ESTIMATING SPACE SHARING BETWEEN SEABIRD, PINNIPED, AND HUMAN USE IN THE NORTHERN CALIFORNIA COAST

By

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ABSTRACT

ESTIMATING SPACE SHARING BETWEEN SEABIRD, PINNIPED AND HUMAN USE IN THE NORTHERN CALIFORNIA COAST

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Rocky coastlines incur high impacts from human use, but these places are also essential habitat for marine wildlife including seabirds and pinnipeds (seals and sea lions). Marine wildlife use coastal rocks to breed, rest, and engage in social interaction and exhibit different habitat use during the breeding and non-breeding season. Peak timing of human use occurs in spring summer, coinciding with breeding seasons for colonial seabirds and gregarious pinnipeds. The high potential of spatial and temporal overlap between human and seabird use of rocky coastlines could lead to high risk of disturbance events. I investigated the relative risk of disturbance to 8 species of marine wildlife including Brandt's Cormorant *(Phalacrocorax penicillatus)*, Double-crested Cormorant *(Phalacrocorax auritus)*, Pelagic Cormorant (*Phalacrocorax pelagicus*), Western Gull *(Larus occidentalis)*, Black Oystercatcher *(Haematopus bachmani)*, Pacific Harbor Seal *(Phoca vitulina)*, California Sea Lion *(Zalophus californianus)*, and Steller Sea Lion *(Eumetopias jubatus)* from varying types of human use to inform science-based cooperative management in areas where humans and wildlife overlap. I estimated space sharing between marine wildlife and human use activities using spatial overlap methods, specifically using the volume of intersection (VI) test statistic in Trinidad, California.

Results of this project identified areas of varying levels of spatial overlap between seabirds, pinnipeds and varying types of human use (including consumptive and motorized activities). The species exhibiting the most space sharing with human use were Western Gulls with a VI score of .741 ± .058, while the least amount of space sharing with human use were Steller Sea Lions with a VI score of .0283 ± .0016. Human use also varied among the study area, with more consumptive and motorized activity in the northern study extent, and more non-consumptive (recreational) use and non-motorized activity in the southern study extent. This project provided an assessment of the volume of intersection index as a spatial tool for identifying specific user groups for education, disturbance risk assessment, outreach and enforcement for marine wildlife protection.

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INTRODUCTION

Coastlines incur high impacts from human use that are greater than most other marine ecosystems (Halpern et al. 2008). Human uses of rocky coastlines include fishing, development, ecotourism, outdoor recreation, non-point-source pollution, boating and other activities (Table 1). Coastal rocky habitats are also essential for many species of marine wildlife including seabirds and pinnipeds (seals and sea lions), which use coastal rocks to breed, rest, and interact socially (Mulder 2011, Jansen et al. 2015). Seabirds and pinnipeds, collectively referred to as “marine wildlife”, are apex predators in the marine environment, and indicators of local and regional oceanic health and changes in productivity and prey availability (Cairns 1988, Cury et al. 2011, Paleczny et al. 2015). Consequences of human use in the coastal environment include displacement of and disturbance to marine wildlife (Boyle and Samson 1985). Human-caused disturbance in the context of this project was any anthropogenic activity that resulted in a change in behavior or physiology that may negatively affect an individual’s fitness. Disturbance *risk* was defined as the potential for a disturbance event to occur, and *realized* disturbance was defined as an observed disturbance event.

Table 1. Regionally-specific coastal human use activities that may pose a disturbance risk to marine wildlife.

Observed human use activity	Activity location
Recreational boating	at-sea
Recreational boating - actively fishing	at-sea
Recreational kayaking	at-sea
Kayaking - actively fishing	at-sea
Commercial Fishing Vessel	at-sea
Commercial Fishing Vessel actively fishing	at-sea
Surfing / stand-up paddle boarding	at-sea
Aircraft (plane / helicopter/ drone)	in-air
Hiking/tide pooling on islands	shore-based
Freediving/SCUBA/snorkeling/fishing from shore	shore-based
Off-leash Dog	shore-based

Seabirds in general are globally threatened and declining rapidly, and human disturbance is a major threat to nesting success (Croxall et al. 2012, Paleczny et al. 2015). Coastal nesting and roosting seabirds are particularly sensitive to human activity, and they will often flush following disturbance events (Carney and Sydeman 1999). A disturbance event can result in short-term relocation or permanent nest abandonment, which may increase the likelihood of predation events (Conover and Miller 1979, Hockin et al. 1992, Carney and Sydeman 1999). Although long-term impacts are difficult to quantify on a population level, the accumulation of physiological responses to stressful stimuli like human-caused disturbance events can lead to fitness consequences on an individual level (Walker 2005, Gill 2007).

Many species of pinnipeds also experience a wide range of threats, including human disturbance to available haul-out space used for breeding behaviors (Sullivan 1980*a*, Sydeman and Allen 1999). Similarly, negative effects of disturbance to essential pinniped life history behaviors include permanent pup separation, physiological distress, interference with thermoregulatory processes such as molting, and permanent abandonment of otherwise suitable habitat (Fancher 1979, Jansen et al. 2015). The extent of behavioral response to disturbance varies among species and depends on the type, severity and frequency of the event. Evaluating the types of human use that can lead to disturbance of seabird and pinniped populations, and identifying the regionally specific areas of disturbance risk may aid in management and enforcement of marine wildlife space use on the coast.

Table 2. List of study species, with relative relevance and regional significance (NCSPN = North Coast Seabird Protection Network)

Species	Ecological Value	Reported Disturbance Threshold	Breeding within study area?
Brandt's Cormorant	Indicate changes in regional fish assemblages, anomalies in the California Current food web, and are linked to interannual climate variability indices [1,2,3]	**50-100m**[4]	Yes
Double-crested Cormorant	May serve as local indicators of pollutants in the environment[5,6]	**50-100m**[4]	Yes
Pelagic Cormorant	Stable isotope analysis from this species can be used to understand trophic relationships[7]	**50-100m**[4]	Yes
Western Gull	Relative rarity with total population of ~40,000 pairs nesting < 200 colony sites[8]	**100-180m**[4]	Yes

Species	Ecological Value	Reported Disturbance Threshold	Breeding within study area?
Black Oystercatcher	Keystone species along the rocky coastline and is an indicator of the health of an intertidal ecosystem[9]	"highly susceptible to human-induced disturbance"[10]	Yes
Pacific Harbor Seal	Indicate contamination of the marine food chain, and of the local ecosystem due to bioaccumulation [11,12]	Non-power boat: **<0-100m**, Power boat: **<0-100m**[13, 14]	Yes
California Sea Lion	Top consumer and important role in marine community, and an indicator of ocean health[15]	highly variable, contingent on region. **~40m**[16,17]	No
Steller Sea Lion	Critical habitat designation in Humboldt County[18,19], Western U.S. stock is listed as endangered under the ESA and designated as depleted under the MMPA[20]	"react strongly to direct boat approaches, aircraft disturbance contingent on height" [21]	Yes

(Ainley et al. 2018)[1], (Elliott et al. 2015)[2], (Ainley et al. 1995)[3], (Carney and Sydeman 1999)[4], (Derby and Lovvorn 1997)[5], (Vermeer and Rankin 1984)[6], (Piatt et al. 1990)[7], (Pierotti and Annett 1995)[8], (Tessler et al. 2007)[9], (Andres and Falxa 1995)[10], (Ross 2000)[11], (Mössner and Ballschmiter 1997)[12], (Allen et al. 1984)[13], (Schneider and Payne 1983)[14], (Hawes 1983)[15], (Riedman 1990)[16], (French et al. 2011)[17], (Sullivan 1980*a*)[18], (NOAA Fisheries West Coast n.d.)[19], (National Marine Fisheries Service and National Oceanic and Atmospheric Administration 1993)[20], (Kucey 2005)[21]

California marine wildlife exhibit patterns in phenology, with slight shifts in timing across a latitudinal gradient (Figure 1). In seabirds and pinnipeds, habitat use varies by season: the summer breeding (nesting/pupping) and winter non-breeding (roosting/haul-out) season, respectively. Seasonality in attendance is influenced by oceanographic patterns, which can influence prey availability, and varying levels of care for chicks and pups.

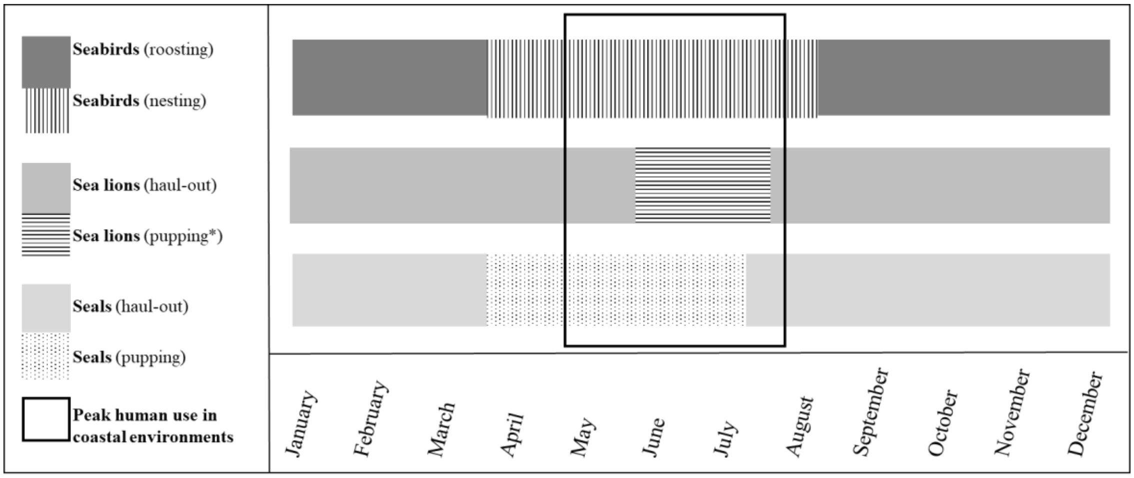

Figure 1. Seasonal variation in habitat use in marine wildlife in the study area. Peak human use and marine wildlife use coincide in the summer months (nesting/pupping for seabirds and pinnipeds respectively). *California Sea Lion pupping occurs in the Channel Islands in southern California.

Seasonality of Marine Wildlife

Peak regional oceanic productivity is typically the spring and summer months, when upwelling yields increased prey availability for marine wildlife (Cury et al. 2011). Regional marine wildlife generally rely on prey that benefit from coastal upwelling via Ekman transport to bring cold nutrient-rich water to the surface (Croll et al. 1998, Sydeman and Allen 1999). This process creates highly productive conditions, which provide food resources for both seabirds and pinnipeds. This seasonal abundance of food resources is thought to be extensively used for feeding offspring, storing fat and molting (Croll 1990).

Peak timing of human use on the coast also occurs in the late spring and summer months when mild weather and ocean conditions correspond with peak colony attendance of many coastal seabirds, and pupping seasons of pinnipeds (Ainley and Boekelheide 1990, Kildow et al. 2005, Dwight et al. 2007). California residents are particularly involved in coastal recreation compared to elsewhere in the United States, with more than 4 million residents participating in boating recreation activities in a single year, and up to 378 million annual beach visits by recreationists (Kildow et al. 2005). The high potential for spatial and temporal overlap between human and seabird use of rocky coastlines (especially in the summer months) could lead to high risk of disturbance events.

Marine wildlife abundance is often lower (due to seasonal variation in distribution) during the non-breeding season in fall and winter (Bartholomew and Boolootian 1960, Croll 1990). Lower abundance can be explained by the lack of obligation to a breeding site, allowing adults to forage further from shore for extended periods of time on more ephemeral prey patches, and terrestrial habitat use transitions to roosting and haul out behavior (Croll 1990). Thermoregulatory requirements for seabirds are sensitive and influence the ability of an individual to properly allocate behaviors in an activity budget. At the extreme, inadequate thermoregulation can lead to mortality (Walsberg 1986). Human disturbance can negatively impact daily energy budgets for pinnipeds during the non-breeding season (Schneider and Payne 1983). Undisturbed and adequate roosting and haul-out time for amphibious marine wildlife can be essential for survival during the non-breeding season.

Utilization Distributions and Space Sharing

To evaluate disturbance risk from humans to marine wildlife, I investigated space use for each marine wildlife species and human use activity listed in Table 1. Utilization distributions are a common measure to describe space use and activity, and several approaches are available for area estimation. Kernel density estimation (KDE) is a probabilistic description of where an animal uses space (Dixon and Chapman 1980, Worton 1989). KDEs are commonly used to identify an animal's home range (Seaman and Powell 1996). In this project, I used kernel density estimation at a population-level to characterize wildlife species and human use within an area. Typically, KDE's are created at an individual level, but I aggregated points at a population-level. This atypical use of kernel density estimation was appropriate for this study, as more individuals using a site represented more spatially explicit points on an area, thus creating a wider kernel. I used

KDEs and spatial overlap analysis as tools to evaluate risk to marine wildlife from human use.

Spatial analysis that estimates space sharing between two species has been used in terrestrial ecology to evaluate interspecies relationships, including wildlife and human interactions (Millspaugh et al. 2000). In order to evaluate the relative disturbance risk to marine wildlife from human use, I conducted a spatial overlap analysis using the volume of intersection (VI) test statistic (Fieberg and Kochanny 2005). This method allowed relative comparison of risk across species and human use types and identification of "hotspots" of risk via overlay of the home range estimates using utilization distributions. Greater space-sharing suggested higher disturbance risk to marine wildlife, and less sharing may have indicated a lower risk of disturbance.

Goals and Objectives

In order to guide local management efforts to reduce and mitigate coastal marine wildlife disturbance, spatial and temporal relationships between human use and marine wildlife use areas must be understood. The goals of this project were to identify targeted management areas on the Humboldt County coastline and to assess disturbance risk based on seasonal use patterns to help target specific user groups for education, outreach and enforcement for marine wildlife protection. The analytical approach described and applied here may be broadly applicable to other situations where a quantitative approach to measuring disturbance risk is needed for management. The objectives were to (1) identify species-specific marine wildlife breeding and non-breeding habitat and human use areas (2) create population-level utilization distributions for marine wildlife and human activities in the summer season and (3) identify areas of overlap between marine wildlife and humans in the summer season and investigate overlap shifts by human use activity.

Management Implications and Partners

The indices produced from this project can inform management by identifying which user groups to target for education and outreach to minimize potential disturbance to marine wildlife, especially during critical life history events like breeding (Tessler et al. 2014). The relative amount of spatial overlap between marine wildlife and humans indicates the level of space sharing and relative disturbance risk. A high volume of intersection score may indicate high relative risk of disturbance, and a low volume of intersection score may indicate low relative risk of disturbance. Eco-tourists and recreational users are generally not aware of some negative impacts their presence has on wildlife and will likely modify their behavior voluntarily (Carney and Sydeman 1999). This project had a direct association and connection with local agencies and stakeholders focusing on conservation, monitoring and outreach programs. The outcome and methods of this project can be applied to other projects in areas lacking information on how to quantify the potential for interactions between sensitive wildlife and people and how to protect vulnerable aggregations of marine apex predators.

This project leveraged preexisting monitoring and conservation efforts by local northern California agencies and NGOs including the North Coast Seabird Protection

Network (NCSPN), California Department of Fish and Wildlife Marine Protected Areas, and the California Coastal National Monument - part of the Bureau of Land Management's National Landscape (BLM) Conservation System. During the California Marine Life Protection Act process of designating a network of California Marine Protected Areas (MPAs), no MPAs were included in the Trinidad area. Instead, in 2011, an alternative to special closures consisting of a community-based conservation program such as the Seabird Protection Network was identified as preferred. Data collection efforts were supplemented by past and current efforts by these local entities facilitated by the NCSPN. Results from this project directly tied in to tangible goals of these local agencies including management action plans, community involvement, and education and outreach efforts.

METHODS

Study Area

I defined my study area as 111 islands and surrounding seascape within 500 meters, an area of $12km^2$ from Moonstone Beach to Patrick's Point State Park (Figure 2). For purposes of surveying marine wildlife, I partitioned the study area into 9 sections, each containing 10-15 islands; I did not survey a 3.5km section of coast owing to limited public access (Figure 2). All sites were within the California Coastal National Monument boundary (Brinkman et al. 2018). Most sites in the study were relatively small (≤50m diameter), rocky, coastal islands and islets exposed at mean high tide, but some sites included beach, intertidal and rocky headlands attached to the mainland. Coastal rocks with historical names, or ancestral and cultural significance to the Yurok Tribe were represented when possible (Waterman 1920). Sites were selected based on the following criteria: (1) at least one marine wildlife species used the site for breeding (nesting/pupping) or non-breeding behavior (roosting/hauling-out) (2) the rocky outcropping or shoreline was observable from the mainland.

The spatial extent of this study included marine wildlife use of coastal islands and islets (rather than marine wildlife in the water) and human use along the coast (on islands and on the water). Though seabird and pinniped species forage and rest in the water, marine wildlife in the water were omitted from this study; instead, only behaviors of nesting, pupping, roosting and haul-out behavior on coastal rocks were recorded.

Narrowing the scope of the study to only include marine wildlife on coastal rocks allowed for more explicit space assessment of disturbance risk at key nesting, roosting, breeding and haul-out sites. Although areas beyond the coast, like the pelagic zone, play major roles in the life history of marine wildlife (Game et al. 2009), it was more practical and potentially beneficial to manage use of and disturbance at islands and islets close to shore than investigating all space used by marine wildlife and humans (Sale et al. 2005).

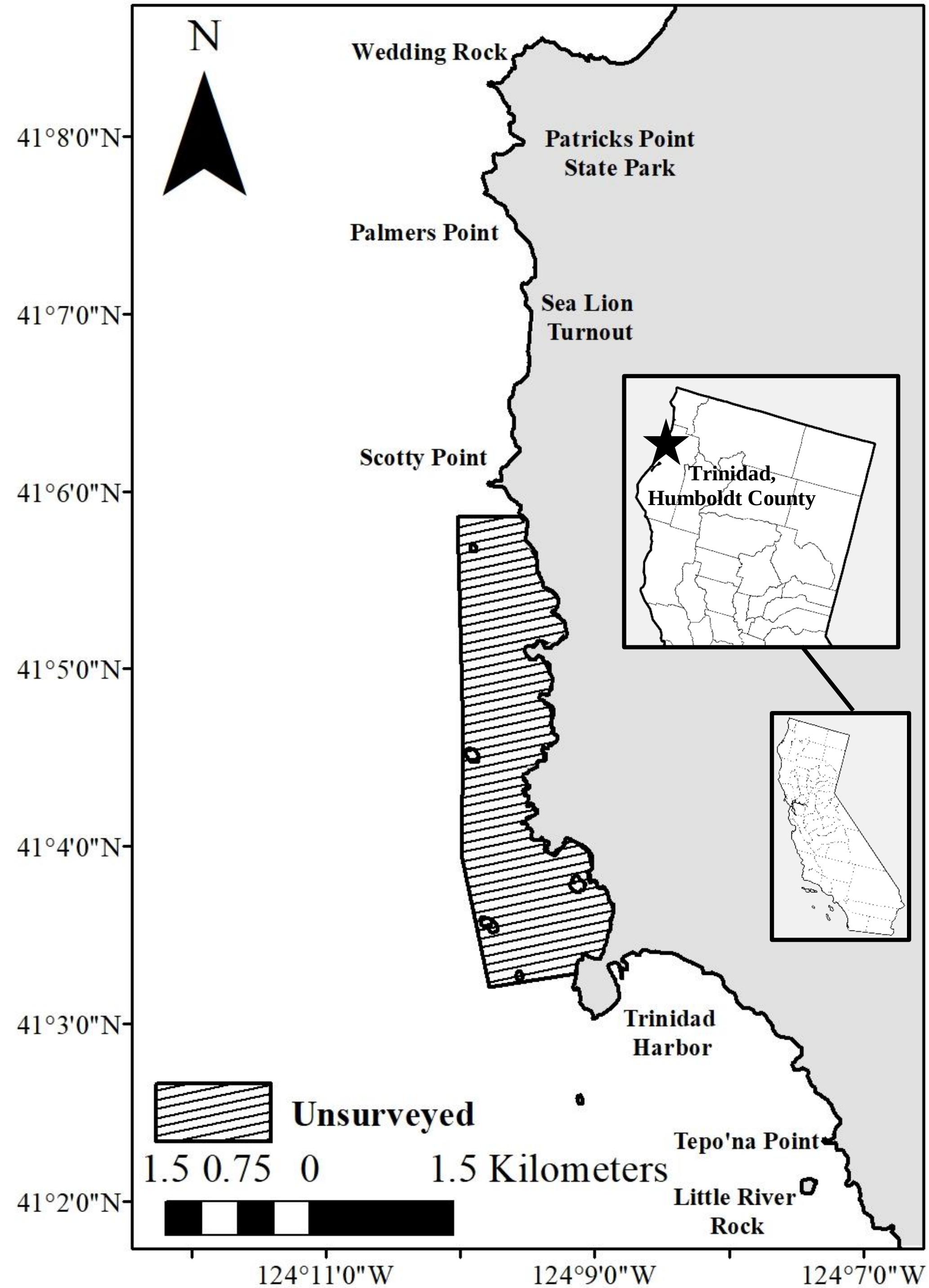

Figure 2. Overview of study area. Areas not surveyed were due to land ownership restrictions and access limitations.

Field Methods: Shore-Based and At-Sea

Shore-based surveys

Observers conducted surveys during the breeding (4 April 2018 – 18 July 2018) and non-breeding season (25 August 2018 – 14 January 2019). A survey consisted of an observer visiting either the northern (study areas 1-5) or southern study sites (study areas 6-9). Breeding season surveys included 25 total visits and non-breeding season surveys included 7 total visits (n=32). A "complete" survey was defined as a visit to every site in a single day (n=17). Surveys were used for kernel density estimation (n=32), and "complete" surveys were only summarized to assess general trends in attendance (n=17).

I adapted the field sampling protocol used by the North Coast Seabird Protection Network and Marine Life Protection Act Initiative (Robinette et al. 2014). During each survey, an observer arrived at an observation point and completed a scan survey. The observer recorded the species, total number of individuals, and relevant breeding behaviors of each individual. Sites had associated coordinates, which were used to assist in estimation of a utilization distribution (UD). Observers recorded time of day and weather conditions including wind speed, sea state, cloud cover and precipitation. In addition, the observer recorded mean tide height during a survey. Observers conducted surveys from 0700-1400 in an attempt to capture peak breeding and non-breeding abundance and use (Brinkman and Parrott 2017). Surveys did not include animals in the water traveling, resting or foraging. All marine wildlife surveys were collected under

Humboldt State University's Institutional Animal Care and Use Committee oversight protocols (16/17.W.57-E, date: January 13, 2017, and 17/18.W.88-E, date: June 27, 2018)

Similar to wildlife use surveys, observers concurrently monitored human use in the summer and winter season, totaling 35 surveys (32 surveys done alongside marine wildlife surveys, and 3 additional surveys within the study area). Human use was defined as any observable activity listed in Table 1, within 500 meters of a study site. Data collected from human use activity included location (Projection: Transverse Mercator, Datum: NAD 1983 UTM Zone 10N), type of activity, time, and type of vessel. Personal information such as CF number, number of passengers, any demographic information or name of vessel was not recorded. Human use data were collected under the approval of the Institutional Review Board at Humboldt State University (IRB #: 17-226, Date: June 04, 2018).

Geographic coordinates of human use activities were calculated by distances and angles captured from a theodolite application (Hunter 2009) by:

$$(\cos \theta_{c}) = \frac{A}{B} \qquad \text{(Eq. 1)}$$

where θ is the observed vertical angle, *A* is the known observer height, and *B* is the calculated distance from the observer to the boat (Figure 3). I used instantaneous scan sampling surveys to quantify human use activities and locations. I observed human use activities with a sampling frequency of two minutes within the bounds of the study site (Altmann 1974).

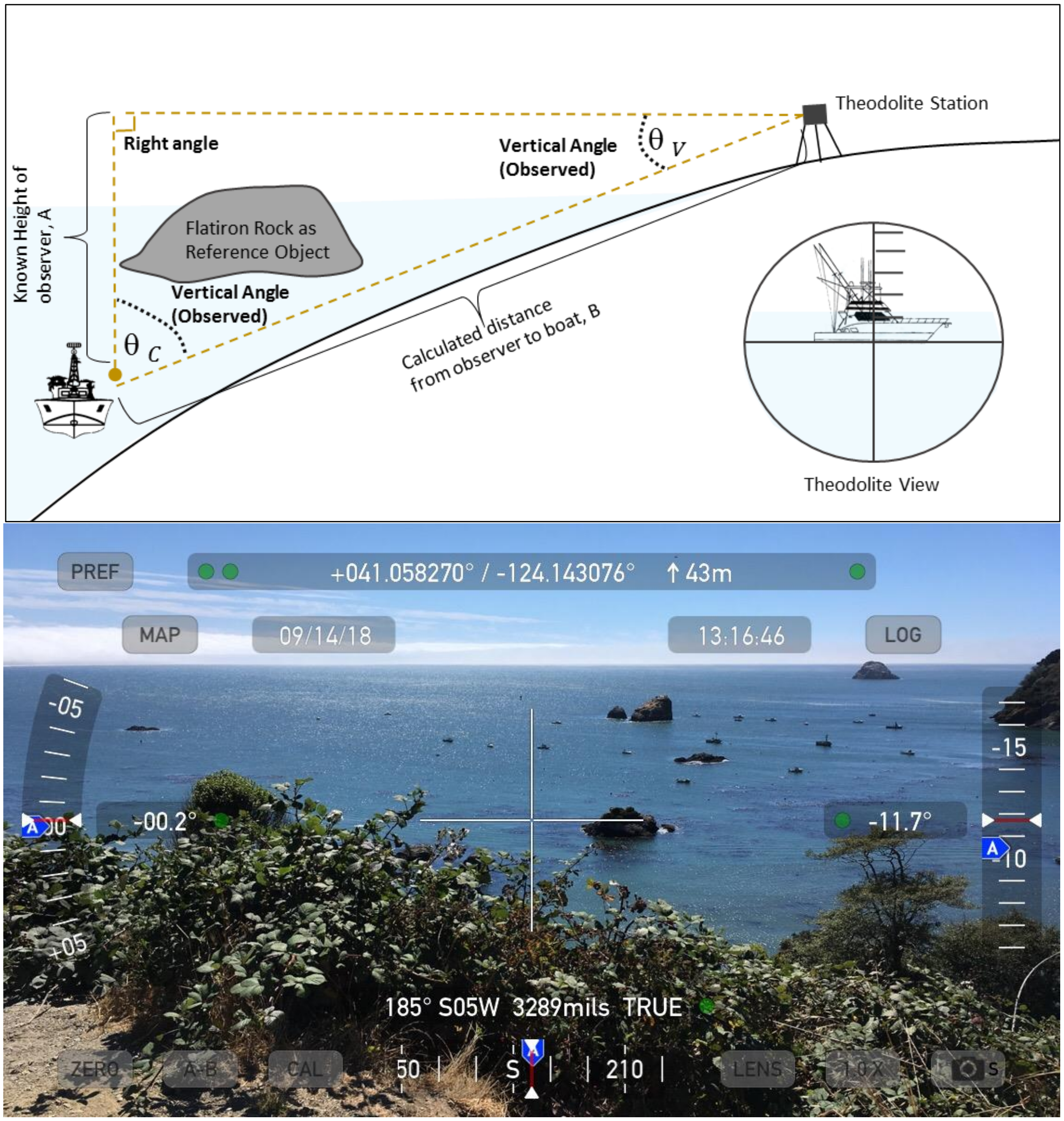

Figure 3. Theodolite application photo and representation of angles that the application calculates. When a boat was detected, the observer pointed the theodolite crosshairs at the target. The downwards tilt of the theodolite telescope provided a vertical angle. By combining the known height of the theodolite, and the vertical angle, the distance to the boat was calculated.

At-sea surveys

Four at-sea surveys were conducted on July 05 2018, July 25 2018, August 10 2018, and September 15 2018 to supplement observations from shore-based surveys, and to observe marine wildlife on the northwest-facing side of islands that could not be seen from shore. At-sea surveys reflected similar methods to shore-based monitoring effort, except observations were made at-sea and several photographs were taken opportunistically when conditions allowed safe access to a site. A boat operator positioned the vessel for the observer to record the species, number of individuals and behaviors from a distance without causing disturbance. Human use data were not collected during at-sea surveys due to complexity of the task and limited crew permitted on the research vessel. A summary of at-sea surveys is provided (Appendix), but none of the surveys were used in data analysis.

Analytical Methods

Marine wildlife and human locations and utilization distributions

Seabirds and pinnipeds chosen for this study were large and readily observable at the distances surveyed on the east-facing sides of islands, so I assumed a detection probability of one. A smaller number of at-sea surveys revealed very few individuals were undetected on shore-based surveys (Appendix). Relative probability of space use through utilization distributions (UD) and average seasonal abundance estimates were determined from shore-based surveys. I used a geographic information system (GIS) in ArcGIS version 10.5.1 (ESRI 2011) to collate data on the spatial distribution of marine wildlife and humans, which enabled estimation of UDs for species and the extent of spatial overlap. Kernel Density Estimates (KDE) were used to create a UD estimate for each species in the summer season (Worton 1989).

Typically UDs are created using information from methods like recapture, GPS, telemetry, triangulation or satellite. In this study, collecting marine wildlife information at the individual level was not possible, so I created population-level KDEs. I categorized human use into consumptive and non-consumptive activity for analysis (Table 3). These groups represent four different categories for which to evaluate disturbance risk. The first pair was motorized vessels and non-motorized vessels and the other pair of human use activities included consumptive vs non-consumptive use (Table 3). Human use activity information (consumptive/non-consumptive, motorized/non-motorized) was aggregated, so spatially explicit points were used to create UD estimates of each human use activity with one exception: humans surfing near Little River Rock (Figure 1). The coordinates used to create UDs at this site were extrapolated by assigning randomly distributed points equal to the number to the daily abundance estimates within a polygon where surfing and stand up paddling occurs (Figure 4).

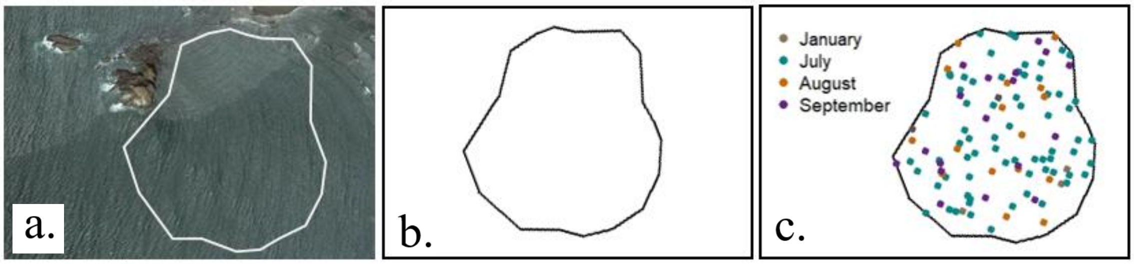

Figure 4. Randomly generated points within a constructed polygon using monthly counts were created to construct the Kernel Density Estimations for surfing and paddle boarding sports. a. satellite image of a study site; b. polygon shape created in ArcMap of bay; c. monthly randomly distributed points within polygon shape of study area (n=115).

Table 3. Observed human activity assigned into different categories based on vessel type and activity type to inform disturbance risk management and outreach effort.

Observed human use activity	Disturbance (vessel type)	Outreach (activity type)
Recreational boating	motorized	non-consumptive
Recreational boating - actively fishing	motorized	consumptive
Recreational kayaking	non-motorized	non-consumptive
Kayaking - actively fishing	non-motorized	consumptive
Commercial Fishing Vessel	motorized	consumptive
Commercial Fishing Vessel actively fishing	motorized	consumptive
Surfing / stand-up paddle boarding	non-motorized	non-consumptive
Aircraft (plane / helicopter)	motorized	non-consumptive
Hiking/tide pooling on islands	non-motorized	non-consumptive
Freediving/SCUBA/fishing from shore	non-motorized	consumptive
Off-leash Dog	non-motorized	non-consumptive

I created 50% and 95% adaptive bivariate kernel density estimates for each marine wildlife species and human use category using either the least-squares cross-validation methods (LSCV) and the reference bandwidth ("href") with the "adehabitatHR" package in R-studio (Calenge 2006). For each species, I selected a bandwidth (*h*) to produce biologically representative kernel density estimates of space use within the relevant scale of this study. For example, a bandwidth using h_{ref} for Western Gulls overestimated relative space use of terrestrial habitats when compared to LSCV methods (Figure 5). Kernel density estimations for each species were then clipped to only include probability of use within the study area – (i.e. excluding the surrounding landscape). Kernel density estimations were created with the sum of the number of breeding and non-breeding individuals of each species per season to account for consistency of marine wildlife use of a site.

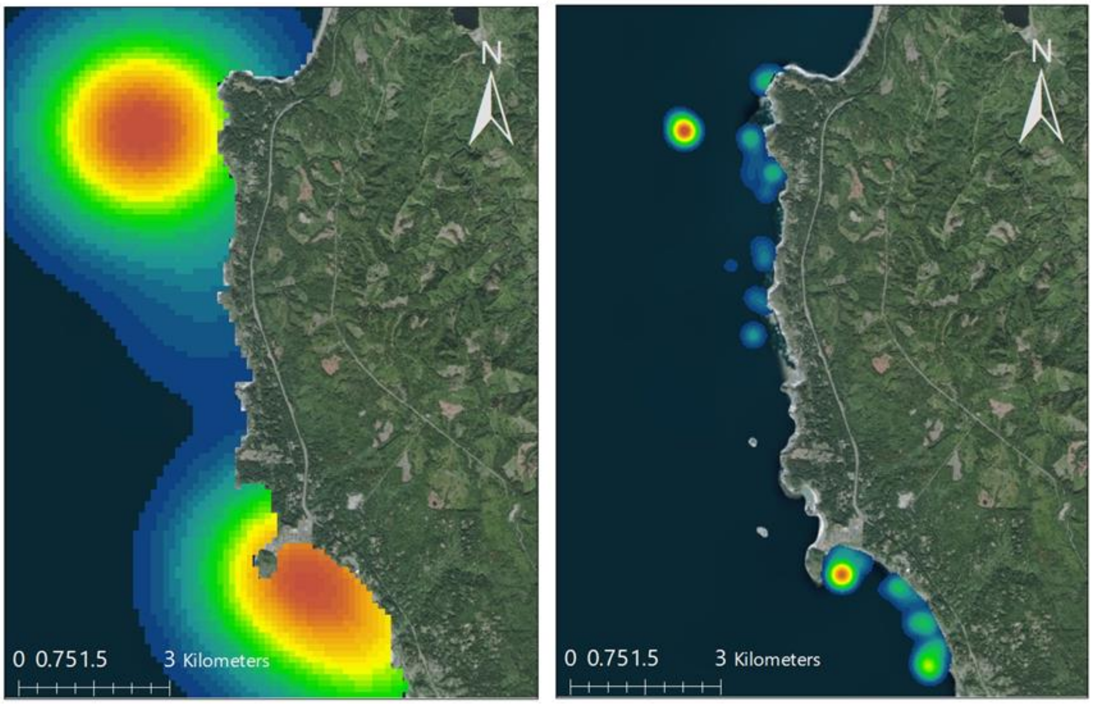

Figure 5. Validation for bandwidth method estimation using Western Gull kernel density estimation as an example. The left image uses href as a smoothing parameter and is a gross overestimation of realistic space use within the scale of this study, while the adjacent figure uses least square cross validation to calculate the smoothing factor and is more representative of Western Gull's use of nesting and roosting sites.

Space sharing analysis

Spatial overlap analysis of marine wildlife and human kernel density estimates assumed a static nature; that is, simultaneous observations of space use were not necessary to run the model. I used the volume of intersection statistic (VI) to quantify the potential overlap in space use between marine wildlife and humans (Fieberg and Kochanny 2005). The VI score uses UD estimates from both species (in this case marine wildlife and human activities) to estimate space sharing (Equation 2).

$$VI = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} min\left[\widehat{UD}_1(x,y), \widehat{UD}_2(x,y)\right] dxdy \qquad \text{(Eq. 2)}$$

The VI produces a value between zero and one, representing zero to complete overlap. I used the VI to investigate combinations of different states, including species and by human activity. Most applications of this test statistic are to simply describe the probability of home range overlap; however, in this study, I used the VI score as a metric to indicate the relative disturbance risk between marine wildlife use and human use at all sites. A higher score (closer to 1) suggests higher risk, and a lower score (closer to 0) indicates a smaller risk of disturbance to marine wildlife from human use.

Finally, to evaluate the sample variance of VI scores, I used a bootstrapping method with replacement, resampling the sampled days for 1000 iterations. Each iteration created a new KDE, using an input of sampled dates of complete surveys of the entire study extent (n=17). I used this bootstrapping to estimate confidence intervals and standard deviations of each VI index score. Due to limited winter season (n=7) and at-sea (n=4, Appendix) survey data, complete space sharing analysis was only conducted for the summer season.

RESULTS

Marine Wildlife Use

Observers recorded most marine wildlife during the summer season, with fewer observations during the winter season (Figure 6). Peak observed abundance of marine wildlife occurred on 5 June, 2018, with a total of 864 observed individuals throughout the entire the study area. The lowest abundance of marine wildlife occurred on 12 January, 2019 with a total of 180 individuals observed in the study area.

Spatial analysis included results from both complete and incomplete surveys (n=32), totaling 7825 locations during the summer season (Figure 7). Results are presented for two sections of the study area (northern sites and southern sites). Marine wildlife were dispersed throughout each surveyed area, with the exception of California Sea Lions and Steller Sea Lions, which were only observed at northern sites.

The 50% and 95% kernel density estimates were created for each species throughout the entire study area by summing total observations for the summer season (Table 4, Figures 8-10). Kernel density area varied by species, with Brandt’s Cormorants demonstrating the largest area of use, followed by Pelagic Cormorants and Black Oystercatchers; pinnipeds exhibited the smallest amount of space use.

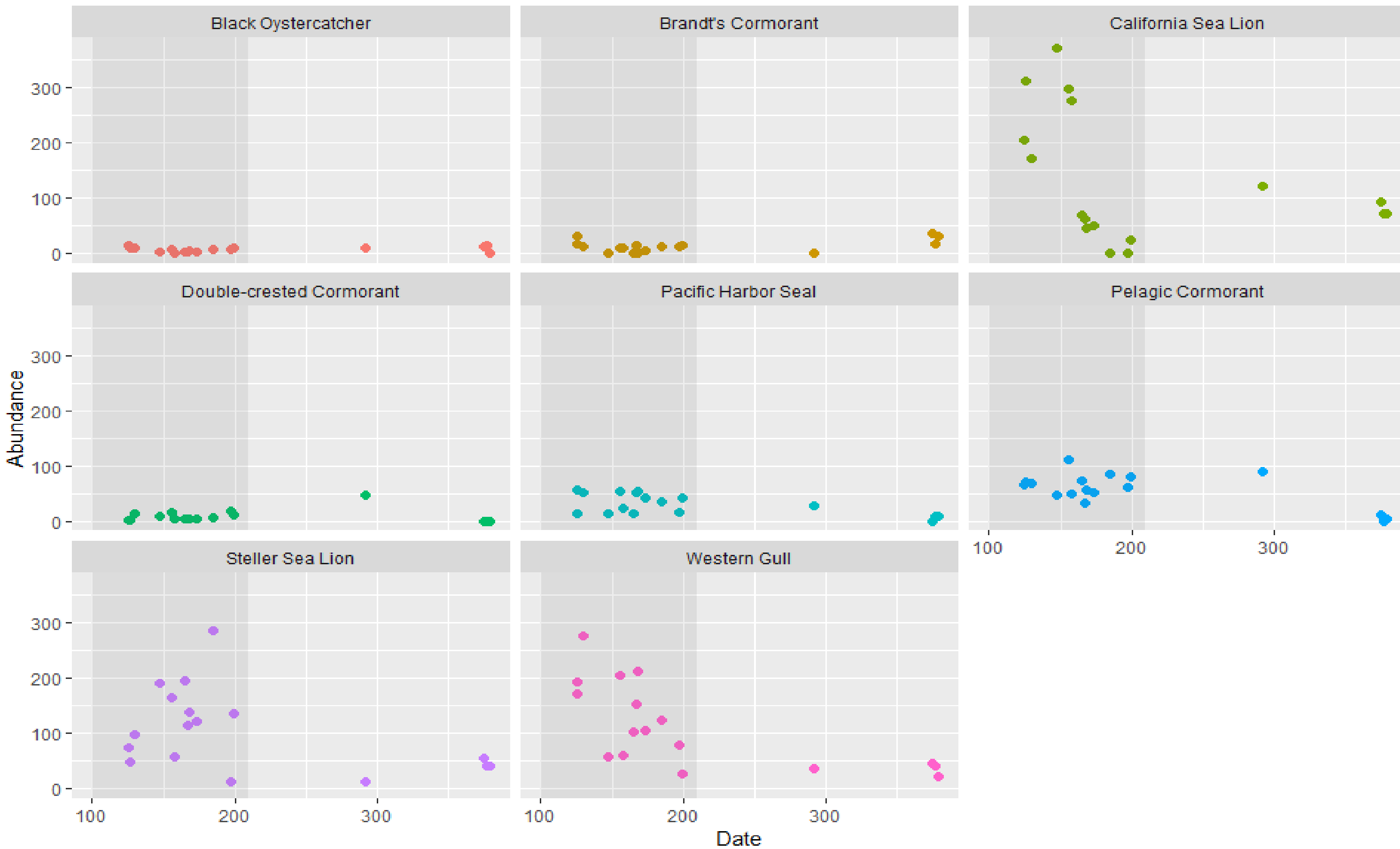

Figure 6. Observed abundance of marine wildlife species among the study area in the breeding and non-breeding seasons. The grey box represents the summer season (Julian Dates 100-213). Only complete surveys (n=17) are included in this plot, and abundance of each species was summed per day. Julian date of 110 corresponds to the start of the breeding season, 20 April, 2018.

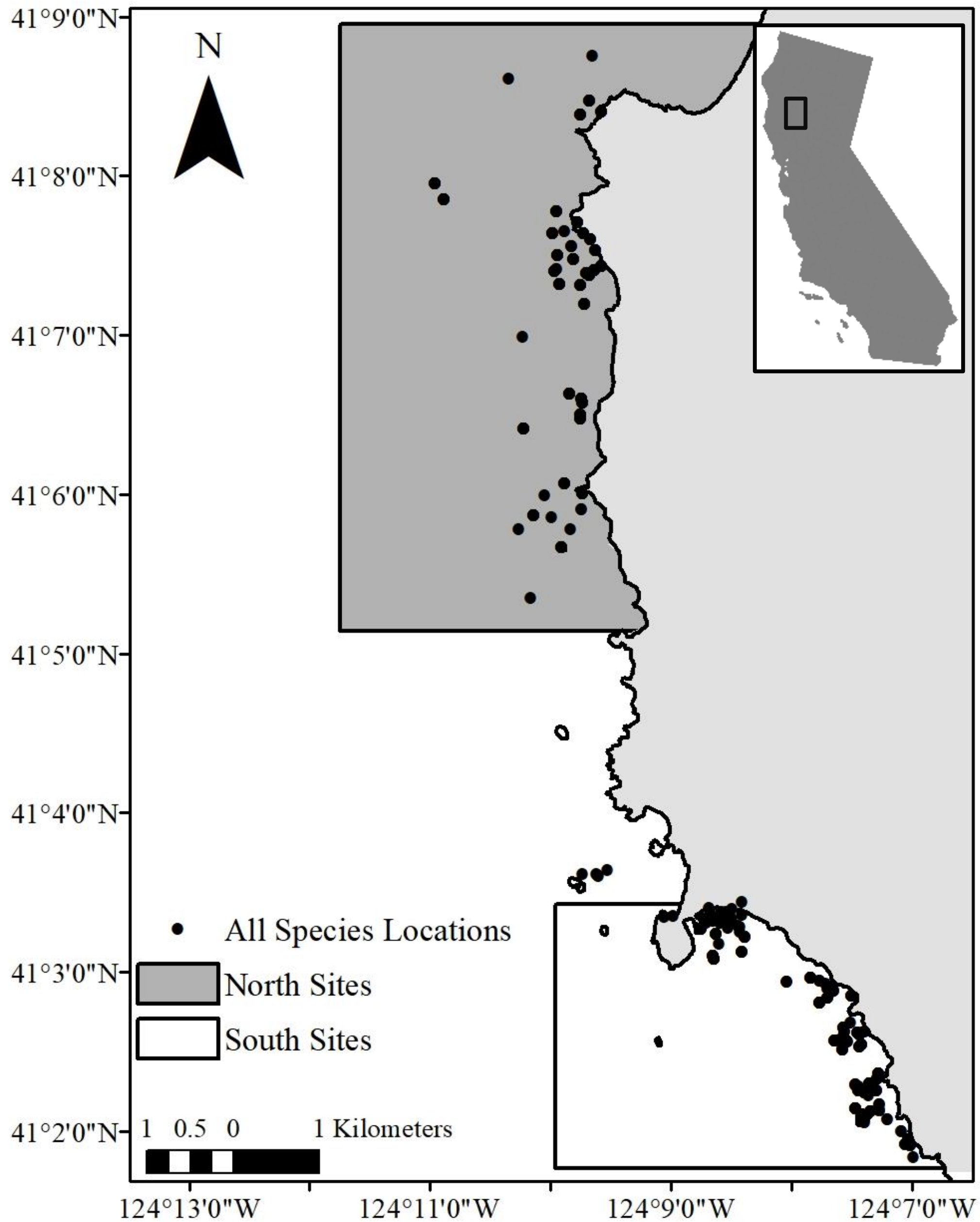

Figure 7. Locations (n=7825) of marine wildlife use of islands and islets at northern and southern sites during the summer season. These locations were used in creation of the kernel density estimates.

Table 4. Summary of kernel density estimates contained within 50% and 95% probability region (α) for each species in the summer season among all sites with defined parameters. Space use used by each species differed, which influences the volume of intersection score with human use. LSCV = least-squares cross validation, href = reference bandwidth.

Species	KDE area (hectares)		Parameters		
	α=.50	α=.95	bandwidth method (h)	cell size (grid)	extent
Western Gull	31.31	380.08	LSCV	750	0.3
Pelagic Cormorant	53.34	348.86	LSCV	750	0.3
Brandt’s Cormorant	89.61	474.64	LSCV	750	0.3
Double-crested Cormorant	33.46	240.90	LSCV	750	0.3
Black Oystercatcher	53.11	314.56	LSCV	750	0.3
California Sea Lion	23.26	109.54	href	750	0.7
Steller Sea Lion	14.82	86.48	href	750	0.7
Pacific Harbor Seal	24.29	125.45	LSCV	750	0.3

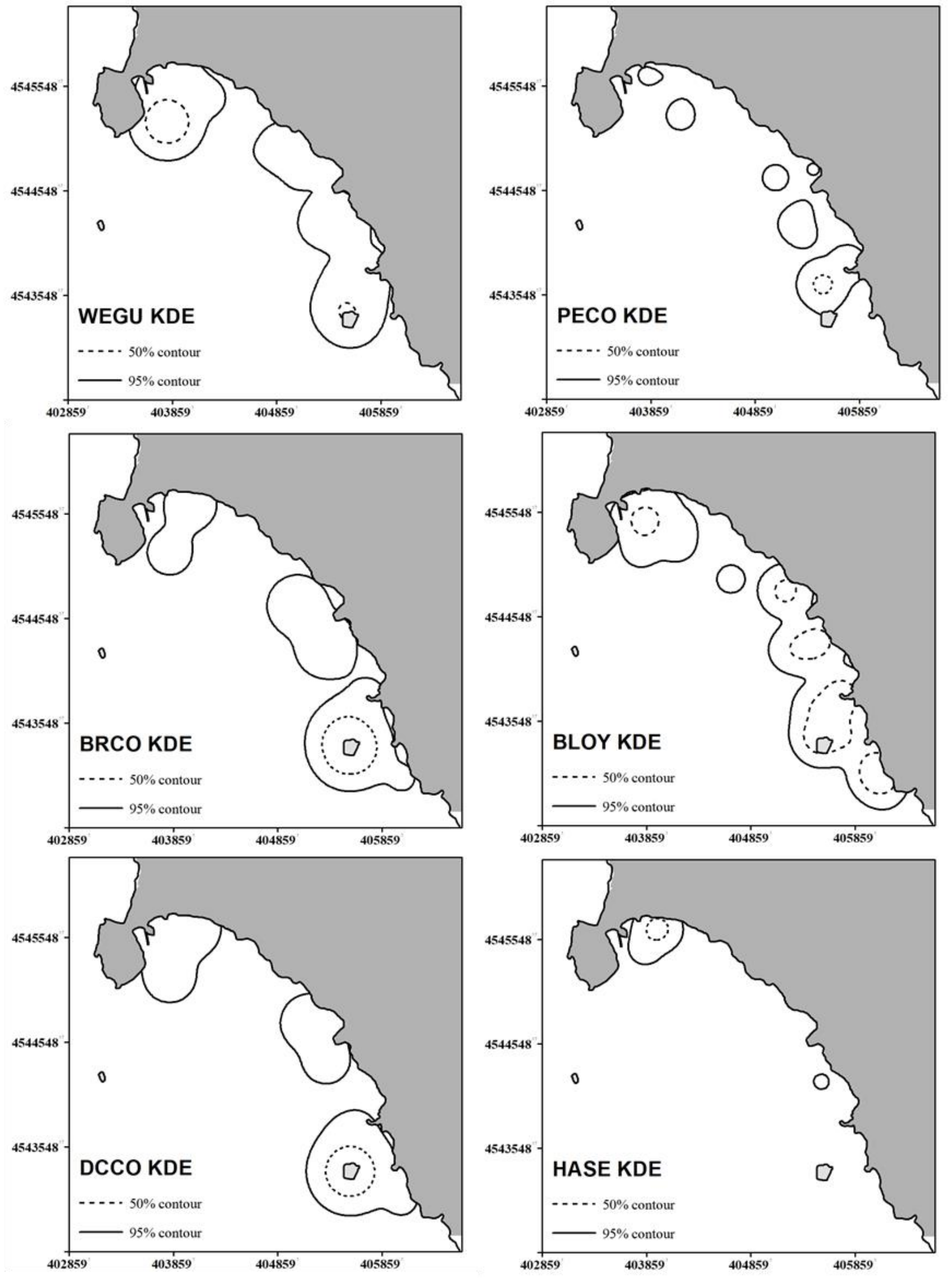

Figure 8. 50% and 95% kernel density estimates of marine wildlife utilizing southern sites. California Sea Lions and Steller Sea Lions were never observed at any of the southern sites. WEGU = Western Gull, PECO = Pelagic Cormorant, BRCO = Brandt's Cormorant, DCCO = Double-crested Cormorant, BLOY = Black Oystercatcher, HASE= Pacific Harbor Seal.

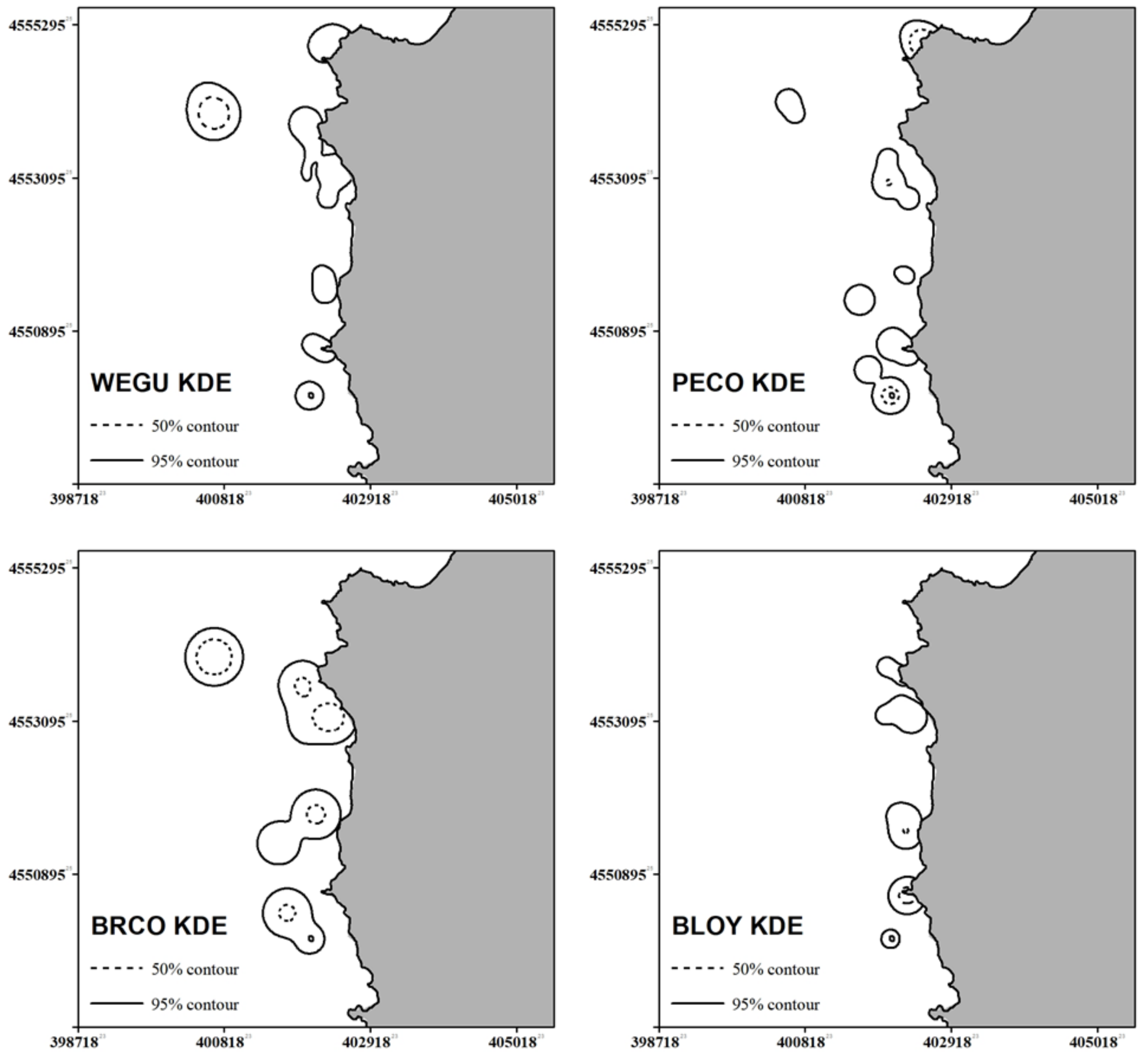

Figure 9. 50% and 95% kernel density estimates of marine wildlife utilizing northern sites. WEGU = Western Gull, PECO = Pelagic Cormorant, BRCO = Brandt's Cormorant, BLOY = Black Oystercatcher.

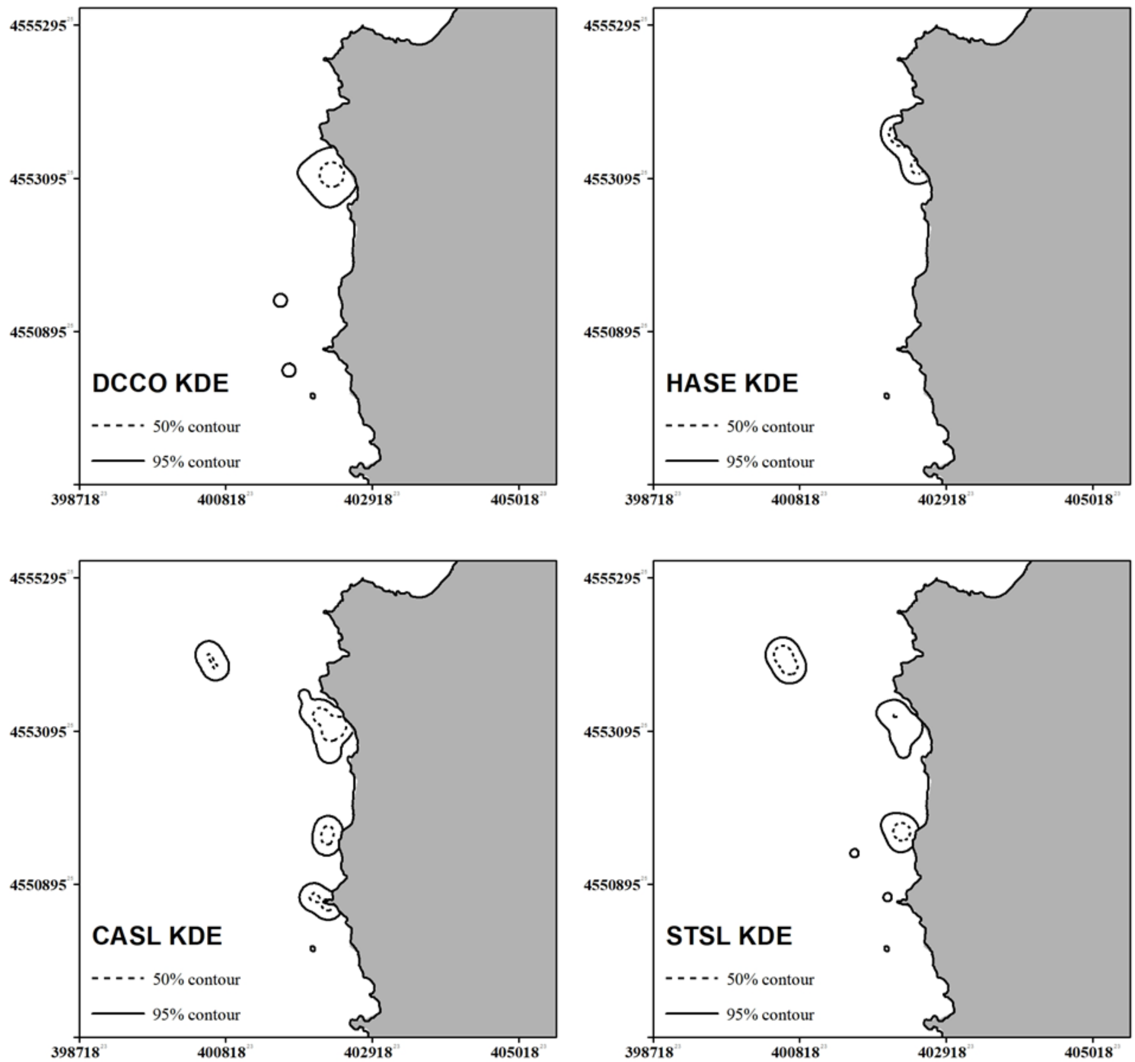

Figure 10. 50% and 95% kernel density estimates of marine wildlife utilizing northern sites. DCCO = Double-crested Cormorant, HASE = Pacific Harbor Seal, CASL = California Sea Lion, STSL = Steller Sea Lion.

Human Use

Observed human use activities (n=304) and locations were consolidated into two groups and four activities: consumptive use (n=91) and non-consumptive activities (n=213); and motorized vessels (n=76) and non-motorized vessels (n=228). Generally, there was more consumptive/motorized vessel activity in the northern sites, and more non-consumptive/non-motorized activity in the southern sites, which was reflected in the differences in kernel density estimates (Figure 11, Figure 12).

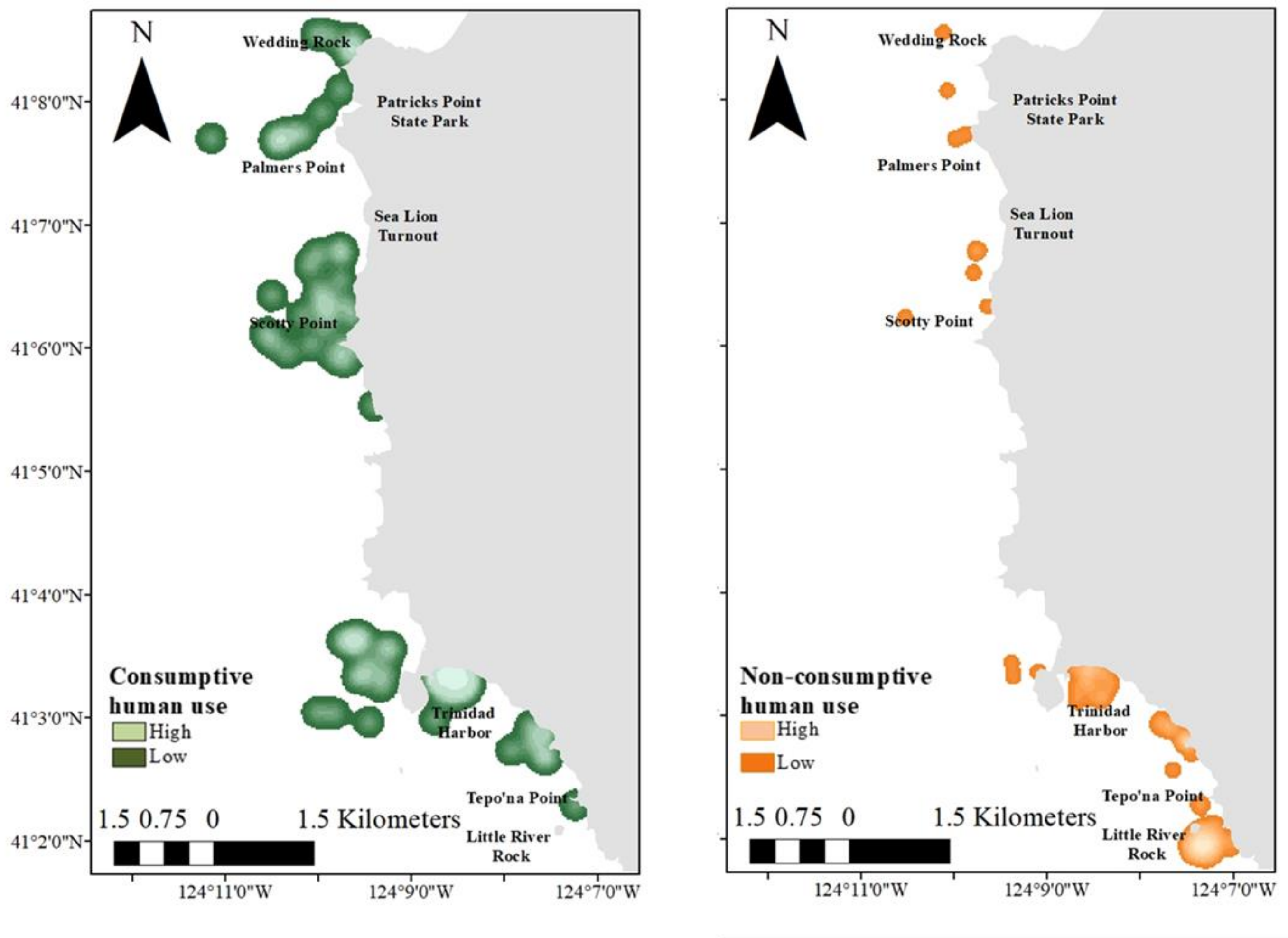

Figure 11. 50% and 95% kernel density estimates of consumptive (left panel) and non-consumptive use (right panel) by humans at both the southern and northern sites (n=304).

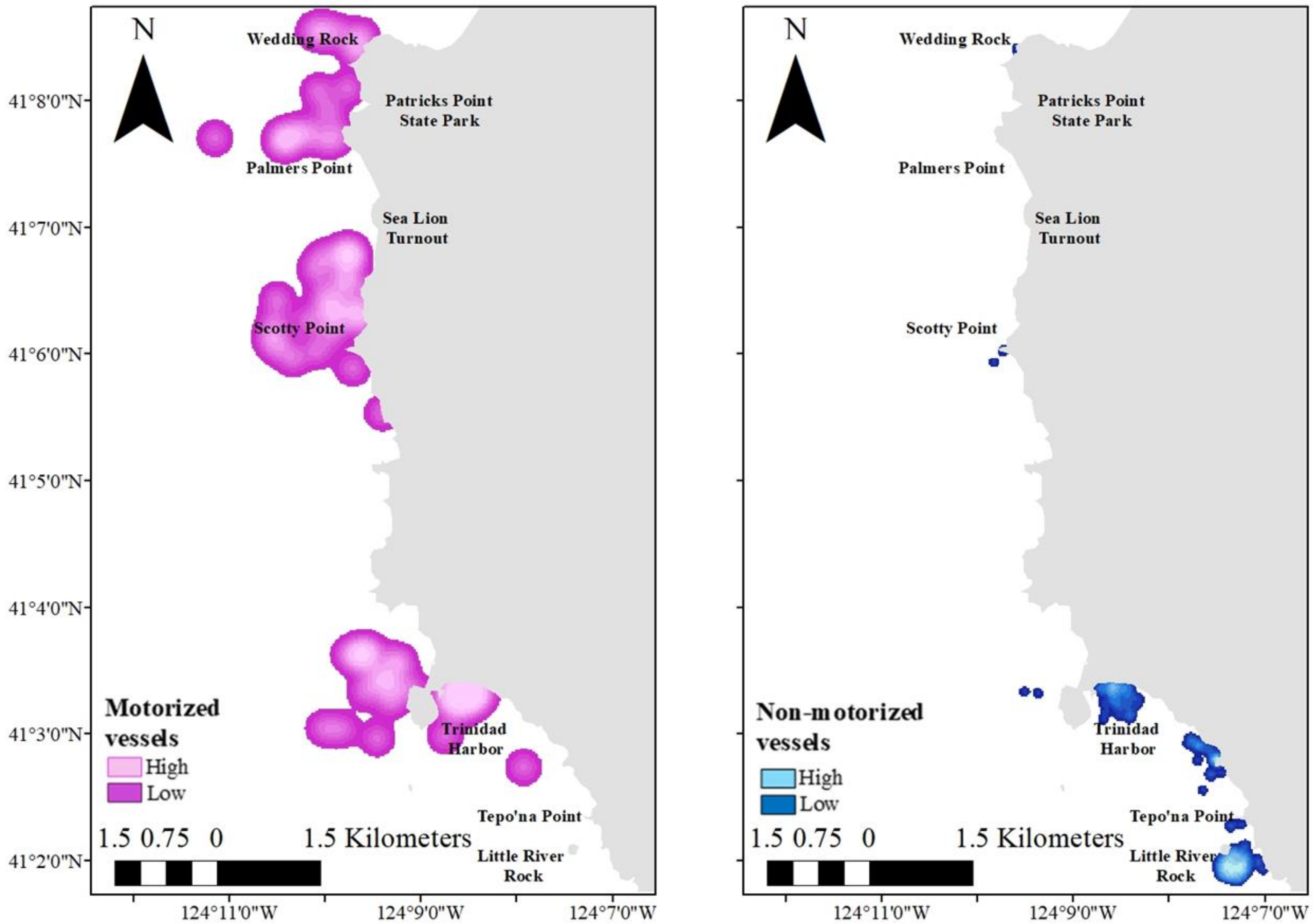

Figure 12. 50% and 95% kernel density estimates of motorized (left panel) and non-motorized vessel use (right panel) by humans at both the southern and northern sites (n=304).

Marine Wildlife and Human Space Sharing

Volume of intersection (VI) scores between marine wildlife and all human use varied among species, from a high of 0.74 for Western Gulls and Black Oystercatchers to low overlap of 0.02 with otariids (sea lions) (Table 5). Most species did not exhibit a difference in VI scores between consumptive activities and non-consumptive activities, with an exception of Double-crested Cormorants and Pacific Harbor Seals. Double-crested Cormorants showed more overlap with non-consumptive use (recreation activities) than with consumptive use (fishing) (Table 6). Pacific Harbor Seals exhibited more overlap with consumptive use compared to non-consumptive use (Table 6). Most species showed a large difference in VI scores between motorized and non-motorized vessels, with more overlap with motorized vessels (Table 6).

Table 5. Volume of Intersection (VI) scores of each marine wildlife species and all human use activities in the summer season. WEGU = Western Gull, PECO = Pelagic Cormorant, BRCO = Brandt's Cormorant, DCCO = Double-crested Cormorant, BLOY = Black Oystercatcher, CASL = California Sea Lion, STSL = Steller Sea Lion, HASE = Pacific Harbor Seal; n=number of detections, VI score = Volume of Intersection Score, SD = Standard Deviation, and VI mean = Volume of Intersection Mean. Standard deviation derived from 1000 bootstrap iterations.

Species	n	VI score	SD	VI mean	Confidence Intervals	
					2.5%	95%
WEGU	2449	0.741	± 0.058	0.638	0.510	0.721
PECO	784	0.264	± 0.098	0.298	0.132	0.471
BRCO	145	0.401	± 0.128	0.452	0.230	0.671
DCCO	98	0.581	± 0.113	0.621	0.377	0.783
BLOY	96	0.702	± 0.093	0.698	0.486	0.818
CASL	2075	0.0283	± 0.0016	0.0337	0.00586	0.0629
STSL	1509	0.0288	± 0.018	0.0365	0.00691	0.0692
HASE	456	0.236	± 0.088	0.256	0.106	0.419

Table 6. Volume of Intersection (VI) scores with standard deviation of each marine wildlife species and four human use activities in the summer season. Standard deviation derived from 1000 bootstrap iterations.

Species	Human use activity			
	Consumptive use	Non-consumptive use	Motorized Vessel	Non-Motorized Vessel
WEGU	0.471 ±0.06	0.481 ±0.07	0.455 ± .06	0.567 ± .09
PECO	0.336 ±0.11	0.381 ±0.13	0.539 ± .11	0.133 ± .01
BRCO	0.364 ±0.12	0.423 ±0.14	0.599 ± .11	0.145 ± .03
DCCO	0.249 ±0.08	0.479 ±0.09	0.592 ± .09	0.341 ± .05
BLOY	0.494 ±0.10	0.470 ±0.11	0.467 ± .14	0.551 ± .07
CASL	0.0372 ±0.03	0.063 ±0.03	0.165 ± .03	0.0 ± .002
STSL	0.0409 ±0.03	0.062 ±0.04	0.183 ± .04	0.0 ± .001
HASE	0.5435 ±0.10	0.454 ±0.11	0.361 ± .11	0.140 ± .03

DISCUSSION

I observed a wide range of spatial overlap between marine wildlife and human uses in the northern and southern study areas. The species exhibiting the most space sharing with human uses were Western Gulls (VI = .741 ± .058), and the species exhibiting the least amount of space sharing with human uses were Steller Sea Lions (VI= .0283 ± .0016). Human use in the northern study area exhibited more consumptive and motorized activity, while human use in the southern study area showed more recreational/non-consumptive use and non-motorized activity. Finally, although there was some indication of a difference between summer and winter space use by marine wildlife (Figure 6), I focused on the summer season (breeding) due to the potential of higher sensitivity of marine wildlife to human use, increased consequences from human-caused disturbance, and a larger sample size.

Northern Study Area

Marine wildlife use

All marine wildlife species were observed in the northern portion of the study areas. Palmers Point in the northern study area had the highest concentration of marine wildlife use (with the exception of the Black Oystercatcher). The high density of marine wildlife use at this site may be due to the presence of a cove, which creates shelter from northwestern wind and wave action. This high density of marine wildlife at Palmers Point could also be explained by the available haul out space. Many of the sites at Palmers

Point are exposed at high tide, which creates ideal roosting and haul out space for seabirds and pinnipeds.

Finally, two rocks offshore named “Turtle Rocks” had consistent use by otariids, Western Gulls, and Brandt’s Cormorants contributing to 50% core use area for each species. Otariids have used these islands consistently for at least 30 years (Sullivan 1980*b*). A previous study concluded that the consistent haul-out use by otariids could be due to its accessibility for pinniped haul-out from all sides (Fuller 2012).

Human use

Human use activities were observed at all northern sites; however, there was considerably more consumptive use (fishing) and motorized activity from boats (including commercial vessels), compared to non-motorized and non-consumptive activities. The lack of non-motorized vessels (like kayaks) and non-consumptive use was likely due to the rugged ocean conditions in this portion of the north coast. Additionally, there is not a boat launch in the northern area, and the nearest launch is in Trinidad Harbor. Non-motorized vessels appear generally unable to utilize this area due to inaccessibility.

Motorized activity observed at these sites were likely vessels that frequent this northern area for commercial or private charter trips out of Trinidad Harbor. Anecdotal observations through a marine VHF radio communications during at-sea surveys indicated that the near-shore fishing adjacent to Patrick’s Point State Park was favorable to many. In addition, several commercial and private charter vessels make routine (sometimes daily) trips out to these fishing sites, a likely explanation for the many observations of motorized activity in this area.

Marine wildlife and human space sharing – northern sites

Volume of intersection scores of marine wildlife with motorized human use activity were greater than for non-motorized activity for almost every species at the northern sites (Table 6, Figure 13) except Black Oystercatchers and Western Gulls. This overlap between motorized vessels is shown in Figure 14, using Pelagic Cormorants and Brandt's Cormorants as examples. These two species also had some of the highest VI scores with motorized vessels (.539 and .599 respectively).

Motorized vessels are unable to get close (<5 meters) to rocky outcroppings and individual islands due to potential damage inflicted on a vessels' hull; however, motorized vessels can present risk of disturbance when approaching colonies of seabirds and pinnipeds. Motorized vessels can lead to unintentional disturbance, like alerting marine wildlife and increased vigilance by marine wildlife. For example, there have been many accounts of Steller Sea Lions reacting to motorized vessels and low flying aircraft by head movements or flushing into the water (Kucey 2005). Additionally, direct and rapid approaches from motorized vessels like boats and aircraft can cause many species of water birds to retreat to the water or the sky (Burger et al. 1995, Carney and Sydeman 1999).

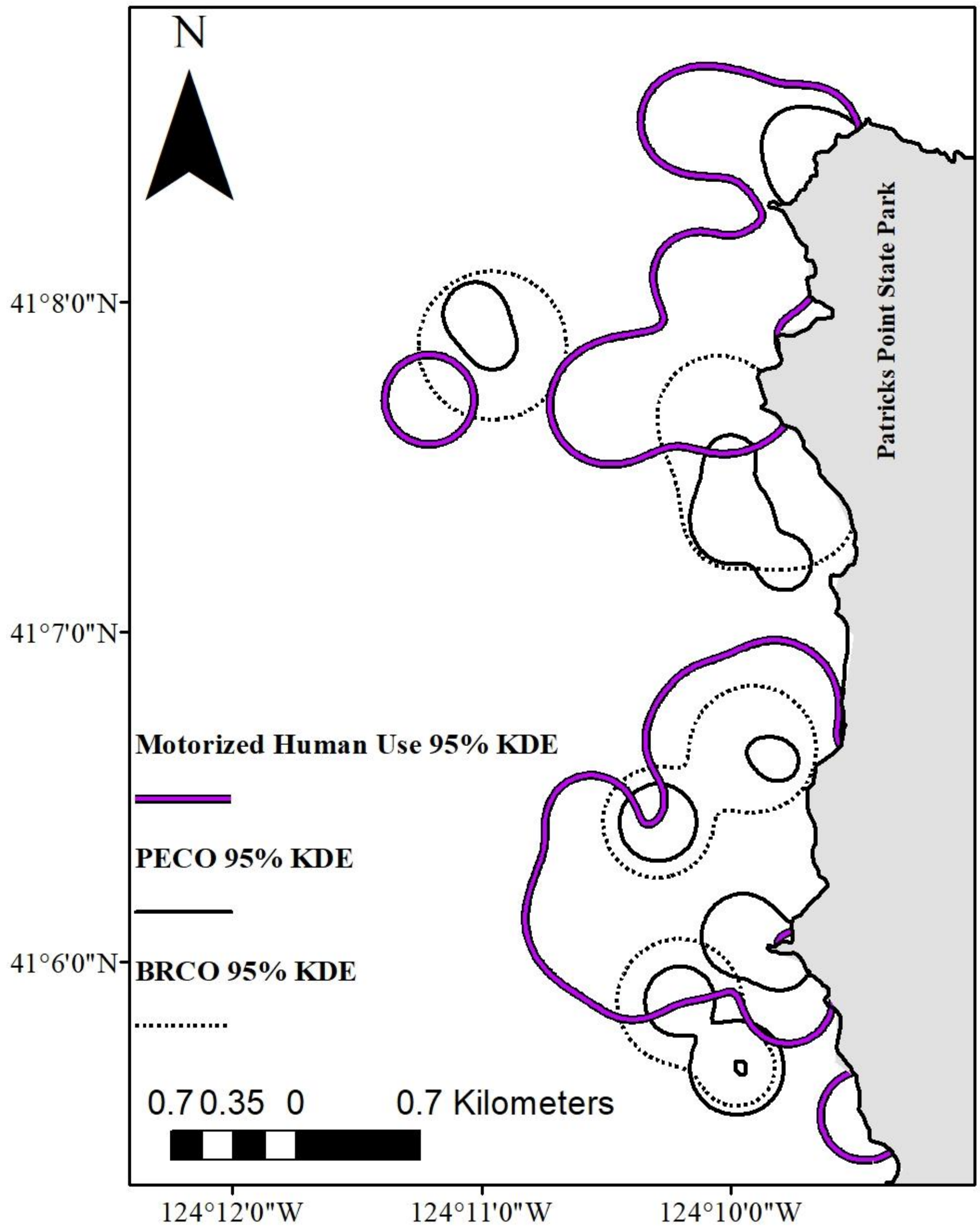

Figure 13. 95% kernel density contours for motorized human use, Pelagic Cormorants, and Brandt's Cormorants near Patrick's Point State Park in the northern study area. Note the spatial overlap between human motorized activity and seabird use areas.

Southern Study Area

Marine wildlife

Nearly all species of marine wildlife were observed at the southern study areas, with the exception of the otariids. Almost all marine wildlife that were present exhibited one of two patterns: core use of the Trinidad Harbor sites, or core use of the Little River Rock sites (Figure 8). Western Gulls and Pacific Harbor Seals utilized the harbor sites, while three species of cormorants utilized the Little River Rock sites. Black Oystercatcher's 50% core use areas were not as patchy, and they were observed throughout the entire study area.

The Double-crested and Pelagic Cormorants occurring on Little River Rock and Tepona Point sites were typically observed nesting, with the largest Double-crested Cormorant colony in the study area nesting on the north-west facing slope of Little River Rock (Appendix). Double-crested Cormorant use of this area may be explained by their diverse habitat use types and distribution and their ability to utilize both trees and exposed areas to roost and nest (Lewis 1929, Hatch and Weseloh 1999). Double-crested Cormorant distribution in the study may also be explained by the close proximity to foraging sites. Double-crested Cormorants are visual hunters and are described as foraging on near-shore, relatively shallow coastal areas or in estuaries or freshwater for small (3-30cm) forage fish (Lewis 1929, Owre 1967, Pilon et al. 1983, Duffy 1995). Pelagic Cormorants typically nest on sheer cliff faces to avoid predation of eggs and chicks, and were observed using this type of habitat on islands in the Tepona Point area likely contributing to the 50% core use area at this site (Manuwal and Campbell 1979, Siegel-Causey and Hunt 1981, Carter et al. 1984, Vermeer and Rankin 1984). When Brandt's Cormorants were observed in these southern sites, they were typically seen roosting (rather than nesting) and were not observed in large numbers.

Western Gull and Pacific Harbor Seal occurrence in Trinidad Harbor was used for nesting and pupping, respectively. Western Gulls nested on Prisoner Rock from May-July, and Pacific Harbor Seals were seen nursing pups during the spring and early summer on the small islands and islets in the bay. Nesting and pupping for seabirds and pinnipeds are very sensitive behaviors, and habitat associations with those behaviors are thought to be particularly important for successful fledging and weaning (Menza et al. n.d., Riedman 1990, Mulder 2011).

Human use

Similar to the marine wildlife patterns, human use could generally be broken down into two types of activity with particular spatial associations: non-consumptive use (recreation) near Little River Rock, and consumptive use (fishing) near Trinidad Harbor. The primary non-consumptive use activity surrounding the southern end of Little River Rock was surfing, while most consumptive use activity observed was fishing from kayak and motorized vessels. These associations are likely a result of coastal access availability.

Surfing locations were limited in this portion of the coast and were difficult to access, similar to the majority of the rocky coastline. Portions of the coast surrounding Trinidad are managed by the Trinidad Coastal Land Trust, including several trails leading to the highest used non-consumptive recreational activity in the study area - Little River Rock. There are several maintained trails leading to the beach to access this popular surfing location.

There are relatively few boat launches with an associated marina in Humboldt County, and Trinidad Harbor is one of the primary launches in the area (Boating Facilities in Humboldt County 2019). The boat launch in Trinidad is open from April – October, aligning with fishing needs but also directly overlapping with nesting and pupping seasons for marine wildlife. The launch is closed for the winter season due to the lack of demand from fisherman and an increase in frequency and intensity of storm events.

Marine wildlife and human space sharing – southern sites

There were three main conclusions and associations between marine wildlife and humans in the southern sites. First, most species did not exhibit a large change in VI score between consumptive and non-consumptive human use behavior with the exception of Pacific Harbor Seals and Double-crested Cormorants. Second, Double-crested Cormorants exhibited more overlap with non-consumptive human use compared to consumptive behavior (Figure 14). This increase in overlap is due to the large Double-crested Cormorant colony nesting on the west-facing slope of Little River Rock near the popular surfing destination (Appendix). Third and finally, Pacific Harbor Seals exhibited high space sharing with consumptive human use near the Trinidad Boat Launch (Figure 14). Pacific Harbor Seals were seen throughout the spring and early summer season associated with pups. Protected bays and estuaries are important pupping habitat, and Pacific Harbor Seals tend to haul out on rocks and islets that are surrounded by deep water. Pacific Harbor Seals also tend to avoid areas of high human presence (Hoover-Miller 1994, Montgomery et al. 2007).

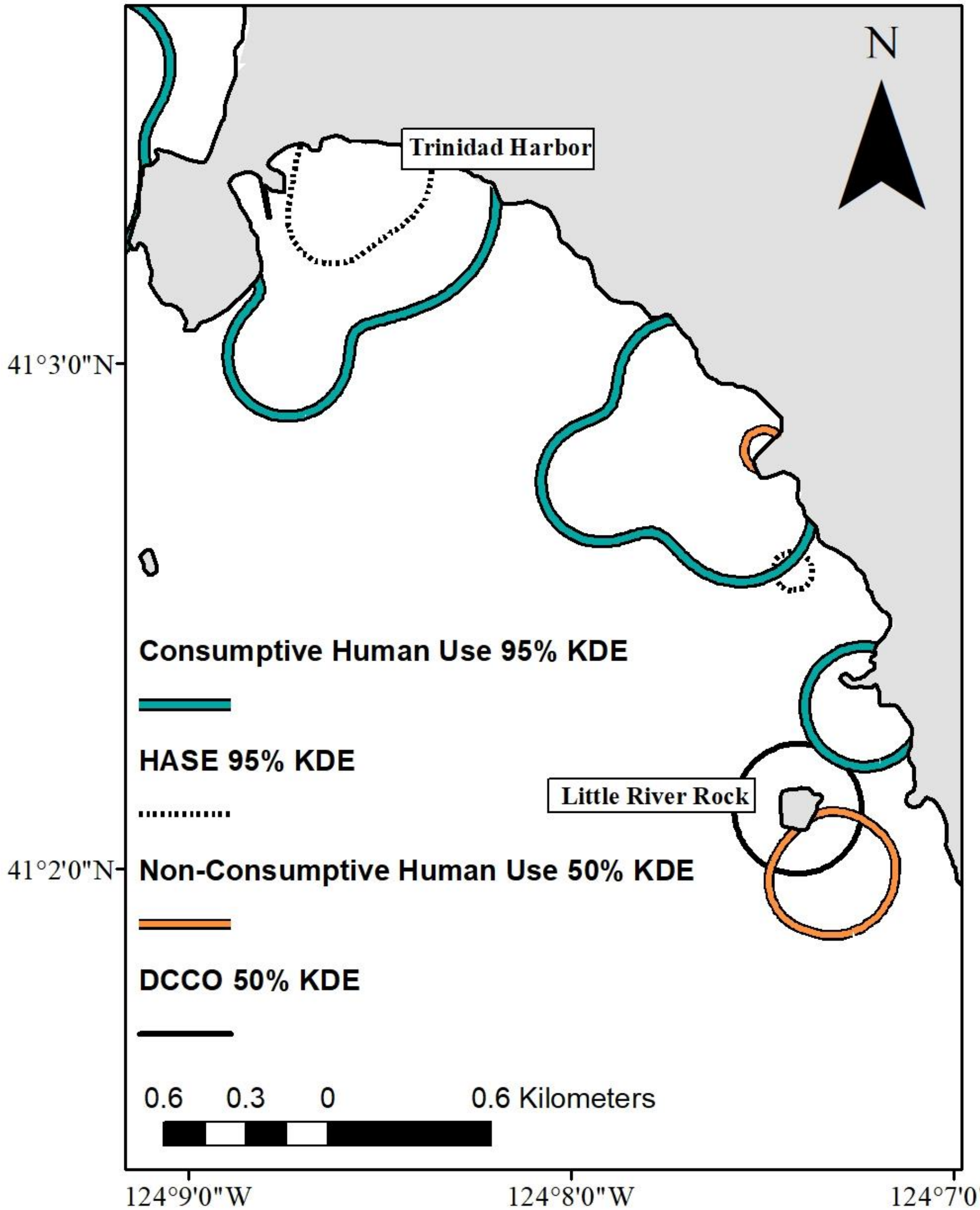

Figure 14. 95% kernel density estimates of Pacific Harbor Seals (HASE) to illustrate overlap with consumptive human use activity (blue), and 50% kernel density estimates of Double-crested Cormorants (DCCO) to show spatial overlap with non-consumptive human use activity (orange).

Considerations and Limitations of the VI Score to Evaluate Disturbance Risk

All seabirds and pinnipeds require terrestrial habitat to perform essential life history behaviors such as breeding, resting, molting, and to care for offspring (Riedman 1990, Schreiber and Burger 2002). Human-caused disturbance negatively influences the success of these life history behaviors, potentially leading to individual fitness consequences and population-level effects. The volume of intersection score may provide a quantitative measure of the potential for a disturbance to occur (disturbance *risk*); however, I provide three considerations and potential limitations when using the VI score to quantify disturbance risk. First, the VI score may not capture current disturbance risk if marine wildlife are avoiding human use areas from past disturbance events (Fancher 1979, Jansen et al. 2015). Secondly, varying levels of tolerance among marine wildlife should be considered when interpreting VI scores. Finally, the time frame in which observations are aggregated in the VI model must be considered. The conclusions drawn from this project focus on the spatial overlap between humans and marine wildlife as a potential tool to measure relative risk of disturbance while marine wildlife are utilizing these essential roosting and haul-out sites.

Do marine wildlife avoid human use areas?

It is widely accepted that human-caused disturbance can cause long-term detrimental effects to both seabirds and pinnipeds at an individual level, and can lead to a fitness cost over time for an individual, which can result in population declines (Warheit et al. 1984, Belanger and Bedard 1989, Hockin et al. 1992, Carney and Sydeman 1999, Engelhard et al. 2002, Kucey 2005, Jansen et al. 2015). Frequent human-caused disturbance can also lead individuals to utilize different areas post-perturbation (Fancher 1979, Burger 1981). However, these responses may not be reflected in observed habitat associations, site-selection preference, or avoidance of human activity by a species. Ultimately, an animal's presence or absence at a site may or may not be a consequence of human avoidance. For instance, it is unclear whether California Sea Lion distribution in the northern study area is the result of human avoidance, or availability of haul-out habitat independent of human avoidance (Figure 15).

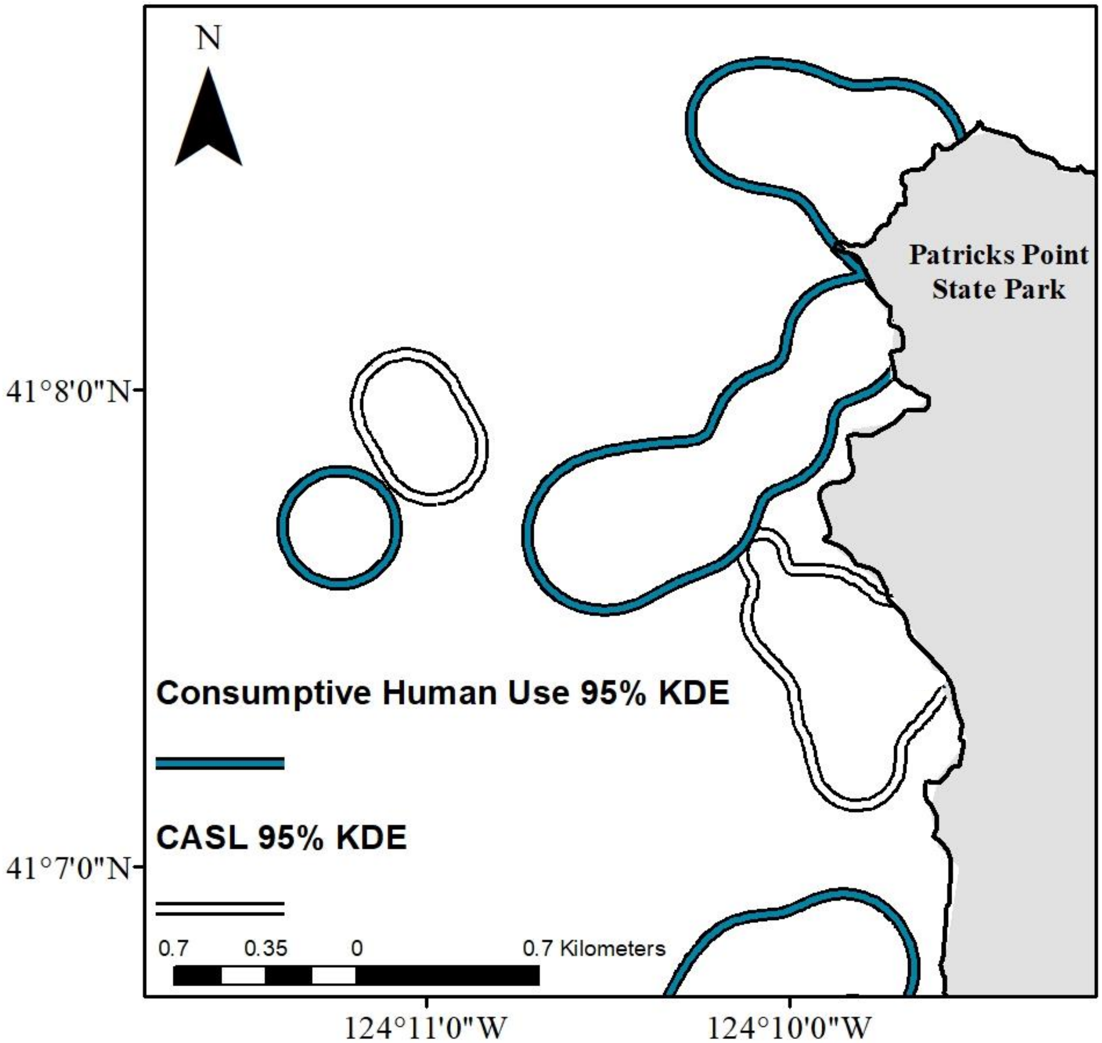

Figure 15. California Sea Lion (blue) and consumptive human use (white) 95% kernel density estimates in the northern study area. The lack of spatial overlap is reflected in the low volume of intersection score (VI = .0372 ±0.03).

California Sea Lion volume of intersection scores were particularly low with consumptive human use (VI = 0.0372 ±0.03). This low volume of intersection score could be due to disturbance in the past, causing sea lions to seek out more remote, undisrupted sites with lower human use and lower relative disturbance risk – thus, an avoidance of human activity. Alternatively, it is possible that the haul-outs surrounding Palmers Point are particularly suitable habitat for behaviors like foraging and avoiding predators, and California Sea Lions are not simply avoiding human use activity. It is also possible that California Sea Lions are observed at Palmers Point due to a lack of available and suitable habitat elsewhere. This example illustrates potential causes of California Sea Lion use of particular haul-out sites including habitat availability, realized habitat use, and the potential influence of human activity. Tradeoffs between fitness costs and habitat availability have been explored by Gill et. al (2001), and while volume of intersection score appears to be a useful measure for managers evaluating alternative explanations for realized habitat use in areas with high wildlife and human use, alternative explanations like historical disturbance events for low or high VI scores are worth considering.

It is important to note that the volume of intersection overlap indicates relative space sharing; however, before making management and conservation decisions based on indices of relative risk, more assessment of the proximate causes of the degree of overlap should be explored. It is also important to glean information regarding disturbance susceptibility of an individual or a population, because varying levels of tolerance must be considered when developing and implementing management solutions for marine wildlife disturbance.

Varying levels of tolerance in marine wildlife

Tolerance of marine wildlife to human-caused disturbance varies among individuals, populations and species. For instance, Pacific Harbor Seals may respond to human use activity within 100 meters (Schneider and Payne 1983, Allen et al. 1984), whereas California Sea Lions are less sensitive, responding to humans at 40 meters (Riedman 1990, French et al. 2011). I observed high VI scores in species thought to have low tolerance for disturbance, suggesting either high risk of disturbance, or varying levels of tolerance. Varying levels of tolerances within a species may be due to a reduction in response to a stimulus (human activity) through multiple exposures (Bejder et al. 2009). The mechanisms controlling varying levels of tolerance within a species and sensitivity of a species to anthropogenic stimuli can be complex (Bejder et al. 2009); however, it is essential to discuss the potential of context-specific responses of marine wildlife to human activities when interpreting VI scores. Reported disturbance thresholds of marine wildlife in the literature (summarized in Table 2) do not necessarily provide insight on site-specific sensitivity of a species to human use. Observations of successfully nesting Western Gulls near human use activity provide a clear example of the potential difference between tolerance in different populations.

Reported Western Gull tolerance to human activity is low (Carney and Sydeman 1999). The literature suggests that Western Gull colonies are relatively sensitive to human use and can be displaced from their roosting or nesting site within 100-180 meters of human activity due to their apparent sensitivity to human intrusion (Carney and Sydeman 1999). This low reported tolerance to human activity conflicts with what was observed at Trinidad Harbor in this study. We observed Western Gulls successfully breeding, and without observable responses to passing vessels, within the suggested 180 meter disturbance threshold, and Western Gulls exhibited the highest VI score out of all species (0.741 ± 0.058). This mismatch between low tolerance levels to human activity predicted by the literature, yet high observed space sharing for Western Gulls and humans may be explained by some level of increased tolerance. Though a VI score is not a direct measure of information regarding a species' tolerance to a human activity, it can provide information regarding local-level species responses to a stimulus when compared to reported tolerance levels.

Volume of intersection model: temporal aggregation and spatial variation

The VI model aggregates observations across time in each species' utilization distribution (Equation 2), and assumes a static spatial distribution of marine wildlife (Fieberg and Kochanny 2005). In this study, only summer (breeding) season observations were included for analysis. Marine wildlife in the summer season are site attached when breeding, meaning their space use is relatively consistent through time. Aggregating data across an entire breeding season was appropriate because breeding individuals exhibit high site fidelity while caring for offspring. However, aggregating observations of individuals during the winter (non-breeding) season may be inappropriate because marine wildlife are not as site-attached and space use may be more inconsistent. If the VI score is used during a season in which marine wildlife space use is variable, it may produce an inaccurate assessment of disturbance risk.

MANAGEMENT IMPLICATIONS

One of the main goals of this project was to provide a tool to quantify disturbance risk for management between multiple species of marine wildlife and humans. Implementation of this protocol with existing monitoring effort was relatively simple, the volume of intersection index methods were inexpensive and relatively low effort, and an effective measure of the potential for interactions between marine wildlife and people. Further, I would encourage managers to consider these additional suggestions.

Defining user groups

Before computing and interpreting VI scores, it is essential to clearly define the user groups included in the human utilization distribution (UD_2 from Eq. 2). I chose to investigate two main groupings, consumptive/non-consumptive use and motorized/non-motorized vessels to glean insight on the potential user groups for outreach effort. There are many other options for managers to investigate relationships between humans and marine wildlife species simply based on categorizing the spatially-explicit observations gathered in the field. For instance, if a manager was only interested in space sharing between stand-up paddlers and surfers and marine wildlife, they can adjust the VI model by only estimating a utilization distribution for recreational paddling activities. The VI score is dependent on utilization distributions put into the model, so managers must decide what types of use to investigate before interpreting the relative amount of overlap.

Collecting vessel identification information

This project did not involve recording any identifiable information on specific marine vessels, but future efforts should consider collecting such data. As mentioned earlier, it is likely that many vessels at the northern sites utilized fishing sites regularly. Outreach efforts could greatly benefit from understanding which vessels frequent a site on a regular basis throughout the summer season.

Creating site-specific disturbance threshold guidelines

In order to clearly define sizes of areas in which marine wildlife respond to human use, managers must first monitor and understand varying levels of tolerance of marine wildlife to human use at a local scale (Kerlinger et al. 2013). Creating guidelines for human use activity in the Trinidad area would benefit greatly by supplementing these space sharing results with reported disturbance events. Western Gulls exhibited high disturbance *risk* in Trinidad Harbor (based on their reported disturbance threshold) but the *realized* disturbance is likely quite low. The volume of intersection score is an important first step in evaluating potential risk of disturbance to marine wildlife but should be supplemented with observations of behavioral responses to humans to guide management of coastal use.

Future effort

Anthropogenic use of the marine environment has created a significant impact in every ocean (Halpern et al. 2008). Activities contributing negatively to the marine environment include habitat loss, disturbance, pollution, overfishing and shipping induced congestion which will likely intensify with an increasing human population (Carpenter et al. 2006, Halpern et al. 2008). In addition to point-source induced human impacts, climate change is a complex global issue leading to increasing sea-surface temperatures contributing to changes in productivity, and rising sea-level which would directly affect available roosting and haul-out space to species in this study (Watson 1998, Harley et al. 2006, Halpern et al. 2008). In addition, many studies have shown that human-caused disturbance to a species can lead to changes in habitat use and altered or reduced home range size (Schneider and Payne 1983, Altmann and Muruthi 1988, McLennan and Shackleton 1989, Bejder et al. 2006).

Climate change induced shifts in the marine environment such as sea level rise and increased frequency and intensity of storm events will likely affect many species included in this study (Bromirski et al. 2003, Harley et al. 2006, Defeo et al. 2009). It is vital we understand the state of how marine organisms are currently utilizing space, because associations with islands will likely change through time. Sites that are currently occupied by and assessable to marine wildlife may either become unavailable, inundated with other marine wildlife species seeking out available roosting or haul out space, or may become encroached upon by humans. Investigating interspecific interactions like competition among marine wildlife species in this study could be integrated from current methods to investigate fine scale space sharing among species. Detrimental effects of diminishing habitat between seabirds and pinnipeds can lead to incidental crushing of burrowing seabird nests and forcing surface nesters into suboptimal habitat (Ainley and Boekelheide 1990). With the appropriate tools to measure fine-scale spatial movement and habitat associations, it would be possible and highly beneficial to measure space sharing within marine wildlife species.

Currently there are several sites that have a species richness of eight marine wildlife species. It is likely that these sites will become more crowded as available roosting and haul out space becomes diminished. Continuing to build upon the current state of marine wildlife species habitat associations outlined in this study is imperative to understanding how they may shift in the future.

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APPENDIX

At-sea survey results. All surveys followed at-sea protocol described in the methods section. These data are a minimum number of individuals observed from a research vessel. Preliminary results served as a confirmation to the general lack of marine wildlife on the northwest slope of the islands not visible from the mainland, with an exception of a large Double-crested Cormorant colony on Little River Rock (Appendix). I utilized Humboldt State University's associated Marine Laboratory boating program with available vessels for graduate students and faculty to complete all at-sea surveys.

Date	Counting block	Location	Species	Abundance
5-Jul-18	other	White Rock	PECO	14
	other	White Rock Headland	PECO	32
	other	Green Rock	PECO	2
	other	Elk Head	PECO	7
	other	Trinidad Head	PECO	106
	8	Palmer's Point Rock	PECO	11
	7	Scotty Point Rock	PECO	7
	4	Behind one tree	WEGU	2
	3	Split Rock, R'Lrgr	WEGU	2
	3	Split Rock, R'Lrgr	BLOY	2
	3	Cap, Yr,mrk	PECO	1
	3	Cap, Yr,mrk	DCCO	2
	2	Sub, Qege't-u-wrl	WEGU	8
	2	Ice Cube	DCCO	4
	2	oml'mos-w-aag	WEGU	1
	2	TBF 1	WEGU	1
	2	TBF 2	PECO	2
	2	Tepo-na Rock	WEGU	1
	2	Tower	PECO	5
	1	Little River	DCCO	52
	1	Snag, *Tewolaa'g*	WEGU	1
25-Jul-18	5	Pego'hpo	WEGU	2
	5	Flat Rock, Rpla'	WEGU	6
	5	Fern, Ego-le'pa	WEGU	2
	5	Frog, Sko'ona	WEGU	1
	5	Frog, Sko'ona	BLOY	1
	5	Prisoner, Nuu'xpoq	WEGU	32

Date	Counting block	Location	Species	Abundance
	5	Prisoner, Nuu'xpoq	BLOY	1
	4	Fin, Mr'rp	WEGU	1
	4	One Tree	WEGU	2
	3	Split Rock, R'Lrgr	WEGU	2
	3	Cap, Yr,mrk	PECO	1
	2	Sub, Qege't-u-wrl	WEGU	17
	2	Sub, Qege't-u-wrl	PECO	1
	2	Sub, Qege't-u-wrl	DCCO	6
	2	Ice Cube	WEGU	2
	2	Ice Cube	DCCO	2
	2	Skull	WEGU	2
	2	Tepo-na Rock	WEGU	2
	2	Tower	WEGU	2
	1	Little River	WEGU	15
	1	Little River	DCCO	20
	1	Little River	BLOY	1
10-Aug-18	9	Corner Rock	WEGU	3
	9	TW	PECO	7
	9	TW	BRCO	11
	9	Wedding Rock	PECO	9
	8	Egg	CASL	22
	8	Egg	STSL	1
	8	Seagull Rock	WEGU	3
	8	Pepper	WEGU	1
	8	Pepper	PECO	3
	8	Pepper	BRCO	3
	8	Pepper	CASL	3
	8	Grape	CASL	3
	8	Grape	HASE	2
	8	Brownie	PECO	14
	8	Brownie	BRCO	5
	8	Mud	WEGU	1
	8	Mud	PECO	12
	8	Mud	BRCO	23
	8	Mint	PECO	11
	8	Mint	BRCO	3
	8	Rockweed	WEGU	1

Date	Counting block	Location	Species	Abundance
	8	Harbor Ride North	HASE	1
	8	Eumatopias	PECO	4
	8	Eumatopias	DCCO	13
	8	Eumatopias	CASL	3
	8	Pancake	WEGU	17
	8	Pancake	PECO	1
	8	Pancake	DCCO	47
	8	Pancake	BLOY	3
	8	Pancake	CASL	4
	8	Pancake	STSL	26
	7	Coal	WEGU	1
	7	Coal	BRCO	31
	7	South Dot	CASL	5
	7	North Dot	CASL	1
	7	SLR 1	CASL	8
	7	SLR 1	STSL	14
	7	SLR 2	CASL	6
	7	SLR 2	STSL	15
	7	SLR 2	WEGU	1
	7	Behind	WEGU	1
	7	Behind	BRCO	9
	6	BB	WEGU	8
	6	BB	PECO	10
	6	BB	BRCO	3
	6	BB	BLOY	5
	6	Nut	WEGU	1
	6	Nut	BRCO	5
	6	Axe	WEGU	1
	6	Bolt	WEGU	1
	6	Bolt	PECO	25
	5	Prisoner, Nuu'xpoq	WEGU	43
	2	Little River	WEGU	6
	2	Little River	DCCO	11
15-Sep-18	9	TW	WEGU	1
	9	TW	PECO	11
	9	TW	BRCO	1
	9	Wedding Rock	PECO	5
	8	Tidepool Chips	HASE	5

Date	Counting block	Location	Species	Abundance
	8	Egg	CASL	28
	8	Egg	STSL	1
	8	Seagull Rock	CASL	11
	8	Pepper	WEGU	1
	8	Pepper	PECO	2
	8	Pepper	BRCO	3
	8	Pepper	DCCO	3
	8	Pepper	CASL	15
	8	Salt	CASL	2
	8	Grape	WEGU	2
	8	Grape	PECO	5
	8	Brownie	PECO	19
	8	Brownie	BRCO	4
	8	Mud	WEGU	1
	8	Mint	WEGU	1
	8	Mint	PECO	4
	8	Mint	BRCO	1
	8	Rockweed	WEGU	1
	8	Eumatopias	WEGU	1
	8	Eumatopias	PECO	6
	8	Eumatopias	BRCO	3
	8	Eumatopias	STSL	12
	8	Pancake	WEGU	21
	8	Pancake	PECO	9
	8	Pancake	BRCO	14
	8	Pancake	BLOY	1
	7	Coal	PECO	9
	7	Coal	BRCO	31
	7	Coal	DCCO	2
	7	South Dot	WEGU	1
	7	South Dot	CASL	6
	7	North Dot	CASL	13
	7	SLR 1	WEGU	2
	7	SLR 1	CASL	31
	7	SLR 1	STSL	1
	7	SLR 2	WEGU	3
	7	SLR 2	CASL	33
	7	Behind	WEGU	1

Date	Counting block	Location	Species	Abundance
	7	Behind	BLOY	1
	6	BB	WEGU	5
	6	BB	PECO	7
	6	BB	BRCO	1
	6	BB	BLOY	1
	6	Chisel	WEGU	2
	6	Nut	WEGU	1
	6	Nut	PECO	2
	6	Nut	BRCO	9
	6	Nut	BLOY	1
	6	Bolt	WEGU	2
	6	Bolt	PECO	9
	5	Pego'hpo	WEGU	1
	5	Flat Rock, Rpla'	WEGU	4
	5	Flat Rock, Rpla'	DCCO	1
	5	Pin, Liqo'men-o-yo'wek	DCCO	1
	5	Pin, Liqo'men-o-yo'wek	BLOY	2
	5	Crusty, O-tse'gep	HASE	1
	5	Fern, Ego-le'pa	WEGU	1
	5	Frog, Sko'ona	WEGU	1
	5	Prisoner, Nuu'xpoq	WEGU	6
	4	Fin, Mr'rp	WEGU	1
	4	Cork	WEGU	2
	4	Behind one tree	PECO	4
	4	Camel, Tso'owin	WEGU	1
	3	Milky B	PECO	5
	3	SS 3	WEGU	1
	3	Cap, Yr,mrk	PECO	15
	3	Cap, Yr,mrk	BRCO	5
	3	Eyes	DCCO	4
	2	Square	WEGU	1
	2	Bald Head	WEGU	1
	2	Sub, Qege't-u-wrl	WEGU	3
	2	Sub, Qege't-u-wrl	DCCO	3
	2	Sub, Qege't-u-wrl	BLOY	2
	2	Pyramid	PECO	1
	2	Ice Cube	BLOY	1
	2	oml'mos-w-aag	PECO	10

Date	Counting block	Location	Species	Abundance
	2	oml'mos-w-aag	DCCO	1
	2	Skull	PECO	2
	2	Tepo-na Rock	WEGU	1
	2	Tepo-na Rock	PECO	1
	1	Rock C, prhrtsr/k	WEGU	1
	1	Rock E	WEGU	1
	1	Little River	WEGU	3