DRAFT (25 April 2011)
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Vulnerability Ranking Criteria for California's At-Risk Birds
To quantify the evidence that a species is vulnerable to climate change, we evaluated seven criteria of exposure and sensitivity. We developed these seven criteria by considering previous work to rank a species vulnerability to climate change (e.g., IUCN, NatureServe, EPA) and information from relevant literature (e.g., Jiguet et al. 2007). While one approach would have been to use one of these existing ranking schemes, we found that because these schemes were generally designed to rank all organisms (not just birds) they were so broad that they both incorporated information that was irrelevant for birds (e.g., sex ratio determined by temperature) or failed to incorporate more detailed information that is available for birds in California. Hence, we chose to develop a modified scheme that is uniquely tailored for California bird populations recognizing that there is not a one-size-fits-all approach to vulnerability analyses (Glick et al. 2011). Additionally, we took advantage of the relative wealth of information on the predicted changes in probability of occurrence of birds in California by using them to inform our "Changes in habitat suitability" criterion.

Sensitivity

1. Habitat specialization. Species of birds and butterflies with a high degree of habitat specialization have been shown to be more sensitive to environmental change than habitat generalists (Warren et al. 2001, Julliard et al. 2004). Furthermore, habitat specialization has been used as a criteria in efforts to quantify sensitivity to climate change for arctic marine mammals (Laidre et al. 2008), butterflies (Heikkinen et al. 2008), and in other vulnerability assessment frameworks (Glick et al. 2011). Therefore, we scored habitat specialization as follows:

      3 – high sensitivity if a taxa uses only specific habitat types or elements

      2 – moderate sensitivity if a taxa tolerates some variability in habitat type or element

      1 – low sensitivity if taxa uses a wide variety of habitat types

2. Physiological tolerances. Some species have very narrow physiological tolerances to climate conditions, such as temperature or water availability. Such physiological limitations may make species less resilient to changing conditions and extreme weather events (Bernardo and Spotila 2006, Jiquet et al. 2006). We scored this criterion as:

      3 – highly physiologically sensitive to climatic conditions

      2 – moderately physiologically sensitive to climatic conditions

      1 – minimal or no evidence of physiological sensitivity to climatic conditions

3. Migratory status. Because migratory birds depend on timing their movements and arrival and departure with conditions that facilitate successful survival and reproduction, they are often considered to be more sensitive to changing climatic conditions than species that do not migrate (Both et al. 2006, Both et al. 2010). We scored this criterion as:

      3 – taxon is primarily a long-distance migrant (migrates at least to the neotropics)

      2 – species is a short-distance migrant (primarily restricted to the nearctic zone)

1 – species is a year-round resident

4. Dispersal ability. Species with poor dispersal ability, or lack of ability to shift distributions (e.g., geographic barriers, philopatry, neophobia), are less able (or likely) to adapt to spatially shifting conditions, habitats, or resources. Dispersal ability has been included in efforts to quantify sensitivity of climate change for butterflies (Heikkinen et al. 2008) and it is likely to be important for birds (e.g., Jiguet et al. 2007). We scored this criterion as:

3 – high sensitivity due to low dispersal ability

2 – moderate sensitivity due to average dispersal ability

1 – low sensitivity to high dispersal ability

Exposure

5. Changes in habitat suitability. Taxa will be exposed to a wide variety of changes to their habitat including broad scale changes in major vegetation types and changes in key habitat elements. We used existing habitat suitability models (sometimes called probability of occurrence models or distributional models) available for California birds to compare the current probability of occurrence in California to the probability projected for 100 years in the future. Although model outputs gave a percent change, we still used expert opinion to interpret them and make the final score. When models were unavailable, we used expert opinion based on best available evidence for changes in vegetation types or critical habitat elements (PRBO 2011). This criterion includes the effects of sea-level rise, loss of nest sites, etc. We scored this criterion as:

3 – changes in habitat expected to decrease by > 50%

2 – changes in habitat expected to decrease by 50-10%

1 – changes in habitat expected to increase or decrease by 0-10%

6. Changes in food availability. Bird populations may be exposed to climate-change effects if the timing, availability, and abundance of critical food resources are altered. The linkage between climate-change effects of food availability and changes in reproductive success or survival are believed to be important for some birds (e.g., seabirds; Wolf et al. 2010).

3 – major negative impacts from projected changes in food availability

2 – moderate negative impacts from projected changes in food availability

1 – positive or no major changes in food availability

7. Changes in extreme weather. Survival and fecundity of some species are impacted by extreme weather events (e.g., McKechnie and Wolf 2009). We scored this criterion as:

3 – projected changes in the number and duration of extreme weather events are likely to cause major negative impacts

2 – projected changes the in number and duration of extreme weather events are likely to cause moderate negative impacts

1 – no evidence for changes in extreme weather events to cause impacts

Dealing with Uncertainty

Because it is inherently difficult to predict how a species will respond to climate change, we developed a Confidence Score that we applied to each Criteria Score. Uncertainty arose because of a lack of available information and/or the uncertainty within the quantitative studies (Glick et

al. 2011). In most cases, our uncertainty scores were based on expert opinion rather than quantitative evidence.

The Confidence Score was assigned subjectively as:

      1 – high confidence

      0.5 – moderate confidence

      0 – low confidence

Scoring of Taxa

We scored each of the seven climate change vulnerability criteria as described above based on the best available information including published papers and in particular the Birds of North America species accounts (The Birds of North America Online 2010). After scoring each of the taxa ourselves, a panel of experts (listed in acknowledgements section) reviewed the scores and suggested specific score changes.

Some criteria were more easily scored than others simply because of available information and state of the knowledge of a particular trait or characteristics. For example, information on a species migratory status are widely known and hence easily scored. In contrast, information on physiological tolerances is not widely known. When this was the case, our scores were based on the best available information from closely related taxa (following Williams et al. 2008).

Climate change vulnerability criteria scores were determined solely with respect to the portion of a taxon's life cycle spent within California; this scaled approach in the scoring system was appropriate for developing a vulnerability assessment system applicable to conservation planning and resource management at the state level. Thus, exposure criteria were scored independently of climate change impacts outside of California. For example, sea level rise will likely impact nesting habitat for Laysan Albatross and other pelagic seabirds, but probably will not impact their foraging habitat off the coast of California. Similarly, habitat specialization (a sensitivity criterion) was scored according to the habitat requirements of a taxon during the portion of its life cycle spent in California (e.g., species that only occur in California during the winter were scored according to their wintering [non-breeding] habitat requirements).

For scoring change in habitat suitability, we primarily relied on habitat suitability models independently developed by the National Audubon Society (National Audubon Society 2008) and PRBO Conservation Science (Stralberg et al. 2009, PRBO unpubl. data). Expert opinion was also used to interpret model results or for where models were not available. Expert opinion was informed by an extensive literature review of projected climate change effects in California (PRBO 2011). If the Audubon and PRBO models agreed with each other in magnitude and direction, and was consistent with expert opinion, the resulting habitat score was given a high level of confidence. Conversely, if the models contradicted each other, the score was decided on expert opinion and given a low to medium level of confidence. Habitat suitability models were not available for most waterbirds, however climate models suggest that water availability will decrease and thus freshwater wetland habitat will decline throughout California (NRDC 2010, PRBO 2011); freshwater wetland dependent taxa were therefore all given a habitat change score of 2 (10-50% change in habitat). Taxa largely restricted to tidal marsh, tidal mudflats, coastal beach strand, and rocky intertidal zones will likely be impacted by sea level rise and were therefore assigned a habitat change score of 3 (>50% change in habitat).

According to current predictions, seabirds depending on the seasonally productive California Current may experience significant reductions in food supply due to increasing ocean acidification and delayed upwelling during the breeding season (Wolf et al. 2010, PRBO 2011).

Therefore, we scored food supply declines for most seabirds as moderate (2) to high (3), depending on the diet specialization of each taxon. The confidence for these scores, however, is low given the uncertainty of these oceanographic predictions. For most terrestrial bird species, virtually no information exists on how climate change will affect food supply. The food and habitat of certain species are inextricably linked (e.g. sagebrush is both the primary habitat component and food source for Greater Sage Grouse (Schroeder et al. 1999). However the relationship between climate and food for most landbird species is often more complicated. For insectivorous birds, climate change may actually increase invertebrate prey populations because invertebrate productivity generally increases with an increase in temperature (Yom-Tov & Geffen, in press), though the long-term effects of climate change on invertebrate prey populations is unknown.

Extreme weather could mean exceptionally stormy weather, storms outside normal seasons, and/or prolonged conditions such as draught and unusually high temperatures. We relied on the climate change literature for California to inform our assessment of the extreme weather each taxon may experience throughout its geographic range (PRBO 2011). Of all the ecoregions in California, the deserts, Central Valley, and low elevation Sierra Nevada are predicted to experience the most extreme hot weather events for extended periods, therefore the taxa of those ecoregions were assigned high (3) extreme weather scores. Coastal and tidal marsh taxa scored moderate (2) to high (3) due to the potential for increased nest failure caused by coastal storms and tidal flooding.

Habitat specialization scores were determined through a combination of expert opinion and review of each taxon's habitat requirement as described in the Birds of North America species accounts (Cornell Lab of Ornithology 2011). Habitat specialization was largely defined by nesting requirements for the taxa that nest in California, whereas foraging habitat requirements were the determining factor for species that just overwinter in California. For example, two highly specialized taxa are the Western Yellow-billed Cuckoo and Sanderling- the former requires large patches of mature gallery riparian forests and the latter relies on the wash zone of sandy beaches for winter foraging (Hughes 1999, Macwhirter 2002).

Published information on the physiological tolerances (or thermal rages) of North American bird species is very limited. The exceptions include a few studies on owls, which found that certain owl species are particularly sensitive to high temperatures (Ligon 1969, Weathers et al. 2001). Additionally, anecdotal evidence suggests that some of California's seabirds, which are not typically exposed to high temperatures, may be sensitive to extreme heat events (PRBO unpbul. data). Beyond these limited accounts, we deduced physiological tolerances based using a theoretical approach. Jiguet et al. (2006) found that the greater the thermal range normally experienced by a species, the greater its resilience to extreme temperatures. In other words, species adapted to extreme environments (e.g., deserts) are more resilient to extreme temperatures than species adapted to more moderate climates (e.g., coastal areas). Therefore, we scored physiological tolerance based on each taxon's geographic range and its corresponding thermal range. Our confidence for physiological tolerance scores was low.

In general terms, the migratory status of all the nominated taxa are widely known and described in literature and field guides, making it relatively straightforward to establish which taxa are resident and which are migratory. However, we established basic migration criteria in order to the classification of taxa as either long distance or short distance migrants. The criteria we used was as follows: taxa were classified as long-distance migrants if they migrated between the temperate zone and the tropics (Tropic of Cancer latitude or further south, i.e. southern

Mexico, Central and South America); taxa were classified as short-distance migrants if their migrations were restricted to North America/northern Mexico.

Taxa scored with a high dispersal ability include those that are nomadic (irruptive) or migratory and therefore have the capacity to move great distances. Taxa scored with medium dispersal ability were generally non-migratory, though possess the ability to move moderately long distances between habitat patches. Taxa scored as having low dispersal ability were generally small sized, non-migratory, sedentary species with a relatively small home range and specialized habitat requirement. A useful approach for evaluating dispersal ability was to consider which taxa had been recorded on the southeast Farallon Island, a 57 ha rocky island located 43 km west of San Francisco where daily bird records have been maintained since 1968 (Richardson et al. 2003). Virtually every bird species in California that is migratory, irruptive, or nomadic has been documented on the Farallon islands. Birds with the capacity to reach the remote southeast Farallon Island are considered have a high dispersal ability, whereas species that have never been recorded on the island have medium or low dispersal ability.

Literature Cited

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