RESTORATION AND MONITORING OF COMMON MURRE COLONIES IN CENTRAL CALIFORNIA: ANNUAL REPORT 2022

REPORT TO THE *LUCKENBACH* TRUSTEE COUNCIL

Lauren C. Scopel, Gerard J. McChesney, Melanie Birch, Emma Lachance Linklater, Samuel Lei, Sarah Morrow, Deklyn Wood, and Richard T. Golightly

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FINAL REPORT
October 2024

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Cover photo: Devil's Slide Rock from the "Traditional Pullout" on the adjacent mainland, 14 July 2022 (Cal Poly Humboldt)

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ABBREVIATIONS USED

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

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

LHR = Lighthouse Rock

MPR = Millers Point Rocks

NOAA = National Oceanic and Atmospheric Administration

NPFC = National Pollution Funds Center

OSLTF = Oil Spill Liability Trust Fund

PRH = Point Reyes Headlands

PRS = Point Resistance

SPN = Seabird Protection Network

SPR = San Pedro Rock

UAS = Uncrewed Aircraft System (drone)

USCG = U.S. Coast Guard

USFWS = U.S. Fish and Wildlife Service

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ACKNOWLEDGMENTS

In 2022, the *Luckenbach* Oil Spill Trustee Council, comprised of California Department of Fish and Wildlife (CDFW), National Oceanic and Atmospheric Administration (NOAA), and Department of the Interior through U.S. Fish and Wildlife Service (USFWS) and National Park Service, provided funding and oversight.

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

EXECUTIVE SUMMARY

Efforts in 2022 were the 27th year of restoration and associated monitoring of central California seabird colonies by the Common Murre Restoration Project. This project first conducted fieldwork 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, natural resource damage assessment settlement funds from the 1998 *Command* and extended *Luckenbach* oil spills have supported the project since 2005 and 2010, respectively. 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 other central California colonies. Since 2005, we have incorporated standardized procedures for the surveillance and assessment of human disturbance at central California Common Murre colonies. Additionally, we continue to monitor the outcome of initial recolonization efforts at DSR and recovery of other central California murre colonies. The human disturbance assessments are used to inform outreach, education, and regulatory efforts by the Seabird Protection Network (SPN; coordinated by the Greater Farallones National Marine Sanctuary; GFNMS) and allow for evaluation of the success of those efforts. The goal of the SPN is to protect seabird breeding colonies in central California primarily through reduction of human disturbance, which also enhances the restoration of previously injured colonies.

The timing of the start to the 2022 field season was typical and was not affected by COVID-19 with the exception that owing to concerns of virus transmission, we did not monitor the Castle-Hurricane Colony Complex. Fieldwork began in early to mid-April at Devil's Slide Rock & Mainland and Point Reyes Headlands. We conducted monitoring of human disturbance (mainly aircraft and watercraft), non-anthropogenic disturbance, seabird productivity, seabird attendance patterns, and relative population sizes at Devil's Slide and Point Reyes. A volunteer also conducted less-intensive monitoring of Common Murre attendance at Bird Island.

Detection rates of aircraft and watercraft were below the long-term mean at Point Reyes, but above the long-term mean at Devil's Slide, especially via elevated aircraft rates. Detection rates at Point Reyes (0.05 detections/hr) were higher than in 2021, but generally lower than other recent years. Long-term trend analysis (2005-2022) at Point Reyes indicated recent increasing trends in watercraft and overall detection rates, especially in 2020. Seabird disturbance rates at Point Reyes (0.022 disturbances/hr) were the highest observed since 2019 and included 14 aircraft disturbance events. We found no long-term trends in disturbances by aircraft or watercraft. At Devil's Slide, as usual, detection rates in 2022 (0.46 detections/hr) were higher than at Point Reyes. Long-term trend analysis showed that the detection rate of aircraft, planes, helicopters, watercraft, and overall detections at Devil's Slide initially decreased, but have recently increased rapidly since 2019. Seabird disturbance rates at Devil's Slide (0.25 disturbances/hr) were the highest since 2012, especially by events involving planes (63%) and helicopters (33%). We recorded 95 total disturbance events at Devil's Slide, 34 (36%) of which involved the displacement or flushing of Common Murres. Similarly, disturbances from aircraft, planes, and all sources at Devil's Slide decreased early in the time series, but they have all increased since 2019; watercraft disturbances decreased over time and remain low.

Among all detected aircraft, general aviation planes (e.g., private or charter) were the most common (74%), followed by U.S. Coast Guard (USCG) helicopters (11%) and military aircraft (10%). Among sources of aircraft disturbance, most were caused by general aviation planes (64%), military aircraft (15%) and USCG helicopters (14%). Most watercraft detections (91%) and all watercraft disturbances were caused by private recreational craft. Only two watercraft caused disturbances in 2022, each at Devil's Slide. Three watercraft at Point Reyes and two at Devil's Slide were observed within Special Closure areas in 2022.

In our study of non-anthropogenic disturbance, we recorded 145 events causing displacement, flushing, or seabird egg or chick loss; 47 occurred at Devil's Slide while 98 occurred at Point Reyes. Brown Pelicans (*Pelecanus occidentalis*) caused major disturbances at Devil's Slide and Point Reyes in 2022, both by large aggregations of loafing birds and by single juvenile birds apparently searching for discarded fish to scavenge or adult murres to kleptoparasitize. These disturbances were particularly severe for murres, and breeding murres on both Devil's Slide Rock and Lighthouse Rock were disrupted multiple times in July. At Devil's Slide, pelicans caused 45% of recorded non-anthropogenic disturbance events: 87 displaced eggs or chicks; 35 exposed eggs or chicks; and one instance of kleptoparasitism. Pelicans caused 19% of non-anthropogenic events at Point Reyes, including 20 displaced eggs or chicks, 37 exposed eggs or chicks, 4 eggs or chicks forced out of the colony, 18 instances of kleptoparasitism, and 16 depredated eggs or chicks. Common Ravens (*Corvus corax*) also caused major disturbance at both field sites. At Devil's Slide, ravens caused 51% of non-anthropogenic disturbance events and depredated 18 murre eggs or chicks. At Point Reyes, ravens caused 56% of non-anthropogenic disturbance events, depredated 20 murre eggs or chicks, and instigated 17 kleptoparasitism events by other avian predators. Western Gulls (*Larus occidentalis*) frequently followed in the wake of pelicans or ravens to try scavenging and depredating eggs and chicks. They were involved in 19% of non-anthropogenic events at Devil's Slide, and caused one instance of kleptoparasitism, but no eggs or chick depredation was recorded. At Point Reyes, 22% of events involved Western Gulls, which successfully kleptoparasitized 18 Common Murres and depredated 22 murre eggs or chicks. At Point Reyes, we saw frequent disturbance by scavenging Turkey Vultures (*Cathartes aura*, 14% of events, 16 scavenged eggs or chicks, 7 acts of kleptoparasitism). We also observed the first case of disturbance caused by a Bald Eagle (*Haliaeetus leucocephalus*) at Point Reyes.

In 2022, seasonal attendance patterns of Common Murres at Point Reyes were generally similar to long-term means. Attendance at many plots fluctuated, and at some plots counts increased notably in mid- to late July, delaying the departure of adults from their breeding colonies compared to long-term means. We also observed greater counts of murres at subcolonies that were typically sparsely attended in the past. At Devil's Slide Rock, murre seasonal attendance was similar to the long-term mean from April-June, but counts were elevated in July compared to the long-term mean (~26%). Murre attendance at Devil's Slide Mainland was ~450% greater than the long-term mean, a result of increasing numbers of breeders and perhaps prospecing birds.

Common Murre productivity (chicks fledged per pair) in monitored plots was near average at Point Reyes (0.58 chicks/pair), Devil's Slide Rock (0.65 chicks/pair), and Devil's Slide Mainland (0.34 chicks/pair). Brandt's Cormorant (*Urile penicillatus*) productivity was above average at Devil's Slide (2.26 chicks/pair) and Point Reyes (2.12 chicks/pair). The land-based seasonal total of 383 nests at Devil's Slide (4% greater than 2021), and 640 nests at Point Reyes (100% greater than 2021). At Devil's Slide, productivity of Pelagic Cormorants (*U. pelagicus*) was near average (1.55 chicks fledged/pair), and productivity of Western Gulls was above average (1.14 chicks fledged/pair). Black Oystercatchers (*Haematopus bachmani*) from one breeding site at Devil's Slide fledged three chicks.

Aerial photographic surveys of Brandt's Cormorant, and Common Murre colonies were not conducted in 2022. Thus, no breeding population estimates are available for 2022. Although these surveys have been conducted in past years with separate funding, they provide invaluable information on total breeding population sizes and trends of these species.

INTRODUCTION

In central California, Common Murre (*Uria aalge,* hereafter "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 20-40 km offshore of San Francisco (Carter et al. 1992, 2001). A steep decline in the central California population occurred between 1980 and 1986, which was attributed primarily to mortality associated with gill-nets and oil spills, including the 1986 *Apex Houston* oil spill (Page et al. 1990; Takekawa et al. 1990; Carter et al. 2001, 2003). Between 1982 and 1986, a colony of about 3,000 breeding murres on Devil's Slide Rock (DSR) in northern San Mateo County was extirpated. Since 1995, the Common Murre Restoration Project (CMRP) has sought to restore DSR and other central California colonies using several techniques, including social attraction. Social attraction techniques were used at DSR between 1996 and 2005 (McChesney et al. 2006; Parker et al. 2007), but they 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 size of the central California murre population has increased owing to the implementation of restoration efforts including restrictions on gill-net fishing, re-colonization of Devil's Slide Rock utilizing social attraction techniques, and human disturbance reduction, as well as favorable prey conditions and other factors (Carter et al. 2001; Parker et al. 2007; McChesney et al. 2022; USFWS, unpublished data). However, anthropogenic impacts to murres may continue to affect the population. Gill-net mortality persisted 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 m (60 fathoms) deep from Point Reyes to Point Arguello (Forney et al. 2001; CDFW). 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) killed thousands of murres in central California (Carter 2003; Carter and Golightly 2003; Hampton et al. 2003; Roletto et al. 2003). Disturbances from aircraft and watercraft have also affected colonies (Rojek et al. 2007; Fuller et al. 2018; USFWS, unpublished data).

Beginning in 1995, restoration and associated monitoring of murre colonies in central California have been funded primarily 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 m of water approximately 27 km southwest of San Francisco. The *S.S. Jacob Luckenbach* was loaded with 457,000 gallons of bunker fuel, which subsequently leaked periodically during winter storms. Using chemical analysis, oil that was associated with several mystery spills was linked to this vessel, including the Point Reyes tar ball incidents of winter 1997-1998 and the San Mateo Mystery Spill of 2001-2002. In the summer of 2002, the U.S. Coast Guard (USCG) and the *Luckenbach* trustees removed much of the oil from the vessel and sealed the remaining oil inside (Hampton et al. 2003). An estimated 51,569 seabirds were killed between 1990 and 2003 from Bodega Bay to Monterey Bay, including 31,806 murres (*Luckenbach* Trustee Council 2006).

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

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

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

Here we summarize colony surveillance and monitoring efforts conducted at nearshore murre colonies in central California in 2022. Like past years, we recorded and categorized aircraft, watercraft and other disturbances to seabirds. We also investigated murre seasonal attendance patterns and productivity (reproductive success). Furthermore, we recorded relative breeding population sizes and productivity of Brandt's Cormorants (*Urile penicillatus*), as well as relative breeding population sizes and/or productivity of Pelagic Cormorants (*U. pelagicus*), Black Oystercatchers (*Haematopus bachmani*), Western Gulls (*Larus occidentalis*), and Pigeon Guillemots (*Cepphus columba*). Aerial surveys, which have been conducted with separate funds to estimate total breeding population sizes of Common Murres, Brandt's Cormorants, and Double-crested Cormorants, were not conducted in 2022.

METHODS

Study Sites

We monitored colonies at PRH and DSCC for productivity, disturbance, and attendance of seabirds in 2022 (Figure 1). PRH (Figure 2) is located within the Point Reyes National Seashore, Marin County. DSCC, located in San Mateo County, consists of the colonies Devil's Slide Rock and Mainland (DSRM) and San Pedro Rock (SPR; Figures 3-4). The offshore rocks of DSCC 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. Bird Island is located near the mouth of the Golden Gate within Golden Gate National Recreation Area in Marin County. 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. We did not monitor CHCC in 2022 owing to concerns of exposure to COVID-19. A volunteer monitored seabird attendance at Bird Island.

Monitoring Effort

Monitoring effort in 2022 followed long-term protocols, with no major disruptions from COVID-19. 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. From these data, we total observation hours irrespective of the number of observers (i.e., *not* a calculation of person-hours). To calculate the total observation hours for a colony or colony complex, we combined observation hours from all vantage points. When multiple observers were present at multiple vantage points simultaneously, the total hours of observation were calculated as hours on site regardless of the number of people observing (i.e., not double counted). Time transiting between vantage points (even on foot) was not included in observation hours.

Disturbance

Anthropogenic Disturbance Events

Anthropogenic (human-caused or -associated) disturbance events affecting murres or other seabirds were recorded at each study colony. These disturbances included any instances in which adult birds were alarmed or agitated (e.g., head-bobbing in murres, raised head or wing-flapping in cormorants), displaced (i.e., birds moved from a breeding or roosting site but did not fly away) or flushed (i.e., birds flew from the colony or roost) owing to human activity. For each disturbance event, we recorded the number of disturbed seabirds within each of the three disturbance categories. Numbers of eggs or chicks exposed, displaced, depredated, or otherwise lost (taken) were also recorded. When seabirds were disturbed by a human source that we identified (e.g., helicopter with recorded tail number), we filed an SPN wildlife disturbance report. These reports included pertinent information on the event and photos (when available). For aircraft disturbances, we used the FlightAware app (https://flightaware.com) live flight tracker to help identify or confirm aircraft observed. Information about the flight and aircraft, including maps, were downloaded from FlightAware and provided in disturbance reports.

To examine long-term spatiotemporal trends, we calculated anthropogenic disturbance rates. These rates represented the number of disturbance events per hour of observation at each colony complex (except at Bird Island). Using generalized linear models, we examined and predicted trends in annual detection and disturbance rates between 2005-2022. For each colony complex and each disturbance source (e.g., helicopters, planes, watercraft), we fit models with linear, quadratic, or cubic polynomial terms, for each of the gamma and gaussian distributions (log link). We also fit a null model, making a total of seven models per disturbance source. All models were compared using Akaike's Information Criterion corrected for small sample sizes (AICc). If the top-ranked model was the null model, we determined that there was no statistically significant change over time. If one of the linear or polynomial models was top ranked, we selected this model to represent the long-term trend for that disturbance source. If statistically significant changes occurred, we then calculated the annual rate of change between consecutive years based on the top-ranked model, which could be complex in cases where quadratic or cubic functions were supported. We report annual, between-year changes in rate and their 95% confidence intervals (CIs). Annual differences compare the preceding year and the current year (e.g., the 2022 rate of change examines the change in disturbance rate between 2021 and 2022).

The annual Pacific Coast Dream Machines festival, which typically takes place at the Half Moon Bay Airport, was cancelled in 2022 for logistical reasons. This event includes an aircraft fly-in and air tours, which in some years has caused high rates of seabird disturbance at Devil's Slide.

In addition to disturbance events, we incidentally recorded all watercraft within a 1,500 ft (460 m) radius, and all aircraft ≤1,000 ft (305 m) above sea level and within a 1,500 ft radius of the nearest seabird breeding or roosting area. We calculated detection rates as the number of aircraft or watercraft observed within these zones per observation hour. We recorded and reported all watercraft entering the Egg Rock/DSR and PRH Special Closure areas on SPN Wildlife Disturbance reporting forms, and to either CalTIP ("Californians Turn in Poachers") or CDFW wardens directly. Special Closures are no-entry zones designated by CDFW under the California Marine Life Protection Act to protect important seabird and marine mammal colonies from disturbance. We also reported any fishing activity in the Point Reyes State Marine Reserve to CalTIP or CDFW wardens, regardless of whether disturbance to seabirds occurred.

Non-anthropogenic Disturbance Events

In 2022, we recorded non-anthropogenic disturbance events that resulted in flushing or displacement of adult seabirds, or any disturbance to eggs and chicks (exposure, displacement, depredation, or scavenging). Events causing agitation only usually were not recorded. At all locations, observers recorded non-anthropogenic disturbance incidentally, from all observation overlooks. For each event, observers recorded the species and number of individuals causing disturbance, the species and number of individuals disturbed, and behaviors of disturbed birds.

Common Murre Seasonal Attendance Patterns

We monitored seasonal attendance patterns of murres at PRH and DSCC. Monitoring occurred at nesting areas throughout the field season until all chicks fledged and adult attendance ceased. Counts were conducted from standardized mainland observation points using 65-130X or 15-60X spotting scopes. Survey frequency and methods varied somewhat depending on location. Most counts were conducted during a standardized period between 1000-1400 h, but count times were sometimes extended if necessary to complete the count. At productivity plots and a subset of subcolonies and subareas, we compared murre counts to weekly long-term patterns (2008-2021) and 95% CIs. Results are reported as above or below average if they fell outside the CIs of the long-term mean.

At several subcolonies within PRH, we recorded attendance at established index plots. Plots were used at subcolonies with large populations, where whole counts were not practical or feasible. We created plot maps using photographs and recognizable landmarks to maintain consistent boundaries between seasons.

Point Reyes Headlands

We recorded counts of murre attendance at PRH once per week between 18 April – 8 August. We performed counts of all murre subcolonies visible from mainland observation points (Figure 2). We counted index plots three times per survey and report the average of all counts. Plots included Lighthouse Rock (LHR; Ledge, Edge, and Dugout plots), Boulder, Flattop, Middle, Beach, and Cone Rocks. We counted all other visible areas of subcolonies once per survey.

Devil's Slide Rock & Mainland and San Pedro Rock

We counted murres on DSR every other day from 15 April to 13 August from the Traditional Pullout overlook (Figure 3). We photographed the DSR colony with a Canon EOS 80D camera with a 300 mm telephoto lens. Birds were counted later using ImageJ software (v. 1.53c, Schneider et al. 2012). On Devil's Slide Mainland (DSM), we monitored attendance patterns once per week wherever we could view murres (Figure 3, Figure 4); we counted murres three times per survey and reported the average. For San Pedro Rock (SPR), we scanned the rock for murres once per week throughout the breeding season from Bunker Overlook (Figure 3).

Bird Island

In 2022, monitoring of this very small and ephemeral colony was conducted by a trained volunteer approximately once per week from 22 April to 29 July. Counts were conducted during late afternoon (after 1600 h) from a south-facing overlook on the bluff above the north end of Rodeo Beach (on the Rodeo Beach Coastal Trail, ~920 meters north of Bird Island).

Common Murre Productivity

Like previous years, productivity (chicks fledged/pair) of murres was monitored at PRH and DSRM. CHCC was not monitored in 2022. We monitored murres from standardized mainland observation points using a modification of the Type I method (Birkhead and Nettleship 1980). Type I monitoring is characterized by daily or near-daily observations from fixed observation points throughout the breeding season to record egg laying, chick hatching, and chick fledging. Type I plots should consist of ~80 breeding pairs of cliff-nesting murres, with a clear view of individuals from a vantage point higher than the colony (Birkhead and Nettleship 1980). We used either 65-130x or 15-60x spotting scopes. At the PRH LHR plots, we mapped and numbered all monitored sites using photographs of the colony from 2019 and 2021. At DSR, we mapped and numbered all monitored sites using digiscoped photographs from 2021.

We classified sites as “breeding” when an egg was observed or inferred based on adult behavior. A site was “territorial” when attendance was ≥15% of monitored days, but no egg was observed or inferred based on adult behavior. Sites were “sporadic” when murres attended ≥2 days but for <15% of monitored days. Some territorial and sporadic sites were likely breeding sites; some eggs were likely lost shortly after laying, but we did not detect them. We considered chicks fledged if they survived to ≥15 days of age and were not known to perish before fledging. In cases when the hatch date was unknown and the chick disappeared before 15 days of observation, we used chick plumage stages to age the chick and determine whether to consider the chick fledged. We compared results from 2022 to long-term means: PRH 1996-2002, 2005-2015, 2017-2019, 2021 (n=22 years), and DSR 1996-2021 (n=26 years).

Point Reyes Headlands

We monitored murre productivity at PRH within two established Type I plots (Birkhead and Nettleship 1980) on LHR. Ledge Plot and Edge Plot were located at the interior and edge of the colony, respectively. We monitored 195 sites, including 111 sites in Ledge Plot and 84 sites in Edge Plot.

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) were established on DSR in 2006 (McChesney et al. 2006; Figure 5). Since 2006, as plots continued to fill with more murres, we adjusted plot boundaries based on the visibility of sites. In 2014, we dropped Plot C owing to poor viewing conditions, and in 2015 we added Plot D to monitor the edge effects previously captured in Plot C (Figure 5). We periodically dropped sites from the sample if poor viewing conditions obstructed our ability to record productivity data. We added new sites as birds established new territorial or breeding sites (Figure 5).

In 2022, we monitored 208 sites within DSR plots beginning 27 April (Figure 5). Also, we monitored an additional 61 sites in a mainland plot on DSRM-05-A-Lower.

Nest Surveys

When performing murre colony attendance surveys, we concurrently surveyed nests and birds of other seabird species. These surveys of other seabirds assessed locations of nesting areas, relative breeding population sizes, and potential impacts from disturbance. We conducted surveys weekly at PRH and DSRM, from mid-April to July 10. We classified Brandt’s Cormorant nests and territorial sites into five groups that described nesting stages: territorial site, poorly built nest, fairly built nest, well-built nest, and nests with brooded chicks. We also counted large, wandering ("creching") cormorant chicks. See McChesney et al. (2007) for more detailed descriptions of nest categories. For other species, we counted only well-built nests (i.e., those beyond the poorly built stage). Nest counts typically report the sum of seasonal peak counts of well-built nests (including nests with chicks) at each subcolony or subarea.

Brandt's Cormorant Productivity

When vantage points provided adequate viewing at PRH and DSRM, we monitored Brandt's Cormorants for breeding phenology and reproductive success (clutch sizes, brood sizes, and chicks fledged per pair). CHCC was not monitored. Because Brandt's Cormorants often switch nesting areas between years, we select new "plots" each year near overlooks with clear vantages. At PRH in 2022, we monitored Brandt's Cormorants at SC11 West Area (PRH-11), Chip Rock (PRH-11-A), Arch Rock (PRH-11-D), Wishbone Point (PRH-11-E), Cone Rock West (above Sloppy Joe; PRH-13), Cone Shoulder (PRH-13-CS), Upper Cone (PRH-13-CU), Border Rock (PRH-14-C), Miwok Rock (PRH-14-D), and Area B Mainland (PRH-14-E; Figure 2). At DSRM, we monitored Devil's Slide Rock (DSRM-01), Lower Mainland South (DSRM-05-A Lower), Upper Mainland South (DSRM-05-A-Upper), Mainland South Roost (DSRM-05-A-Roost), Turtlehead (DSRM-05-B), DSRM-05-C, and April's Finger **(**DSRM-05-AF; Figure 3, Figure 4).

We observed monitored nests every 1-7 days from mainland observation points using binoculars and spotting scopes. We considered chicks fledged if they survived to ≥30 days of age and were not known to perish afterwards. After that age, chicks typically begin to wander from their nests and become impossible to identify without marking (Carter and Hobson 1988, McChesney 1997). We compared results from 2022 to long-term means for PRH (1997-2001, 2006-2015, 2017-2019, 2021; n=19 years) and DSRM (1997-2007, 2009-2019, 2021; n=23 years).

Pelagic Cormorant, Black Oystercatcher, and Western Gull Productivity

At DSRM, we monitored the productivity of Pelagic Cormorants, Black Oystercatchers, and Western Gulls at subcolonies or subareas that were easily visible from mainland observation points. We examined nests at least once per week. We considered chicks fledged if they survived to ≥30 days of age and were not known to perish afterwards. If hatch dates were unknown, we used feathering status as a proxy for chick age (i.e., chicks >75% feathered were considered fledged). We compared 2022 results to long-term averages (2006-2019, 2021; n=15 years).

Pigeon Guillemot Surveys

To assess relative population sizes and seasonal attendance patterns of Pigeon Guillemots, we conducted standardized counts from mid-April to late June at PRH and DSCC. We conducted surveys twice per week from mid-April to 5 May, when peak counts are often obtained, and once per week thereafter. We conducted surveys at all colonies between 30 minutes after sunrise and

0830 h, counting birds rafting on the water and roosting on land (intertidal and nesting areas). In previous years, we conducted Pigeon Guillemot surveys only in Beaufort states <4. In 2019, however, we started conducting surveys in all weather states to examine if weather affected counts. At PRH, we surveyed the area within view of the Point Reyes Lighthouse (PRH-01, -02, -03 and -04; Figure 2). At DSCC, we surveyed the entire area from the south side of SPR to the South Bunker (DSRM-04; Figure 3, Figure 4).

Common Murre and Brandt's Cormorant Breeding Population Sizes

We did not conduct aerial surveys in 2022. Thus, total breeding populations estimates are not available.

RESULTS

Anthropogenic Disturbance

During the 2022 field season, we performed 1015 hours of monitoring effort at PRH and DSCC combined (Table 1). In 2022, detection rates were below the long-term mean at PRH, but detection rates were above average at DSRM, continuing a recent trend. Detection and disturbance rates were higher at DSRM than at PRH, as is typical. We recorded 175 aircraft within our detection zones at PRH and DSRM; these included 40 helicopters, 133 planes, and 2 other aircraft (Tables 2-3). Overall, 107 (61%) of these overflights resulted in disturbance to seabirds (agitation, displacement, or flushing). The sources of disturbance events included 69 planes, 36 helicopters, and 2 other aircraft. Flushing or displacement of murres resulted from events involving 28 helicopters and 12 planes. The most frequently detected aircraft types were general aviation, military, and USCG (Figure 6, Appendix 1-2).

At PRH between 2005-2022, there were no significant trends in detection or disturbance rates of aircraft (Appendix 3). At DSRM from 2005-2022, there were significant declining trends in annual plane, and helicopter and all aircraft detection rates early in the time series, but trends since 2019 indicate increasing detection rates (Appendix 4). Disturbance rates of all aircraft and helicopters at DSRM also show increasing trends since 2019.

We observed 33 watercraft within the 1,500-ft detection zone around our monitored colonies, including 25 recreational motor vessels, 2 charter motor vessels, 2 sailboats, 1 commercial motor vessel, 1 jet ski, 1 kayak, and 1 paddleboard (Tables 2-3, Figure 7, Appendix 2). We observed 2 disturbance events involving watercraft, and both caused flushing (Table 3). Long-term trend analysis at PRH and DSRM indicated that watercraft detection rates declined early in the time series but they increased in recent years, especially in 2020. There were no significant trends in watercraft disturbance rates at PRH and declines of small magnitude at DSRM (Appendix 3-4). Owing to inconsistencies in the recording of watercraft detections at DSRM between 2015-2018, trends including those years should be considered with caution.

We submitted 106 SPN Wildlife Disturbance Reports in 2022 (13 from PRH, 93 from DSCC). These included 41 reports of flushing or displacement, and 65 reports where only agitation was documented. We reported 104 events involving aircraft disturbance and 2 involving watercraft disturbance.

We recorded multiple watercraft in Special Closures in 2022. At PRH, 3 motor vessels entered the Special Closure but caused no disturbance. At DSRM, one kayak and one paddleboard caused disturbance events on different days, both causing flushing of seabirds.

Point Reyes Headlands

At PRH, we recorded 8 watercraft and 24 aircraft within our detection zones in 2022 (Table 2; Figure 8); we saw fewer watercraft but more aircraft compared to 2021. We recorded 14 disturbance events, most of which involved agitation to murres (Figures 9-10). We recorded 0.050 detections/hr, and 0.022 disturbances/hr, reflecting an increase in detections and disturbance rates in 2022 (Figures 8, 11; Appendix 3). The largest disturbance event occurred on 16 June, when a military plane caused 2000 murres to be agitated, and 400 murres and 10 Pelagic Cormorants to flush.

Long-term trends at PRH were complex. Watercraft detection rates decreased between 2006-2013 (annual mean rate of change 19%, range 4-33%) but increased thereafter (annual mean rate of change 30%, range 6-51%; Appendix 3). Among all anthropogenic sources, watercraft were the most commonly observed (47% of total detections, annual range 0-83%), so long-term total trends showed a similar pattern to watercraft detection rates. Disturbance rates were generally very low, and there were no significant long-term trends (Appendix 3).

Devil's Slide Rock and Mainland

At DSRM, we detected 117 planes, 32 helicopters, 2 other aircraft, and 25 watercraft in 2022 (Table 3). We recorded 0.46 detections/hr and 0.25 disturbances/hr (Figures 8, 11). Disturbance rates in 2022 were the highest recorded since 2012, reflecting increasing rates of aircraft disturbance (Appendix 4). We recorded 93 overflights resulting in disturbance to seabirds (60 planes, 31 helicopters, and 2 other aircraft), as well as 2 watercraft (Table 3).

There were 32 flushing events caused by aircraft, including 10 general aviation helicopters, 8 USCG helicopters, 5 military planes, 4 general aviation planes, 3 military helicopters, and 2 unknown helicopters (Appendix 1). Watercraft caused 2 additional flushing events, one by a kayak and the other by a paddleboard. The largest disturbance event occurred on 18 July when a USCG helicopter caused 1,000 murres to be agitated, and 600 Heermann's Gulls (*Larus heermanni*) and 100 Brown Pelicans (*Pelecanus occidentalis*) to flush (Figure 12, 13).

Long-term trends in aircraft detection and disturbance rates showed similar cubic patterns. Most rates increased between 2005-2008, decreased from 2010-2017, and increased from 2019-2022. This applies to overall detection and disturbance rates, aircraft and helicopter detection and disturbance rates, and plane detection rates (Appendix 4). Watercraft detection rates were quadratic, decreasing between 2006-2013 (annual mean rate of change 20%, range 3-36%) and increased afterwards (annual mean rate of change 32%, range 3-65%). Watercraft disturbance rates are negative over time (annual mean rate of change 12%, range 5-33%). Recent increases in detections and disturbance have been driven by increases in aircraft (mean annual proportion of aircraft 91%, range 63-100%).

Non-Anthropogenic Disturbance

Point Reyes Headlands

Incidental Non-Anthropogenic Disturbance

We recorded 98 incidental events of non-anthropogenic disturbance at PRH in 2022; 95 involved displacement or flushing (97%). Common Ravens (*Corvus corvax*) caused most of the disturbance events (56%), including depredating 20 murre eggs or chicks, and kleptoparasitizing 17 murres. Brown Pelicans, despite being involved in only 19% of disturbance events, caused extensive disturbance when loafing and roaming through the colony looking for discarded fish to scavenge or murres returning with fish to kleptoparasitize. We recorded pelicans displacing 20 eggs or chicks, exposing 37 eggs or chicks, forcing 4 eggs or chicks off of the breeding area, kleptoparasitizing 18 birds, and depredating or scavenging 16 eggs or chicks. These events were most disruptive at LHR, and murre productivity was likely reduced as a result.

We also observed disturbance, kleptoparasitism, predation, and scavenging by Western Gulls (*Larus occidentalis*) and Turkey Vultures (*Cathartes aura*), often in association with pelican disturbances. Western Gulls were involved in 22% of events, including depredating 22 eggs or chicks, and kleptoparasitiziing 18 murres. Turkey Vultures were involved in 14% of events, and we recorded them scavenging 16 eggs or chicks and kleptoparasitizing 7 fish from murres. We observed one incident each involving a Pelagic Cormorant, a Peregrine Falcon, an unknown source, a wave, and a Bald Eagle (*Haliaeetus leucocephalus*); this was the first observation of disturbance by eagles at any of our field sites.

The largest disturbance event of the season occurred on 25 July, by pelicans and Western Gulls on LHR. They caused the displacement of 1700 murres and 250 murre chicks, the exposure of 90 murre eggs and 300 murre chicks, the flushing of 1600 murres, the kleptoparasitism of 15 murres, and the predation of four murre eggs and two murre chicks.

Devil's Slide Rock and Mainland

Incidental Non-Anthropogenic Disturbance

We recorded 47 incidental disturbance events, 43 of which caused displacement or flushing (97%). Ravens caused most of the events (51%), as is typical, and they depredated 18 murre chicks or eggs. Pelicans were involved in 45% of events but caused disproportionally greater disturbance; loafing birds near the monitored mainland murre plot caused major displacement, flushing and egg loss there, and young pelicans searching for fish to kleptoparasitize or scavenge caused great disruption on DSR. Pelican disturbance likely led to reduced murre productivity: egg trampling and displacement were rampant in the mainland plot, and chick disruption and displacement were frequent on DSR, especially in Plot A. We recorded pelicans displacing 87 eggs or chicks, exposing 35 eggs or chicks, and kleptoparasitizing one murre. Western Gulls were involved in 19% of non-anthropogenic events, usually following in the wake of disturbance caused by other ravens or pelicans.

The largest event occurred on 16 June by a raven on DSR, causing agitation to 1400 murres, the displacement of 300 murres and one murre egg, the exposure of one murre egg, and the flushing of 75 murres and 5 Brandt's Cormorants.

Common Murre Seasonal Attendance Patterns

Point Reyes Headlands

Attendance patterns at most established count plots resembled long-term patterns, with numbers declining abruptly in late July as adults and chicks departed the colony (Figures 14-15). Counts at Ledge Plot, Dugout Plot, Cone Plot, and Boulder plot were above average in mid- to late July, and may reflect visitation by prospecting subadults, increased attendance by breeders, or both. The mainland subcolony on Sloppy Joe (PRH-12-A) was found to be abandoned in late June where we observed several dead adult murres. We suspect a nocturnal mammalian predator was the cause. Many peak counts occurred later in the season (Figures 16-19) when prospecting by subadults often increases. Clubbing (or, roosting) areas around LHR (like PRH-03-A) had many fewer murres than is typical, potentially because of large aggregations of pelicans displacing birds from these areas. We first observed unattended subcolonies on 1 August (PRH-10-A, PRH-10-D, PRH-11-B; not counting PRH-12-A on 6 July), and by the last count on 8 August, 58% of active subcolonies had been vacated for the season.

Subcolonies with more variable counts usually reflected more activity from socializing non-breeders in clubs. At the South Lighthouse Cliffs (PRH-04), Trinity Point (PRH-08-A), Greentop (PRH-08-B), Cliff Colony East (PRH-09-A), Arch Rock (PRH-11-D), and Cone Shoulder (PRH-13-CS), murre attendance didn't begin until June or July, but murres were still attending these subcolonies in August. This likely reflected either some late season breeding, late season prospecting, or both.

Devil's Slide Rock & Mainland and San Pedro Rock

Devil's Slide Rock

Murres were present on all count days until the colony was found to be vacated for the season on 8 August (Figure 20). The peak count of 1,547 murres on 12 July was 11% lower than the peak count of 1,731 murres in 2021. Attendance patterns fluctuated through the breeding period; between 18 April and 10 June, counts averaged 1112 murres (range: 608-1413), increased to an average of 1289 murres between 12 June and 16 July (range: 1008-1547), then rapidly decreased afterwards as chicks and adults departed from the colony.

Attendance patterns in 2022 were similar to the magnitude of the long-term pattern (2011-2021), exceeding it by ~14%; counts in April and early May were close to the long-term mean, whereas values in June and July were considerably greater than the mean (Figure 20). However, counts in recent years have been closer to counts in 2022. We changed our counting protocols in 2018 from real-time counts through spotting scopes to digital counts from photographs. Digital counts from photographs appear to be much less variable than counts by spotting scope, and this may affect comparisons to previous years. Any use of these data for long-term analyses should take these differences into account.

Devil's Slide Mainland and San Pedro Rock

We observed murres consistently attending Lower Mainland South (DSRM-05-A Lower), Upper Mainland South (DSRM-05-A-Upper), and Turtlehead (DSRM-05-B), where breeding was confirmed in each of these subareas. Additionally, we observed murres intermittently amongst nesting and roosting Brandt's Cormorants at other Mainland South subareas (DSRM-05-A-Roost, DSRM-05-AF), but we did not confirm breeding. In 2022, seasonal attendance at mainland subcolonies was much greater than the long-term pattern (2011-2021; Figure 20), although counts were very similar to 2021. Most attended subareas were vacated for the season by 8 August.

We observed no murres on San Pedro Rock in 2022.

Common Murre Productivity

Point Reyes Headlands

In 2022 we monitored 195 sites in Ledge (n=111) and Edge (n=84) plots on LHR; 159 of these were breeding sites (82%), 27 were territorial sites (14%), and 9 were sporadic sites (4%). The mean egg laying date (including only first clutch dates) was 3 June ± 8.84 (range 16 May–3 July, n=149; Table 4), eight days later than the long-term mean (26 May ± 1.8 days). We recorded 18 replacement eggs. Hatching success was 65%, and fledging success was 81.6%. Productivity of 0.58 chicks fledged/pair was near the upper confidence limit of the long-term mean (0.48 chicks fledged/pair) and very similar to 2021 (0.60 chicks fledged/pair, Figure 21). Chicks fledged at a mean age of 24.69 ± 0.43 days, and the last chick was observed on 15 August (Table 4).

On LHR, eggs disappeared frequently early in the season, sometimes only 1-2 days after we first confirmed their presence. We suspect the likely cause was raven predation of these more vulnerable, early breeders. Beginning 15 July, pelicans caused major disturbance on LHR, typically immature birds trying to kleptoparasitize murres. Their wanderings around LHR caused major exposure, displacement, and flushing of COMU adults, eggs, and chicks – these totaled 12 total events on LHR, 5 of which involved flushing of murre chicks off the rock. Chicks were flushed out of Edge plot during one event, but no chicks were observed being flushed out of the Ledge productivity plot.

Devil's Slide Rock and Mainland

Of 208 attended sites at DSR, 156 (75%) were breeding, 52 (25%) were territorial, and 0 (0%) were sporadic. We observed the first murre egg on 8 May in productivity Plot D. At all sites combined, the mean egg-laying date for first eggs (i.e., excluding replacement eggs) was 21 May ± 5.04 (range 8 May–8 June, n = 132; Table 5), near the long-term mean (26 May ± 1.6 days). We recorded 157 eggs laid, including one replacement egg. Overall productivity of 0.65 chicks fledged/pair was near average (0.66 ± 0.05; Figure 18). Average productivity was accompanied by moderately high hatching (80.9%) and fledging (80.3%) success. Chicks that fledged remained on DSR for an average of 23.26 ± 0.33 days (n = 110), and the last chick was seen on 30 July (Table 5).

Of 61 sites monitored on DSM, 51 (84%) were breeding, 6 were territorial (10%), and two (6%) were sporadic. We observed the first murre egg on 7 May. The mean egg-laying date for first eggs was 21 May ± 6.92, two weeks earlier than the long-term mean (4 June ± 3.5 days). We recorded 52 eggs laid, including one replacement egg. Overall productivity of 0.35 chicks fledged/pair was lower than 2020 and 2021, but near the long-term mean (0.34; Table 5, Figure 21). Hatching success was very low (46.2%), but fledging success was higher (70.8%). Chicks fledged on average at 22.17 ± 0.49 days (n = 18), and the last chick was seen on 29 July (Table

5). Murres in the mainland plot were especially disrupted by roosting pelicans in May and June, which caused considerable chaos in this plot with resulting low productivity.

Brandt's Cormorant Nest Surveys and Productivity

We report seasonal peak nest counts of Brandt's Cormorants obtained from weekly land-based surveys (PRH and DSRM; Table 6). Not all nests were visible from our observation points, so nest counts should be considered a minimum. Consequently, comparisons to previous years should be considered with caution.

Point Reyes Headlands

Nest surveys

We conducted Brandt's Cormorant nest surveys weekly from 18 April to 6 July. Active nesting occurred at a larger number of subcolonies than is usual. We recorded well-built nests at The Hooves (PRH-07-A), Trinity Point (PRH-08-A), Greentop (PRH-08-B), Cliff Colony West (PRH-09-A), Cliff Colony East (PRH-09-B), SC10 Area (PRH-10), Beach Rock (PRH-10-E), Tim Tam (PRH-10-H), SC11 Area (PRH-11), Chip Rock (PRH-11-A), Face Rock (PRH-11-B), Arch Rock (PRH-11-D), Wishbone Pt. (PRH-11-E-Wish), Cone Shoulder (PRH-13-CS), Upper Cone Rock (PRH-13-CU), West Cone Rock (PRH-13-WC), Area B (PRH-14-B), Border Rock (PRH-14-C), Miwok Rock (PRH-14-D), and Area B Mainland (PRH-14-E). The single-day high count of well-built nests occurred on 29 June and totaled 579 nests. The sum of seasonal peak counts from each subcolony was 640 nests (Table 6), an increase of 100% over the count in 2021 (320 nests). The sum of seasonal peak counts may reflect a more accurate measure of relative total breeding population size because of nesting asynchrony between subcolonies; however, it also could over-inflate total numbers if some birds failed, then re-nested at another subcolony.

Productivity

At PRH, we monitored 104 egg-laying sites at 9 subareas (Table 7). The first eggs observed was on 18 April, and the mean date of clutch initiation was 8 May ± 10.3 (range 18 April–7 June, n=105), about 10 days earlier than the long-term mean (18 May ± 2.9 days). The first chicks hatched on 18 May. For all subareas combined, productivity was 2.12 chicks fledged/pair (n=105; subarea range 0.00–2.83), above the long-term mean (1.86 ± 0.13 chicks fledged/pair, Figure 22). Breeding success/nest (egg-laying nests that fledged at least one chick) was 0.85 (subarea range = 0.00–1.00; Table 7), indicating low nest failure.

Devil's Slide Rock and Mainland

Nest surveys

We conducted standardized counts of nests and territorial sites between 18 April–6 July. We observed the first well-built nests on an earlier visit to the field site on 30 March. Active nesting occurred at a larger number of subcolonies than is usual. The peak count of nests on DSR was 16 on 14 June. On the mainland, nesting occurred on April's Finger (DSRM-05-AF; peak count 106 nests), Turtlehead (DSRM-05-B; 54 nests), Upper Mainland South (DSRM-05-A-Upper; 99 nests), Lower Mainland South (DSRM-05-A-Lower; 25 nests), Mainland South Roost (DSRM-05-A-Roost, 24 nests), Mainland North (DSRM-02-MN, 33 nests), SC04 (DSRM-04, 1 nest), and South of Turtlehead Cliffs (DSRM-05-C; 3 nests). The single-day peak count of well-built nests was 354 on 14 June (Table 6). The sum of seasonal peak counts by subcolony totaled 383 nests, 11% higher than in 2021 (346 nests). The sum of seasonal peak counts may reflect a more accurate measure of relative total breeding population size because of nesting asynchrony between subcolonies; however, it also could over-inflate total numbers if some birds failed, then re-nested at another subcolony.

Productivity

We monitored 102 egg-laying sites at 7 subareas in 2022 (Table 8). We first observed eggs on 30 March on DSRM-05-B, during our first site visit for the season. For all subareas combined, the mean clutch initiation date was 22 April ± 15.7 days (range = 26 March–17 June, n = 91), three weeks earlier than the long-term mean (13 May ± 2.1 days). We recorded the first hatched chicks on 27 April. Overall productivity was 2.26 chicks fledged/pair (n = 102, subcolony range = 1.67–2.56), which was significantly higher than the long-term mean (1.73 ± 0.15 chicks fledged/pair; Figure 22). Overall breeding success/nest was 0.90 (subarea range 0.80-1.00; Table 8), indicating low nest failure.

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) were determined from land-based observations (Table 6). Nesting areas for these species, especially Pelagic Cormorants and Black Oystercatchers, vary annually, and nests are often not visible from land-based vantage points, especially at PRH. At PRH, our survey area only included the western 2/3 of the distributions of these species on the headlands, and many nesting areas are not visible from land-based vantage points even within our study area. Past work showed that a combination of boat-based and land-based surveys were necessary for more complete surveys of these species at all colonies. Thus, comparisons to previous years should be considered with caution.

The 2022 peak standardized count for Pigeon Guillemots of areas visible from the lighthouse at PRH was 66 birds on 29 April, 7% lower than the peak count in 2021. We noted rough seas frequently during the first half of the field season at PRH, which may have resulted in lower counts because of the difficulty observing birds. The 2022 peak standardized count at DSRM was 140 guillemots on 23 April, 37% higher than the peak count in 2021.

Productivity

Pelagic Cormorant

At DSRM, we monitored Pelagic Cormorant productivity at 11 nests on Mainland North (DSRM-02-MN), SC04 (DSRM-04), and Lower Mainland South (DSRM-05-A-Lower). The first confirmed egg was observed on 13 May at Mainland North. Overall productivity of 1.55 chicks fledged/pair was near the long-term mean (1.44 ± 0.19; Table 9, Figure 23).

Western Gull

We monitored 7 Western Gull nests at DSRM in 2022. We observed the first egg on 20 May. Gull productivity at DSRM was 1.14 chicks fledged/pair, which was greater than the long-term mean (0.64 ± 0.12; Figure 24) and the productivity of other recent years.

Black Oystercatcher

One Black Oystercatcher nest was visible and followed for productivity. We first observed a bird incubating on 3 May on Keyhole Point (within DSRM-07). For the first time in our monitoring, the pair was successful, and we observed three fledged chicks on 12 July.

DISCUSSION

After two seasons (2020 and 2021) of fieldwork impacted by COVID-19, we were able to resume largely unrestricted efforts in 2022. An exception was the continued suspension of monitoring at the Castle-Hurricane Colony Complex along the Big Sur Coast, where highly increased tourism has hampered our ability to work safely.

Anthropogenic Disturbance

Like past years, Devil's Slide was subject to the highest anthropogenic detection and disturbance rates among our study areas because of its greater proximity to Bay Area airports and boat launches. In 2022, plane, helicopter, and total aircraft detection and disturbance rates were among the highest recorded in a decade or more, continuing recent increasing trends. Similarly, watercraft detections continued an increasing trend but few resulted in seabird disturbance. Bednar et al. (2022) surmised that an increase in watercraft detections and disturbance in 2020 was likely associated with the pandemic. Whether or not increasing rates for aircraft and watercraft at Devil's Slide continue to reflect pandemic-related human behavior is not clear. At Point Reyes, detections and disturbances from anthropogenic sources were at typical relatively low levels following elevated watercraft detection and disturbance rates in 2020.

Much like past years, general aviation aircraft and USCG helicopters, along with military planes in 2022, were the main sources of aircraft disturbance to seabirds. The Pacific Coast Dream Machines event was cancelled in 2022 for the third straight year; this event has resulted in substantial aircraft disturbance at Devil's Slide is some past years.

We recorded five instances of watercraft in Special Closures, three (all recreational motor vessels) at Point Reyes and two at Devil's Slide Rock (one kayak and one paddleboard). Both the kayak and paddleboard at Devil's Slide Rock resulted in the flushing of seabirds.

Non-Anthropogenic Disturbance

Avian and likely mammalian disturbance and predation were problematic in 2022. As is now typical at both Point Reyes and Devil's Slide Rock, Common Ravens were observed depredating multiple murre eggs and chicks. Large numbers of Brown Pelicans, especially immature birds, were present along the central California coast this season. Roosting birds caused several disturbances to murre colonies at both Point Reyes and Devil's Slide. More problematic was when individual young pelicans chased murres through the colonies in attempts to kleptoparasitize adults trying to deliver fish to their chicks. These events caused havoc, with murres being pushed off many eggs and chicks. Some murre chicks were forced to jump into the surrounding waters, their fates unknown but survival unlikely. We have observed similar pelican disturbance and predation in several past years, usually when local numbers of young pelicans were high and/or during prey shortages. Numbers of breeding Brown Pelicans at California Channel Islands colonies have been some of the greatest ever recorded in the last few years, including 2022, with relatively high productivity (California Institute for Environmental Studies & Channel Islands National Park, unpubl. data; M. Parker, pers. comm.).

Extensive depredation of murre eggs and chicks by pelicans also was observed. Western Gulls, and Turkey Vultures at Point Reyes took advantage of scavenging opportunities created by pelicans and ravens, creating further disturbances to the murre colonies. At Point Reyes, carcasses of several adult murres at one abandoned mainland subcolony, Sloppy Joe (PRH-12), suggested mammalian predation from perhaps a weasel. These disturbance and predation events certainly had an impact on murre productivity, and possibly other seabirds, in 2022.

A Bald Eagle flying over Point Reyes Headlands caused the first disturbance by this species we have recorded on this project. Bald Eagles only recently began breeding locally, and numbers have been increasing (Allen et al. 2023; S. Allen, pers. comm.). Eagle disturbance and predation has greatly impacted murre colonies in Oregon and Washington for decades, including colony abandonment and major population declines (Carter et al. 2001). Over just the last few years, Bald Eagles began harassing and depredating murres at major colonies in northern California (K. Bensen, Redwood National and State Parks, unpubl. data; D. Barton, Cal Poly Humboldt, unpubl. data). Bald Eagles were not known to breed historically in the Point Reyes area, and their spread to this area poses a major threat to breeding Common Murres and potentially other seabirds.

Attendance and Reproductive Success

Colony attendance by Common Murres and Brandt's Cormorants was high in 2022. For murres, attendance patterns showed greater than average numbers present at most subcolonies through much of the season. Numbers of breeding Brandt's Cormorants were especially high, with birds utilizing considerably more nesting subcolonies than has been typical.

At the restored Devil's Slide Rock colony, numbers of breeding murres appeared similar to other recent years even though the peak count of 1,547 birds was 11% lower than the 2021 peak count. Abundance at this colony may be near saturation. On the Devil's Slide mainland, murre attendance was similar to 2021 but much greater than average, with breeding confirmed at several subareas.

At both Point Reyes and Devil's Slide, murres attended several areas where birds are not observed every year. In all or nearly every case, murre attendance at those areas was in association with nesting Brandt's Cormorants. In California, Brandt's Cormorant nesting is often a precursor to murre prospecting and formation of new colonies (Carter et al. 2001, McChesney et al. 2022).

For Brandt's Cormorants, 2022 was a banner year for both high numbers of nests and greater than average productivity at both monitored colonies. Numbers of breeders have been increasing over the last few years and productivity also has been consistently high.

While Common Murre breeding success was near average at all monitored plots, productivity was impacted by extensive avian disturbance and predation, especially by Common Ravens and Brown Pelicans. Without those impacts, we suspect that murre breeding success would have been greater, perhaps by a considerable margin, particularly on the Devil's Slide Mainland which experienced extensive pelican disturbance. The Devil's Slide Mainland subcolony, where breeding first occurred in 2005, has been susceptible to pelican disturbance and changes in

Brandt's Cormorant breeding distribution in the past, and breeding success historically has been very low most years. Fewer breeding cormorants typically has been associated with fewer breeding murres and redistribution of the mainland murre breeding areas, with murres moving to wherever the cormorants nested. Furthermore, murre breeding phenology at Point Reyes was about a week later in 2022 than average, surprising given the productive marine conditions. The potential impact of late breeding is not clear and it may have little effect.

Numbers of Pelagic Cormorant and Western Gull nests were within the ranges of other recent years, but determining trends is difficult because nesting areas shift from year-to-year and many nesting areas are not visible from our mainland vantage points. Past work by the Project found that a combination of land-based and boat-based surveys were necessary to provide more complete colony coverage. At Devil's Slide, the only colony where we monitor these species, Pelagic Cormorant productivity was near average while Western Gull productivity was well above average, consistent with Brandt's Cormorants and murres. At Devil's Slide, we watched our first ever recorded successful Black Oystercatcher breeding attempt, with three chicks fledged.

In 2022, many marine indices in the central California Current Ecosystem were indicative of a third straight year of La Niña conditions, including high upwelling, chlorophyll, and prey (e.g., northern anchovies *Engraulis mordax*), and low sea surface temperatures (Spears et al. 2023, Thompson et al. 2024). La Niña conditions typically result in productive ocean conditions including abundant prey resources for marine predators like seabirds. These productive conditions have likely been a driving force behind increasing numbers of Brandt's Cormorants, and to some degree, Common Murres, along with high chick production for the last two years or more.

At the nearby South Farallon Islands, which serve as a reference colony in this region, patterns observed were consistent with our colony observations. Most of the multiple seabird species monitored at the Farallones over the last several decades were present in relatively high numbers, particularly Brandt's Cormorants and Common Murres. Nearly all species also experienced above average productivity. An exception was the Common Murre, where one of two monitored plots showed below average productivity, while another had above average productivity. It is suspected that the plot with below average productivity experienced chick predation from some undetected source, perhaps an owl. Both murres and Brandt's Cormorants fed their chicks primarily high-calory northern anchovies (Spears et al. 2023), a preferred prey item.

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 of disturbance. We suggest outreach focus on general aviation aircraft, USCG helicopters, and private recreational fishermen. Outreach efforts to military helicopter operators may also help reduce seabird disturbances.

• Efforts to develop personal communications with CDFW wardens should be continued for real-time reporting of MPA and Special Closure violations. Wardens are often responsive and able to contact boat operators quickly, making this an effective outreach tool.

• New online tools are becoming available to identify and document aircraft flying over colonies. Efforts are needed to continually search for, identify, and use the methods that are most effective and user-friendly.

• Avian disturbance and nest predation, including from Common Ravens, Brown Pelicans, Turkey Vultures, and Bald Eagles (new threat) should be monitored closely for potential increases in impacts to murre and other seabird colonies.

• The Devil's Slide pedestrian trail was completed in March of 2014, and the 2021 field season marked the eighth year of pedestrian access to the span of road above DSM. We have not observed any pedestrian-related disturbances to seabirds associated with the trail, likely attributed to area closures and fencing designed to protect seabirds, falcons, and rare plants. These protective measures should be continued, and we should continue to monitor for new types of potential disturbance.

• The presence of thousands of visitors on Devil's Slide Trail throughout the seabird season provide a great opportunity for outreach about seabirds and the prevention of human disturbance. These outreach opportunities could be expanded further.

• Annual aerial surveys of central California murre and Brandt's Cormorant colonies cannot be sustained at current funding levels. These surveys provide the best (and preferred) method of monitoring these species' breeding population sizes in a standardized fashion (Carter et al. 2001, Capitolo et al. 2014, Bridgeland et al. 2018). Aerial surveys also provide a good method of evaluating and documenting the success of murre restoration efforts, via the number of murres added to the population.

• As the numbers and densities of murres on monitored breeding colonies increase, continued evaluation of monitoring methods for productivity (especially at Devil's Slide Rock) will be necessary. This will include adjustments to plot boundaries and elimination of sites that are difficult to view. The number of murres at Devil's Slide Mainland have also been increasing rapidly, and we should consider the protocols and plots for their productivity monitoring.

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Table 1. Monitoring effort of study colonies, April 2022 to August 2022.

Colony or Colony Complex	**Start date**	**End date**	**Observation days**	**Total hours**
Point Reyes Headlands	04/8/2022	8/15/2022	117	635
Devil's Slide Rock & Mainland	4/14/2022	8/24/2022	110	376
San Pedro Rock	4/20/2022	6/28/2022	14	4

Table 2. Total observed watercraft, aircraft, land-based sources, and resulting disturbances to seabirds (Common Murres, Brandt's Cormorants, Western Gulls, and Brown Pelicans) at Point Reyes Headlands, 2022. UAS indicate uncrewed aerial systems (i.e., drones). Disturbances indicate events that included alert, displaced, and flushed birds. Detection and disturbance rates are reported as numbers per observation hour.

Disturbance Source	Plane	Helicopter	UAS	Aircraft Total	Watercraft	Total
Total # of Detections	16	8	0	24	8	**32**
Detections/Hour	0.025	0.013	0.000	0.038	0.013	**0.050**
# of Agitation Events	6	0	0	6	0	**6**
# of Displacement Events	0	0	0	0	0	**0**
# of Flushing Events	3	5	0	8	0	**8**
Total Disturbed/Hour	0.014	0.008	0.000	0.022	0.000	**0.022**
Total Flushed or Displaced/Hour	0.005	0.008	0.000	0.013	0.000	**0.013**

Table 3. Total observed watercraft, aircraft, land-based sources, and resulting disturbances to seabirds (Common Murres, Brandt's Cormorants, Western Gulls, and Brown Pelicans) at Devil's Slide Rock & Mainland, 2022. UAS indicate uncrewed aerial systems (i.e., drones). Disturbances indicate events that included alert, displaced, and flushed birds. Detection and disturbance rates are reported as numbers per observation hour.

Disturbance Source	Plane	Helicopter	Other Aircraft	UAS	Aircraft Total	Watercraft	Total
Total # of Detections	117	32	2	0	151	25	**176**
Detections/Hour	0.308	0.084	0.005	0.000	0.397	0.066	**0.463**
# of Agitation Events	51	8	2	0	61	0	**61**
# of Displacement Events	0	0	0	0	0	0	**0**
# of Flushing Events	9	23	0	0	32	2	**34**
Total Disturbed/Hour	0.158	0.082	0.005	0.000	0.245	0.005	**0.250**
Total Flushed or Displaced/Hour	0.024	0.060	0.000	0.000	0.084	0.005	**0.089**

Table 4. Common Murre breeding phenology and reproductive success at Point Reyes Lighthouse, 2022. Means (range; n) are reported. We calculated mean hatch date using first eggs only (i.e., does not include replacement clutches). Hatching success represents the number of eggs hatched per egg laid (includes both first and replacement clutches). Fledging success represents the number of chicks fledged per egg hatched (includes both first and replacement clutches). See Results section for details.

Plot	Number of Sites Monitored	Number of Egg Laying Sites	Mean Lay Date	Number of Eggs Laid	Mean Hatch Date	Hatching Success	Mean Fledge Date	Fledging Success	Chicks Fledged per Pair
PRH-03-B Edge	84	69	31 May (16 May – 3 July; 64)	77	1 July (14 June – 21 July; 47)	70% (77)	25 July (14 July – 5 August; 39)	74% (54)	0.57 (68)
PRH-03-B Ledge	111	90	4 June (22 May – 30 June; 85)	100	7 July (24 June – 5 August; 54)	61% (100)	31 July (20 July – 15 August; 51)	88% (60)	0.59 (87)
Plots Combined	**195**	**159**	**3 June (16 May – 3 July; 149)**	**177**	**5 July (14 June – 5 August; 101)**	**65% (177)**	**28 July (14 July – 15 August; 90)**	**82% (114)**	**0.58 (155)**

Table 5. Common Murre breeding phenology and reproductive success at Devil's Slide Rock and Mainland, 2022. Plots A, B, and D are on Devil's Slide Rock, and DSRM-05-A is located on the mainland. Means (range; n) are reported. We calculated mean hatch date using first eggs only (i.e., does not include replacement clutches). Hatching success represents the number of eggs hatched per egg laid (includes both first and replacement clutches). Fledging success represents the number of chicks fledged per egg hatched (includes both first and replacement clutches). See Results section for details.

Plot	Number of Sites Monitored	Number of Egg Laying Sites	Mean Lay Date	Number of Eggs Laid	Mean Hatch Date	Hatching Success	Mean Fledge Date	Fledging Success	Chicks Fledged per Pair
DSRM-01-Plot A	107	81	27 May (13 May – 8 June; 67)	81	28 June (15 June – 13 July; 63)	84% (81)	20 July (12 July – 27 July; 49)	72% (68)	0.59 (75)
DSRM-01-Plot B	74	58	25 May (13 May – 6 June; 49)	59	26 June (14 June – 12 July; 44)	80% (59)	20 July (8 July – 30 July; 41)	92% (47)	0.74 (58)
DSRM-01-Plot D	27	17	21 May (8 May – 1 June; 16)	17	23 June (15 June – 2 July; 12)	71% (17)	15 July (9 July – 19 July; 4)	83% (12)	0.59 (17)
DSR Plots Combined	**208**	**156**	**26 May (8 May – 8 June; 132)**	**157**	**27 June (14 June – 13 July; 119)**	**81% (157)**	**20 July (8 July – 30 July; 94)**	**80% (127)**	**0.65 (150)**
DSRM-05-A	61	51	21 May (7 May – 7 June; 47)	52	21 June (10 June – 12 July; 25)	46% (52)	13 July (3 July – 29 July; 18)	71% (24)	0.35 (48)

Table 6. High counts of nests and breeding birds from land-based surveys for Brandt's Cormorants, Pelagic Cormorants, Western Gulls, and Black Oystercatchers, 2022. Counts for Brandt's Cormorants, Pelagic Cormorants, Western Gulls, and Black Oystercatchers are the sum of high season nest counts. Pigeon Guillemot counts reported are for bird (not nest) peak counts only and as Land/Water counts.

Colony	Brandt's Cormorant	Pelagic Cormorant	Western Gull	Black Oystercatcher	Pigeon Guillemot
Point Reyes Headlands[1]	640	19	82	2	66[2]
Devil's Slide Rock & Mainland	383	21	6	1	140

[1] At Point Reyes Headlands, only minor portions of the Pelagic Cormorant, Western Gull, Black Oystercatcher, and Pigeon Guillemot breeding areas are surveyed.
[2] Survey area includes only the area around the lighthouse. See Methods for more detail.

Table 7. Brandt's Cormorant breeding phenology and reproductive success from monitored subareas at Point Reyes Headlands, 2022. Means are reported (range; n). Clutch initiation date includes first clutches only. Breeding success includes replacement clutches. Breeding success per nest represents the proportion of egg-laying nests that fledged at least one chick. See Results section for details.

Colony or Subcolony	Number Breeding Sites	Clutch Initiation Date	Clutch Size	Breeding Success	Number Chicks Fledged/Pair	Breeding Success/ Nest	Fledging Success
Chip Rock (PRH-11-A)	17	6 May (28 April – 16 May; 17)	3.18	65% (61)	2.41 (0-3; 17)	0.94 (17)	95% (16)
Arch Rock (PRH-11-D)	7	23 May (4 May – 2 June; 7)	2.14	54% (18)	1.86 (0-3; 7)	0.71 (7)	90% (5)
Wishbone Pt. (PRH-11-E-Wish)	23	9 May (2 May – 18 May; 23)	3.04	80% (70)	2.39 (0-3; 23)	0.91 (23)	94% (22)
Cone Rock (western side; PRH-13)	4	6 June (5 June – 7 June; 4)	2.25	0% (9)	0.00 (0; 4)	0.00 (4)	---
Cone Shoulder (PRH-13-CS)	17	4 May (18 April – 20 May; 16)	3.06	64% (57)	2.12 (0-3; 17)	0.88 (17)	85% (17)
Upper Cone (PRH-13-CU)	23	4 May (28 April – 13 May; 22)	3.27	69% (73)	2.09 (0-3; 23)	0.91 (23)	94% (22)
Border Rock (PRH-14-C)	6	1 May (23 April – 9 May; 6)	3.00	63% (20)	2.17 (0-3; 6)	0.83 (6)	100% (5)
Miwok Rock (PRH-14-D)	6	29 April (24 April – 9 May; 6)	4.00	71% (24)	2.83 (2-4; 6)	1.00 (6)	96% (6)
Area B Mainland (PRH-14-E)	4	21 May (13 May – 28 May; 4)	3.25	33% (13)	1.00 (0-2; 4)	0.50 (4)	50% (4)
Point Reyes Total	**107**	**8 May (18 April – 7 June; 105)**	**3.09**	**65% (345)**	**2.12 (0-4; 107)**	**0.85 (107)**	**91% (97)**

Table 8. Brandt's Cormorant breeding phenology and reproductive success from monitored subareas at Devil's Slide Rock and Mainland (DSRM), 2022. Means are reported (range; n). Clutch initiation date includes first clutches only. Breeding success includes replacement clutches. Breeding success per nest represents the proportion of egg-laying nests that fledged at least one chick. See Results section for details.

Colony or Subcolony	**Number Breeding Sites**	**Clutch Initiation Date**	**Clutch Size**	**Breeding Success**	**Number of Chicks Fledged/Pair**	**Breeding Success/ Nest**	**Fledging Success**
DSRM-01-Upper	4	8 April (2 April – 14 April; 2)	3.50	54% (13)	1.75 (1-2; 4)	1.00 (4)	88% (4)
DSRM-05-A-Lower	15	25 April (4 April – 11 June; 13)	3.38	48% (51)	1.67 (0-3; 15)	0.80 (15)	82% (13)
DSRM-05-A-Roost	9	24 April (14 April – 5 May; 9)	3.33	77% (30)	2.56 (2-3; 9)	1.00 (9)	82% (9)
DSRM-05-A-Upper	8	17 April (1 April – 28 April; 8)	3.38	52% (27)	1.75 (1-3; 8)	1.00 (7)	75% (8)
DSRM-05-B	41	20 April (26 March – 17 Jun; 36)	3.44	72% (138)	2.49 (0-4; 41)	0.85 (41)	94% (36)
DSRM-05-C	2	22 April (22 April – 22 April; 2)	4.00	50% (8)	2.00 (2-2; 2)	1.00 (2)	100% (2)
DSRM-05-AF	23	27 April (12 April – 24 May; 21)	3.57	67% (83)	2.43 (0-4; 23)	0.96 (23)	86% (23)
DSRM Combined	**102**	**22 April (26 March – 17 June; 91)**	**3.46**	**65% (350)**	**2.26 (0-4; 102)**	**0.90 (102)**	**87% (95)**

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Table 9. Productivity of Pelagic Cormorants and Western Gulls at Devil's Slide Rock and Mainland, 2022. Means (range; n) or (n) are reported. Breeding success per nest represents the proportion of egg-laying nests that fledged at least one chick.

Species	**Pelagic Cormorant**	**Western Gull**
Number Breeding Sites	11	7
Number Chicks Fledged	17	8
Number of Chicks Fledged/Pair (Productivity)	1.55 (0-3; 11)	1.14 (0-3; 7)
Breeding Success/Nest	0.73 (11)	0.71 (7)

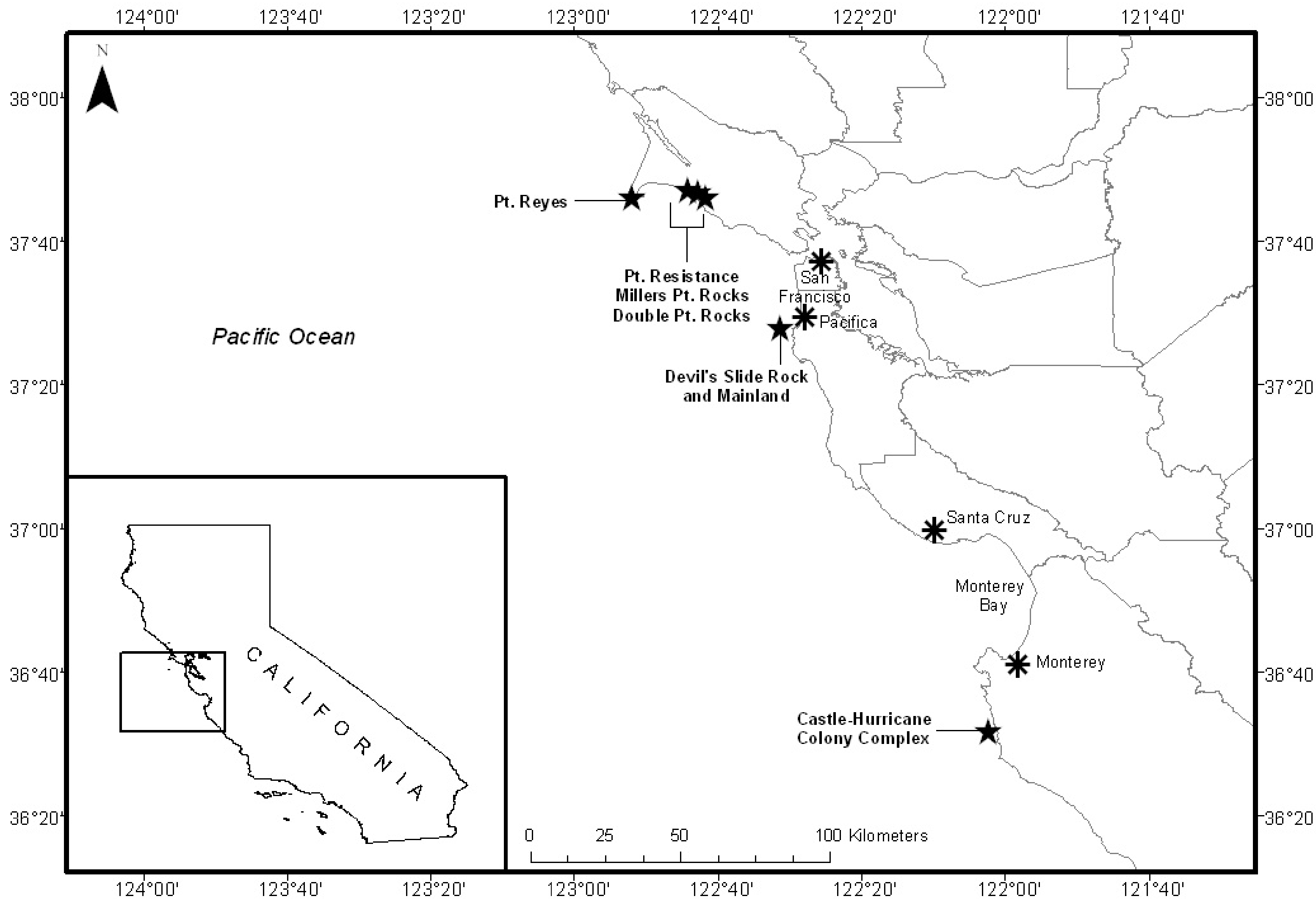


Figure 1. Study area, showing locations of study colonies or colony complexes along the Central California coast where we monitored seabird disturbance, attendance, and reproductive success. Pt. Resistance, Miller's Pt. Rocks, Double Pt. Rocks, and Castle-Hurricane Colony Complex were not monitored in 2022.

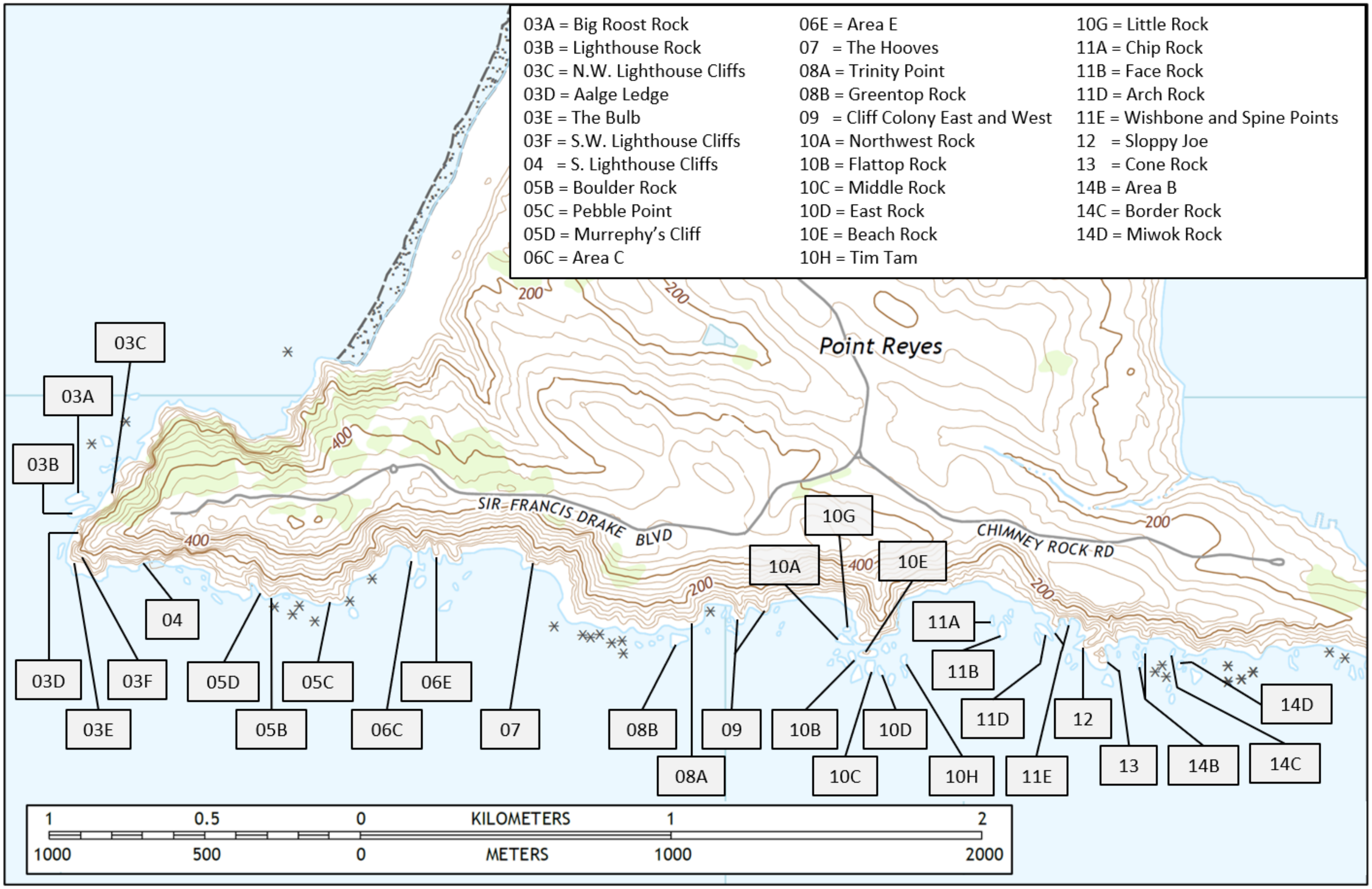


Figure 2. The western 2/3 of Point Reyes Headlands including seabird subcolonies 03A through 14D monitored on this project.

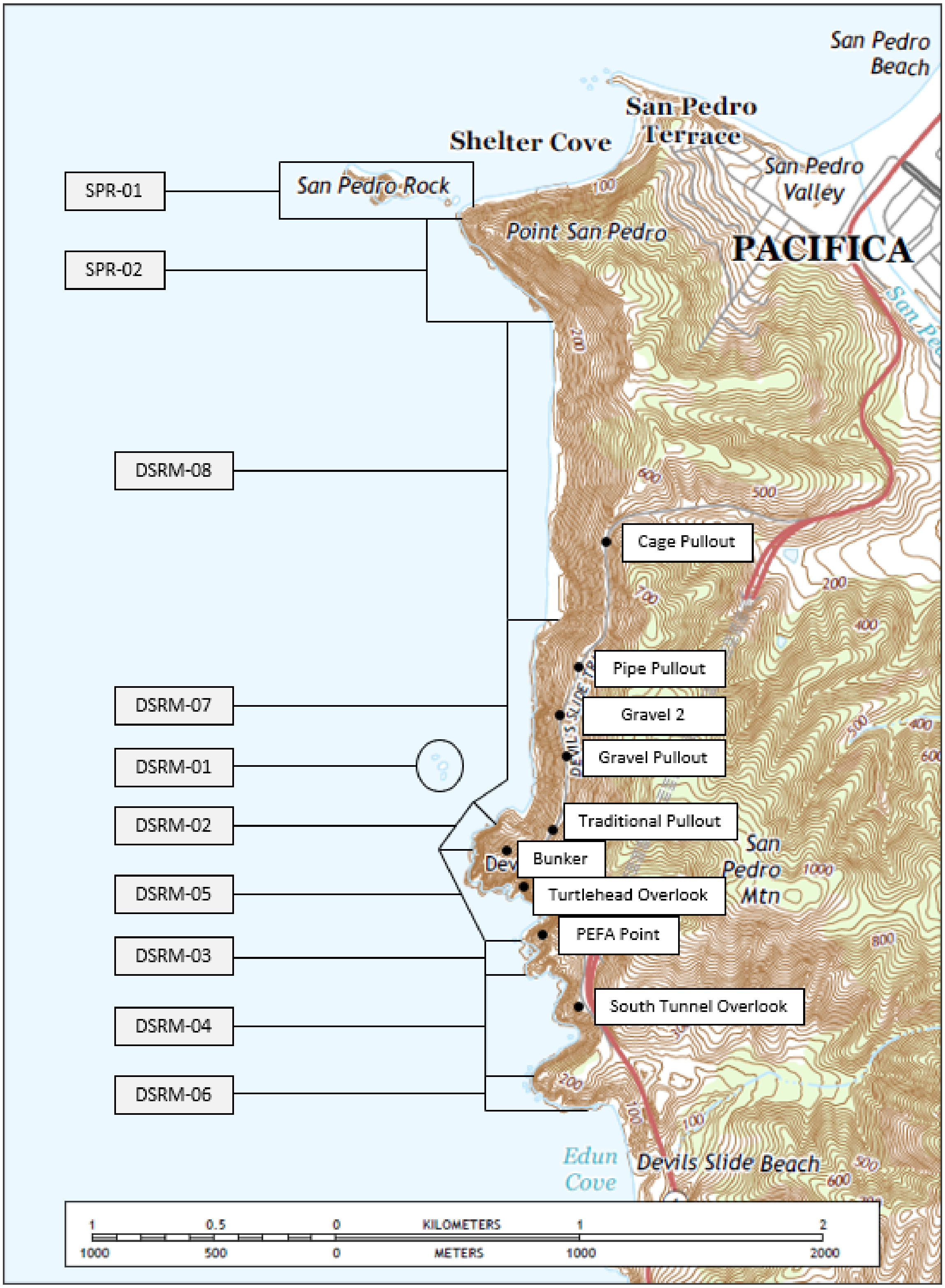


Figure 3. Devil's Slide Colony Complex, including San Pedro Rock and the seabird subcolonies within the Devil's Slide Rock & Mainland colony.

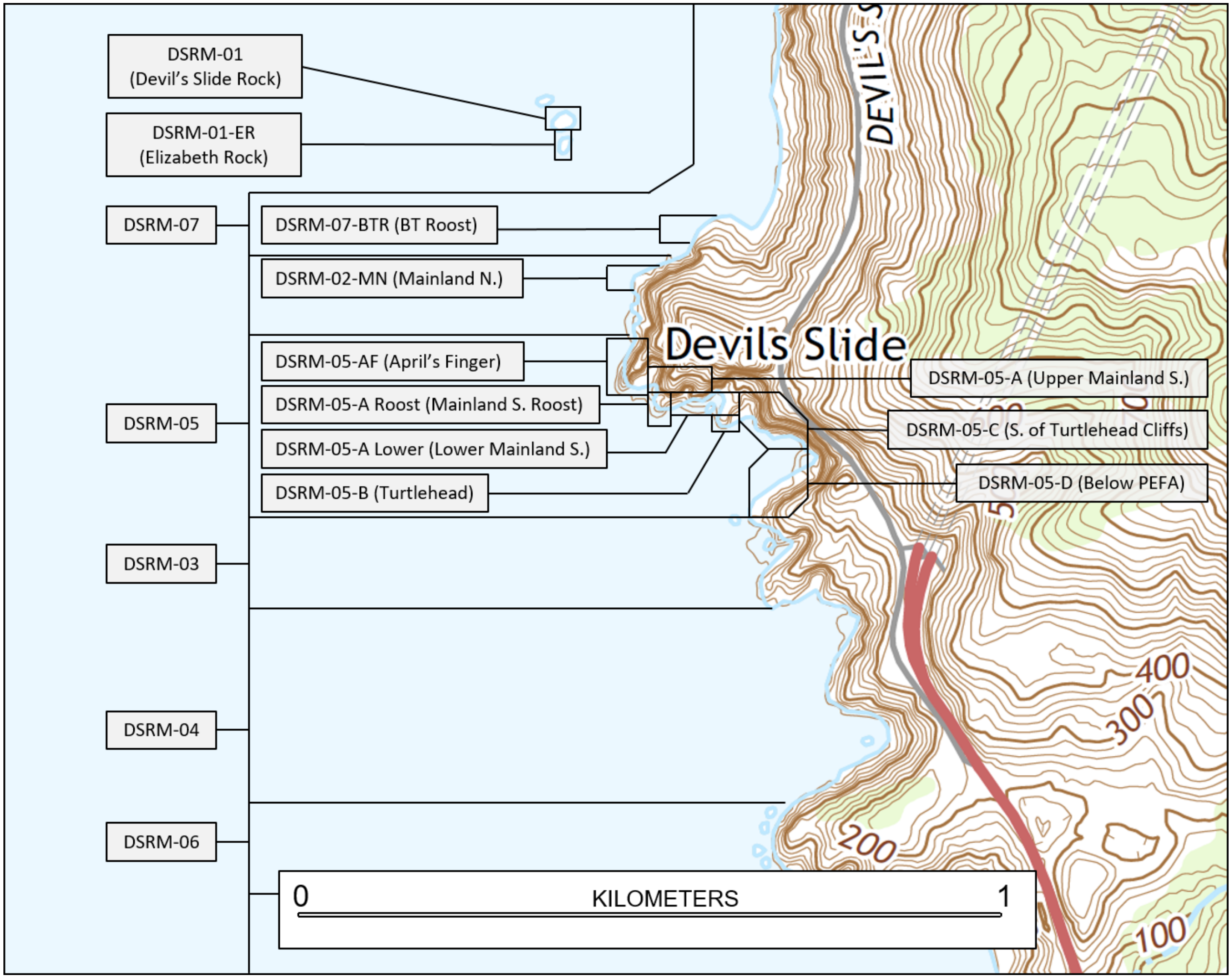


Figure 4. Detailed view of Devil's Slide Rock & Mainland (DSRM) subcolonies.

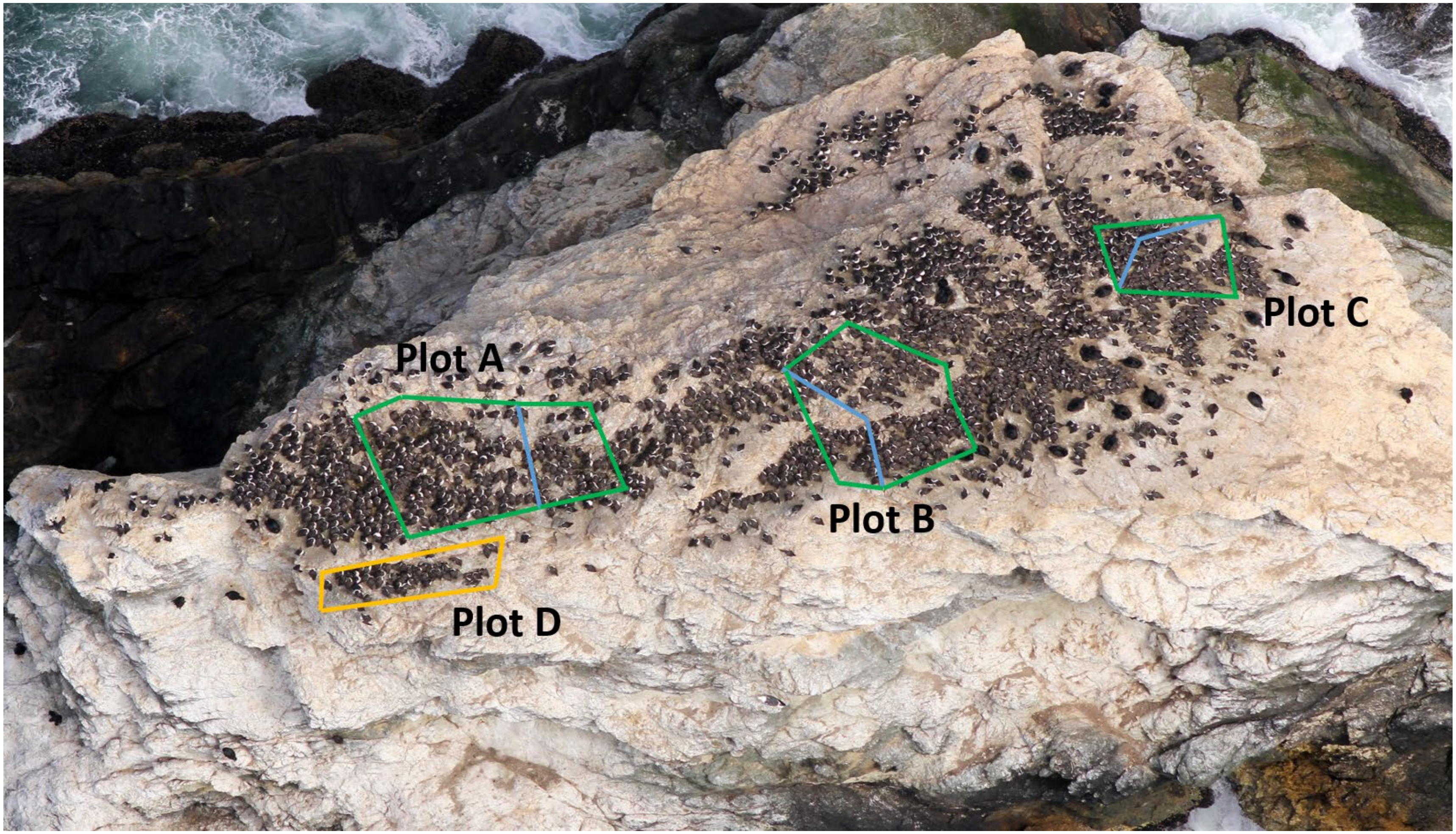


Figure 5. Aerial view (from the south) of Common Murre plot boundaries used on Devil's Slide Rock from 2006-2022. Green polygons show plot boundaries for the 2006 season, blue boundaries show adjustments made to Plots A, B, and C for 2007 and subsequent seasons (productivity was followed in remaining larger sections only). Plot C was no longer followed beginning in 2014, and Plot D was added for the 2015 and subsequent seasons.

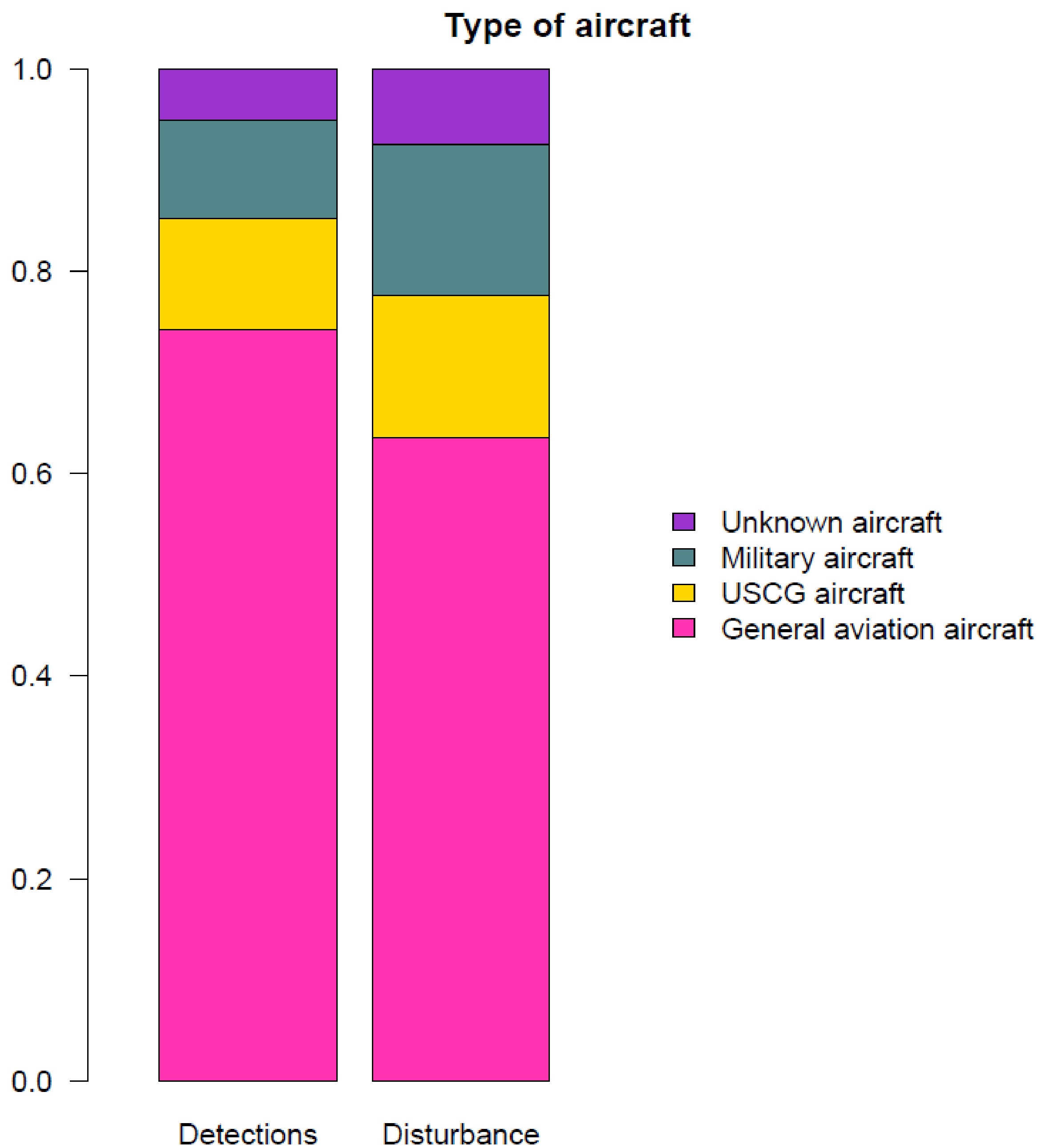


Figure 6. Aircraft detections (n = 175) and disturbances (n = 107) at Point Reyes Headlands and Devil's Slide Rock & Mainland, 2022, categorized by type.

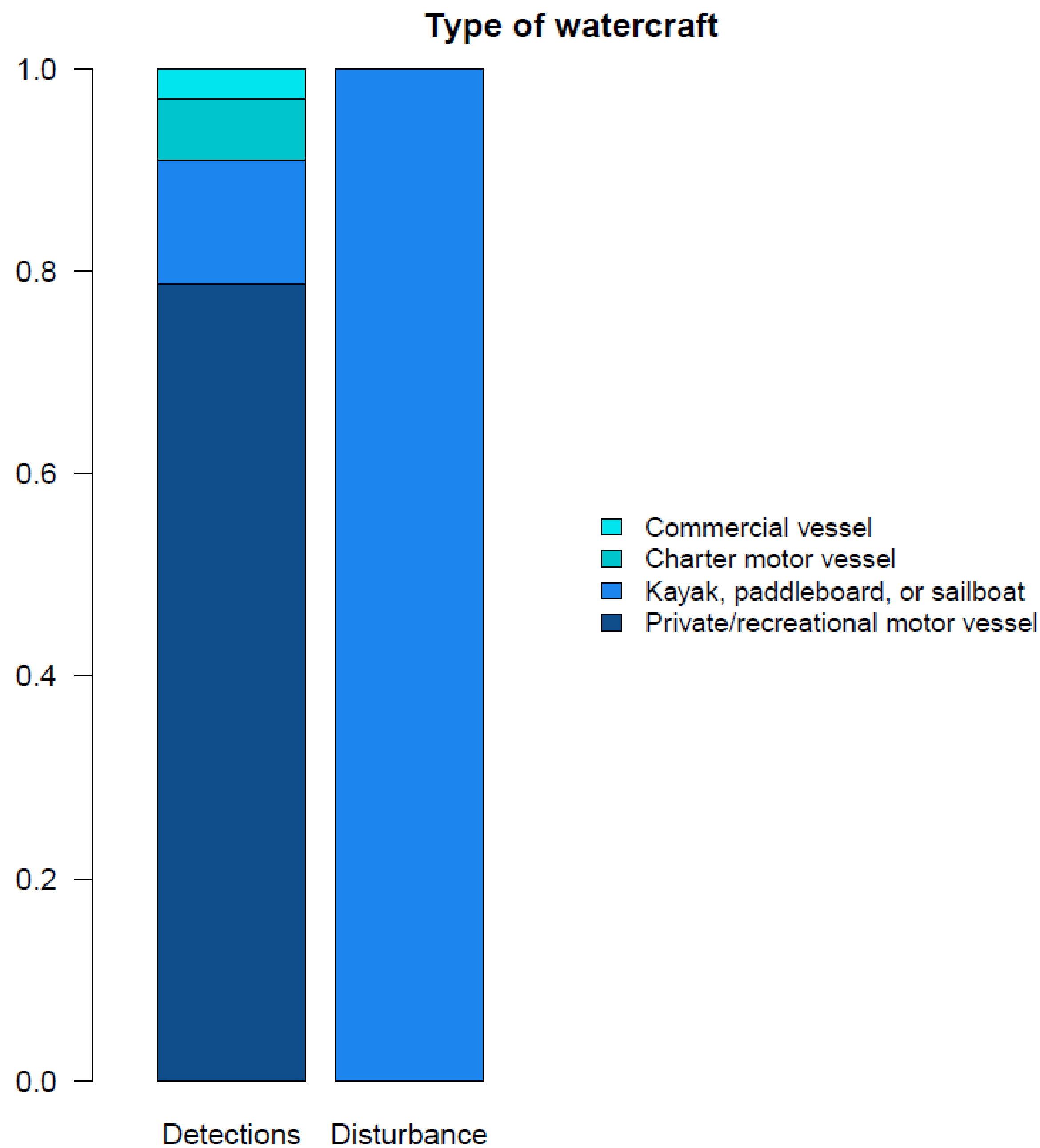


Figure 7. Watercraft detections (n = 33) and watercraft disturbances (n = 2) at Point Reyes Headlands and Devil's Slide Rock & Mainland, 2022, categorized by type.

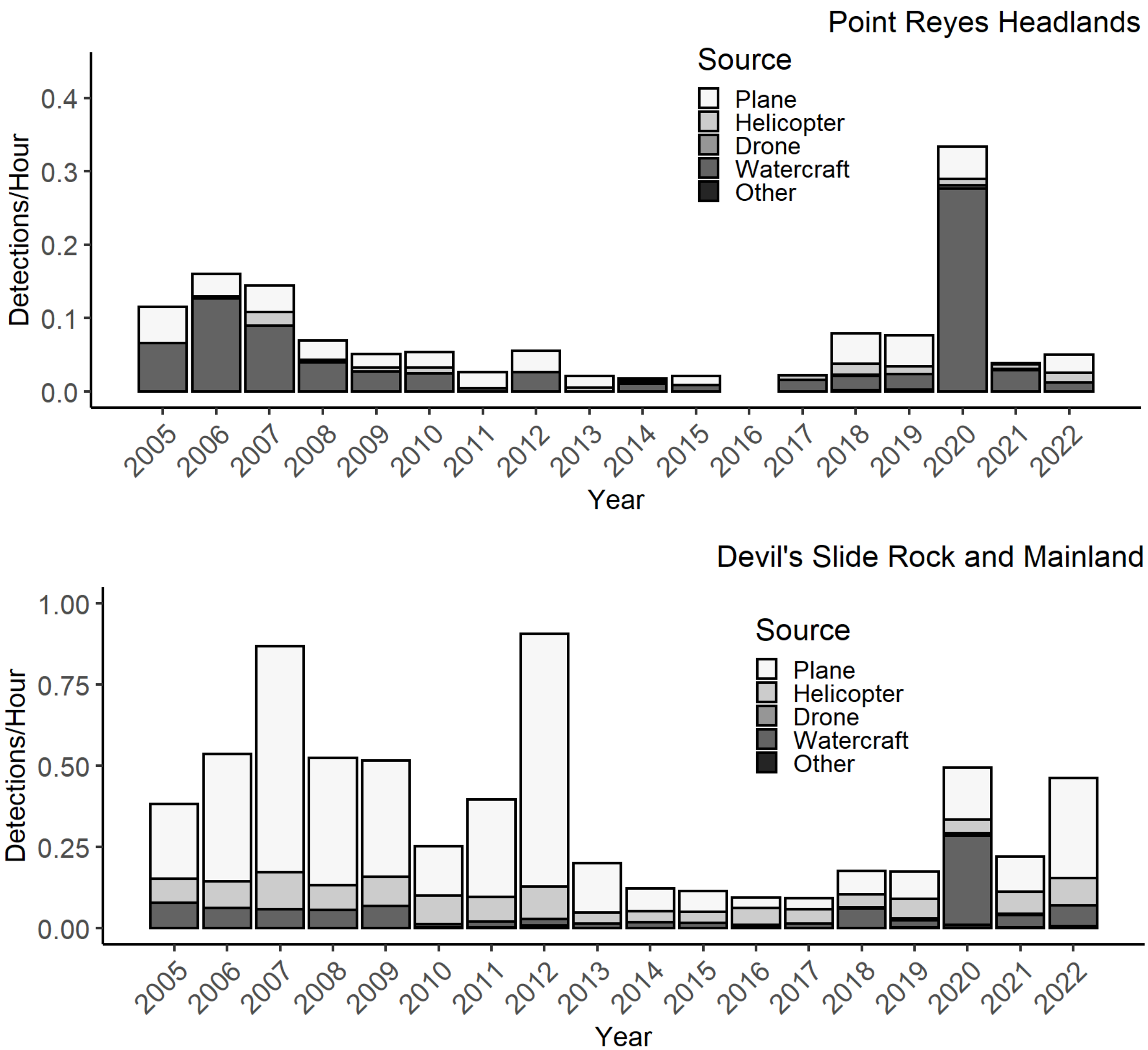


Figure 8. Detection rates (number of detections per observation hour) of watercraft, helicopters, planes, drones, and other anthropogenic sources at Point Reyes Headlands and Devil's Slide Rock & Mainland, 2005-2022. Note different scales between graphs. Point Reyes Headlands was not monitored in 2016.

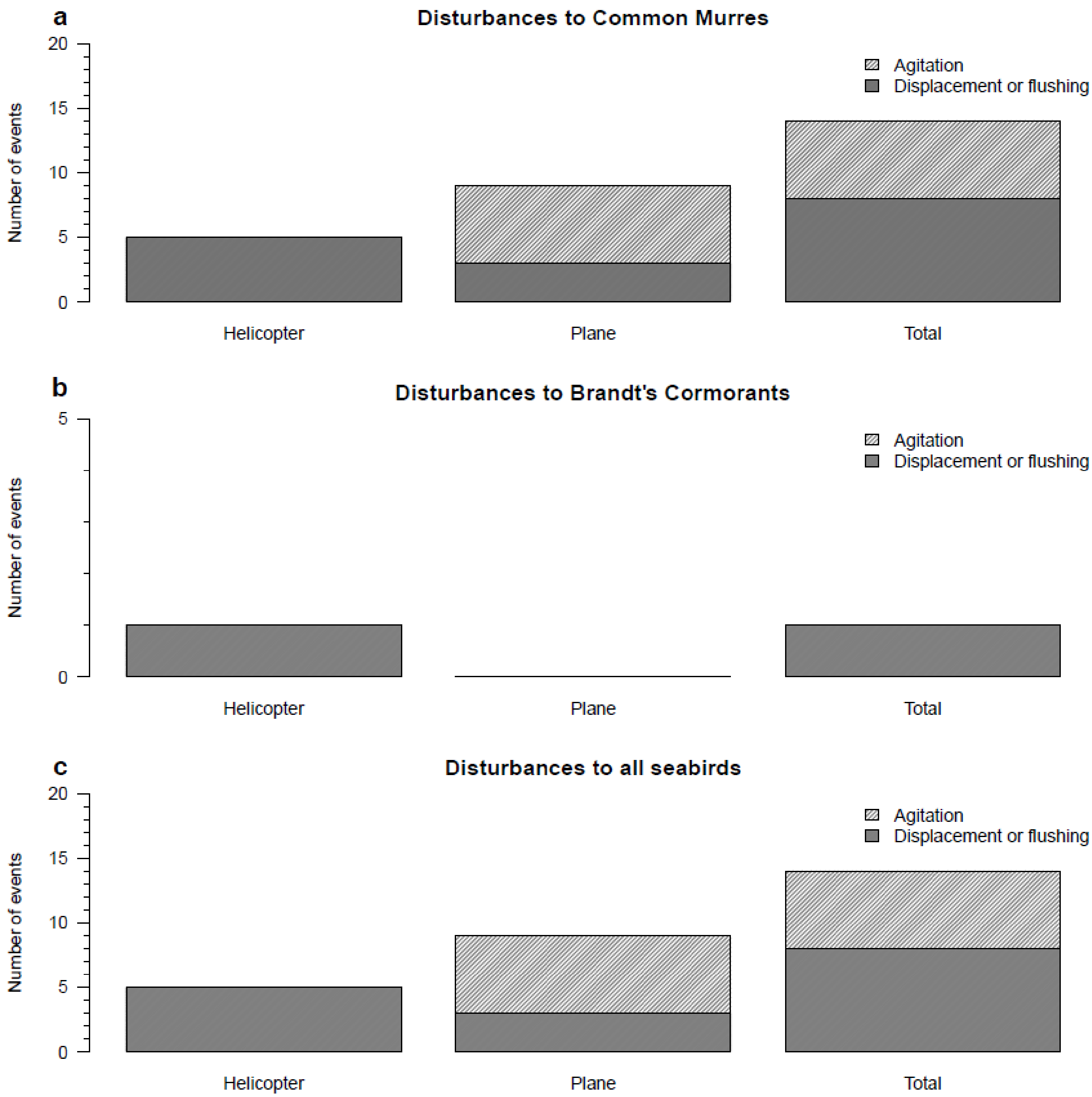


Figure 9. Number of disturbance events from anthropogenic sources of (a) Common Murres, (b) Brandt's Cormorants, and (c) total seabirds disturbed (agitated, displaced and/or flushed) at Point Reyes Headlands, 2022.

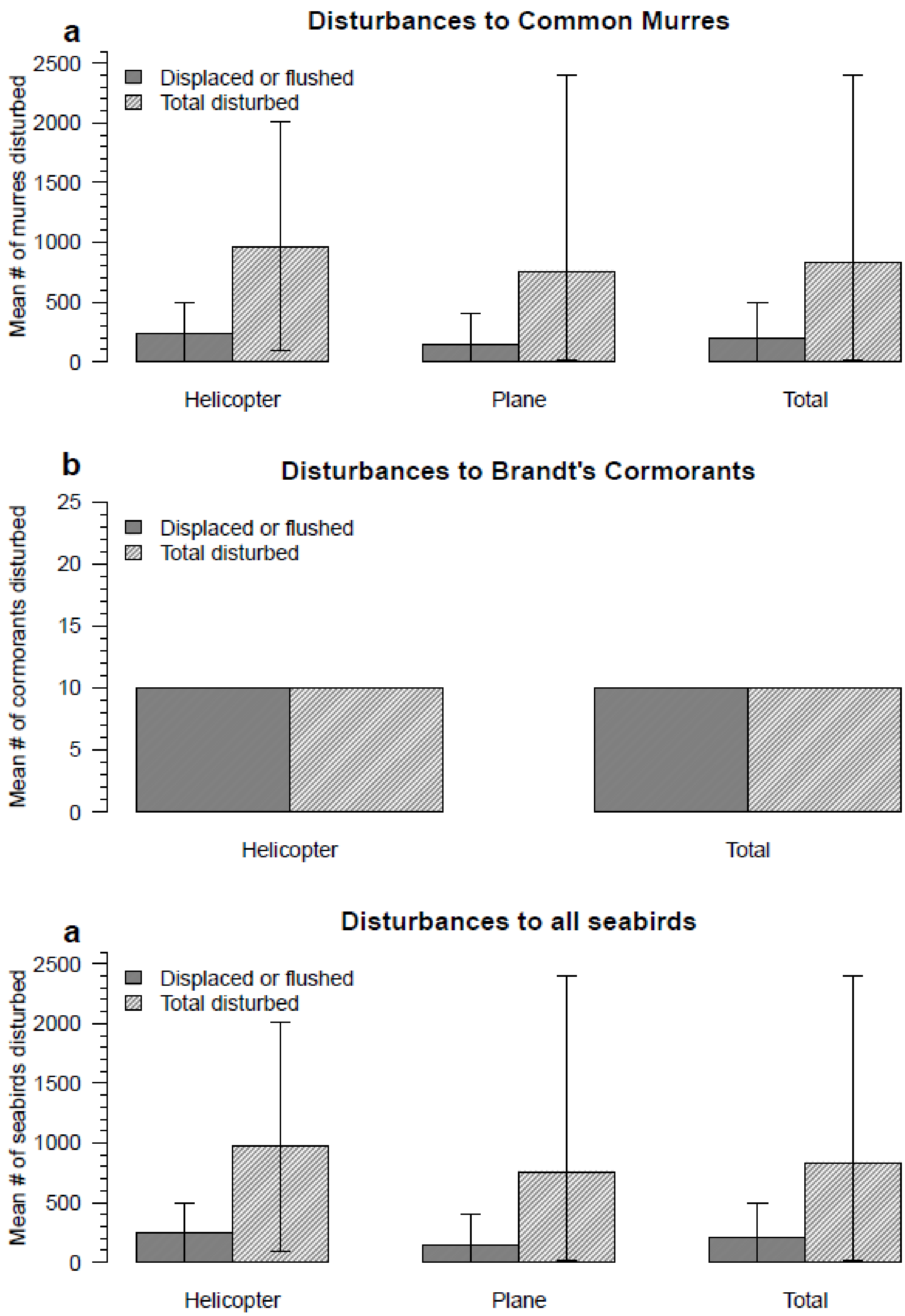


Figure 10. Mean numbers of (a) Common Murres, (b) Brandt's Cormorants, and (c) total seabirds disturbed (agitated, displaced, and/or flushed) by anthropogenic sources at Point Reyes Headlands, 2022. Error bars indicate ranges.

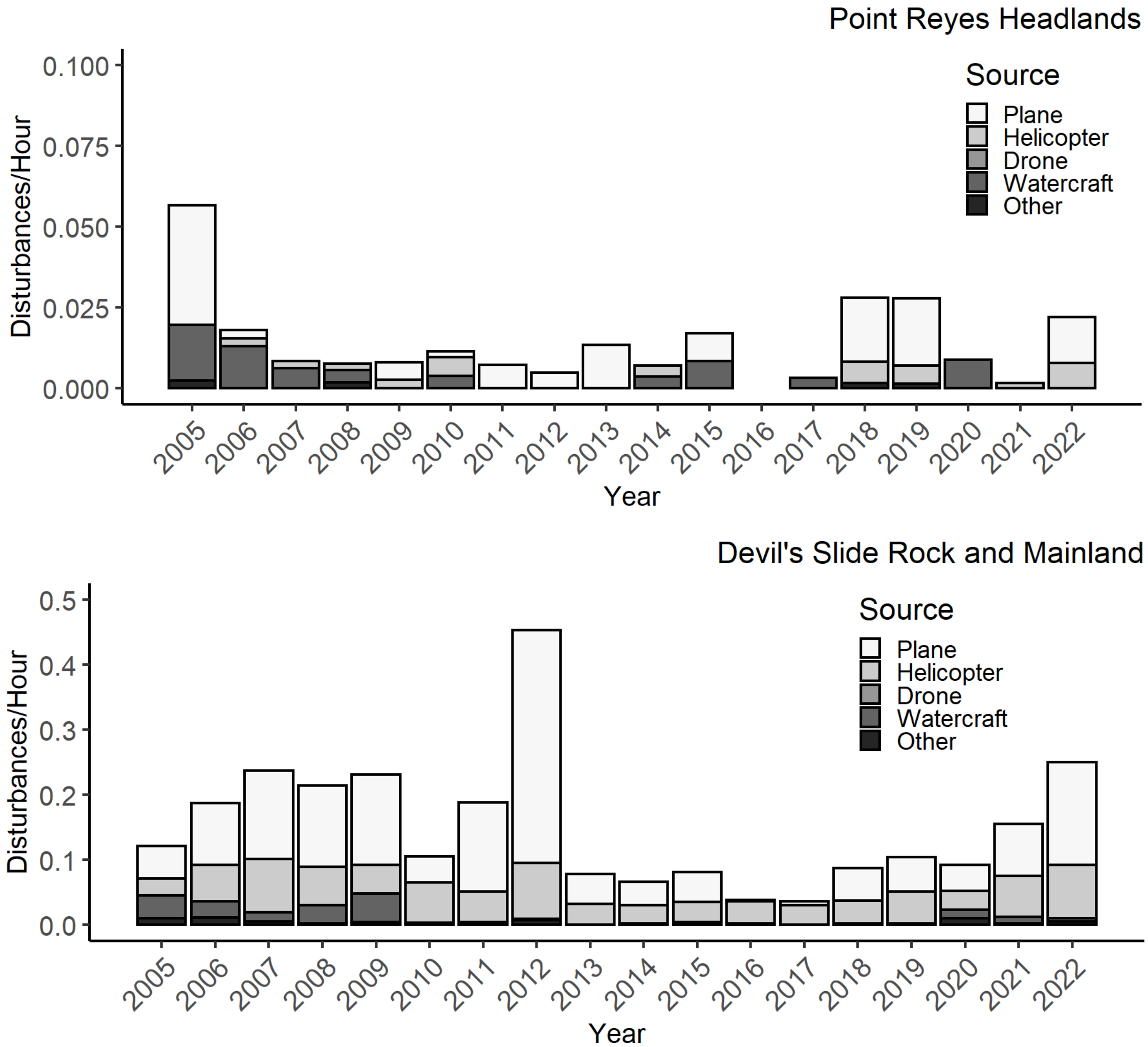


Figure 11. Disturbance rates (number of disturbances per observation hour) of watercraft, helicopters, planes, drones, and other anthropogenic sources at Point Reyes Headlands and Devil's Slide Rock & Mainland, 2005-2022. Note different scales between graphs. Point Reyes Headlands was not monitored in 2016.

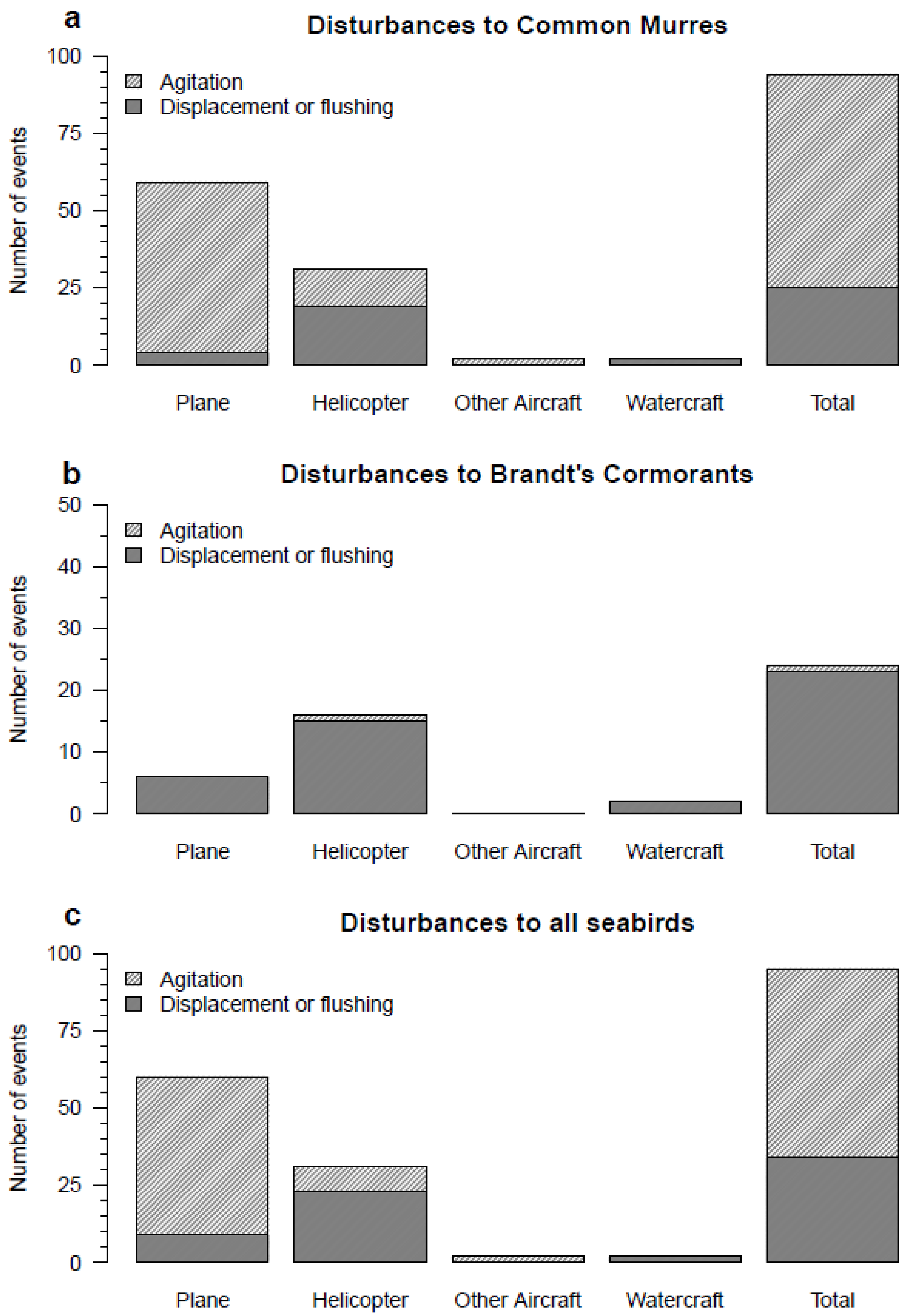


Figure 12. Number of disturbance events from anthropogenic sources of (a) Common Murres, (b) Brandt's Cormorants, and (c) total seabirds disturbed (agitated, displaced and/or flushed) at Devil's Slide Rock and Mainland, 2022.

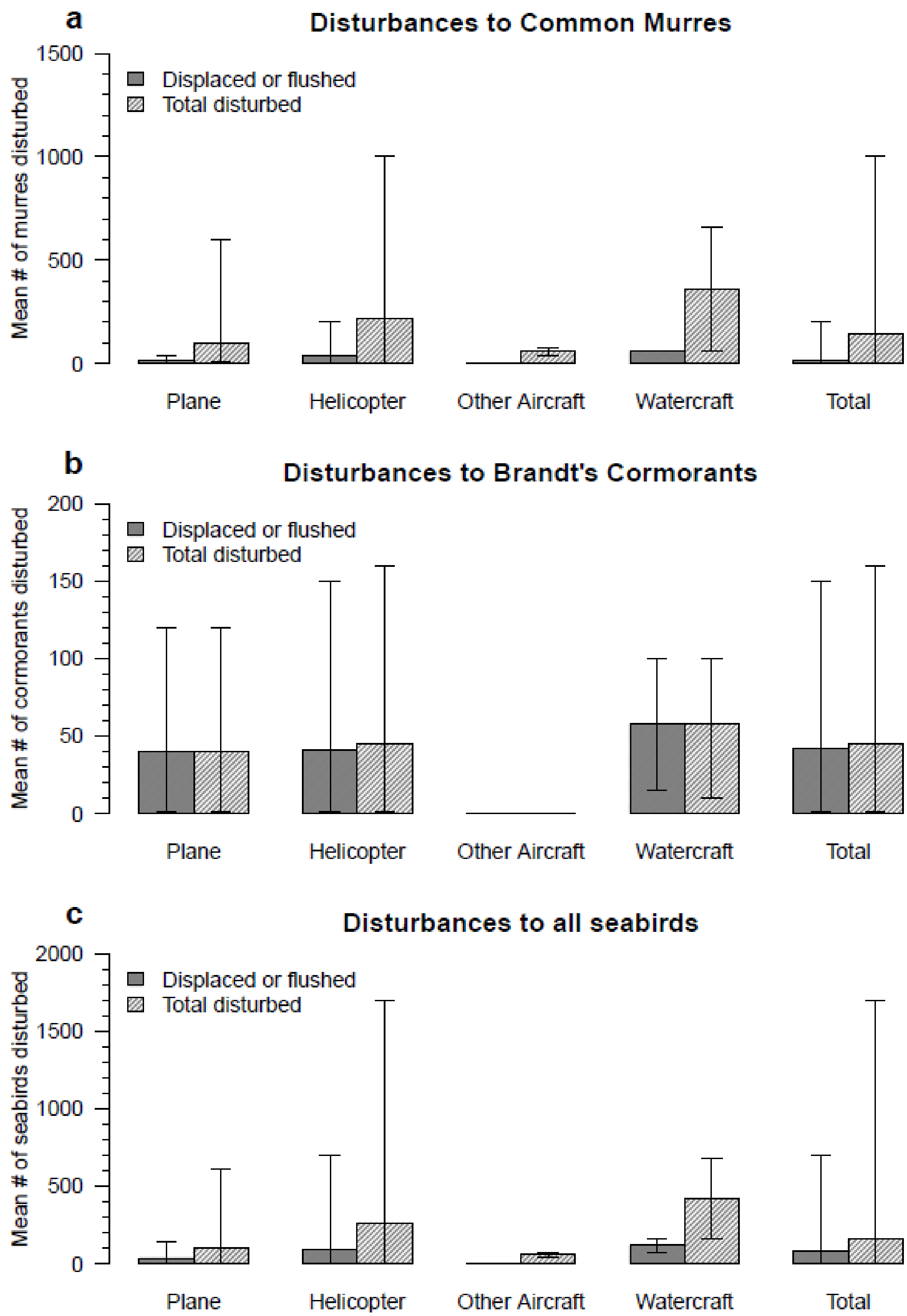


Figure 13. Mean number of (a) Common Murres, (b) Brandt's Cormorants, and (c) total seabirds disturbed (agitated, displaced and/or flushed) by anthropogenic sources at Devil's Slide Rock and Mainland, 2022. Error bars indicate ranges.

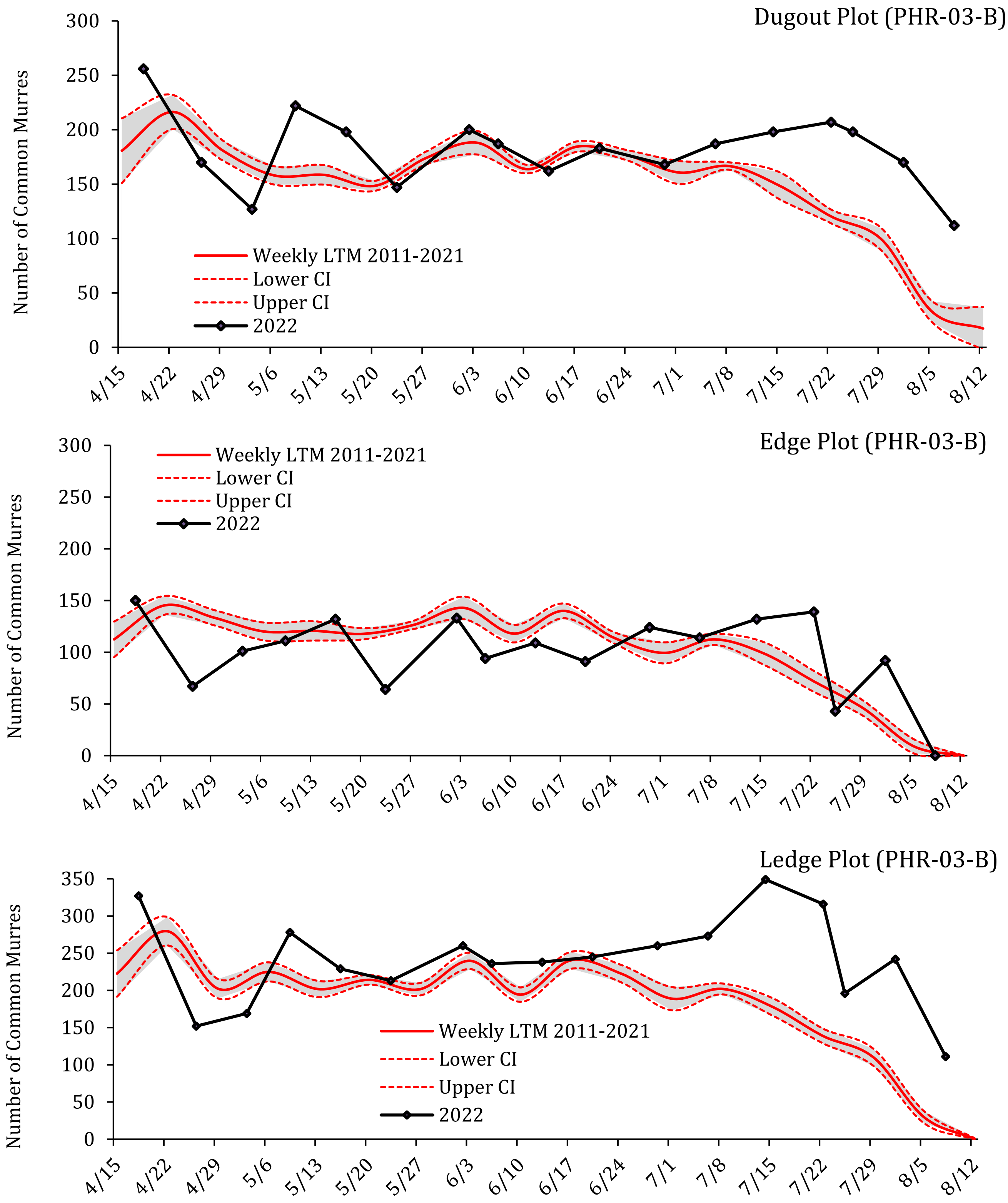
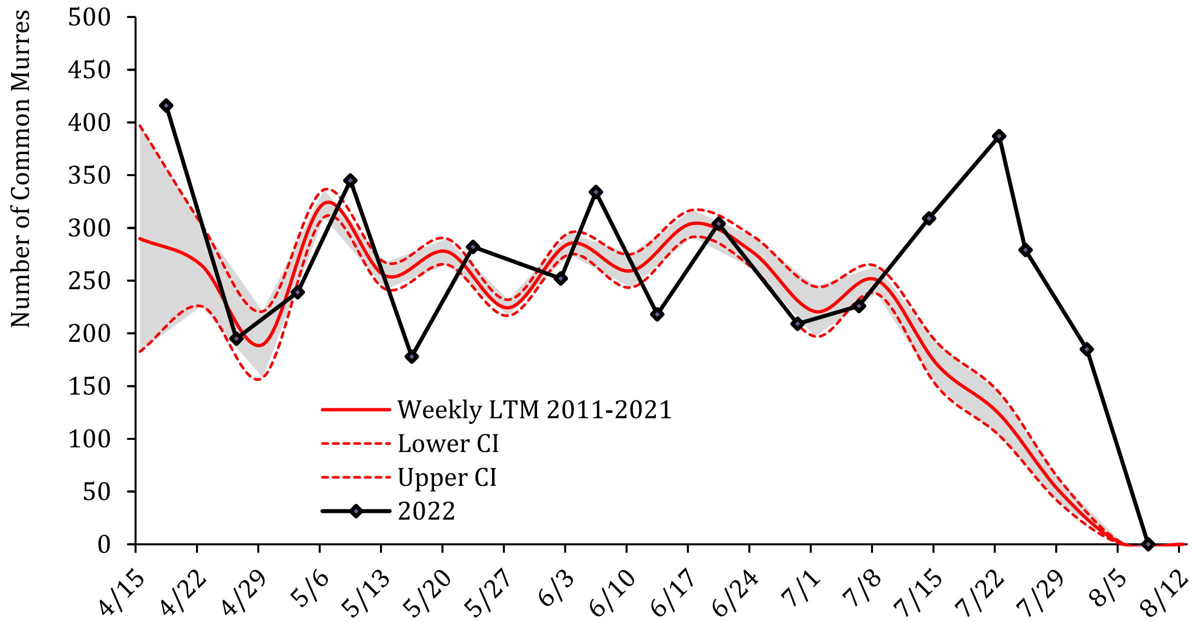


Figure 14. Seasonal attendance of Common Murres at Point Reyes Headlands Lighthouse Rock plots (PRH-03-B; three plots) in 2022 compared to the long-term mean pattern (LTM, 2011-2021).

Boulder Plot (PHR-05-BP)



Cone Plot (PHR-13-CP)

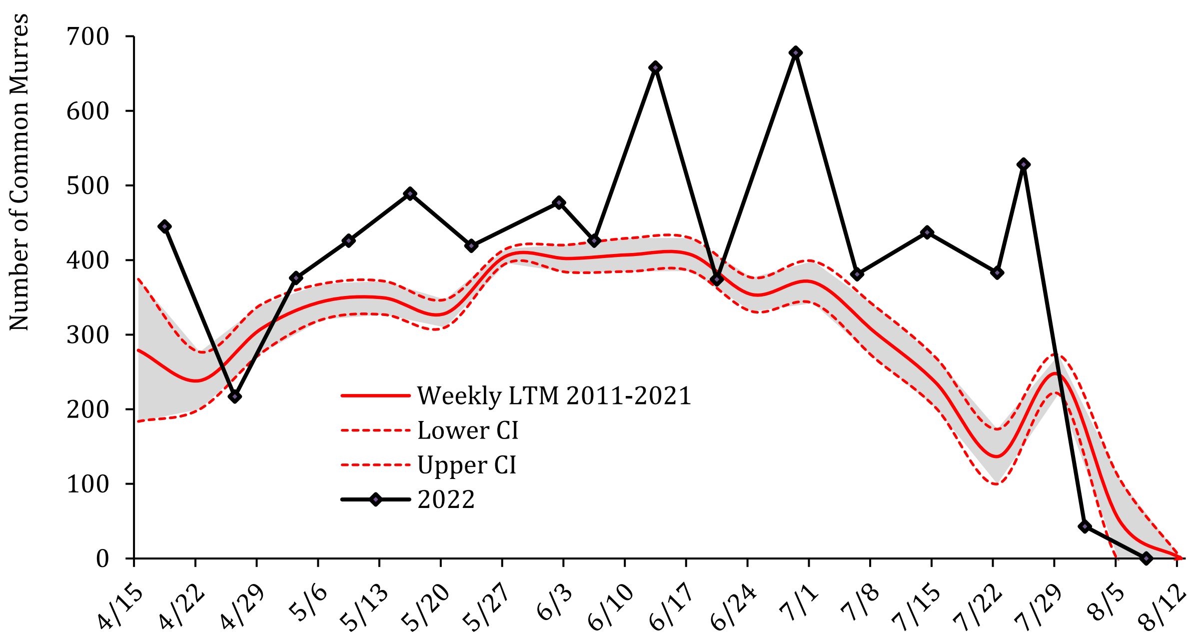


Figure 15. Seasonal attendance of Common Murres at Point Reyes Headlands plots on Boulder and Cone Rocks (subcolonies: PRH-05-BP and PRH-13-CP) in 2022 compared to the long-term mean pattern (LTM, 2011-2021).

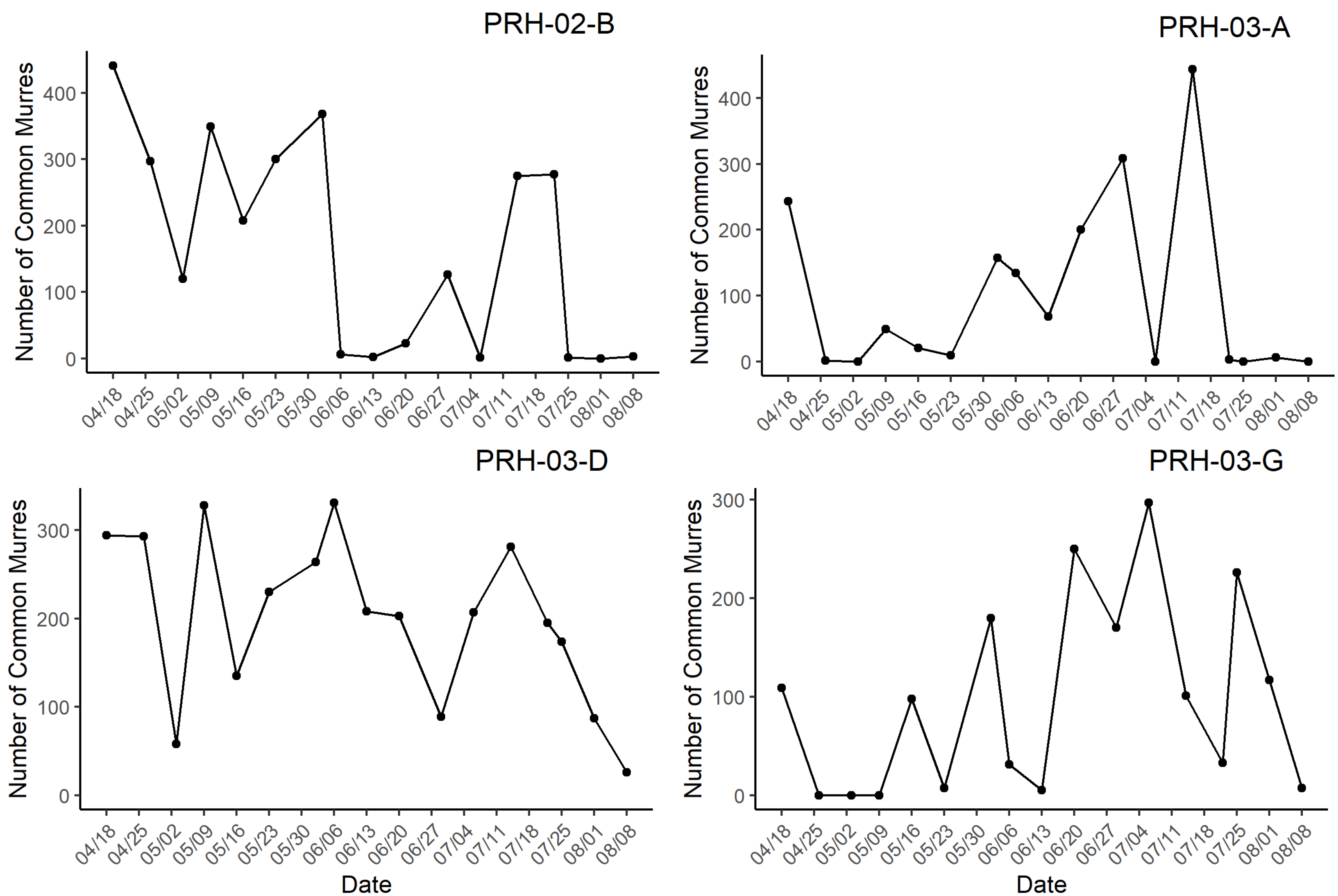


Figure 16. Seasonal attendance of Common Murres at Point Reyes Headlands (subcolonies: PRH-02-B (Rock 2), PRH-03-A (Big Roost Rock), PRH-03-D (Aalge Ledge), and PRH-03-G (Levin's Rock)) from 18 April to 8 August, 2022.

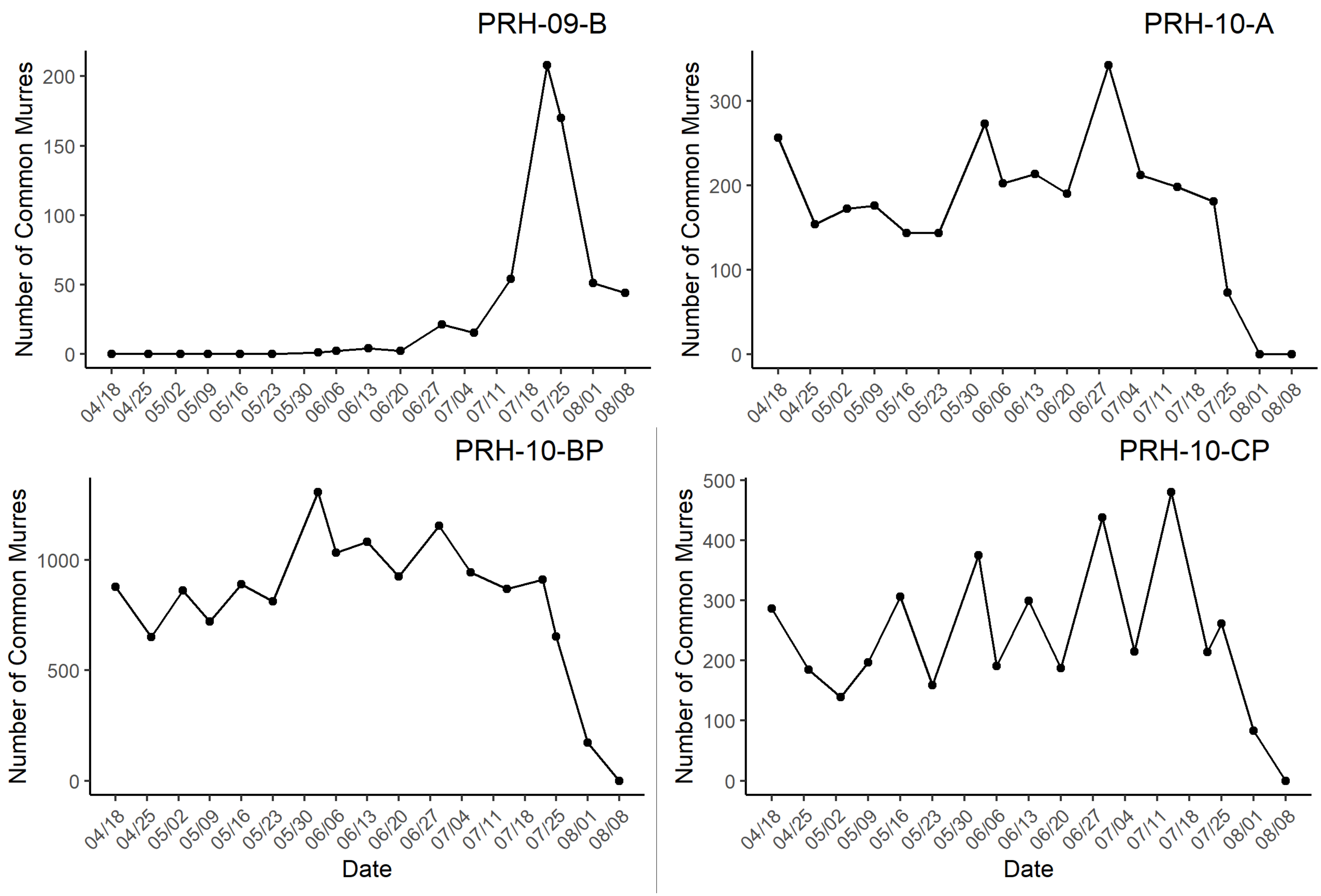


Figure 17. Seasonal attendance of Common Murres at Point Reyes Headlands (subcolonies: PRH-09-B (Cliff Colony East), PRH-10-A (Northwest Rock), PRH-10-BP (Flattop Rock Plot) and PRH-10-CP (Middle Rock Plot)) from 18 April to 8 August, 2022.

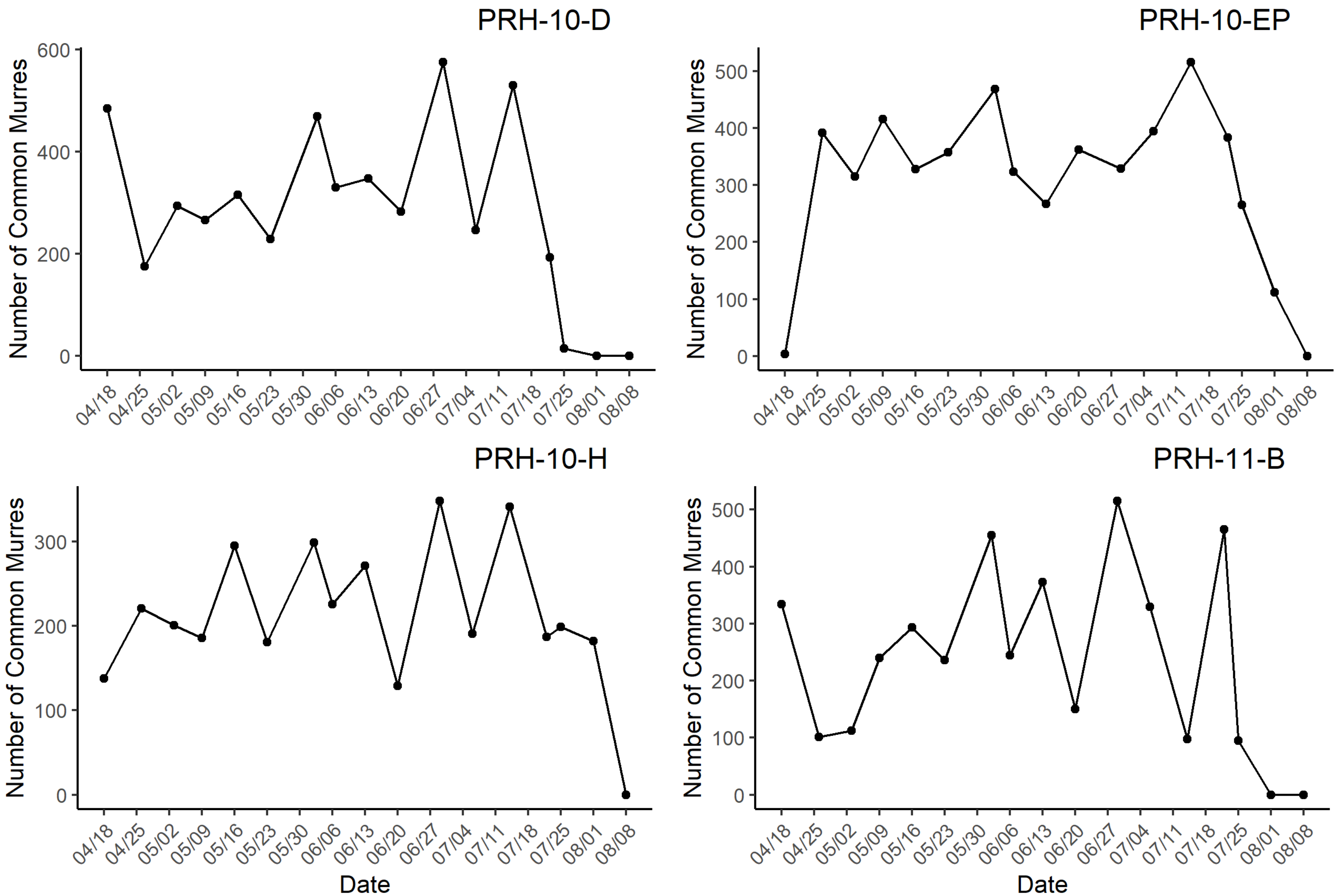


Figure 18. Seasonal attendance of Common Murres at Point Reyes Headlands (subcolonies: PRH-10-D (East Rock), PRH-10-EP (Beach Rock Plot), PRH-10-H (Tim Tam Rock) and PRH-11-B (Face Rock)) from 18 April to 8 August, 2022.

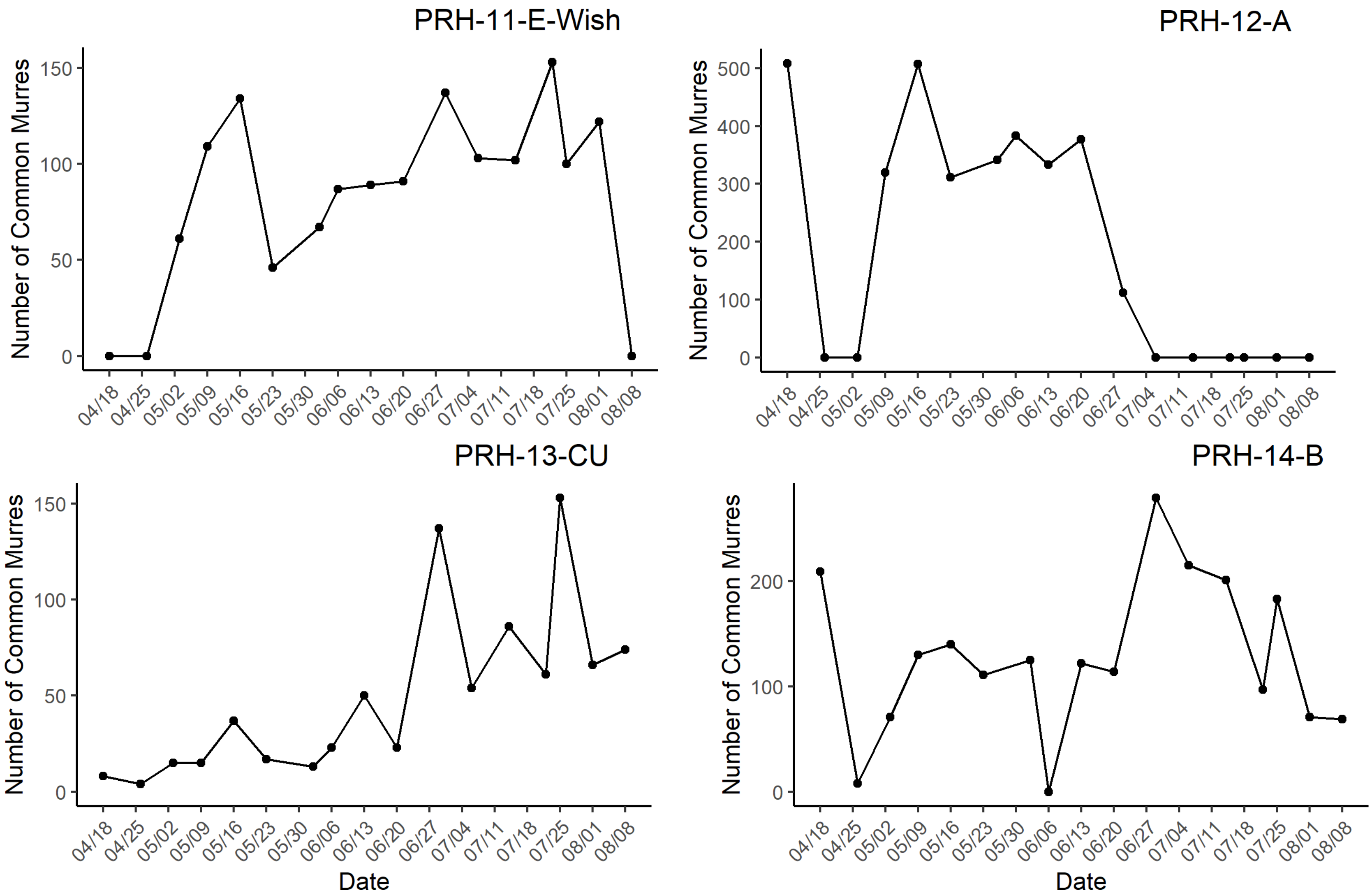


Figure 19. Seasonal attendance of Common Murres at Point Reyes Headlands (subcolonies: PRH-11-E-Wish (Wishbone Point), PRH-12-A (Sloppy Joe), PRH-13-CU (Upper Cone Plot), and PRH-14-B (Area B)) from 18 April to 8 August, 2022.

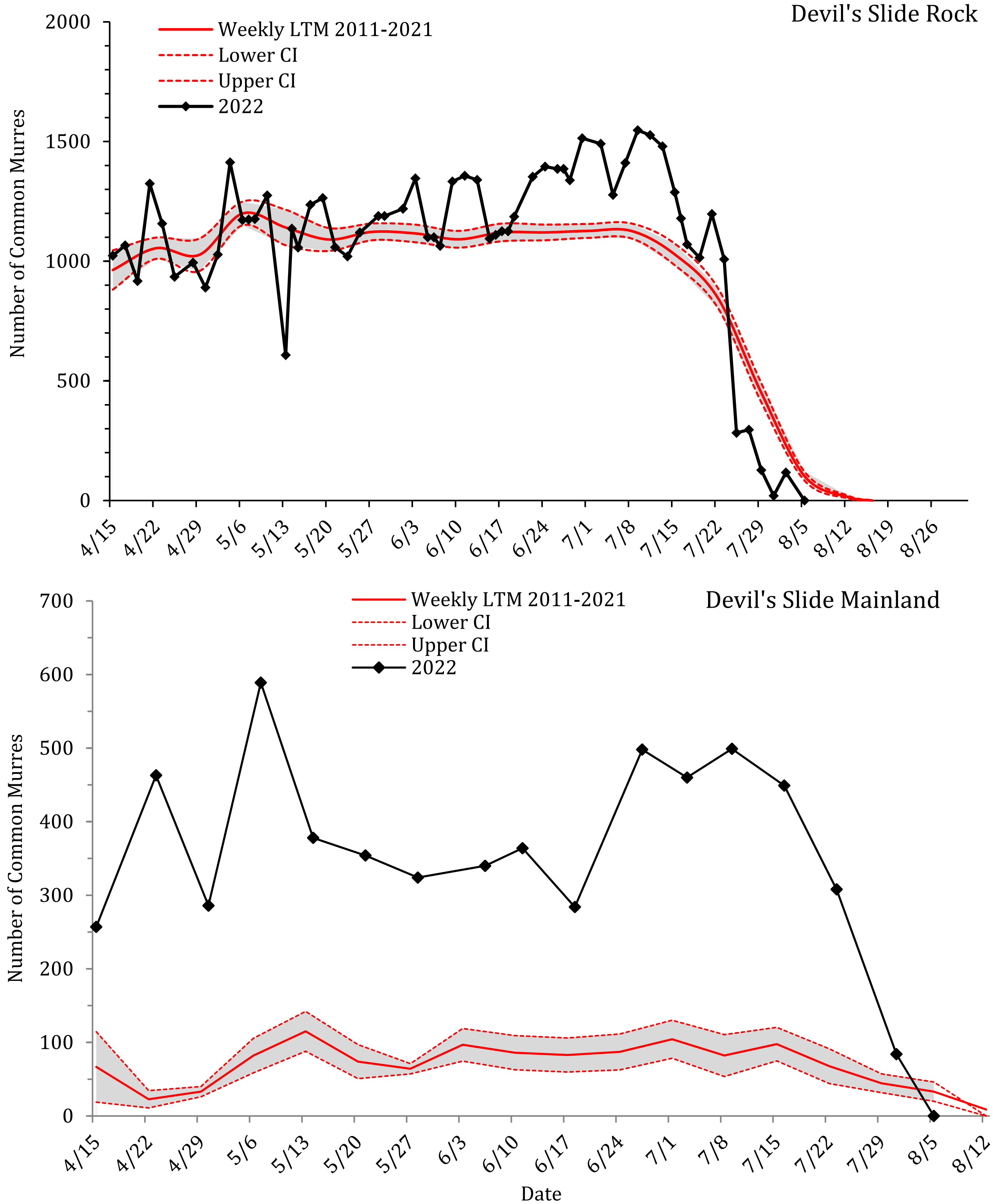


Figure 20. Seasonal attendance of Common Murres at Devil’s Slide Rock (DSRM-01) and all Devil’s Slide Mainland (DSM) subcolonies in 2022 compared to the long-term mean patterns (LTM, 2011-2021).

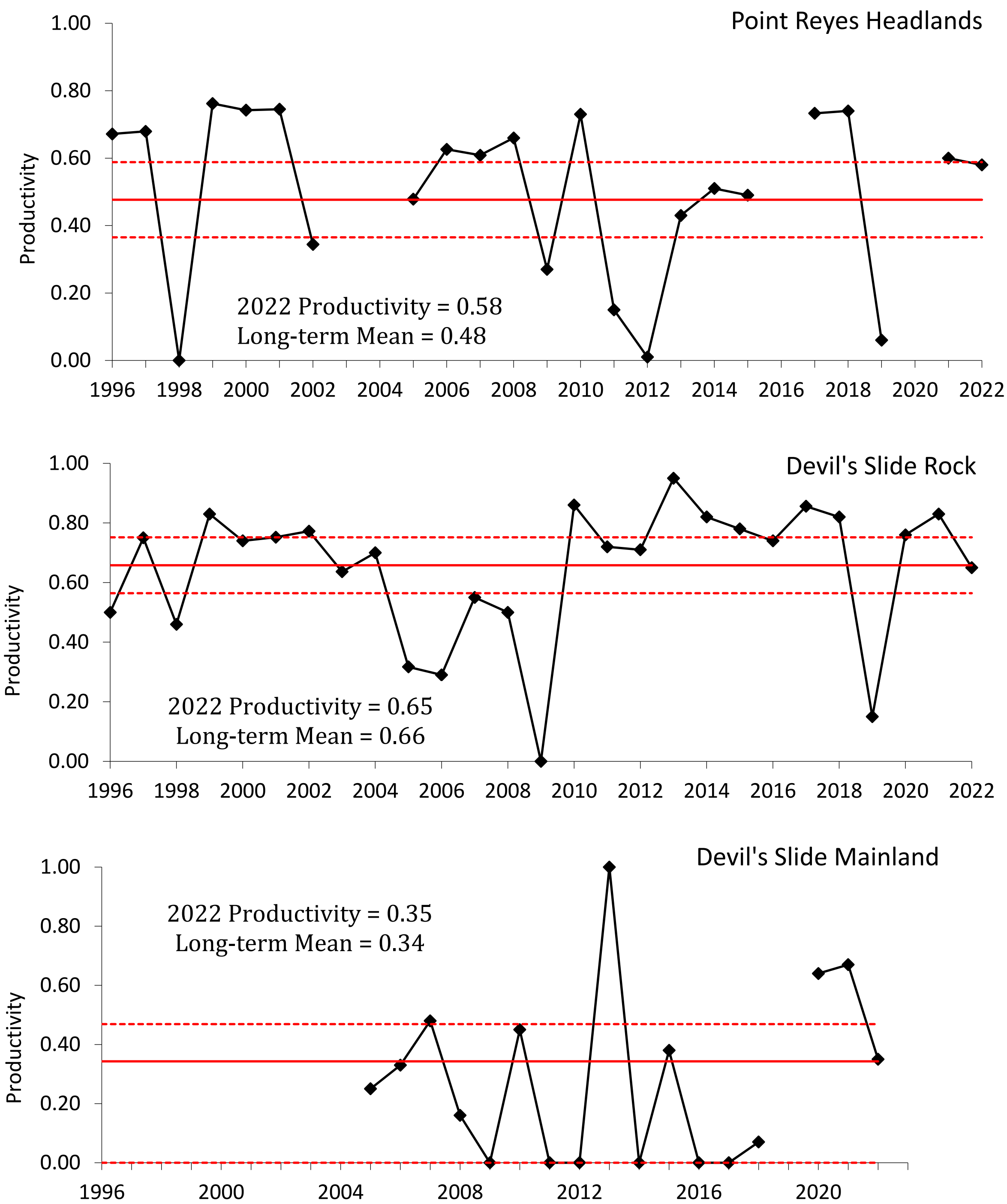


Figure 21. Productivity (chicks fledged per pair) of Common Murres at Point Reyes Headlands, Devil's Slide Rock, and Devil's Slide Mainland from 1996-2022. The solid horizontal line indicates the long-term weighted mean (1996-2021), and the dashed lines represent the 95% confidence interval.

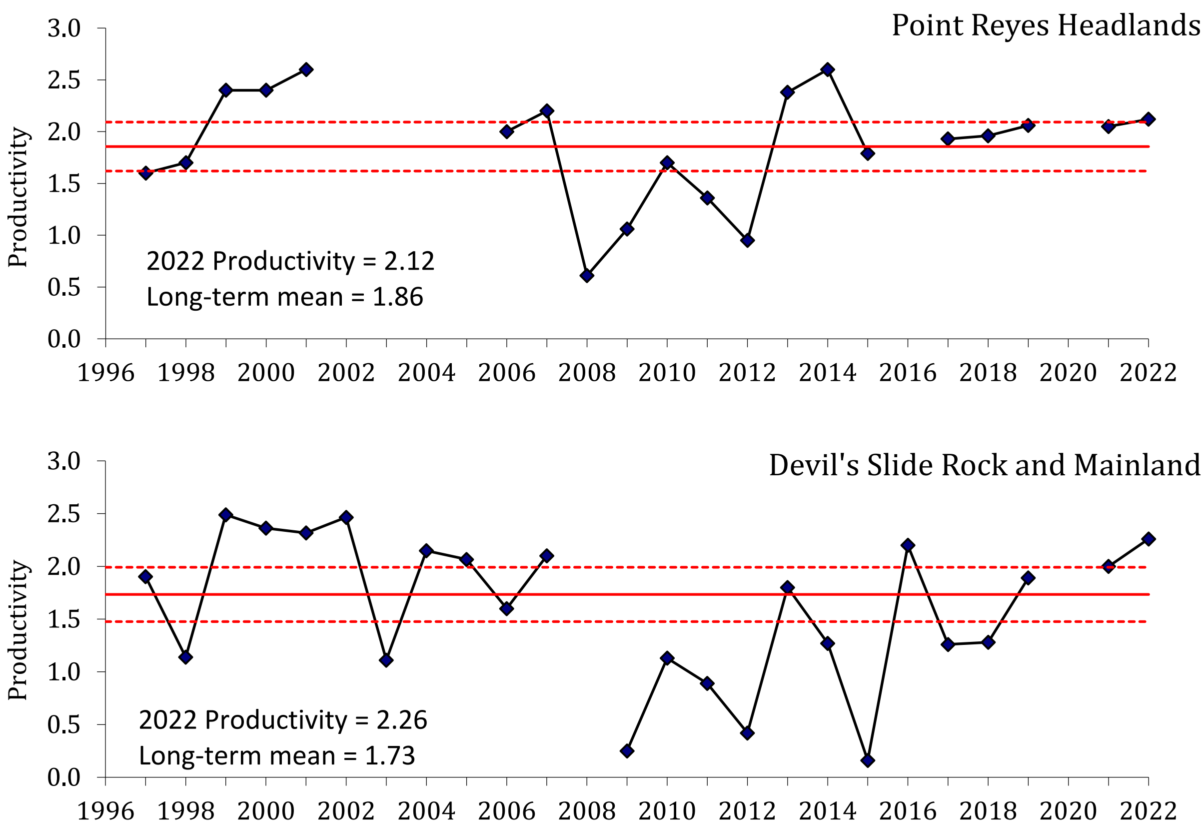


Figure 22. Productivity (chicks fledged per pair) of Brandt's Cormorants at Point Reyes Headlands and Devil's Slide Rock & Mainland, 1997-2022. The solid horizontal line indicates the long-term weighted mean (1997-2021), and the dashed lines represent the 95% confidence interval.

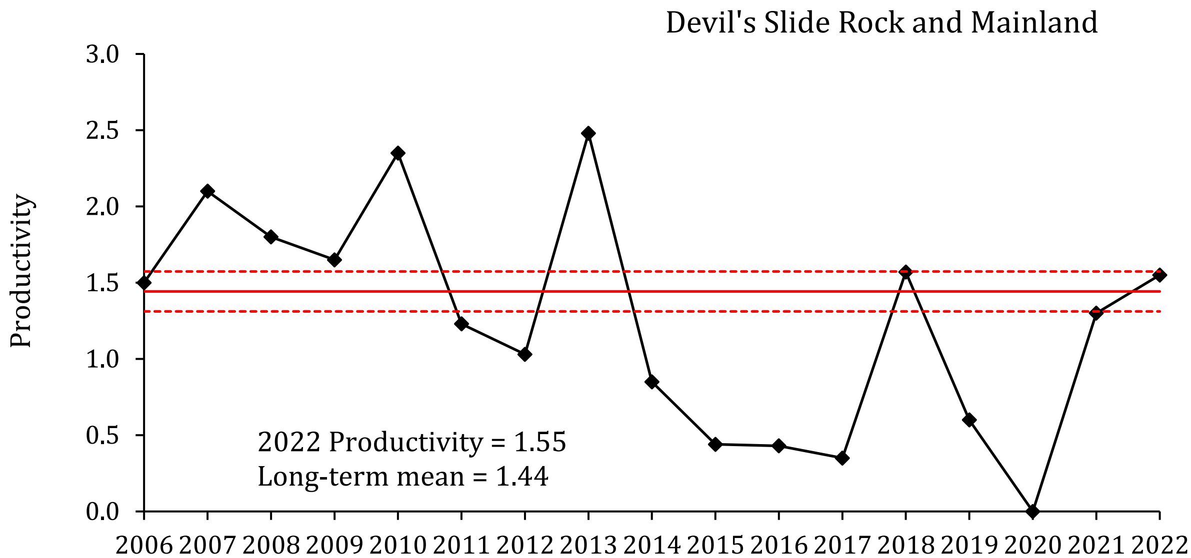


Figure 23. Productivity (chicks fledged per pair) of Pelagic Cormorants at Devil's Slide Rock and Mainland from 2006-2022. The solid horizontal line indicates the long-term weighted mean (2006-2021), and the dashed lines represent the 95% confidence interval.

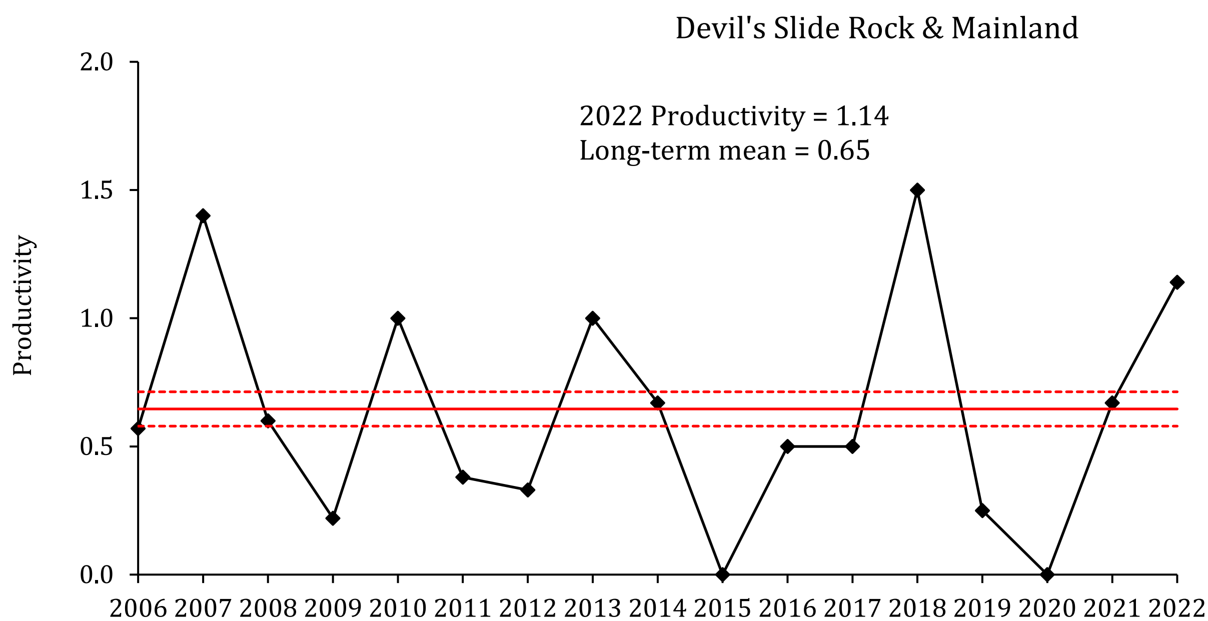


Figure 24. Productivity (chicks fledged per pair) of Western Gulls at Devil's Slide Rock & Mainland from 2006-2022. The solid horizontal line indicates the long-term weighted mean (2006-2021), and the dashed lines represent the 95% confidence interval.

Appendix 1. Number of aircraft overflights and land-based sources observed (detections and disturbances), separated by aircraft use and type, at Point Reyes Headlands and Devil's Slide Rock & Mainland, 2022.

a) Detections

Use	Helicopter	Plane	Other Aircraft	Total
Military	3	14	0	17
Private/recreational	15	113	2	130
Unknown	3	6	0	9
USCG	19	0	0	19
Total	**40**	**133**	**2**	**175**

b) Disturbance events

Use	Helicopter	Plane	Other Aircraft	Total
Military	3	13	0	16
Private/recreational	15	51	2	68
Unknown	3	5	0	8
USCG	15	0	0	15
Total	**36**	**69**	**2**	**107**

Appendix 2. Number of watercraft observed (detection and disturbances), categorized by use and type, at Point Reyes Headlands and Devil's Slide Rock and Mainland in 2022.

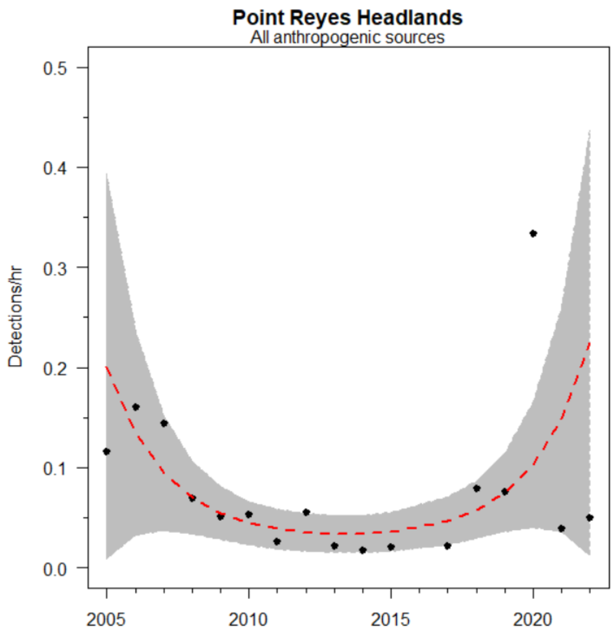
a) Detection events

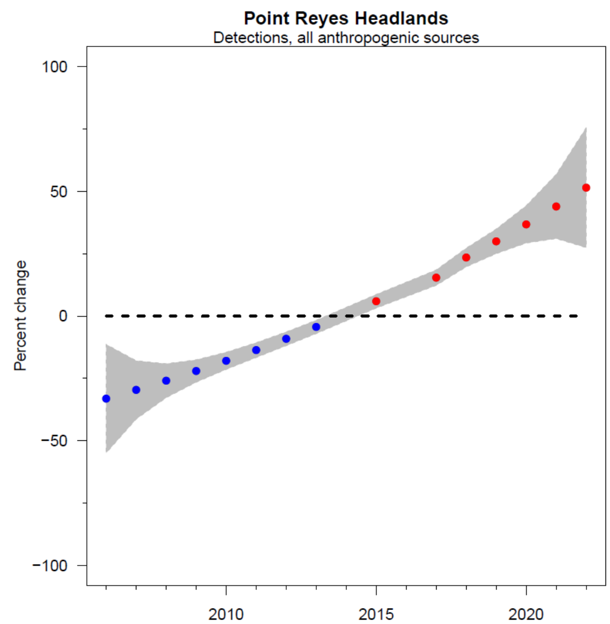
Use	Motor Vessel (<25')	Motor Vessel (>25')	Jet Ski (<25')	Kayak/Canoe (<25')	Paddleboard (<25')	Sailboat (<25')	Sailboat (>25')	Total
Charter		2						2
Commercial		1						1
Private/Recreational	23	2	1	1	1	1	1	30
Total	**23**	**5**	**1**	**1**	**1**	**1**	**1**	**33**

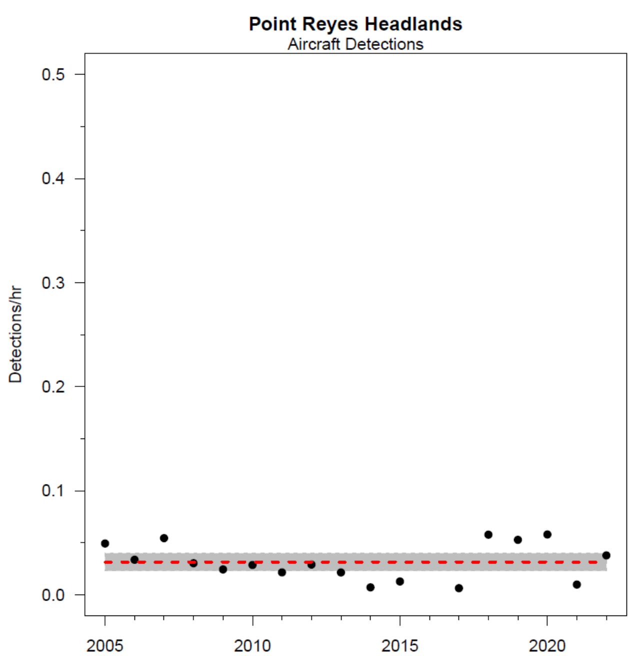
b) Disturbance events

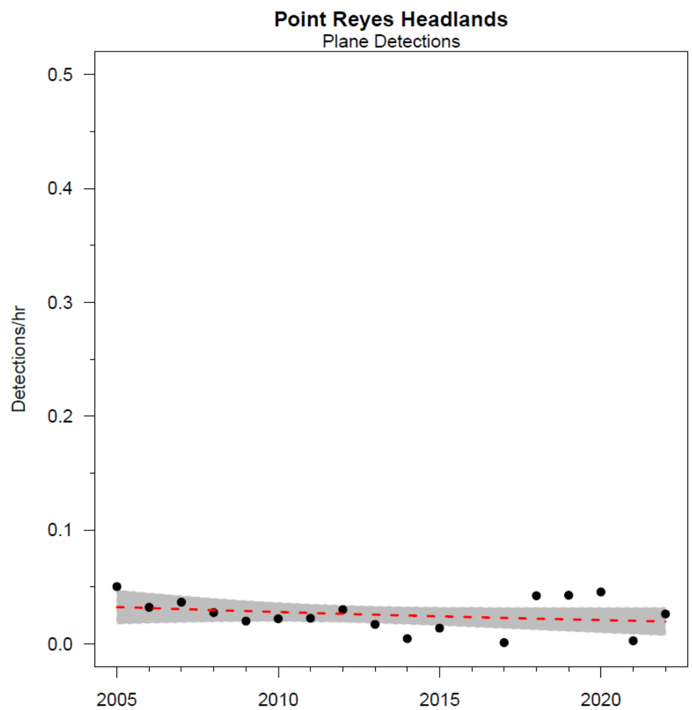
Use	Kayak/Canoe (<25')	Paddleboard (<25')	Total
Private/Recreational	1	1	2
Total	**1**	**1**	**2**

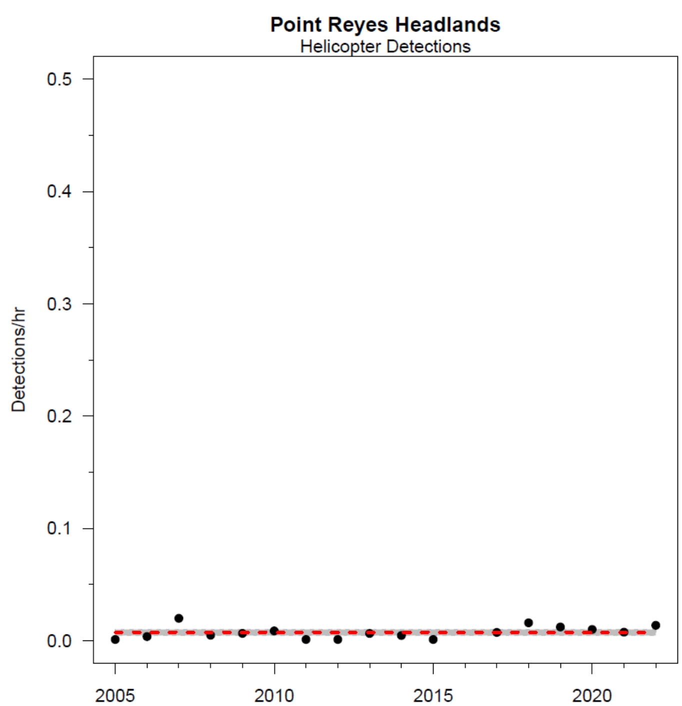
Appendix 3. Trends in anthropogenic detection rates, disturbance rates, and annual rates of change at Point Reyes Headlands, 2005-2022. The left column shows rates and their trendlines based on generalized linear models. The right column displays the percent annual change in detection or disturbance rates. Percent annual changes are shown only if the relationships are statistically significant, with 95% confidence intervals that do not bound 0. Red dots indicate increasing rates, whereas blue dots indicate decreasing rates. Missing dots are not statistically significant.

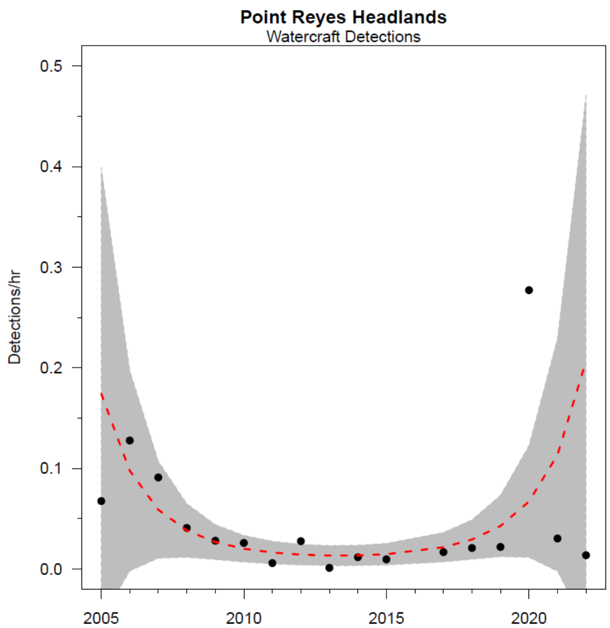


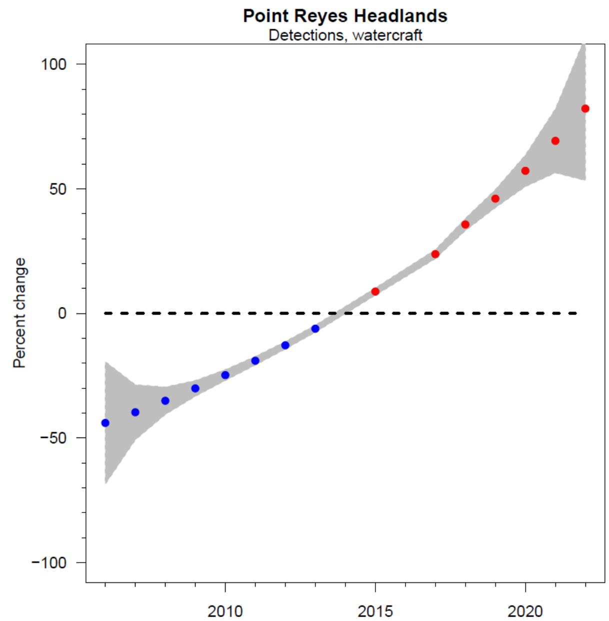


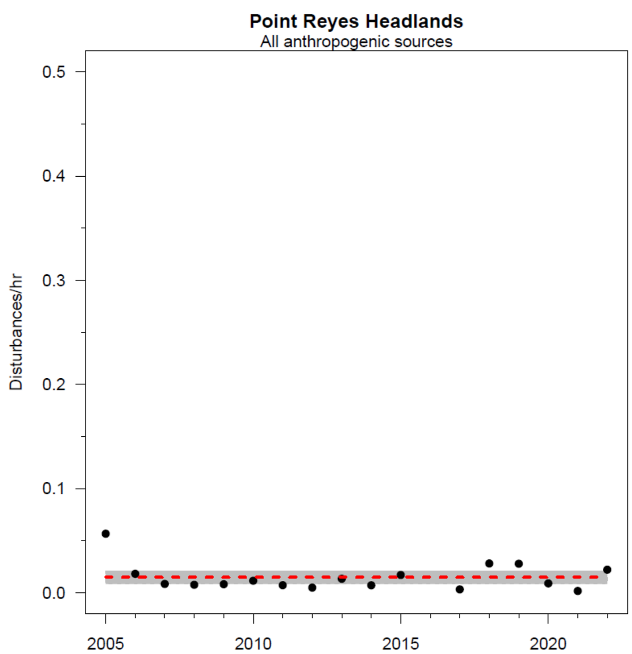


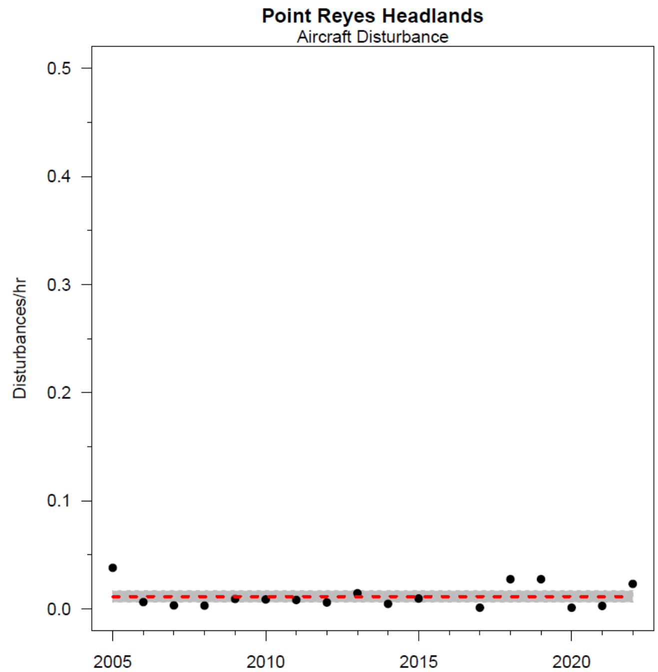

Point Reyes Headlands
Plane Detections
Detections/hr
0.5
0.4
0.3
0.2
0.1
0.0
2005
2010
2015
2020


Point Reyes Headlands
Helicopter Detections
Detections/hr
0.5
0.4
0.3
0.2
0.1
0.0
2005
2010
2015
2020

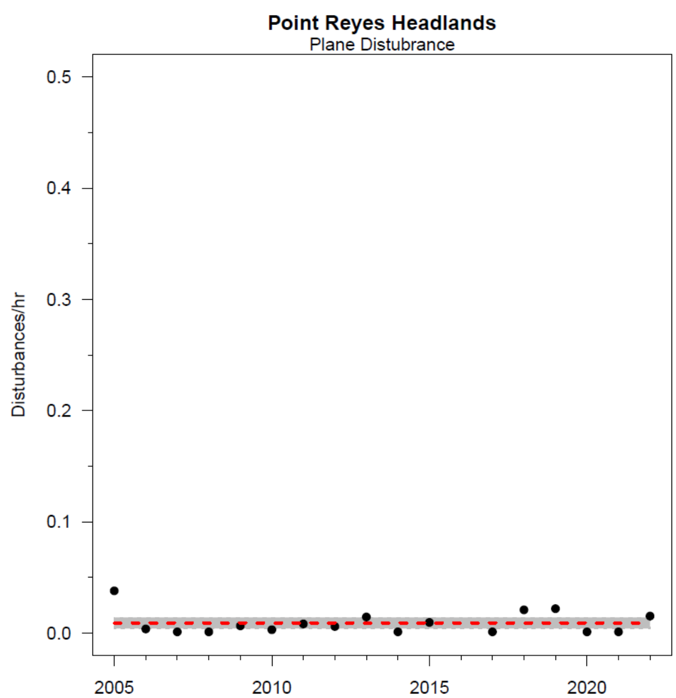

Point Reyes Headlands
Watercraft Detections
Detections/hr
0.0
0.1
0.2
0.3
0.4
0.5
2005
2010
2015
2020


Point Reyes Headlands
Detections, watercraft
Percent change
100
50
0
−50
−100
2010
2015
2020

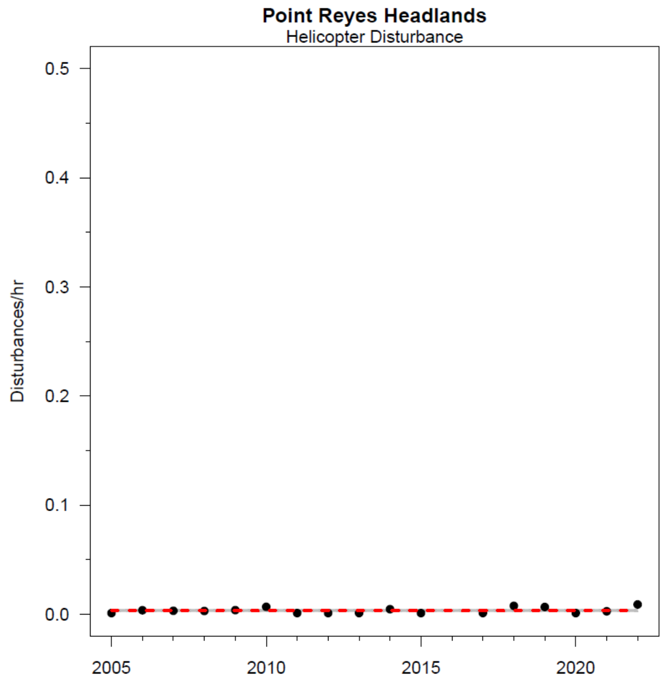

Point Reyes Headlands
All anthropogenic sources
Disturbances/hr
0.0
0.1
0.2
0.3
0.4
0.5
2005
2010
2015
2020

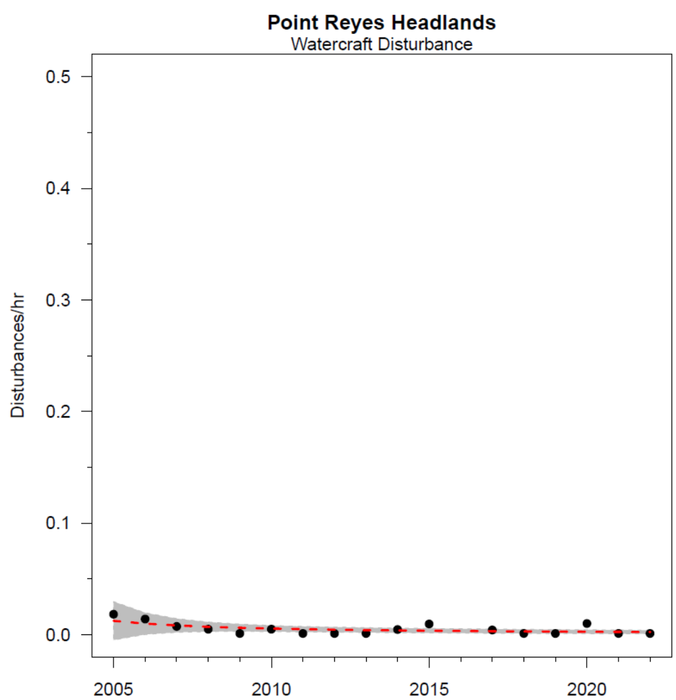


Point Reyes Headlands
Aircraft Disturbance
Disturbances/hr
0.5
0.4
0.3
0.2
0.1
0.0
2005
2010
2015
2020

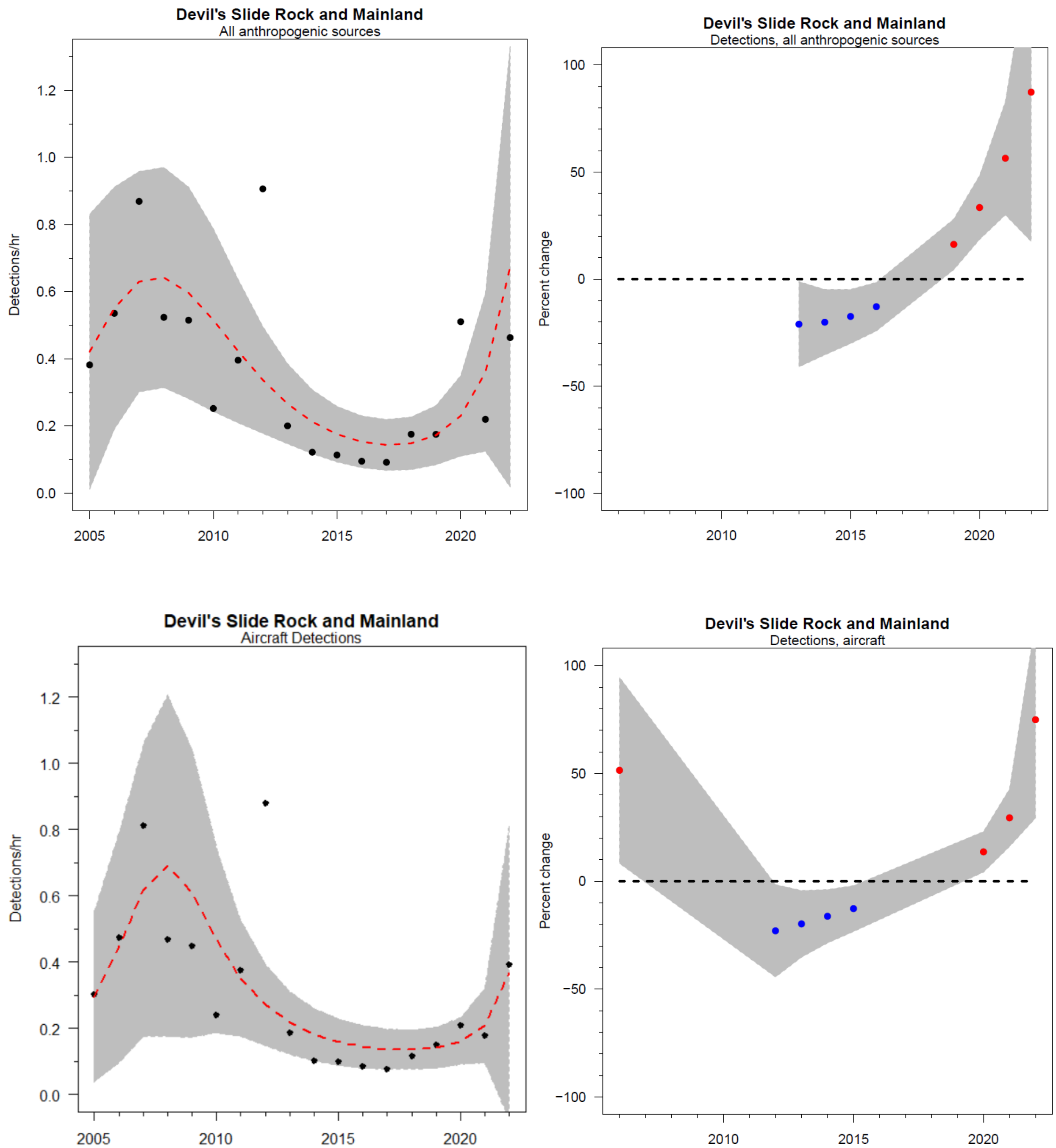


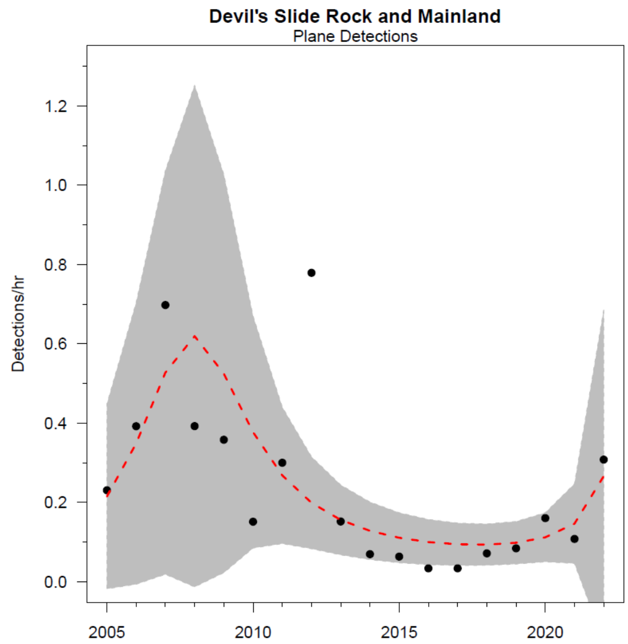
Point Reyes Headlands
Plane Distubrance
Disturbances/hr
0.5
0.4
0.3
0.2
0.1
0.0
2005
2010
2015
2020

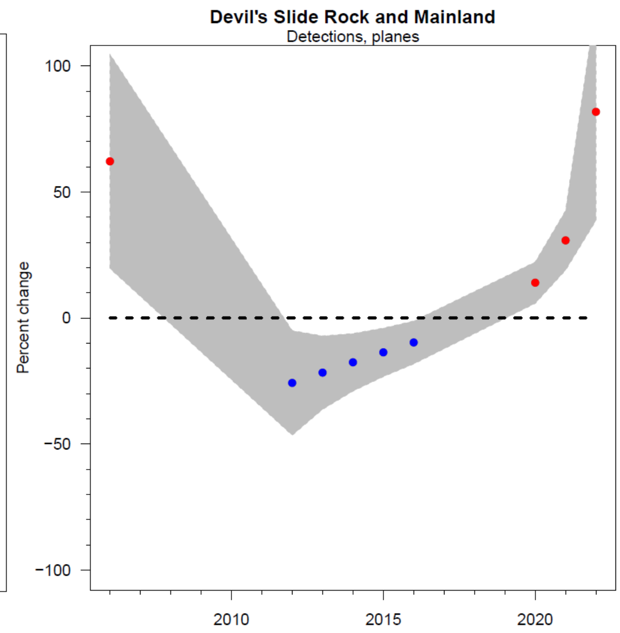

Point Reyes Headlands
Helicopter Disturbance
Disturbances/hr
0.5
0.4
0.3
0.2
0.1
0.0
2005
2010
2015
2020

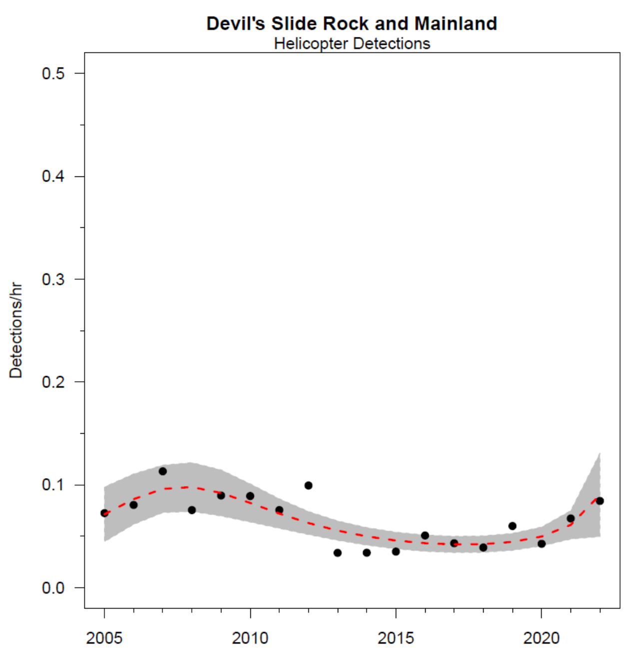

Point Reyes Headlands
Watercraft Disturbance
Disturbances/hr
0.5
0.4
0.3
0.2
0.1
0.0
2005
2010
2015
2020

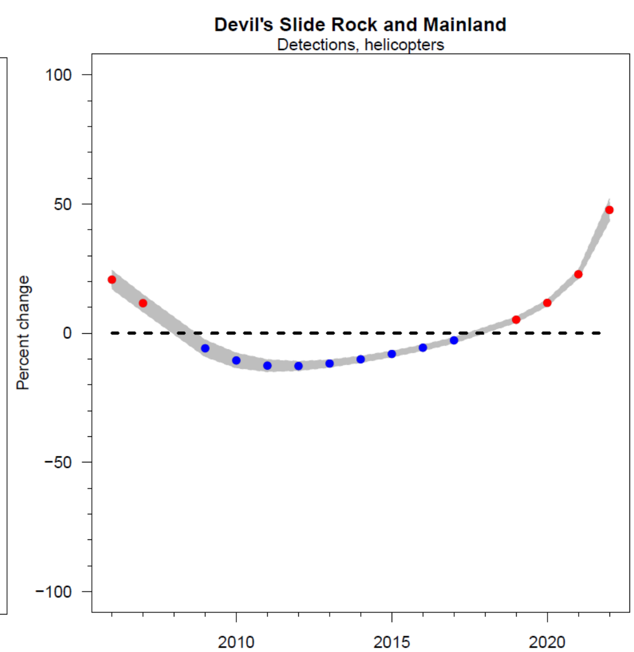
Appendix 4. Trends in anthropogenic detection rates, disturbance rates, and annual rates of change at Devil's Slide Rock & Mainland, 2005-2022. The left column shows rates and their trendlines based on generalized linear models. The right column displays the percent annual change in detection or disturbance rates. Percent annual changes are shown only if the relationships are statistically significant, with 95% confidence intervals that do not bound 0. Red dots indicate increasing rates, whereas blue dots indicate decreasing rates. Missing dots are not statistically significant.

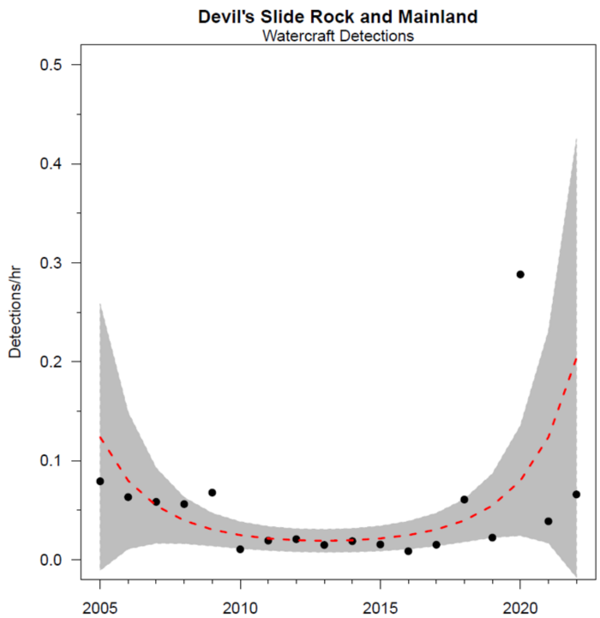


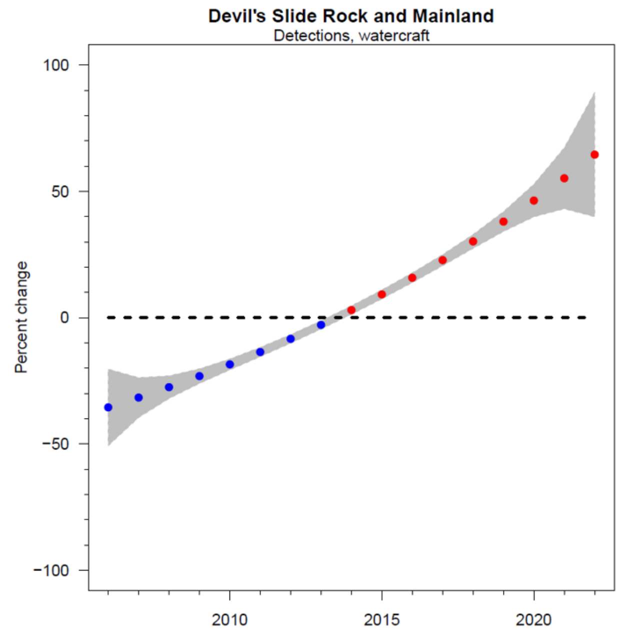

Devil's Slide Rock and Mainland
Plane Detections
Detections/hr
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2005
2010
2015
2020

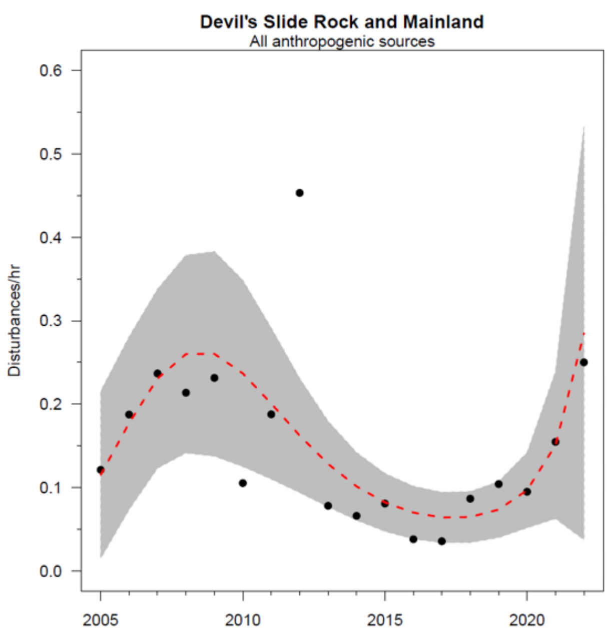

Devil's Slide Rock and Mainland
Detections, planes
Percent change
100
50
0
−50
−100
2010
2015
2020

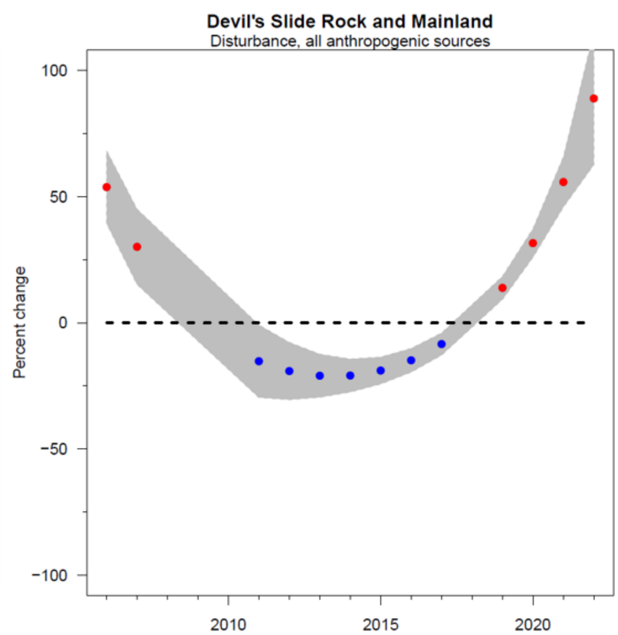

Devil's Slide Rock and Mainland
Helicopter Detections
Detections/hr
0.5
0.4
0.3
0.2
0.1
0.0
2005
2010
2015
2020

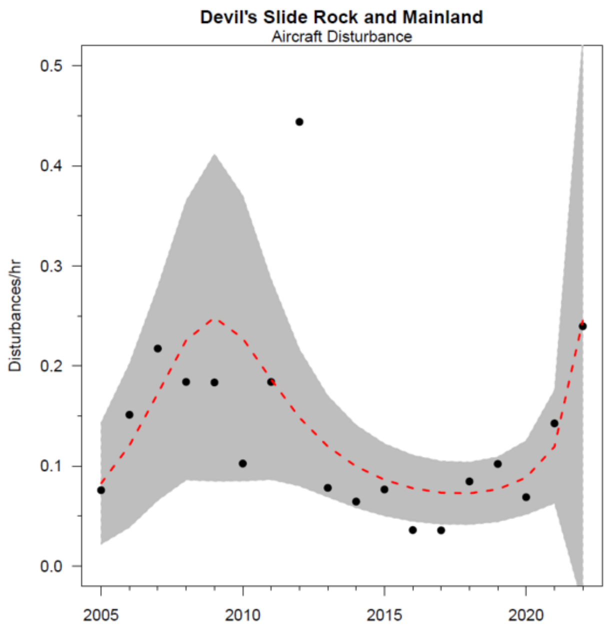

Devil's Slide Rock and Mainland
Detections, helicopters
Percent change
100
50
0
−50
−100
2010
2015
2020

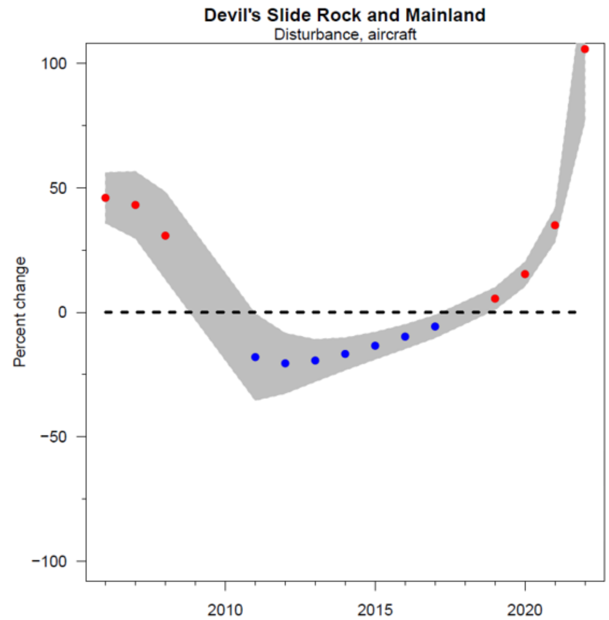

Devil's Slide Rock and Mainland
Watercraft Detections
Detections/hr
0.0
0.1
0.2
0.3
0.4
0.5
2005
2010
2015
2020

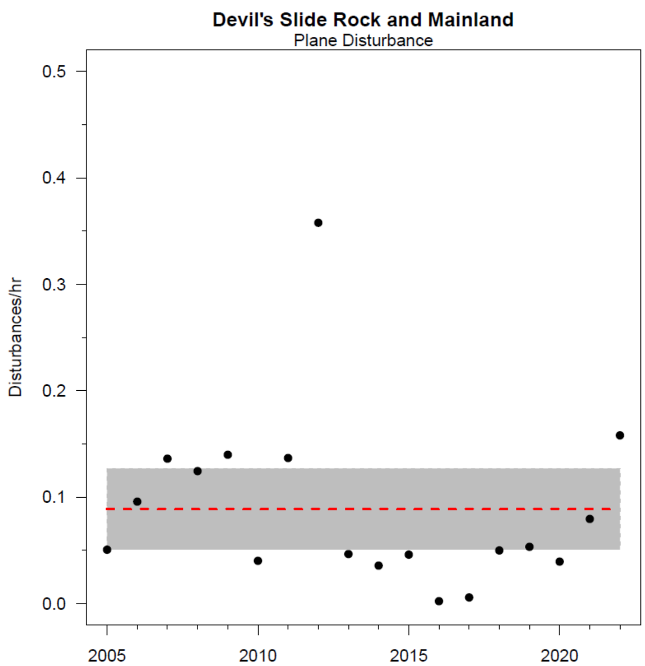

Devil's Slide Rock and Mainland
Detections, watercraft
Percent change
−100
−50
0
50
100
2010
2015
2020

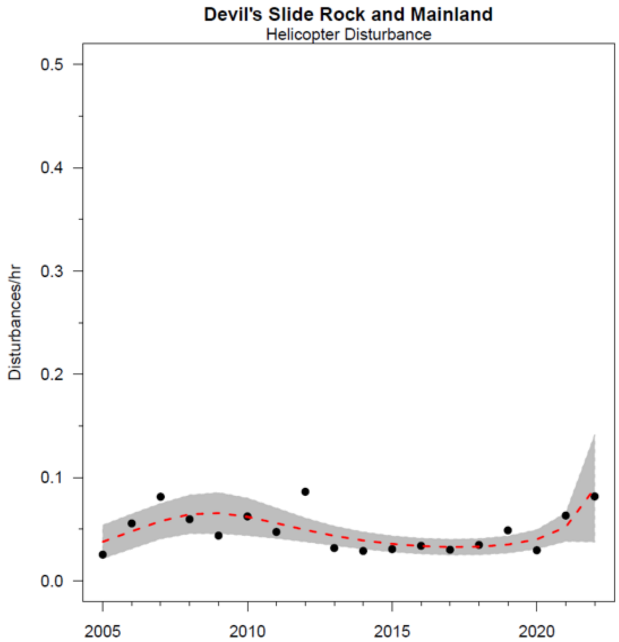

Devil's Slide Rock and Mainland
All anthropogenic sources
Disturbances/hr
0.0
0.1
0.2
0.3
0.4
0.5
0.6
2005
2010
2015
2020

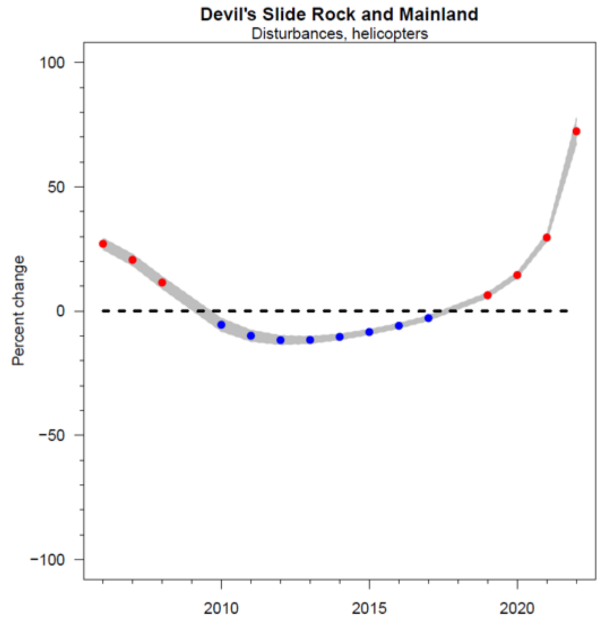

Devil's Slide Rock and Mainland
Disturbance, all anthropogenic sources
Percent change
−100
−50
0
50
100
2010
2015
2020

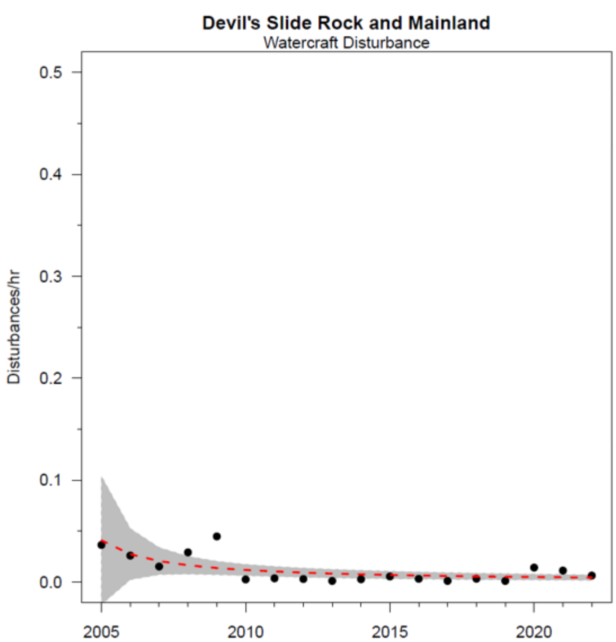

Devil's Slide Rock and Mainland
Aircraft Disturbance
Disturbances/hr
0.0
0.1
0.2
0.3
0.4
0.5
2005
2010
2015
2020

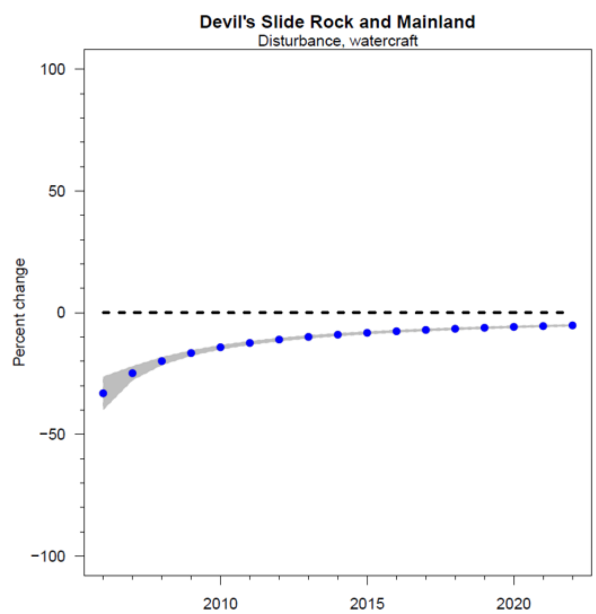

Devil's Slide Rock and Mainland
Disturbance, aircraft
Percent change
100
50
0
−50
−100
2010
2015
2020


Devil's Slide Rock and Mainland
Plane Disturbance
Disturbances/hr
0.0
0.1
0.2
0.3
0.4
0.5
2005
2010
2015
2020


Devil's Slide Rock and Mainland
Helicopter Disturbance
Disturbances/hr
0.5
0.4
0.3
0.2
0.1
0.0
2005
2010
2015
2020


Devil's Slide Rock and Mainland
Disturbances, helicopters
Percent change
100
50
0
−50
−100
2010
2015
2020


Devil's Slide Rock and Mainland
Watercraft Disturbance
Disturbances/hr
0.5
0.4
0.3
0.2
0.1
0.0
2005
2010
2015
2020


Devil's Slide Rock and Mainland
Disturbance, watercraft
Percent change
100
50
0
−50
−100
2010
2015
2020