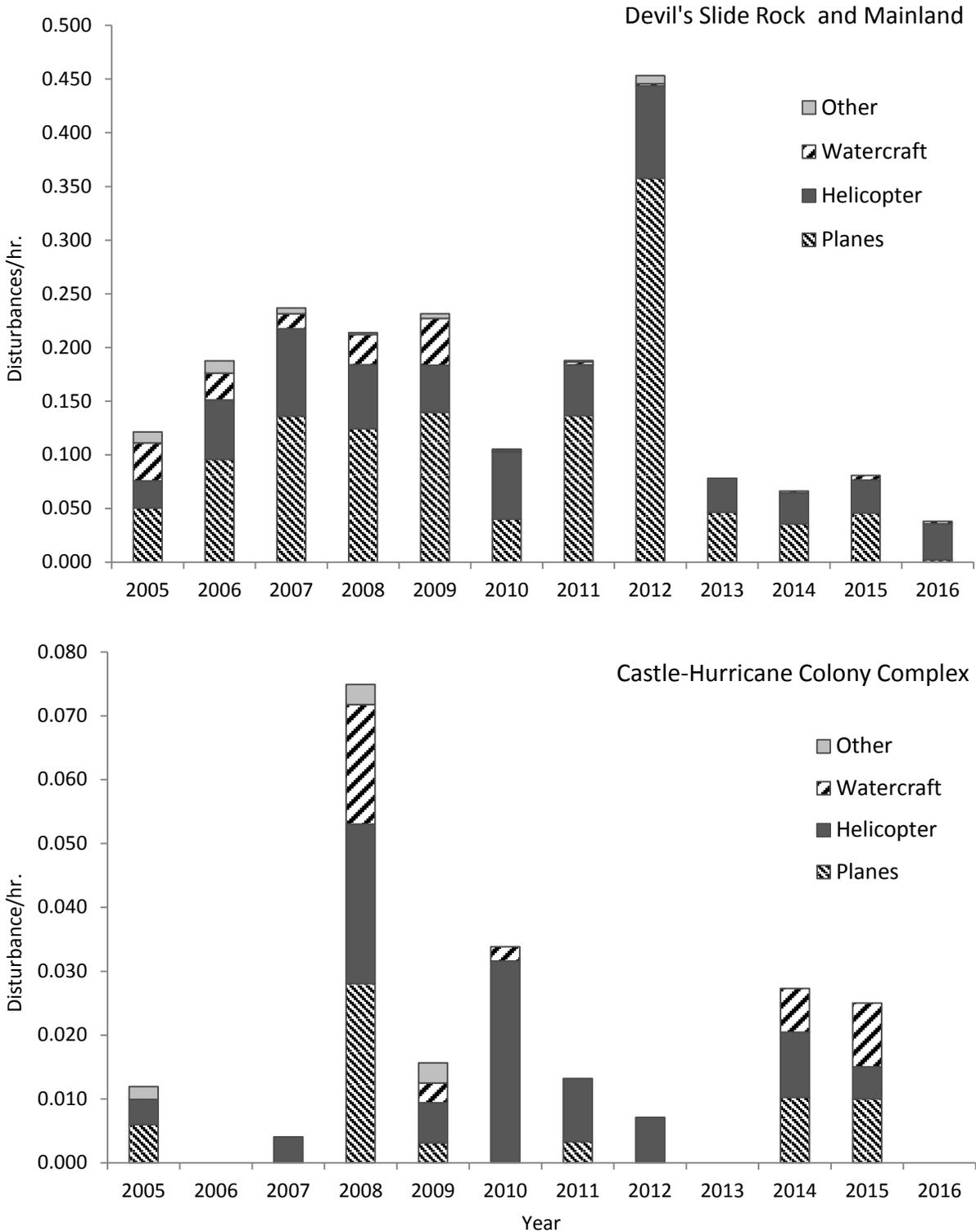


Figure 9. Disturbance rates (number of seabird disturbances per observation hour) from boats, helicopters, planes, and other anthropogenic sources at Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex from 2001 to 2016. Note different scales between graphs.

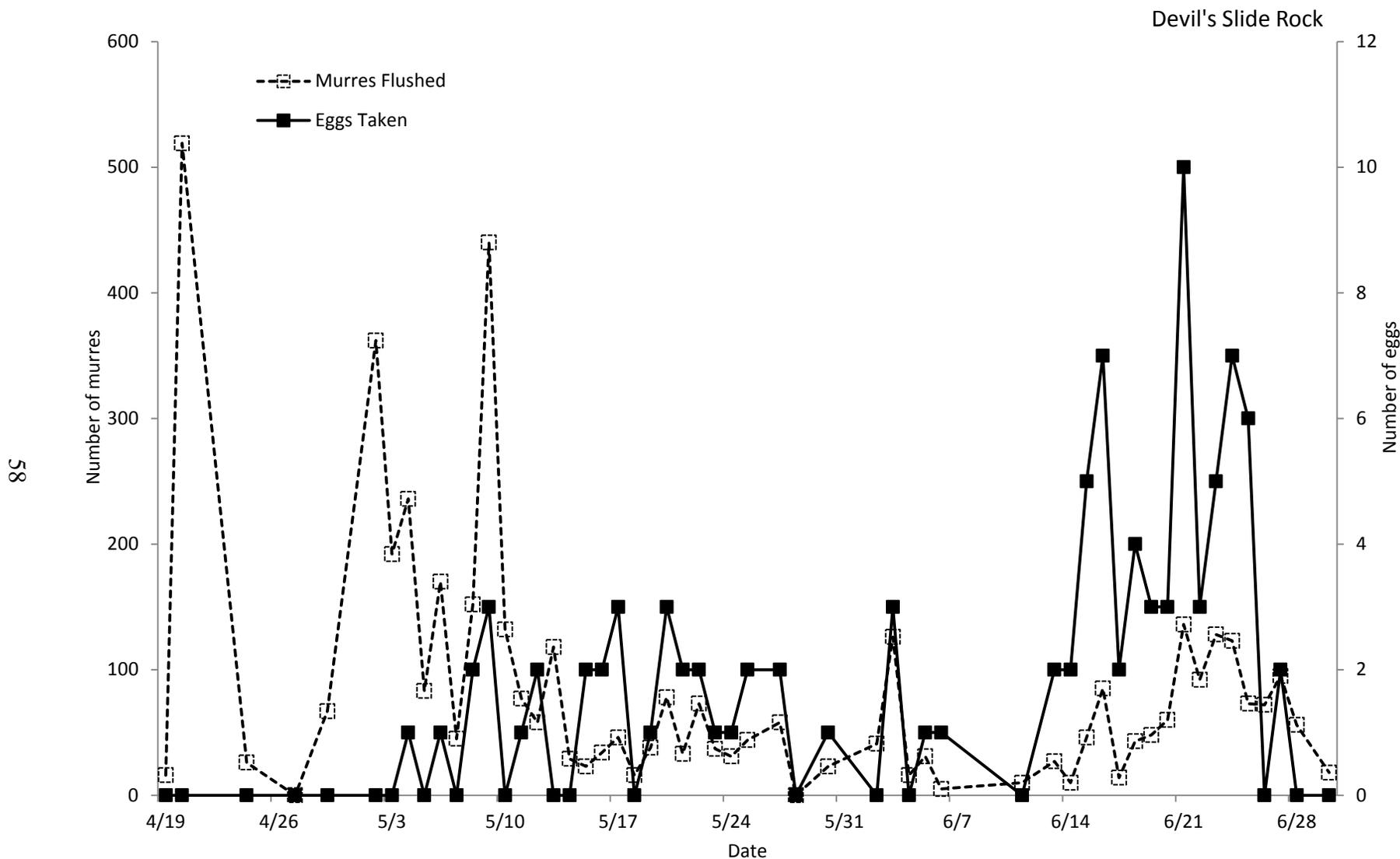


Figure 10. Recorded daily disturbance from Common Ravens at Devil's Slide Rock (DSRM-01) in 2016. Total number of murre eggs flushed and total number of murre eggs depredated are shown.

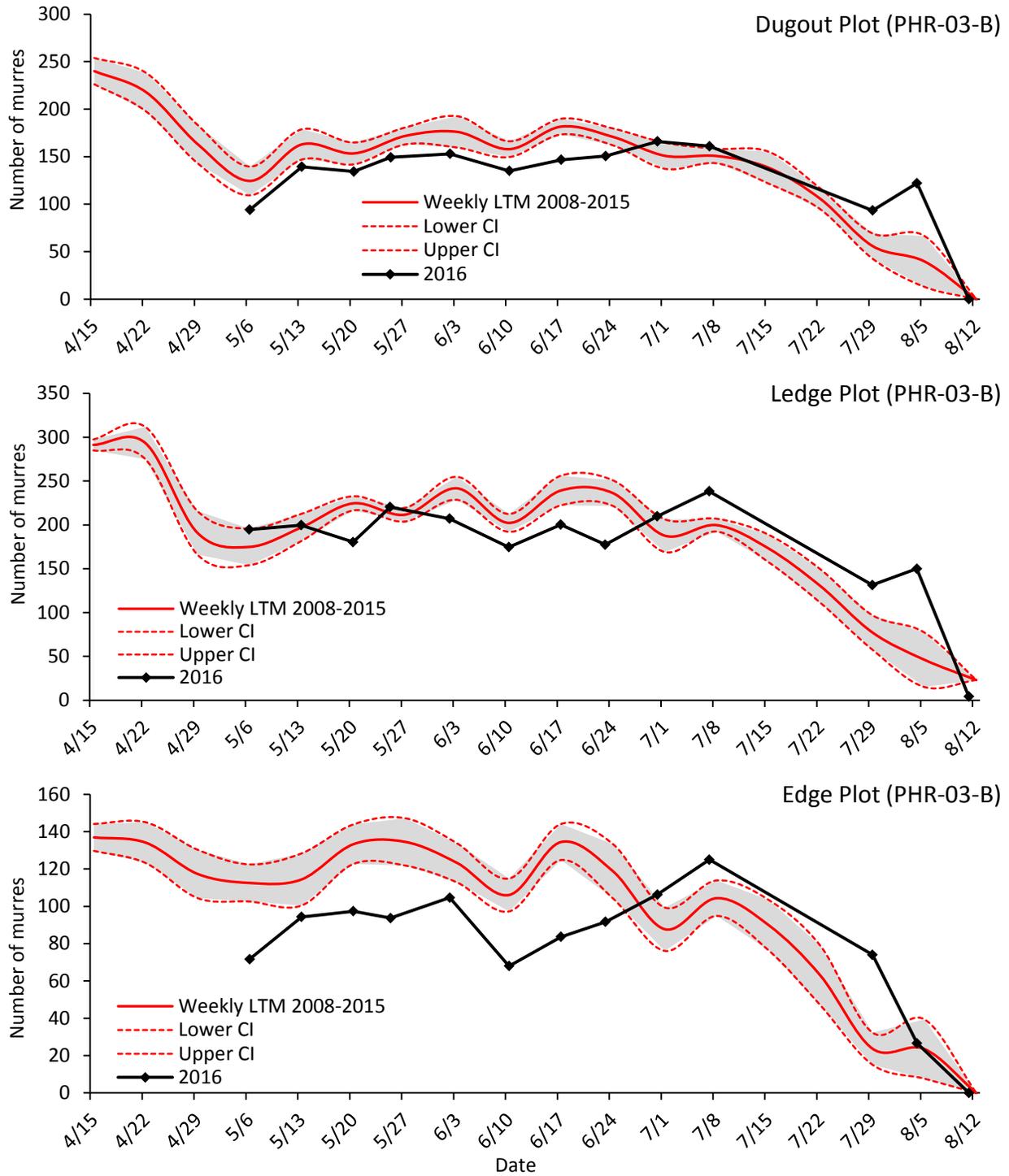


Figure 11. Seasonal attendance of Common Murres at Point Reyes Lighthouse Rock (PRH-03-B) plots Dugout, Ledge and Edge in 2016 compared to long term (2008-2015) mean patterns.

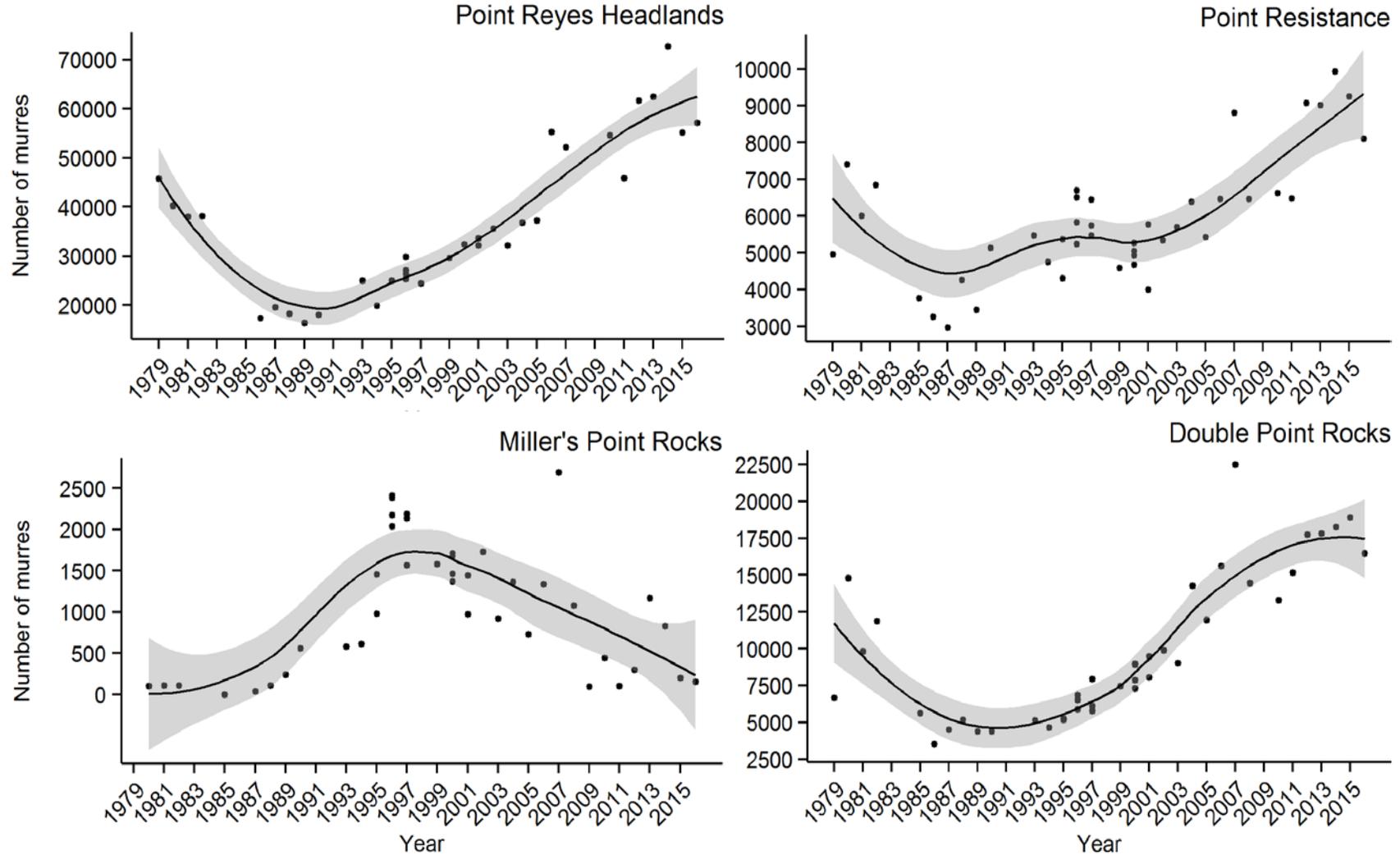


Figure 12. Common Murre breeding population trends at Point Reyes Headlands, Point Resistance, Millers Point Rocks and Double Point Rocks, 1979-2016. Data points are raw counts from aerial photographic surveys multiplied by correction factors (see Methods). LOESS curves (R Core Team, 2013) are shown with 95% confidence intervals. Note different scales between graphs.

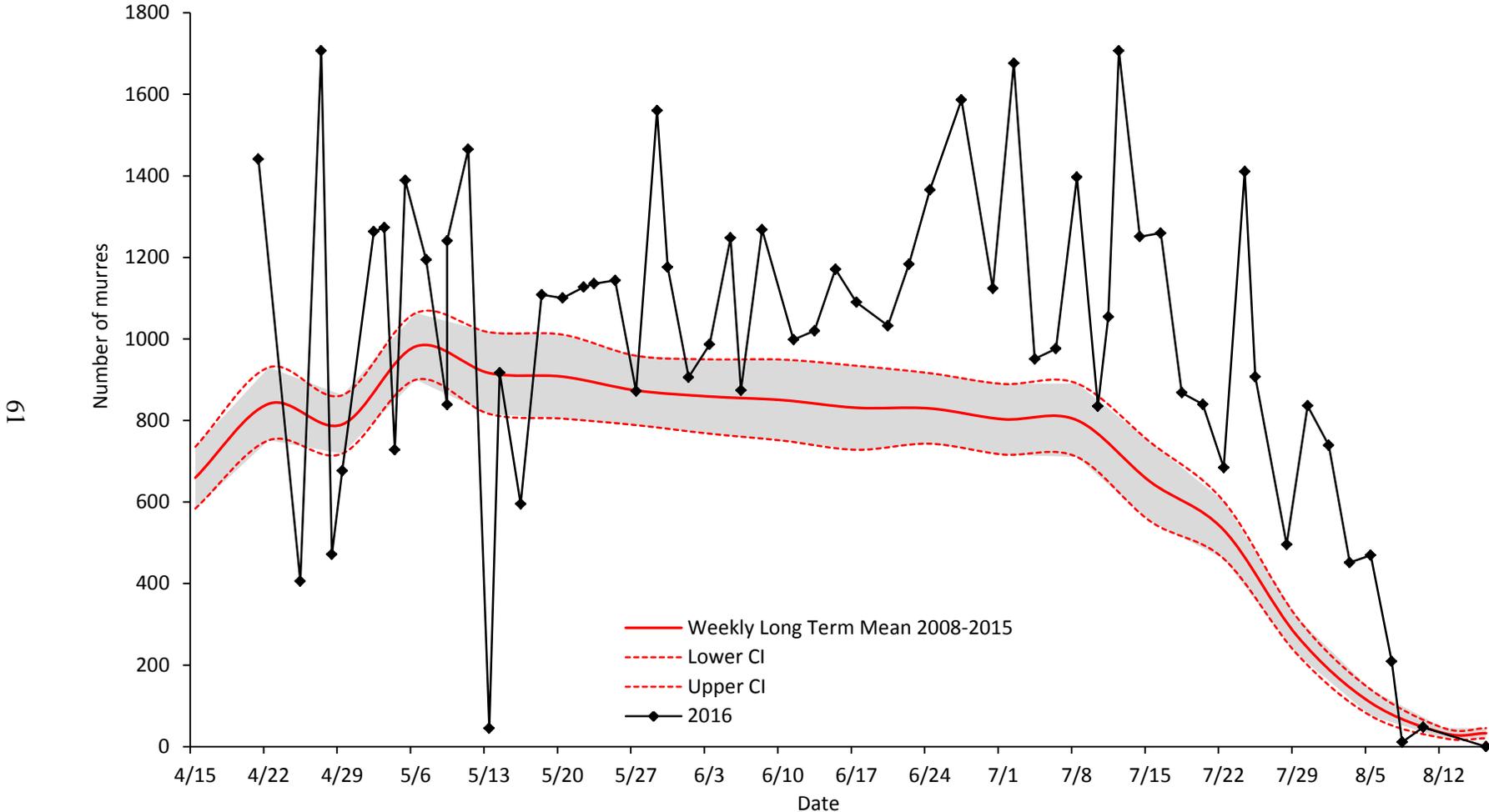


Figure 13. Seasonal attendance of Common Murres at Devil's Slide Rock (DSRM-01) in 2016 compared to long term (2008-2015) mean pattern.

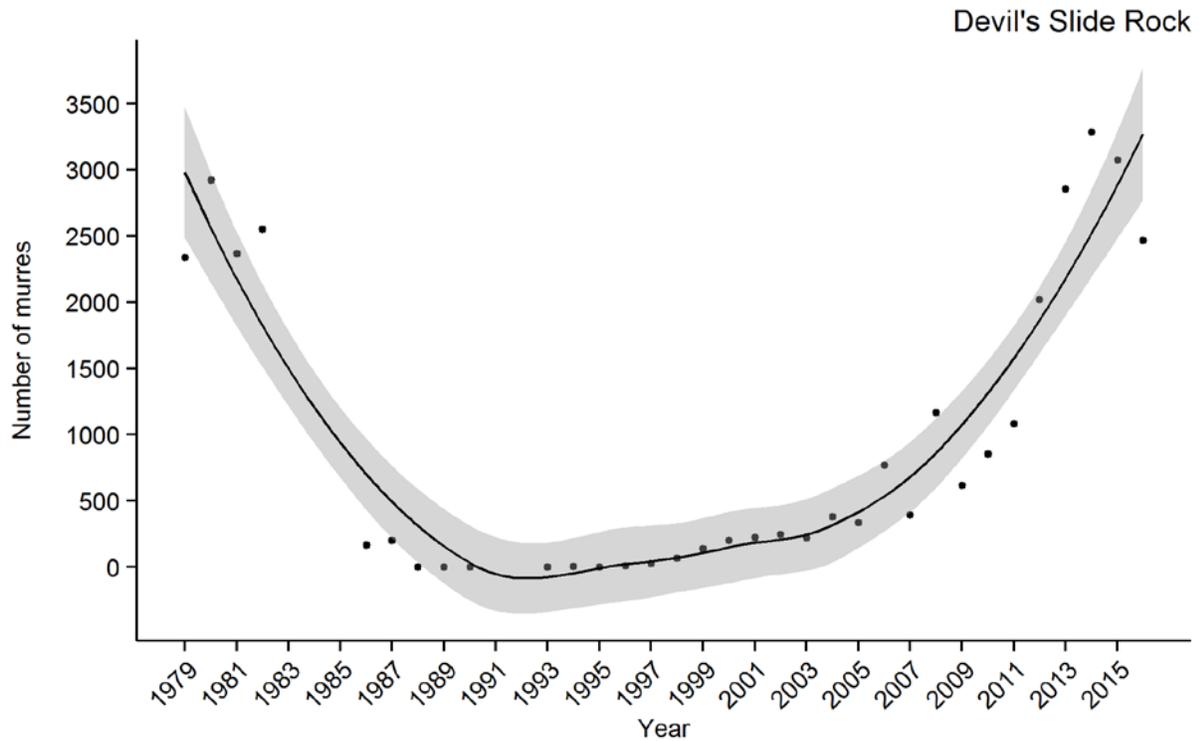


Figure 14. Common Murre breeding population trends at Devil’s Slide Rock, 1979-2016. Data points are number of breeding birds from colony monitoring (1996-2007) or raw counts from aerial photographic surveys multiplied by correction factors (all other years; see Methods). LOESS curve is shown with 95% confidence intervals (R Core Team, 2013).

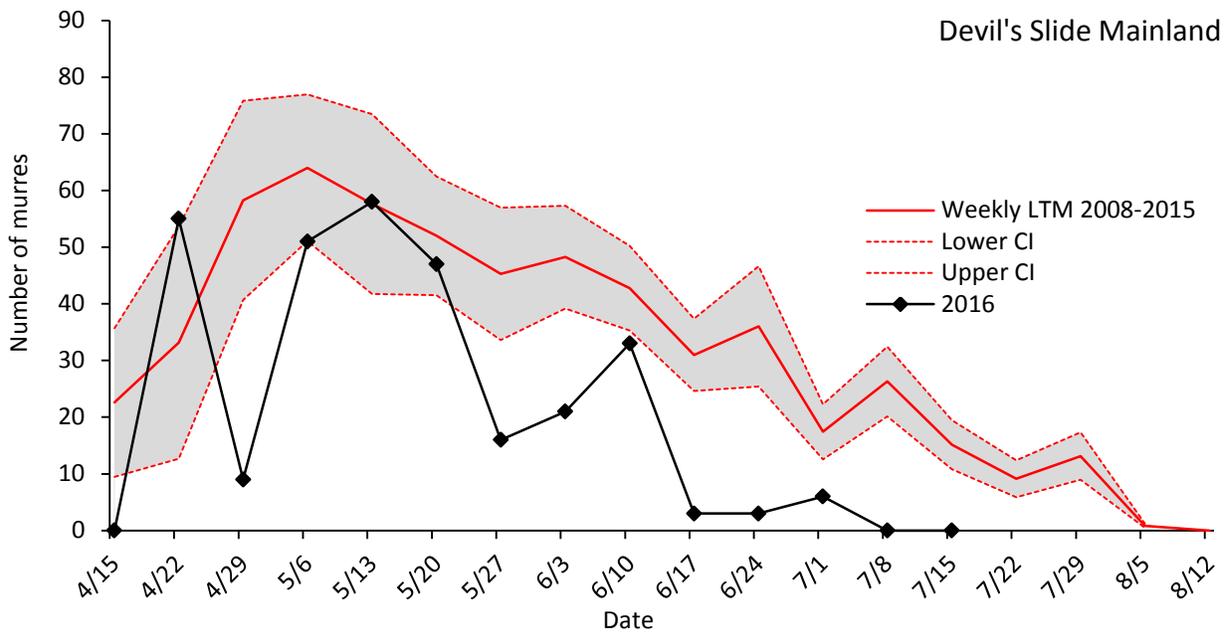


Figure 15. Seasonal attendance of Common Murres at Devil’s Slide Mainland (DSRM-05) in 2016 compared to long term (2008-2015) mean pattern.

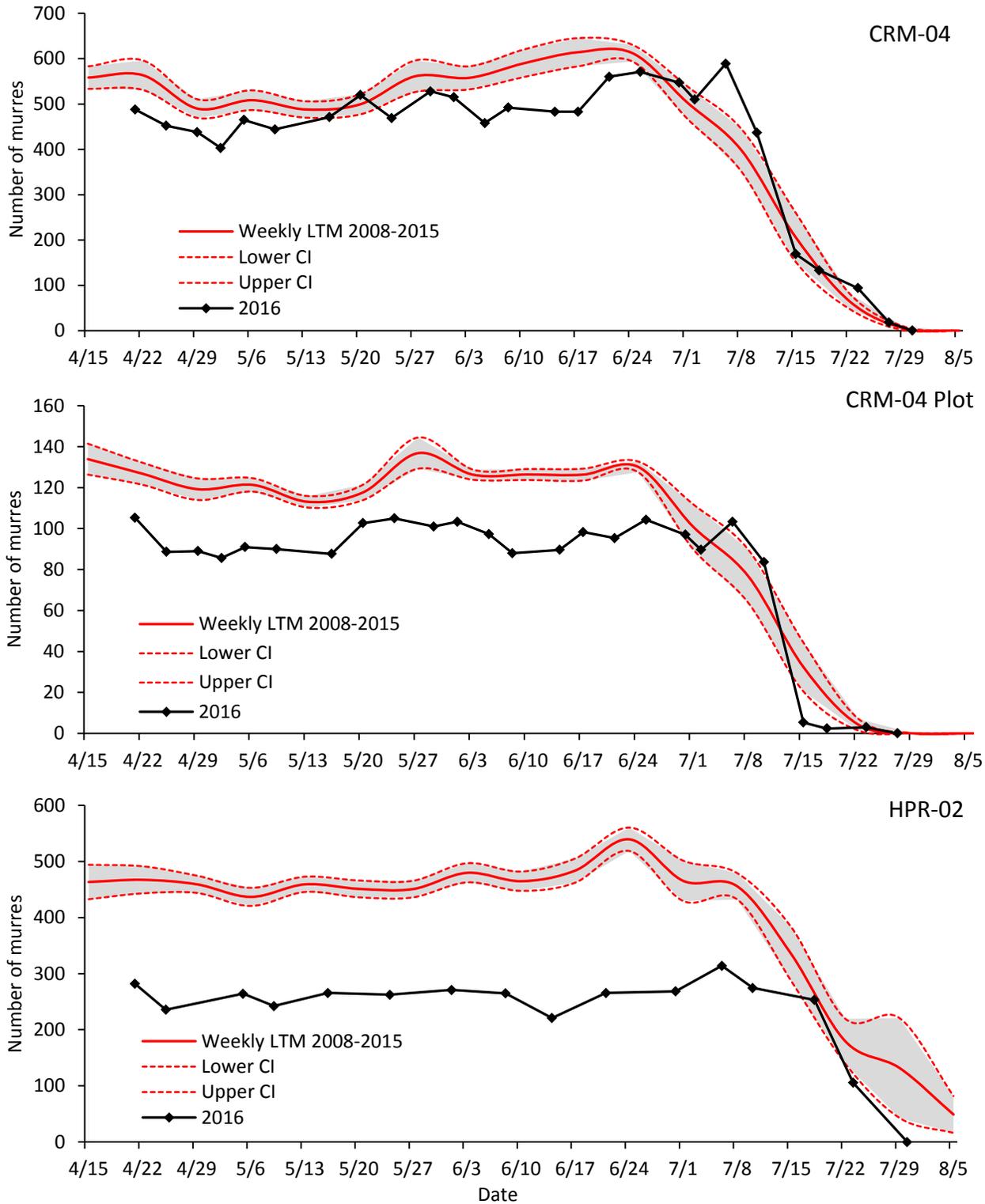


Figure 16. Seasonal attendance of Common Murres at Castle-Hurricane Colony Complex (subcolonies: CRM-04, CRM-04 Plot and HPR-02) in 2016 compared to long term (2008-2015) mean patterns.

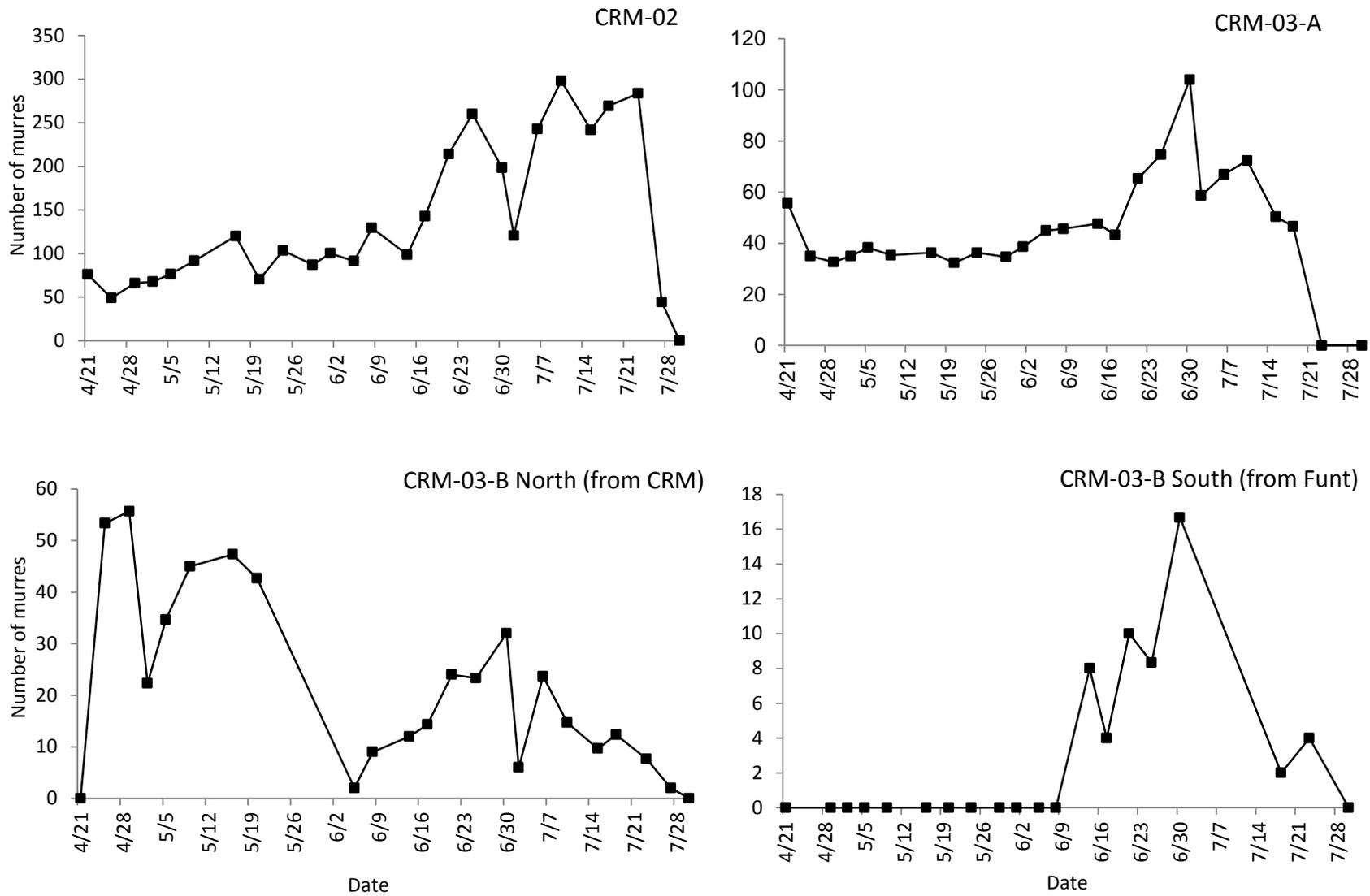


Figure 17. Seasonal attendance of Common Murres at Castle-Hurricane Colony Complex (subcolonies: CRM-02, 03-A, 03-B North and CRM-03-B South) from 21 April to 30 July, 2016.

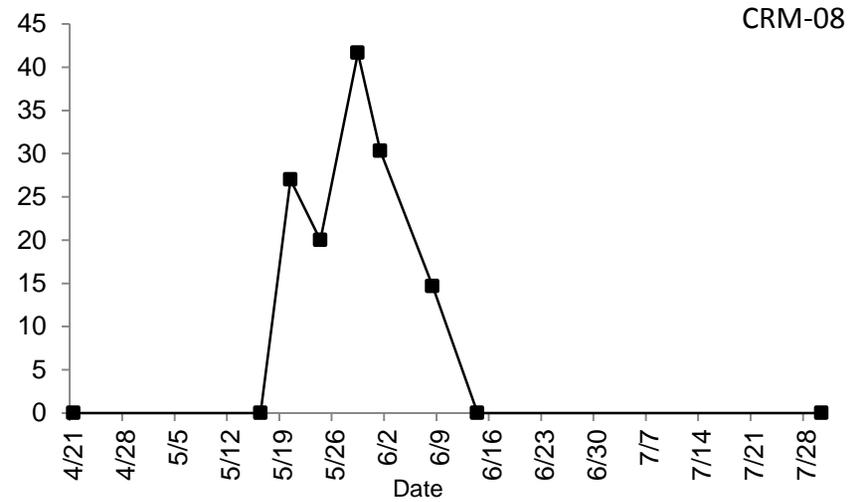
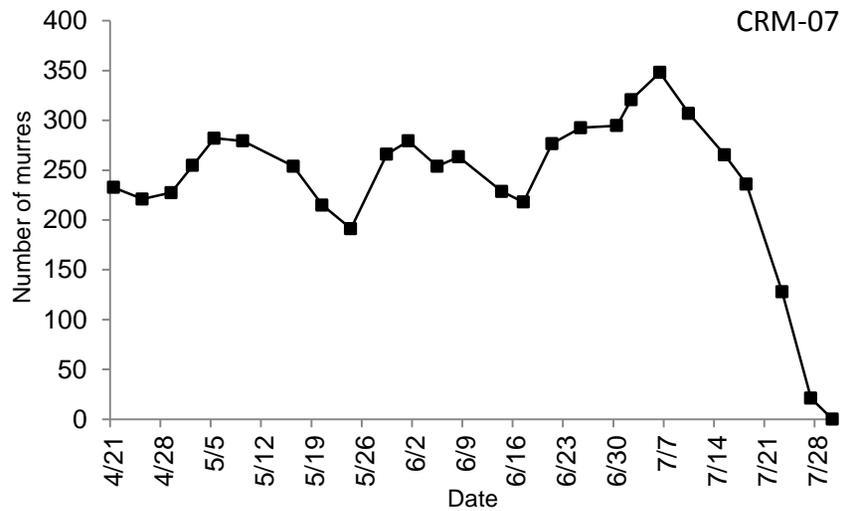
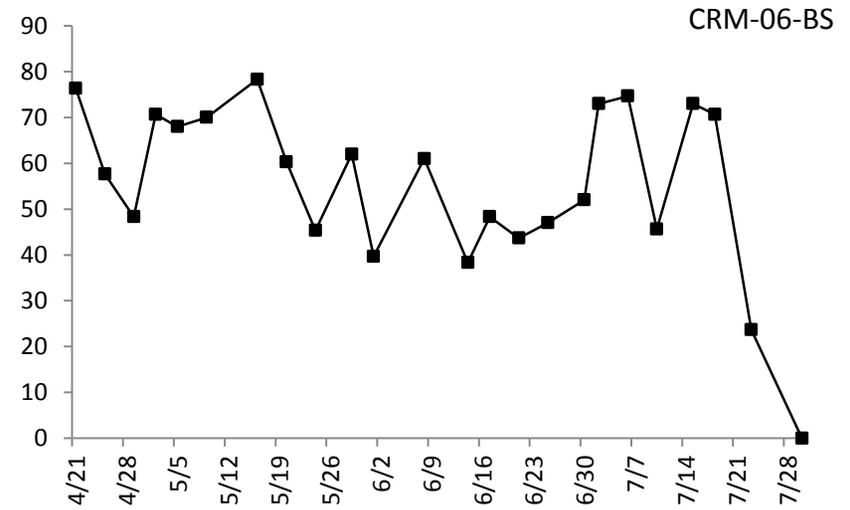
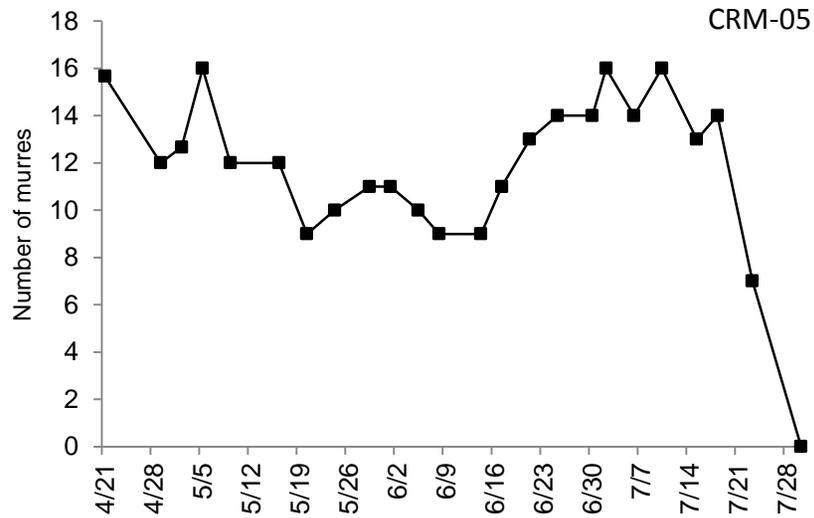


Figure 18. Seasonal attendance of Common Murres at Castle-Hurricane Colony Complex (subcolonies: CRM-05, 06-BS, 07 and 08) from 21 April to 30 July, 2016.

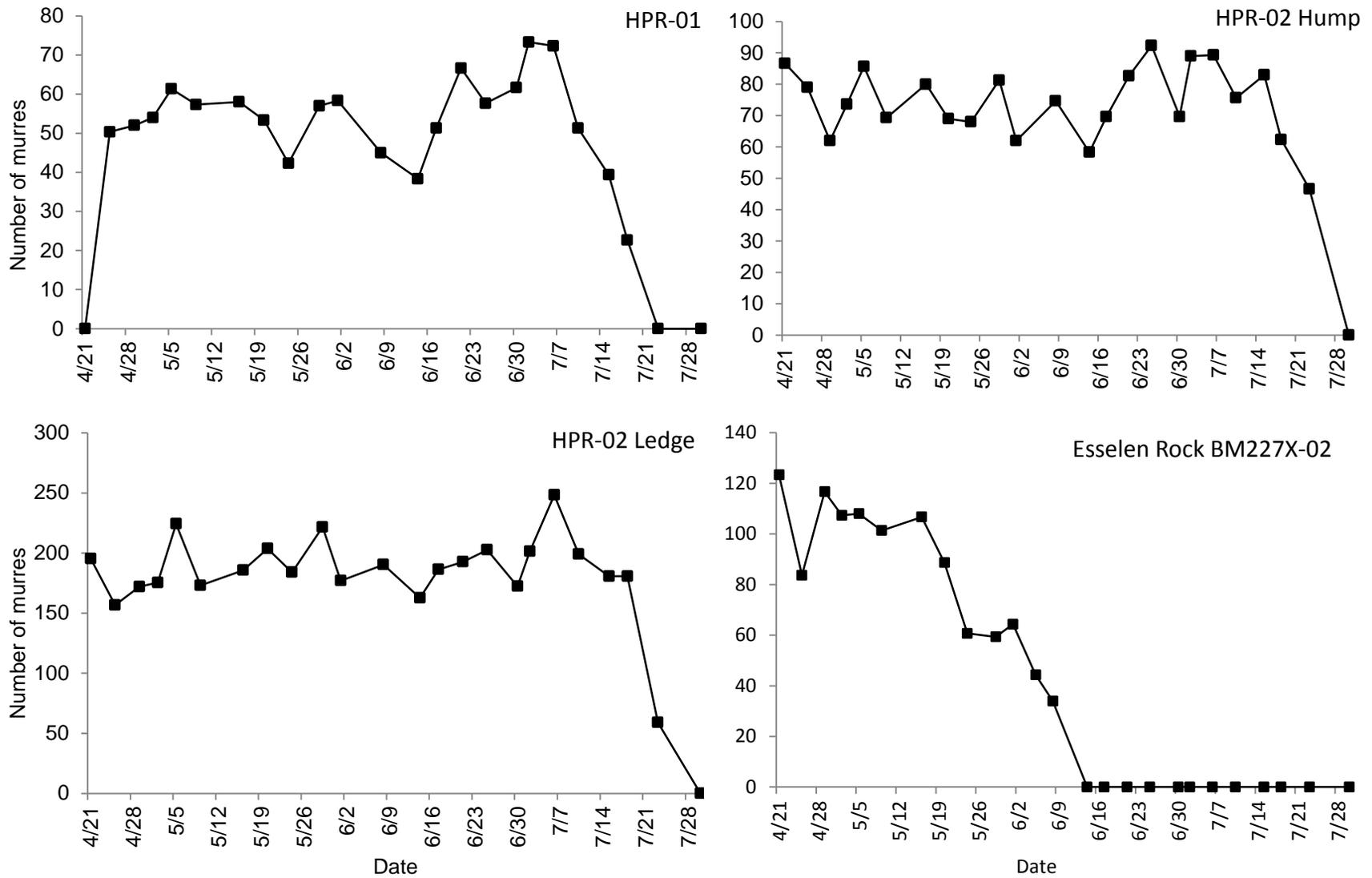


Figure 19. Seasonal attendance of Common Murres at Castle-Hurricane Colony Complex (subcolonies: HPR-01, 02-Hump, 02-Ledge and Esselen Rock, BM227X-02) from 21 April to 30 July, 2016.

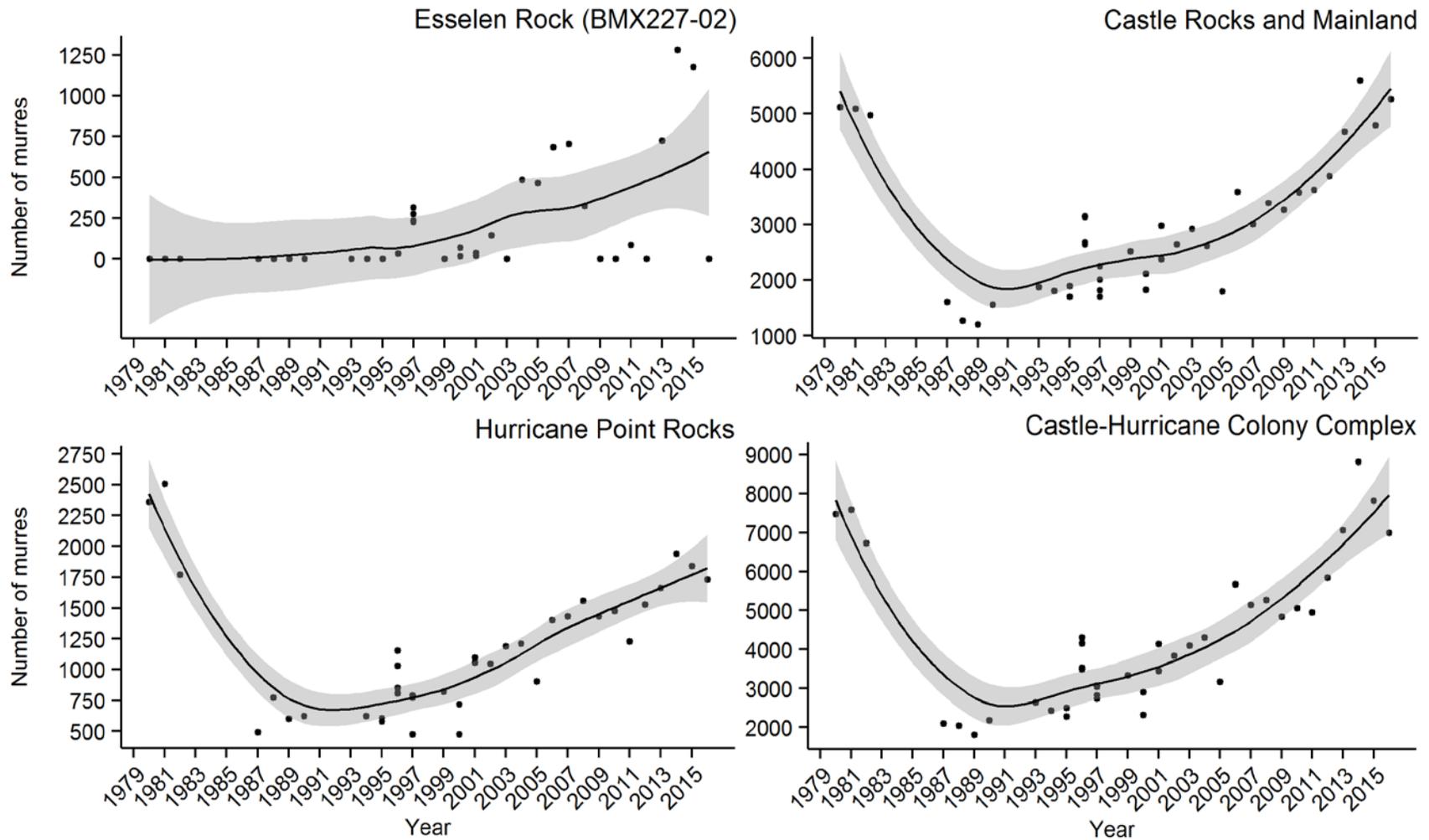


Figure 20. Common Murre breeding population trends at Esselen Rock, Castle Rocks and Mainland, Hurricane Point Rocks and Castle-Hurricane Colony Complex (all three colonies) combined, 1979-2016. Data points are raw counts from aerial photographic surveys multiplied by correction factors (see Methods). LOESS curves are shown with 95% confidence intervals (R Core Team, 2013). Note different scales between graphs.

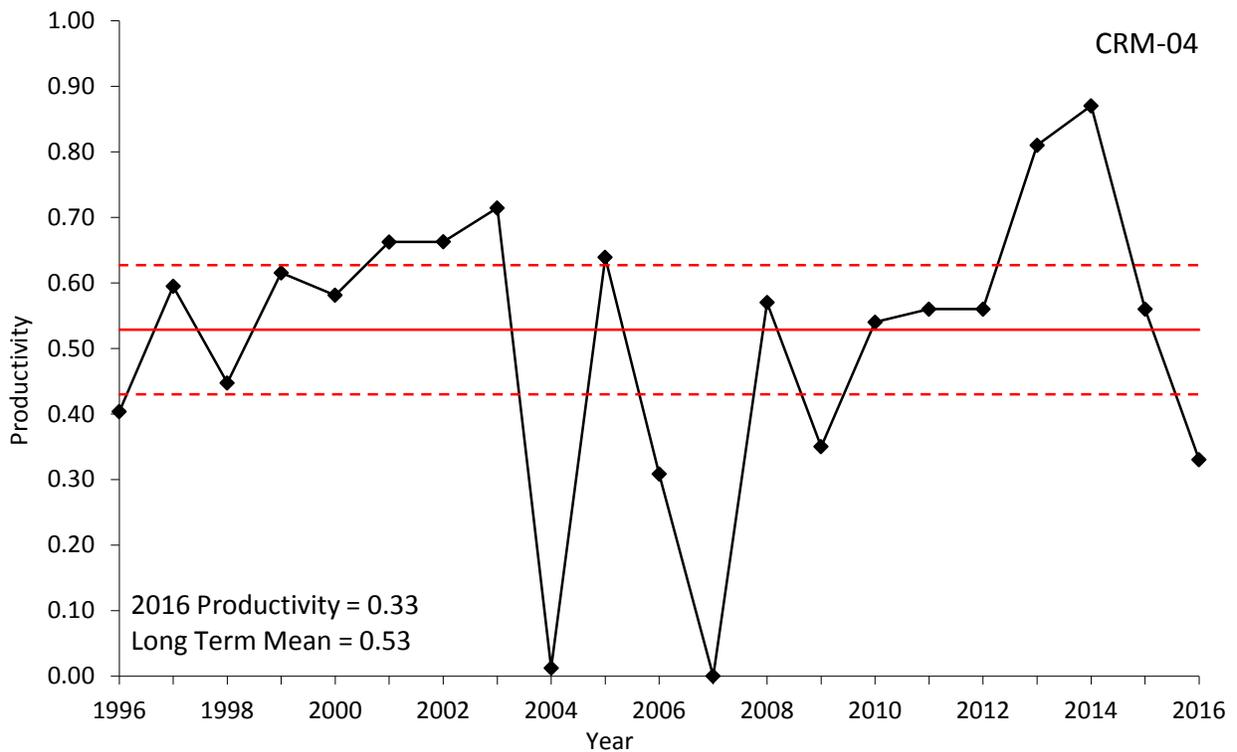
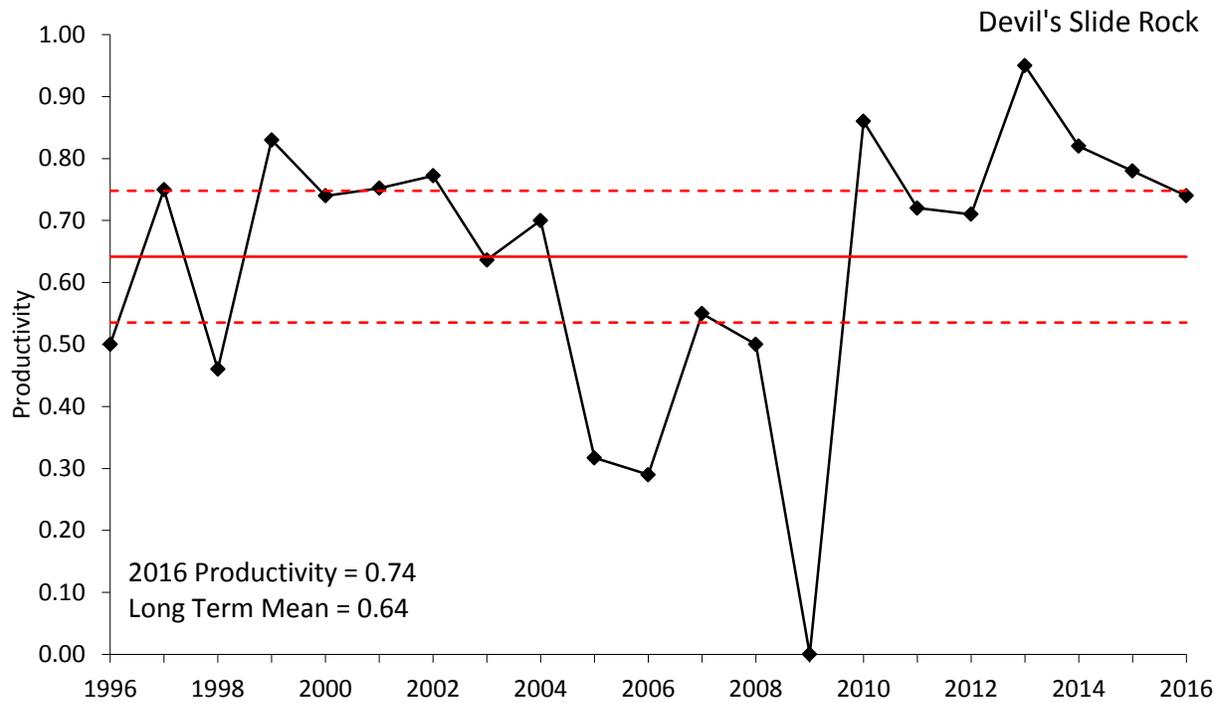


Figure 21. Productivity (chicks fledged per pair) of Common Murres at Devil's Slide Rock and Castle Rocks & Mainland-04 from 1996-2016. The solid horizontal line indicates the long-term weighted mean (2006-2015) and the dashed lines represent the 95% confidence interval.

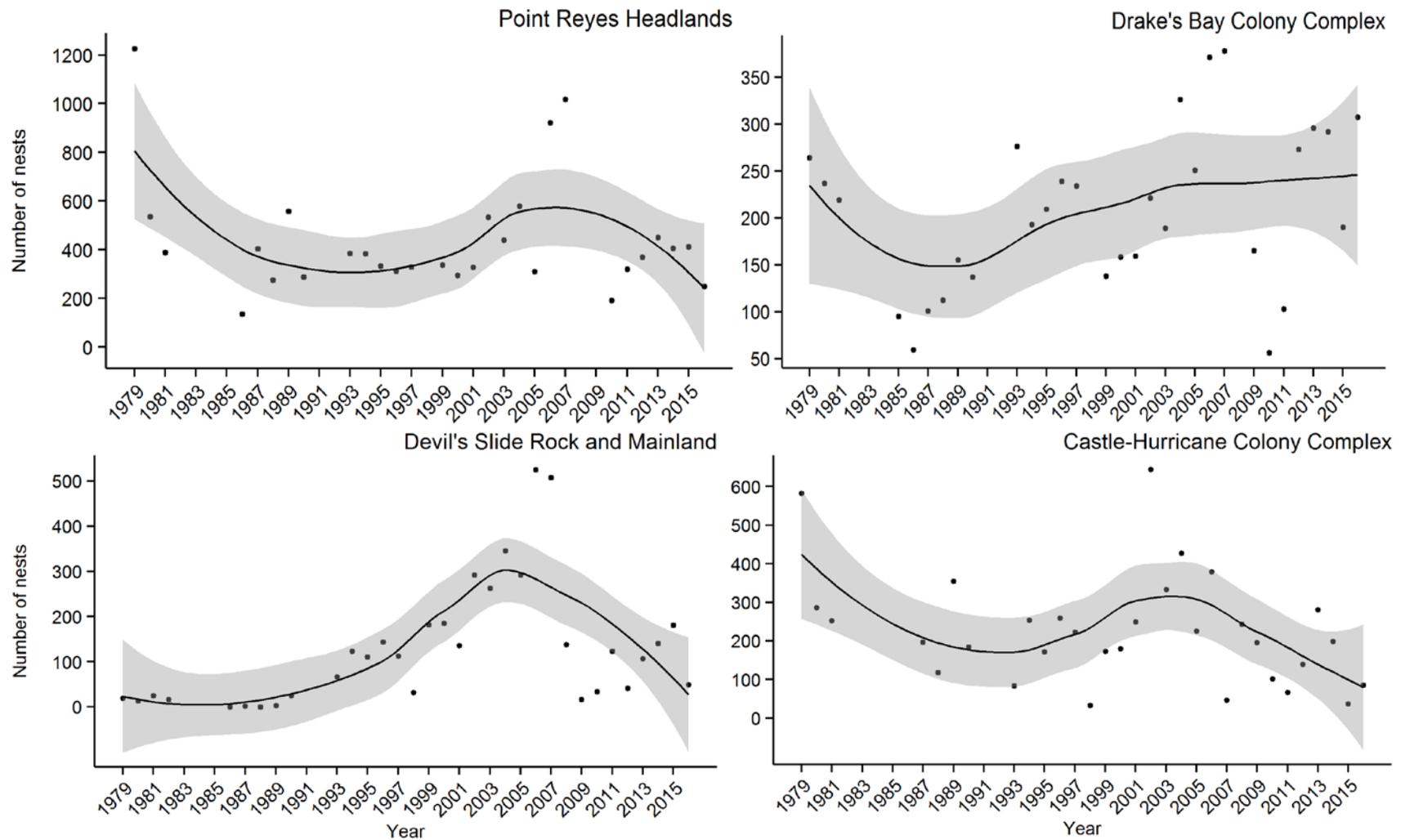


Figure 22. Brandt's Cormorant nest count trends from aerial photographic surveys for Point Reyes Headlands, Drake's Bay Colony Complex, Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex, 1979-2016. LOESS curves are shown with 95% confidence intervals (R Core Team, 2013). Note different scales between graphs.

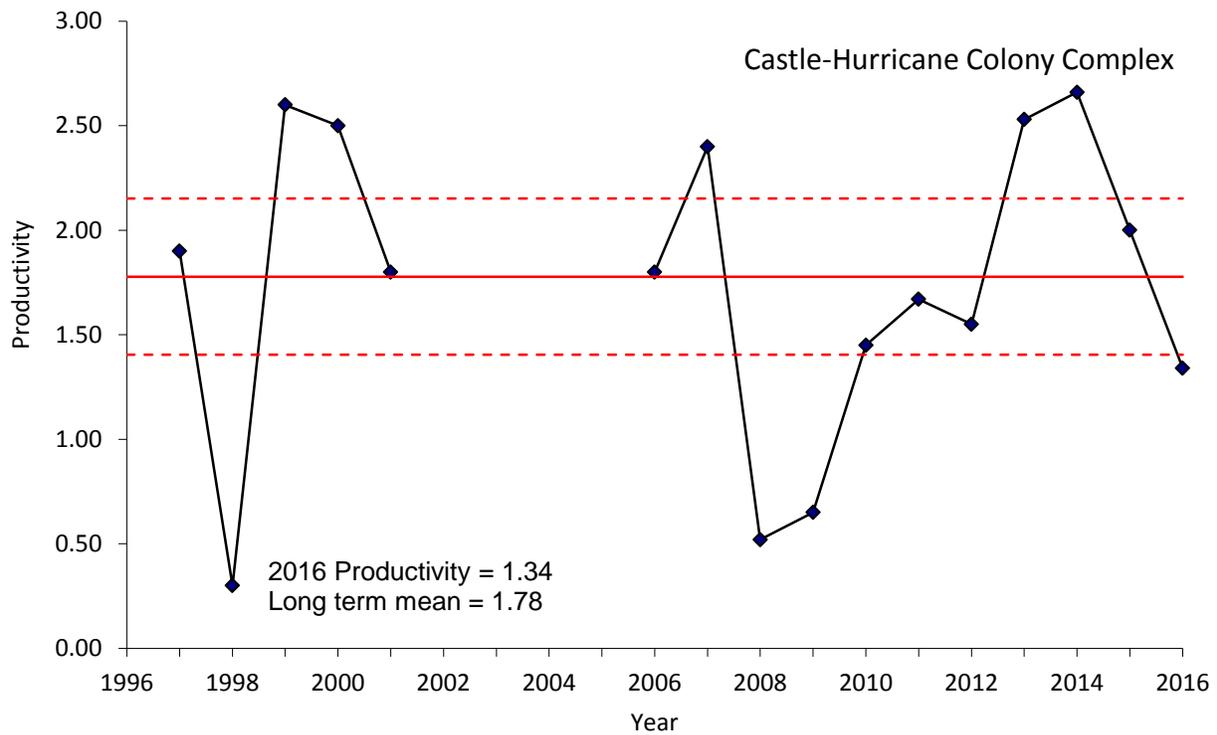
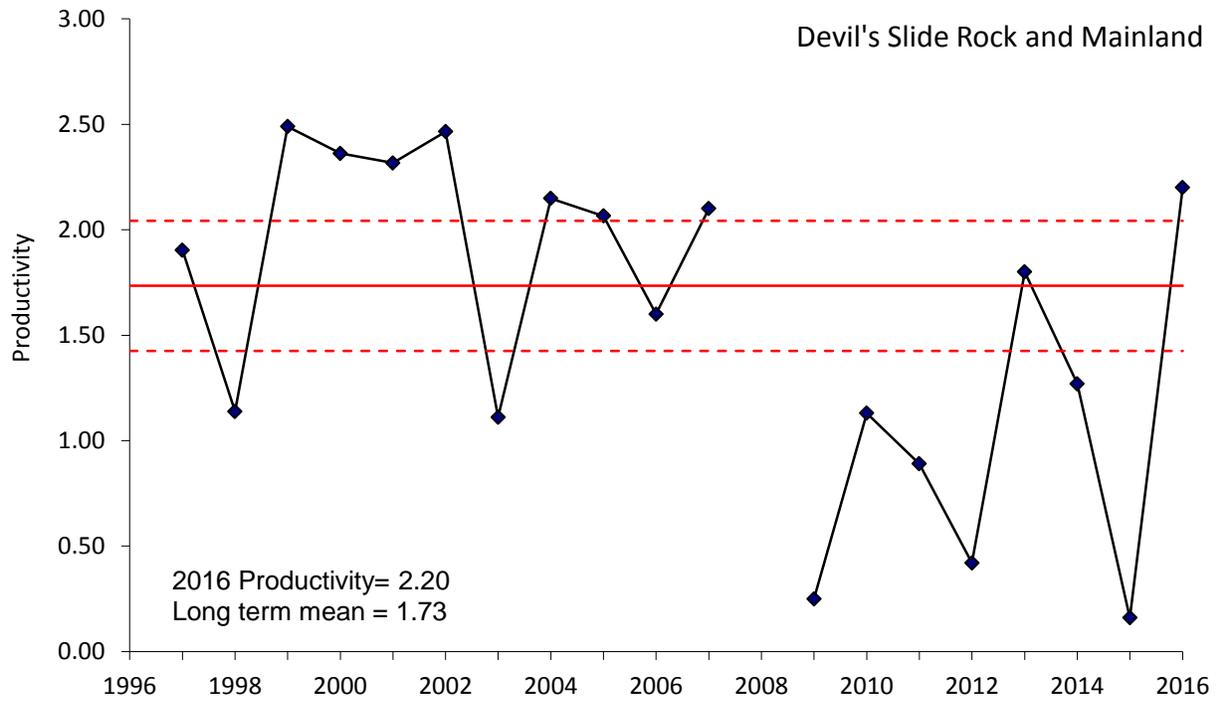


Figure 23. Productivity (chicks fledged per pair) of Brandt's Cormorants at Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex from 1996-2016. The solid horizontal line indicates the long-term weighted mean (1996-2015) and the dashed lines represent the 95% confidence interval.

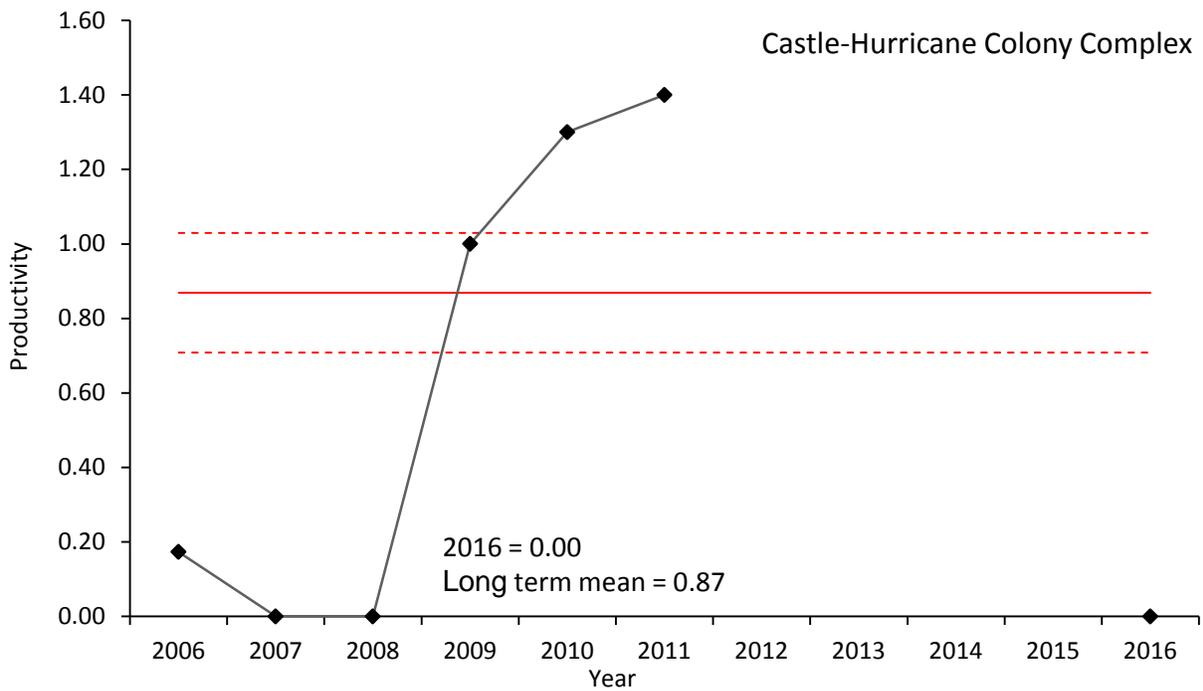
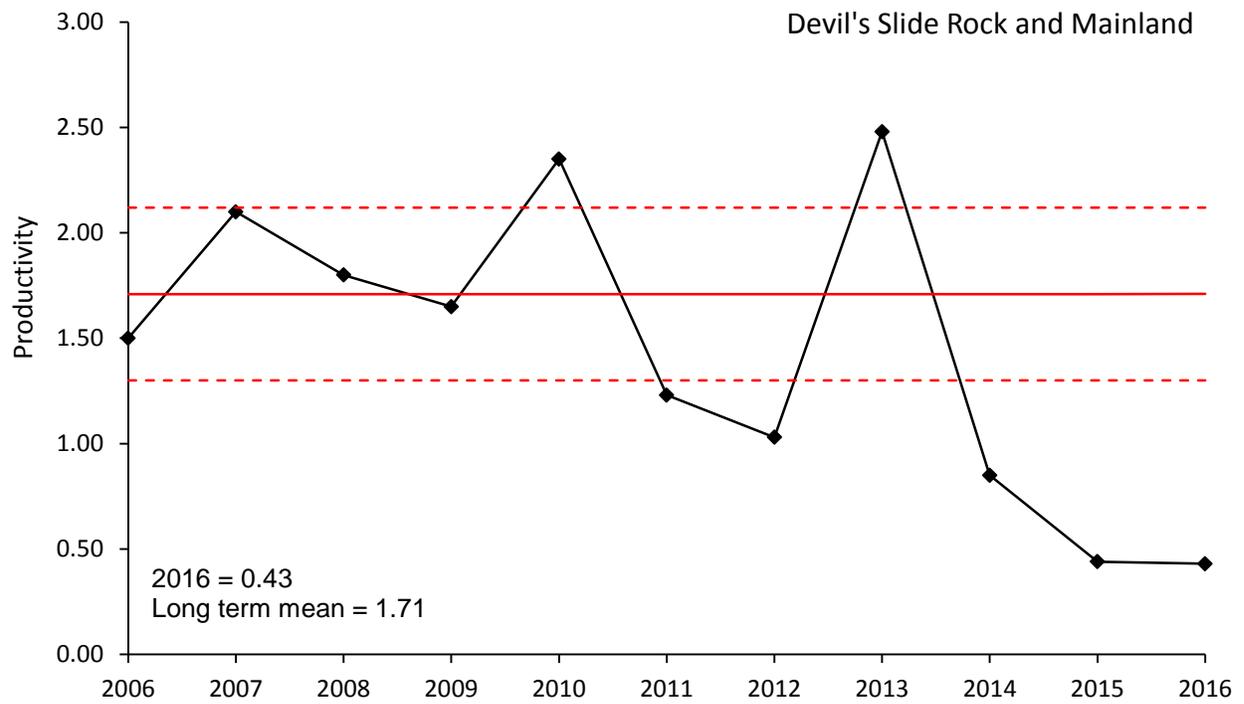


Figure 24. Productivity (chicks fledged per pair) of Pelagic Cormorants at Devil’s Slide Rock and Mainland and Castle-Hurricane Colony Complex from 2006-2016. The solid horizontal line indicates the long-term weighted mean (2006-2015) and the dashed lines represent the 95% confidence interval. Data was not collected at CHCC for Pelagic Cormorants between 2012 - 2015.

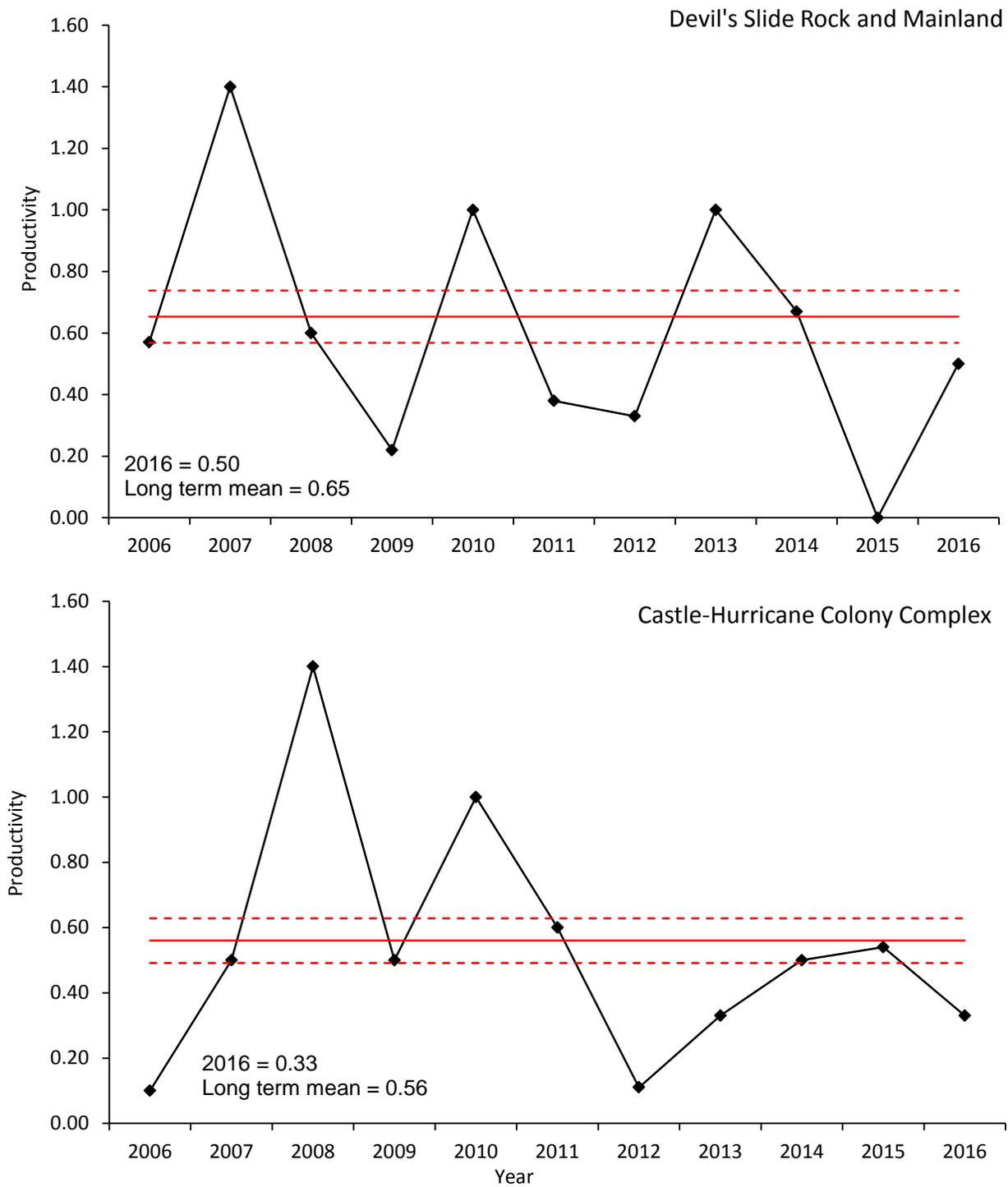


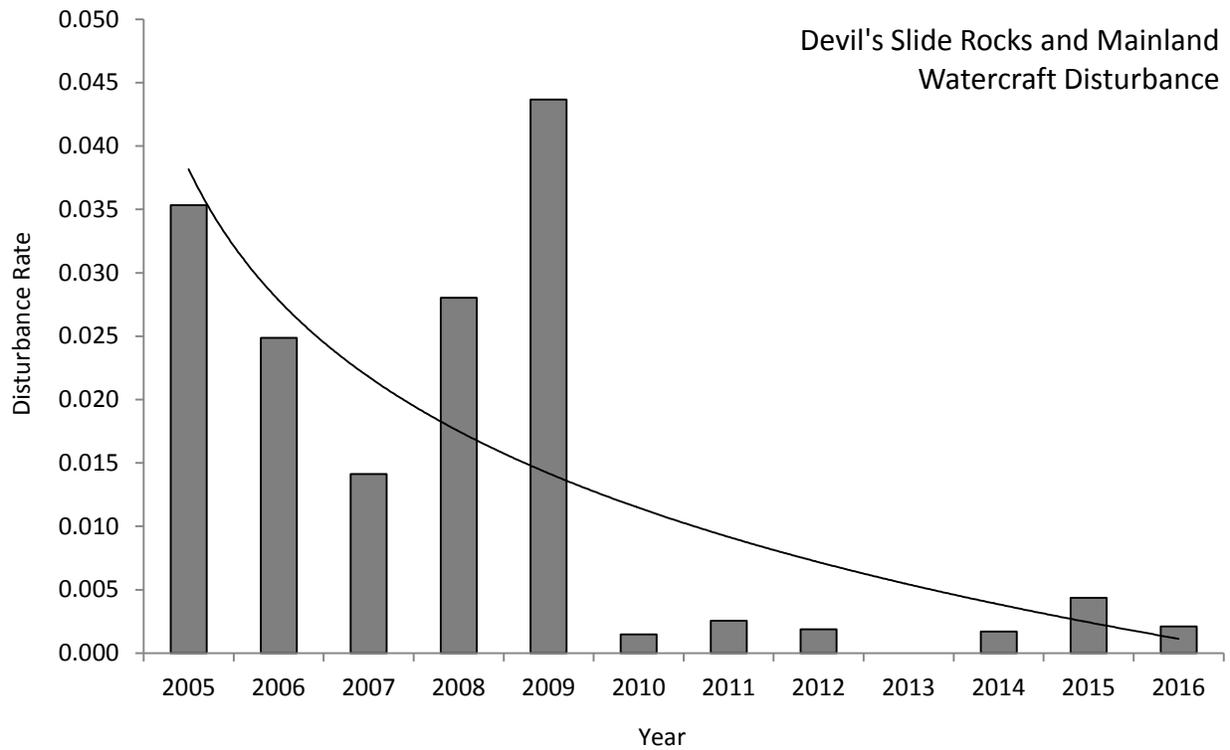
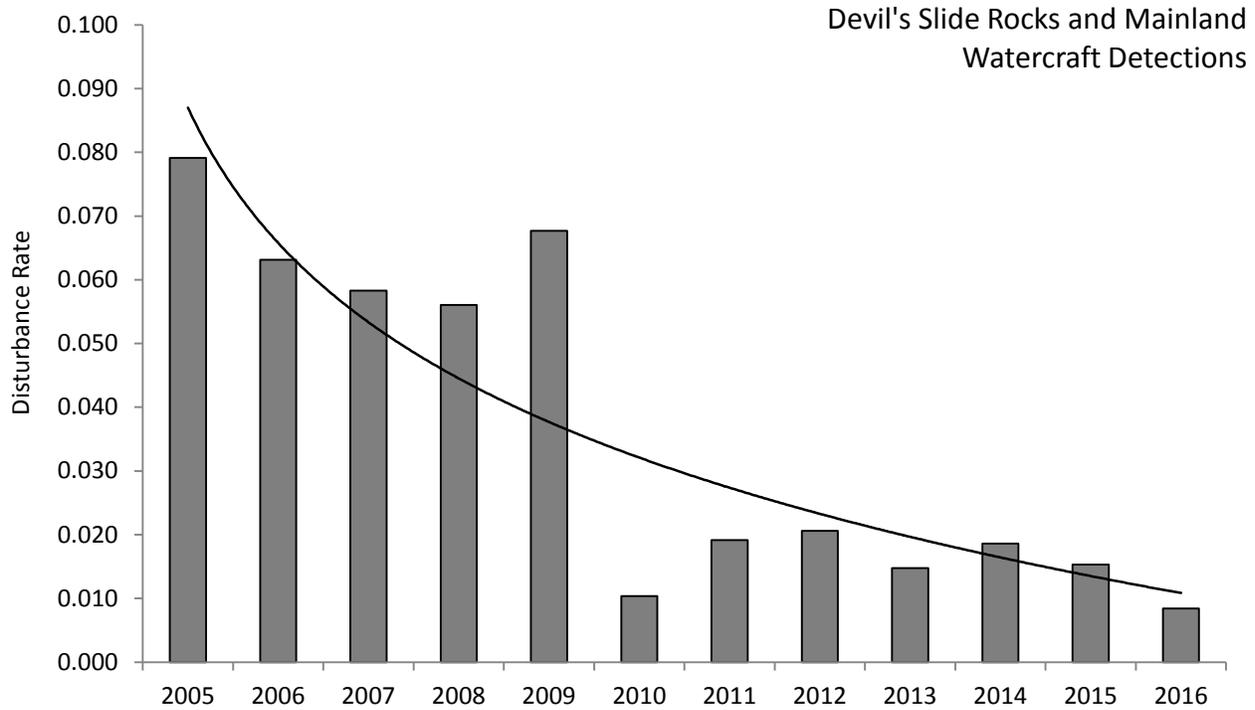
Figure 25. Productivity (chicks fledged per pair) of Western Gulls at Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex from 2006-2016. The solid horizontal line indicates the long-term weighted mean (2006-2015) and the dashed lines represent the 95% confidence interval.

Appendix 1. Number of aircraft overflights detected categorized by type and resulting disturbance events recorded at Devil's Slide Rock and Mainland, and Castle-Hurricane Colony Complex in 2016.

Aircraft Type	Total Detections			Number of Agitation Events			Number of Displacement Events			Number of Flushing Events			Total Disturbance Events		
	Plane	Drone	Helo	Plane	Drone	Helo	Plane	Drone	Helo	Plane	Drone	Helo	Plane	Drone	Helo
Devil's Slide Rock and Mainland															
Military	-	-	10	-	-	3	-	-	-	-	-	6	-	-	9
Private/Rec	12	1	10	1	-	1	-	-	-	-	-	3	1	-	4
USCG	-	-	1	-	-	-	-	-	-	-	-	1	-	-	1
Media	-	-	1	-	-	-	-	-	-	-	-	1	-	-	1
Law Enforcement	-	-	1	-	-	-	-	-	-	-	-	1	-	-	1
Unknown	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Research	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Castle-Hurricane Colony Complex															
USCG	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Military	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Research	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Private/Rec	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Law Enforcement	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Total	25	3	28	1	-	4	-	-	-	-	-	12	1	-	16

Appendix 2. Number of watercraft detected categorized by type and resulting disturbance events recorded at Devil's Slide Rock and Mainland and Castle-Hurricane Colony Complex, 2016.

Watercraft Type	Total Observations	Number of Agitation Events	Number of Displacement Events	Number of Flushing Events	Total Disturbance Events
Devil's Slide Rock and Mainland					
Recreational (<25') Small Private	3	-	-	-	-
Kayak/Canoe	1	-	-	1	1
Castle-Hurricane Colony Complex					
Recreational (>25') Large Private	-	-	-	-	-
Total	4	-	-	1	1



Appendix 3. Watercraft detection and disturbance rates at Devil's Slide Rock and Mainland from 2005-2016. Logarithmic trendlines are shown.