

A FIRST POPULATION ASSESSMENT OF BLACK OYSTERCATCHER *HAEMATOPUS BACHMANI* IN CALIFORNIA

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SUMMARY

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Black Oystercatcher *Haematopus bachmani* is considered vulnerable to decline owing to small global population size, low reproductive success and complete dependence on rocky intertidal shorelines that are impacted by human use and rising sea levels. In response to poor baseline knowledge of the population of the species in California, during 2011 we undertook the first targeted survey measuring distribution and abundance. For the mainland, we used a standardized protocol developed specifically for detecting Black Oystercatchers during the early breeding season, when pair fidelity to breeding territories is highest and movement is lowest. For the Channel Islands, government biologists used a standardized seabird monitoring protocol adapted to detect Black Oystercatchers. For the Farallones, data are taken from the literature. On the mainland, 164 observers participated in the survey in 12 of the state's 15 coastal counties. Observers surveyed approximately 9% of the mainland California coast, equalling approximately 18% of the state's mainland suitable habitat, defined below. A total of 1 160 Black Oystercatchers were detected in this subset of habitat, more than the previous estimate for the entire state (<1 000 individuals). Average density of individuals in mainland surveyed areas was 3.14 birds/km; 135 nests were positively identified, and average nest density was 0.4 nests/km surveyed. On the Northern Channel Islands, approximately 20% the total coastline (66 km), and 20% of the suitable habitat (58 km) of San Miguel, Santa Rosa, Santa Cruz, Anacapa and Santa Barbara islands was surveyed. A total of 176 adult or sub-adult Black Oystercatchers were detected. Average density of individuals in surveyed areas was 2.7 individuals/km, comparable to mainland densities. In areas thoroughly surveyed, observers found densities of nesting territories comparable with those in Alaska and British Columbia, considered the core of the species' range. Based on observed densities in surveyed areas, and including estimates from the literature and more recent observations of a population of 60 at the Farallones, we conservatively estimate a total mainland and Farallones population between 3 971 and 5 213 and a Northern Channel Islands population between 779 and 854, for a total statewide population between 4 749 and 6 067. Our results indicate that California is a critical rather than peripheral part of the Black Oystercatcher range. This result, plus ongoing threats, emphasizes the need to monitor Black Oystercatcher population trends and to identify and protect the most important habitats for Black Oystercatchers in California. The Black Oystercatcher appears highly amenable to citizen science monitoring, particularly at smaller spatial scales, owing to its life history characteristics and charismatic appeal to the public.

Key words: California, Channel Islands, citizen science, Black Oystercatcher, rocky intertidal shoreline

INTRODUCTION

Baseline ecological information on species' population size, distribution, reproductive success, adult survivorship and preferred habitats is necessary to understand and protect biodiversity. Black Oystercatcher *Haematopus bachmani* has been declared a special status species in the US, Canada and Mexico, owing to a small global population size (~10 000–12 000 individuals), low overall reproductive success and complete dependence on rocky intertidal shorelines, which are easily disturbed by humans and vulnerable to rising sea level. It has been studied in some detail in Alaska, British Columbia and Oregon, but is poorly understood in California and Baja California, the southernmost portion of its global range (Tessler *et al.* 2007).

Black Oystercatchers occur from the Aleutian Islands to Baja California Sur, preferring low-gradient intertidal areas with high densities of macroinvertebrates. Of the guild of six bird species relying on rocky intertidal habitat—also including Ruddy Turnstone

Arenaria interpres, Black Turnstone *Arenaria melanocephala*, Wandering Tattler *Tringa incana*, Rock Sandpiper *Calidris ptilocnemis* and Surfbird *Aphriza virgate*—it is the only species using this habitat year-round. In the nonbreeding season, Black Oystercatchers may aggregate in groups of tens or hundreds, but breeding pairs segregate into discrete territories dispersed along suitable habitat. Breeding Black Oystercatchers tend to return annually to the same territories to nest, and can be highly territorial and aggressive toward conspecifics as well as other avian species. Indeed, they feed within their breeding territory (Andres & Falxa 1995, Tessler *et al.* 2007).

The overall status of Black Oystercatchers is unclear. Local extirpations of breeding populations have occurred on islands off the coast of Baja California, Mexico and Alaska (Tessler *et al.* 2007), and the species was absent as breeders and otherwise rarely seen for over 100 years at the Farallon Islands up to 1972 (Ainley & Lewis 1974). However, there is evidence of range expansion in parts of the Strait of Georgia, British Columbia (Butler & Golumbia

2008), San Francisco Bay (San Francisco Bay Bird Observatory 2008), and southern California (E. Almanza pers. comm.). They recolonized the Farallones once disturbance was reduced and cats removed (Ainley & Lewis 1974). Changes were also reported from Sitka Sound, Alaska (Andres & Christensen 2009). An analysis of long-term data collected from the National Audubon Society's Christmas Bird Count shows stability from British Columbia through California, with the exception of Oregon, where a moderate decline is evident (Fig. 1) (Niven 2011).

Until this study, the only population estimate for large sections of the California coast was generated from boat-based surveys of seabird colonies conducted in 1989–1991 (Carter *et al.* 1992). However, as noted by Tessler *et al.* 2007, these surveys were typically conducted later in the breeding season, when Black Oystercatchers are less vocal and visible. More importantly, these monitoring approaches are designed for seabirds that aggregate to breed at colonies, whereas Black Oystercatchers breed diffusely at widely distributed islets and headlands. The Black Oystercatcher Conservation Action Plan, developed as part of the US Fish and Wildlife Service Focal Species Program, recommends increased baseline understanding in California and Mexico “to establish a strong foundation from which to initiate specific conservation actions and assess changes in trend over time” (Tessler *et al.* 2007, p. 67). In response to these information gaps, we undertook the first directed survey of Black Oystercatchers in California, undertaken by trained amateur ornithologists—‘citizen scientists’—and agency biologists, using standardized protocols developed and previously applied by experts in Oregon.

STUDY AREA AND METHODS

Survey

Surveys were conducted at selected sites and routes mainly in northern through central California from 2 to 5 and 9 to 12 June 2011 (Fig. 2). For the mainland, we used a survey protocol designed by experts specifically for Black Oystercatcher and refined over four years of field use in Oregon (Elliott-Smith & Haig 2011). The protocol minimizes or eliminates bias through double counting.

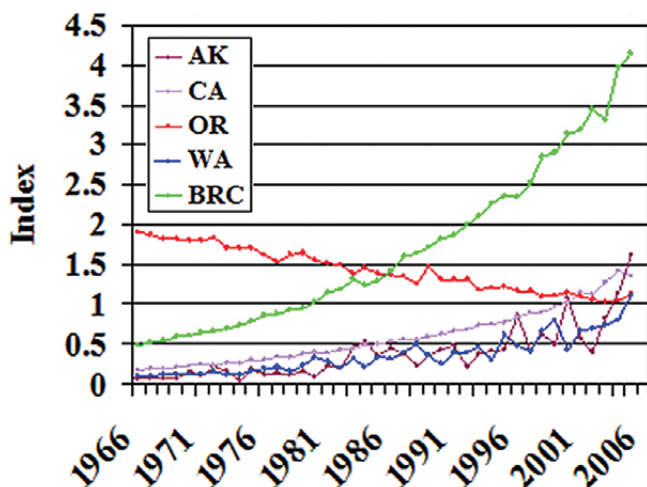


Fig. 1. Trends in annual indices of abundance of Black Oystercatcher from 1966/67 through 2005/06 in Alaska (AK), California (CA), Oregon (OR), Washington (WA) and British Columbia (BRC) based on Audubon Christmas Bird Count (CBC) data.

Key elements of the protocol include the requirement that counters remain at each survey point for 30 min, a procedure estimated to produce a 69% probability of detecting Black Oystercatchers (Lyons *et al.* 2012); a procedure for locating cryptic nests; and geospatial referencing of the locations of individuals and nests using electronic devices such as handheld GPS units, or by marking a paper map. We selected the survey dates to maximize the number of Black Oystercatchers defending territories, attending nest sites and incubating eggs or brooding chicks.

We obtained a geodatabase developed by the California Department of Fish and Wildlife in conjunction with the state's California Marine Life Protection Act Initiative. This source characterizes shoreline habitats according to >60 specific habitat sub-types. We identified potentially suitable habitat for Black Oystercatchers in California by selecting for “rocky intertidal” habitat types, a reasonable proxy for suitable Black Oystercatcher habitat, from the geodatabase. Next, we contacted experienced amateurs and leaders from Audubon chapters and bird clubs, as well as independent, federal and state agency biologists, to assess interest and gain commitment to a statewide survey. Participants were assembled from these groups.

A smaller subset of participants, composed of experienced amateurs and independent and agency biologists, served as survey coordinators, tasked with identifying and assigning survey routes or points. Survey routes or points were chosen by the presence of suitable habitat, access on private property and surveyor availability. All routes and points were dominated by rocky intertidal habitat with areas of beach or other habitat types as defined by the state's shoreline habitat type spatial data layer and augmented by photographs from <http://www.californiacoastline.org/> to determine the presence of suitable habitat. Participants also used local



Fig. 2. Areas included in the survey.

knowledge, eBird reports (Sullivan *et al.* 2009) and Christmas Bird Count data to help identify survey routes and points.

For the Channel Islands, Channel Islands National Park biologists and seasonal assistants searched for Black Oystercatchers and nests from boats using protocols designed to best detect Black Oystercatchers under the constraints of coastal ocean conditions. Included were San Miguel, Santa Rosa, Santa Cruz, Anacapa and Santa Barbara islands. These are primarily the Northern Channel Islands with the addition of the more southern Santa Barbara. For the Farallon Islands, data were taken from the literature (Ainley & Lewis 1974, Ainley & DeSante 1980; confirmed by more recent data collected by R. Bradley, Point Blue Conservation Science, pers. comm.).

Data were recorded on standard data sheets and returned to Audubon California. We assembled the data into Excel spreadsheets, Google maps, and Esri's ArcGIS.

We mapped the survey routes (Fig. 2) and calculated total distance surveyed, ascribing a 200 m default viewshed to each point including the north and south point of each survey route. As described above, the California coastline has been characterized according to a number of specific habitat sub-types. We associated each observed bird with the type of coastline closest to it using the Spatial Join tool in ArcGIS. Within each of the two regions, we calculated the total number of observed birds associated with each type of coastline habitat. We define suitable habitat as all types of coastline associated with at least 1% of the observed birds in the region (Table 1).

TABLE 1
Habitat association of detected Black Oystercatchers

Shoreline category	Associated birds observed ^a	Distance surveyed, ^b km	Average bird density, ^c per km	Total length, ^d km	Estimated population ^e
Mainland					
Exposed wave cut platforms in bedrock	479	135	3.5	316	1 119
Exposed rocky cliffs	139	32	4.3	176	762
Mixed sand and gravel beaches/exposed wave cut platforms in bedrock	138	27	5.1	122	629
Fine to medium grained sand beaches	51	42	1.2	458	559
Riprap/fine- to medium-grained sand beaches	73	2	42.7	11	473
Riprap	21	15	1.4	313	428
Gravel beaches/exposed wave cut platforms in bedrock	77	17	4.4	83	368
Gravel beaches	32	8	4.0	80	322
Mixed sand and gravel beaches	29	14	2.1	121	249
Coarse-grained sand to granule beaches	22	19	1.1	167	191
Fine- to medium-grained sand beaches/exposed wave-cut platforms in bedrock	21	22	1.0	55	52
Total					5 153
Channel Islands					
Exposed rocky cliffs	111	37	3.0	136	411
Wave cut rocky platforms	48	14	3.5	85	301
Coarse-grained sand to granule beaches	8	4	1.8	37	67
Fine- to medium-grained sand beaches	5	2	2.5	21	53
Mixed sand and gravel beaches	2	1	1.4	16	23
Total					854
Statewide^f					6 067

^a Each bird observation is associated with the closest type of shoreline. Shown is the number of observed birds associated with each category of shoreline. The list is limited to those shoreline categories associated with at least 1% of the observed birds in a region.

^b Total distance surveyed for each shoreline category, by region. A 200 m viewshed is assumed for observations.

^c Average bird density is calculated as the number of associated bird observations divided by the total distance surveyed for each shoreline category, by region.

^d Total length of each shoreline category, by region.

^e Population is estimated by multiplying the average bird density by the total length of each shoreline category, by region. Populations are summed across all shoreline categories.

^f Includes Farallones population, estimated at 60 birds from the literature.

For each region, we calculated the average bird density within each type of coastline habitat by dividing the number of observed birds by the distance surveyed. To generate a current statewide population estimate, we multiplied the average bird density within each type of habitat by the total length of that habitat in the region. We based our estimates on three options, using only habitat where at least 1%–3% of the birds were detected. We summed the population estimates from the mainland and the Northern Channel Islands, along with the population estimate for the Farallones (Table 2).

Other information on Black Oystercatcher population size in California

We did not survey the Farallon Islands. We compiled information from the literature on the Black Oystercatcher population, and we calculated the expected density of Black Oystercatchers based on the linear distance of suitable habitat.

As a potential basis of comparison, we reviewed Black Oystercatcher population trends in California available through the National Audubon Society's annual Christmas Bird Count (CBC). A citizen science program initiated in 1900, CBC annually records observations of birds in predefined count circles from 14 December to 5 January. The data are recorded at the scale of count circles 24.1 km in diameter, tracking of coarse trends accounting for effort. Niven (2011) expanded upon standardized approaches to trends

TABLE 2
Population estimates based on percentage of Black Oystercatchers in classified habitats

Population estimate	1%	Population estimate	2%	Population estimate	3%
Mainland	5 153	Mainland	4 482	Mainland	3 911
Channel Islands	854	Channel Islands	831	Channel Islands	779
Farallones	60	Farallones	60	Farallones	60
Total	6 067	Total	5 373	Total	4 749

TABLE 3
Black Oystercatcher survey results for the mainland and the Northern Channel Islands, June 2011

Parameter	Mainland	Northern Channel Islands	Total
Birds observed, individuals	1 160	176	1 336
Birds/km, average number	3.14	2.68	3.07
Nests observed, number	135	36	171
Nests/km, average number	0.4	0.5	0.4
Coastline surveyed, km (% of total coastline)	369 (9)	66 (20)	435
Suitable habitat surveyed, km (% of total habitat)	334 (18)	58 (20)	392
Overall population estimate (modeled, range) ^a	3 911–5 153	779–854	4 749–6 067

^a Total population estimate includes Farallones population, estimated at 60 birds from the literature.

analysis for CBC (Link *et al* 2006) to generate a trends analysis specific for Black Oystercatcher in British Columbia, Washington, Oregon and California. This analysis was based on an abundance index approach, taking into account survey effort, proportion of coast included in count circles and other variables for the period 1966/67 through 2005/06 (Fig. 1).

RESULTS

A total of 1 336 individual Black Oystercatchers and 171 nests were detected. Based on observed densities of Black Oystercatchers in this study, we conservatively estimate for 2011 a statewide mainland population of Black Oystercatchers of 3 911 to 5 153 birds, a Northern Channel Islands population of 779 to 854 birds, and a Farallon population of 60 birds, for a total estimated statewide population between 4 749 and 6 067 birds (Tables 2, 3). Results for the mainland, Farallones and Northern Channel Islands are reviewed separately below.

Mainland survey results

In addition to the coastal strip, *mainland* areas also include sea stacks, islets and near-shore rocks that were easily visible from shore. For the mainland, 164 observers participated in the survey in 12 of the state's 15 coastal counties during 2011. We calculated that 9.2% of the state's coastline was surveyed (369 km length surveyed/4 029 km length of coast excluding San Francisco Bay), and that 18% of the state's suitable habitat was surveyed (334 km suitable habitat surveyed/1 902 km total suitable habitat).

A total of 1 160 Black Oystercatchers were detected (Fig. 3). Average density of individuals in surveyed areas was 3.14 birds/km (1 160 birds/369 km). A breakdown of the habitat classifications

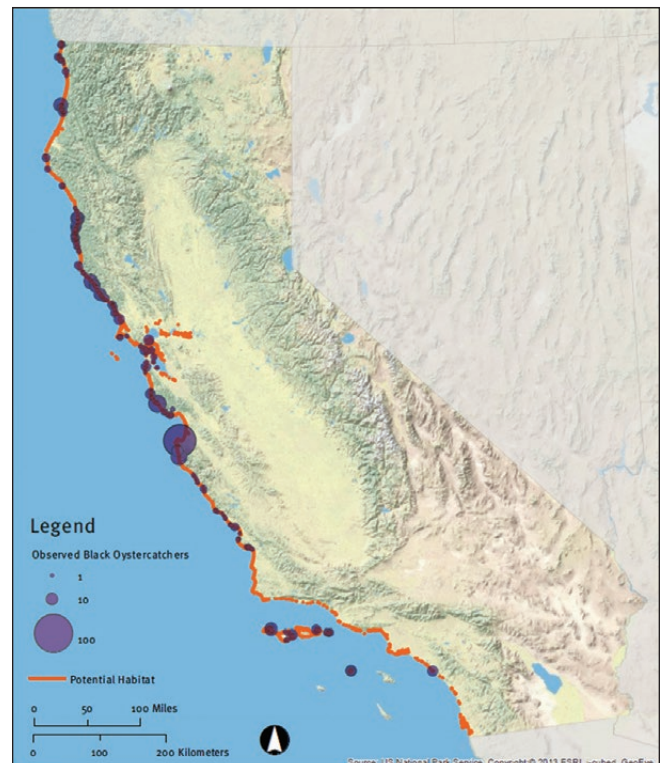


Fig. 3. Distribution of Black Oystercatchers observed.

and the frequency of detections is shown in Table 1. An estimate of 1 160 Black Oystercatchers is likely to be less than the true number of birds in surveyed areas; the detection rate using this protocol has been calculated to be ~69% (Lyons *et al.* 2012), and observers frequently reported difficulties viewing their entire survey route or point area, owing to varied topography of the rocky coast and lack of access to good vantage points. Also, a subset of observers (~10%) did not use a spotting scope, and used only binoculars, which may have limited their ability to detect all birds visible in a given area.

A total of 135 Black Oystercatcher nests were positively identified. Overall, average nest density was 0.4 nests/km surveyed. Nests were not uniformly distributed, and in several instances separate nests from discrete pairs of birds occurred within 30 m of each other. The vast majority of nests were observed on tidally separated offshore rocks >10 m high. The southernmost nest record in California was at Dana Point in Orange County (33.456209°N, -117.695722°E), also coincident with the southernmost point included in the survey.



Fig. 4. Potential habitat ranked by average density of Black Oystercatchers in 2011.

Latitudinal gradients existed in densities of individual nests and in breeding phenology: densities of individuals were highest in north-central (Sonoma County) and northern California (Mendocino County), and lowest in south-central to southern California (Monterey through Orange counties; Fig. 4). Chicks were observed from the southern through north-central part of the state but not in the northern portion through June 6, the end of the survey period. There was a new southernmost US breeding record found in the survey, in Orange County (cf. Andres & Falxa 1995). In four areas, in addition to counts of individual birds, nests were counted with a high degree of confidence that most or all nests were accurately detected (Table 4). Outside of these thoroughly surveyed areas, only a portion of the often highly cryptic nests were likely detected.

Northern Channel Islands survey results

Approximately 20% the total coastline (66 km) and 20% of the suitable habitat (58 km) of San Miguel, Santa Rosa, Santa Cruz, Anacapa and Santa Barbara islands was surveyed. The percentage of coastline surveyed ranged from 7.5% of suitable habitat for Santa Rosa Island, to 79% for Anacapa Island.

A total of 176 adult or sub-adult Black Oystercatchers were detected (Table 1). Average density in surveyed areas was 2.7 individuals/km. Densities were 4.5 individuals/km for Santa Barbara Island, 3.0 individuals/km for San Miguel Island, 2.1 individuals/km for Anacapa Island, 1.2 individuals/km for Santa Cruz Island and 4.4 individuals/km for Santa Rosa Island. Overall average densities were 2.7 individuals/km, slightly lower than the mainland average density.

Farallon Islands

Black Oystercatchers recolonized the Farallones in the late 1960s, after an absence as breeders, and sporadic sightings otherwise, of more than 100 years. By 1972, 52 individuals were found, including 20 breeding pairs (Ainley & Lewis 1974). The total number of individuals grew to 60 by 1979 (Ainley & DeSante 1980), and it was thought that the breeding population would be unable to expand further owing to competition for nesting space. Numbers have varied annually up to that total ever since (R. Bradley, Point Blue Conservation Science, pers. comm.). Suitable habitat on the islands comprises 10.9 km of a total of 11.4 km. Assuming a total population of 60 birds, the density of Black Oystercatchers is 5.5 birds/km within suitable habitat. Several color-banded individuals have been seen on the mainland in the Pt. Reyes area (D. Ainley, pers. comm.), the dispersal seemingly a response to the competition for nesting habitat on the islands.

TABLE 4
Densities of Black Oystercatchers and nests at selected surveyed areas in California

Location	Linear distance surveyed, km	Total individuals observed	Individuals observed/km	Total nests observed	Nests/km surveyed
Van Damme State Park	3.2	19	5.9	10	3.1
Sea Ranch	10.0	61	6.1	13	1.3
Humboldt County	12.0	22	1.8	11	0.9
Morro Bay	1.0	6	6.0	3	3.0

DISCUSSION

Survey results and population estimate

In this first targeted, standardized survey for Black Oystercatchers in California, a total of 1 336 individuals were observed in a subset of suitable habitat during the breeding season from Del Norte to Orange counties. This equals approximately 50% more individuals than the 888 previously estimated for the entire state by seabird colony surveys (Carter *et al.* 1992). The subset of suitable habitat we surveyed was $\leq 18\%$ of the mainland and 20% of the Channel Islands suitable coastal habitat.

The statewide estimate of 4 749 to 6 067 individuals proposed here would benefit from future refinement. However, this estimate is a reasonable benchmark generated from observed densities in combination with geospatially defined extent of potentially suitable habitat, as defined above. Even if the true population of Black Oystercatchers in California is only 3 000 individuals, just over twice the number observed in our survey, this substantially enhances the importance of habitat in California for this species.

Furthermore, where expert amateurs and professional biologists surveyed California mainland areas that were amenable to a thorough assessment of active nesting territories, they found high densities of breeding territories (Table 4), rivaling or possibly exceeding densities in southeast Alaska and British Columbia. Information we are collecting on breeding densities and reproductive success from areas of the state will be discussed in a future paper. Collectively, this new information on observed and estimated numbers of Black Oystercatchers, and observed breeding densities, indicates that at least certain regions in California are a critical segment of the global range of the species.

The geomorphology of California and southern Oregon's coastal zone may represent a *de facto* refuge from climate change for Black Oystercatchers, at least in regard to nesting habitat. The marine terrace and sea stack geomorphology found in central to northern California and in southern Oregon provide some refuge against predicted increases in sea level and storm frequency associated with climate change by providing nest sites 5 m to 20 m or more above high tide line. Where tidally separated from the mainland, these rocks provide large numbers of suitable nest sites that are free from terrestrial mammals and close to foraging areas. In Alaska, breeding islands are typically low elevation, and studies in these areas that evaluate causes of nest loss have shown or suggested that nearly one-half of nests are lost to inundation caused by natural and anthropogenic wave action and high tides (Tessler & Garding 2006, Morse *et al.* 2006). In California as in other areas, intertidal foraging habitat remains highly vulnerable: recent modeled projections of the loss of intertidal habitats to inundation have shown a 10%–70% loss with a sea level rise of 1 m to 2 m (Haig & Hollenbeck 2012). Key will be the speed by which the sea level rises, and whether intertidal invertebrates can adjust.

The surprisingly high number of individual Black Oystercatchers we counted and subsequently estimated for all of California contrasts with low numbers reported in Washington, Oregon and Baja California, together considered the southern portion of the species' range. Oregon hosts an estimated 330 individuals,

Washington an estimated 340 individuals (Lyons *et al.* 2012) and Baja California an estimated 100 individuals (Palacios *et al.* 2009). These low populations can be largely attributed to the smaller extent of rocky intertidal habitat in these states. Oregon, for example, has approximately 132 km of rocky intertidal habitat, compared with over 1 000 km in California.

Review of Black Oystercatcher population trends from Christmas Bird Counts

Niven (2011) showed that, for the period 1966/67 through 2005/06, Black Oystercatcher abundance increased non-significantly in California, Washington and Alaska, increased significantly in British Columbia and decreased non-significantly in Oregon (Fig. 1). In a comparison between a northern count circle (Circle 5) and a southern count circle (Circle 32) within the state of California, abundances were significantly higher in northern California.

Our CBC analysis found that in California the total count within CBC count areas has been rising slightly over recent years (2007–2011), with an annual average of 457 individuals (SD = 32; Fig. 5). Birds per count hour, a proxy for abundance, are higher in northern and central California than in southern California, consistent with the higher abundances in northern versus southern California found by Niven (2011) and with our survey results.

CBC annually samples a small area of California's coast, but this resource provides valuable insights into Black Oystercatcher populations because of the long time scale of the data set and because count effort is accounted for. The factors underlying the significant increase in population of Black Oystercatchers found by Niven (2011) in British Columbia, and the non-significant decrease in Oregon, have no obvious explanation.

Citizen science as a tool for monitoring Black Oystercatchers

Black Oystercatchers appear to be highly amenable to citizen science monitoring—ecological observations collected by

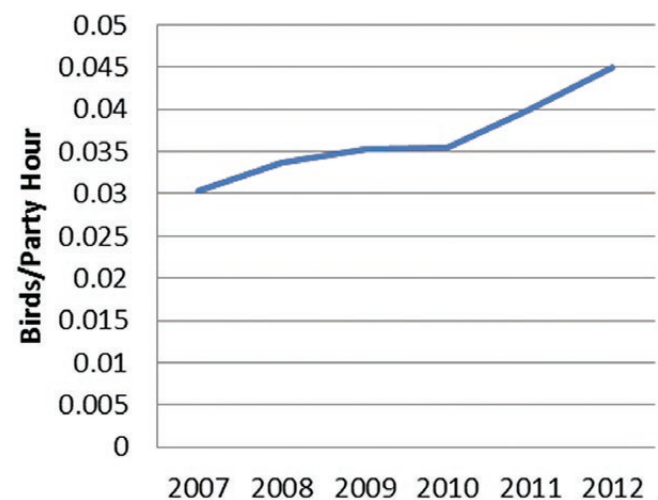


Fig. 5. Trends in annual indices of abundance of Black Oystercatcher, 2007–2012, in California based on Audubon Christmas Bird Count (CBC) data.

experienced volunteers via a standardized protocol. Black Oystercatchers are charismatic and inspiring to people, which helps attract and retain volunteers. They are large, visually and aurally unmistakable, confined to the rocky intertidal zone, and relatively stationary during the breeding season, all of which reduces the chance of double counting. The population and reproductive success protocols developed by Elliott-Smith & Haig (2011) enable standardized comparisons of Black Oystercatcher numbers and densities across the species' range. While it is unlikely that every Black Oystercatcher and every territory will be detected at larger scales in California through citizen science or any other approach, owing to constraints associated with coastal access, visibility, weather and safety concerns, detection is clearly possible at smaller spatial scales (~1–20 km).

A challenge we encountered using the protocol, which must be addressed in future survey efforts, was confusion associated with georeferencing of bird and nest observations. Participants used three approaches to georeference observations: GPS devices, paper maps and/or narrative descriptions. GPS devices are sometimes unreliable, and coordinates were delivered to us in at least three different geodetic systems or datums. We discarded some data (<3%) owing to confusion associated with georeferencing. We found that the most reliable method of recording and reporting location information was to mark locations on a paper or electronic map originating from the US Geological Survey or Google Earth. Data collected in the .kmz Google Earth file format for storing placemarks and other related data were incorporated into our Google Earth platform, and the data on paper maps was usually easy to transfer by hand. Data were then brought into Esri's ArcGIS platform for analysis. We found that a well-labeled .kmz file was the optimal format for georeferencing observations.

Most participants (>80%) used a spotting scope to aid in observing and identifying Black Oystercatchers. While recognizing that the lack of a spotting scope probably resulted in under-counting in some areas, we did not discard or treat differently data collected with binoculars and without a spotting scope. We also encouraged people to work in pairs, as the protocol suggests, because of the potentially higher detection rates achievable with two observers than with one, but we did not treat differently data collected by individual observers. Lyons *et al.* (2012) found the Black Oystercatcher detection rates between single observers and a pair of observers using scopes was not significant. Foggy conditions along parts of the coast during the survey probably also led to under-reporting.

Future conservation activities

The information generated from our study, plus CBC data, support the idea that the Black Oystercatcher population in California may be stable and that suitable habitat may be hosting a healthy population. Yet, even if this is the case, the species is highly vulnerable to decline given the gravity of the threats faced by this species and all shorebirds: changes in carrying capacity of intertidal habitat as a result of projected sea level rise; changes in prey resources as a result of warming sea surface temperatures; and increased disturbance and pollution resulting from coastal development, shipping and urbanization (Lyons *et al.* 2012). This vulnerability underscores the need to

identify, monitor and protect the most important habitats for Black Oystercatchers. An additional justification for directing scarce conservation dollars to the species is its position as a keystone species for the rocky intertidal. Black Oystercatchers have a strong and cascading effect on the intertidal community, especially mussel beds (Lindberg *et al.* 1987), based in large part on their tendency to feed preferentially on limpets of >10 mm at their largest dimension (Wootton 1992, Coletti & Bodkin 2009). These factors provide validation for directed conservation activities, such as the following:

1. Conduct habitat mapping and analyze vulnerability of nest sites and foraging areas to impending climate change impacts. Further investigation is needed to create and refine a geospatial description of good-to-optimal breeding habitat for Black Oystercatchers in California, likely characterized by low-gradient marine terraces hosting mussel beds and close to tidally separated islets and rocks of sufficient height to avoid inundation. Appropriate geologic data at sufficiently fine scale would, if available, enable this analysis and provide a clearer picture of the importance of California to the global status of the species, and show areas of potential focus for conservation activities including monitoring and protection. This map would be the basis for a modeled analysis of the vulnerability of these breeding territories to predicted climate change impacts—primarily sea level rise in combination with increased storm events (Haig & Hollenbeck 2012, Tessler *et al.* 2007).
2. Track reproductive success at enough sites for sufficient duration (at least five years) to create sufficient analytical power to understand overall rates and trends as well as latitudinal gradients or other patterns of heterogeneity in nest success. Sampling covariates should include weather, storm and tide events; disturbance from pinnipeds, gulls, peregrine falcons, humans and other taxa; predation events; and the density and species composition of the invertebrate prey community (limpets, mussels and snails; Haig & Hollenbeck 2012, Tessler *et al.* 2007).
3. Track breeding territory occupancy and overall numbers of individuals for a set of reference sites that would serve as long-term indicator of Black Oystercatcher abundance. In combination with reproductive success information and modeled impacts of climate change, generate a population viability analysis for the species in California.
4. Better understand and describe conservation best practices for coastal agencies, landowners, businesses and constituent groups, especially at sites of known importance to Black Oystercatchers. These practices may include reducing disturbance from kayakers, fishermen, algae collectors, abalone divers and beach explorers, by posting signs at public access points in areas with high densities of Black Oystercatchers, or by other means. Signs based on children's art might be used: they are thought to be successful in reducing disturbance at sites important for the Snowy Plover and California Least Tern, and are less likely to be vandalized than conventional signage.
5. Sustain and increase the existing corps of citizen scientists who aid in surveys of Black Oystercatchers.

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