Plover: a Subpopulation-Based Model of the Effects of Management on Western Snowy Plovers

Michele M. Tobias

University of California, Davis, One Shields Avenue, Davis, CA 95616
mmtobias@ucdavis.edu

Abstract.
Plover is a program written in VB.net to model a subpopulation of Western Snowy Plovers (*Charadrius alexandrinus nivosus*). The model is based on data and observations in scientific literature. It was intended to assist managers in understanding how management decisions could potentially affect a local population. The results of this model underscore the need to protect Western Snowy Plovers from human impacts.

Keywords: Western Snowy Plover; Charadrius alexandrinus nivosus; model

Introduction

The Western Snowy Plover (*Charadrius alexandrinus nivosus*) is small shorebird that was federally listed in 1993 as threatened under the Endangered Species Act. These birds make their homes on sandy beaches often near natural water outfalls, such as river mouths, on the west coast of North America from Washington State, USA, to Baja California, Mexico (Page et al. 1995). Parental care is mainly the responsibility of the male. Females leave the nest shortly after the eggs hatch to start a new nest with a new male (Warriner et al. 1986). Unfortunately, their breeding grounds are frequently places humans use for recreation, and development often grows around these areas. Human activities lead to destruction of the Western Snowy Plovers' habitat and an increase in predation on adults and nests by creating larger edge areas and introducing predatory species, such as house pets (Ruhlen et al. 2003).

Western Snowy Plovers have specific habitat requirements, especially during the breeding season. They need a sandy beach with limited vegetation, minimal disturbance by humans, and an adequate food source. Invasive species have reduced the quality of some habitat by vegetating once open areas (USFWS 2001). The beach should also be broad enough to accommodate their habit of nesting at least 100 meters from the high water line (USFWS 2001). Western Snowy Plovers hunt for invertebrates that hide in kelp washed up on the shore, so beaches without beach wrack are unsuitable (Lafferty 2000). Because they nest directly in the sand, foot and vehicle traffic need to be at a minimum to prevent crushing of the birds or their eggs (Ruhlen et al. 2003).

A variety of approaches have been taken in the past to increase the numbers of Western Snowy Plovers. Limiting human access to occupied beaches, restricting dogs and other pets, as well as fencing off breeding grounds and predator removal are common management tools (Lafferty 2000). A common belief expressed in Western Snowy Plover literature is that seemingly small management actions could make a dramatic difference in the size of a subpopulation. Lafferty (2000) articulates this directly and Sandoval (2004) quantifies this, to an extent, with data showing that numbers of adult birds and fledglings increase quickly after management efforts are taken to protect breeding areas from foot traffic.

Deciding which threat to manage is difficult. Management of human behavior in Western Snowy Plover habitat may be the most important factor in their recovery. Lafferty (2000) and Ruhlen et al. (2003) point out that Western Snowy Plover breeding success seems to be inversely proportional to the amount of human use of their habitat. A study by , Neuman et al. (2004) shows that mammalian predators can negatively impact the number of eggs a male Western Snowy Plover can hatch. Observations from this study also suggest that avian predators can significantly reduce the number of chicks surviving to become adults.

Western Snowy Plover research is far from complete. Several researchers have quantified the birds' fecundity (USFWS 2001, Neuman et al. 2004, Powell 1996), effects of human interaction (Ruhlen et al. 2003), and predation (Neuman et al. 2004), but no one has combined all these important factors to determine their collective effect on a population. There seems to be a need for a population growth model on a small spatial scale that incorporates the effects of human decisions.

Only one paper has applied a population model of any kind to Western Snowy Plovers. Nur et al. (2001) developed a population viability model for the entire subspecies of Snowy Plovers (from Washington State, USA, to Baja California, Mexico). This model employed six metapopulations and took a spatial approach. The model used was

A Western Snowy Plover at Rancho Guadalupe Dunes Preserve County Park. Photo credit: Alex Mandel a commercially available program that specializes in metapopulations in which the authors set various parameters to produce an estimate of the population size after 100 years. Each metapopulation covered at least one county but some contained several counties. Both the temporal and spatial scale of this model is not applicable to a management situation.

Because management decisions are often made on a local scale, a model focusing on one nesting site could be useful to managers.

Model Parameters

Plover is a model written in VB.net that represents a subpopulation, the birds present at a single stretch of beach, of Western Snowy Plovers at any habitat location. The size of the subpopulation depends on the size of the available breeding habitat, and whether the subpopulation is protected from predation and human disturbance. The spatial scale is small – limited to one habitat area – since management decisions are made at this scale. The temporal scale is also somewhat limited because of the lack of availability of long-range data for comparison to the model results.

Each subpopulation has distinct characteristics and is likely to have different optimal plans. This model was built to test management alternatives before they are put into action to avoid potentially detrimental experimentation with this threatened subspecies. Given the model output, managers should be able identify the best strategy when several combinations of options are available. Since some management choices are controversial, like restricting human beach access, better compliance and less dissent might be gained by describing the potential outcomes of such decisions.

The user must enter four pieces of information before running the model - the initial number of breeding males, the size of the breeding habitat, whether the subpopulation should be protected from predation or human disturbance. The average number of nests per male can also be changed by the user. The number of eggs laid per breeding male, however, is hardwired into the code because females lay three eggs per nest fairly consistently and the number of eggs laid is not affected by human influence (Warriner et al. 1986).

Plover is a stage-based population model (see figure 1), similar in some respects to Wemmer et al.'s (2001) model of a Piping Plover (Charadrius melodus) population. Rather than calculating the number of individuals in each age class from birth to death (up to fifteen years, in the case of the Western Snowy Plover; Page et al. 1995), the model has four life stages: adults, eggs, hatchlings, and juveniles. These life stages have no specific units with respect to time in Plover because the output happens after each year. The life stages happen in succession, but do not require a particular length of time. For each year the model calculates the number of individuals in each stage based on the number of individuals in the stage before. For example, the number of eggs laid depends on the number of reproductive adults present and the number of eggs laid will partly determine the number of hatchlings in the next stage. The model tracks only reproductive males because males tend the nest and females leave shortly after the chicks hatch to start new nests with a different male (Warriner et al. 1986).

Calculations for each stage are determined by three factors. The first, as mentioned above, is the number of individuals present in the previous time step. The second is the rate of survivorship between each stage for non-adults and between each year for adults. The third is comprised of human-introduced circumstances that have some capacity to limit Western Snowy Plover survivorship. These are regulating factors.

Dispersal, another regulating factor, affects the juvenile and adult stages but not the other two. About twenty five percent of juveniles disperse to other beaches (Nur et al. 2001). Juveniles that dispersed from other beaches to the population in the model immigrate as adults in the next year. The amount of emigration and immigration to the adult pool is also affected by the size of the habitat and the number of humans using the habitat area for recreation. In observational studies, as the breeding area decreases in size or the number of people increases, the rate of Western Snowy Plovers emigration increases (Powell 1996). If conditions improved (i.e. more habitat area or fewer people) individuals from other areas will immigrate into the subpopulation. The dispersal factors reflect these observations in the model. The amount of human interaction and the size of the habitat remain static in each model run but some simulation of dynamics in these factors can be achieved by changing the inputs on separate model runs.

The majority of the parameters were found in literature about Western Snowy Plover studies that sought to quantify some aspect of their life history (see table 1) but two elements were calibrated. The affects of human disturbance was calibrated to reflect Powell's (1996) observations that where humans are present, Western Snowy Plovers are not. In the interface, there is an option to either protect the population from humans or not. When the box on the interface to protect the birds from human presence is not checked, the model increases the rate of emigration to between 85 and 95 per cent of the adults present in the model population and immigration is limited (Nur et al. 2001). The general immigration rate was taken from Nur et al. (2001), but if the subpopulation drops to zero in one year, one or two adults will appear in the next year. This was done to incorporate the fact that one or two pairs seem to try to nest at a location even if a subpopulation was unsuccessful in previous years (Sandoval 2004 and Powell 1996).

Results

Plover's output (see figure 2 for example output) shows that a subpopulation of Western Snowy Plovers can only successfully breed when humans and predators are kept at a minimum. When the birds are unprotected, the population in the model drops rapidly and inevitably disappears regardless of the size of the starting population. This is consistent with field observations (Sandoval 2004). Beaches with high rates of human use and no protection from predators have few or no Plovers in spite of the high suitability of the habitat (Powell 1996). No Snowy Plovers are found in areas where human activity has increased. Observations show, however, that on sites with few breeding pairs, numbers rapidly increase when a portion of the nesting area is protected (Sandoval 2004). Plover also has the same result.

Plover was tested against the brief population data available from Sandoval (2004). These data were ideal because they span a period in which a highly effective management plan was enacted that dramatically reduced the amount of human interaction with the birds and protected nests from both avian and mammalian predation, although they only provides specific counts for a few years. The quality of the site was otherwise high so the study resulted in good information for comparison. The output from Plover is very similar to the observed data that show the population increasing rapidly when no threats were present in the breeding area. Unfortunately, longer term data were unavailable at the time of writing so the plausibility of later model predictions for the combined management strategies cannot be confirmed, however, the results of the Plover model do make ecological sense: growth in the population slows and fluctuates below the maximum nesting density. The effects of no management on the subpopulation in both the model and the observations match. Without management, few adults will be present at a site and those that are present will have very low reproductive success.

The optimal management strategy for a subpopulation of Western Snowy Plovers with average life history parameters (i.e. three eggs per nest, average survivorship between life stages, etc.) is to protect the subpopulation from both predation and human interference (see figure 2). Employing both options significantly increases the number of adults at a site more than simply protecting the birds from humans. Excluding humans from the nesting area is a good option, however, if only one action can be selected for a site. A subpopulation that only receives protection from predation, according to the model, will not survive. In the model, this is due to the stipulation that when humans are present, the majority of the birds leave in spite of any increased fledging success from the protective predator exclosures. Subpopulations receiving no protection will also fail.

Limitations of Plover

Plover's limitations stem mainly from a lack of research on its subject species. At this time the model cannot take into account the amount of human activity on a beach or the number of predators present because data on the effects of these factors does not exist in a form that is useful for a model like Plover. Because only short-term data is available, the long-range predictions the model can make cannot be substantiated and therefore the model should not be used for such predictions. The results can only be applied to the number of adults because some of the regulating factors have not been developed completely in the model. For example, human activity only affects immigration and emigration rates but not hatching success and predation only affects hatching and not the rates of fledging, juvenile survival, and adult survival.

Another important aspect of Western Snowy Plover ecology was intentionally left out of this model. While beach grooming plays a large role in determining how much food is available for nesting birds, not enough is known about Western Snowy Plover energetics at this time to include it in this model. One paper (Tucker & Powell 1999) describes and quantifies their diet, but little is known about how food availability limits the number of birds. Powell's (1996) study of southern California beaches showed that Western Snowy Plovers are unlikely to be found on raked beaches. Until more is known about their energetics, it is unnecessary to include beach grooming in a model like Plover because it can be assumed that raked beaches cannot support a breeding population of Western Snowy Plovers.

Conclusion

More information is needed before Plover can fulfill its ultimate objective of being a tool that weighs management options against one another, however, the current results have important implications for the management of this threatened subspecies of shorebird. Western Snowy Plovers must be protected in some fashion. At the very least their interactions with humans must be limited, but combining this strategy with reducing predation is the most effective.

In the future, Plover will be able to predict the implications of more specific goals. The number of encounters with humans and the number and type of predators around the breeding habitat will be included in the model to give a more complete picture of how a subpopulation will grow or decline. Plover also has the potential to expand to encompass the entire population of Western Snowy Plovers by connecting various subpopulations with each other, each with their own set of management strategies, to see how the birds move between different beaches.

Obtaining the Program

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