Use of Coastal Islands by Seabirds: A tool to guide future Marine Protected Areas in California

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USE OF COASTAL ISLANDS BY SEABIRDS: A TOOL TO GUIDE FUTURE MARINE PROTECTED AREAS IN CALIFORNIA

Dana Page
Use of Coastal Islands by Seabirds: A tool to guide future locations of Marine Protected Areas in California

by

Dana Anne Page

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Master of Science
in
Environmental Management

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1 INTRODUCTION

For centuries humans have depended and relied on the bounty of the world’s oceans to deliver a seemingly endless supply of food. Yet, the ecosystems that lie beneath the surface of the oceans had remained unstudied for generations. The complex ecosystems that make up the marine environment supply goods and services to people throughout the world. Management of this natural resource has become the center of much debate as species decline and habitat degradation continues. Establishing a framework of regulation to protect and conserve marine environments is going to be imperative if we wish to sustain the economic and societal benefits provided. Many countries throughout the world, including the USA have taken the first step to protection. This includes the design and implementation of marine reserves and networks. The federal government has set up a series of National Marine Sanctuaries, while California has created a series of Marine Protected Areas (MPAs). As pressures intensify on the marine environment the establishment of MPAs is going to be crucial to help preserve our natural resources.

Marine ecosystems provide ecosystem services that can be categorized into four groups; provisioning, regulating, cultural and supporting services. Provisioning services include the more obvious benefits such as food, timber, water, fiber and pharmaceutical compounds. These provisioning services currently employs over 200 million people within the fisheries industry (Pauly et al. 2003). Cultural services consist of recreational, spiritual and esthetic benefits, such as coastal tourism. Tourism makes up approximately 10% of the world GDP (Balmford et al. 2009) and coastal tourism and recreation attributes $70 billion per year to the US GDP (Kildow et al. 2009). Cultural services also provide indigenous peoples who are intimately connected to marine ecosystems with the resource they need and depend upon (Moller et al. 2004). Marine system also provide services such as water quality, waste and disease regulation. These regulative services also provide protection from natural hazards like floods and climate change. Supporting service encompass the processes that are not a direct benefit such as soil formation, nutrient cycling and habitat for young marine species. Table 1 summarizes the ecosystem services provided by marine
ecosystems.

For more than a hundred years the activities of humans have altered and degraded the oceans. Threats to the marine environment are continuing at alarming rates. Many of the human impacts are a result of activities such as overfishing, recreation, pollution, aquaculture, energy production, and shipping. Human activities have resulted in the loss of more than 65% of wetland and seagrass habitats worldwide (Lotez et al. 2006). Reducing these threats is key to helping the ecosystem recover. The focus of local, regional and global marine reserves is to prevent further degradation and to conserve unaltered areas that can help reduce the detrimental impacts of overuse and exploitation.

Over exploitation of fish stocks has reduced the amount of fish available to humans, but also to the animals that rely upon the same fish for food. Regulating fisheries can be challenging because each country only has control over the boundaries within the designated Exclusive Economic Zone (EEZ). Fish and marine life have life histories that do not lie within political boundaries. Protection and regulations within one country’s EEZ does not safeguard migratory species. Commercial fishing creates incidence of bycatch and it is estimated that 8% to 25% of the yearly global catch is thrown overboard dead or dying (Davies et al. 2009). Bycatch consists of non-target species that are incidentally caught during the fishing process. This can include other fish species, marine

**Figure 1** (from Worm et al. 2006) **(A)** The displayed trajectories show fish and invertebrate taxa collapse over the past 50 years. Triangles indicate cumulative collapse and diamonds are collapse per year. Red denotes areas with more than 500 species, blue less than 500 species and black for all. **(B)** Species richness in the 64 large marine ecosystems, color-coded.
Coastal and Marine Ecosystem Services

<table>
<thead>
<tr>
<th>PROVISIONING SERVICES</th>
<th>REGULATING SERVICES</th>
<th>CULTURAL SERVICES</th>
<th>SUPPORTING SERVICES</th>
</tr>
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<tbody>
<tr>
<td>Food provision:</td>
<td>Water purification:</td>
<td>Recreation/Tourism:</td>
<td>Soil formation:</td>
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<tr>
<td>1. fishing activities</td>
<td>1. Treatment of</td>
<td>1. Coastal</td>
<td>1. Pedogenesis near</td>
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<td>(commercial or</td>
<td>human wastes</td>
<td>Activities</td>
<td>wetlands and</td>
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<td>subsistence)</td>
<td>(nitrogen</td>
<td>(snorkeling,</td>
<td>mangroves.</td>
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<td>2. Trapping or</td>
<td>2. Wilderness,</td>
<td>conditions that</td>
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<td>sequestering</td>
<td>sports (sailing,</td>
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<td></td>
<td>pollutants.</td>
<td>recreational</td>
<td>pedogenesis.</td>
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<td>3. Filtration and</td>
<td>fishing).</td>
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<tr>
<td></td>
<td>absorption.</td>
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<td>Water storage/provision:</td>
<td>Water quality</td>
<td>Symbolic/Aesthetic Values:</td>
<td>Nutrient Cycling:</td>
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<td>2. Aquifers</td>
<td>1. Vegetation, soil and waterbodies help uptake pollutants.</td>
<td>2. Natural and cultural sites, traditional and religious in coastal zone.</td>
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<td>4. Industrial Cooling</td>
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<td>5. Water quality</td>
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<td>regulation:</td>
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<td>6. Water flow</td>
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<td>regulation:</td>
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<tr>
<td>Biotic Materials/Biofuels:</td>
<td>Climate regulation/coastal protection:</td>
<td>Cognitive Effects:</td>
<td>Habitat/ Life Cycle Maintenance:</td>
</tr>
<tr>
<td>1. Medicinals (drugs, cosmetics)</td>
<td>1. Sink for green house gases.</td>
<td>1. Source of materials for research and education.</td>
<td>1. Nurseries (spawnig areas)</td>
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<tr>
<td>2. Ornamentals (shells, corals)</td>
<td>2. Organic carbon production.</td>
<td>2. Inspirations for applications and arts.</td>
<td>2. Migratory routes</td>
</tr>
<tr>
<td>3. Commercial/industrial resources (whale oil, fish meal, plant fertilizer)</td>
<td>3. Inorganic carbon dissolved into seawater.</td>
<td>3. Awareness and information through natural observations of marine wildlife.</td>
<td>3. Pollination and seed dispersal.</td>
</tr>
<tr>
<td>4. Biomass for energy (wood from mangroves, fuels from animals.)</td>
<td>4. Coastal zones can buffer against storm surges, waves and sea level rise.</td>
<td>4. Maintenance of genetic diversity.</td>
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</tbody>
</table>

Table 1: Ecosystem services provided by coastal and marine habitats. These services are divided into the provisioning, regulating, cultural and supporting services. Adapted from Liquete et al. 2013.
mammals, sharks, seabirds and turtles. Many fisheries go unregulated and species are commercially fished to unsustainable levels (Coll et al. 2008). Figure 1 shows the trajectory of fish and invertebrate collapse over the past 50 years and also includes a map depicting species richness throughout the 64 large marine ecosystems worldwide.

Pollution threatens all aspects of the marine environment. Plastics debris, agricultural runoff, petroleum spills and waste discharge can result in degraded marine environments. Plastic pollution is the most abundant anthropogenic source of marine pollution globally (Derraik 2002). Confounding the existing problems of pollution is climate change. There are a multitude of stressors that adversely influence the marine environment and the unpredictability of climate change further escalates the threats to marine life. As climate variations continue, shifts and patterns within the oceans will become unpredictable. Allowing adaptive management within the design of MPA’s can account for climate change and is going to be key in reducing adverse effects to marine life. Adaptive management could include flexible boundary designs and regulations that support future changes as new information becomes available and environmental conditions fluctuate (Agardy et al. 2011). The coastal zones where humans live will be increasingly vulnerable and MPA’s can help mitigate the hazards. Marine species who rely heavily upon predictable currents, such as the California current system (CCS), could find food resources unavailable, in different locations or reduced.

Marine protected areas that currently exist in California need to be expanded (McLeod et al. 2009, CDFW 2008). New sites locations need to be explored and evaluated to further develop the conservation of California’s natural resources. Marine ecosystems are extremely complex and devising marine spatial planning efforts that allows for economic gain and providing habitat for wildlife is a delicate balance. Along the California coast, islands provide unique habitat for breeding seabirds. Seabirds have long been regarded as indicators of ocean health (McGowan et al. 2013, Furness & Camphuysen 1997, Cairns 1987). They are predators at the top of the food web that are highly visible and have predictable behaviors (Péron et al. 2013). In order to prioritize locations for candidate MPAs, the life history traits of seabirds can be used to distinguish areas essential for
conservation of critical marine habitat (Louzao et al. 2011, Montevecchi et al. 2012). Seabirds should be used to target zones that are highly productive and frequented by multiple species which will help protect biodiversity throughout marine ecosystems and within MPAs (Kyriazi et al. 2013). Highly productive zones with available prey are integral for seabird foraging, but also provide food sources for other marine taxa and commercial fisheries (Newton & DeVogelaere 2013). Marine spatial planning has shown an unconscious bias to certain habitats, such as near shore rocky environments in temperate regions and tropical coral reefs (Agardy et al. 2011). An integration of methods that including locating areas frequently used by seabirds in open ocean waters would provide useful insight into expansion of MPAs.

Ecosystem based management is a concept that considers all interactions within an environment rather than focusing on a single species or process. An ecosystem based approach to protection has the potential to increase the efficiency of marine spatial planning (Day et al. 2008, Douvere 2008) and seabirds can facilitate this process (Thaxter et al. 2012). Seabirds that breed on islands allow a chance for scientific interaction. Marking and tracking techniques used on seabirds could help define areas that are used by more elusive marine species foraging in the same nutrient rich sites, including certain whale species and large predatory fish (Hyrenbach & Veit 2003). This paper will examine existing tracking and habitat modeling techniques used on seabirds to determine foraging range and behaviors to adjudicate candidate MPA locations off the coast of California, while considering increasingly unpredictable climate patterns. An analysis of a specific locations will be done to determine potential expansions of a MPA within a national marine sanctuary. Designing MPAs that take into account climate variability and allowing for adaptive management will ensure the preservation of marine resources.

1.1 Existing Marine Protection Framework in the USA

The management and regulation of marine resources has been increasing throughout the world, as awareness is heightened about the many threats that continue to
alter the ecosystem services provided (Adelaars et al. 2012). Nations have become aware of the decreasing socioeconomic benefits created by the adverse risks to ocean ecosystems. Protecting marine environments is key to ensuring that the ecosystem services and economic integrity of coastal environments are not abolished. Within the United States there are federal and state laws that protect the nation’s marine resources. At the federal level there is the National Marine Sanctuaries network and California has implemented one of the first state based networks. To fully understand the role that science plays in developing the policy and legislation for protection, the next section will give background on both networks.

1.1.1 California's Marine Life Protection Act

Various policies and regulation have been implemented throughout the past two decades to address the issue of protecting California's marine resources. California has 1100 hundred miles of coastline and depends heavily on this ocean ecosystem for economic resources (CDFW2008). Beginning in 1998 the Marine Life Management Act (MLMA; Stats. 1998, Chapter 1052), began to restrict recreational and commercial takes of fish in an effort to maintain sustainable fisheries. This began a huge shift in overall fishery management goals by beginning to develop an ecosystem perspective based approach, in contrast to the traditional management based on maximum yields of a single species. The governor and state legislators then passed the Marine Life Protection Act (MLPA) in 1999, followed by the Marine Managed Areas Improvement Act of 2000 (MMAIA; Stats. 2000, Chapter 385), and California Ocean Protection Act of 2004 (COPA; Stats. 2004, Chapter 719). Each of these regulations have been an integral step in developing the most current adoption of the MLPA, which is the legislation that initiated California's marine protected area network.

There are various designations within the marine protected areas in California, with varying degrees of protection. The three classifications are state marine reserve (SMR), state marine park (SMP), and state marine conservation area (SMCA). SMRs are the most restrictive because they are no-take areas. There is no commercial, recreational or
extractive activities allowed, except by scientific collecting permit or authorized research. State marine park (SMP) can allow some recreational take, but commercial take is not allowed. State marine conservation area (SMCA) limit recreational and commercial take to protect a specific habitat or resource.

### The goals of California’s Marine Life Protection Act

*(Fish and Wildlife Code section 2853 (b)).*

<table>
<thead>
<tr>
<th>Goal</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Goal 1</strong></td>
<td>To protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems.</td>
</tr>
<tr>
<td><strong>Goal 2</strong></td>
<td>To help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.</td>
</tr>
<tr>
<td><strong>Goal 3</strong></td>
<td>To improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity.</td>
</tr>
<tr>
<td><strong>Goal 4</strong></td>
<td>To protect the natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value.</td>
</tr>
<tr>
<td><strong>Goal 5</strong></td>
<td>To ensure that California’s MPAs have clearly defined objectives, effective management measures, and adequate enforcement, and are based on sound scientific guidelines.</td>
</tr>
<tr>
<td><strong>Goal 6</strong></td>
<td>To ensure that the MPAs are designed and managed, to the extent possible, as a component of a statewide network.</td>
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</table>

*Table 2 (adapted from Kirlin et al. 2013) Goals established by the MLPA, not in order of importance.*

The MLPA was recently updated and is one of the largest scientifically based network in the United States and second-largest in the world. The MLPA has incorporated a multitude of stakeholders, scientist and an advisory panel to advocate for ecosystem based management approaches. Table 2 shows the goals established by the Marine Life Protection Act, which are not rated in order of importance. The improved network consists of 124 designated areas which replace the 63 existing MPAs. Now 9.4 % of state waters are designated as “no-takes” MPAs and this accounts for 60% of all no-take MPAs within the continental U.S. (Kirlin et al. 2013).
1.1.2 National Marine Sanctuaries

The National Marine Sanctuaries Act (NMSA) is a federal regulation that authorizes the protection and designation of the marine environment based on recreational, historical, scientific, conservation, ecological, educational, archeological, cultural, or esthetic value by the Secretary of Commerce. The act was first passed in 1972 and has been amended several times since its inception. National marine sanctuaries (NMS) are managed by National Oceanic and Atmospheric Administration (NOAA). The designation as a NMS provides the opportunity to declare regulations within the sanctuary boundaries regarding what activities that can or cannot occur.

**Figure 2:** (from ONMS 2010) [http://sanctuaries.noaa.gov/](http://sanctuaries.noaa.gov/)  
Locations of national marine sanctuaries throughout the United States.

Unlike the MLPA used throughout California, the NMSA does not establish specific laws prohibiting levels of take. The NMSA gives the Secretary of Commerce the authority to decide based on a public process what types of extractive uses can take place in certain sanctuaries. Five national marine sanctuaries exist along the coast of California. This includes 12,843 square miles and all of the sanctuaries are strategically located in areas of rich marine resources which are intimately connected. Figure 2 shows locations of the national marine sanctuaries within the United States. The National Marine Sanctuaries
Figure 3 This map shows the three National Marine Sanctuaries (NMS) located along central California including (from the top) Cordell Bank NMS, Gulf of the Farallones NMS and Monterey Bay NMS. The red areas indicate California’s Marine Protection Network.

differ from MPAs in that they encompass larger areas, however they are not as specifically regulated as California MPAs. Figure 3 shows NMS and MPAs off the central coast of California. The NMS are managed from a natural resources perspective (NMSA 200), while MPAs are managed from an ecosystem based perspective (CDFW 2008). Along the west coast most of the MPAs exist within NMS and together they create unique protection of the marine environment.
2 Habitat Modeling

Seabird breeding colonies found on islands throughout California offer a unique opportunity to provide an interface for research and study. Seabirds depend on terrestrial and marine resources for survival, as do humans. Protecting and conserving marine locations that are imperative to seabirds can also help preserve other marine taxa that use these productive areas. Functioning marine ecosystems contribute to economies and the wellbeing of humans around the world and regulation needs to be enacted to ensure that the services provided remain. Habitat modeling near breeding colonies is a key tool that can be used to understand how seabirds are using ocean environments to inform planning. This next section will examine habitat modeling used to study seabirds within National Marine Sanctuaries along California’s coast.

2.1 Case Study: Seabirds on the Farallon Islands

Recognizing factors that prompt seabird habitat preference can help delineate key conservation locations and boundaries that can potentially dictate future marine protected area sites. In an analysis by McGowan et al. (2013) key habitat features including surface ocean characteristics, spacing between geographic features and climate indices were used to establish patterns in favored habitat foraging areas. This study predicted areas that were used for foraging by the most abundant bird species breeding on the Farallon Islands by interpreting oceanographic habitat and bird surveys.

The data used for analysis was collected by the Applied California Current Ecosystem Studies Program (ACCESS), from within the Gulf of the Farallones (GFNMS, est. 1981) and Cordell Bank (CBNMS, est. 1989) National Marine Sanctuaries, see figure 4. The GFNMS and CBNMS offer breeding grounds and habitat for more than half a million seabirds in addition to some endangered species such as the Marbled Murrelet and the Ashy-storm petrel (Locke & Fox 2010). The five most abundant species nesting on the Farallon Islands were analyzed by McGowan et al. (2013); western gull (*Larus occidentalis*), common murre
(Uria aalge), Cassin’s auklet (Pychorampus aleuticus), rhinoceros auklet (Cerorhina monocerata) and Brand’t cormorant (Phalacrocorax penicillatus). Seabird surveys included line transects at 3 km intervals and were performed from the flying bridge of research vessels (2004-2011).

Habitat conditions are highly variable in marine environments and climatic changes alter prey availability and locations. To understand changes in habitat conditions McGowan et al. (2013) looked at three climate indices in relation to the birds studied. Climates indices were based on inter-annual and seasonal variations influenced by the California Current System (CCS) and upwelling trends. Various ocean climate indices are known to influence conditions in the CCS and were considered in the analysis. The main climate indices are: 1) the North Pacific Gyre Oscillation (NPCO) influencing salinity and productivity seen by chlorophyll-a; 2) the Pacific Decadal Oscillation (PDO) controlling the North Pacific SST towards the poles; and 3) the Southern Oscillation Index (SOI) that documents the trends of the tropical Pacific oceans impacts by El Niño and La Niña events.

Specifically, relating to the idea of climate indices effecting overall prey sources at the lower trophic levels, Sydeman et al. (2014) looks at multivariate ocean-climate indicators (MOCI) within the California Current Ecosystem (CCE). MOCI are a culmination of variables that effect oceanic conditions including factors such as; climate indices, wind stress, sea level, sea surface temperature, salinity, air temperature and
precipitation. Sydeman et al. (2014) further predict that large scale climatic changes occurring at regional scales is causing focal variations throughout the system. Focal variations are defined as fundamental shifts in specific locations. These focal variations can effect breeding success of seabirds, creating bottom-up control of the food web (Jahncke et al. 2008, Ainley & Hyrenbach 2010).

There is a strong association between seabird breeding success and spring MOCI (McGowan et al. 2013, Sydeman et al. 2014) suggesting that MOCI are influencing the structure of the coastal food web. Predictive tools and applications such as the MOCI can be useful in management application for climate indices modeling.

Figure 5 (from McGowan et al. 2013) This figure shows conservation targets based on Scenario 1 (without human activities) and Scenario 2 (with human activities). Conservation targets of 10%, 30% and 50% are displayed. Proposed energy footprint is included as well as existing MPAs. Gradient is based on selection frequency shading starting at those above 50%.
A layer of human use was implemented in the study of birds breeding on the Farallon Islands to determine how this can influence, manipulate and alter the factors of foraging behavior. These activities include: Military use, wildlife viewing, commercial benthic fishing with fixed and mobile gear, industrial shipping and potential alternative energy sites that would include wind and wave farm structures that can have detrimental effects of marine life (Tchou & Russel 2009, Montevecchi et.al 2012). Regarding conservation, the authors of McGowan et al. (2013) intended to consider the human use areas and how that would conflict with potential MPA sites (Fig. 5).

The results indicate that seabird associations exist with most of the habitat parameters presented. Both of the alcid species, Cassin’s and rhinoceros auklets displayed a statistically significant relationship with salinity and fluorescence while none of the other three bird species did. The alcid species also showed significant influence from the climate indices as all the common murre distributions. Western gulls were highly influenced by coastal upwelling. Surface temperature (SST) was an important factor for Brandt’s cormorants’ and common murres. All the models reveal that bathymetric features, specifically distance to shelf break and Southeast Farallon Island (SEFI) was meaningful to each bird species. Temporal relationships were examined throughout the breeding season (May, July, and September) and little variation was seen.

This modeling implies that potential conservation areas can be located in GFNMS based on varying climate indices and oceanographic conditions. Seabirds breeding on SEFI can help establish high priority areas for protection. Locating foraging grounds based on behaviors and habitat conditions can be important indicators of highly valuable protection sites. Human usage is a key factor when designating MPA location, especially since no-take areas have been found to be more lucrative in protecting marine resources (Edgar et al. 2014). Placing MPAs in locations where there is less conflict with human activities is not the best management strategy because the birds will continue to forage and move to sites with sufficient prey sources. To meet higher conservation targets, as suggested by McGowan et al. (2013) designated MPAs should include small high quality foraging sites rather than larger lower quality areas. Utilizing the foraging behaviors of seabirds found on
islands throughout California can help initiate MPAs that provide protection for the many species that exploit these nutrient rich areas. Pelagic species that utilize the nutrient areas include: tunas, sharks, squid, elephant seals, sword fish and sperm whales (Brown et al. 2013)

2.2 Bathymetric Habitat Considerations

Bathymetry is the measurement of depth in a body of water and a bathymetric habitat includes the distinguishing topography below the surface. Bathymetric habitats varies depending on natural features such as seamounts, canyons and transitional features like the continental shelf. Along the coast of California where upwelling is prevalent during certain seasons, the bathymetric features play a key role in foraging habits of upper trophic-level predators, including seabirds and certain whale species. The relationship of bathymetric habitats throughout central California in relation to aggregative response by seabirds and cetaceans (baleen whale species) was studied by Yen et al. (2004). They focused on eight species, five of which were bird species, including the common murre (Uria aalge), sooty shearwater (Puffinus grieus), Cassin’s auklet (Ptychoramphus aleuticus) and phalarope species (red, and red-necked: Phalaropus fulicaria, Phalaropus lobatus). The remaining three were cetaceans species.

The bathymetric habitats that exist along the California coastline are particularly important because of the California Current System (CCS). Upwelling creates highly productive locations as cooler nutrient rich water rise from the depths, specifically at locations such as the continental shelf. Yen et al. (2004) explored the various bathymetric habitats and examined features such as average depth, contour, and shortest distances to locations including: the continental shelf-break (200 m isobath), the continental slope (1000 m isobath), pelagic waters (3000 m isobath) and the mainland. The study area was within the Gulf of the Farallones and Monterey Bay National Marine Sanctuaries.
All five seabird species were associated with bathymetric features. The common murre was found at the greatest numbers closer to land at shallower depths and near the Farallon Islands. Cassin’s auklets seemed to congregate in highest densities at locations with consistent bathymetry near the 200 m isobath of the continental shelf and favored the Farallones and Cordell Bank. The sooty shearwater preferred to be further from the Farallones in areas with steep and fluctuating bathymetry. Both phalarope species exploited areas near the 200 m isobath closer to land near the Monterey Canyon. The Monterey Canyon is a submarine canyon located within the MBNMS, it is a distinct feature that ranges in depths up to 11,800 feet below the surface of the ocean. The sooty shearwater and phalaropes were consolidated adjacent to the Monterey Canyon, a location that is associated with an

Figure 6 (from Yen et al. 2004) All five species of seabirds showed associations to bathymetric features located within the National Marine Sanctuaries. Sooty shearwater and phalarope species aggregated near the Monterey Canyon, while the Cassin’s auklet and common murre were located near Cordell Bank and Farallones locations.
upwelling center situated near Davenport. Figure 6 shows the distribution of each seabird species throughout the study area.

Bathymetric habitats are stable geographic features that influence ocean productivity (Checkley & Barth 2009). Locating aggregations areas around these features can help isolate regions that are crucial for upper trophic-level predators such as seabirds. Unlike variable oceanographic conditions, bathymetric habitats and features offer a stable platform to help locate critical upwelling events that can advise management strategies to optimize resources protection for food webs and fisheries. Seabirds are visible species that have foraging ranges that overlap with other top species such as cetaceans (Hebshi et al. 2008). The prey consumed by seabirds constitute an extensive variety which include a portion that are economically relevant to commercial fisheries (Lascelles et al. 2012). Adapting information from seabird foraging that have been linked to bathymetry, such as Yen et al. (2004) can aid in marine protected area design which will also benefit the conservation of important commercial fisheries stocks.

3 Tracking Methodologies Assessment

Addressing the importance of designating conservation areas for seabirds in all aspects of their life histories has become an issue of increasing awareness (Anadón et al. 2011, Makino et al. 2013). Technologies have become progressively sophisticated and a greater understanding of how seabirds utilize resources, which are constantly fluctuating is a testament to their ability to adapt and survive. In the face of climate change, population growth and dwindling natural resources humans need to be proactive in managing the precious services that functioning ecosystems provide. Tracking seabirds is going to be a key component in addressing and understanding shifts in prey resources. This section will analyze and discuss tracking methodologies for seabird.

Determining foraging ranges is a key component to identify locations for new marine protected areas. How foraging areas are investigated highly influences the quality of data collected. Protection of seabird breeding colonies is common, however more protection is needed outside of breeding zones to include areas used during other stages of
life (Péron et al. 2013, Croxall et al. 2012). Thaxter et al. (2012) suggest more protection at off shore locations and describe several varieties of conservation that should include: (1) extending existing breeding colonies to incorporate areas used for upkeep behaviors, (2) offshore areas used during the breeding season for foraging which aid in breeding success, (3) near shore areas for non-breeding birds, and (4) areas defined as migratory bottlenecks.

The methodology types were put into categories that include: (1) direct, (2) indirect, (3) speculative, and (4) survey methods. The results from Thaxter et al. (2012) established that of the 304 studies reviewed, 46% utilized land-based, boat or aerial surveys, 21% using direct tracking, 21% were comprised of speculative estimates, and indirect assessments contributed only 12%. The foraging ranges were assigned confidence levels based on amount and type of tracking including: uncertain, low, moderate and highest confidence for predicted ranges. The northern gannet (Morus bassanus), black-legged kittiwake (Rissa tridactyla) and the guillemot (Uria aalge) were given the highest ranking because they had the most direct studies compared to the Mediterranean gull (Larus melanocephalus) which had survey data assigned uncertain. The results indicate that regardless of the type of methods used it was possible to approximate foraging ranges for the majority of species. A variety of methods can be applied to survey seabird foraging near breeding colonies. This information can be used to ascertain basic minimum and maximum foraging ranges that can help guide where further study should take place. Focusing efforts within predicted foraging ranges can reduce the cost and time associated with seabird surveys. The more information gathered prior to designating candidate marine protected areas, the more likely it is that these locations will offer the most protection.

3.1 GPS, GLS and PTT to Track Migration and Foraging

Tracking methods have become very complex and can be used in a sophisticated manner to assess multiple parameters when evaluating seabird distributions, such as location across various time scales. Combining numerous tracking techniques can help distinguish specific habitat preferences that are influencing site selection. Montevecchi et
al. (2012) uses this approach to identify candidate MPA locations, while also considering risk areas associated with the Gulf of Mexico oil crisis. Three seabird species were tracked; northern gannet (*Morus bassanus*), thick-billed (*Uria lomvia*) and common murre (*Uria aalge*). Global Location Sensors (GLS), satellite platform terminal transmitters (PTTs) and GPS were used in combination with vessel surveys to locate seabird ranges on colonies found in the western North Atlantic. These colonies are all found on islands off the coast of Newfoundland, Canada.

Montevecchi et al. (2012) found that all species had predictable foraging during the breeding and non-breeding seasons. Aggregations were concentrated in important areas where other species of marine animals were also present including: minke (*Balaenoptera acutorostrata*), fin (*Balaenoptera physalus*) and humpback whales (*Megaptera novaeangliae*). These marine hotspots have traditionally been hard to locate but with combined direct tracking and vessel surveys, information can be now be collected and assessed. Direct tracking in itself is useful, however vessel surveys strengthen locating these hotspots by gathering data on environmental conditions, such as oceanographic data, discussed in the previous section. These spots tend to be used more frequently during the breeding seasons and potential MPA sites should considered protection during periods of peak usage (Worm et al. 2003, Melvin and Parrish, 2001).

The important foraging areas identified in Montevecchi et al. (2012) also had conflicting use with fishing interests. Many of the smaller fish that the seabirds are feeding on are targeted by larger fish of commercial interest. Considering the multitude of stakeholders is a necessary facet of MPA designation. Specifically, the murre species examined that were occupying various inshore locations near the colony had high rates of mortality due to drowning in gillnets set by fishermen trying to catch cod and other species. High mortality during the summer month was in contrast to the winter months, when they had a higher incidence of problems associated with ship-source oil pollution. Acknowledging the many factors affecting seabird health and survival based on temporal scales can allow for adaptive management of ocean resources to benefit all interests whether economic or biological.
The direct tagging of the northern gannet from this study helped estimate a more precise number of individuals that wintered in the Gulf of Mexico near the location of the Deepwater Horizon oil crisis. Montecucchi et al. (2012) points out that using GLS on northern gannets allowed for location recovery occurrence rates of 28%, compared to a 6% recovery rate of banded adults. It was also discussed that PTTs, GLS and GPS procedures are less labor intensive and reduce disruption to the colony because smaller samples are needed. These new tracking technologies can help harbor information on distribution that further assist scientists in comprehending the stochastic events seabirds are faced while traveling to need habitat areas.

3.2 At-Sea Surveys combined with GPS loggers and Satellite Tracking:

Traditional methods utilized to track and locate seabirds have depended greatly on visual ship-based surveys (Douvere 2008). New direct methods have begun to be instituted, such as GLSs and PTTs attached to individual birds discussed in the previous section (Adams & Takekawa 2008). Both of these methods are an integral part of understanding seabird behavior to help designate MPA locations. Systematic approaches in data collection protocols need to be defined in order to maintain high quality, reliable information. Camphuysen et al. (2012) have defined and explored the most recent data on tracking of seabirds and hope that this can be used to reveal important insight into how offshore distribution and activity can help guide and designated marine protected areas. Two particular case studies were evaluated by Camphuyen et al. (2012) based on at-sea surveys and data collected from loggers on the birds. The birds compared were the Northern Gannets in the North Sea and the Lesser Black-backed Gulls in the Southern North Sea. Comparison of observed behavior to tracking data in the case of the Gannet was complementary, however the Lesser Black-backed Gull (LEGU) results were contradictory. The tracking data showed clusters and aggregations of LEGU near and around the breeding colony, however observations suggest that these were birds in route to foraging locations and adults from the nearby colony, not feeding birds. This suggest that at-sea surveys and distribution recorded from tracking could have misleading results. Integrating
the results of both methods by accounting for observed foraging behaviors with logged locations from trackers would strengthen predictions of habitat usage. Table 3 portrays strengthens and weaknesses of each survey method that can be combined to become a powerful management tool. The Año Nuevo Island analysis discussed later in the paper utilizes ship-based surveys to determine birds densities, which according to Table 3 is considered a very good tool for identifying ecologically important marine protected areas.

Combining at-sea surveys with behavioral information, such as foraging ranges and breeding characteristics, plus satellite tracking would give complementary insight into where marine protected areas would be most beneficial. These two tracking methods provide distinctly different information, but when analyzed together could become a major tool in marine spatial planning for seabirds and ultimately other marine species. The islands where seabirds breed allow for an area of interface where researchers can interact with the seabirds allowing for capture to put the satellite or GPS loggers on the birds.

3.3 Radio Telemetry Tracking: Ashy Storm Petrel Case Study

Direct tracking of seabirds has become an increasing field of study as technologies have advanced to produce lighter and more resilient hardware. This section will highlight the use of radio telemetry tracking. In a study by Adams and Takekawa et al. (2008), 70 Ashy Storm Petrels (Oceanodroma homochroa) were radio tagged, and then 57 individuals were subsequently relocated during 29 telemetry surveys ranging for San Nicolas Island to the Farallon Islands. The birds were captured at three different colonies within the California Channel Islands: Scorpion Rocks, Santa Barbara Island and Prince Island. They found that the 57 birds regularly aggregated in specific locations over the continental slope near the Channel Islands and some individuals went as far north as the Gulf of the Farallones National Marine Sanctuary. The distribution of Ashy Storm Petrels was the goal of this study, with the intention to help predict foraging areas used between April and July. The radio telemetry took place for a two year period and in 2004 the majority of locations (92%) occurred over the continental slope domain, a depth that is approximately 200-2000 meters. In 2005 that percent increased to 98% of the locations over the continental slope
Table 3 (adapted from Camphuysen et al. 2012) Displays the strength and weaknesses of each survey method. These methods include ship-based survey with and without behavior data as well as satellite tracking with and without time depth as well as GPS logging with an accelerometer. MSFA = multiple-species foraging associations.

<table>
<thead>
<tr>
<th>Survey Method</th>
<th>Densities at sea</th>
<th>Foraging range of breeding birds</th>
<th>Information related to breeding population</th>
<th>Information related to all birds at sea</th>
<th>Ecological significance (feeding area)</th>
<th>MSFAs, feeding, associations, resources, biodiversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship-based surveys-plain</td>
<td>Very good</td>
<td>Poor/indirect</td>
<td>Poor</td>
<td>Very good</td>
<td>Poor/indirect</td>
<td>Limited</td>
</tr>
<tr>
<td>Ship-based surveys + behaviors</td>
<td>Very good</td>
<td>Poor/indirect</td>
<td>Poor/limited</td>
<td>Very good</td>
<td>Very good</td>
<td>Very good</td>
</tr>
<tr>
<td>Satellite tracking-plain</td>
<td>Very limited (sample size and representation)</td>
<td>Very good</td>
<td>Very good</td>
<td>Limited</td>
<td>Poor/indirect</td>
<td>Not known</td>
</tr>
<tr>
<td>Satellite tracking + time-depth recorder (only diving birds)</td>
<td>Limited (sample size and representation)</td>
<td>Very good</td>
<td>Very good</td>
<td>Limited</td>
<td>Very good</td>
<td>Not known</td>
</tr>
<tr>
<td>GPS logger + accelerometer</td>
<td>Limited (sample size and representation)</td>
<td>Very good</td>
<td>Very good</td>
<td>Limited</td>
<td>Good</td>
<td>Not known</td>
</tr>
</tbody>
</table>

domain. Locations per unit effort (LPUE) were calculated to locate areas of the greatest aggregation. Figure 7 shows the areas of greatest LPUE during surveys and patterns can be distinguished as favorable foraging areas during the breeding season.

This information gathered from the radio tracking of Ashy Storm Petrels reveals that although the sample size was small the study supplies considerable information about at-sea habitat use of colony specific individuals. This data also
Figure 7 (from Adams & Takekawa 2008) Grids showing the greatest locations per unit effort (LPUE) in 2004 (A) and 2005 (B). LPUE does control for unequal survey area cover. Between 92% and 98% of all the locations were found between the 200m and 2000m isobath, this is considered the continental shelf domain.

Substantiates other evidence that three main aggregation areas exist for Ashy Storm Petrals off the Southern California coast; Santa Cruz Island, western Santa Barbara Channel and the continental slope near Point Buchon.

According to Adams and Takekawa (2008) some of the areas identified are also considered important summer foraging areas for other species including the Cassin’s Auklet (PTYCHORAMPHUS ALEYTICS) and blue whales (Balaenoptera musculus). Direct tracking methods can be deployed to infer greater at-sea habitat use. These island breeding seabird species allowed an interface where scientists can interact with the birds to implement direct tracking hardware, which can yield information that may otherwise be unavailable. The conservation potential of studying island dwelling seabirds and their foraging aggregations can be applied various marine taxa. Other marine species are exploiting the same prey resources and may not be as obvious as above water seabird feeding observations.
3.4 Bio-loggers

Recent scientific frontiers have adopted a new process of acquiring information on species that have proved in the past to be challenging to study, such as marine species. A new phenomenon referred to as bio-logging is gaining appreciation in the field of biology (Boyd et al. 2004, Robert-Coudert & Wilson 2005, Montevecchi et al. 2012, and White et al. 2013). Not to be confused with data loggers, bio-loggers are the newest version that can not only track outside variables, but physiological response simultaneously. These bio-loggers are placed on the animals and can measure an assortment of responses to environmental factors. This can improve scientific research because scientists will no longer have to be present to observe behavioral response and this will also reduce the number of individuals in the sample population needing to be tagged and tracked (Boyd et al. 2004). Bio-logging also includes implantable devices that can measure physiological changes, such as heart rate and body temperature. This complex data can then be transmitted to satellite. The capabilities of bio-logging can help collect data from species that are generally not easily observed from terrestrial environments. Ropert-Coudert & Wilson (2005) explain the main ideas behind bio-logging which include: the recording of multiple parameters at rates of many.

Figure 8 (from Ropert-Coudert & Wilson 2005) This great cormorant has a video-logger attached to the back, to allow viewing of foraging areas and prey selection.
times per second, monitoring variables that range from feeding habits to social behaviors and environmental parameters, this allows for intensive study that can expand the understanding of animals within their environments, as well as, their interactions with each other.

Technologies used to track seabirds are advancing, as bio-loggers become smaller and do not interrupt the daily activities of animals they offer a realistic approach to data collection. Figure 8 shows a picture of a great cormorant near Greenland with a digital-still video camera located on the back. This camera has allowed scientists to see the foraging grounds and their prey in the cold waters. Seabirds located on islands are useful in allowing the opportunity to interact and facilitate deployment of devices such as this video-logger. These transmitters have also been used to gather data for non-avian species such as Southern Elephant Seals (SES) to collect temporal oceanographic data. In a study by Jaud et al. (2012) an array of equipment that analyzed time/depth, a fluorometer (for chlorophyll), and a light logger were attached to seals. The results confirm that SES did show a relationship to temperature and light availability. Bio-logging is a tool that can help managers fully define variables effecting foraging and can help advice areas of key importance to marine species that are hard to observe.

3.5 Case Study: Black-footed Albatross (*Phoebastria nigripes*) utilizes marine sanctuaries

The Black-footed Albatross breeds in Hawaii and satellite tracking in combination with vessels sightings were used by Hyrenbach et al. (2006) to distinguish how the seabird used Cordell Bank, Gulf of the Farallones and Monterey Bay National Marine Sanctuaries. Individual albatross that were breeding on Tern Island, Hawaii regularly made flights form the colony to the California Current System (CCS). Vessel and aerial surveys between 1985 and 2002 have documented high numbers of albatross along the central California coast during upwelling season of March-August (Hyrenbach et al. (2006). Satellite telemetry methods revealed that individuals were flying over 4500 km to the CCS from breeding colonies in Hawaii. Satellite tracks were combined with environmental data consisting of: (a) chlorophyll a, (b) water depth, and (c) sea-surface temperature (SST). The satellite-
tracked birds showed a tendency to be found along the continental shelf break, approximately a 201-2000 m depth, with 67% of the satellite fixes found in this range, see figure 9. The albatross was found to be occupying areas with warmer SST (12.9 °C – 13.1 °C) and low-chlorophyll a water along the slope and continental shelf break. The statistical analysis showed dispersion to be significance with SST. Water depth and chlorophyll a were also predictors of dispersal as suggested by previous studies mentioned in Steger et al. (2000).

Locations within National Marine Sanctuaries where the albatross has the most abundant distribution could be further studied to aid in regulation of fishing practices. The designation of a NMS only protects the surrounding marine environment from activities such as dumping liter from vessel and oil extraction as discussed previously (NMSA 2000). The satellite fixes gathered from the black-foot albatross can be used to design fishery closure during peak usage time, which could reduce by-catch in gill-nets and long line fishing gear. Geographic features should be used to determine key marine protected areas. Enforcement and creation of MPAs can be established by features such as those highlighted in the study by Hydrenach et al. (2006) at distinct isobaths defining the continental shelf and high productivity zone. These productive zones are associated with bathymetric features as determined in other studies (Jaud et al. 2012, Hyrenbach et al. 2000). The albatross is one of the many species that would benefit from defining specific fishery zone restrictions throughout the CCS. Marine protected areas can offer extensive

![Figure 9](from Hydrenbach et al. 2006) This graphs shows the density of albatross satellite fixes within the CB, MB and GF National Marine Sanctuaries. The majority of fixes (67%) were between the 200m and 2000m isobaths.
benefits if they are strategically located based on sound information (Anadón et al. 2011).

4 Identifying Candidate MPA Expansions in the Monterey Bay National Marine Sanctuary

4.1 Important Bird Area Protocol

Birdlife International has worked for over three decades to help established important bird areas (IBAs) in terrestrial and freshwater environments through the IBA Programme. The intentions of the IBA programme is to develop methodologies to help locate the most essential areas for birds throughout the world, which can establish a basic criteria for further conservation planning, advocacy, action and monitoring. Birdlife International defines IBAs as:

- Locations of international significance for the preservation of birds and biodiversity
- Specific areas that can be used for practical conservation and action
- Areas distinguished using standardized criteria
- Sites that can form a larger network of protection to help aid in integrated conservation of the natural environment. (BirdLife International 2010).

A recently established protocol helps distinguish important bird areas (IBAs) in marine environments (BirdLife International 2010). This protocol helps create a global standard that can now be used to advice scientists and managers making key decisions regarding what open ocean areas should be conserved to protect IBAs. Figure 11 shows a conceptual model that helps to define the IBAs selection process as discussed in the IBA programme. This conceptual model is simplified to help understand the complex process that is described in the most recent literature from BirdLife International.
4.2 Case Study: Año Nuevo Marine Conservation Area

Año Nuevo Island (ANI) is located within the Monterey Bay National Marine Sanctuary and is has the most diverse and largest breeding colony of seabirds within the sanctuary (Thayer & Sydeman 2004). The island is located within the Año Nuevo State Marine Conservation Area (ANMCA) which is adjacent to Greyhound Rock State Marine Conservation Area (GRSMCA). Seabird breeding populations on the island consist of Rhinoceros Auklets (Cerorhinca monocerata), Cassin’s Auklets (Ptychoramphus aleuticus), Brandt’s Cormorants (Phalacrocorax penicillatus), Pelagic Cormorants (P. pelagicus), Western Gulls (Larus occidentalis), Pigeon Guillemots (Cepphus columba) and Black Oystercatchers (Haematopus bachmani). The state-listed Ashy Storm-Petrels (Oceanodroma homochroa) has been known to occur on the island in low numbers (Hester et al. 2013).

Based on the BirdLife International IBA programme protocol the areas surrounding ANI were the focus of the analysis. This analysis was intended to determine locations that could be expanded and incorporated into the existing marine conservation areas. Data from the Biogeographic Assessment off the Northern/Central California performed

\[\text{Figure 11 (adapted from concepts in BirdLife International 2010) This conceptual model helps define how marine IBAs can be distinguished based on available data. Data can be classified as primary or supplementary, depending on the quality and type. Two primary layers that overlap give you the strongest case for an IBA, while 1 primary and 1 supplementary layer with overlap constitute a strong case. Locations classified as candidate IBAs can have either 1 primary layer or 2 supplementary layers with overlap.}\]
by the National Center of Coastal Ocean Science under the National Oceanic and Atmospheric Administration (NOAA) was used. This data offer bird density data, in 5 minute grid cells for 76 seabird species throughout the three national marine sanctuaries (MBNMS, GFNMS & CBNMS). One primary source of data was used, which was vessel based surveys.

The available density data was put into ArcGIS map. Some simple bathymetry available for the MBNMS, with 100 m and 500 m isobaths was included in the map figures. Regions within the sanctuary that have been designated as sanctuary ecologically significant areas (SESA) have also been included in the maps. These SESA have been surveyed by the national marine sanctuary and indicate locations of key ecological processes that are intended to guide future research and study within the sanctuary boundaries.

Figure 12 is a general view of the entire central California coast in regard to marine bird density. This figure encompasses all three National Marine Sanctuaries (CBNMS, GFNMS and MBNMS). Areas around the Farallon Islands, near Año Nuevo Island and above the Monterey Canyon all show high bird density. With an increase in direct tracking technologies more funding should be allocated for research of seabirds breeding on coastal islands throughout California. With climate variations, population growth and an increase demand for food, protecting these hotspots now is going to be imperative for long term viability of the ecosystem service provided by functioning marine ecosystems.

Figure 13 focused on the focal regions surrounding ANI and displays marine bird density. The bathymetric lines show two deep canyons beyond the island and the grids above show elevated marine bird diversity. This indicates that the bathymetric conditions at these sites could be producing optimal conditions for foraging. Areas south of the ANI, near the Monterey Canyon also show high bird density. The regions showing high bird density southwest of ANI are also considered part of a SESA, discussed in the previous paragraph. This analysis further supports the national marine sanctuaries claim that this is an area of ecological significance, offering optimal foraging grounds for seabirds. Based on the marine IBA protocol, these finding suggest that the locations above the sub-
marine canyons found off of ANI are considered candidate marine IBAs. Further information should be collected, such as direct tracking data to classify them as the strongest cases for marine IBA designation.

Specific seabird species that breed on ANI and two listed species were mapped in the ANI region to get a bigger picture of how the areas in and around the ANSMCA are being utilized. Figure 14 includes both breeding cormorant species from ANI, Brandt’s Cormorants (*Phalacrocorax penicillatus*) and Pelagic Cormorants (*P. pelagicus*). Figure 14 also includes the two listed species, Ashy Storm-Petrels (*Oceanodroma homochroa*) and Marbled Murrelets (*Brachyramphus marmoratus*). Petrels (ASSP) have been documented on the ANI, but no confirmed breeding sites. Marbled Murrelets (MAMU) breeding in old growth conifer forest up to 50 miles inland from the ocean. Both of the cormorant species are seen at the highest densities in similar coastal areas, suggesting that they are using similar locations. The ASSP, which are known to be more pelagic feeders, can be seen at higher densities in open ocean areas, while the MAMU based on the analysis are found closer to shore.

Figure 15 looks at both auklet species, Rhinoceros Auklets (*Cerorhinca monocerata*) and Cassin’s Auklets (*Ptychoramphus aleuticus*). Although they are both auklets, they consume different prey, which would explain why there is little overlap in their density maps. Rhinoceros Auklets (RHAU) eat small fish and Cassin’s Auklets (CAAU) are planktivores. Both gull species, Western Gull (*Larus occidentalis*) and California Gull (*Larus californicus*) have similar density maps. Western Gulls (WEGU) breed on ANI and California Gulls do not, but a comparison of a similar species helps to explore the habitat usage overlap. Expanded analysis considering all species breeding on ANI would give sound evidence for how to expand ANSMCA and GRSMCA. Direct tracking of the species within the breeding colonies of ANI could be useful in helping focus areas deemed for future protection and conservation through marine protected area designation. The maps produced in this analysis can help guide further study and research in the Monterey Bay National Marine Sanctuary.
Figure 12: Marine bird densities along the central California coast within the Cordell Bank, Gulf of the Farallones and Monterey Bay National Marine Sanctuaries. Densities are from records of over 76 marine bird species. Areas near the Farallon Islands and Año Nuevo Island have 5 minute grid cells indicating high densities. This data can help focus where candidate MPA could potentially be located, expanding existing MPAs.
Figure 13: Marine bird density near Año Nuevo State Marine Conservation Area (ANSMCA), where Año Nuevo Island is located. This density maps shows 5 minute grids within the Monterey Bay National Marine Sanctuary. Notice the density hotspots located southwest of the ANSMCA, isobaths of 100m and 500m show deeps canyons lie below. Yellow utlines indicate designated Sanctuary Ecological Significant Areas (SESA). Density based on 76 species of marine birds. Notice that regions above Monterey Bay also has many high bird density grids.
Figure 14: Density maps display specific seabird species density. Cormorant species (A,B) both breed on Año Nuevo Island and have similar coastal density locations. Two listed species Ashy Storm Petrel (C) and Marbled Murrelet (D) have contrasting density maps. MAMU densities seem to be located along the coast, while ASSP frequent more open ocean areas. This highlights the different foraging strategies and areas utilized by various seabird species, indicating the complexities associated with seabird foraging locations.
Figure 15: Comparison of two auklet species, Rhinoceros Auklet (E) and Cassin’s Auklet (F), density maps show contrasting location, which could be portraying differences in prey consumption. RHAU and CAAU both breed on Año Nuevo Island (ANI). Western Gull (G) and California Gull (H) have similar densities along the coast. WEGU breed on ANI and CAGU do not. Panel G shows high densities near ANI and panel H highlights increased densities above Monterey Bay Canyon.
5 Conclusion and Management Considerations

The worldwide effort to protect seabird habitats in terrestrial landscapes has been beneficial to many seabird species (Croxall et al. 2012). Many of the important seabird breeding colonies have been protected and the need for conservation of these areas is a widely accepted idea (Klien et al. 2008). As suggested throughout this paper, the potential to protect seabirds in other crucial life history aspects, such as foraging, would help maintain seabird feeding locations, but also has relevant implications for protecting the many marine taxa that utilize the same foraging areas. Using seabirds as an umbrella species to help protect specific location of ecological importance throughout our marine ecosystems would help maintain the many ecosystem services that humans depend upon worldwide. The analysis of bird densities along the coast of central California highlight productive zones that seabirds are using. The regions southwest of ANI have previously been designated as sanctuary ecologically significant areas and the seabird density supports this claim.

Establishing marine protected areas in locations that are highly productive will conserve the human and ecological services that marine ecosystems provide. To maintain the ecosystem services that humans depend on, protection and conservation need to extend into areas that have not previously been protected. Seabirds breeding on islands off California’s coast offer a unique opportunity that should be exploited. The GIS maps indicate that areas near ANI have high bird densities and the breeding colonies found here should be further studied. Ashy Storm Petrels’ were tracked by Adam and Takekawa et al. (2008) to determine where the highest aggregations were located. The Black-footed Albatross, breeding in Hawaii was tracked to locate foraging areas within the National Marine Sanctuaries. Direct tracking of birds on island off California’s coast needs to be promoted so that more data is available, similar to that of the petrels and the albatross. The regions near ANI that had the highest marine bird density could be designated as the strongest case for a marine IBA if direct tracking data was provided. The density maps of the ANI show candidate MPA locations and supplying direct tracking data from species that breed on Año Nuevo Island would offer concrete evidence. Having a straightforward
source of data can help heighten efforts for marine spatial planning. As methodologies for modeling habitat become more advanced and as direct tracking techniques develop, improvements in how we manage and conserve marine habitats should follow.

Feeding aggregations along the California coast are hotspots for marine taxa and understanding how climate change will alter this delicate ecosystem is necessary to ensure biodiversity and sustainability throughout the marine environment. Allowing adaptive management to be a feature of MPAs is key for success. Balancing the needs of local economies and wildlife can be easily accomplished with appropriate knowledge. This knowledge is at our fingertips and implementing further study should be prioritized to safeguard the resources that can provide for generations. The livelihoods of people throughout the world depend on a functioning marine ecosystems and conservation should focus on perceptive regulation of this complex system.
6 Literature Cited


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