Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico, 28 – 31 August 2012

Final Report

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Workshop organized by: US Department of Agriculture (USDA); US Fish and Wildlife Service (FWS); Puerto Rico Department of Environmental and Natural Resources (PRDNER); and the IUCN SSC Conservation Breeding Specialist Group (CBSG)

Workshop financial support provided by: US Department of Agriculture

Cover photos courtesy of Roseanne Medina-Miranda and Tirtsa Porrata-Doria.

Section divider photos courtesy of Roseanne Medina-Miranda, Tirtsa Porrata-Doria, Mike Morel, José Cruz-Burgos, Elvin Binet, and Kathy Traylor-Holzer.

A contribution of the IUCN SSC Conservation Breeding Specialist Group.

Medina-Miranda, R., López-Ortiz, R., Ramos-Álavarez, K., Cruz-Burgos, J., McKenzie, P., Swinnerton, K., Ortega, C., Cruz, A., Liu, I., Lacy, R., Miller, P., Díaz-Soltero, H. and Traylor-Holzer, K. (eds.). 2013. *Yellow-shouldered Blackbird/Shiny Cowbird Population and Habitat Viability Assessment Workshop Final Report*. IUCN SSC Conservation Breeding Specialist Group, Apple Valley, MN.

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January 2013

CONSERVATION BREEDING SPECIALIST GROUP

Yellow-Shouldered Blackbird/Shiny Cowbird Population and Habitat Viability Assessment Workshop

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28 – 31 August 2012

CONTENTS

Dedication of PHVA Workshop in memory of Jorge Saliva

Jorge Enrique Saliva-González, PhD.
February 21, 1963 - July 23, 2012

Caribbean sea bird expert, Jorge Saliva, spent over two decades as a Wildlife Biologist with the US Fish and Wildlife Service. He joined the Caribbean Ecological Services Field Office, when it was known as the Boquerón Field Office in 1990. He was a passionate individual, actively promoting conservation of fish and wildlife resources, particularly sea birds, migratory shorebirds, neotropical migrant birds and marine mammals. His lifework allowed him to make valuable contributions to the conservation of many threatened and endangered species such as the brown pelican, piping plover, Puerto Rican plain pigeon, broad-winged hawk, sharp-shinned hawk, yellow-shouldered blackbird, the Antillean manatee, and endangered plants and wildlife in general. He also listed and designated critical habitat for the *coqui guajón*, and the plant *cobana negra*.

His most significant work was devoted to the study and conservation of the roseate tern, conducting over 20 years of uninterrupted census and nesting surveys. The information gathered through his research, allowed the Service to develop a Recovery Plan and long-term recovery strategies for the roseate tern in the US Caribbean, wider Caribbean and the Northeast Region of the United States.

Jorge was a prolific scientist with over 25 professional publications that are recognized today as primary reference in the field of wildlife conservation. He was currently contributing with the Puerto Rico Climate Change Working Group in the development of a Climate Change Adaptation Strategy for Puerto Rico. He was loved and admired by everyone with whom he interacted for his precise analysis and prankster sense of humor. His knowledge and love for nature and conservation was a key asset to the Service, especially when he interpreted nature during presentations, interviews, nature walks and other educational activities.

Jorge was an integral member of the yellow-shouldered blackbird team and key contributor to the two PVA workshops and metamodeling discussions that led to the PHVA workshop shortly after his death. His relentless questioning and probe for deeper analysis challenged the team to deeper understanding as we moved into this first effort to use PHVAs to understand better the interactions of an invasive species and its affected endangered species. His energy and spirit remain as a motivation and challenge to conserve the yellow-shouldered blackbird and other native bird species of Puerto Rico. He will be deeply missed by the PHVA workshop team and the conservation community. We dedicate this meeting and report to Jorge.

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

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Final Report

SECTION 1

Executive Summary

Executive Summary

The yellow-shouldered blackbird (*Agelaius xanthomus*, YSBL) population has declined by more than 50% since 2004, leaving fewer than 400 individuals in its native habitat in southwestern Puerto Rico by August 2012. While many factors such as habitat conversion contributed to this decline, a primary threat for this blackbird species (also known as *La Mariquita* or *El Capitán* in Spanish) stems from the encroachment of the shiny cowbird (*Molothrus bonariensis*, SHCO), an invasive species originally native to South America, Trinidad and Tobago. A brood parasite, the shiny cowbird is a prolific breeder and lays its eggs in the nests of other bird species, including the yellow-shouldered blackbird, coercing the surrogate parents to raise cowbird young at the expense of their own reproductive success.

A Novel Application of New Metamodeling Tools to Invasive Species Management
As part of its Invasives Causing Extinction (ICE) program, the US Department of Agriculture (USDA) wanted to explore if Population Viability Analysis (PVA) and the Population and Habitat Viability Assessment (PHVA) workshop process, using the new MetaModel analysis, could be used to create a new science tool to understand the interactions between a pair of invasive and endangered species. PVA has been a powerful tool in species conservation for the past 30 years, helping to provide: assessments of species population trajectories and viability; tests of the most important factors in determining viability; projections of the impacts of possible changes to the habitat or direct threats to the populations; assessments of the likely relative efficacy of proposed management actions; and predictions for population growth under management. Single-species PVA remains a powerful tool in those cases where the external biotic, human, and abiotic factors impinging on the species populations are relatively constant or changing in predictable ways that are not in turn affected by feedback from the focal species of conservation concern. However, in the case of endangered species impacted by invasive species (as well as in other cases of complex interactions, such as those involving newly emergent disease or disrupted ecological communities), understanding the interactions between the endangered species and the invasive species requires that we analyze both species individually and simultaneously, as well as the impacts of each species on the other.

Metamodels are a novel approach that links together previously independent models of species dynamics and the environmental systems that impact them. For assessing the impacts of invasive species, the metamodel approach allows us to use two or more PVAs in synchrony (e.g., one for the invasive species and one for the endangered species being affected by the invasive). The interactions between both species are represented in the metamodel by having the projected numbers and activities of each species affect the demographic rates of the other species. This allows for analysis of the impacts of management actions that are directed at the invasive species, or at the endangered species, or at the interactions between the two species. ***This report presents the first test of using of the metamodel approach to understand better and improve conservation planning for a case in which an invasive species is believed to be a major threat to an endangered species.***

Unfortunately, there are many invasive species, and their numbers and impacts are increasing. It is believed that they are a significant threat to many endangered species. However, the impact of invasive species on endangered species has rarely been quantified. Therefore, it has been difficult to assess the likely effectiveness of management actions – other than by trial and error in the field, which often will be too late for the survival of the endangered species and perhaps a waste of resources if ineffective. The meta-model approach tested here provides a new tool to help rectify these deficiencies in conservation assessments and planning, and provide insights to existing or new management actions that can recover the endangered species when implemented.

The metamodel analyses presented in this report are complex, and many aspects of the models are uncertain. The analyses are complex because the factors that drive the dynamics of species with fates that are coupled to other species are multiple and interact in complex ways. ***The analyses completed in Puerto Rico would not have been possible if we did not have available the extensive data that had been collected by the Puerto Rico Department of Natural and Environmental Resources (PRDNER) and partners over more than 20 years.*** Funding for this long-term effort was provided by the US Fish and Wildlife Service and the PRDNER.

The metamodels that have been created offer insights into which current and potential management strategies are likely to have the greatest positive effects on the YSBL, based on our current understanding of the data and the species interactions. The models also identify aspects of the system for which more data are needed. The metamodel analyses completed to date (January 2013) can and should form a basis for continuing to identify data gaps, refining the description of the YSBL-SHCO system as new data and analyses are available, adding to these assessments additional species and factors that might be important, and testing additional conservation management actions that might be proposed.

USDA invited the IUCN SSC Conservation Breeding Specialist Group (CBSG) to collaborate along with the US Fish and Wildlife Service (USFWS) Caribbean Field Office and the PRDNER to conduct a population viability analysis and conservation planning exercise for this endangered Puerto Rican species. Three workshops were conducted over an eight-month period of 2012, augmented between face-to-face meetings with additional conference calls, electronic discussions, and short-term research efforts aimed to better understand the status and threats of the blackbird, the influence of shiny cowbirds on blackbirds, evaluation of current management actions, and possible future effective management actions to promote blackbird persistence, using the new metamodel approach and the new *METAMODELMANAGER* analysis tool for multi-species population models.

The initial focus was to develop a two-species population simulation model to assess the viability of the yellow-shouldered blackbird in the presence of, and interacting with, the shiny cowbird. Two PVA meetings were held in Boquerón, Puerto Rico in January and April of 2012 to compile the best available data and expert opinion on the two species. This information was used to develop a population model for each bird species and to link these models into a two-species metamodel using the *VORTEX* and *METAMODELMANAGER* software programs. The metamodel allowed YSBL viability to be projected into the future under both current conditions and under various alternative management scenarios. This enabled the participants to better assess the impact of shiny cowbird population abundance and management on YSBLs.

Project participants joined additional stakeholders in Mayagüez, Puerto Rico from 28-31 August 2012 for a PHVA workshop, facilitated by CBSG. Participants presented new additional research findings from Summer 2012 and revised the metamodel, set a vision and population goals for the YSBL, completed a threats analysis, and used this analysis in working groups to establish goals and recommend management actions targeting these threats and promoting viability of the YSBL in Puerto Rico (see Appendix I). The workshop focused on the YSBL population on the island of Puerto Rico, specifically in southwestern Puerto Rico. The Mona Island subspecies was not assessed and may be subject to different threats that require different conservation management strategies.

In addition to the threat posed by shiny cowbirds, the workshop participants identified climatic factors, human activities and other species interactions that jeopardize the viability of this endangered blackbird species. Several high priority goals were identified that target improving YSBL reproductive success (e.g., increased foraging habitat, improved artificial nest structures), reducing sources of mortality, and reducing the impact of invasive species, including the shiny cowbird. The USFWS and the PRDNER plan to implement many of the recommended management actions by the next breeding season. For USDA and CBSG, this project represents a milestone in two-species metamodel development to better address the challenges of managing invasive species. Development of this model will continue, and can be used as part of an adaptive management strategy for these two bird species in the future.

Summary of Workshop Findings

Workshop participants reviewed the historical and current status of the YSBL population and after some discussion developed the following vision:

> *VISION: To develop and maintain viable yellow-shouldered blackbird populations throughout suitable habitat compatible with ecosystem and human changes, and embraced as an iconic species of Puerto Rico.*

The group defined a viable population as one that has no more than 5% risk of extinction in the next 50 years, starting in 2012. Other population criteria that were suggested included the retention of at least 95% gene diversity, at least 65% annual adult survival, and at least 50% fledging success. Population goals are to:

1. Maintain a minimum of 3,000 YSBLs in Southwest Puerto Rico for at least 25 years;
2. Maintain a minimum of 1,000 YSBLs on Mona Island for at least 25 years;
3. Establish two additional self-sustaining YSBL populations on Puerto Rico island; and
4. Increase the area of occupancy for the species.

Building upon the PVA discussions, a threat analysis was conducted in a plenary discussion to identify key factors affecting YSBL (and to a lesser extent, SHCO) population viability. For each factor the specific impact on blackbirds was identified (i.e., effect on reproduction, juvenile survival and/or adult survival). Participants considered additional factors and conditions that lead to each threat to create a threat diagram of interacting causal chains. Participants then divided into two threat-based working groups, one focusing on issues related to human activities, habitat, and climatic factors and a second group dealing with the impacts of other species on YSBLs. These groups further defined the threats, their causes and consequences, and the degree of certainty in terms of the impact on YSBLs. Goals were developed to address each threat and management and research actions were recommended to help achieve these goals.

The ***Human Activities and Habitat Working Group*** explored a diversity of human-related issues and identified the following as potentially having high impact on the viability of YSBL populations: lack of land use planning; politics; lack of public awareness; limited resources for management; insufficient law enforcement; and spotlighting activities on YSBL. Human activities that decrease YSBL habitat, reduce blackbird reproduction, increase blackbird mortality, and/or promote the expansion and viability of invasive species all contribute to YSBL decline. Goals and recommended actions focused on increased protection of YSBL nesting and foraging habitat and protection of YSBL populations from human and invasive species disturbance through a variety of mechanisms, from habitat management and improved land use planning to increased law enforcement, public awareness activities, and incentives for landowners to support YSBL conservation. A major tenet of this group's discussion was the relationship between various climatic variables and resulting habitat changes to the viability of YSBLs and SHCOs and prey abundance for the two species. There was also considerable discussion on how land use changes, especially those related to human and agricultural development, impacted populations of both species.

The ***Interactions with Other Species Working Group*** explored threats to YSBLs potentially posed by other species or pathogens, including the SHCO. These included natural and invasive predators, parasites, and disease. The group identified a primary goal to increase nest success of the YSBL and four sub-goals to help achieve this. High priority actions are to control invasive rats and shiny cowbirds, especially near nesting areas, improve the design of artificial nest structures (ANSs), add ANSs to existing nest sites, and increase and maintain active management of ANSs to remove SHCO eggs and chicks.

VORTEX MetaModeling Results

A third working group continued refinement of the YSBL-SHCO metamodel and explored various alternative scenarios. The metamodel analyses indicated that the best estimate of the current situation for the YSBL projects a slow population decline due to mortality rates that are too high to be sustained by the observed recruitment. This projected rate of population decline could lead to a significant risk of YSBL population extinction in southwestern Puerto Rico within the next few decades. Reversing the decline of YSBLs and adequately assuring the persistence of the species will require either the nearly complete and immediate elimination of SHCOs from the island or the nearly complete elimination of the impacts of SHCOs on YSBLs. The current strategy of removing SHCOs from YSBL nests is probably more feasible than removing all SHCOs from southwestern Puerto Rico. However, even these aggressive management measures (either removing all SHCOs or removing all SHCO eggs from YSBL nests) may not be sufficient to protect the YSBL from extinction and allow it to recover to safer numbers unless other causes of mortality are also reduced. Various combinations of management strategies were observed in the model to be especially effective at securing the future of the YSBL. A modelling platform is now available that will allow refinement of the analyses as new data or new ideas about possible management actions become available.

Recommendations and Next Steps

Workshop participants considered all of the threats and goals in view of the modeling results and as a group identified the top priority goals that are thought to have the "greatest immediate positive impact on yellow-shouldered blackbird population viability and conservation." Five goals stood out as **urgent and immediate priorities for conservation action:**

1. **Decrease egg and chick predation at YSBL nests;**
2. **Improve efficiency of artificial nest structures;**
3. **Reduce impact of shiny cowbirds on nest success;**
4. **Protect YSBLs against <u>other</u> invasive predator disturbance; and**
5. **Provide sufficient foraging habitat for adult YSBLs during peak breeding season.**

Actions that address these goals are of high priority for implementation.

With the completion of the PVA and PHVA workshops, the participants discussed the next steps to continue momentum and progress. The following actions were recommended:

1. Conduct a conference call on DNA work with the University of Puerto Rico, Mayagüez;
2. PRDNER will implement possible management actions before the next YSBL (2013) breeding season;
3. USFWS will implement possible management actions before next YSBL (2013) breeding season;
4. Convene a follow-up meeting for this PHVA in Sept-Oct 2014 to see the results of management changes and status of the YSBL (revised PVA).
5. After PHVA final report is completed, conduct a conference call every six months for updates from all of the PHVA team;
6. Island Conservation and PRDNER continue drafting a feasibility plan to remove invasive vertebrates from Mona; and
7. Revision of the YSBL Recovery Plan by USFWS.

This PHVA report and the recommendations within it are considered advisory to the local and regional management teams for the yellow-shouldered blackbird and other collaborators to help guide actions thought to be beneficial to the long-term survival of the yellow-shouldered blackbird in Puerto Rico.

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Mayagüez, Puerto Rico
28 – 31 August 2012

Final Report

SECTION 2

Status Review and Presentations

Status Review and Plenary Presentations

Information Compilation and Distribution

An extensive literature review on the YSBL, including its relationship to the SHCO, was conducted to inform the first two PVA workshops, population model and metamodel development, and PHVA workshop. This included 121 scientific publications and 28 unpublished documents. Sixty-three of these documents were identified as priority references for information included in development of a population metamodel for these two bird species (see Appendix II).

Copies of these documents were made available electronically to the PVA and PHVA participants. Included among these were scientific publications and management- and population status-related information, including the 1996 USFWS Recovery Plan for the YSBL, the USFWS Five-Year Review, and the Annual Progress Reports for the Puerto Rico Endangered Species Program for YSBL Recovery Actions for 2002-2011.

In addition, several presentations were given at the PHVA workshop that provided overviews and updates on various Summer 2012 research efforts and analyses relevant to the status of YSBLs, threats to this species in Puerto Rico, and details of demographic rates valuable for model development.

Status Summary *(provided by Roseanne Medina-Miranda)*

The yellow-shouldered blackbird (*Agelaius xanthomus*, YSBL) is endemic to Puerto Rico, with a subspecies located in Mona Island (*A.x. monensis*). The YSBL was considered common and widespread in Puerto Rico, including the mountainous regions of the island, until the 1940s, after which no information of the species was obtained until 1972 (Post and Wiley, 1976). These researchers estimated the YSBL population at 2,400 individuals, concentrated in the coastal areas of the southeastern Puerto Rico (200 individuals), southwest Puerto Rico (2,000) and 200 individuals in Mona Island.

Between 1974-75 and 1981-82, the YSBL population in southwestern Puerto Rico declined by about 80% (to 300 individuals in 1982; Wiley *et al*., 1991; USFWS, 1996). Post and Wiley (1976) determined that the decline of the YSBL populations was caused by a number of factors, including nesting and feeding habitat destruction, predation by exotic mammals (i.e., *Rattus rattus*, *Herpestes javanicus*)**,** diseases, and principally brood parasitism by the shiny cowbird (*Molothrus bonariensis*, SHCO). Due to the drastic decline of the species, the YSBL was determined to be an endangered species, and critical habitat was designated in 1976 (USFWS, 1976).

In 1984, the Puerto Rico Department of Natural and Environmental Resources (PRDNER) with the cooperative agreement of the US Fish and Wildlife Services (USFWS) established the YSBL Recovery Project (Project) to monitor the YSBL reproduction and conduct the SHCO Control Program (USFWS, 1996).

In YSBL nesting habitats (i.e., Salinas and mangrove in coastal zones), project staff monitor YSBL nests in natural substrates and over 200 artificial nest structures (ANS). This monitoring includes the removal of SHCO eggs from YSBL nests and trapping SHCOs as part the SHCO Control Program. Also, the project coordinates YSBL surveys to estimate the YSBL population status twice per year (pre- and post-breeding season, Fig. 1).

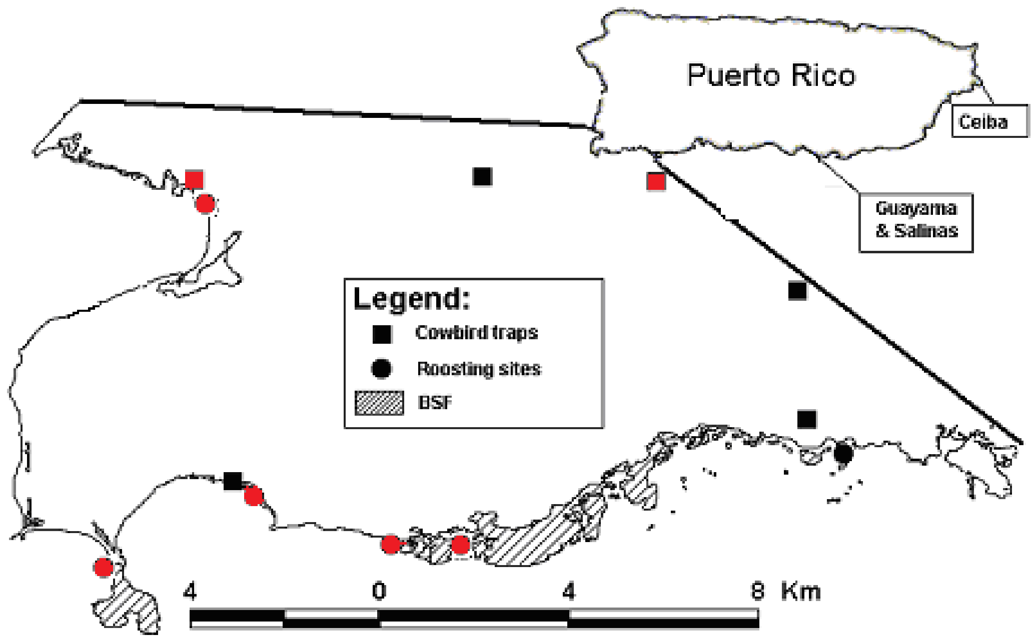


Figure 1. Historical YSBL roosting areas and cowbirds traps locations (current locations in red).

Today YSBLs still concentrate principally in coastal southwestern Puerto Rico, Mona Island (372 individuals in 2010), and a population founded in 1991 in the coastal southern Puerto Rico (municipalities of Guayama and Salinas; 82 individuals in 2012). The eastern Puerto Rico population is almost extirpated, with only one individual observed in 2007. The YSBL population in southwestern Puerto Rico has declined by more than 50% since 2004, leaving fewer than 400 individuals (pre-breeding survey) as of the time of the PHVA workshop in August 2012. However, in the post-breeding survey in October 2012 (Fig. 2), the population was estimated at more than 650 individuals, suggesting partial recovery from the recent decline. Extensive predator control (to increase survival in natural nest and fledglings in general) and modification of the ANS will be the proximate management to reduce the YSBL population trend in southwestern PR.

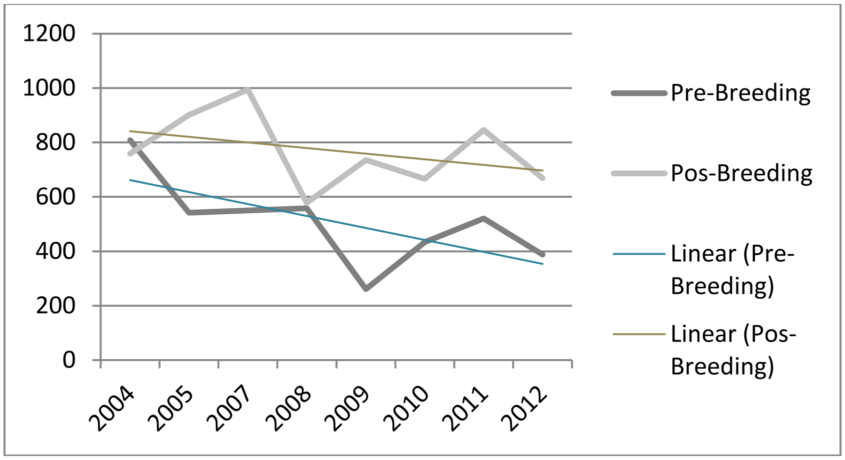


Figure 2: Data shows two different trends in YSBL population counts from 2004 to 2012. Pos-breeding counts show a positive trend and pre breeding count a negative one. Data from 2006 is not shown.

Overview Presentations

The following presentations were given at the PHVA workshop:

1. Status of YSBL population in southwest Puerto Rico (Roseanne Medina-Miranda, PRDNER)
2. Habitat mapping of land use and impacts on YSBL (Alexis Dragoni, GAP Analysis Consultant)
3. Roosting habitat survey (Oscar Díaz, USFWS)
4. YSBL and SHCO fecundity analyses (Tammie Nakamura, Univ. of Colorado, Denver)
5. YSBL fledging survival (Roseanne Medina-Miranda, PRDNER)
6. YSBL genetic diversity and extra-pair mating (Irene Liu, Duke University)

These Powerpoint presentations can be found in Appendix III.

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez , Puerto Rico
28 – 31 August 2012

Final Report

SECTION 3

Vision Statement and Population Goals

Vision Statement and Population Goals

Vision Statement

A vision statement is a short statement that outlines the desired future state of the species (i.e., describes what it means to "save the species") and is long term and ambitious. There may be several different components to a vision statement, including the scope (geographic range, time period, etc.) and representation, functionality, and desired degree of management intervention.

At the beginning of the PHVA workshop, participants were asked to answer the following question:

"What is your vision for the yellow-shouldered blackbird in Puerto Rico? Describe the situation that you would like to see for YSBLs 50 years from now."

Participants' responses were reviewed and the key concepts gleaned to form the basis of a plenary brainstorming discussion on setting a vision for the YSBL population in Puerto Rico. Initial responses included the following vision components and suggestions that span a broad diversity of possible futures or visions for the YSBL:

Population viability:

- Stable
- Self-sustaining
- Numbers restored
- Secure
- Able to withstand fluctuations from extreme events
- No risk from invasive species (eradication of invasive species)

Scope/representation/replication:

- Stable in Southwest PR, with additional populations in coastal or other areas
- Expansion into new habitat
- Utilizes/breeds in all available suitable habitat
- Across the island
- Across Puerto Rico Territory (including offshore islands)
- Historical range restored

Functionality/management:

- Functions as an important component in the ecosystem
- Little to no human management needed
- Minimal management, with no extraordinary actions needed
- Survives with help (management)
- Delisted from the Endangered Species Act

Relationship with humans:

- Recognized and valued part of Puerto Rico avifauna
- Flagship species for Puerto Rico

After much group discussion the following vision statement was developed:

To develop and maintain viable yellow-shouldered blackbird populations throughout suitable habitat compatible with ecosystem and human changes, and embraced as an iconic species of Puerto Rico.

This helped to define a common understanding among the workshop participants on the ultimate goal for the species and to guide the development of objectives and actions to help achieve this vision.

Population Goals

While a commonly supported overall vision for the species is important, it is valuable to also consider more detailed and measurable population goals to meet this vision.

Viability

A viable population is one that is likely to persist and not go extinct. The likelihood of persistence, however, varies over time and under certain conditions, such as population size, genetic composition, and threats, human management actions, and other factors that affect the population. The exact definition of a "viable population" is political as much as it is biological, and depends upon the amount of risk that a stakeholder group is willing to take that the population will disappear. Viability is often defined in terms of a maximum risk of extinction over a specified time period; population size; number of populations; population trend (growth rate); range of extent and/or occupancy; and/or maximum allowable loss of genetic diversity.

In plenary the PHVA workshop participants discussed their views on viability with respect to YSBL populations. The IUCN Red List criteria, and the criteria necessary to downlist or delist the species, were considered. Also considered were the preliminary results of the *VORTEX* population modeling efforts. The workshop participants agreed to the following definition of viability with respect to the YSBL vision statement:

A viable population is defined as one that has no more than 5% risk of extinction in 50 years.

This led to a discussion of YBSL population characteristics that would meet this condition.

Population Numbers and Criteria

The desirable size, extent, and timeline for YSBL populations in Puerto Rico were discussed, as well as criteria for these populations with respect to genetic variation and demographic rates that will promote the desirable level of viability, resulting in the following recommended population goals:

1. Maintain a minimum of 3,000 YSBLs in Southwest Puerto Rico for at least 25 years.
2. Maintain a minimum of 1,000 YSBLs on Mona Island for at least 25 years.
3. Establish two additional self-sustaining YSBL populations on Puerto Rico island (there are possibly two existing populations already now in 2012, SW and Salinas populations).

4. Increase the area of occupancy (possible mechanisms include translocation and captive breeding/reintroduction). Vieques is a possible site for establishing a YSBL population.
5. Maintain at least 95% gene diversity (of the current population in SW Puerto Rico). This measure does not necessarily require genetic sampling and molecular analysis but could be estimated through a combination of periodic censusing and modeling.
6. Maintain at least 65% annual adult survival.
7. Maintain at least 50% fledging success.

The minimum population numbers recommended above were based on the historic distribution and population estimates of YSBLs on the island of Puerto Rico and Mona Island and recognizing the potential for the species to become more abundant if various current threats could be reduced or eliminated through management. It was noted that various levels, intensities, and length of management actions may be required to meet these criteria.

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico
28 – 31 August 2012

Final Report

SECTION 4

Threat Analysis
Plenary Discussion

Plenary Discussion: Threats Analysis

A thorough understanding of factors that impact the viability of the YSBL population is important to identify and evaluate management strategies to address threats and promote viability. Prior to the PHVA workshop, the following list of previously identified threats (from the first two PVA meetings and/or in the Five-Year Review of the YSBL) was compiled by Eduardo Ventosa-Febles, a member of the YSBL Team:

1. Destruction of YSBL feeding, roosting, and nesting habitat as the major threat to the species (USFWS 1996); stating that destruction of YSBL foraging and nesting habitat on the mainland Puerto Rico for residential and tourist development, as well as agricultural activities continued in southwestern Puerto Rico (5 year review USFWS).
2. The revised recovery plan states that nest infestation by two species of blood-feeding mites (*Ornithonyssus bursa* and *Androlaelaps casalis*) may lead to nest abandonment by adult YSBLs and premature nest desertion by young birds (USFWS 1996).
3. Lice (*Philopterus agelaii*, *Machaerilaemus* sp., and *Myrsidea* sp.) may also affect nesting YSBLs, particularly those in cavity (covered) nests and re-used nests from the previous breeding event (Cruz-Burgos *et al*. 1997).
4. Avian pox was identified in the revised recovery plan as a potential problem for the YSBL (USFWS 1996).
5. Major causes of egg failure in artificial nest structures during 1996-1997 were disappearances (egg missing), abandonment (unpunctured eggs more than two weeks old and without YSBL parents in the vicinity), and failure of eggs to hatch. The reasons for disappearance, abandonment, and failure to hatch are not known, but predation and presence of avian and mammalian predators around artificial nest structures were suspected, and has been suspected (Díaz and Lewis 2006) or observed on other occasions (DeLuca *et al.* 2010, unpublished data).
6. The black rat *(Rattus rattus*) is an important predator of YSBLs; being the major cause of egg and chick loss in certain breeding areas (USFWS 1996). Rats climb artificial nest structures and either prevent YSBLs using nest structures, remove or eat the eggs and chicks, or cause adult nest abandonment (Cruz-Burgos *et al.* 1997).
7. Reitsma (1998) found that predation was the greatest cause of nest failure (37.5%) for all YSBL nests known to fail. He inferred predation by a combination of circumstantial evidence including broken eggs, dislodged nests, observation of predators (*e.g*., feral cat near nesting area, rat coming out of a YSBL nest, pearly-eyed thrasher (*Margarops fuscatus*) pecking at YSBL chick in a nest), stage of nest combined with condition of nest at subsequent visit, and predator tracks around the nesting area (probably Rhesus monkeys, *Macaca mulatta*) (Reitsma 1998).
8. Besides the previously-reported predators, López-Ortiz *et al.* (2002) indicated that other possible predators of eggs, fledgling, or adult YSBLs also seen within the vicinity of the artificial nest structures were smooth-billed ani (*Crotophaga ani*), mangrove cuckoo (*Coccyzus minor*), yellow-billed cuckoo (*C. americanus*), black-crowned night heron (*Nycticorax nycticorax*), yellow-crowned night heron (*N. violaceus*), osprey (*Pandion haliaetus*), and red-tailed hawk (*Buteo jamaicensis*). They further suggested that the greater predation found in natural nests compared to artificial nest structures could be caused by

rats, cats, and avian predators (e.g., Pearly-eyed thrashers, *Margarops fuscatus)* not found near the artificial nest structures (López-Ortiz *et al.* 2002).

9. López-Ortiz (PRDNER, pers. comm., 2010) suggested that the introduced invasive green iguana (*Iguana iguana*) and the invasive constrictor boa (*Boa constrictor*) are known to consume bird eggs and chicks. Green iguanas have been found in close proximity to YSBL nesting areas and may also prey on eggs and chicks in YSBL natural nests. If the invasive boa population is not controlled in time, boas could also get into the YSBL breeding zone and prey on eggs, chicks and adult YSBLs.
10. Feral house cats (*Felis catus*) (Reitsma 1998), merlin (*Falco columbarius*), red-tailed hawks, and small Indian mongoose (*Herpestes auropunctatus*) (Lewis *et al*. 1999) may prey on adult YSBLs.
11. Observations of YSBLs tending and caring for house sparrow (*Passer domesticus*) fledglings suggest that YSBLs are pre-disposed to incubate eggs and raise nestlings from other bird species; a behavior that is exploited by the SHCO (Ramos-Álvarez and López-Ortiz 2009).
12. Human activities have indirectly and directly affected the YSBL population. Reitsma (1998) reported breeding failure of a YSBL nest at Villa La Mela, Cabo Rojo, due to pruning of coconut palm fronds.
13. YSBLs have been observed foraging in cultivated fields where insecticides are commonly applied to the crops. Therefore, some authors believe that YSBLs may be negatively affected by such insecticides (Lewis *et al.* 1999).
14. Inclement weather has been implicated in nest failure and mortality of YSBLs. After Hurricane Georges in 1998, there was an estimated 29% reduction in the YSBL population of southwestern Puerto Rico (Reitsma 1999). In 1999, one YSBL nest in mangrove was lost due to rain, and four nests in coconut palm trees were lost due to high winds (Reitsma 1999).
15. Coastal forest birds will be more affected by a climate change (Faaborg 2013).
16. Drought : frequency 1 every 6.5 yrs; affects reproduction by 0.8 of adult females breeding; it does not affect their survivorship (López-Ortiz *et al.* unpublished data).

Using this initial list of threats as a starting point, workshop participants were asked to consider and expand upon this list of threats or challenges to YSBLs. They wrote each threat or challenge on a card and placed it on an emerging diagram on the wall. Arrows were used to illustrate proposed causal relationships among factors that affect blackbird population viability either directly and/or indirectly by affecting shiny cowbird population viability. The specific impact on blackbirds was identified (i.e., effect on reproduction, juvenile survival, and/or adult survival). Participants considered additional factors and conditions that lead to each threat.

Once this initial diagram was developed, it was possible to identify clusters of related factors to form the basis of more detailed working group discussions. The complex interconnectivity of factors makes it difficult to subset them into mutually exclusive categories. However, it was possible to identify two primary categories of threats: 1) impacts related to human activities and/or habitat (including the influence of climatic factors); and 2) impacts related to interactions with other species (including SHCOs) (see Figures 1 and 2). Other challenges pertinent to both groups included: lack of knowledge about the system; lack of coordinated management; limited resources for management; and lack of evaluation of artificial nest structures (ANSs).

Figure 1. IMPACT OF HUMAN ACTIVITIES AND HABITAT ON YSBL POPULATION VIABILITY

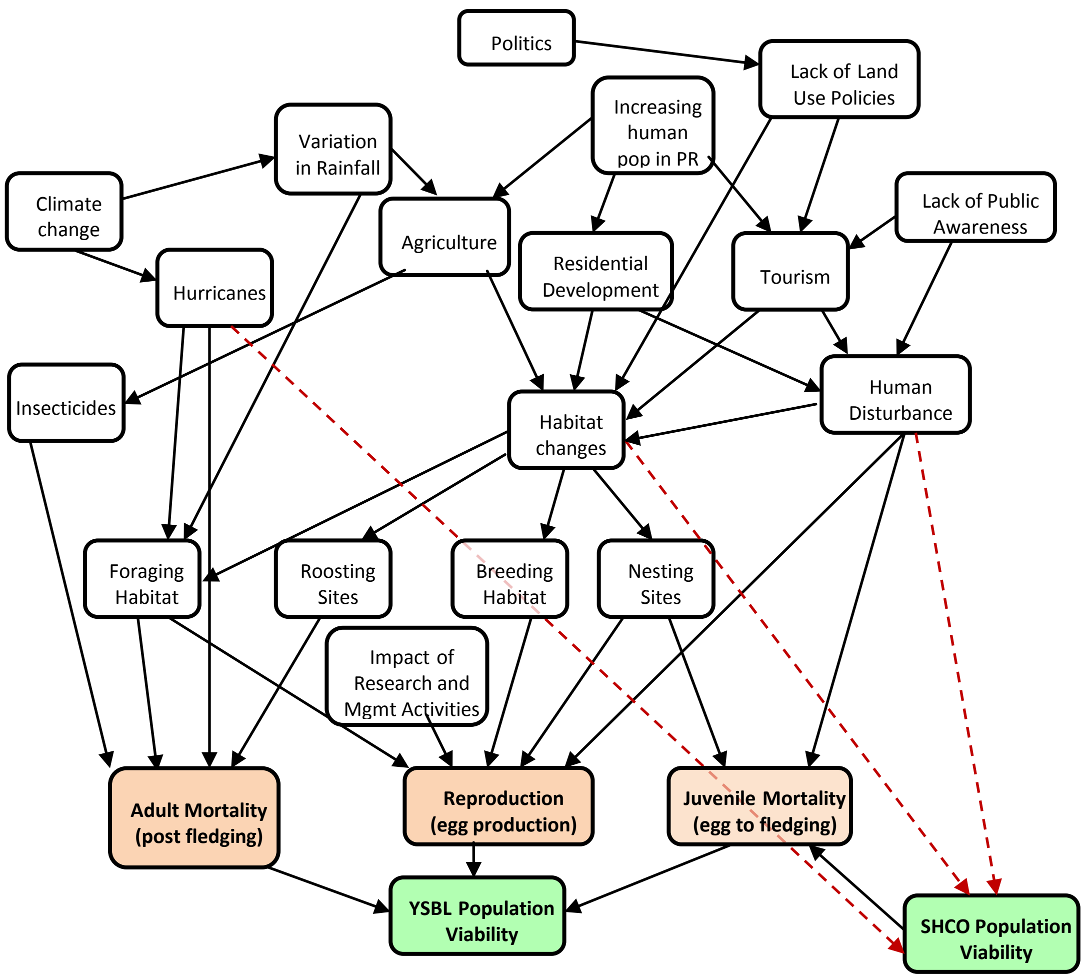
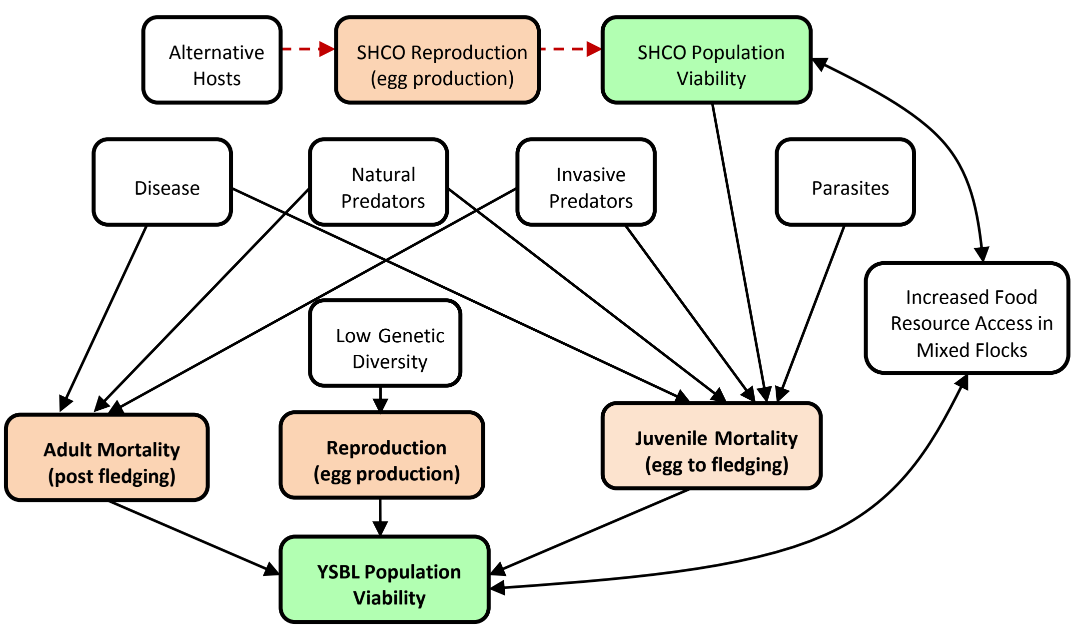


Figure 2. IMPACT OF SPECIES INTERACTIONS ON YSBL POPULATION VIABILITY



Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico
28 – 31 August 2012

Final Report

SECTION 5

Human Activities and Habitat Changes Working Group Report

Working Group Report: Potential Impact of Human Activities and Climatic Variability

Members: José Cruz-Burgos, Oscar Díaz, Alexis Dragoni, Paul McKenzie (facilitator), Fernando Núñez, Idelfonso Ruiz, Eduardo Ventosa-Febles

General Problem Statement

Human activities and climatic variability could have positive or negative effects on the population viability of YSBLs and expansion of SHCOs into areas occupied by the blackbird in southwestern Puerto Rico.

Background

Group 1 was charged with addressing issues related to human activity and climate variability and their potential impact on the viability of YSBL. The group examined how these variables affected (positively or negatively) YSBLs and SHCOs.

Approaches to addressing potential impacts were first expressed as goals. Subsequently, the group identified actions, often expressed in terms of management recommendations that could be undertaken to address issues or threats identified. Throughout the work session during the week the group prioritized or ranked these actions that were deemed to provide the greatest benefits to YSBLs, were most likely to be successful, and whether identified issues were based on data or assumptions. For the sake of the discussion, personal observations were considered as data even if such information had not been published or documented in a written report.

In discussing the effects of human-related activities on the population viability of YSBLs, the group noted that all effects, whether positive or negative, were undoubtedly related to continued human growth and expansion.

The group subsequently discussed climatic variability but noted that there were generally no possible suggested actions to address the potential impact because climate was beyond human control. Issues were grouped based on similarity of theme or context and those that would result in the greatest impact to YSBLs were addressed first and given the highest priority for discussion.

Major Issues Considered

Activities Beneficial to SHCOs

<u>Problem statement</u>

Human-related actions that have positively benefited SHCOs likely negatively impacted YSBLs.

<u>Related issues discussed by other groups</u>

Because SHCOs have steadily increased in SW Puerto Rico and are known brood parasites on YSBLs, Group 1 did not spend any time discussing the potential negative impacts on the species as we understood that issue would be discussed by the Group 2. Another reason is that it would be difficult to assess possible changes in SHCO numbers if the trapping efforts that have been taking place for several decades had not been conducted. Instead, Group 1centered its discussions on how various human-related activities and climatic factors impacted habitats in Puerto Rico and what effects such impacts may have had and continue to have on YSBLs.

Land Use Policies and Other Political Issues

Problem statement

Some declines of YSBLs are undoubtedly attributable to politics and land use policies.

Issue

Human behavior in Puerto Rico is influenced by political atmosphere and land use policy. In many cases there is a deficiency of public awareness, a lack of or failure to implement land use policy, ineffective enforcement of existing regulations that prohibit either the take of YSBLs or adverse impacts to its roosting or nesting habitat, and limited resources for management and research. There was agreement that regulations restricting impact to YSBL habitat was adequate but violations against such activities were not consistently or subsequently enforced. The failure of PRDNER law enforcement officers to enforce regulations is partly due to the fact that most lack a biological background, are unaware of the YSBL and existing regulations, or fail to give violations protecting endangered species the same priority as other criminal acts. The result of these inadequacies is that areas (especially roosts and breeding sites) used by YSBLs are disturbed and negatively impacted. Disturbance of roosts has led to abandonment of well-established roosts by YSBLs and perturbation of nesting sites has surely resulted in reduced reproductive success.

Development

Problem statement

Many changes in habitats and areas used by YSBLs were the direct result of activities associated with the continued expansion and growth of the human population.

Issue

Multiple human-related activities have resulted in changes to YSBL habitats. These include direct and indirect effects of residential, tourism, industrial, or commercial development of coastal areas and inland location used by YSBLs. Such development has resulted in the destruction and reduction of roosting, feeding and nesting habitat or the alteration of native natural communities due to the expansion of exotic, non-native and invasive species.

Tourism

Problem statement

An increase in tourism along coastal areas has contributed to roost disturbance.

Issue

Tour boat operators commonly spotlight mangrove islets to show tourists roosting wading birds such as cattle egrets (*Bubulcus ibis*) and night herons (*Nycticorax nycticorax* and *N. violaceus*). This practice, however, is believed to be responsible for the abandonment of a major YSBL roost near La Parguera. Invariably, the spot-lighting practice overlaps the problem statement involving land use policy issues identified above because PRDNER law enforcement officers fail to enforce such illegal disturbances to YSBL habitats.

Indirect Effects (Non-Native Invasive Species)

Problem statement

Expansion of the human population and increased development has resulted in indirect impacts to YSBLs.

Issue

In addition to direct impacts to roosting habitat, Group 1 also noted that one indirect effect of human activity was that they were also responsible for the introduction of rats that are documented predators of YSBLs. Because Group 2 was responsible for addressing the impacts of other predators on YSBLs, we did not discuss this issue in great detail. However, one aspect of human activity that was subsequently discussed, was that development along coastal areas adjacent to YSBL foraging and roosting habitat could indirectly contribute to adult mortality of YSBLs due to the presence of pet cats that can prey on blackbirds when birds are attracted to bird feeders.

Prohibited Activities

Problem statement

Other illegal human disturbance of YSBL habitats has likely contributed to the species' decline.

Issue

There have been continued adverse impacts to YSBL nesting habitats due to other human activities such as the use of all-terrain vehicles (ATVs), horses, bicycles, or disturbance of roosts by night spotlighting. Such activities have resulted in the degradation of nesting habitat along the coast and even inland where the nesting of YSBLs in palm trees has likely been impacted by the trimming of older branches at the Boquerón beach as part of the maintenance of the beach area by the Puerto Rico National Parks Company.

Incidental Drowning

Problem statement

Watering troughs constructed for livestock have contributed to mortality by YSBLs.

Issue

One interesting report from a group member was the fact that a rancher found the leg bands of no fewer than seven YSBLs that had drowned in his cattle troughs that were constructed to provide water to livestock. Given that there are likely as many as 300 of such troughs in SW Puerto Rico, mortality of YSBL due to drowning was considered significant but a threat that could be easily addressed if ranchers used "anti-drowning" platforms similar to those developed by Mariano Rodriguez and in use on the USFWS Cabo Rojo National Wildlife Refuge.

Artificial Nest Structures

Problem statement

Use of human-made nest structures by YSBLs may have negative impacts on the species.

Issue
There is a general consensus that the construction, placement, and maintenance (nest monitoring, removal of SHCO eggs) of artificial nest structures for YSBLs by individuals concerned with the species have contributed to nesting success. The dependency and reliability of such structures, however, could have a negative impact on the species. Such artificial structures need to be modified to reduce the drowning of fledglings that fall into the coastal water from them. Another impact that will be difficult to assess is if the use of ANS by YSBLs may have some long-term effect on the species by continued reliance on human-made nesting structures rather than use of natural cavities or construction of nests in native trees.

Agricultural Development

Problem statement
Agricultural and pasture development or management in SW Puerto Rico may have resulted in ongoing both negative and positive effects on YSBLs.

Issue
On one hand, agricultural development in SW Puerto Rico has resulted in the fragmentation, alteration, and disturbance of native forests and grasslands. Such disturbances have surely facilitated the expansion of SHCOs in SW Puerto Rico. The expansion of SHCOs in Puerto Rico has been well documented and the resulting impacts of brood parasitism on YSBLs is being discussed and analyzed by Group 2. The types and changes in agricultural crops grown and pasture development for livestock have also surely resulted in impacts to the distribution of YSBLs and SHCOs in SW Puerto Rico. Group 1 members noted there has been a shift in cultivated crops to pasture and hay production due to an increase in the population of monkeys in southwestern Puerto Rico that destroyed or stole fruit before it could be sold by farmers. Other factors likely also played a role in the shift from cultivated crops to pasture. One minor point mentioned by the group is that the use of fire on grasslands and woodlands is believed to be mostly detrimental to YSBLs. This obviously would be the case if YSBLs use black olive (also known as úcar) (*Bucida buceras*) woodlands away from coastal mangroves.

Climatic Variability

Problem statement
Climatic variability, especially related to rainfall abundance, has had a direct effect on foraging habitat for YSBLs in SW Puerto Rico.

Issue
There was considerable discussion of the interactive relationship between the management of agricultural land and mesquite/black olive woodland in southwestern Puerto Rico and climatic variability. Grassland or woodlands with a grass understory can provide an abundance of caterpillars when there is sufficient rainfall as documented in McKenzie's (1990) doctoral research. Exotic and natural grasses in southwestern Puerto Rico provide habitat for *Mocis latipes*, a noctuid moth responsible for massive infestations of caterpillars when there is sufficient rainfall. McKenzie (1990) demonstrated that the periodic outbreaks of *Mocis latipes* larvae are utilized by SHCOs, Greater Antillean grackles (*Quiscalus niger*) (GAGR), and YSBLs (McKenzie and Noble 1989; Cruz-Burgos 1999).

The periodic abundance of *Mocis latipes* larvae facilitated the communal foraging of SHCOs, YSBLs, and GAGRs that often feed in large mixed-species flocks when there is an abundance of caterpillars. McKenzie (1990) observed that GAGRs were usually the first individuals in a mixed-species flock that would be able to locate caterpillars. At first, YSBLs and SHCOs would run behind GAGRs in attempts to steal prey but quickly learned from GAGRs how to find caterpillars on their own. McKenzie (1990) postulated that the sharing of information on the location of caterpillar outbreaks by the three species helped maintain communal bonds between the bird species. Additionally, McKenzie (1990) as well as Cruz-Burgos (1999) noted several instances of allopreening between YSBLs and SHCOs where the blackbirds accepted invitations from the cowbirds to preen their head and neck. The significance of allopreening between a bird species and its brood parasite has been a matter of considerable debate but McKenzie (1990) believed that the behavior helped facilitate communal bonds between YSBLs and SHCOs. He found a significant positive relationship between YSBsL and flocks of SHCOs that consisted of 50 or more birds in a flock.

Related to management of grassland and pastures in southwestern Puerto Rico based on McKenzie (1990), the group concluded that mowing and light to moderate grazing enhanced caterpillar infestation of *Mocis latipes* larvae and facilitated foraging by YSBLs. On the downside, it also facilitated foraging by SHCOs. Group 1 discussed at length the mosaic of habitat in the agricultural areas and adjacent lowlands of southwestern Puerto Rico and its relationship on the distribution and abundance of YSBLs and SHCOs. The group contended that the contiguous arrangement of foraging, nesting and roosting habitat was absolutely essential to the largest remaining population of YSBLs in southwestern Puerto Rico. Group members noted that despite the fact that historical nesting and roosting habitat currently exists along the coast east of La Parguera, these areas presently do not support healthy populations of YSBLs. The group agreed that along with GAGRs and SHCOs, YSBLs have adapted to the mixture of habitats between Cabo Rojo and La Parguera and suggested that the distribution and abundance of YSBLs in this area was likely related, in part, to the availability of foraging habitat.

Pesticides

<u>Problem statement</u>

The decline of YSBLs may be due, in part, due to pesticide poisoning.

<u>Issue</u>

During initial discussion among participants at the PHVA workshop, insecticides were identified as a potential cause issue associated with agriculture. However, in a following discussion within Group 1, it was determined that insecticides were currently not an issue in southwestern Puerto Rico due to the shift from cultivated crops to pasture or hay. Nonetheless, DDT has been documented on Ceiba and Vieques.

There are two other related issues that should be discussed. The first was that insecticide use in southwestern Puerto Rico could increase due to the threat and expansion of West Nile Virus. The second issue was related to observations made by retired USFWS Cabo Rojo NWR employee Mariano Rodríguez who observed YSBLs in large numbers in southwestern Puerto Rico when he was approximately 10 years old. Rodríquez (personal communication, 8-29-12) noted seeing “thousands and thousands” of YSBLs in the 1950s. In fact, he reported that the numbers of

YSBLs flying from foraging areas to mangrove roots were so large they would blacken the sky for several minutes. Rodríguez also reported that he frequently observed YSBLs foraging on an abundance of caterpillars that infested corn fields. Based on McKenzie's (1990) research on the history of *Mocis latipes* in Puerto Rico, it is highly likely this moth was the same species whose larvae are now observed in abundance in southwestern Puerto Rico under the appropriate environmental conditions.

Rodríguez also noted that caterpillar infestations were treated with the application of DDT and that he observed YSBLs that were sick or dead from consuming caterpillars covered with DDT. Although DDT was banned in 1972, there is a possibility that DDT and its metabolite DDE may still be persistent in the environment as their half-life can be as much as 30 years. DDT and DDE have been documented as inhibitors of the brain enzyme acetylcholinesterase (abbreviated as AChE in the published literature; reduction can cause reproductive failure) and implicated in the egg shell thinning [For an excellent review of its persistence and impacts see Walker (2003) http://www.bio-nica.info/Biblioteca/Walker2003NeurotoxicPesticides.pdf and Wikipedia at http://en.wikipedia.org/wiki/DDT]. The potential persistence in the environment could adversely impact YSBL due to the inhibition of AChE. While habitat destruction, exotic mammals, and brood parasitism by SHCOs have been listed as the main reasons for the decline of the YSBL, little attention has been given to the potential impact of DDT. Rodríguez mentioned that the numbers of YSBLs noticeably declined soon after the use of DDT in southwestern Puerto Rico in the 1950s. Thus, YSBLs could have experienced significant declines prior to SHCOs reaching population levels that impacted blackbirds due to brood parasitism, which was likely sometime in the 1960s or 1970s although Post and Wiley (1977a) suggested the arrival of SHCOs may have occurred earlier on the island. Even if such was the case, that does not negate the likely decline due to the use of DDT through at least 1972.

Climatic Events

Problem statement

Storms and hurricanes could have significant impacts on the YSBL and its habitats.

Issue

The relationship between climatic variability and the viability of YSBLs was further analyzed among Group 1 members. Cyclic fluctuations in hot and dry periods are not uncommon in Puerto Rico. Large rain events or droughts regularly occur on the island, especially associated with El Niño and La Niña events. Depending on the year, Puerto Rico may be impacted by tropical storms or hurricanes. The impact of such events is dependent upon the intensity, duration and timing of the storms. High winds and heavy rain may destroy YSBL nesting or roosting habitat and this could result in adult, juvenile, or nestling mortality or cause a loss in reproduction due to loss of eggs or nest, especially if such storm events coincide with the peak nesting season. On the upside, however, large rain events can stimulate the growth of grass necessary for caterpillar infestations from larvae that provide food for YSBLs.

Global Warming

Problem statement

Global warming could affect sea levels but this is not anticipated to be a major impact on YSBL.

Associated with climatic variability, our group noted that some scientists anticipate that projected global warming associated with climate change could result in the melting of polar ice caps that may cause sea levels to rise. If such projections are accurate, it is anticipated that elevated sea levels could adversely affect coastal mangroves that are critical for YSBL roosting and nesting needs. Nonetheless, the consensus of the group was that the potential impact of a rise in sea level on YSBLs is likely to be low because any alterations in sea levels that occur would be gradual and the YSBL is likely to be able to adapt to such change. Group 1 believed that the YSBL is more of a generalist than some species and able to adapt to changes in habitats it frequently uses. This would explain how the species has well adapted to the periodic availability of caterpillars [mostly *Mocis latipes* but others were documented by McKenzie (1990)] that infest exotic and native species of grasses in the agricultural lands and mesquite/ucar woodlands of southwestern Puerto Rico. While the projected impact from an elevated sea level is anticipated to be low, the group agreed that the issue should be further researched.

Following an in-depth discussion of the major issues associated with human activities and climatic variability and the categorization of impacts based on similarity in theme and concept the group ranked the magnitude of potential effects between high and low (see Table 1). Concepts involving policy and human behavior issues (i.e., public awareness, politics, limited resources and personnel necessary to perform the job, lack of or failure to implement land resource management plans and disturbance to mangrove roosts due to illegal spot lighting by tour boats) were all considered high impact actions. The general impacts associated with tourism, except illegal spot lighting as discussed above and activities involving management of pasture for livestock were deemed to be of moderate importance while coastal development and research activities by biologists monitoring YSBL nest productivity were judged to be of low impact. Group 1 determined that of the issues discussed, most were based on data with the exception that public awareness, politics, and abandonment of YSBL roosts due to illegal spotlighting were based on assumptions. While the abandonment of the roost at La Parguera is well documented, the cause of the halted use of this site by YSBLs is based on assumptions.

Table 1. Impact ratings and basis for human-related issues that are thought to affect YSBL viability.

Impacts on Viability of YSBL	High	Moderate	Low	Basis for determination
Human Related Issues	X			Data
Public awareness	X			Assumption
Politics	X			Assumption
Lack of land use plan	X			Data
Limited resources	X			Data
Inefficient law enforcement	X			Data/Assumption
Limited resources for management	X			Data
Tourism		X		Assumption
Development		?		Data
Agriculture (Pasture/Livestock)		X		Data/Assumption
Agriculture (Cropland/Hay)			X	Data
Research/Management related mortality			X	Data
Spot lighting	X			Assumption

The last two days of the workshop centered on developing timelines, estimating costs, establishing priorities for the actions listed and identifying the main responsible part and collaborators. Due to limited time we worked first on the actions that would likely have the greatest impact on benefitting the viability of the YSBL – lower priority actions or those anticipated to have less overall impact on the viability of YSBLs were discussed as time allowed.

Special note: it was the consensus of the Group 1 working group that the official common name of the YSBL should be changed from "la Mariquita" to "el Capitán" because the term mariquita is often mistaken as an insect that goes by the same common name and also has a human social slang connotation. El Capitán has been used in the past as the common name for the YSBL and should be reinstated as the main non-scientific name.

GOAL 1: Protect mangrove islets from disturbance due to spotlighting of roosts and enforce regulations that prevent roost disturbance.

Protecting these areas would provide benefits to 90% of the entire roosting populations of YSBL in southwestern Puerto Rico. At one time the roost at La Parguera was ~680 birds out of possible 800-1,000 in southwestern Puerto Rico. Undertaking this action would not only make the La Parguera roosting area once again attractive to roosting YSBL but would also likely increase the carrying capacity of the species. This action could increase populations from 409 in 2010 and a low of 105 in 2011 to a bare minimum of the 2,000 birds that were estimated in SW Puerto Rico in 1976 (Post and Wiley 1977b).

***ACTION*: Construct and erect signs at roosting areas that clearly indicate that disturbance of these areas is prohibited.**

Resources needed: 15 signs @ $200 each= $ 3,000
Responsible party: PRDNER and USFWS (Coastal Program)
Collaborators/potential partners: Puerto Rican Ornithological Society, Effective Environmental Restoration, universities
Potential impact: High
Likelihood of success: High
Timeline: Immediate
Basis of determination: Data (personal observations of PRDNER personnel)

***ACTION*: Develop and train task force to educate administrators and attorneys on need for law enforcement.**

Resources needed: None; part of regular duties and responsibilities
Responsible party: PRDNER
Collaborators/potential partners: USFWS
Potential impact: High
Likelihood of success: High
Timeline: Immediate
Basis for determination: Assumption

ACTION: Affect attitude change through outreach and education such that enforcement of regulations protecting YSBL and its habitat is a priority with administrators, managers, and law enforcement officials.

Resources needed: $27,000/yr for 3yrs ($81,000 total)
Responsible party: PRDNER and USFWS
Collaborators/potential partners: Puerto Rican Ornithological Society
Potential impact: High
Likelihood of success: Moderate
Timeline: Immediate
Basis for determination: data (personal observations of PRDNER personnel)

ACTION: Identify boat clubs, fishing clubs, and outfitters who have licenses to take out tourists and provide technical assistance to them on regulations that protect YSBL and need for enforcement of Wildlife Law of Puerto Rico, Endangered Species Act (ESA), and Migratory Bird Treaty Act (MBTA); outline consequences for failure to follow regulations.

Resources needed: Brochures developed for outreach ($2,000 for art + $2,000 for printing, for a total of $4,000)
Responsible party: PRDNER Law Enforcement Officers
Collaborators/potential partners: FWS (Coastal Program)
Potential impact: High
Likelihood of success: High
Timeline: Immediate, ongoing
Basis for determination: data (personal observations of PRDNER personnel)

GOAL 2: Protect and prioritize offshore mangrove islet roosting sites from predators (rats, cats, iguanas, jungle fowl).

ACTION: Expand existing efforts to control and eradicate predators (especially rats) and identify and prioritize roosts where eradication efforts are likely most effective (e.g. islets that have the longest distance between roosts and the main island).

Resources needed: $30,000/year x 3yrs ($90,000 total)
Responsible party: PRDNER
Collaborators/potential partners: Puerto Rican Ornithological Society, Island Conservation, Effective Environment Restoration, FWS (Coastal Program)
Potential impact: High
Likelihood of success: High
Timeline: 3 years
Basis for determination: Data (indirect evidence from studies involving other species)
Priority for action: Immediate

GOAL 3: Study the thriving YSBL population at Guayama and Salinas, Puerto Rico by examining habitat use, movement patterns, and survival of YSBL.

ACTION*: *Assess status of YSBL at Guayama and Salinas in the absence of management to adapt management actions in Pitahaya.

Resources needed: $25,000/year x 2yrs ($50,000 total)
Responsible party: University student (potential thesis)
Collaborators/potential partners: PRDNER, USFWS, Puerto Rican Ornithological Society, Effective Environment Restoration
Potential impact: High
Likelihood of success: High
Timeline: 2 years
Basis for determination: Data (personal observation and PRDNER surveys)
Priority for action: Immediate

GOAL 4: Prevent accidental death of additional adult YSBLs due to drowning in cattle troughs.

ACTION*: *Assess which troughs cause mortality, construct and install anti-drowning devices; develop drown proof drinking troughs as developed and in use on Cabo Rojo NWR; have NWR and PRDNER personnel coordinate trough design with cattle rangers.

Resources needed: 100-300 troughs in SW Puerto Rico/$20 each for construction = $2,000-6,000 for troughs; $15,000 (1/4 FTE) personnel; $10,000/yr for monitoring
Responsible parties: USFWS (Cabo Rojo National Wildlife Refuge, Caribbean Ecological Services Field Office and Partners for Fish and Wildlife) and PRDNER
Collaborators/potential partners: Puerto Rican Ornithological Society, BirdLife International, local ranchers, Effective Environmental Restoration
Potential impact: High
Likelihood of success: High
Timeline: 1 year
Basis for determination: Data (personal observations of ranchers reported PRDNER personnel)
Priority for action: Immediate

ACTION*: *Monitor troughs on Mona Island to determine if drowning is a problem for YSBLs.

Resources needed: None (part of area PRDNER biologist’s job)
Responsible party: PRDNER
Collaborators/potential partners: Island Hunters clubs; Amigos Amoná
Potential impact: High
Likelihood of success: High
Timeline: 1 year

Basis for determination: Assumption
Priority for action: Immediate

GOAL 5: Provide sufficient foraging habitat for adult YSBL during peak breeding season.

ACTION: Mow and irrigate when necessary areas on USFWS Cabo Rojo National Wildlife Refuge; manage grassland habitat (mowing, disking, irrigating) on refuge to encourage outbreak of caterpillars; monitor success.

Resources needed: 1 full time refuge biologist at GS-9 ($70,000); $6,000 for site preparation
Responsible party: USFWS- Refuges, Region 4; Cabo Rojo NWR
Potential collaborators/partners: USFWS- Cabo Rojo NWR; Boquerón, Caribbean Ecological Services Field Office, Region 4 Refuge Division personnel in Atlanta, GA
Potential impact: High
Likelihood of success: High
Timeline: Ongoing
Basis for determination: Data (McKenzie 1990)
Priority for action: Immediate, especially in hiring full time biologist
Data gap: Monitor restoration efforts on refuge to see if managed areas are attractive to YSBL; erect artificial nest boxes to facilitate nesting of YSBL on the refuge.

ACTION: Identify existing grassland habitat on Puerto Rico DNER lands, PR Land Administration (Administración de Terrenos) lands, and PR Land Authority (Administración de Tierras – part of the PR Department of Agriculture) lands that can be managed to create foraging habitat; outreach to adjacent private landowners that may have suitable available habitat adjacent to PRDNER lands; develop co-op agreements and provide technical assistance to private land owners through existing programs of federal and state agencies: USFWS Partners for Fish and Wildlife, US Forest Service (USFS) and Natural Resources Conservation Service (NRCS); create foraging habitat on adjacent private land by appropriate management of grasses through landowner incentive programs listed above.

Resources needed: $60,000/ year from NRCS and USFWS restoration programs.
Responsible parties: USFWS and PRDNER
Potential collaborators/partners: USFS, NRCS, PRDNER lands, PR Land Administration, PR Land Authority (PR Department of Agriculture), University of Puerto Rico (Mayagüez) Department of Agriculture, Caborojeños Pro Salud y Ambiente, USFWS (Coastal program), USFWS Cabo Rojo NWR; Caribbean Ecological Services Field Office, Region 4 ES and Refuge Division personnel in Atlanta, GA
Potential impact: High
Likelihood of success: High
Timeline: Immediate, ongoing
Basis for determination: Data (McKenzie 1990)
Priority for action: Immediate

ACTION: Have YSBL added as a priority species for NRCS habitat restoration programs.

Resources needed: none (part of job responsibilities)
Responsible party: Wildlife and Forestry subcommittee (USFWS, NRCS, USFS, PRDNER)
Potential collaborators/partners: NRCS
Potential impact: High
Likelihood of success: High
Timeline: Ongoing
Basis for determination: Data (McKenzie 1990; Cruz- Burgos 1998)
Priority for action: Moderate

GOAL 6: Coordinate implementation of Municipality of Cabo Rojo Land Resource Management Plan (LRMP)

ACTION: USFWS and PRDNER personnel should be more proactive in contacting the Planning Coordinator of the Cabo Rojo Municipality to outline the needs of the YSBL as written in their land resource management plan (LRMP). Additionally, USFWS and PRDNER staff should work closely with the Municipality of Cabo Rojo and with Planning Coordinator to ensure that the implementation of their LRMP is compatible with the conservation needs of YSBL.

Resources needed: None; part of regular duties and responsibilities
Responsible party: USFWS Cabo Rojo NWR, Caribbean Ecological Services Field Office, PRDNER
Potential collaborators/partners: Municipio de Cabo Rojo
Potential impact: Moderate
Likelihood of success: Moderate
Timeline: Ongoing
Basis for determination: Data (as written in municipality LRMP and the Recovery Plan for the YSBL).
Priority for action: Moderate

ACTION: Work with the Lajas Municipality when developing their LRMP to incorporate the conservation needs of the YSBL.

Resources needed: None; part of regular duties and responsibilities
Responsible party: USFWS- Cabo Rojo NWR, Caribbean Ecological Services Field Office, PRDNER
Potential collaborators/partners: Municipio de Lajas
Potential impact: Moderate
Likelihood of success: Moderate
Timeline: Ongoing
Basis for determination: Data (as needed, based on experience with municipality of Cabo Rojo).
Priority for action: Moderate

GOAL 7: Increase public awareness of conservation value and regulations that protect YSBL and its habitat.

<u>ACTION</u>: Have USFWS and PRDNER provide information on YSBL during local festivals.

<u>Resources needed</u>: T-shirts, pins: $2,000
<u>Responsible party</u>: Cabo Rojo NWR, Caribbean Ecological Services Field Office, PRDNER
<u>Potential collaborators/partners</u>: Caborrojeños Pro Salud y Ambiente, Puerto Rican Ornithological Society, Municipality of Cabo Rojo and Lajas, University of Puerto Rico Marine Science Department at Lajas, Puerto Rican Tourism Company
<u>Potential impact</u>: High
<u>Likelihood of success</u>: High
<u>Timeline</u>: Ongoing
<u>Basis for determination</u>: Data (based success for other species in Puerto Rico and the US)
<u>Priority for action</u>: High

GOAL 8: Affect policy change that allows implementation of federal land owner incentive programs on private lands in Puerto Rico.

<u>ACTION</u>: Work with policy makers that outline the importance of being able to implement federal land owner incentive programs on private lands. Create and implement incentive programs that provide conservation benefits to YSBL. Under existing Puerto Rico laws and regulations to protect wildlife, taking of a federally listed species is not allowed, preventing the implementation of the Safe Harbor Incentive Program on private lands. Amend existing regulations and/or develop a MOU between PRDNER and FWS to allow for the Safe Harbor Incentive Program to be implemented on private lands.

<u>Resources needed</u>: None (part of regular duties and responsibilities)
<u>Responsible party</u>: PRDNER and FWS
<u>Potential collaborators/partners</u>: FWS- Cabo Rojo NWR, Caribbean Ecological Services Field Office; Hilda Díaz Soltero, USDA Senior Invasive Species Coordinator.
<u>Potential impact</u>: High
<u>Likelihood of success</u>: High
<u>Timeline</u>: 1 yr
Basis for determination: Data
Priority for action: High

GOAL 9: Garner support from NGOs and conservation organizations that provide support for funds and personnel needed to benefit YSBL.

Action: Initiate contacts to various user groups to establish support for the YSBL.

Resources needed: None (part of regular duties and responsibilities)
Responsible party: FWS and PRDNER
Potential collaborators/partners: FWS- Cabo Rojo NWR, Caribbean Ecological Services Field Office; BirdLife International, Caborrojeños Pro Salud y Ambiente; Puerto Rican Ornithological Society, Island Conservation, Effective Environmental Restoration
Potential impact: High
Likelihood of success: High
Timeline: As needed, ongoing
Basis for determination: Data (personal observation and experience)

RESEARCH NEED: Determine if DDT/DDE is still persistent in SW Puerto Rico.

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico
28 – 31 August 2012

Final Report

SECTION 6

Interactions with Other Species Working Group Report

Working Group Report:
Threat Impacts of Other Species on the Yellow-shouldered Blackbird

Members: José Colón, Alexander Cruz, Roseanne Medina-Miranda, Katsí Ramos Álvarez, Ivelisse Rodríguez, Kirsty Swinnerton (facilitator)

Introduction

This working group was responsible for the discussion on the actual and possible threats caused by other species or pathogens on yellow-shouldered blackbird (YSBL) nesting success and the subsequent viability of the species. This report considered several actions to increase the nest success, starting from egg stage until three days after the fledglings leave the nest (preliminary telemetry studies found that 50% of the YSBL fledglings died by the third day). Most of the threats mentioned in this report also affect the shiny cowbird (SHCO) viability, a brood parasite of YSBL and other host species (see Fig. 1). The main threats of YSBL and SHCO include: predators (natural and invasive predators) and diseases (ecto- and endoparasites).

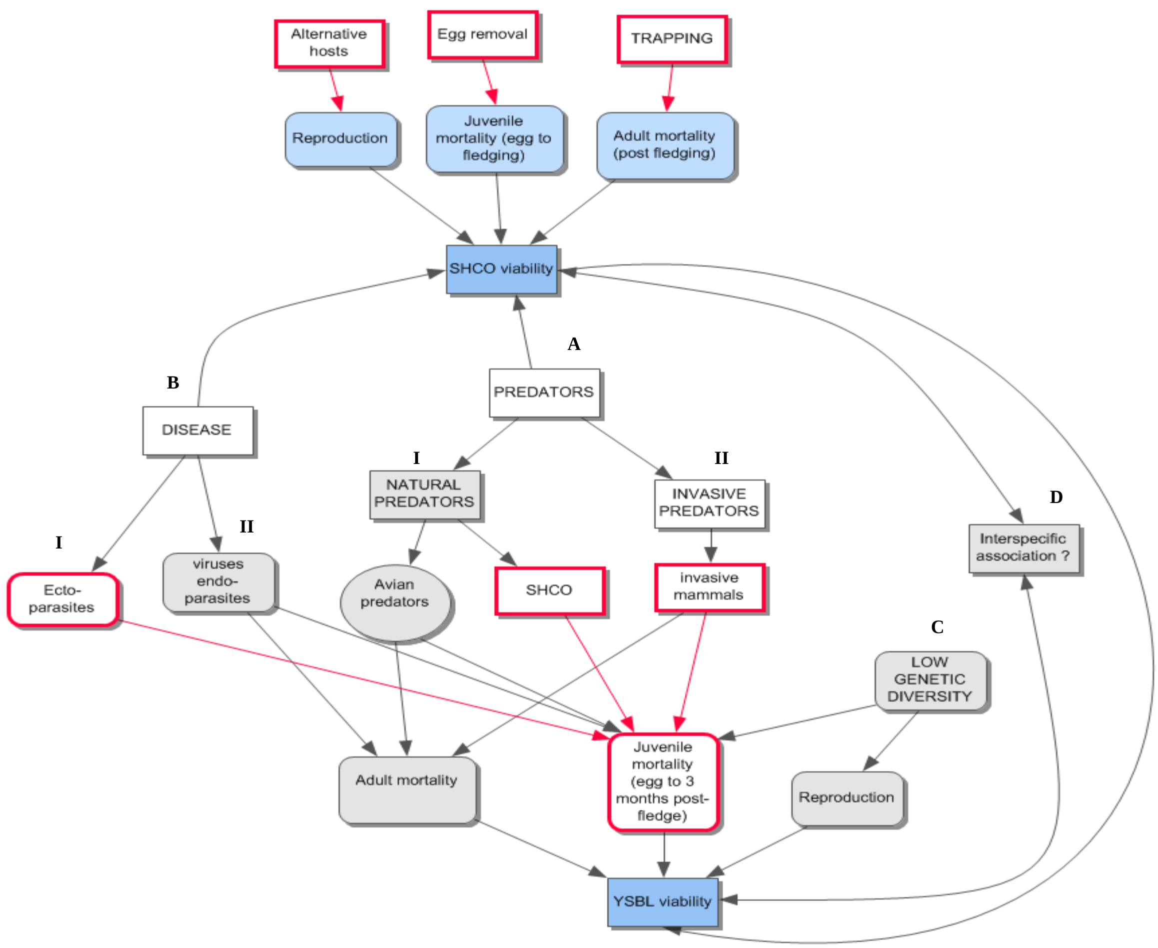


Figure 1. Diagram of interactions between YSBL and SHCO threats. SHCO itself is recognized as a threat to YSBL.

Predators

Natural Predators

Most of the natural predators are avian predators. The avian predators are presented in Table 1 have not been documented as a threat to YSBL directly, although some of them share the same breeding, roosting and foraging habitats of the YSBL.

Table 1. Possible predators of yellow-shouldered blackbirds.

Common Name	Scientific Name	Shared Habitat with YSBL	Prey	Possible prey
Merlin	*Falco columbarius*	Flying near roosting areas	Small birds as shorebirds	YSBL fledglings
American kestrel	*Falco sparverius*	Breeding and foraging	Lizards, large insects and in occasion small birds (Cruz 1976, Oberle 2003)	YSBL chicks
Short-eared owl	*Asio flammeus*	Breeding	Small mammals, occasionally birds (Wiley 1986a, Oberle 2003)	YSBL fledglings (one possible evidence in 2012)
Great egret	*Ardea alba*	Breeding	Frogs, insects, crustaceans, on occasion small birds (Oberle 2003)	YSBL eggs and chicks (is suspected to reach YSBL Artificial Nest Structures and natural nest)
Yellow-crowned night heron	*Nyctanassa violacea*	Breeding	Crabs, insects, small fishes, eggs, chicks (Oberle 2003)	YSBL eggs and chicks (chicks that cannot reach upper branches)

Other avian predators include the shiny cowbird. This brood parasite reduces the clutch size of the host they parasitize (e.g., YSBL) by removing or destroying some of their eggs (Nakamura and Cruz 2000). Similarly, nestling competition between parasite and host chick may be detrimental to the success of the host offspring (Wiley 1986b). Accordingly, the working group considered the interaction between the YSBL and SHCO as predation, by the loss of eggs and the possible reduction of their nest success.

After establishing the YSBL Recovery Project by the PRDNER in 1984, part of the management program has included the removal of SHCO eggs and chicks from artificial nest structures (hereafter ANS). In 2004, this program was expanded to YSBL natural nests (hereafter NN, nests found in natural substrates). The abundance of SHCOs in YSBL breeding areas depends on: SHCO reared in YSBL NN not found by the PRDNER staff, availability of alternative hosts (e.g., yellow warbler, *Setophaga petechia*), the influx of the species and capture efficiency on SHCO live traps installed by PRDNER.

The preferred nesting habitat of YSBL is in mangroves. In addition to avian predators, other known predators exist in this type of habitat, for example: crabs (e.g. blue land crabs, *Cardisoma guanhumi)* and medium-sized fishes (e.g. Atlantic tarpon, *Megalops atlanticus*). Those YSBL chicks and fledglings that are unable to reach trees branches and fall in the water have a greater chance of either being preyed upon or drowning.

Invasive Predators (Current)
Rats (*Rattus rattus* and *R. norvegicus)*: Rats have the ability to climb trees. This ability offers an opportunity to eat eggs and prey on YSBL nestlings and also adult birds (USFWS 2008). ANSs were primarily implemented as part of the YSBL management to protect the nests from predators. However, rats may reach the ANS through trees branches growing in close proximity to an ANS. ANSs that are occupied by rats are prevented from being used by YSBL for nesting or cause adult nest abandonment (Cruz-Burgos *et al. 1997).* From 1977-1982, Post and Wiley (1977) found a predation rate of 31.9% in natural nests and 18.3% in cavity/ANS. In 2012, from 19 NN monitored by PRDNER only one nest was successful (with at least one fledgling), principally due nest predation.

Mongoose (*Herpestes javanicus)* and Feral Cats (*Felis catus)*: The mongoose was introduced to Puerto Rico to control rats, resulting in only temporary or insufficient rat population suppression. More likely, the abundant rats supplement cat and mongoose diets (Engeman 2006). This terrestrial predator had an omnivorous diet consisting of small mammals, birds, herpetofauna, invertebrates and plants (Villela 1995, Tariq M. *et al* 2011). For example, R. Medina observed a mongoose preying on a small bird captured in the lower part of the mist nest and A. Cruz (pers. obs.) had a similar observation in Jamaica – in this case predation on a stripe-headed tanager (*Spindalis zena).*

Cats arrived in Puerto Rico as domestic pets and are well-known for their extraordinary climbing abilities. Increase in urbanization and the eventual abandonment of cats have resulted in a feral cat population in Puerto Rico. Although the information of the effect of predators on Puerto Rican wildlife is almost unknown, worldwide documentation of the predatory impacts of cats and mongoose exist on islands (USDA 2003). Both mongoose and cats are widespread in the YSBL breeding areas. YSBL eggs, nestlings, and adults may be considered to be predated by these two predators.

Invasive Species (Potential Predators)
Green iguana (*Iguana iguana*): The introduced green iguana has increased its distribution in Puerto Rico. For the last three years the green iguana has been established in Boquerón Commonwealth Forest, the main breeding area of YSBL in Puerto Rico. Although considered an herbivore, the green iguana may indirectly affect the nesting success of the YSBL. For example, its feeding might affect the YSBL habitat. Also, the green iguana lay a high number of eggs/hatchlings annually (approximately 50 eggs), this source of food may increase potential predators. Similarly, probable physical disturbance caused by the iguana while they climb the trees damage YSBL nests.

Common red-tailed boa (*Boa constrictor sp.*): Boa constrictors are carnivorous generalists. Their diet consists of small mammals, including bats, and birds. Boa constrictors are found in a variety of habitat but mainly in rainforest clearings or edges. For the moment, this predator has not been observed in YSBL breeding or roosting habitats. However, boas have been found in Mayagüez, which is approximately 35 kilometers from Pitahaya. Their potential dispersion and semi-arboreal behavior should be considered as a possible threat to YSBL, especially juveniles.

Rhesus monkey (*Macaca mulatta)* and patas monkey *(Erythrocebus patas*): Rhesus and patas monkeys escaped from the Parguera islets in Lajas (southwest PR) during the decades of 1960 to

1980 (Gonzalez-Martinez 2004). They were mainly established between Lajas, Cabo Rojo and Guánica municipalities. Both monkey species have a diverse diet that includes: fruits and insects but also includes leaves, roots, and bird eggs. These monkeys are uncommon in the YSBL breeding areas. In 2005, more than four consecutive ANSs were depredated presumably by monkeys (loss of eggs and climbing marks in the PVC pipe). At present, a PRDNER Primate Control Program established since 2007 has reduced dramatically the population of patas monkeys and neutralized the population growth of rhesus monkeys.

Future potential invasive predators not included in this report may be introduced through the pet trade to Puerto Rico.

Disease and Parasites

Ectoparasites

Post (1977) found that three species of *Mallophaga* (bird lice) were present on YSBL: *Philopterus agelaii, Machaerilaemus sp. and Myrsidea sp.* Post also documented two species of blood sucking mites (*Ornithonyssus bursa* and *Androlaelap casalis*) in YSBL open, cavity and artificial nests (Post 1981a, 1981b). Post documented four cases of adult YSBLs deserting young in nesting cavities infected with mites. Similarly other studies found a reduction of growth rates nestlings infected with mites (Clayton and Tompkins. 1995).

In Puerto Rico *Philornis* ectoparasite was responsible for the deaths of 93% of the chicks in pearly-eyed thrashers (Arendt 1985). Larvae of this ectoparasite suck the nestlings blood causing high blood loss, multiple body wounds and infections, and reduced growth rates. At present, there are been no *Philornis* or lice in YSBL and mite infestation in ANSs are controlled by the use of insecticide (Sevin 5%). Sevin has also been used to control other ectoparasites (e.g. lices) in nestlings. (http://purplemartin.org/forumarchives/archive/sevinpro.htm)

Endoparasites (Viruses)

Avian Pox**:** Avian pox is a slowly developing disease of birds caused by several different strains of avipoxvirus (http://www.nwhc.usgs.gov). Post (1981b) reported 19% of YSBLs examined from 1974 to 1975 were infected with avian pox, and infected birds had significantly lower survival rate compare with birds not infected. The presence of this disease leads to difficulty in seeing, breathing, feeding, perching or swallowing. At present, approximately one YSBL nest with chicks every two year approximately has the disease (R. Medina, pers. obs.).

West Nile virus (WNV): WNV was detected in Greater Antillean grackle and house sparrow (*Passer domesticus*) in the municipality of Ceiba, east PR (Komar *et al*. 2012). WNV in birds may cause deadly brain inflammation. In early 2000, the Center for Disease Control and Prevention (CDC) staff took blood samples of SHCOs captured by PRDNER in the southwest part of the island. No traces of the virus were found in their samples.

Avian malaria: Avian malaria is caused by a group of protozoan species of *Plasmodium* and *Haemoproteus*, which infect, among other tissues, peripheral red blood cells of their vertebrate hosts. This disease cause lethargy and low food injection from the infected bird (Fallon *et al*. 2003).

Future potential disease may be carried by vectors to the wildlife of PR.

Low Genetic Diversity

In small populations, genetic drift tends to reduce genetic variation, leading eventually to homozygosity and loss of evolutionary adaptability to environmental changes (Zhang *et al* 2002), or may reduce reducing an effective defense against pathogens (Schultz *et al*. 2009). A low genetic diversity may increase the risk of extinction, especially in an endangered species like the YSBL.

In 2012, doctoral student Irene Liu surveyed the genetic diversity and mating system of the YSBL, sampling 63 adults and 106 chicks across the Pitahaya region of Boquerón Commonwealth Forest (Liu in prep). Part of her results showed that the YSBLs have low allelic diversity (at nine microsatellite loci) and a low effective population size, possibly from the severe bottleneck in the 1980s or from variation in individual reproductive output. She also found that the behaviorally monogamous YSBL mated with individuals other than their territorial mate. This pattern was not found to contribute significantly to variation in individual reproductive output, indicating that the bottleneck is likely to have played a larger role than mating behavior in shaping the current effective population size. Liu also found low evidence of inbreeding and expected levels of heterozygosity in YSBLs. Combined with the findings of low effective population size and allelic diversity, these data suggest that while genetic diversity on the individual level may be intact, the population as a whole remains vulnerable to adverse stochastic events. These last findings are very important knowing the low population size of the species.

Interaction with Other Native Species

<u>Great Antillean grackle</u>: GAGR may have both positive and negative interactions with YSBL. GAGRs are aggressive, can exclude YSBLs in some areas and will chase them away. But GAGRs also facilitate location of food resources for YSBLs. Grackles and YSBLs roost together and might be needed for social facilitation at roost sites (e.g., if no grackles, YSBLs might have a changed roosting behavior or higher mortality at roost sites).

Goal, Sub-Goals, and Recommended Actions

The working group identified its primary goal as increasing nest success of YSBL. This main goal has four sub-goals determinates to improve YSBL nest success. From these four sub-goals, seven actions (highlighted in yellow in the table) were chosen as high priority and high achievability to accomplish with more assertiveness the main goal. Descriptions of actions, possible methods, research among others, are described in the following table (Table 3). Some columns were categorized as high, medium and low based on the best knowledge of members of the group.

OVERALL GOAL: To increase YSBL nest success (from egg stage until 3 days after the fledglings leave the nest)

SUB-GOALS:

1. Decrease predation at YSBL nests;
2. Improve efficiency of ANSs;
3. Reduce impact of SHCO on nest success; and
4. Increase number of ANSs.

OVERALL GOAL: INCREASE YSBL NEST SUCCESS (from egg stage until 3 days after the fledglings leave the nest)

Sub-Goals	Action	Methods	Research	Agency implementing actions	Conservation benefit	Priority	$ cost	Other cost	Likelihood of success	Achievability	Obstacles
Decrease predation at YSBL nests	A. Control rats within nesting areas (ANS and NN)	1: <u>Rat Trapping</u> - Install rats traps within already known nesting areas. Trap for 4-6 weeks before start of breeding season and throughout breeding season.	Do rats reduce YSBL nest success? Can test this by reducing rat numbers.	PRDNER & USFWS at Cabo Rojo National Wildlife Refuge (NWR)	Increases egg and chick survival to fledge	HIGH	MEDIUM	-	HIGH	HIGH	-
		2: Poisoning (e.g. diphacinone): This control rat method needs to evaluate potential impact to non-target species, especially crabs which are eaten by humans				LOW	MEDIUM	-	-	LOW	-
	B. Control cats within natural nesting areas	1. Implement cat, mongoose & rat trapping program together. Install cats live box traps within entire nesting area. Trap will be activated approximately 2 weeks prior to breeding season start and throughout breeding season.	Do cats/mongoose impacts nest/fledging success?	PRDNER & USFWS at Cabo Rojo NWR	Increase breeding female survival	LOW	MEDIUM	HIGH	HIGH	HIGH	-
		2. For cats, use shotgun to target cats that can't be trapped.	Do cats impacts nest/fledging success?		-	LOW	MEDIUM	HIGH	HIGH	LOW	-
	C. Control new possible exotic predators (green iguana, boa constrictor, etc.) within nesting areas.	1. Literature review related of the possible effects of the new exotic predators on birds.	Do the high density of Iguana and the herbivorous consumption may affect the YSBL habitat?	PRDNER	Unknown	LOW	-	-	-	-	-
		2. Initiate a predator control program depending of the literature analysis (e.g., traps, shotgun, hooks, etc).	How much the Green Iguana may disturb the nests while they climb the trees? Iguana eggs and juveniles may have indirect impact in mongoose densities?								
	D. Change human activities to reduce access by cats/rats/mongoose	Workgroup 1 Task			Increases egg and chick survival	LOW	LOW	-	HIGH	HIGH	-
Improve efficiency of ANS	E. Improve ANS design to prevent predation by avian predators and delay chick fledging	1. <u>Lower wire mesh inside ANS</u>: Modified all the ANS with deeper nest grid, to reduce early chick fall, prevent drowning and predation This modification had been used in some ANS with positive observations retaining the chicks in the nest with sufficient growth to fly properly.	Can the ANS deeper grid increase YSBL chick and fledgling survival?	PRDNER	Increases post-fledging survival	HIGH	LOW	-	HIGH	HIGH	possible adverse effects on chicks

Sub-Goals	Action	Methods	Research	Agency implementing actions	Conservation benefit	Priority	$ cost	Other cost	Likelihood of success	Achievability	Obstacles
Improve efficiency of ANS, continued		2. Conduct experiments with nests entrance hole to reduce access by native predatory birds: For example, creating an extension in the ANS hole with PVC.	Does the extension in ANS reduce avian predation?								
	F. Reduce distance between each ANS to dry land	1. Conduct experiments to determine the optimal distance (safest & closest) of ANS to mangroves.	What is the optimal distance of ANS to mangrove habitat?	PRDNER	Increases post-fledging survival	HIGH	MEDIUM	-	HIGH	HIGH	-
		2. Relocate all ANS to optimal distance each year or prune branches if possible (because of annual mangrove spread).	-	PRDNER	Increase post-fledgling survival	HIGH	LOW	-	HIGH	HIGH	-
	G. Control mites in ANS (cleaning, insecticide use)	Conduct current pre-breeding ANS cleaning regime. This regimen includes removing all nest material and cleaning the interior part of ANS with alcohol. Mites in NN are uncommon.	-	PRDNER	Increases chick survival	MEDIUM	LOW	-	HIGH	HIGH	-
	H. Design & test rat-proof ANS	-	-	PRDNER	Increases egg and chick survival	HIGH	MEDIUM	-	HIGH	HIGH	-
	I. Modify nest site area to exclude rats from ANS (e.g. prune branches)	Considered in Action F.			Increases egg and chick survival	HIGH	LOW	-	HIGH	HIGH	-
	J. Design and test SHCO-proof nest box	-	-	PRDNER or graduate student	Increases egg and chick survival	HIGH	MEDIUM	-	LOW	LOW	-
	K. Develop experiments to test alternative strategies to prevent SHCO parasitism	Literature review	-	PRDNER or graduate student	Increases egg and chick survival	HIGH	HIGH	-	MEDIUM	MEDIUM	-
Reduce impact of SHCO on nest success	L. Maintain existing trapping program	Maintain two trap sites (currently Lajas & Boquerón). Traps are open Mon-Fri, traps checked alternate days during week outside of the breeding season from August to April (to prevent YSBL captures).	Do the traps outside the YSBL breeding areas reduce the SHCO brood parasitism in YSBL?	PRDNER	Reduces parasitism	HIGH	MEDIUM	LOW	HIGH	HIGH	some social costs, some people don't like trapping & killing birds
	M. Develop new trapping schedule before breeding & closer to nesting area	1. Set two traps in private land near Pitahaya. Locate traps about 500m-1km from nesting area. These traps should be monitored constantly (every four hours) and deactivated (close) every day.	How many traps would be needed to reduce impacts to nest success (ex. what proportion of population do we need to trap)	PRDNER	Reduces parasitism	HIGH	MEDIUM	LOW	HIGH	HIGH	some social costs, some people don't like trapping & killing birds

Sub-Goals	Action	Methods	Research	Agency implementing actions	Conservation benefit	Priority	$ cost	Other cost	Likelihood of success	Achievability	Obstacles
Reduce impact of SHCO on nest success, continued		2. Add use of shotgun to target individual SHCO in YSBL nesting area (to target untrappable SHCO, problem females).	What is the most efficient trapping regime (all birds, males only, females only) considering SHCO biology & population dynamics What impact does SHCO immigration (especially females) have on SHCO parasitism rates? Are there alternative SHCO control methods (ex. contraceptives, reducing egg viability) that could be developed?	PRDNER	Reduces parasitism	LOW	LOW	LOW	LOW	LOW	Some social costs: some people don't like trapping and killing birds. Disturbance to birds by gunshot noise.
	N. Trap year-round in existing area	Set the existing traps in the same area (Action L), year-around.	How much this SHCO may affect the YSBL breeding grounds?	PRDNER	Reduces parasitism	LOW	MEDIUM	LOW	MEDIUM	LOW	some social costs, some people don't like trapping & killing birds
	O. Expand trapping area to all PRDNER offices in SW/SE	Create a SHCO control program in the PRDNER offices in SW and SE of PR. This program will include a SHCO capture record per trap and genus.	Do the trapping program in PRDNER offices of SW and SE influenced in the immigration of SHCO that arrived to YSBL breeding areas?	PRDNER	Reduces parasitism	LOW	HIGH	LOW	LOW	LOW	some social costs, competition of PRDNER resources
	P. Increase & maintain active management of ANS (egg & chick removal)	1. Remove SHCO eggs and chicks found. Removal of SHCO eggs and chicks from ANS are part of the tasks from YSBL Recovery Project.	What are the proportional contributions of the different causes of nest failure to overall nest mortality?	PRDNER	Reduces parasitism	HIGH	LOW	LOW	HIGH	HIGH: It is currently part of the management.	some social costs, some people don't like trapping & killing birds
		2. Increase nest-check rate to twice per week (currently once per week)	Determine effective population size (analyze multi-generational & temporal samples) (Irene)	PRDNER		LOW	MEDIUM	MEDIU M	LOW	LOW: Includes double the cost in personnel, time and use of vehicules.	-
		3. Implement pre-breeding nests assessment early March, check breeding status once per week afterwards. To reduce eggs and SHCO chicks appearance in YSBL nest.		PRDNER	Reduce food competition between SH CO and host chicks.	HIGH	LOW	LOW	HIGH	HIGH	-

Sub-Goals	Action	Methods	Research	Agency implementing actions	Conservation benefit	Priority	$ cost	Other cost	Likelihood of success	Achievability	Obstacles
Reduce impact of SHCO on nest success, continued	Q. Increase density of traps in existing trapping areas	See Action M	Does the increasing of SHCO traps decreases brood parasitism in YSBL nests?	PRDNER	Reduces parasitism	MEDIUM	MEDIUM	LOW	MEDIUM	HIGH	some social costs, some people don't like trapping & killing birds
Increase number of ANS	R. Add ANS to existing natural nest sites	Install ANS in known areas with YSBL natural nests. These ANS will have the design modifications and distance to mangrove presented in Action E.	Do the YSBL pairs shift the use of natural nest to ANS? YSBL population in natural nests areas increase over time?	PRDNER	Increases nest availability	HIGH	LOW	-	HIGH	HIGH	-
	S. Increase density of artificial nest	Increase the density of ANS in existing areas. These ANS will have the design modifications and distance to mangrove presented in Action E.	Does the increasing of ANS will reflect over the time a positive YSBL population growth in the SW?	PRDNER	Increases nest availability	HIGH	LOW	-	HIGH	HIGH	-
Avian Diseases Threats	T. Identify possible disease that could threats PR avifauna	1. Literature review of possible diseases that can affect PR avifauna (Ex. West Nile Virus, Avian Pox) and their treatments.	Do the infected YSBL chicks with avian pox survived?	PRDNER	Increase chicks and adult survival	HIGH	LOW	-	HIGH	HIGH	-
		2.Create a list of contact persons that are related to avian diseases (e.g. Center for Disease Control)	-	PRDNER	-	HIGH	LOW	-	HIGH	HIGH	-

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico
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Final Report

SECTION 7

Blackbird and Cowbird MetaModelling Report

YSBL and SHCO MetaModeling Report

Members: Elvin Binet, Alexander Cruz, Hilda Diaz-Soltero, Rafael González, Gustavo Kattan, Bob Lacy, Irene Liu, Ricardo López-Ortiz, Phil Miller, Tammie Nakamura, Catherine Ortega

Introduction

Population viability analysis (PVA) can be an extremely useful tool for investigating current and future demographic dynamics of yellow-shouldered blackbird (YSBL) and shiny cowbird (SHCO) populations in southwest Puerto Rico. The need for and consequences of alternative management strategies can be modeled to suggest which management practices may be the most effective in conserving the blackbird populations. *VORTEX*, a simulation software package written for PVA (Lacy and Pollak 2012; Miller and Lacy 2005), was used here as a vehicle to study the interaction of a number of blackbird life history and population parameters and to test the effects of selected management scenarios.

The *VORTEX* package is a simulation of the effects of a number of different natural and human-mediated forces – some, by definition, acting unpredictably from year to year – on the health and integrity of wildlife populations. *VORTEX* models population dynamics as discrete sequential events (e.g., births, deaths, sex ratios among offspring, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modeled as constants or random variables that follow specified distributions. The package simulates a population by recreating the essential series of events that describe the typical life cycles of sexually reproducing organisms.

PVA methodologies such as the *VORTEX* system are not intended to give absolute and accurate "answers" for what the future will bring for a given wildlife species or population. This limitation arises simply from two fundamental facts about the natural world: it is inherently unpredictable in its detailed behavior; and we will never fully understand its precise mechanics. Consequently, many researchers have cautioned against the exclusive use of absolute results from a PVA in order to promote specific management actions for threatened populations (e.g., Ludwig 1999; Beissinger and McCullough 2002; Reed *et al.* 2002; Ellner *et al.* 2002; Lotts *et al*. 2004). Instead, the true value of an analysis of this type lies in the assembly and critical analysis of the available information on the species and its ecology, and in the ability to compare the quantitative metrics of population performance that emerge from a suite of simulations, with each simulation representing a specific scenario and its inherent assumptions about the available data and a proposed method of population and/or landscape management. In this exercise, the interpretation of this type of output depends strongly upon our knowledge of blackbird and cowbird biology, the environmental conditions affecting the species, and possible future changes in these conditions.

Despite the rigor that a PVA tool like *VORTEX* can bring to endangered species management planning, the traditional approach almost always suffers from being focused on a single species, thereby ignoring important consequences resulting from interactions with other species. This is particularly important when considering invasive species and their impacts on populations of native species with which they may directly compete for resources or have even more direct impacts such as predation of the endangered species. Additionally, traditional PVAs often adopt a relatively simple approach to simulating processes that directly or indirectly threaten wildlife populations, such as disease, habitat destruction, poaching, or climate change. Such a simple treatment of complex processes may miss important interactions that must inform responsible and effective decision-making for endangered species conservation.

To address this shortcoming, the concept and practice of *metamodeling* has been introduced to the conservation planning community (Lacy *et al*. in prep; Miller and Lacy 2003), which allows multiple discipline-specific models to physically share information with one another in real time as each component model runs simultaneously. In this way, each component model is allowed to modify the input data of another, thereby creating a more holistic approach to simulating a complex system of multiple species or multiple threats to species on a given landscape. Information flow is controlled through a central software tool called *METAMODEL MANAGER* (Pollak *et al*. 2012).

Because of the impacts that SHCOs are likely to impose on YSBL population dynamics, we used the metamodeling technology for the analysis discussed in this report. Although this general approach has already been used in a different context to inform wildlife population management (Bradshaw *et al*. 2011), the analysis presented here is the first use of metamodels to explore the complex impacts of an invasive species on the extinction risk of a local native species. **As a first test case of the application of the metamodeling approach to the role of an invasive species threatening an endangered species, we can explore several broad issues while also working to improve the effectiveness of conservation actions for the YSBL.** These include:

- Does the 2-species metamodel help us to understand and describe the impacts of invasive species on endangered species?
- Does the use of a metamodel approach expand our thinking about the possible mechanisms of threats and options for management? Did it lead to new insights or new justifications regarding what field data would be most valuable?
- Does the metamodel help the responsible management agencies to evaluate options for management?

Questions for Population Viability Analysis

Early in the process of the YSBL and SHCO PVA model development (January 2012), experts in species biology and management developed a list of questions that could potentially be informed by the metamodel-based analytical approach:

- What factors influence population growth in SHCOs? In YSBLs?
- How do recent impacts on recruitment factor in to the observed population growth for YSBLs and for SHCOs?
- How does habitat quality influence SHCO and YSBL population dynamics?
- Is the present SHCO trapping strategy effectively impacting YSBLs? Do better strategies exist (timing, intensity, etc?)
- Is the current management strategy enough to support YSBL population viability and long-term recovery?
- What would be the impact of stopping the current SHCO/YSBL management strategy?

- Are the current YSBL downlisting criteria adequate? What should be the criteria for future planning (next recovery plan)?
- What is the minimum YSBL population size required to achieve population stability and growth?
- What is the YSBL recruitment rate needed to achieve significant population growth?
- What roles, if any, can YSBL captive breeding and reintroduction play?
- What role can translocation play?
- What role can head-starting play in YSBL management?
- Do we have enough data to make good estimates of YSBL/SHCO demography? If no, what is needed? How do we prioritize data collection?
- Do we need more YSBL populations? Do we need or want a more widespread distribution?
- How will climate change in Puerto Rico affect YSBL and SHCO populations and their interactions?
- What are the effects of rats, great egrets, monkeys, or other introduced and invasive species on YSBL viability?

Baseline Input Parameters for Population Viability Models: Yellow-Shouldered Blackbird

Parameters describing the demography of the YSBL population in southwestern Puerto Rico were obtained and refined at meetings in January, April, and August 2012. Sources include published reports, census and breeding data provided by Puerto Rico PRDNER, and expert opinion provided by the participants of the workshops. PRDNER provided detailed data on the reproduction at each Artificial Nest Structure (ANS) for the years 2004-2012, including data on nest use, number of YSBL broods, number of eggs in each clutch, number of chicks hatched, number of chicks fledged, and number of SHCO eggs or chicks removed. For some clutches, data were incomplete because nestlings fledged before they could be counted. These cases of missing data were excluded from calculations of mean rates for clutch size and chick survival. PRDNER provided comparable data for each Natural Nest (NN) that was observed in 2005 and 2008-2012, and these data were used to estimate reproductive rates for NN clutches. However, the data on NNs depended on those nests being discovered, and often data were incomplete because of nests not being found early enough or not being observed near the time of fledging. This was especially true in 2012, when the number of YSBLs fledged was observed for fewer than half of the NNs. Therefore, 2012 data were not used for the estimates of NN reproductive rates.

PRDNER provided roost count data from pre-breeding censuses for the years 1986-2005 and 2008-2012, and from post-breeding censuses for the years 1985-2011 (Fig. 1). Censuses were also available for a few, scattered earlier years, but these data were not used for estimating demographic rates.

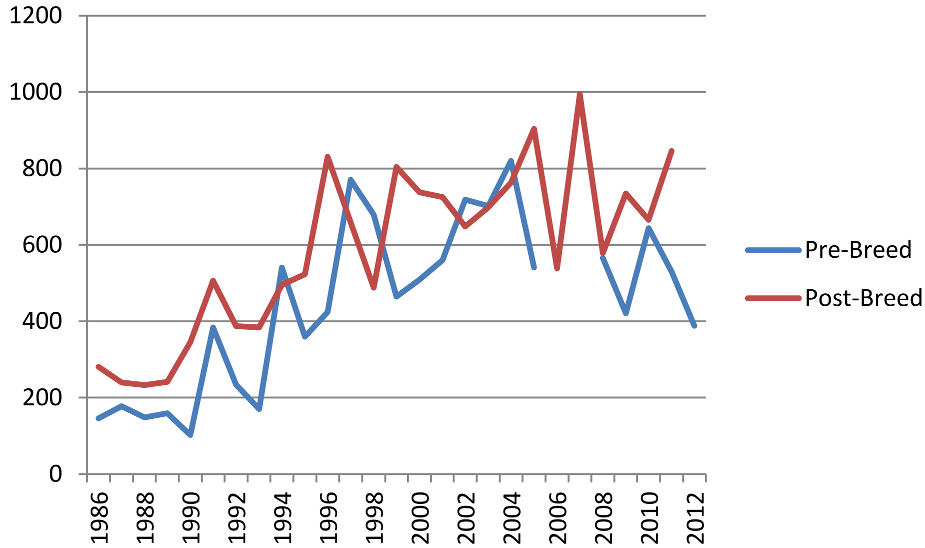


Figure 1. Observed pre-breeding and post-breeding census counts for yellow-shouldered blackbirds from 1986 – 2012.

The demographic rates described below are those that were used in the "baseline" model for the YSBL. As described in the section on Sensitivity Testing, we also tested alternative values for some of the uncertain and key rates.

<u>Time step for all simulations</u>: YSBL reproductive ecology is easily described on an annual basis, with a breeding season approximately 6 months in duration. We therefore have chosen the time step for our simulations as one year. The population was simulated for 50 years, although the results can be analyzed over any time interval up to that limit.

<u>Population structure</u>: For all analyses presented here, our attention is focused on the region defined as the Southwestern Puerto Rico YSBL population unit. There may be a small number of YSBLs living on the island outside of this area, and there is a small population of a different subspecies on Mona Island, but it is assumed that the southwestern Puerto Rico population does not currently exchange individuals with YSBLs in any other areas.

<u>Breeding system</u>: YSBLs have a monogamous breeding system, in which pairs attend to a nest. It is assumed that multiple broods raised within a single nest in a given breeding season are produced by the same pair of YSBLs. Further data from DNA or banding studies might lead to an alternative interpretation of the parentage of multiple broods in a nest. Demographically, it is not important to know which YSBLs produce each brood, because it is the total reproductive output of the population that determines population growth. More genetic variation can be maintained if reproductive success is more evenly distributed among adults, although this effect will be small in our models because we assume that almost all adult males and females are breeding each year. In the PVA model, we assume that YSBL pairs are formed new each year (i.e., monogamous pairs are not sustained across multiple breeding seasons).

Age of first reproduction: Female and male YSBLs can breed at one year of age, i.e., in the next breeding season following fledging.

Maximum age of reproduction: In its simplest form, *VORTEX* assumes that animals can reproduce (at the normal rate) throughout their adult life. YSBLs have been identified to live as long as 13 years. While this is set as the maximum age of reproduction, age-specific mortality rates are high enough so that the probability of any YSBL actually reaching this age is quite small. (Most would be expected to die by age 10.)

Offspring production: For all our models, we are defining reproduction as the production of eggs. First year survival is then the compounded survival from egg to hatching, hatching to fledging, and fledging to one year of age. This will allow us to investigate management strategies that change the hatching rate of eggs and the survival of nestlings to fledging.

We assume that the large majority of adult females are able to successfully breed and lay eggs each year. The average number of nests observed each year is typically about 90% of the estimated number of females (which would be 50% of pre-breeding census size). Of the 10% of adult females in the census that do not breed, some of them will have died between the pre-breeding census and the breeding season. (On average, monthly mortality of adults is about 3%.) We therefore set the percentage of adult females (those alive at the start of the breeding season) producing one or more clutches in a year to 95%. We allowed this percent breeding to vary across years with standard deviation (SD) = 5%, so that typical years would have from 90% to 100% of adult females breeding.

The field data indicate that breeding rates and survival to fledging are different for Artificial Nest Structures (ANSs) and Natural Nests (NNs). However, nesting data are much less complete for NNs, because often a nest is not discovered until later in the breeding season. Averaged across years, 84% of YSBL nests were in ANSs.

From the data on reproduction in ANSs, it has been observed that on average in a year 61% have a single brood, 32% have 2 broods, and 7% have 3 broods. It is difficult to determine how many broods are produced by YSBL pairs using NNs, so we assumed for the initial models that the distribution of broods per year for pairs with NNs was the same as for pairs using ANSs.

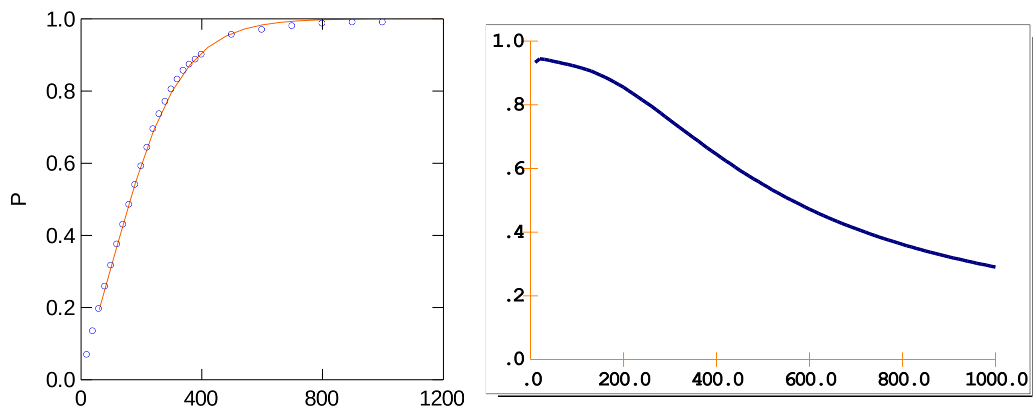
The mean number of eggs per brood was 2.70 (SD = 1.05 variation among clutches) for NNs and 3.04 (SD = 0.83 variation among clutches) for ANSs. NN mean brood size is only 2.53 if we include 2012 data, but many of those nests were not discovered early enough to be very confident that clutch sizes observed are accurate.

We assume that across the entire population, newborn individuals do not deviate from a 50:50 sex ratio.

Density-dependent reproduction: We did not include explicit density dependence in reproductive rates in the YSBLs occupying southwestern Puerto Rico. That is, we did not specify in the model that fewer females breed when the population becomes larger and uses more of the optimal habitat. However, nesting success of the average breeding pair might decline as the population grows. In particular, if YSBLs usually prefer ANSs, but use NNs when ANSs are limiting, then the proportion of pairs that can use ANSs will depend on the ratio of adult females to ANSs available. The reproductive rates (number of eggs per clutch and fledging rate) are higher in ANSs than NNs, so the limited number of ANSs will result in a form of density dependence in which there will be lower average reproductive rates if the population size increases to levels that cause more of the YSBL pairs to use NNs.

To model this effect, a table of plausible values was developed for what number of the ANSs would be used in a year, as a function of the number of adult YSBL females. The function (shown on the left, Figure 2) assumed that at low population densities most females would use ANSs, at densities similar to the current situation 80% of pairs would use ANSs, and at high population densities almost all of the 246 (current) ANSs would be used and breeding females beyond that number will be forced to use NNs. These hypothetical data were then converted into the probability that any given female would be able to use an ANS (with her probability declining as competition for limited ANSs increased) and a curve was fitted to those data (Fig. 2, right side).

Figure 2. Left panel shows a curve fitted to a trend for the proportion of ANSs used by yellows-shouldered blackbirds (P) to be a function of the number of breeding females. Right panel shows, for the same hypothetical data, the relationship between the probability that any given female obtains an ANS (pANS) as a function of the number of breeding females (F): pANS = 246*(1 – exp(-0.0154*F))/F - (246*0.0119*exp(-0.0094*F))



In discussions of the observed differences between success in ANSs vs NNs, it is important to note that although the observed reproductive success (both in terms of the average number of eggs per clutch and the survival from egg to fledging) is lower in NNs than in ANSs, we do not know the reasons for this difference. It may be that the artificial structures are better nesting sites than the nearby mangroves (where the NNs are located), or it may be that the ANSs were placed in traditional nesting sites and in areas that were deemed optimal (even if the structure itself is no better or worse than a natural nest), or it may be that the best breeders (perhaps the oldest birds) are the ones that preferentially get access to the ANS. Until the reasons for the better nesting success in the ANS are known (possible factors may include lower predation rates and abiotic factors – e.g. exposure and rain may be reasons for higher nesting success in ANSs), we cannot be certain if adding more ANSs would be beneficial to the population. In addition, the data on nesting success in NNs are much less complete than the data for nests in ANSs, and SHCO eggs and chicks are often removed less promptly from NNs because of limited PRDNER staff available for this task. For this reason, in the baseline metamodel we assumed that only 75% of YSBL clutches in NNs had any SHCO eggs and chicks removed quickly enough to prevent any impact on YSBL fledging rate (see metamodel description, below).

Mate monopolization: In many species, some adult males may be socially restricted from breeding despite being physiologically capable. This can be modeled in *VORTEX* by specifying a portion of the total pool of adult males that may be considered "available" for breeding each year. We assumed that 100% of the adult YSBL males are available for breeding each year. If some males are excluded from breeding, this would also suppress breeding by females, because the species forms annual monogamous pairs for breeding.

Mortality rates: The *VORTEX* model uses sex-specific estimates of mortality for each pre-reproductive annual age class (just the egg to 1 year old age class for the YSBL) and for annual mortality after reaching breeding age. To estimate the 0-1 year mortality, we need to estimate the mean survival from egg to fledging, from fledging to the post-reproduction census, and from the post-reproduction census to the next breeding season. These three components must then be multiplied to get the total survival rate from egg to 1 year of age. From the recent PRDNER field data on nesting, the mean and SD across years for the number of fledglings per egg was 46% for ANSs with 9% SD variation in the rate across years, and 42% with 11% SD variation in the rate across years for NNs.

The average post-fledging survival from the breeding season to post-breeding census can be obtained as follows: In each year, the number of YSBLs that were fledged can be estimated as the #active nests x #broods/nest x #eggs/brood x survival from egg to fledging. (This calculation was done separately for ANSs and NNs, using their respective rates.) The number fledged cannot be simply tallied from the observed counts of fledglings, because for some to many nests, the number fledged was unknown. The estimated total number of fledglings can then be added to the estimated count of adults from the pre-breeding census to provide the total number of YSBLs at the end of the breeding. The ratio of the subsequent post-breeding census to this total adults + fledglings then provides the estimate of the survival from the breeding season to the October census. When this calculation was done for the years of PRDNER nest data, the mean survival rate was 73% (with variation among years of 13% SD) to the post-breeding census. This calculation assumes that the post-fledging survival for juveniles is the same as the survival of adults during that time. This assumption is likely incorrect (post-fledging survival might be lower and adult survival higher), but it will not affect the projections of population growth. The important numbers for estimating population growth are the total number of YSBLs (first year and older birds) surviving to the next census (and then to the next breeding season). For example, if we assume that 90% of adults survive from the pre-breeding census until the post-breeding census, then we can calculate that the post-fledging survival of juveniles was 55%, producing the overall estimated 73% survival and producing the same number of YSBLs alive at the time of the post-breeding census.

The survival from the post-breeding census to the next pre-breeding census 6 months later can be estimated as the ratio of the count in each pre-breeding census to the count in the prior post-breeding census. This 6-month survival rate has varied over time, with very low survival (56%) in the 1980s, higher survival (89%) from 1990 to 2003, and lower survival (69%) from 2004 to

2012. Survival was very low, at 46%, from October 2011 to April 2012. The reasons for the lower survival in recent years, when compared to the period 1990-2003, are not known. It is possible that the difference is due to the fluctuations that occur across years, and do not represent a trend that will continue. It is also possible that factors have changed and that survival will now continue to be lower. At the PHVA workshop it was decided that the baseline model for analysis should use the data from 1990 to 2012 (an interval over which management has been relatively consistent) for estimating survival rates. Over that time span, the mean 6-month survival from post-breeding to the next pre-breeding census was 83%, with an annual variation of 26% SD. We also tested models in which survival rates were set at the levels observed in the 1980s, the level observed in 1990-2003, and the level observed 2004-2012.

Combining all of the above estimates, the total annual survival of adults was estimated as 0.73 * 0.83 = 0.61, and the overall survival from egg to 1 year of age was estimated as 0.46 * 0.73 * 0.83 = 0.28 for ANS and 0.42 * 0.73 * 0.83 = 0.25 for NN. It is difficult to estimate the true variation across years in survival rates, because some of the variation could be due inaccuracies in census estimates. Therefore, somewhat conservative values of 0.15 were used in the model to estimate variation across years in survival rates. This amount of environmental variation in the model produced fluctuations in population growth rates that were similar to what has been observed (see below).

Note: After the PHVA workshop, the 2012 post-breeding survey was completed in October. A total of 668 YBSLs were counted, indicating that good survival after the breeding season had allowed the population to partially recover from the decline that had occurred from October 2011 to March 2012. Using the methods described above, the survival from March 2012 to October 2012 can be estimated as 88.6%, which is approximately the same as mean 6-month survival rates that had been observed from 1990 to 2004. These recent data were not used in the analyses at the PHVA workshop, but would have led to a mean 76% April to October survival (rather than the 73% used in the baseline modeling) if the 2012 data were included in the estimates above.

Catastrophes: Catastrophes are unusual environmental events that are outside the bounds of normal environmental variation affecting reproduction and/or survival. Natural catastrophes can be tornadoes, floods, droughts, disease, or similar events. These events are modeled in *VORTEX* by assigning an annual probability of occurrence and a pair of severity factors describing their impact on mortality (across all age-sex classes) and on the proportion of females successfully breeding in a given year. These factors range from 0.0 (maximum or absolute effect) to 1.0 (no effect) and, in its most basic implementation in *VORTEX*, are imposed during the single year of the catastrophe, after which time the demographic rates rebound to their baseline values.

We have identified three significant events to include as catastrophes in our models:

- Large hurricanes, such as Hurricanes Georges and Hugo, are estimated to occur about three times in a century, i.e., 3% probability of occurrence in any given year. We assumed that 50% of the birds in the region will die as a result of the storm (survival severity = 0.50). Data collected after these storms suggested a reduction in successful nesting of up to 46% in the year following the event for YSBLs using ANSs. Based on this information, we included a reproduction severity value of 0.54.

- Small hurricanes, such as Tropical Storm Jeanne in 2004, are estimated to occur approximately once every 15 years, i.e., 6.67% probability of occurrence in any given year. We estimate a 19% decline in total population abundance due to a storm of this type (López-Ortiz, unpublished data), and data on ANSs collected after the storm suggested a reduction in successful nesting of up to 20% in the year following the event. Based on this information, we included a reproduction severity value of 0.80.
- Drought, which has been identified over the past few decades as having a measurable impact on YSBL populations, is estimated to occur approximately once every 6.5 years (15.4% annual probability of occurrence). During drought years, survival is not impacted but the percentage of successfully breeding females drops by approximately 20% (reproductive severity value = 0.80).

Initial population size: The most recent pre-breeding census in March 2012 was 388. This is a substantial decline from the prior post-breeding census of 846 birds six months earlier, but the pre-breeding census is consistent with the nest counts of 182 pairs in 2012, so there is no reason to suspect that the reported decline is not real. The *VORTEX* model begins in the point of the annual cycle just before the start of the breeding season, so an initial population size of 388 was assumed in the model.

Carrying capacity: The ecological carrying capacity, K, for a given habitat patch defines an upper limit for the population size, above which additional mortality is imposed randomly across all age classes in order to return the population to the value set for K. Based on the observation that YSBLs had been more numerous before the population declines of the 1970s and 1980s (with a count of 1,537 in 1965), we assumed that the carrying capacity to which the YSBL population could grow if threats were mitigated would be K = 2,000.

Inbreeding depression: If the population is large enough so that inbreeding would not accumulate quickly, there may be little value to including inbreeding depression in the model. In those case in which the simulated population declines to very low numbers (e.g., the quasi-extinction of N < 20 – see below), inbreeding could become a factor, but the population would clearly be in collapse with or without inbreeding impacts. In the simulated scenarios in which the population was not in rapid demographic decline, the average amount of inbreeding accumulated in the 50 year simulations was typically 0.02 to 0.07 (see results), a level that would be expected to begin to have a small effect on reproduction and survival. The damaging effects of inbreeding could be a factor that would reduce the ability of the population to recover after a decline (i.e., the inbreeding would be more severe in those simulations in which the population did experience a decline). The workshop participants decided to include in the model an average of 6 recessive lethal alleles per individual – which would cause a level of inbreeding depression (modeled as a reduction in juvenile survival if birds become inbred) that is comparable to values reported for wild populations of other bird species (Keller 1998; Jamieson *et al*. 2007).

Criterion for quasi-extinction: We decided to consider a population to be functionally extinct if the number of YSBLs dropped below 20 birds. This definition of quasi-extinction was used in the reporting of the probability of “extinction”, and it determined the lower threshold below which the mean population size, population growth, and gene diversity would no longer be tallied for a simulation.

Baseline Input Parameters for Population Viability Models: Shiny Cowbird

Parameters describing the demography of the shiny cowbird (SHCO) population in southwest Puerto Rico were obtained and refined at meetings in January, April, and August 2012. Sources include published reports, rough census data provided by PRDNER, and expert opinion provided by the participants of the workshops. Data on SHCO population demography in southwest Puerto Rico are relatively scarce, so data from other parts of the species' range, in combination with expert judgment, was an important source of data for this analysis. Especially valuable in this regard is the work on SHCOs by G. Kattan in Colombia and A. Cruz in North America, and the work of Cruz and C. Ortega on brown-headed cowbirds (*Molothrus ater*) in North America.

Timestep for all simulations: Since SHCO reproductive ecology is easily described on an annual basis, we have chosen the time step for our simulations as one year.

Population structure: For all analyses presented here, our attention is focused on the region defined as the Southwestern Puerto Rico YSBL population unit. Therefore, we consider SHCOs within that same geographic extent, but with the addition of potential dispersal of birds into and out of the region on an annual basis (see below).

Breeding system: Shiny cowbirds are known to display a polygynous breeding system, where a single male may mate with multiple females during a given year. This is simulated in *VORTEX* by allowing adult males to be sampled multiple times as mates for the set of available females.

Age of first offspring: *VORTEX* considers the age of first reproduction as the age at which the first clutch of eggs is laid, not simply the onset of sexual maturity. We assume that females can breed at one year of age, i.e., the next breeding season following fledging (Payne 1977). Males often do not breed until their second year of age due to social limitations among younger individuals (Payne 1977). We therefore assigned the age of first offspring for males as two years of age. Due to the polygynous nature of the breeding system, male breeding age is likely not going to be a very sensitive parameter unless the population becomes very small and male abundances become a limiting factor.

Maximum age of reproduction: In its simplest form, *VORTEX* assumes that animals can reproduce (at the normal rate) throughout their adult life. Brown-headed cowbirds have been identified to live as long as 16 years (http://www.pwrc.usgs.gov/bbl/longevity/longevity_main.cfm). While this is set as the maximum age of reproduction, age-specific mortality rates may be set so that the probability of actually reaching this age is quite small.

Offspring production: For all our models, we are defining reproduction as the production of eggs. This will allow us to investigate specific cowbird management strategies focused on egg removal from host nests. Shiny cowbirds have very high rates of fecundity, being commonly referred to as "passerine chickens". Much of the evidence used for estimating reproductive parameters for this species in our model comes from Kattan (1993).

We assume that the large majority of adult females are able to successfully breed and lay eggs in host nests within a given year. Specifically, a recent study of gonad status among a group of 59 adult female SHCO specimens revealed that five birds showed no evidence of reproductive activity. We therefore set the proportion of adult females breeding in a given year at 54/59 = 92%.

Kattan (1993) and others have estimated that the breeding season for SHCOs in this part of their range lasts from 1 March to 30 September, i.e., approximately 210 days. However, a typical SHCO adult female is only reproductively active for about 1/3 of that time, or just 70 days. If we assume that a reproductively active female lays about 0.3 eggs per day, the mean egg production for reproductively active adult SHCOs is (70)*(0.3)/(0.92) = 23 eggs. We assumed a standard deviation of 4 eggs around this mean, representing annual variability through environmental stochasticity.

We assume that across the entire population, newborn individuals do not deviate from a 50:50 sex ratio.

<u>Density-dependent reproduction</u>: *VORTEX* can model density dependence with an equation that specifies the proportion of adult females that reproduce as a function of the total population size. In addition to including a more typical reduction in breeding in high-density populations, the user can also model an Allee effect: a decrease in the proportion of females that bread at low population density due, for example, to difficulty in finding mates that are widely dispersed across the landscape.

In our initial models presented here, we do not include explicit density dependence in reproductive rate in the SHCO occupying southwestern Puerto Rico. Later models may include this as an additional feature.

<u>Mate monopolization</u>: In many species, some adult males may be socially restricted from breeding despite being physiologically capable. This can be modeled in *VORTEX* by specifying a portion of the total pool of adult males that may be considered “available” for breeding each year. We assume here that each adult shiny cowbird male has an opportunity to breed. Therefore, we assume that 100% of the adult males have an opportunity to breed in a given year.

<u>Mortality rates</u>: *VORTEX* defines mortality as the annual rate of age-specific death from year x to $x + 1$; in the language of life-table analysis, this is equivalent to $q(x)$. Our initial models will attempt to describe a shiny cowbird population that is free from human interaction so that we can explore the growth dynamics of the species in a relatively undisturbed state.

Because of the aggressive program aimed at limiting SHCO population growth over the past 25 years in southwestern Puerto Rico, specific data on age-specific mortality rates are scant at best. In general, due to the high rates of egg production in this species, we assume that pre-fledging mortality rates must be correspondingly high. Specifically, in our initial models we assume 90±3% mortality of cowbirds age 0-1 – where age-0 individuals are classified as eggs. Moreover, we have included a simple form of density dependence in juvenile mortality where this value increases to 93.85% when the population reaches its carrying capacity, according to the mathematical formulation:

%Females Breeding = 100-((10-((10-6.15)*((N/K)^24)))

The functional form for this relationship is shown below in Figure 3. This approach was taken to generate a population with relatively high growth potential at lower population densities, and a growth rate approaching zero when it has reached its ecological carrying capacity.

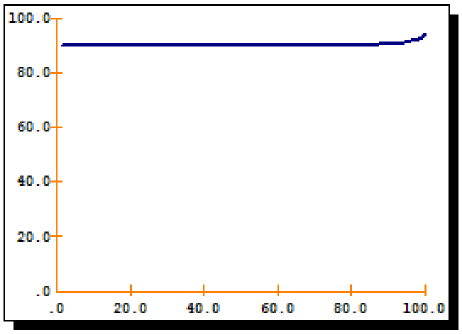


Figure 3. Functional form of density dependence for annual juvenile (age 0-1) mortality in the shiny cowbird PVA model. The vertical axis is the % mortality, while the horizontal axis is population density, defined as 100*(pop size/carrying capacity). See accompanying text for more information on model structure and function.

Furthermore, we assume that adult female mean mortality rates are approximately 50±10%, with male subadult and adult birds having slightly lower mean mortality rates (40±10%) in accordance with observation in similar species summarized in Payne (1977).

Catastrophes: Catastrophes are singular environmental events that are outside the bounds of normal environmental variation affecting reproduction and/or survival. Natural catastrophes can be tornadoes, floods, droughts, disease, or similar events. These events are modeled in *VORTEX* by assigning an annual probability of occurrence and a pair of severity factors describing their impact on mortality (across all age-sex classes) and the proportion of females successfully breeding in a given year. These factors range from 0.0 (maximum or absolute effect) to 1.0 (no effect), and in its most basic implementation in *VORTEX*, are imposed during the single year of the catastrophe, after which time the demographic rates rebound to their baseline values.

We have identified three significant events to include as catastrophes in our models:

- Large hurricanes, such as Hurricanes Georges and Hugo, are estimated to occur about three times in a century, i.e., 3% probability of occurrence in any given year. We assumed that 50% of the birds in the region will die as a result of the storm (survival severity = 0.50). Data collected after these storms suggested a reduction in successful nesting of up to 46% in the year following the event for YSBLs using ANSs. Based on this information, we included a reproduction severity value of 0.54.
- Small hurricanes, such as Tropical Storm Jeanne in 2004, are estimated to occur approximately once every 15 years, i.e., 6.67% probability of occurrence in any given year. We estimate a 19% decline in total population abundance due to a storm of this type, and data on ANSs collected after the storm suggested a reduction in successful YSBL nesting of up to 20% in the year following the event. Based on this information, we included a reproduction severity value of 0.80.
- Drought, which has been identified over the past few decades as having a measurable impact on YSBL populations, is estimated to occur approximately once every 6.5 years (15.4% annual probability of occurrence). During drought years, survival is not impacted but the percentage of successfully breeding females drops by approximately 20% (reproductive severity value = 0.80).

Initial Population Size: Very little data exist on current abundance of SHCOs in the region studied here. Data on cowbird trapping efforts since 1985 suggests a population well in excess of 5,000 individuals. For our initial modeling work, we assume an initial population size of 7,500 individuals in the southwestern Puerto Rico region.

Carrying capacity: The ecological carrying capacity, K, for a given habitat patch defines an upper limit for the population size, above which additional mortality is imposed randomly across all age classes in order to return the population to the value set for K.

Information on the carrying capacity for SHCOs in SW Puerto Rico is almost nonexistent. We assume that the region is nearly saturated with cowbirds, leading us to believe that the population could be close to its ecological carrying capacity. Based on a general lack of specific data on this parameter, we assume that the cowbird carrying capacity is currently equal to the initial population size chosen for our models. This would lead to an estimate for K of 7,500 individuals.

Inbreeding Depression: Because of the relatively large size of the SHCO population under consideration in this analysis, we decided against including inbreeding depression in this component of the PVA. Inbreeding levels would be negligible with this rather large abundance, and the inclusion of this feature would result in a very significant increase in model computational time for no detectable benefit.

Structure of the Yellow-Shouldered Blackbird – Shiny Cowbird Metamodel

The metamodel (MM) is a means to link two or more sub-models – in this case the Population Viability Analysis (PVA) models for the YSBL and the SHCO – so that the models can exchange information and thereby allow the MM to represent interactions between the models. The advantage of such an approach is that it allows examination of the impacts of factors (e.g., specific threats, changes to the system, management actions) on each component, through the interactions that link them. This is in contrast to a traditional PVA model, in which the focus is on the population dynamics of just one species, and all external processes (such as other species with which it might interact in critical ways) are assumed to be constant, or at most represented by simple trends that are not themselves affected by the changes in the focal species.

A challenge to linking PVAs into a metamodel is to define the impacts of each species on the other(s). These interactions need to be specified in quantitative rules that specify functional relationships in demographic rates (such as reproduction and mortality rates) or other processes that drive the population dynamics (such as dispersal or habitat limitations). For the YSBL-SHCO MM, it is assumed that the primary interaction between the species is via the parasitism of YSBL nests by SHCOs. The rates of parasitism on YSBL nests in Artificial Nest Structures (ANSs) may be very different than the parasitism of Natural Nests (NNs), perhaps because of differential visibility to SHCOs of YSBL nests in ANSs vs NNs. The proportion of ANSs that are cleaned of SHCO eggs and nestlings by managers may also be different, because of different visibility to the human managers and available personnel to do the tasks. As a starting point, we assumed that the relative decrease of YSBL fledging success in a parasitized nest that has not been cleared of SHCO eggs and nestlings is the same for ANSs and NNs. Future analyses could test alternative assumptions, if sufficient data to estimate the effects of parasitism independently for ANSs and NNs become available. Figure 4 shows the interactions between the YSBL and SHCO in the metamodel.

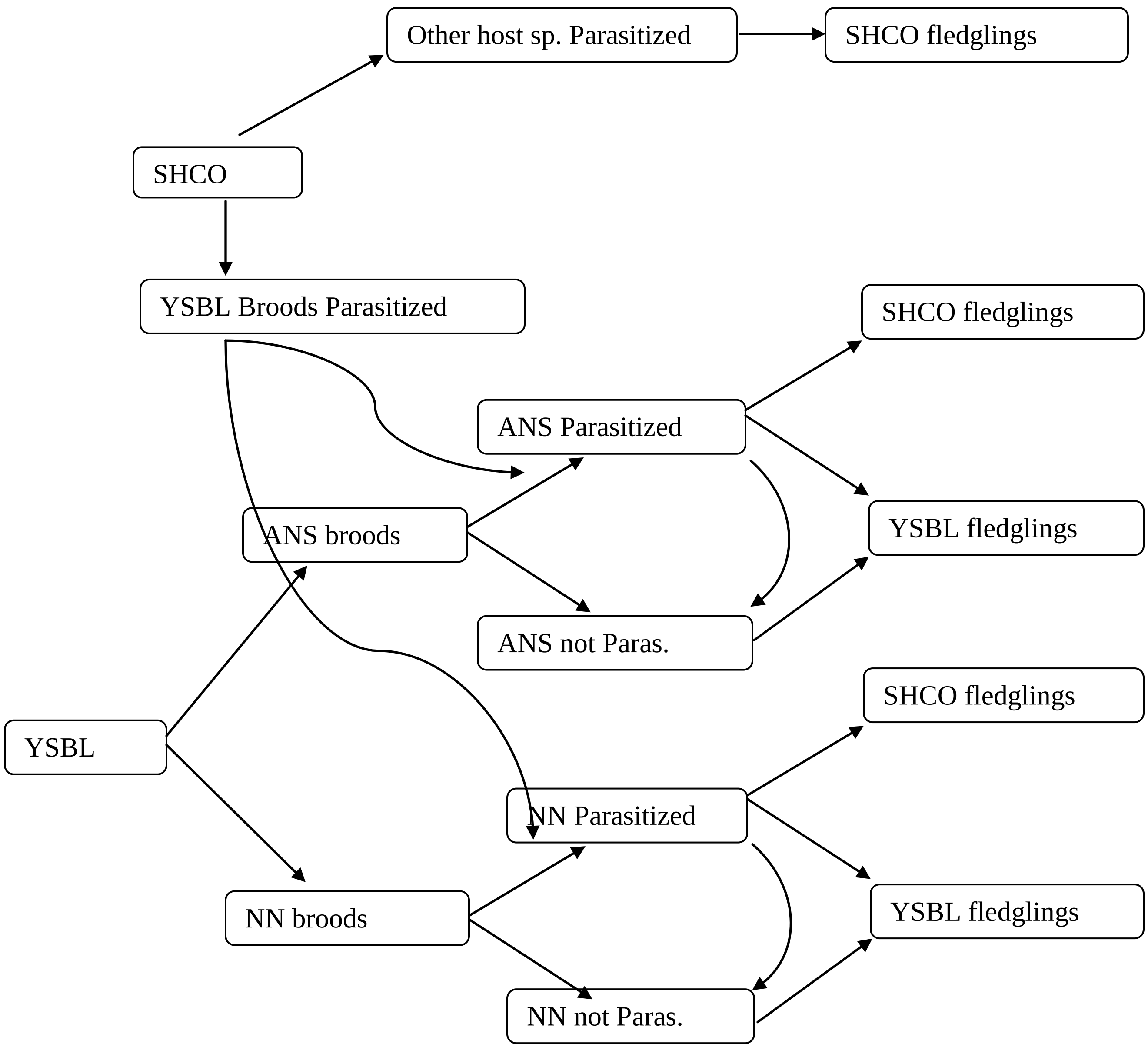


Figure 4. Diagrammatic representation of the structural relationships between Yellow - Shouldered Blackbirds (YSBL) and Shiny Cowbirds (SHCO) when YSBL use both artificial nests (ANS) and natural nests (NN). See accompanying text for more information on metamodel structure and function.

Results from Simulation Models I:
YSBL Dynamics in the Absence of SHCO Impact

The simulation with the parameters above was run for 500 iterations to determine the mean and range of possible outcomes. In order to validate that the PVA model was projecting population dynamics similar to what has been observed in recent years (during which SHCO eggs and chicks were removed from all ANSs and all NNs that were discovered), the simulation model was run initially under the assumption that SHCOs were not affecting the YSBL. That is, a standard PVA was conducted for the YSBL, with no link yet to the dynamics of the interactions with the SHCO nest parasite. The model was also run for a scenario that applied to all nests the reproductive rates (clutch size and fledging rates) estimated for ANSs, and for a scenario that applied the rates estimated for NNs. The summary results are given in Table 1.

Table 1. Baseline PVA results for yellow-shouldered blackbird (YSBL) in the absence of any effects of shiny cowbirds (SHCO), and results for scenarios with all nests having reproductive rates as in ANS or as in NN. Summary values reported are: *r* = mean population exponential growth rate averaged across all years and iterations; SD(*r*) = variation in *r* across years and iterations; %PE = probability of extinction, defined as *N* < 20 at year 50; meanTE = mean time to extinction in those iterations that did have an extinction; *N*-ext = mean population size at year 50 for those populations that were extant (*N* >=20); *N*-all = mean population size at year 50 across all iterations, extant and extinct; SD(*N*) = variation in final *N*, for the *N* in the previous column; %GD = percent of initial gene diversity (heterozygosity) remaining in extant populations at year 50.

Scenario	r	SD(r)	%PE	meanTE	N-ext	SD(N)	N-all	SD(N)	%GD
Baseline	-0.008	0.410	37	30	648	637	406	593	94
ANS rates	0.030	0.410	25	29	901	708	679	726	93
NN rates	-0.059	0.402	77	27	451	556	103	324	95

If SHCOs do not affect the YSBL, the PVA model of the YSBL projects a slightly negative (about 1% per year) mean population growth rate, and a moderate (37%) probability of extinction within 50 years. The mean population growth in the model will have been depressed some by those simulations in which the population became small (possibly following a simulated hurricane) and suffered from inbreeding depression and other risks of small populations. The mean growth rate in the model (*r* = -0.008) was a little less than what has been observed since 1990 (*r* = 0.042). The population showed much more positive growth from 1990-2003 (*r* = 0.149), but an even more rapid decline (*r* = -0.159) from 2004-2012.

The mean population trajectory may not be a good prediction of the fate of the population, because the model predicts that the population can do much better or much worse in any one simulated trajectory, just because of the large variability in the system. Figure 5 shows just 10 repeats (iterations) of the simulation of the baseline scenario, demonstrating the large fluctuations and unpredictability of the YSBL population dynamics. Although the simulations show large variation from year to year, the fluctuations in the model are a little less extreme than the fluctuations in the census counts since 1990. The simulated populations fluctuated with SD(r) = 0.41, while the fluctuations in census size have been SD(r) = 0.51 since 1990 and SD(r) = 0.34 since 2004. This high variability between iterated simulations appears to represent well the true uncertainty in the system and the large fluctuations over time, but it also means that the mean results should be interpreted cautiously. With such high fluctuations, a population can have a positive population growth, when averaged over many iterations, but still have a moderate probability of extinction. Conversely, a population with a negative predicted mean population growth can still be lucky and grow to large size, as sometimes happened in the 10 iterations shown in Figure 5.

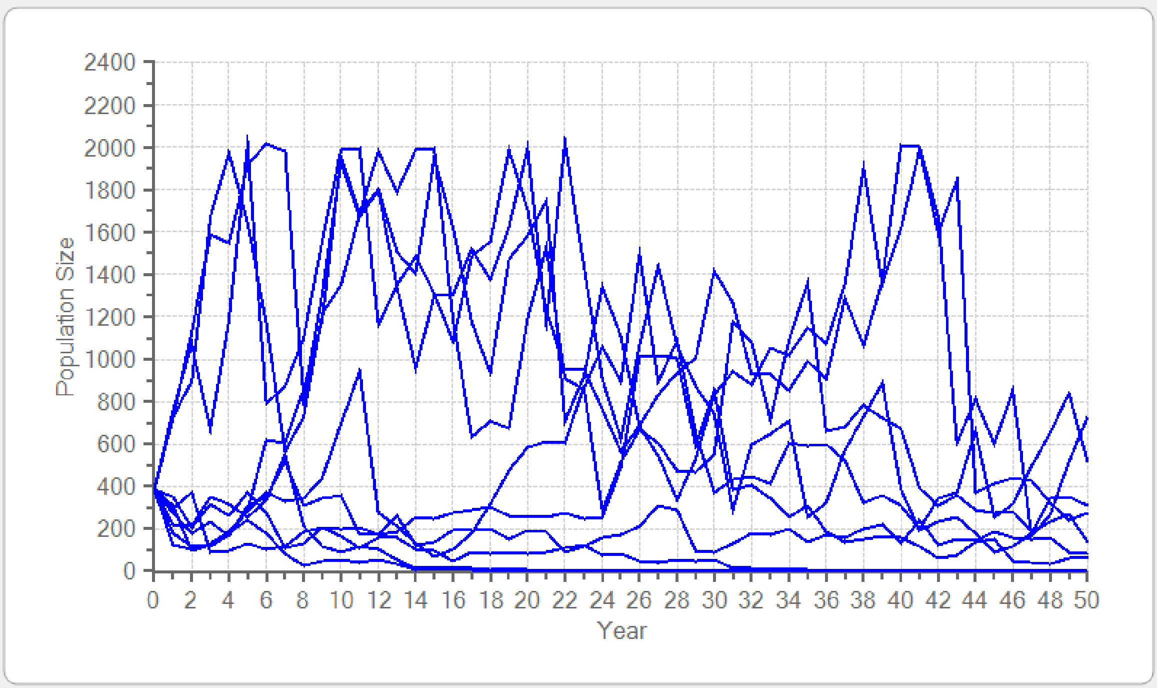


Figure 5. A sample of 10 iterations of simulation of the YSBL population, in the absence of impacts of SHCO nest parasitism.

As shown in Table 1, if all breeding pairs of YSBLs experienced the reproductive rates that have been observed in ANSs, the population would be projected to experience, on average, slow population growth (mean r = 0.03), but still be vulnerable to extinction (PE = 25%). Reproductive rates as reported for NNs are not sufficient to sustain the population (mean r = -0.06), and the likelihood of extinction is high (PE = 77%).

Although the above results from the YSBL PVA model suggest that the model represents reasonably well the dynamics of the population, many of the parameter values used could be only approximately estimated from incomplete and sometimes rapidly changing values estimated from field research. Therefore, it is important to test alternative possible values for key parameters to demonstrate the range of possible outcomes if rates are better or worse than has been estimated, or if rates continue to change, or if management actions can alter rates to improve population stability and growth. The sensitivity tests of alternative values for YSBL demographic rates were conducted on the full metamodel (below), in which the interactions with the SHCO nest parasites are included via linkages to the SHCO PVA model. The combined YSBL-SHCO metamodel will also allow testing of the impacts of SHCO management (e.g., nest management and trapping) on the performance of the YSBL population.

Results from Simulation Models II:
SHCO Dynamics without Linkage to YSBL

Figure 6 shows a representative group of abundance trajectories for the baseline SHCO model without an explicit linkage to YSBL dynamics via the metamodel. The mean stochastic population growth rate from this simulation is 0.148; in other words, the simulated SHCO population is expected to grow at an annual rate of approximately 15% in the absence of limitations imposed by carrying capacity. Note that the population may experience significant declines in abundance periodically, but because of the high reproductive capacity – coupled with the reduced juvenile mortality at lower densities – the population will quickly increase in abundance and will quickly return to its carrying capacity. This demonstrates the strong reproductive potential of the species and its ability to rapidly expand its numbers in suitable habitats.

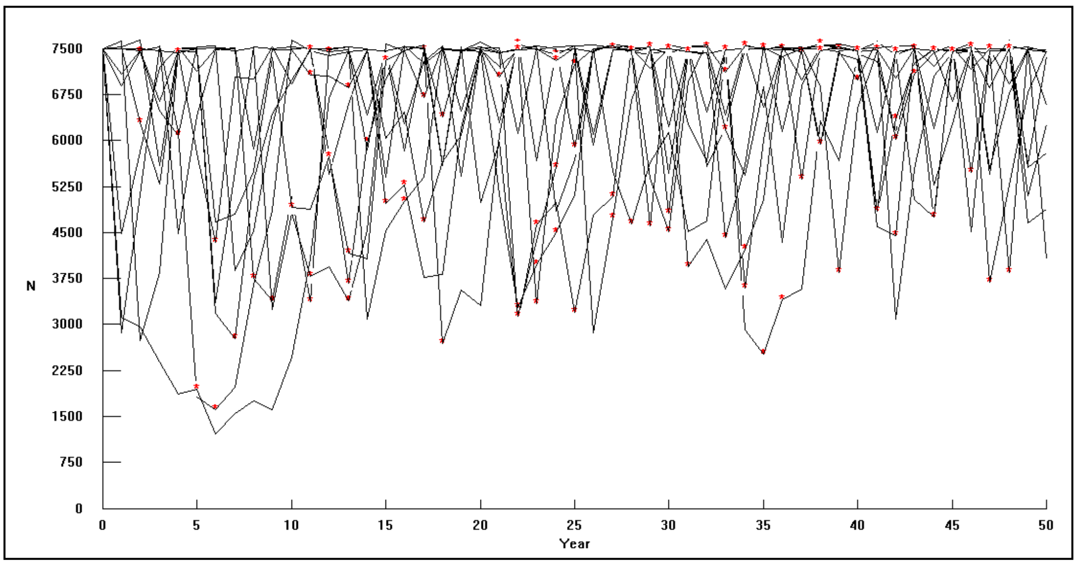


Figure 6. A sample of 10 iterations from the baseline SHCO population model, in the absence of linkage to the YSBL component of the metamodel.

A simple demographic sensitivity analysis can identify which model input parameters make the greatest contributions to the growth of the simulate population. Application of this methodology to our SHCO model (results not presented here) demonstrated that juvenile mortality is by far the most sensitive parameter in the SHCO model, as predicted by simple life history theory (e.g., Heppell *et al*. 2000). Other aspects of reproductive success were also critically important in driving population growth, suggesting that management directed towards reducing chick/ fledgling production may possibly be an effective means of reducing overall SHCO population abundance. This assumes, of course, that the population is not stabilized by dispersal of birds into the population from nearby sources – in other words, our model assumes a closed population. Connectivity of the population of interest to other populations on the island of Puerto Rico would make management of cowbirds in the southwestern region considerably more difficult.

Results from Simulation Models III:
Metamodel Projection for the Baseline Scenario and Sensitivity Tests of YSBL Demographic Rates

Table 2 shows the summary results for the metamodel analyses of the YSBL in southwest Puerto Rico when impacted by nest parasitism from SHCOs. T**he "baseline" metamodel representing the best estimate of demographic rates for YSBLs and SHCOs and the interactions between the two species, under the current intensity of management, projects that the YSBL population will decline, on average, 1.2% per year (r = -0.012), and will have a 38% probability of becoming extinct (defined as dropping below N = 20).** The mean population size at 50 years is projected to be N=379. In those simulations in which the population did not go extinct, the mean population size at 50 years is N=606. Gene diversity in the extant populations is projected to decrease by 7% relative to the current levels, which is approximately equivalent to the birds being related, on average, at the level of first-cousins. The SHCO population is expected to remain near its carrying capacity, as its demography is driven primarily by its parasitism of the much more common hosts rather than YSBLs.

The high fluctuations in the YSBL population in the model are reflected in a large year-to-year variation in population growth, with SD(r)=0.407 for the baseline model and SD(r) in the range of 0.36 to 0.45 in other models in Table 1 that were used in sensitivity tests of alternative demographic rates. The variation among simulated populations in the final population size was also large, with SD(N)=603 in the baseline model and typically of similar magnitude in the other models. Thus, with SD(N) of about the same size as mean N, the final population of the baseline model after 50 years is predicted to be almost any value between 0 and the population carrying capacity (K=2,000), and this results in the 38% probability of extinction.

The effect on YSBLs of nest parasitism by SHCOs was small in the baseline scenario (compare the baseline in Table 2 to the baseline scenario with no SHCO impact in Table 1), because the baseline metamodel assumes that almost all SHCO eggs or chicks are removed from YSBL nests before they reduce the YSBL fledging rate. Moreover, in the metamodel, the number of SHCO females that prefer to parasitize YSBL nests is typically only about 2, also because very few SHCOs successfully fledge from YSBL nests under the current intensive management of nests. However, just two SHCO females that prefer YSBL nests would be expected to parasitize more than 10 YSBL nests. Also, the large number of SHCO females that were raised in and therefore prefer other host species still parasitize many YSBL nests, even as non-preferred hosts when they cannot find a nest of their preferred host, with typically 40% to 50% of the YSBL clutches being parasitized each year in the metamodel. This rate of parasitism in the model is very similar to the rate that has been reported by PRDNER over the past few years – increasing our confidence that the metamodel is representing the actual dynamics well.

Survival Rates Estimated from Various Time intervals
As described earlier, the workshop participants believed that the survival rates from the time interval 1990-2012 provide the best estimate of the demography of the YSBL under current conditions. However, it is also recognized that the survival rates increased from the 1980s to the 1990s, as the population showed some recovery, but then survival decreased since 2004, and the population has declined. The top set of sensitivity tests in Table 2 show the results if the annual survival rates of YSBLs are as observed from 1985-1989 (and with an assumption of no

management of nests and with a starting population of 200), as observed from 1990-2003, and as observed from 2004-2012. The projection based on conditions thought to replicate conditions from the 1980s indicates that if those rates had persisted and intensive management of the nests had not occurred, it is expected that the yellow-shouldered blackbird would have rapidly declined to extinction, probably disappearing during the 1990s. **Although the slow and possibly stalled recovery is reason for continuing concern, it appears that the intensive management to date has prevented an otherwise likely extinction.**

Table 2. Baseline results and sensitivity tests of uncertain parameters describing YSBL demography. Columns as in Table 1, with the addition of SHCO = mean number of SHCO at year 50. Data for the baseline scenario (in italics) are repeated for ease of comparison within some of the sets showing sensitivity tests. See text for further explanation of each set of tests.

Scenario	r	SD(r)	%PE	meanTE	N-ext	SD(N)	N-all	SD(N)	%GD	SHCO
Baseline	-0.012	0.407	38	30	606	603	379	559	93	6734
Survival rates from various time intervals										
1980s no mgt	-0.398	0.499	100	6	--	--	0	0	0	6607
1990-2003	0.042	0.396	11	31	1027	684	918	720	96	6759
2004-2012	-0.185	0.472	100	14	--	--	0	0	0	6736
Increases in fledging rate										
5%	0.006	0.406	27	28	711	630	518	624	94	6680
10%	0.027	0.399	15	32	922	678	784	706	95	6676
15%	0.043	0.394	8	32	1010	670	927	699	96	6671
20%	0.062	0.399	6	28	1147	679	1079	712	96	6648
25%	0.084	0.390	1	29	1293	649	1280	658	97	6693
30%	0.108	0.381	2	21	1490	575	1466	601	98	6677
40%	0.145	0.372	0	--	1593	509	1593	509	98	6640
50%	0.179	0.361	0	--	1673	485	1670	490	98	6656
Annual survival rates										
51%	-0.169	0.454	100	16	--	--	0	0	0	6609
56%	-0.093	0.430	90	24	256	406	27	151	88	6715
59%	-0.043	0.416	62	27	423	469	161	354	93	6607
61%	-0.012	0.407	38	30	606	603	379	559	93	6734
63%	0.020	0.401	21	30	864	686	684	704	95	6605
66%	0.067	0.382	4	32	1226	653	1179	681	97	6689
71%	0.133	0.369	0	--	1606	520	1603	525	98	6647
Carrying capacity										
1000	-0.008	0.405	41	31	340	304	201	286	92	6626
2000	-0.012	0.407	38	30	606	603	379	559	93	6734
3000	-0.019	0.411	39	29	688	755	419	677	94	6618

The scenario that used the better survival rates from 1990-2003 shows that if the YSBL can again experience those levels of survival (65% annual survival of adults), then the population would be expected to grow at an average rate of 4% per year. However, there would still be large fluctuations (as large as 50%) from year to year, and these fluctuations led to population extinction in 11% of the simulations.

If the lower survival rates since 2004 persist, then the metamodel projects that the recent decline in the population will continue, driving the YSBL population extinct within a few decades. The most serious decline in numbers occurred during the winter of 2011-12, and it is not known what caused the loss of greater than 50% of the population. It will not be known until data are available from November 2012 if the next post-breeding count shows the same rapid drop in numbers as did the March 2012 pre-breeding census. However, the number of active nests was also reduced by 25% in 2012, so there is no reason to be optimistic that the post-breeding counts will show population recovery. Although it is possible that the recent high mortality was simply due to bad luck (because in a population as small as the YSBL, chance events can cause large fluctuations in population numbers), at the workshop it was recognized that it will be important to identify ways to improve YSBL survival and reproductive success.

Note: After the PHVA workshop and the analyses presented in this report, the data from the 2012 post-breeding census became available. That recent survey found 668 YSBLs, indicating that better survival from April 2012 to October 2012 had allowed a partial recovery by YSBLs from the large decline that had occurred in the prior 6 months (see section on "Baseline input parameters for Population Viability Models" for more details).

Increases in Fledging Rate

The next set of scenarios in Table 2 show the metamodel projections if the fledging rate (survival from egg to fledging: currently 46% for ANSs and 42% for NNs) is increased proportionally by percents ranging from 5% up to 50%. (Increases of the same percents in the post-fledging survival rate would have the same impact on population growth, so the benefit of improved recruitment of young YSBLs into the population might be achieved either by increasing nestling survival or by increasing survival in the weeks just after fledging.) The results show that even a small (5%) increase in the fledging rate can shift the population from slow decline to slow average growth, although improvements in recruitment of 15% would be needed to achieve high enough population growth so that the risk of extinction drops below 10%.

Annual Survival Rates

The tests of alternative annual survival rates (for all age classes after fledging) show that even **small changes to the survival rate can have large effects on the likely fate of the population.** If survival decreases by even 2%, the probability of extinction rises from 38% to 62%, while an increase of 2% drops the probability of extinction to 21%. Shifts in the survival rate down or up of 4% change the projection from near certainty of extinction to a near certainty of population persistence.

Carrying Capacity

In contrast to the large impact of changes in survival, a change in the carrying capacity has very little effect on the metamodel projections. Reduced carrying capacity of the habitat would reduce the expected mean population size and consequently accelerate inbreeding and other risks. However, because the population is not currently growing, an increase in the carrying capacity alone will provide very little benefit. Other improvements to YSBL demography would be necessary to allow the YSBL to be able to expand into any additional habitat.

Results from Simulation Models IV:
Sensitivity Tests of Uncertain Parameters Describing SHCO – YSBL Interactions

Workshop participants were able to estimate values describing the SHCO parasitism of YSBLs that lead to a baseline metamodel that represents a plausible description of the population dynamics for use in testing relative impacts of possible management actions. However, there is a lot of uncertainty about the nature of the interactions between the YSBL and SHCO. For example, it is not known with what fidelity a SHCO female seeks host nests of the same species as the host in whose nest she was raised, or if the host preferences of SHCO females remain constant over their lifetimes. When a female SHCO does not find a nest of her preferred host, it is not known how likely it is that she will place her eggs in a YSBL nest rather than in the nest of a yellow warbler or some other species. The impact of SHCO nest parasitism on the fledging success of YSBL was estimated at the workshop from summaries of field observations. However, these estimates were based on relatively few data that were mostly from earlier field research, because PRDNER has recently been intensively managing the nests by removing all SHCO eggs and chicks that are found. Table 3 shows some sensitivity tests that were run to determine how much our projections change if we used some alternative estimates of the parameters that describe the relationship between SHCOs and YSBLs.

Table 3. Sensitivity tests of uncertain parameters describing SHCO – YSBL interactions. Columns as in Table 2. Data for the baseline scenario (italics) are repeated for ease of comparison within some of the sets showing sensitivity tests. See text for further explanation of each set of tests.

Scenario	r	SD(r)	%PE	meanTE	N-ext	SD(N)	N-all	SD(N)	%GD	SHCO
Baseline	-0.012	0.407	8	30	606	603	379	559	93	6734
Host fidelity by SHCO										
60%	-0.009	0.408	37	29	628	606	394	567	94	6664
70%	-0.014	0.408	40	29	571	536	345	500	94	6614
75%	-0.012	0.407	38	30	606	603	379	559	93	6734
80%	-0.016	0.404	42	29	616	622	360	563	94	6726
90%	-0.014	0.408	41	29	616	618	367	563	93	6728
Probability that a SHCO that is parasitizing a non-preferred host will choose a YSBL nest										
0.002	-0.012	0.412	38	30	585	596	366	549	94	6683
0.004	-0.012	0.407	38	30	606	603	379	559	93	6734
0.006	-0.018	0.408	41	29	519	520	309	474	93	6552
Impact of parasitism on YSBL fledging rate										
50%	-0.010	0.407	39	28	645	627	393	581	94	6594
59%	-0.012	0.407	38	30	606	603	379	559	93	6734
70%	-0.012	0.408	38	30	573	576	358	533	93	6593

The tests of a range of values for the host fidelity of SHCO females for the species in whose nest they were raised indicates that changes to this uncertain parameter have very little effect on the metamodel results. The differences in the results from scenarios with 60% to 90% host fidelity are probably all within the random sampling error that occurs with 500 iterations of a highly variable system. As host fidelity increases, the few SHCOs that prefer YSBLs will place more of their eggs in those nests, but the many SHCOs that have other host preferences will place fewer of their eggs in YSBL nests. These effects might largely cancel each other out; although the impact of host fidelity could become much greater if nest management was reduced, allowing SHCO parasitism to have a greater impact on the YSBL population.

The likelihood that a SHCO female that has a preference for a host species other than YSBL, but which does not find a nest of its preferred host, will put its egg into a YSBL nest was estimated at the workshop from the number of YSBL nests parasitized in recent years and the estimated total egg production of SHCO across southwest Puerto Rico (see above). If this estimate of 0.4% probability that a SHCO would use a YSBL nest rather than some other nest is increased or decreased by 50%, there was little effect on the metamodel dynamics. Again, however, the effect of greater or lesser parasitism of YSBL nests would be much greater if the nests were not actively managed.

Similarly, with the current removals of SHCO eggs from all ANSs and many NNs, changes to the impact of any SHCO nestlings not removed from YSBL nests on the YSBL fledging rates have little effect on the metamodel results.

Because each of these parameters describing the SHCO parasitism of YSBL is uncertain, the results (below) for tests of management actions should be assumed to demonstrate the *relative* benefits of various possible actions, but it should not be presumed that the model results will be accurate predictions of the absolute measures of population performance. For example, the effect of reduced management of YSBL nests would be much greater than projected in the metamodel scenarios that we tested if the estimated rate at which SHCO parasitize YSBL nests is greater than we estimated, or if the impact of SHCO parasitism on YSBL fledging success is worse than we estimated. However, the results (below) that show a very large negative effect on YSBL if nest management is reduced will likely still be valid, even if we are not certain exactly how large that effect will be.

Results from Simulation Models V:
Tests of Alternative YSBL Management Actions

In the risk assessment phase of our analysis, we developed a series of alternative management strategies and evaluated their effectiveness in improving overall viability of the southwestern Puerto Rico YSBL population. Our first set of alternatives focused on impacts of direct management of YSBL if the following scenarios occurred:

- Abandoning all forms of nest management;
- Abandoning management of natural nests, thereby focusing solely on artificial nest structures;
- Adding artificial nest structures;
- Improving the rate of YSBL fledging from artificial nest structures through, for example, reducing local predator densities, improving artificial nest design and/or placement, etc.;
- Improving post-fledging survival rate; and
- Combinations of the above measures.

The results of these analyses are presented in Table 4, with those of selected scenarios show in Figure 7.

If YSBL nest management is abandoned completely, the population is projected to decline very rapidly (r = -0.231), and YSBL become extinct after a little more than a decade. Increasing the ANS effort reduces the rate of population decline and extinction risk, but even when all ANSs are cleared of SHCO chicks, the abandonment of NN management leads to a risk of YSBL extinction (%PE = 48) that still exceeds our baseline estimate of 38%. This clearly points to the value of including natural nest management in any YSBL management scheme.

Relaxing both ANS and NN management, even for just one year, leads to a decrease in long-term population growth and an increased risk of YSBL population extinction over the baseline scenario. As defined in our metamodel structure, the impacts of SHCO nest parasitism on YSBL recruitment (fledging) is clearly a highly sensitive parameter in determining overall YSBL population viability.

Table 4. Tests of management actions focused on improved survival or reproduction of YSBL. Columns as in Table 2. Data for the baseline scenario (italics) are repeated for ease of comparison within some of the sets showing sensitivity tests. See text for further explanation of each set of tests.

Scenario	r	SD(r)	%PE	meanTE	N-ext	SD(N)	N-all	SD(N)	%GD	SHCO
Baseline	-0.012	0.407	38	30	606	603	379	559	93	6734
Management of SHCO in ANS (with no management of NN)										
0%	-0.231	0.453	100	12			0	0	0	6697
50%	-0.113	0.429	96	21	76	70	4	21	88	6729
75%	-0.069	0.419	78	25	306	365	69	214	92	6682
100%	-0.034	0.411	48	29	414	493	216	411	92	6740
No nest management for a few years, after which management resumes										
1 year	-0.018	0.407	45	27	651	643	362	577	93	6708
3 years	-0.033	0.414	54	24	538	578	246	473	93	6587
5 years	-0.056	0.420	67	20	495	568	166	402	90	6613
Addition of ANS										
+100	0.004	0.415	30	30	754	657	527	648	95	6717
+200	0.011	0.410	28	30	794	673	574	673	95	6696
+300	0.012	0.414	25	29	723	657	542	649	94	6615
10% increase in fledging rate of ANS, combined with other sets of management actions										
+10%	0.013	0.400	20	29	808	654	650	668	95	6590
+100ANS	0.040	0.398	7	30	990	652	919	677	96	6713
+200ANS	0.054	0.397	7	31	1111	657	1036	693	96	6759
+200ANS 66% surv	0.107	0.385	0	--	1441	575	1440	575	98	5116
+200ANS 66% surv K=4000	0.086	0.387	0	--	2617	1240	2606	1249	98	6674

The addition of artificial nest structures within appropriate YSBL breeding habitat appears to have a significant impact on population viability. When 100 ANSs are added – representing a 40% increase from the 246 available in our baseline model – the population growth rate increases from -0.012 to 0.004 and the risk of extinction declines to 30% over the time period of the simulation. If a total of 300 ANSs are added, representing more than a 100% increase in the number available, the growth rate increases further to 0.012 and the risk of extinction declines to 25%. This risk remains relatively high despite the large increase in artificial nests. This is likely due to the fact that, in the early stages of the simulation, the

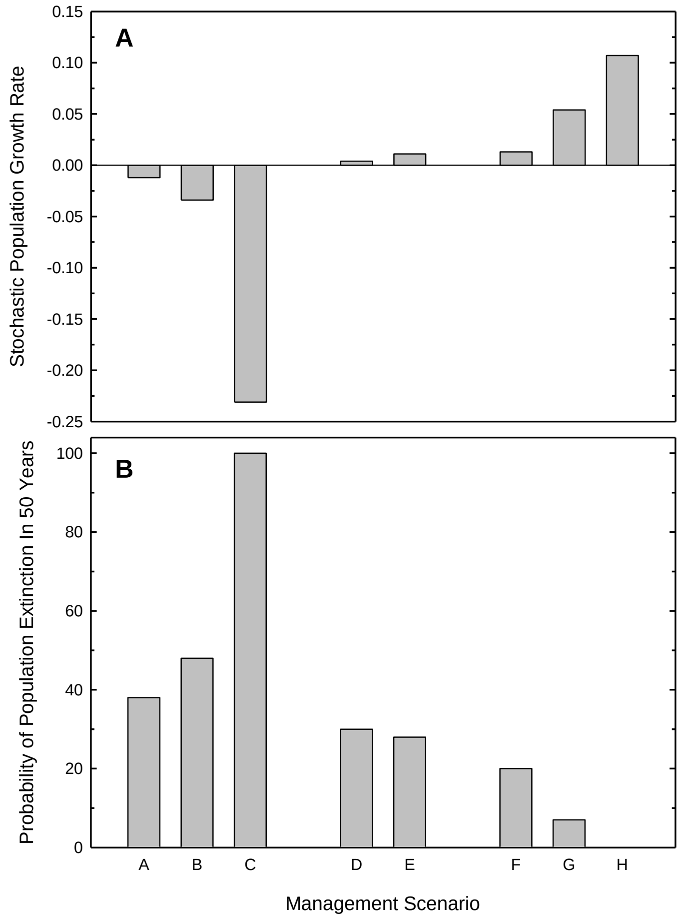


Figure 7. Estimates of stochastic population growth (A, top) and extinction risk (B, bottom) of yellow-shouldered blackbird populations under alternative simulated management scenarios.
Scenario A: baseline;
Scenario B: 100% management of ANS (no NN management);
Scenario C: No nest management;
Scenario D: addition of 100 ANS;
Scenario E: addition of 200 ANS;
Scenario F: 10% increase in fledging rate;
Scenario G: 10% increased fledging rate, addition of 200 ANS;
Scenario H: 10% increased fledging rate, addition of 200 ANS, 5% increase in adult survival.

breeding population remains small compared to the total number of nests available, so the population is not able to utilize the larger number of nests. Other factors, such as the infrequent but severe weather events included in the model, can act to reduce population growth rate in the short term and put a given population at risk of extinction. Nevertheless, the addition of ANSs shows promise as a valuable management tool to boost YSBL population viability, especially if combined with other management actions.

Compared to the management actions just discussed, the YSBL population in southwestern Puerto Rico appears to respond most effectively to an increase in the fledging rate. An increase in this rate of just 10% results in a strong rate of population growth (r = 0.013) and a reduction in the extinction risk of nearly 50% compared to the baseline metamodel scenario (38% risk compared to 20% risk). It is clear that this relatively modest increase in survival leads to considerable improvement in population viability. When other management strategies are employed in combination with those designed to increase the fledging rate, YSBL population growth rate steadily increases and extinction risk drops to much lower levels over the time period of the simulation. The results in the last few rows of Table 4 show that when a 10% increase in the fledging rate is combined with additional ANSs and better annual adult survival (66% rather than 61% in the baseline), population growth is projected to be above 10% and there is minimal probability of extinction. Addition also of increased habitat carrying capacity does not improve mean population growth, but does allow that growth to result in a much larger final population size.

Results from Simulation Models VI:
Tests of Management Alternatives Targeting Both YSBL and SHCO

Our final set of management scenarios combined selected methods for direct YSBL management summarized in the previous section with a more direct SHCO management method, namely, trapping and removing adult birds. This was implemented through the Harvest module in *VORTEX*, which allows the user to specify the total number of individuals of a given age and sex to be removed from the population each year. For each of the scenarios listed in Table 5, the specific YSBL management method was imposed along with the addition of varying levels of SHCO removal through trapping.

Table 5. Tests of management actions focused on improved survival or reproduction of YSBL with the explicit addition of SHCO trapping. Columns as in Table 1, with the addition of SHCO = mean number of SHCO at year 50. See text for further explanation of each set of tests.

Scenario	r	SD(r)	%PE	meanTE	N-ext	SD(N)	N-all	SD(N)	%GD	SHCO
Baseline	-0.012	0.407	38	30	606	603	379	559	93	6734
No nest management, SHCO trapping only										
Trap 0%	-0.231	0.453	100	12			0	0	0	6697
Trap 20%	-0.209	0.453	100	13			0	0	0	5323
Trap 40%	-0.075	0.426	75	17	512	530	126	343	92	6
Trap 60%	-0.026	0.414	49	24	585	591	296	511	92	0
Trap 80%	-0.015	0.407	44	24	650	594	366	550	94	0
Baseline management, SHCO trapping										
Trap 10%	-0.013	0.411	36	30	551	555	351	515	93	6107
Trap 20%	-0.011	0.402	35	30	618	600	400	565	94	5233
Trap 40%	-0.005	0.408	36	29	695	630	444	604	94	8
100% ANS management (no NN management), SHCO trapping										
Trap 0%	-0.034	0.411	48	29	414	493	216	411	92	6740
Trap 10%	-0.031	0.410	48	29	434	489	228	414	93	6194
Trap 20%	-0.033	0.413	49	29	442	494	227	416	93	5137
Trap 40%	-0.012	0.408	36	27	636	632	405	589	93	8
75% ANS management (no NN management), SHCO trapping										
Trap 0%	-0.069	0.419	78	25	306	365	69	214	92	6682
Trap 10%	-0.065	0.410	73	27	270	354	73	217	90	6162
Trap 20%	-0.063	0.416	73	27	249	379	68	225	91	5175
Trap 40%	-0.019	0.410	44	26	636	630	357	567	93	6
Addition of 200ANS, SHCO trapping										
Trap 0%	0.011	0.410	28	30	794	673	574	673	95	6696
Trap 10%	0.010	0.412	28	28	811	675	588	679	94	6276
Trap 20%	0.010	0.412	26	28	740	659	547	653	95	5298
Trap 40%	0.016	0.409	23	28	852	675	653	692	95	8
10% increased fledging success from ANS, SHCO trapping										
Trap 0%	0.013	0.400	20	29	808	654	650	668	95	6590
Trap 10%	0.015	0.402	19	30	843	669	682	687	95	6336
Trap 20%	0.009	0.402	21	29	756	624	596	634	95	5261
Trap 40%	0.018	0.404	19	29	837	690	680	702	95	10
5% increased adult survival, SHCO trapping										
Trap 0%										
Trap 10%	0.067	0.385	3	30	1201	656	1165	678	97	6151
Trap 20%	0.064	0.387	3	30	1131	668	1098	686	96	5010
Trap 40%	0.075	0.385	3	28	1269	669	1233	692	97	14

As shown in the top section of table 5, YSBL management defined solely through an attempt to trap SHCOs from the population – thereby limiting their ability to parasitize large numbers of YSBL nests – is not likely to be an effective management alternative. Very aggressive trapping efforts – on the order of no less than 40% of the standing population every year – will lead to high levels of SHCO extinction risk (see also Figure 8). However, the absence of YSBL nest management still leads to high YSBL extinction risk after SHCOs have been eliminated through trapping, because the damage to the YSBL population can already be severe and irreversible by the time that the SHCOs are eliminated. Extremely high trapping rates of SHCOs will reduce this YSBL extinction risk to less than 50%, but it is likely that such large trapping efforts, sustained over long periods of time, are not feasible. Moreover, it is important to recognize that our models are likely to represent optimal conditions for SHCO trapping, since we assume a closed population, i.e., no immigration of birds from neighboring areas of the island.

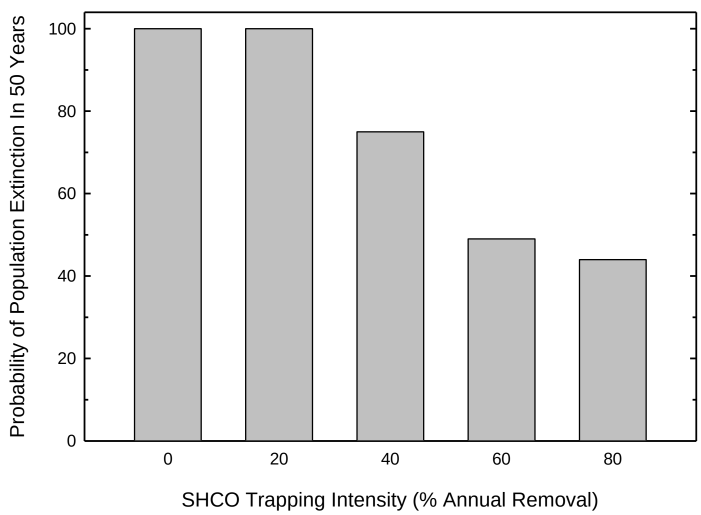


Figure 8. Yellow-shouldered blackbird extinction risk projections under shiny cowbird trapping scenarios of increasing intensity. Trapping is defined as the percentage of the standing adult population removed each year.

The addition of SHCO trapping to baseline (current) levels of nest management does not result in increased levels of YSBL population viability (Table 5, Figure 9). In other words, the addition of SHCO trapping does not provide any benefit to the YSBL population above and beyond that which is conferred by the existing nest management activities. This is likely because the current nest management removes most of the impact of SHCOs. In a similar vein, only aggressive rates of SHCO trapping in combination with varying levels of ANS management (abandoning NN management) confer just modest gains in YSBL population viability above and beyond what can be achieved in the absence of trapping. Similarly, even higher levels of trapping does not confer significantly higher levels of YSBL population viability when other more effective means of management are employed – namely, increasing the number of artificial nest structures or, to an even greater degree, increasing the YSBL fledging rate.

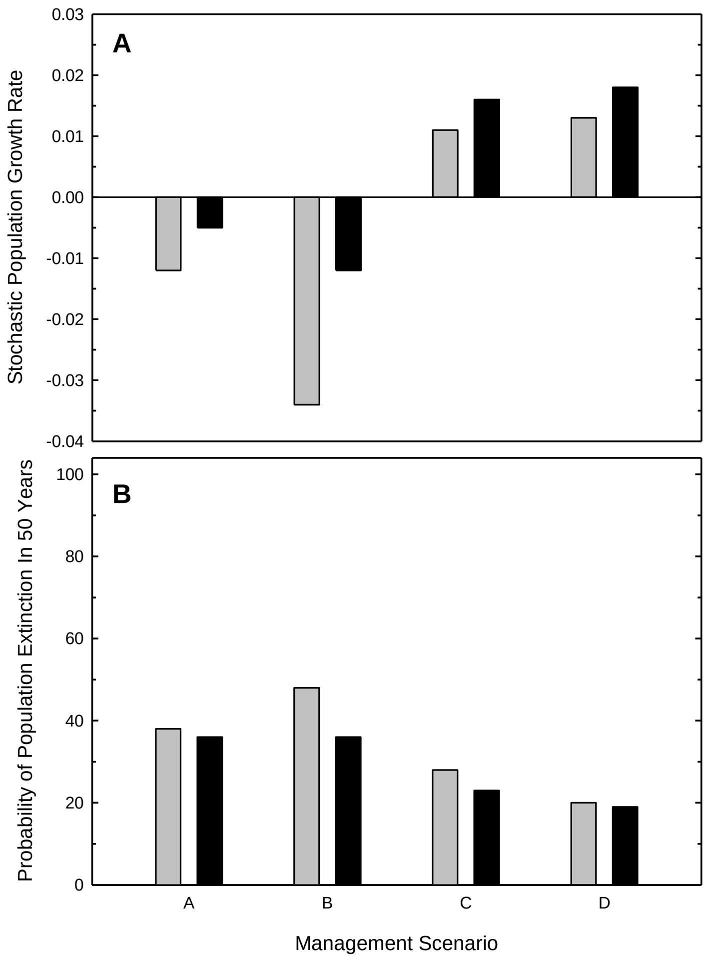


Figure 9. Stochastic population growth (A, top) and extinction risk (B, bottom) of yellow-shouldered blackbird populations under alternative management scenarios, in the absence (gray bars) and presence (black bars) of shiny cowbird trapping.
Scenario A: baseline;
Scenario B: 100% management of ANS (no NN management);
Scenario C: addition of 200 ANS;
Scenario D: 10% increase in fledging rate.

Overall, our initial exploration of SHCO trapping effort to manage YSBL populations suggests that it is not an effective strategy for increasing the viability of associated YSBL populations. The reproductive rate of SHCOs is high enough that even a relatively small number of extant adults can produce a large cohort of fledglings that will facilitate a rapid increase in abundance.

Conclusions

Value of a Two-Species Metamodel

The development of a metamodel to describe the dynamics of each of the two species – the endangered yellow-shouldered blackbird and the invasive shiny cowbird – and the interactions between them served multiple purposes:

- The data on each species and the effects of the SHCO nest parasitism of YSBLs were summarized through extensive efforts by workshop participants.
- Detailed discussions were held on the hypothesized impacts of SHCO on YSBL, the effects of ongoing management, and the possible and possibly necessary further management that might achieve recovery of the YSBL.
- Gaps in data, as well as available data that had not previously been utilized, were identified.

- A metamodel that appears to represent well the recent dynamics of the YSBL was developed. The model predicts both plausible mean rates of population growth under various assumptions, and the extent of fluctuations in population size that occur.
- Model results helped to indicate the most critical threats to the YSBL, thereby informing the other discussions at the PHVA workshop regarding possible management actions.
- The projected results of various proposed management strategies were generated from this metamodel.
- A modelling platform is now available that will allow refinement of the analyses as new data or new ideas about possible management actions become available.

Model Outcomes for YSBL Viability

Specific outcomes of the metamodel indicated:

- The best estimate of the current situation for the YSBL projects a continued slow, mean population decline due to mortality rates that are too high to be sustained by the observed recruitment.
- The population is projected to be subject to large fluctuations in size (as indeed has been observed). These fluctuations increase the risk of extinction.
- If the lower survival rates of YSBLs observed in the 1980s, prior to aggressive management of SHCO at YSBL nests, had persisted, the species probably would have gone extinct a decade or more ago. Either the species was lucky or, more likely, the active management has thus far prevented an extinction.
- Survival rates in the 1990s were sufficiently high to have allowed steady population growth, would have resulted in a larger population than currently exists, and would have made extinction much less likely if those rates had persisted.
- For reasons that are not fully known, survival rates have been much lower since 2004, and consequently the population has declined.
- Increases in either the nestling and fledging survival or the adult survival could achieve positive population growth again and minimize the probability of extinction. . Specifically, mechanisms to increase post-fledging and adult survival, which would likely be independent of SHCO population management, may be important to improve long-term YSBL population viability.
- Adding habitat alone would have little effect, because without a positive population growth rate the species is unlikely to be able to exploit new habitat.
- If nesting conditions could be improved by providing all YSBLs with access to reproductive success that mirrors the success of YSBLs in ANSs, then the population is projected to grow, although year-to-year fluctuations would still be large enough to put the fate of the species at risk. It might be that such breeding rates could be achieved by providing more ANSs, but more research is needed to determine if it is the nest structures themselves or some other factor that results in better breeding success of YSBLs that use ANSs.
- Although there is much uncertainty in how the SHCO females select the nests to parasitize (e.g., do they preferentially parasitize the species that reared them? How often do they parasitize non-preferred species?), and what is the impact of that parasitism on fledging success of YSBL, under current conditions these rates have little effect on our projections of the YSBL populations. This is because almost all SHCO eggs or chicks are removed from YSBL nests, so the potential impact of parasitism is prevented.

- If removal of SHCOs from YSBL nests was stopped or reduced, the impacts would be much greater. A decrease in the removals would result in much more rapid YSBL population decline and higher probability of extinction. Even the cessation of nest management for just a few years would substantially increase the risk of extinction of the YSBL.
- Adding more ANSs would appear to have some, but limited, benefit, because that action would not address the unsustainably high mortality of both post-fledging and adult birds.
- Adding more ANSs and reducing adult mortality, while continuing to protect nests from SHCOs, is projected to result in rapid population growth and a minimal probability of extinction.
- The very high fecundity of the shiny cowbird allows the species to grow rapidly, to sustain a large harvest, and to recover in numbers rapidly after any temporary decline.
- To substantially reduce the size of the SHCO population might require trapping as many as 40% of the SHCO annually.
- However, even trapping 40% of SHCOs each year, if all other management remains the same, would not provide much protection for the YSBL. This is because the blackbird population could decline before the cowbirds were substantially reduced in number, and just a small number of cowbirds can parasitize and further threaten the small population of blackbirds.

In summary, the metamodel results indicate that reversing the decline of YSBLs and adequately assuring the persistence of the species will require either the nearly complete and immediate elimination of the SHCO from the island or the nearly complete elimination of the impacts of the SHCO on YSBL. The current strategy of removing SHCOs from YSBL nests is probably more feasible than removing all SHCOs from southwestern Puerto Rico. However, even these aggressive management measures (either removing all SHCOs or removing all SHCO eggs from YSBL nests) may not be sufficient to protect the yellow-shouldered blackbird and allow it to recover to safer numbers unless other, as yet not fully known, causes of mortality are reduced.

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Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico
28 – 31 August 2012

Final Report

SECTION 8

Group Prioritization of Goals and Next Steps

Group Prioritization of Goals and Next Steps

The metamodeling results indicate that aggressive management measures (either removing all SHCOs or removing all SHCO eggs from YSBL nests) may not be sufficient to protect the yellow-shouldered blackbird and allow it to recover to safer numbers unless other, as yet not fully known, causes of mortality are reduced. The threats analysis and subsequent working group discussions led to a series of goals to increase YSBL population viability overall in the face of *all* threats.

Prioritization of Goals

Once the two threats working groups had developed all of their goals, they presented and discussed these goals with the rest of the workshop participants in plenary so that all participants were able to have input into all issue and goals. Goals were examined across the two groups and were consolidated, split, or otherwise refined to equalize the level of action and to increase clarity. This resulted in 13 goals endorsed by the workshop participants, all of which are recommended in order to benefit yellow-shouldered blackbird populations.

An overall prioritization of all workshop goals helps to guide working groups in developing recommended actions, especially if resources (funding, time, staff) are limited, and can help focus attention on the primary issues of concern. Once the goals were finalized and the results of the population modeling had been presented and discussed, the participants were asked to consider the important of each goal in terms of its expected impact on YSBL populations. The goals were displayed on flip charts, and participants were asked to prioritize these goals (using sticky dots) with respect to the following criteria. Priority goals are those that have the:

"*greatest immediate positive impact on yellow-shouldered blackbird population viability and conservation*".

This activity identified five goals that stood out as priorities for action (number of dots given in parentheses):

1. **Decrease egg and chick predation at YSBL nests. (16)**
2. **Improve efficiency of artificial nest structures. (12)**
3. **Reduce impact of shiny cowbirds on nest success. (12)**
4. **Protect YSBLs against invasive predator disturbance. (10)**
5. **Provide sufficient foraging habitat for adult YSBLs during peak breeding season. (9)**
6. Prevent accidental death of adult YSBL due to drowning in cattle troughs. (3)
7. Protect mangrove islets from human disturbance (e.g., spotlighting from tourists). (2)
8. Garner support form NGOs and conservation organizations that provide support for funds and personnel needed to benefit YSBLs. (1)
9. Increase public awareness of conservation value of YSBL and regulations that protect YSBL and its habitat. (1)
10. Affect policy change that allows implementation of federal landowner incentive programs on private land in Puerto Rico.
11. Work with Lajas municipality to develop a land resource management plan for YSBLs.

12. Coordinate implementation of Cabo Rojo Land Resource Management Plan (LRMP).
13. Increase number of artificial nest structures.

Working groups were asked to pay particular attention to any actions they might recommend to address the top priority goals (as appropriate within their discussion topic).

Next Steps: Beyond the PHVA Workshop

The working groups will revise and submit their final reports to CBSG for inclusion in the PHVA report along with summaries of the PHVA plenary discussions and metamodeling results. A draft report will be circulated for comments to ensure clarity and accuracy. Target deadline for the final report is 31 January 2013.

In addition, the following actions were recommended:

1. Conduct a conference call on DNA work with the University of Puerto Rico, Mayagüez (Tammie and group).
2. PRDNER will implement possible management actions before the next (2013) breeding season.
3. USFWS will implement possible management actions before next (2013) breeding season (e.g., manage for caterpillars).
4. Convene a follow-up meeting for this PHVA in Sept-Oct 2014 to see the results of management changes and status of the YSBL (revised PVA).
5. After PHVA final report is completed, conduct a conference call every six months for updates from all of the PHVA team.
6. Island Conservation and PRDNER are drafting a feasibility plan to remove invasive vertebrates from Mona. Due mid-2013 (funds from FWS and PRDNER available).
7. When will FWS revise the YSBL Recovery Plan – next year?

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico
28 – 31 August 2012

Final Report

APPENDIX I

Workshop Participants

Workshop Participant List

Name of participant	Organization	Email	Phone
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Yellow-Shouldered Blackbird / Shiny Cowbird PHVA

Mayagüez , Puerto Rico, 28 – 31 August 2012

Draft Agenda

<u>28 August 2012 (Tuesday)</u> – 8:00am to 5:00pm

AM Welcome
Remembrance of Jorge Saliva
Participant introductions and questions
Overview of previous work and meetings (Hilda Diaz-Soltero)
Introduction to workshop and PHVA process (Kathy Traylor-Holzer)
Status of YSBL population in southwest Puerto Rico (Roseanne Medina-Miranda)
Short updates on analyses for the PHVA:

- Habitat mapping of land use and impacts on YSBL (Alexis Dragoni)
- Roosting habitat survey (Oscar Diaz)
- YSBL and SHCO fecundity analyses (Tammie Nakamura)
- YSBL fledging survival (Roseanne Medina-Miranda)

Identification and diagramming of threats/challenges to YSBL viability
Recent changes in threats/land use/management

PM Overview of small population biology/PVA/Vortex/Metamodels (Phil Miller and Bob Lacy)
Review of YSBL Vortex model and metamodel (Bob Lacy)
Review of SHCO Vortex model (Phil Miller)
Discussion of vision for YSBLs in Puerto Rico
Definition of viability and potential criteria for assessment/recovery
Clarification of desired workshop outcomes
Management questions to be addressed by the model
Instructions to working groups
Initial working group session: assign roles, issue generation

<u>29 August 2012 (Wednesday)</u> – 8:00am to 5:00pm

AM Plenary session:

- Modeling update (if available)
- YSBL genetic diversity and extra-pair mating (Irene Liu)
- Working group instructions

Working groups: Issue generation

- Issue descriptions, causes and consequences, prioritization
- Identifying facts vs hypotheses

PM Working groups (continued): Identification of

- Recent changes that may affect YSBL populations
- Intervention opportunities
- Data gaps (research questions, modeling questions)

Plenary session: Working group reports and discussion

<u>30 August 2012 (Thursday)</u> – 8:00am to 5:00pm

AM Plenary session: Modeling report (refinement of base model, other model scenarios)
Working groups: Goals and objectives
- Generation of long- term goals to address issues
- Identification of short-term objectives to achieve goals

PM Working groups: Actions
- Identification and evaluation of potential actions and model scenarios

Plenary session: Working group reports
Working groups: Revisions to goals, objectives and potential actions

<u>31 August 2012 (Friday)</u> – 8:00am to 4:00pm

AM Plenary session: Modeling report (impact of potential alternate scenarios)
Group prioritization of goals
Working groups: Development of recommended actions

PM Plenary session: Final working group reports
Plenary discussion of downlisting/delisting criteria
Next steps forward – beyond the PHVA workshop
Evaluation of PVA/PHVA/metamodeling process
- Effectiveness for YSBL
- Lessons learned for using multi-species metamodel of invasive species

Revision of recommended actions
Closing of workshop

Working Groups: Topics

GROUP 1: Threats Related to Human Activities and Habitat Changes

- Changes in land use (e.g., development, agriculture)
- Impacts of climatic conditions (e.g., drought, rainfall, hurricanes)
- Impacts of tourism, insecticide use, and other human-related activities

GROUP 2: Threats/Impacts of Other Species

- Shiny cowbirds, including impacts of additional host species
- Natural and exotic predators
- Other parasites (e.g., mites, lice)
- Other species (e.g., spiders)
- Disease (and host/vector species)

GROUP 3: Model Development Group

- Model parameterization and scenario development

Working Groups: Task 1

Defining Factors Affecting YSBL Viability

1. Identify the roles within your group.
2. Discuss the issues that fall within your group's topic. Add or modify issues and relationships as needed, considering both the causes of the issue or threat and the consequences of YSBLs. Consider how each issue may affect the viability of YSBLs and SHCOs.
3. Group the issues/causal chains into categories or themes.
4. Prepare a written problem statement of a few sentences for each issue or group of issues that describes the root cause, intermediate steps, and resulting impact on YSBLs. Include the direction and relative strength of the relationship.
5. Categorize each issue or theme as High, Moderate or Low impact on YSBL viability.
6. For each relationship (arrow), identify if there are data that support this relationship (and provide reference) or if this relationship is an assumption.
7. Examine all issues and causes, and identify any which are thought to have changed in the past decade. Indicated if this change is known (fact) or hypothesized (assumption).

Working Groups: Task 2

Setting Goals

1. Taking into account the vision and threats to YSBL populations, examine each problem statement and develop specific goals to address the problem.
   - Goals should be measurable and contribute to conservation of the YSBL.
   - You can have one or several goals per problem statement or chain.
   - You may choose to develop long-term and shorter term goals.
2. Prioritize your goals (see facilitator for assistance in prioritization techniques).

Working Groups: Task 3

Identifying and Evaluating Potential Actions

1. For each threat chain, identify those relationships (arrows) that can be influenced in some way that may break the chain (or in the case of positive impacts, strengthen the chain). These become potential points for action.
2. For each point of influence, identify any potential actions that could be taken.
3. For each potential action, assess the following:
   - Conservation benefit level (High/Moderate/Low)
   - Financial costs to implement (estimated $$)
   - Other costs or risks (e.g., political)
   - Likelihood of success (High/Moderate/Low, and describe any obstacles)

   Consider model scenarios that can assist with assessment.
4. Choose one or more actions per goal as appropriate based on your evaluation in #3.

Working Groups: Task 4

Recommending Management and Research Actions

For each recommended action, develop the following:

- Description (short statement of the action)
- Responsible party
- Timeline
- Resources needed
- Collaborators and partners
- Priority for action

Characteristics of an Action Step:

Specific – for each goal
Measurable – outcome or an indicator
Attainable – can be accomplished under current conditions
Relevant – helps solve the specific problem and needs to be done
Timely – can be undertaken in time to achieve the goal

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico
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Final Report

APPENDIX II

List of Citations and Priority References

Citations and Priority References for YSBLs and SHCOs

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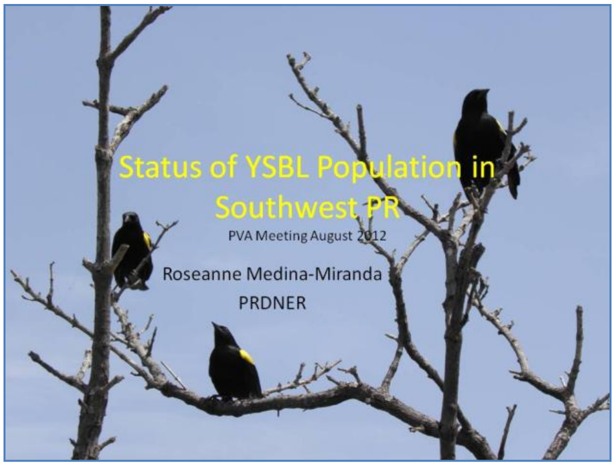
APPENDIX III

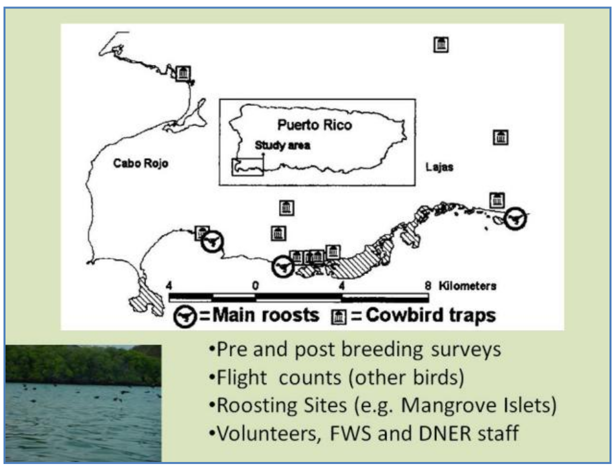
Plenary Presentations

Overview and Research Update Presentations

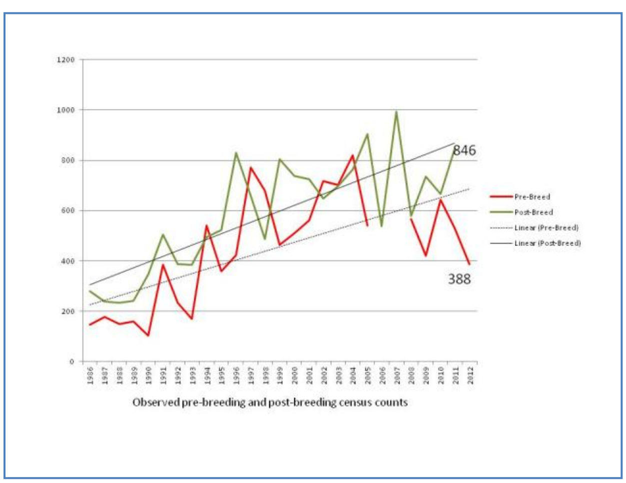
Status of the YSBL Population in Southwest Puerto Rico (Roseanne Medina-Miranda, PRDNER)



YSBL Project has collected information on the YSBL population for almost 30 years (1986 to present).



These surveys are conducted when birds arrive at the roosting site, counting birds in flight. Until 2006, most of the YSBLs were in the mangrove in La Parguera. Since 2006, YSBLs have shifted to a new roosting site in Bahia Salinas. This effort has been made possible thanks to the help of volunteers and FWS and DNER staff.



Despite increasing, this population has an unfavorable trend in net reproduction rate through the years. We divided the post-breeding census (N_{t+1}) by the pre-breeding census (N_t) to estimate the net population growth rate (R_0) during the breeding, per year ($R_0 = N_{t+1} / N_t$). R_0 is decreasing per year. In September-October 2011 the post breeding survey counted 846 YSBLs and the pre-breeding survey in March was 388 YSBLs.

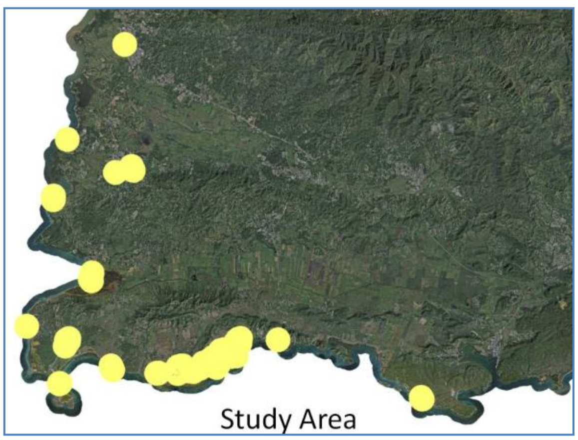
Habitat Mapping of Land Use and Impacts on YSBL (Alexis Dragoni, GAP Analysis Consultant)

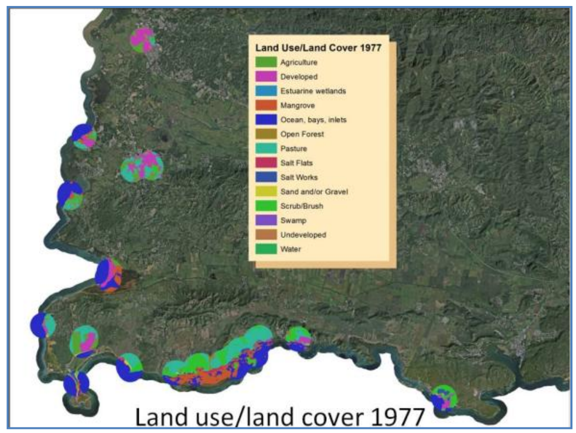
Land Cover Changes in Southwest Puerto Rico

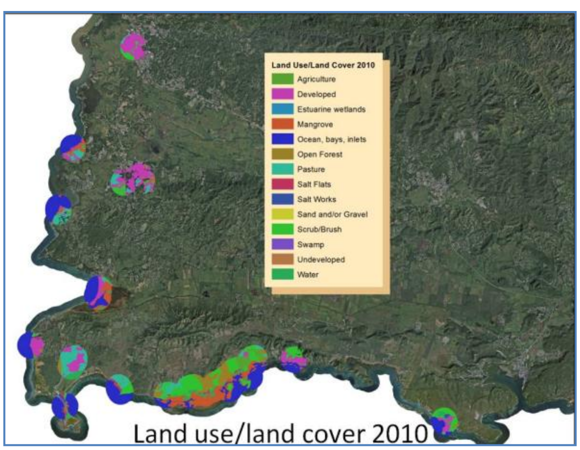
Habitat change and persistence in YSBL habitat

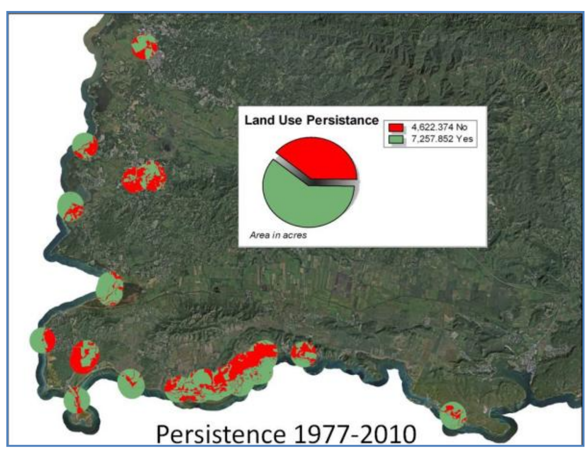
Sources and Procedures

- Procedure:
  - 1977 to 2010: vector based overlay analysis
    - By calculating a geographic intersection of both layers, change in uses can be identified
  - 1991 to 2000: raster based analysis utilizing pre-existing coverage data
    - Module "Land Change Modeler" from Idrissi Taiga software package
- Sources:
  - 1977 Land Use: PRDNER vector coverage from air photos.
  - 2010 Land Use: developed for this effort from 2010 air photos.
  - 1991 and 2000: Data obtained from Caribbean Island Land Cover Project
  - (access: http://fsgeodata.fs.fed.us/rastergateway/caribbean/index.php)



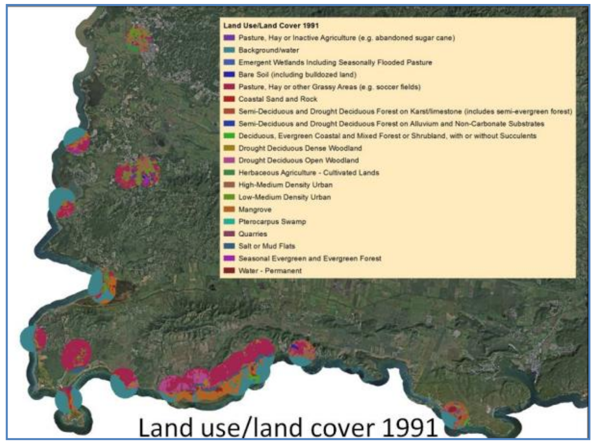


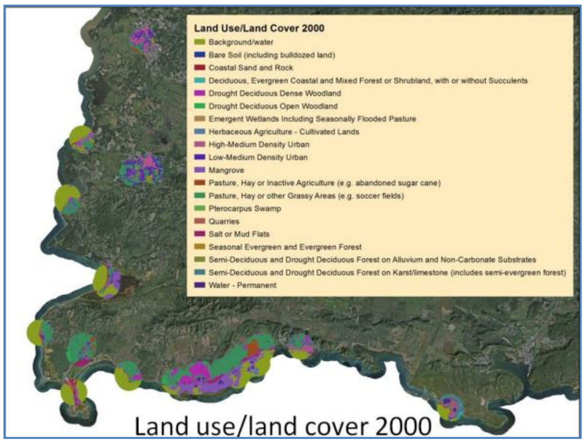


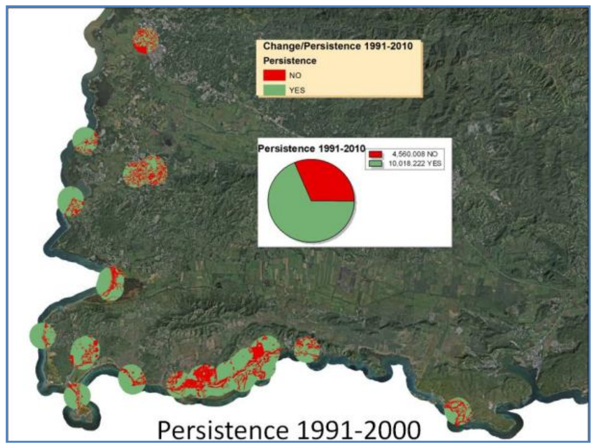


Land Cover Change 1977-2010

Land Cover Class Change	Area (Ha.)
Pasture to Scrub/Brush	226.041
Pasture to Open Forest	201.58
Pasture to Developed	193.703
Agriculture to Pasture	176.382
Pasture to Agriculture	85.7904
Pasture to Closed Forest	65.1076
Ocean, bays, inlets to Mangrove	60.2646
Ocean, bays, inlets to Water	59.1788
Scrub/Brush to Developed	56.7282
Scrub/Brush to Open Forest	53.3539
Developed to Pasture	48.9027
Agriculture to Developed	48.6022
Mangrove to Water	41.4995
Agriculture to Scrub/Brush	41.1432
Agriculture to Closed Forest	30.2618
Mangrove to Ocean, bays, inlets	29.5899
Salt Flats to Water	23.0981
Salt Works to Water	22.5569
Agriculture to Mangrove	21.2578



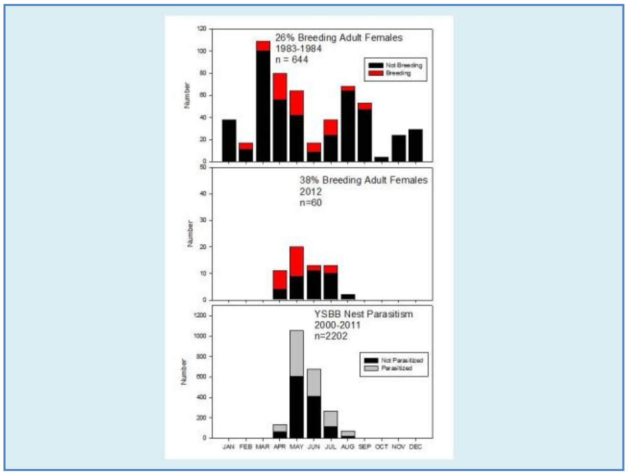




Land Cover Change 1991-2000

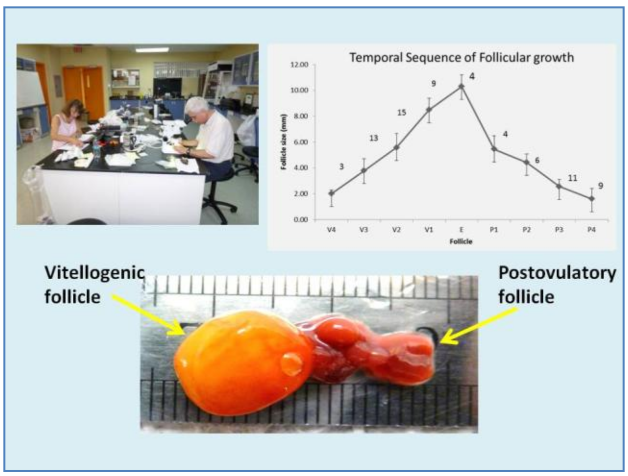
Land Cover Class Change	Area (Ha.)
Drought Deciduous Open Woodland to Drought Deciduous Dense Woodlan	124.42
Low-Medium Density Urban to High-Medium Density Urban	86.07
Pasture, Hay or other Grassy Areas to Pasture, Hay or Inactive Agriculture	85.51
Pasture, Hay or other Grassy Areas to Drought Deciduous Dense Woodland	78.48
Pasture, Hay or other Grassy Areas to Low-Medium Density Urban	74.15
Drought Deciduous Open Woodland to Pasture, Hay or other Grassy Areas	50.64
Low-Medium Density Urban to Pasture, Hay or other Grassy Areas	50.04
Mangrove to Water/ Ocean	45.26
High-Medium Density Urban to Low-Medium Density Urban	43.72
Pasture, Hay or other Grassy Areas to Drought Deciduous Open Woodland	37.09
Herbaceous Agriculture - Cultivated Lands to Pasture, Hay or other Grassy Areas	27.19
Water/ Ocean to Mangrove	26.66
Salt or Mud Flats to Mangrove	24.77
Water - Permanent to Mangrove	20.91
Salt or Mud Flats to Pasture, Hay or other Grassy Areas	17.26
Drought Deciduous Dense Woodland to Pasture, Hay or other Grassy Areas	16.73
Pasture, Hay or other Grassy Areas to Semi/Drought Deciduous Fores	16.50
High-Medium Density Urban to Pasture, Hay or other Grassy Areas	15.43
High-Medium Density Urban to Salt or Mud Flats	15.22

YSBL and SHCO Fecundity Analyses (Tammie Nakamura, University of Colorado, Denver)



GONAD SCORING CRITERIA

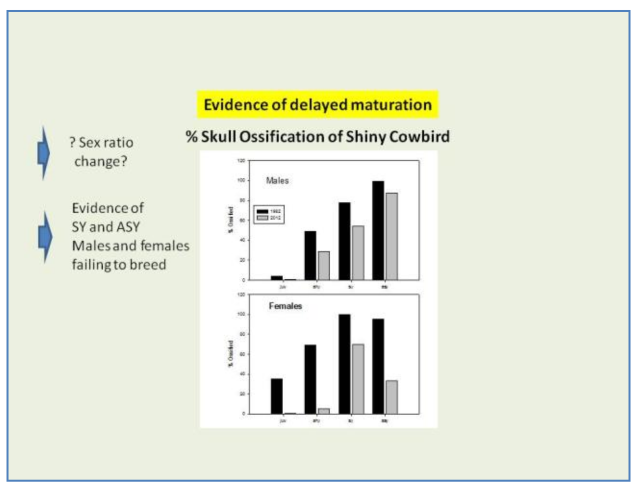
Gonad Classes	Male	Female
Type1	Testes v tiny <= 2 mm	No visible follicles <= 3 mm
Type2	Small: 2-4 mm	Tiny follicles of uniform size, total gonad size 4-6mm
Type3	Mod size 4-6	Follicles of non-uniform size from 2-5 mm / rudimentary or no oviduct/ total gonad size 7-15 mm
Type4	Enlarged: left test diam >=6mm	large Asym follicles /unenlarged oviduct / total gonad size 10-20 mm
Type5	Enlarged: left test diam >=8mm	Large Asym follicles / well developed ovidduct /Egg in oviduct



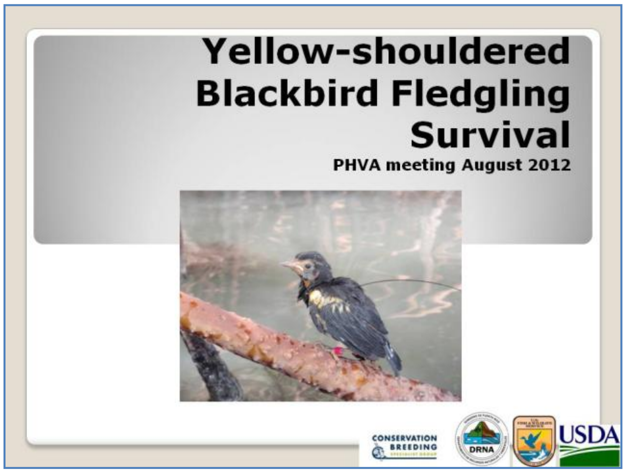
Vitellogenic follicles (mm)				Egg in oviduct	Postovulatory follicles (mm)				Potential number of eggs laid	Clutch size	Gap
d4	d3	d2	d1		d1	d2	d3	d4			
	3.8								1	1	
		5.5							1	1	
		4.5							1	1	
							3		1	1	
								1.2	1		
								2.1	1		
	3.3						2.2		2	1	4
2.3							2.1		2	1	5
	5.1					4.7			2	1	3
		5.5	7.2						2	2	
	3.3	5.1							2	2	
							3.1	1.7	2		
	3.7						2.3	1.1	3	1	6
	3.9	6.5		9.3	5.1				3	1.5	1
			10			5.2	2.5		3	1.5	1
		5.1	8.2					0.8	3	2	3
		4.4	9.4					1	3	2	3
1.7	2.3	5.8							3		
	4.1	5.9		9.8	4.9	3.9			4	2	1
	5.4	7.6		11.3	7	4.5			4	2	1
	4.6	7.1					3.6	2.5	4	2	3
		4.7	7.7	10.8	4.8		2.8		4	3	1
	2.5	4.7	9				2		4	3	2
2	4.1	7.1	9						4	4	
	3.1		7.9			4.8	2.7	2.3	5	1.7	1
		4.1	8			3.4	1.9	0.8	5	2.5	1

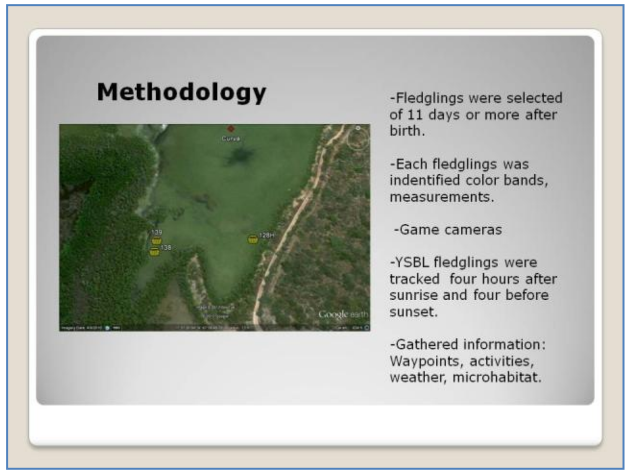
SHINY COWBIRD FEMALE FECUNDITY ESTIMATES. 2012 SWPR

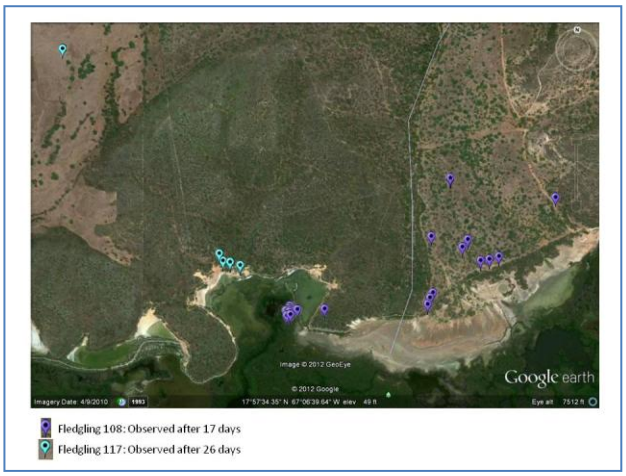
						TOTAL COWBIRD EGGS LAID	
	% reprod F	TOT Ave # EGGs	Clutch size	Gap between clutch	Egg/da	YSBB SEASON (Apr-Jun)	Total Cowbird season (Mar-Sept)
AHY	0.25 (24)	3.14 ± 1.46	1.83 ± 0.55	2.25 ± 1.5	0.39 ± 0.18	7 ± 12	24 ± 43
		1-5	1-2.5	1-4	0.13 - 0.63	0 - 37	0-131
SY	0.55 (29)	2.53 ± 1.18	1.63 ± 0.70	2.27 ± 1.42	0.32 ± 0.15	11 ± 12	39 ± 41
		1-4	1-3	1-5	0.13 - 0.50	0 - 30	0 - 105
ASY	0.17 (6)	2.50 ± 2.12	4.00	--	0.31 ± 0.27	6 ± 12	22 ± 42
		1-4	4		0.13 - 0.50	0 - 30	0 - 30
Total	0.38 (59)	2.69 ± 1.29	1.78 ± 0.81	2.27 ± 1.39	0.34 ± 0.13	9 ± 12	31 ± 42
		1-5	1-4	1-5	0.13 - 0.63	0-37	0-131

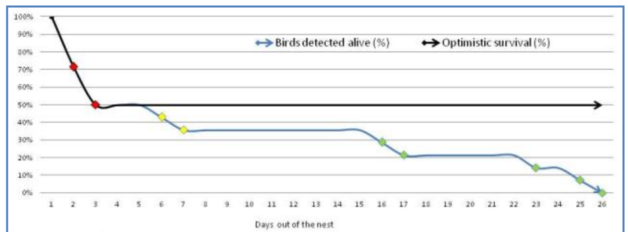


YSBL Fledging Survival (Roseanne Medina-Miranda, PRDNER)









Dead or undetected but probably survive	Days out of nest	Observations
4D	2	Except the carcass of bird 121VO found on a low branch, the others were found in the mud/water (Example bird 118VW, Example bird 119OB & Example bird 114RR).
3D	3	All found in the mud/water. Some very cryptic, therefore difficult to observed in the mud (example bird 110OY).
1Ups	6	Bird 101WY was settled at the end of the season when most birds were flying away from the breeding ground. This bird probably survives and it was out of range.
1Ups	7	Bird 100RO did not have transmitter. Parents disabled the transmitters left it in the nest. It was flying in a huge flock, both siblings survive for at least over 15 day. This bird probably survives.
1Ups	16	Bird 116WR or WO did not have transmitter. Parents disabled the transmitters and left it in the nest.
1Ups	17	Bird 108PB or OG, Sibling of 100RO & 116WR or WO. Transmitter recovered 6/4/12. Parents helped in disabling the jacket.
1Ups	23	Bird 103WW. Sibling of 112WY. Out of range
1Ups	25	Bird 113VG. Sibling of 117BW. Out of range
1Ups	26	Bird 117BW. Sibling of 113VG. Out of range


Bird 121VO

Bird 101WY

Bird 116

Bird 100RO

Bird 110

Bird 103WW


Bird 119OB


Bird 116WR


Bird 108PB

YSBL Genetic Diversity and Extra-pair Mating (Irene Liu, Duke University)

Extra-pair mating and genetic diversity in yellow-shouldered blackbirds

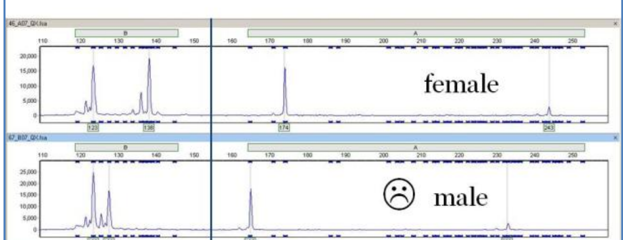
Irene Liu
Duke University
29 August 2012

Agelaius blackbirds

Questions

What is the rate of extra-pair mating in YSBL?
What is the genetic health of the population?
- Pairwise relatedness
- Evidence of bottleneck
- Effective population size
- Allelic diversity
- Heterozygosity
- Inbreeding

Detecting extra-pair young



EPP rates in RWBL vs. YSBL

	Extra-pair young	%	Nests with ≥1 EPY	%
RWBL				
Bahamas	16/57	28	10/20	50
Canada	31/111	28	14/31	45
KY	593/1479	40	295/537	55
MI	50/147	34	22/44	50
NY	55/232	24	28/68	41
PA	23/90	26	13/28	46
WA	136/403	35	72/134	54
WI	33/100	33	21/35	60
	Weighted $\bar{x}$ = 35.8 ± 5.6		**Weighted $\bar{x}$ = 52.9 ± 4.4**	
YSBL				
Puerto Rico	20/87	23	11/30	37
	GLM (binomial), z = -1.94, P = 0.053		**z = -1.67, P = 0.095**	

Questions

What is the rate of extra-pair mating in YSBL?

What is the genetic health of the population?

- Pairwise relatedness
- Evidence of bottleneck
- Effective population size
- Allelic diversity
- Heterozygosity
- Inbreeding

YSBL population genetics

Metric	Method	Estimate
Pairwise relatedness	Lynch and Ritland (1999) matrix	r = -0.06 ± 0.08 (range: -0.20-0.47)
Evidence of bottleneck	M-ratio	No evidence
Effective population size	$\theta = 4N_e\mu$	N_e = 336 birds*

YSBL genetic diversity

Locus	N	N_a	N_e	H_{obs}	H_{exp}	F_{IS}
Aph54	80	8	4.64	0.85	0.78	-0.08
LTMR6	80	3	2.92	0.68	0.66	-0.03
Qm10	80	13	8.31	0.85	0.88	0.03
Dpu16	80	3	2.11	0.55	0.53	-0.05
Ap38	80	5	3.33	0.71	0.70	-0.02
Pca3	80	3	1.79	0.41	0.44	0.06
Ap107	80	13	8.07	0.90	0.88	-0.03
Ap144	80	8	3.88	0.74	0.74	0.01
Ap79	80	2	2.00	0.48	0.50	0.05
Mean	80	**6.44**	**4.11**	**0.68**	**0.68**	**-0.01**
SE	--	1.43	0.83	0.06	0.05	0.02

Comparison with Bahamas RWBL

Locus	N	N_a	N_e	H_{obs}	H_{exp}	F_{IS}
Aph54	66	28	14.21	0.92	0.93	0.01
LTMR6	66	6	2.39	0.55	0.58	0.06
Qm10	66	6	2.88	0.68	0.65	-0.04
Dpu16	66	5	2.92	0.65	0.66	0.01
Pca3	66	2	2.00	0.52	0.50	-0.03
Ap107	66	22	11.34	0.94	0.91	-0.03
Ap144	66	18	11.27	0.82	0.91	0.10
Ap79	66	8	4.87	0.79	0.79	0.01
Mean	66	**10.60**	**5.80**	**0.72**	**0.73**	**0.01**
SE	--	2.78	1.45	0.05	0.05	0.01

Summary

The bad news

- Low allelic diversity (at microsat loci)
- Low effective population size

The good news

- Extra-pair mating maintains diversity
- Expected levels of heterozygosity
- Little evidence of inbreeding
- No evidence of recent bottleneck
- 169 DNA samples for future analyses

Recommendations

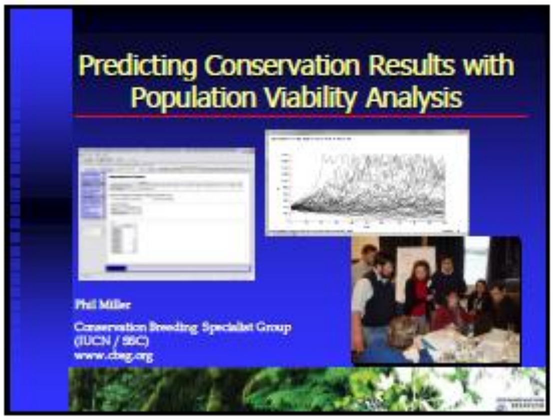
Multigenerational sampling: collect blood samples when banding chicks to better estimate N_e (or N_b)

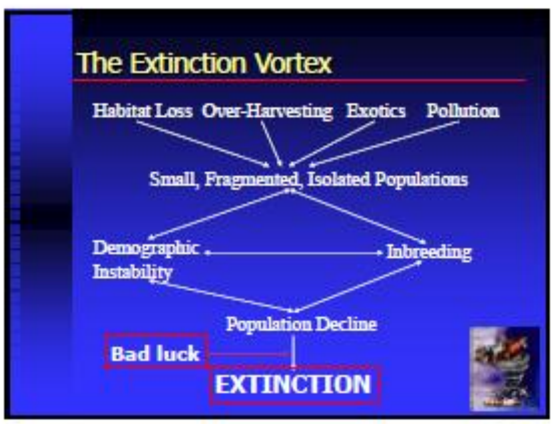
Pedigrees: combine banding and relatedness data to examine dispersal of kin

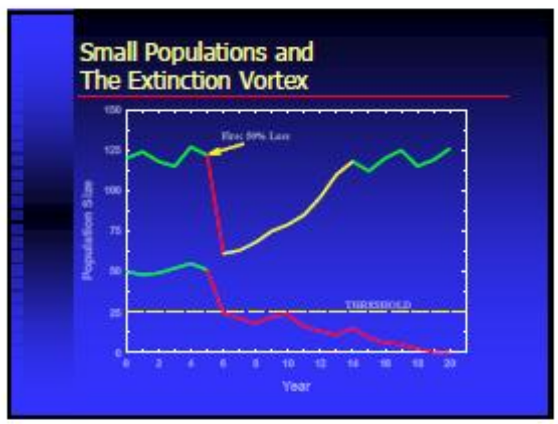
Sampling across multiple populations

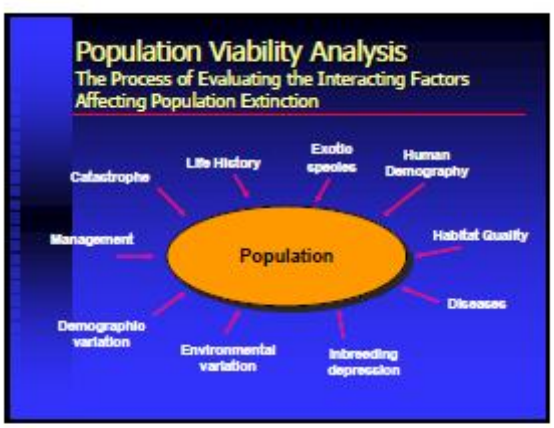
- Examine population structure (F_{ST} values, clusters, pop. pairwise relatedness)
- Compare all values from current analysis

Predicting Conservation Results with Population Viability Analysis (Phil Miller, CBSG)

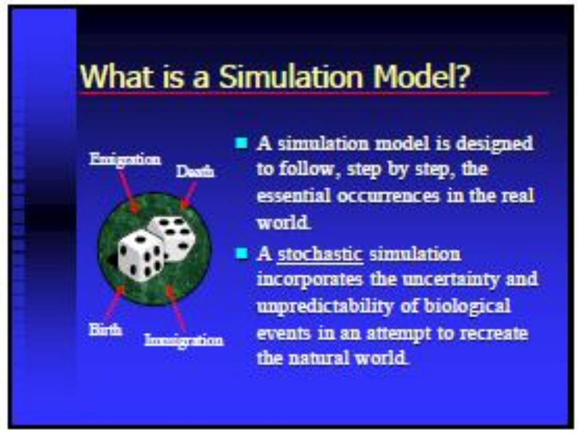


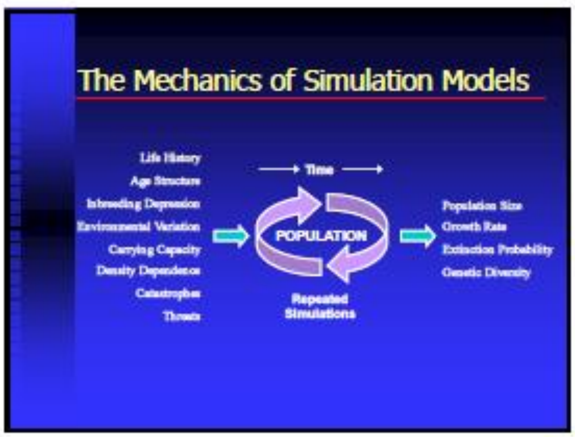


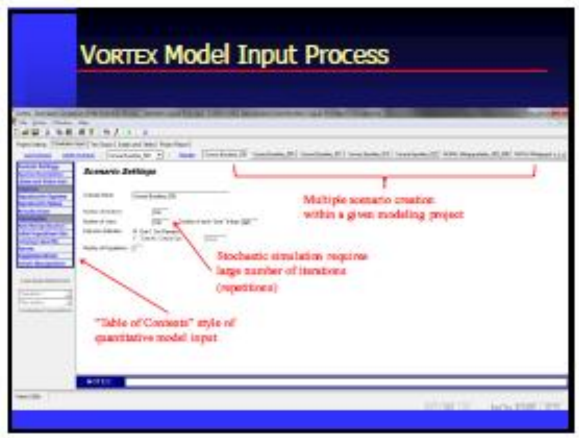


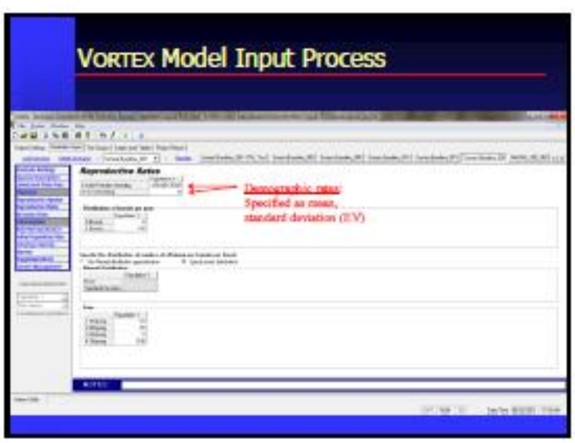


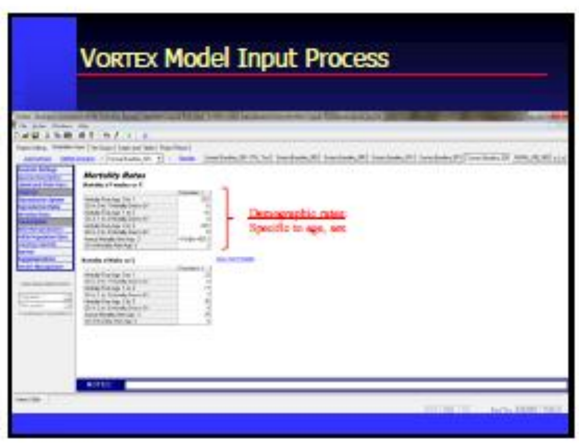

Vortex 9.99b
A stochastic simulation of the extinction process
Click graphic and enter program
Copyright 2009 Chicago Zoological Society

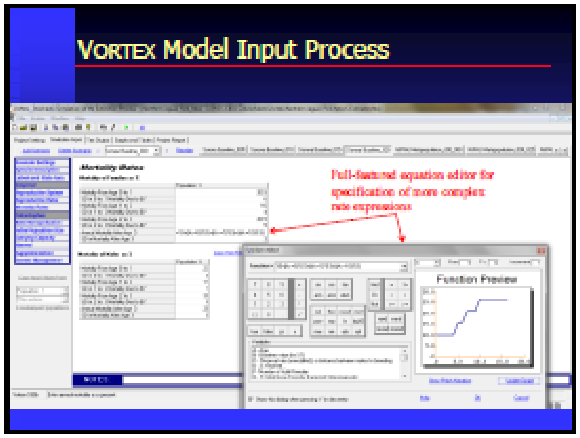

What is a Simulation Model?
Emigration
Death
Birth
Immigration
A simulation model is designed to follow, step by step, the essential occurrences in the real world.
A stochastic simulation incorporates the uncertainty and unpredictability of biological events in an attempt to recreate the natural world.

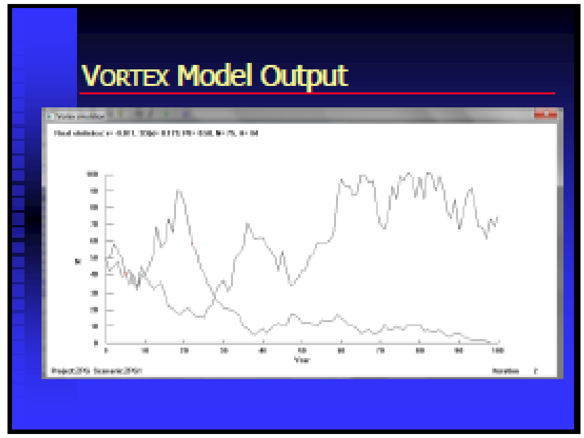

The Mechanics of Simulation Models
Life History
Age Structure
Inbreeding Depression
Environmental Variation
Carrying Capacity
Density Dependence
Catastrophes
Threats
Time
POPULATION
Repeated Simulations
Population Size
Growth Rate
Extinction Probability
Genetic Diversity

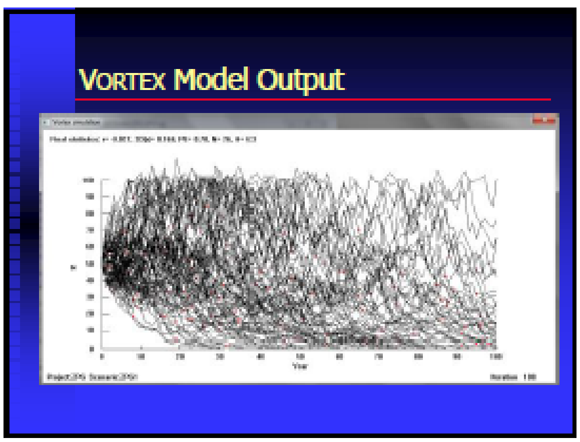

VORTEX Model Input Process
Scenario Settings
Multiple scenario creation within a given modeling project
Stochastic simulation requires large number of iterations (repetitions)
"Table of Contents" style of quantitative model input

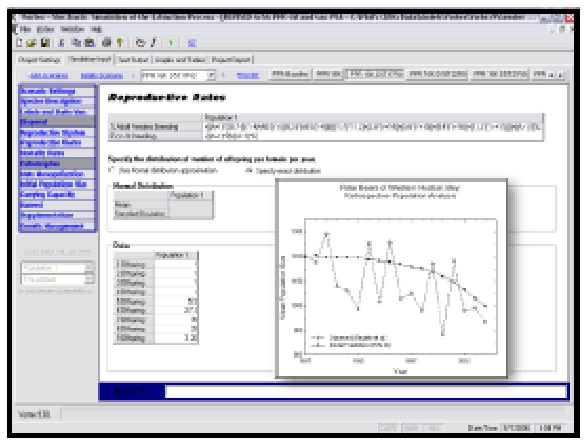

VORTEX Model Input Process
Reproductive Rates
Demographic rates: Specified as mean, standard deviation (EV)

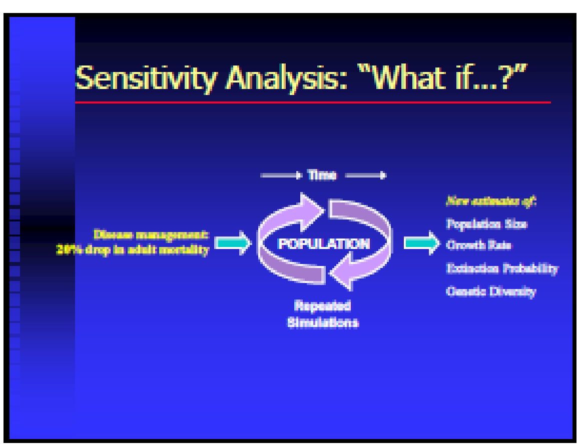

VORTEX Model Input Process
Mortality Rates
Demographic rates: Specific to age, sex

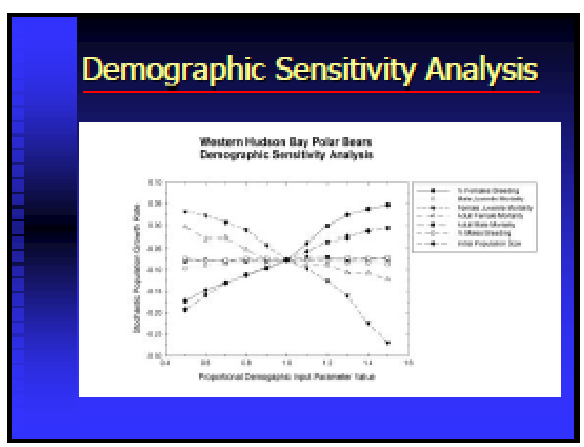

VORTEX Model Input Process
Full-featured equation editor for specification of more complex rate expressions
Function Preview

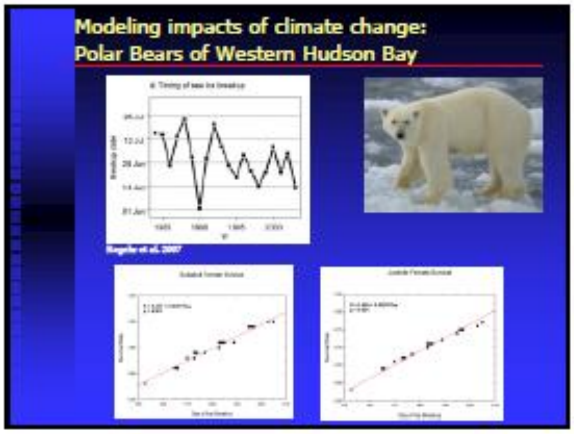

VORTEX Model Output

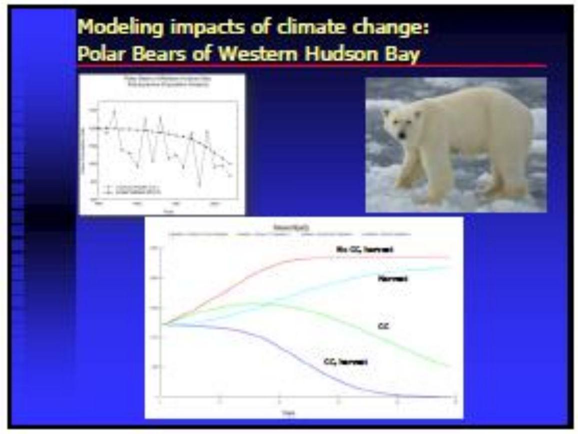

VORTEX Model Output


Reproductive Rates

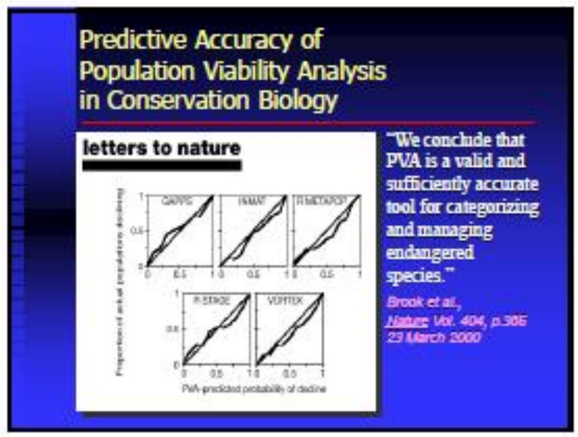

Sensitivity Analysis: "What if…?"
Time
Disease management:
20% drop in adult mortality
POPULATION
Repeated Simulations
New estimates of:
Population Size
Growth Rate
Extinction Probability
Genetic Diversity


Demographic Sensitivity Analysis
Western Hudson Bay Polar Bears
Demographic Sensitivity Analysis
Stochastic Population Growth Rate
Proportional Demographic Input Parameter Value


Modeling impacts of climate change:
Polar Bears of Western Hudson Bay
Regehr et al. 2007

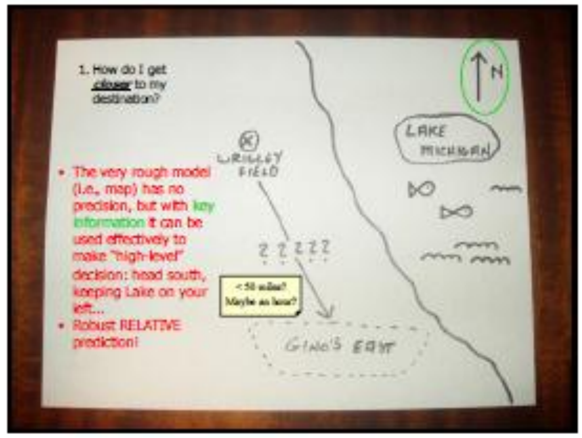

Modeling impacts of climate change:
Polar Bears of Western Hudson Bay
No CC, harvest
Harvest
CC
CC, harvest


The Science
of PVA
Quantitative Methods for Conservation Biology
2000
2002
VIABLE POPULATIONS FOR CONSERVATION
1987
QUANTITATIVE CONSERVATION BIOLOGY
2002


Predictive Accuracy of
Population Viability Analysis
in Conservation Biology
letters to nature
GAPPS
INMAT
RAMAS/METAPOP
RAMAS/STAGE
VORTEX
PVA-predicted probability of decline
Proportion of actual population declining
"We conclude that PVA is a valid and sufficiently accurate tool for categorizing and managing endangered species."
Brook et al.,
Nature Vol. 404, p.385
23 March 2000


The Art
of PVA
Let's take a drive to Chicago…
But what happens if our understanding of the system isn't very good?
Can PVA still be a useful tool for species conservation??


Our dilemma…
How do I get from Wrigley Field (near Northside) to Gino's East Pizzeria (downtown)?
What's the fastest route I can take?



So…Why Conduct a PVA??

- To make RELATIVE predictions from complicated data about complicated and uncertain processes.
- To test alternative scenarios of our future – management changes, climate changes, emerging threats, etc.
- To clarify scientific ignorance and the costs of that ignorance to successful management.
- To stimulate conversation between (often divergent) parties involved in species conservation.

Therefore…

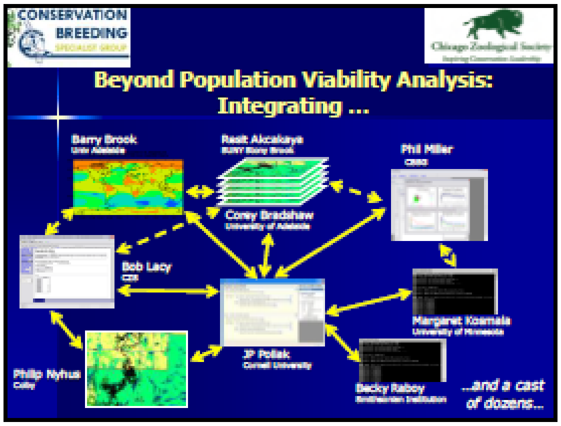
- To make more informed (i.e., <u>better</u>) decisions.

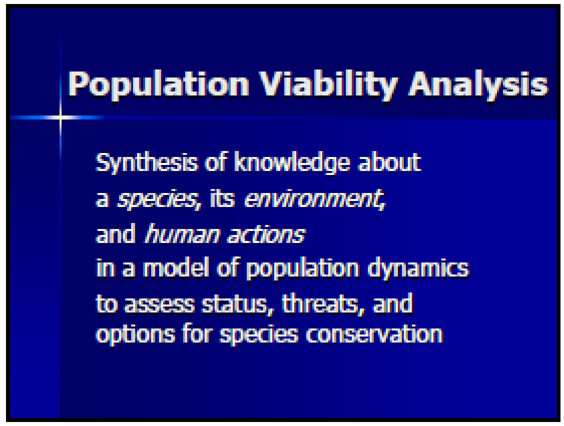
PVA and Decision Analysis

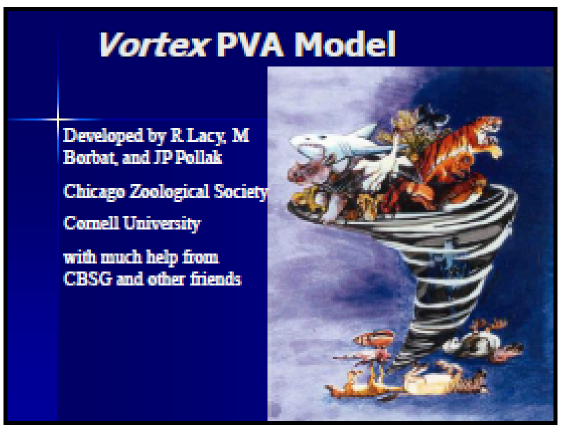
	Possible Environmental States		
	State 1	State 2	State 3
Management Scenario 1	Outcome 1,1	Outcome 1,2	Outcome 1,3
Management Scenario 2	Outcome 2,1	Outcome 2,2	Outcome 2,3
Management Scenario 3	Outcome 3,1	Outcome 3,2	Outcome 3,3

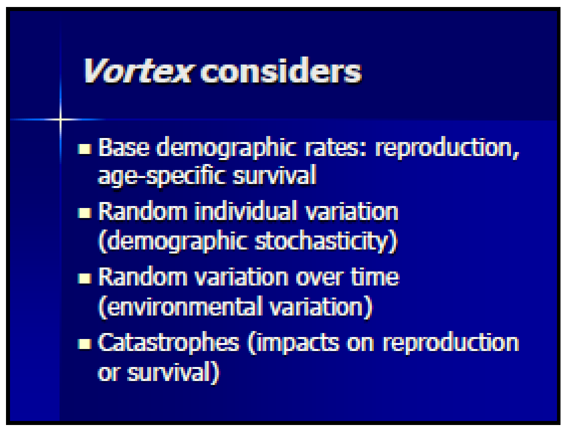
- Our uncertainty is represented by a set of "hypotheses" concerning the state of the population / habitat under analysis
- Individual cells contain the outcome of applying a given management strategy under a given set of proposed environmental conditions
- Ideally, some scenarios will be superior to others across all described states; i.e. management is not impaired by our lack of knowledge regarding population behavior.

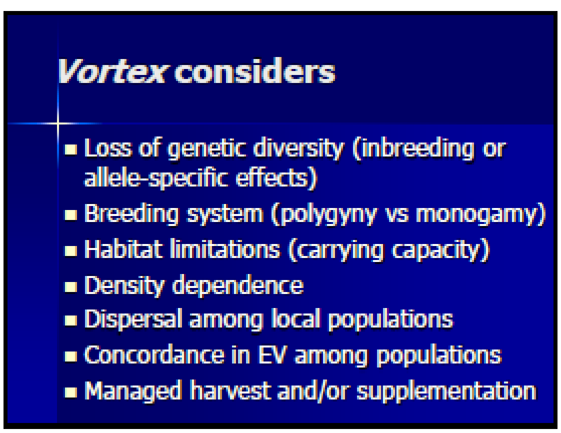
Beyond Population Viability Analysis: Integrating Models into MetaModels (Bob Lacy, CBSG)

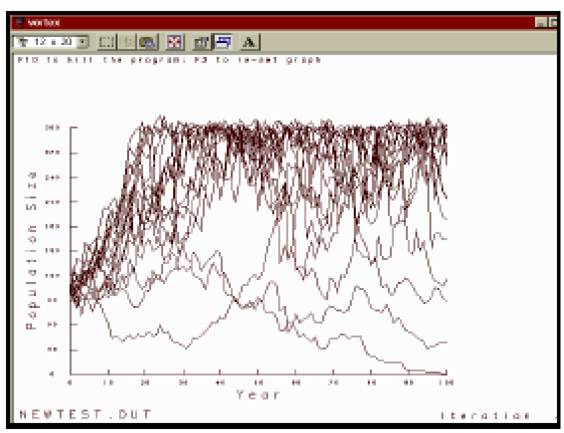


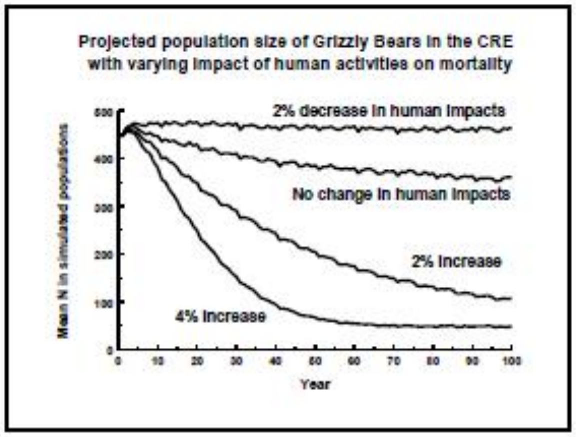








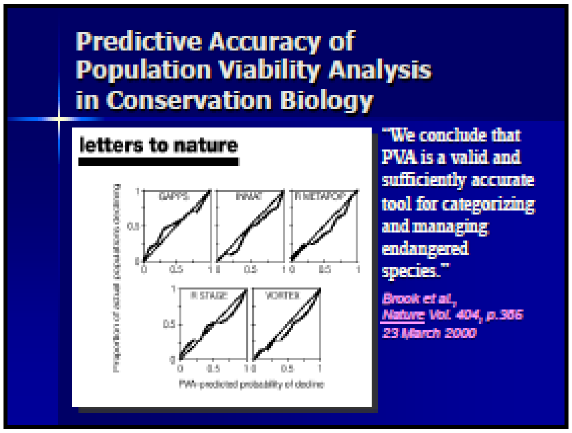


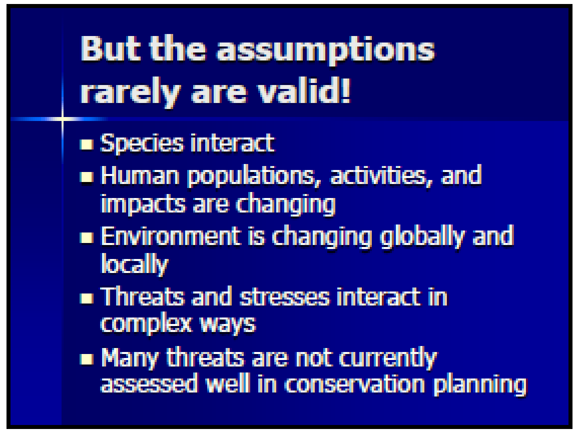


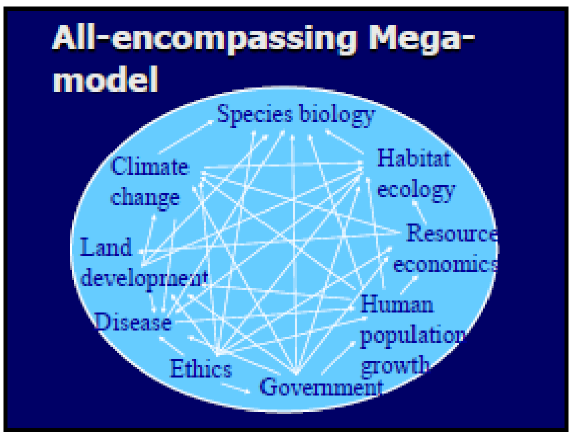
Existing ("standard PVA") models for wildlife risk assessment

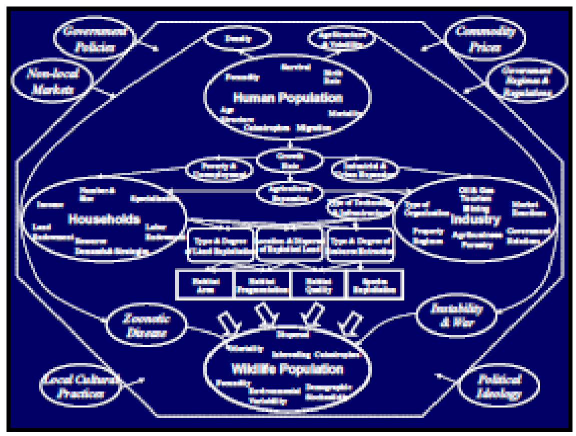
- Single-species
- Assume constancy of impacts of humans
- Assume constancy of environment
- Lack of complex interactions among stresses
- Model only threats that have been observed and parameterized

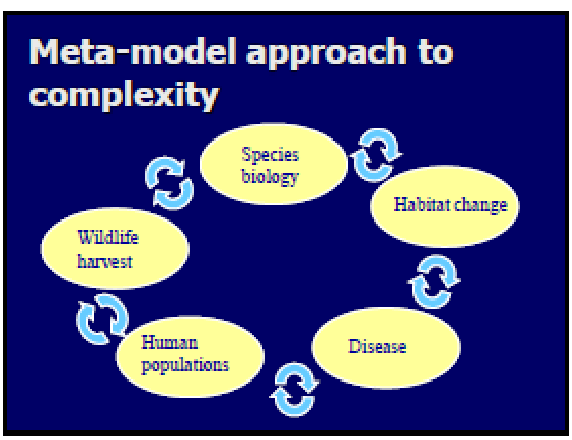
- Work well when above assumptions hold

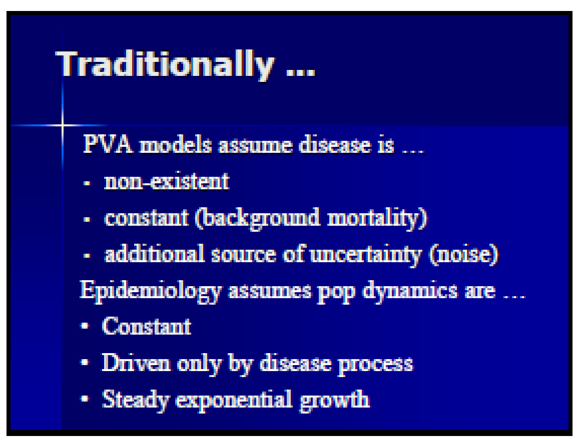

Predictive Accuracy of Population Viability Analysis in Conservation Biology
letters to nature
"We conclude that PVA is a valid and sufficiently accurate tool for categorizing and managing endangered species."
Brook et al., Nature Vol. 404, p.385 23 March 2000


But the assumptions rarely are valid!
Species interact
Human populations, activities, and impacts are changing
Environment is changing globally and locally
Threats and stresses interact in complex ways
Many threats are not currently assessed well in conservation planning


All-encompassing Mega-model
Species biology
Climate change
Habitat ecology
Land development
Resource economics
Disease
Human population growth
Ethics
Government


Government Policies
Commodity Prices
Non-local Markets
Human Population
Households
Industry
Zoonotic Disease
Instability & War
Wildlife Population
Local Cultural Practices
Political Ideology


Meta-model approach to complexity
Species biology
Habitat change
Wildlife harvest
Human populations
Disease

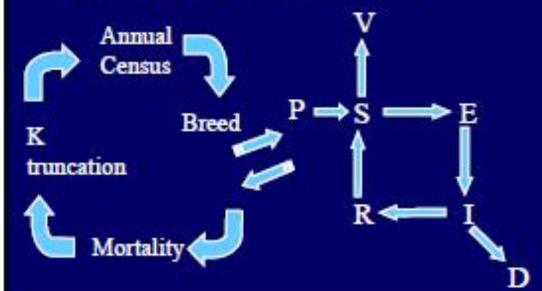

Traditionally ...
PVA models assume disease is …
non-existent
constant (background mortality)
additional source of uncertainty (noise)
Epidemiology assumes pop dynamics are …
Constant
Driven only by disease process
Steady exponential growth

Hypotheses about PVA-Epidemiology linkage

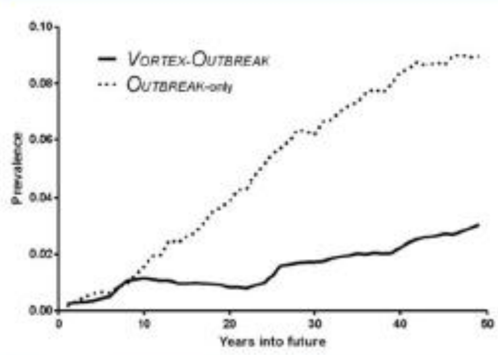
Linking will …

- Lead to different projections of overall dynamics than obtained from either in isolation
- Lead to different dynamics of disease than when details of population model are omitted
- Lead to different dynamics of the population than when details of disease are omitted
- Lead practitioners on both sides to a richer understanding of their fields

Linkage of Vortex with Outbreak



Data flow between Outbreak and Vortex

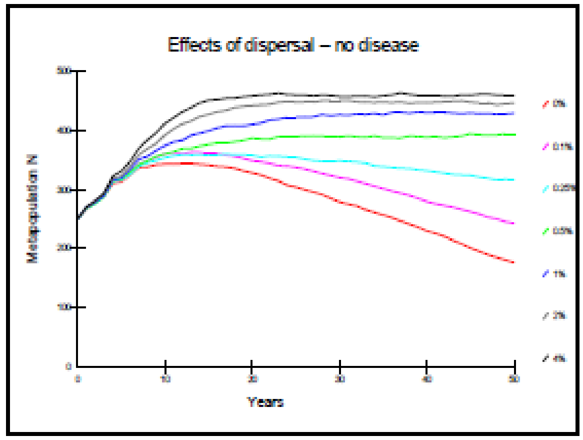


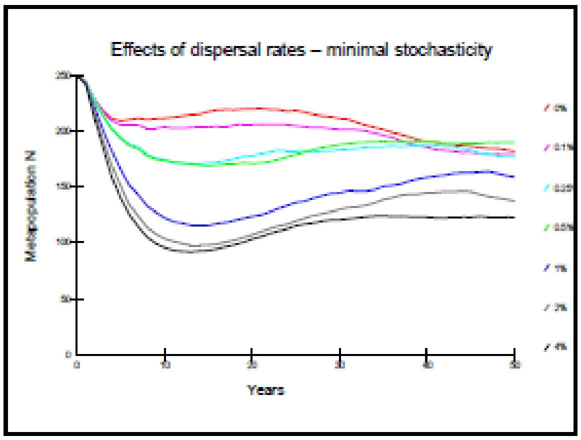
Demography-Disease Interactions matter!

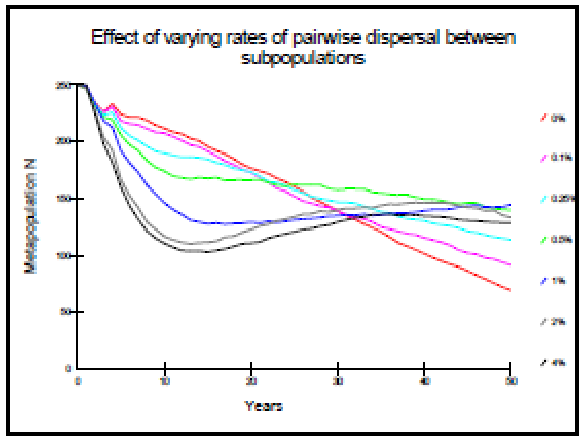
- Disease prevalence different
  - Likely detectable vs not
- Monitoring works if population constant and spatially homogeneous – but it isn't!
- Demographic variables more important than disease variables in determining prevalence – e.g., age of breeding
- Spatial models and management are needed

Is population fragmentation good or bad?

- Population ecologist: Dispersal helps to stabilize the metapopulation by leveling out the fluctuations in isolated populations, and allowing recolonization
- Wildlife veterinarian: Connectivity is bad because it allows spread of disease
- Evolutionary geneticist: It all depends – dispersal prevents inbreeding but also can disrupt local adaptation



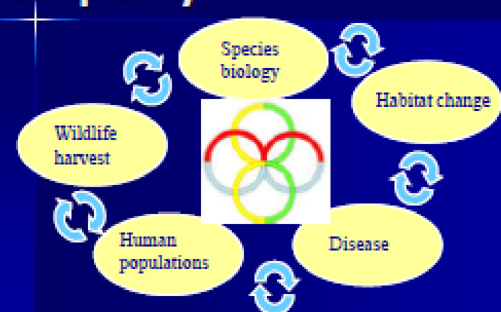


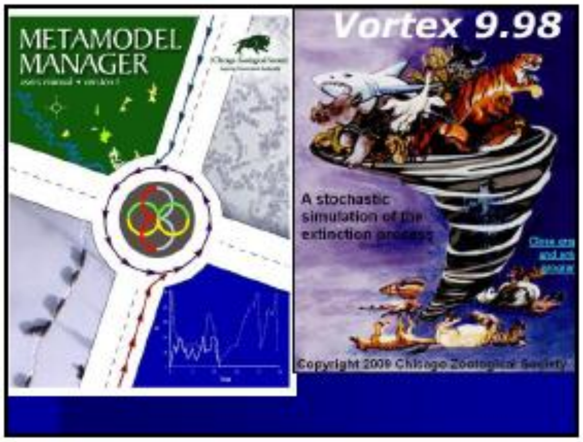


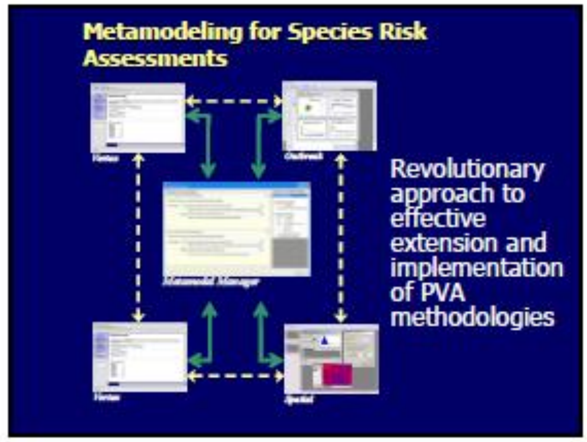
Interactions among population processes and threats matter!

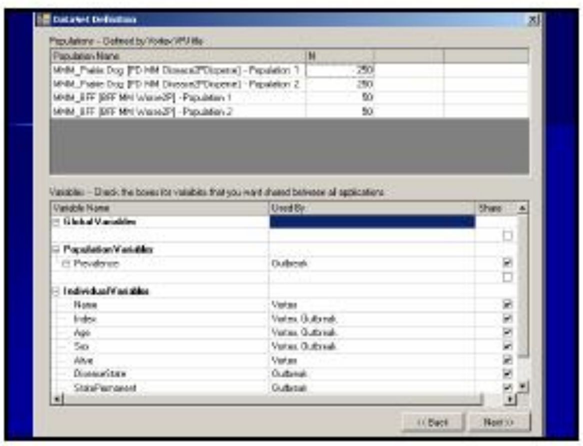
… and they are very hard to predict

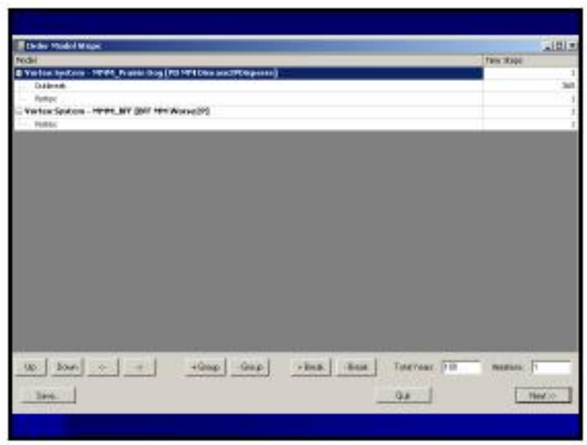
Meta-model approach to complexity

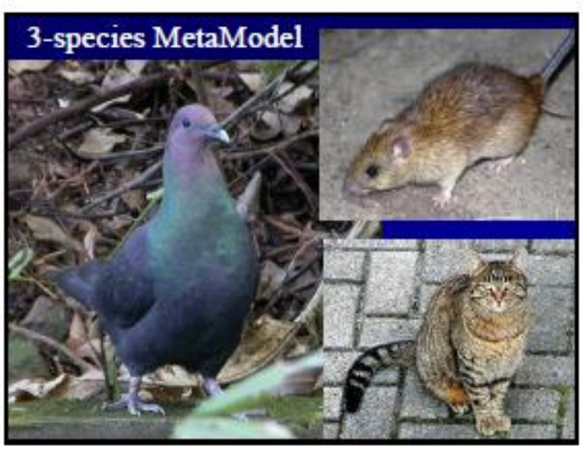


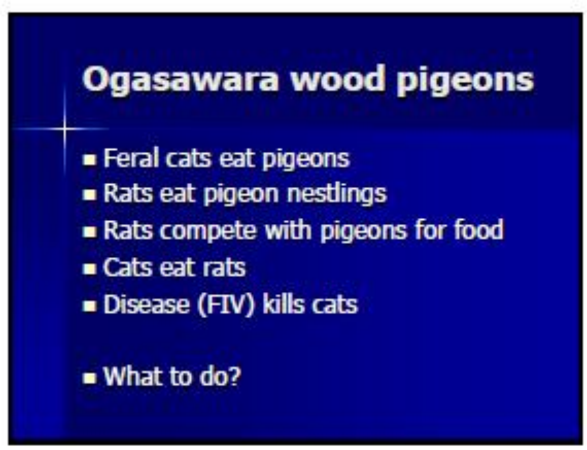

METAMODEL MANAGER
Vortex 9.98
A stochastic simulation of the extinction process
Copyright 2009 Chicago Zoological Society

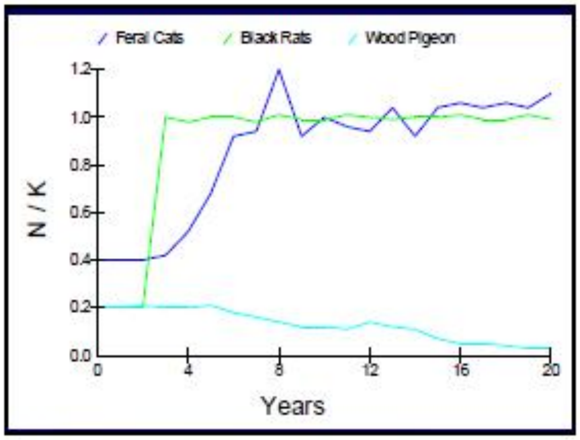

Metamodeling for Species Risk Assessments
Metamodel Manager
Revolutionary approach to effective extension and implementation of PVA methodologies

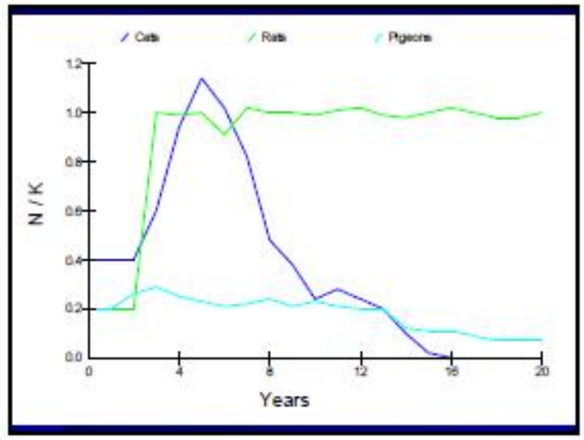


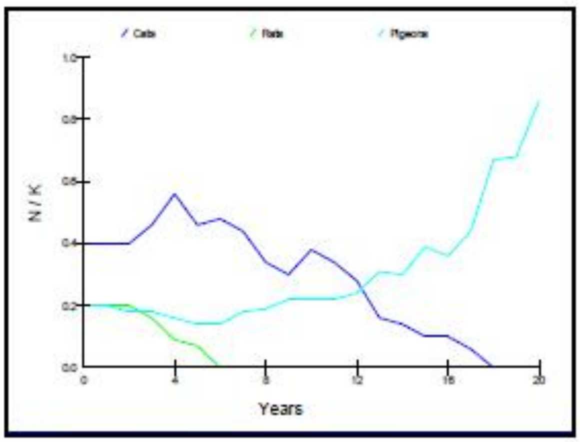


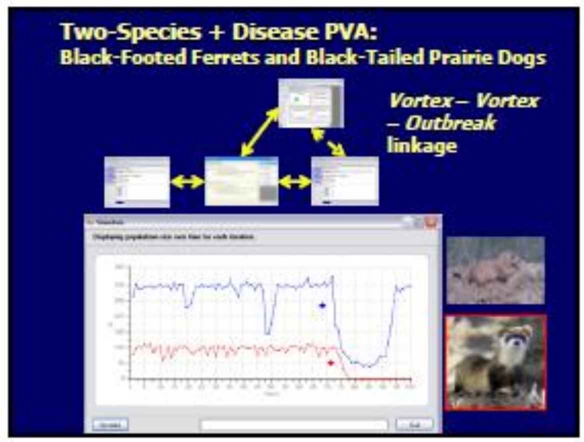

3-species MetaModel

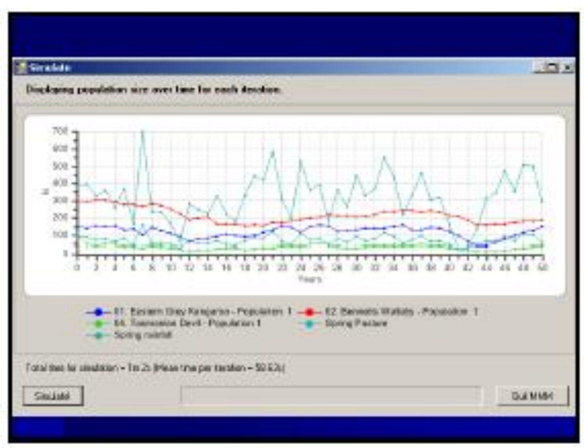

Ogasawara wood pigeons
Feral cats eat pigeons
Rats eat pigeon nestlings
Rats compete with pigeons for food
Cats eat rats
Disease (FIV) kills cats
What to do?

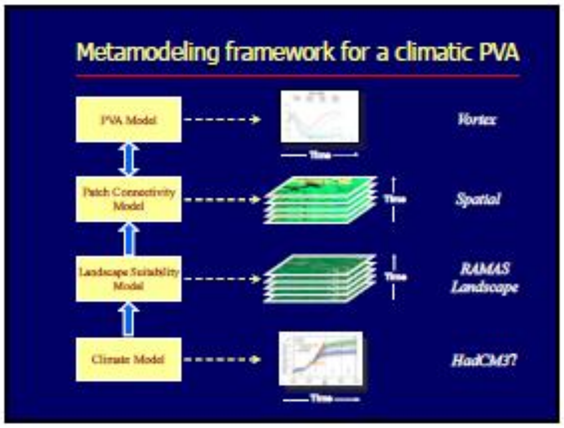

Feral Cats
Black Rats
Wood Pigeon
N / K
Years

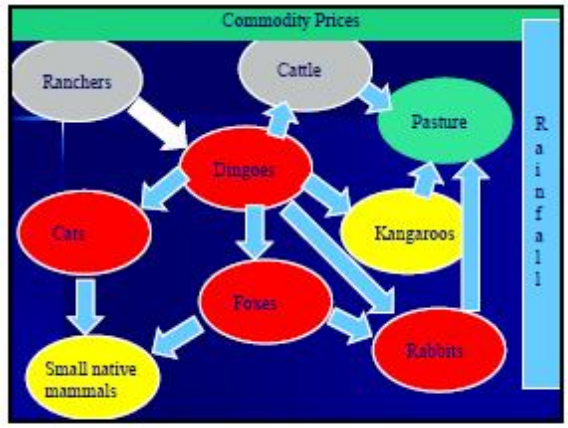

Cats
Rats
Pigeons
N / K
Years


Cats
Rats
Pigeons
N / K
Years


Two-Species + Disease PVA:
Black-Footed Ferrets and Black-Tailed Prairie Dogs
Vortex – Vortex – Outbreak linkage


Displaying population size over time for each iteration.
Years





Does it work?

- Technical programming – yes
- Provide better models and projections?
  - Rather than chaos
- Provide better understanding of complex systems?
  - Rather than confusion
- Provide useful tool for conservation and management?
- Lead to more conservation success?

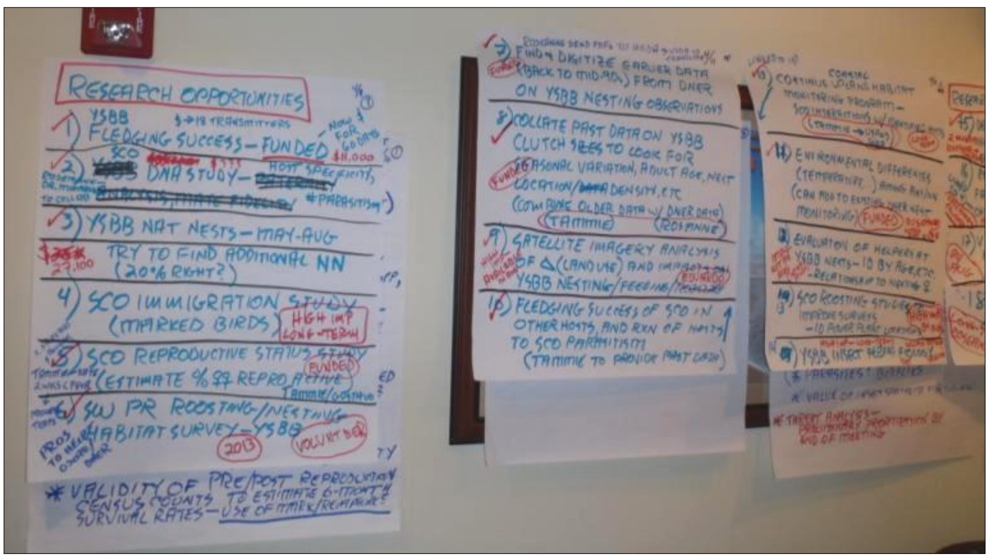
Possible outcomes

- Robust metamodel representing the system well, producing confident projections to guide management
- Plausible metamodel, providing guidance for adaptive management
- Basis for exploring possible effects
- Means to identify key gaps in our understanding
- Inadequate knowledge to proceed
- Confusion

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico
28 – 31 August 2012

Final Report



APPENDIX IV

Summaries of PVA Workshops

Summaries of Previous PVA Workshops

YSBL/SHCO PVA Meeting I, January 2012, Boquerón, PR – Executive Summary

Hilda Diaz-Soltero, USDA, explained the "USDA Program on Invasives Causing Extinction (ICE)." As part of ICE, this is the first of a series of meetings to use the Population Viability Analysis (PVA) and the new MetaModel analysis tools and apply them to a pair of species, one endangered (yellow-shouldered blackbird (YSBL)) and one invasive (shiny cowbird (SHCO)) impacting the endangered species and driving it to extinction. This is an effort to develop a new tool for science that will enhance our ability to look at the impact of an invasive species to a threatened species, and ultimately, help us manage the invasive species to enhance the protection of the endangered species and conserve biodiversity.

- Dr. Phil Miller and Dr. Robert Lacy explained the PVA process and the *VORTEX* model used by CBSG.
- Participants provided their knowledge and experience to input data to populate the SHCO PVA model. Major gaps in knowledge of SHCO biology were identified.
- Participants provided their knowledge and experience to input data to populate the YSBL PVA model. Some gaps in knowledge of YSBL biology were identified.
- The group suggested additional research of the literature was needed. Eduardo Ventosa was tasked to work with Eileen Welch, APHIS librarian, to identify the literature on both the SHCO and YSBL and provide the information in the literature that could fill the data gaps in each one of the species PVAs. USDA provided time and funds for this essential part of the effort.
- A decision was made to create a DROPBOX for the project to host minutes of the meetings and literature review documents.
- Some ideas for management of the YSBL and SHCO were discussed.
- The group prepared a list of PVA Questions that should be addressed in later meetings (see list below).

The group decided to have a second meeting in April 2012 with all of the participants from the first meeting and additional participants that were identified to fill gaps in knowledge of SHCO and YSBL essential to complete the data needs for the two species PVA models. USDA agreed to host the meeting, travel and organize the April meeting.

PVA Questions:

1. What factors influence population growth in SHCO? In YSBL?
2. How does recruitment factor in to population growth for YSBL, for SHCO? What is the current recruitment rate for YSBL? For SHCO?
3. How does habitat quality influence population dynamics of the SHCO? Of the YSBL? (former dairy farms habitat availability. Present hay farms…)
4. Is the present SHCO trapping strategy effectively impacting the YSBL? The SHCO? Do better strategies exist (timing, intensity, etc.)?

5. Is the current management strategy enough to support YSBL population viability? YSBL long-term recovery?
6. What is the impact of stopping the current management?
7. Is the current downlisting criteria for YSBL reasonable (to downlist from endangered to threatened species)? What should be the criteria for future planning (next recovery plan)?
8. What is the minimum YSBL population size to achieve population growth?
9. What is the YSBL recruitment rate needed to achieve significant population growth?
10. What role can YSBL captive breeding and reintroduction play? Is it desirable? Consider YSBL population genetics.
11. What role can translocation play? Consider YSBL population genetics.
12. What role can head-starting play in YSBL? Consider YSBL population genetics.
13. Do we have enough data to make good estimates of YSBL/SHCO demography? If no, what is needed? How to prioritize? How to obtain it?
14. Do we need more than one YSBL population? Do we need/want a widespread YSBL distribution?
15. How will climate change in Puerto Rico affect YSBL and SHCO populations and their interactions?
16. What are the effects of rats, white egrets, monkeys on YSBL? The habitat is available but not used by YSBL, why? Are corridors an issue?

YSBL/SHCO PVA Meeting II, April 2012, Boquerón, PR – Executive Summary

Hilda Diaz-Soltero reviewed the USDA Invasives Causing Extinction (ICE) Program and the role of the YSBL –SHCO Population and Habitat Viability Assessment (PHVA) effort in the ICE Program. We welcomed to this meeting and effort three experts in SHCO.

The group provided data and expertise for input to the PVA of the SHCO in the SW Puerto Rico population. Eduardo Ventosa added new parameters for the SHCO PVA discussed in scientific literature that he reviewed.

There were brief discussions on the Mona and Salinas YSBL populations, and the possibility of translocation of YSBL to Vieques to start a new population.

Detailed species interactions between the SHCO and the YSBL were identified and discussed. The group provided data and expertise for input to the PVA of the YSBL in the SW Puerto Rico population. Eduardo added new parameters for the YSBL PVA discussed in scientific literature that he reviewed. Data gaps were identified in the discussion and group members were assigned to identify answers.

It became evident that additional short-term research during the summer was needed before the last (third) meeting of the group in August 2012. Twenty-two projects were identified with goals, project leaders and participants, funding, and results with due dates to populate the YSBL and SHCO PVA models. USDA and CBSG funded projects; USFWS and PRDNER provided in-kind contributions. A summary of the projects follow:

1. Additional staff and equipment to assess fledging success of YSBL.
2. SHCO DNA project: compare YSBL and YW from same female—host specificity, # parasitism (estimate?).
3. YSBL Natural Nests (May to August 2012) - Additional staff to identify more natural nests of YSBL.
4. SHCO Immigration Study (marked birds) - Influx of SHCO to the SW population of SHCO: trap, mark and release birds for immigration of birds. How much influx of SHCO is required to see the observed level of trapping in SW population? **(High importance, long term).**
5. SHCO: Determining reproductive status analysis (estimate of female productivity) (gonad data and study).
6. SW PR roosting/nesting habitat survey (intensive survey of potential areas for YSBL in SW (roosting or nesting). PR Ornithological Society will do six censuses in YSBL season 2013.
7. Find and digitize earlier data (back to mid1990s) from PRDNER on YSBL nesting observations. Get PDFs translated into documents and Excel spreadsheets. Use the same columns as in PRDNER reports. Send product to PRDNER and CBSG for PVA models.
8. Collate the past data on YSBL clutch sizes to look for seasonal variation, adult age, nest location/density, etc. (combine older data w/PRDNER data).

9. Satellite imagery analysis of change (in land use) and impacts on YSBL nesting/ feeding/roosting. Need layers of historical roosting, nesting and feeding areas, home range. **HIGH IMPORTANCE**.
10. Fledging success of SHCO in other hosts, and RxN of hosts to SHCO parasitism. Continue coastal and upland habitat monitoring program—SHCO interactions with identified hosts. **LONG TERM.**
11. Place temperature monitor in ANS (artificial nests) and NN. Add to existing PRDNER nest monitoring work.
12. Who are the potential YSBL helpers that are not breeding? Evaluation of helpers at YSBL nests—how often? Age of helpers? Relationship to nesting female birds they are helping? **IMPORTANT, BUT NOT BEFORE AUGUST 2012. INTENSIVE STUDY, get a graduate student**.
13. SHCO roosting studies to improve surveys: 10 power plant locations. Oscar leader. Ask PR Ornithological Society help in six surveys. **HIGH IMPORTANCE.**
14. YSBL insect feeding ecology (feeding ecology of SHCO: collect fecal from nests to track what they are eating). William Beltran has baseline data on insects in CRNWR used by five insectivorous birds. **HIGH IMPORTANCE, LONG TERM.**
15. Detailed analysis of individual nest recorded to identify the first, last observation dates.
16. Retrospective analysis of factors that may influence changes in YSBL roosting sites. This is linked to project # 9; this project happens after #9 is done. **AFTER AUGUST 2012.**
17. Validation of open/closed nest occupy rates. This project is linked to #8.
18. Additional staff and equipment to assess fledging success of YSBL ($3,600 personnel (CBSG) and $4,680 equipment (USDA)).
19. SHCO DNA project: compare YSBL and YW from same female-host specificity, # parasitism (estimate?).
20. YSBL Natural Nests (May to August 2012) - Additional staff to identify more natural nests YSBL.
21. SHCO Immigration Study (marked birds) - Influx of SHCO to the SW population of SHCO: trap, mark and release birds for immigration of birds. How much influx of SHCO is required to see the observed level of trapping in SW population? **(High importance, long term).**
22. SHCO: Determining reproductive status analysis (estimate of female productivity). Work on gonad data.

Bob Lacy presented a “Baseline April *VORTEX* (PVA) for YSBL,” and the group changed some parameters to see how the PVA would change. Phil Miller presented a “Baseline April *VORTEX* (PVA) for SHCO,” and the group changed some parameters to see how the PVA would change. Bob Lacy made a presentation of the MMM (*METAMODELMANAGER*). Group inserted *VORTEX* PVA for SHCO, inserted *VORTEX* PVA for YSBL, and inserted global variables so the two PVA models could talk to each other (and demonstrate the relationships between the two species). The group discussed metamodel linkages for the SHCO and the YSBL. Bob Lacy did a trial run of the MMM for just 5 yrs, and we could see the populations changes of YSBL and of SHCO every year. More work on the specifics of this MMM will be done in the coming months.

The group prepared a timetable for the rest of the project. A preliminary list of new people to invite to the August 2012 meeting was developed, including the current members and other policy, management and NGO participants.

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

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APPENDIX V

Functional Relationships in the Metamodel

Functional Relationships that Describe the YSBL-SHCO Metamodel

Note: For most readers of this report, the details below that describe the YSBL-SHCO metamodel will not be of interest or important. These details are provided in this report in order to provide more complete documentation of the metamodel that was used to provide the results. Future development and use of this YSBL-SHCO metamodel can build on this framework, and the input files used for our analyses can be made available by the CBSG.

Constant Parameters to be defined for each scenario
left unchanged through years, except if we test a temporal trend (initial, baseline values are given for each parameter):

CBFidelity = 0.75
Proportion of SHCO eggs laid in nests of preferred host species. It is assumed that the "preferred" host is the species by which the SHCO female was itself raised. It is also assumed the other eggs (those not laid in the nests of the preferred host) are dumped into nests of other species at random.

CBEperNest = 1.72
Mean # SHCO eggs per parasitized YSBL nest.

Pref = 1.8
Relative likelihood (preference) of SHCOs parasitizing ANSs vs NNs

pNest = 0.95
Proportion of YSBL females nesting each year (0.95)

nANS = 246
The number of ANSs available for YSBLs

YSBLBroods = 1.46
Mean # YSBL broods / pair

pAC = 1.0
Proportion of ANS broods cleaned of any SHCO eggs or chicks

pNC = 0.75
Proportion of NN broods cleaned of any SHCOs

Fecund = 21.16
Proportion SHCO breeding (0.92) * Eggs/breeding female (23)

pHost0 = 0.004
Initial probability, based on recent numbers, that a SHCO egg from a non-YSBL preferring female will be put in a YSBL nest. Determined from:

- 240 SHCO eggs removed since 2004, on average, from YSBL nests
- 137 pre-breeding census SHCO in YSBL breeding areas
- 137 * 0.46 (females/SHCO) * Fecund = 1333 eggs
- 240 / 1333 = 0.18 (proportion of SHCO eggs in YSBL area that have been laid in YSBL nests)
- 0.18 * 0.022 (proportion of SW PR that is in YSBL breeding areas) = 0.004

Individual Variables describing preference of individual SHCOs for YSBL nests:

Host (1 if raised in YSBL nest; otherwise 0)
Initially = 0
Birth = Host(of dam) * (RAND1 < CBFidelity) + (RAND < pHost /(1-CBFidelity))*(RAND1 < CBFidelity), in which RAND1 is the same random number in both places
Transition = Host [i.e., no change through lifetime]

HostF (Host, but only for adult females – used for determining which female SHCO prefer YSBL nests)
Initially = 0 (i.e., the model starts with the assumption that no SHCO adults were fledged in YSBL nests)
Birth = Host, if adult female; otherwise 0
Transition = HostF

Individual Variables describing properties of individual YSBLs:

momANS (1 if mother used ANS for the brood; used for determining juvenile survival)
Initially = pANS > RAND
Birth = ANS(of dam)
Transition = momANS [i.e., no change]

ANS (1 if individual is using ANS for its broods)
Initially = pANS > RAND
Birth = pANS > RAND
Transition = pANS > RAND
(i.e., each year, a nest site is selected based on the likelihood that a YSBL nest is in ANSs vs NNs)

Global Variables shared between YSBL and SHCO models, calculated each year:
(Note: many variables describing even the YSBLs are calculated in the SHCO model [shown in italics], so that the values can be used to determine the host selection behavior and chick survival of SHCOs.)

SHCO = 7500
Initial total abundance of SHCOs in the metamodel

FYSBL = 194
Initial number of female YSBLs

pHost
Probability a SHCO egg from a non-YSBL preferring female will be placed in a YSBL nest = pHost0 * FYSBL/ FYSBL0, with FSYBL0 = 260.6, the mean number of FYSBL across years for which values going into the pHost0 (=0.004) calculation were determined. This calculation assumes that as the number of FYSBLs in the area goes up or down in the future, that the probability that a SHCO (one not preferring YSBLs) will dump an egg in a YSBL nest will go up or down proportionately.

FSHCO = 3600
Initial abundance of female SHCO

pANS = 0.865
Probability a YSBL pair uses ANS, given as a function of FYSBL and nANS
= nANS*(1-EXP(-0.0154*FYSBL))/YSBL+(nANS*(-0.0119)*EXP(-0.0094*FYSL))

ANSbroods = 233
Number of YSBL broods to be produced in ANS that year.
= pANS * FYSBL * pNest * Broods

NNbroods = 36
Number of YSBL broods to be produced in NN that year.
= (1 – pANS) * FYSBL * pNest * Broods

probANS = 0.921
Probability that a SHCO parasitizes ANS rather than NN.
= 1/(NNbroods/(ANSbroods*Pref)+1)

probNN = 0.079
Probability that a SHCO parasitizes NN rather than ANS.
= 1 - probANS

totP
The total number of SHCO females that prefer YSBL nests.

= sum(HostF)
BroodsPara = 151
Based on eggs laid in YSBL by YSBL-preferring and by non-preferring SHCO
= (totP*CBFidelity+(FSHCO-totP)*pHost)*Fecund/CBEggPerNest
[An additional check is made in the calculations to be sure that this doesn't exceed the number of YSBL broods that year, as can happen if the YSBL population had suddenly crashed to very small numbers (relative to the number of YSBL-preferring SHCO in the area)]

pN = 0.33
Probability an NN brood is parasitized.
= BroodsPara / (Pref * ANSbroods + NNbroods)

pA = 0.60
Probability an ANS brood is initially parasitized.
= Pref * pN

pNadj
= pN adjusted if there are not enough ANS broods to accommodate the SHCO that would otherwise have been calculated to parasitize ANS broods. If such an adjustment is needed, it is assumed that all ANS are parasitized and then enough NN are parasitized to account for the total BroodsPara.

pAadj
= pA adjusted if there are not enough NN broods to accommodate the SHCO that would otherwise have been calculated to parasitize NN broods. If such an adjustment is needed, it is assumed that all NN are parasitized and then enough ANS are parasitized to account for the total BroodsPara.

<u>Population Variables describing YSBL rates that do not need to be shared with the SHCO PVA model</u>

relSurv = 0.41
Relative survival of nestlings in parasitized nests compared to non-parasitized nests.

pAPeff
Probability that an ANS is effectively parasitized (not cleaned)
= pAadj * (1-pAC)

pNPeff
Probability that an NN is effectively parasitized (not cleaned)
= pNadj * (1-pNC)

survA
Multiplicative 0-1 survival factor to account for parasitism

= pAPeff * relSurv + (1 – pAPeff)
survN
= pNPeff * relSurv + (1 – pNPeff)

surv1 = 0.61
Annual post-fledging survival rate

Mortality from 0 to 1 year
= 100 – [surv1*((momANS=0)*0.42*survN + ((momANS=1)*0.46*survA)]
[0.42 and 0.46 are the fledging rates for NN and ANS nests, respectively]

Variables describing SHCO recruitment from YSBL nests:

survSC
= % survival of SHCO from egg to 1 year
Density dependent function, with maximum at 10% and minimum at 6.15%, steeply declining as N gets very close to K
= 10-((10-6.15)*((N/K)^24))

relSHCOSurv = 0.02
Relative Age 0-1 survival of SHCO that parasitize YSBL (i.e., Host =1)
= probANS* (1-pAC)+probNN* (1-pNC)

Mortality from 0 to 1year
= 100-survSC*[(Host=0) + relSHCOsurv*(Host=1)]

Some Notes about How the Metamodel was Constructed

The SHCO *VORTEX* model simulates its year before the YSBL model goes through its year. In the SHCO *VORTEX* model, a number of variables need to be calculated at the beginning of each year to define the number of YSBL nests, proportion of nests in ANSs vs NNs, number of YSBL broods parasitized, and the probability that any ANS or NN brood is parasitized. Therefore, these values are calculated in the SHCO model before breeding occurs each year, so that the values will be available to both the SHCO and YSBL models to determine breeding and survival rates.

These various rates are determined by the number of SHCO females present at the beginning of each year, and the proportion of these that have a host preference for YSBL (because of being raised in a YSBL nest) vs preferring some other host species (see López-Ortiz *et al*. 2006 re: SHCO imprinting). Therefore, the calculations on these numbers need to be made before the breeding for that year is simulated in *VORTEX*. (In *VORTEX* terminology, this means that the updating of state variables must be done each year after EV is determined, but before Breeding is invoked.) However, the "population state variables" for the SHCO model are used to keep tallies of a number of measures of SHCO population dynamics (such as N, N/K, # preferring YSBL). Therefore, these variables need to be updated at the end of each year of the simulation, so that they are reporting the current values. (In *VORTEX* terminology, this means that PSvars must go through a second update after all demographic events of the year are completed.)

Yellow-Shouldered Blackbird / Shiny Cowbird Population and Habitat Viability Assessment Workshop

Mayagüez, Puerto Rico
28 – 31 August 2012

Final Report

APPENDIX VI

Introduction to CBSG Processes

CBSG Workshop and Training Processes

Information on capabilities of the Conservation Breeding Specialist Group (CBSG/SSC/IUCN)

Introduction

There is a lack of generally accepted tools to evaluate and integrate the interaction of biological, physical, and social factors on the population dynamics of threatened species and populations. There is an urgent need for tools and processes to characterize the risk of species and habitat extinction, on the possible impacts of future events, on the effects of management interventions, and on how to develop and sustain learning-based cross-institutional management programs.

The Conservation Breeding Specialist Group (CBSG) of IUCN's Species Survival Commission (SSC) has more than 15 years of experience in developing, testing and applying a series of scientifically-based tools and processes to assist risk characterization and species management decision making. These tools, based on small population and conservation biology (biological and physical factors), human demography, and the dynamics of social learning are used in intensive, problem-solving workshops to produce realistic and achievable recommendations for both *in situ* and *ex situ* population management.

Our workshop processes provide an objective environment, expert knowledge, and a neutral facilitation process that supports sharing of available information across institutions and stakeholder groups, reaching agreement on the issues and available information, and then making useful and practical management recommendations for the taxon and habitat system under consideration. The process has been remarkably successful in unearthing and integrating previously unpublished information for the decision making process. Their proven heuristic value and constant refinement and expansion have made CBSG workshop processes one of the most imaginative and productive organizing forces for species conservation today (Conway 1995; Byers and Seal 2003; Westley and Miller 2003).

Integration of Science, Management, and Stakeholders

The CBSG PHVA Workshop process is based upon biological and sociological science. Effective conservation action is best built upon a synthesis of available biological information, but is dependent on actions of humans living within the range of the threatened species as well as established national and international interests. There are characteristic patterns of human behavior that are cross-disciplinary and cross-cultural which affect the processes of communication, problem-solving, and collaboration: 1) in the acquisition, sharing, and analysis of information; 2) in the perception and characterization of risk; 3) in the development of trust among individuals; and 4) in 'territoriality' (personal, institutional, local, national). Each of these has strong emotional components that shape our interactions. Recognition of these patterns has been essential in the development of processes to assist people in working groups to reach agreement on needed conservation actions, collaboration needed, and to establish new working relationships.

Frequently, local management agencies, external consultants, and local experts have identified management actions. However, an isolated narrow professional approach which focuses primarily on the perceived biological problems seems to have little effect on the needed political and social changes (social learning) for collaboration, effective management and conservation of habitat fragments or protected areas and their species components. CBSG workshops are organized to bring together the full range of groups with a strong interest in conserving and managing the species in its habitat or the consequences of such management. One goal in all workshops is to reach a common understanding of the state of scientific knowledge available and its possible application to the decision-making process and to needed management actions. We have found that the decision-making driven workshop process with risk characterization tools, stochastic simulation modeling, scenario testing, and deliberation among stakeholders is a powerful tool for extracting, assembling, and exploring information. This process encourages developing a shared understanding across wide boundaries of training and expertise. These tools also support building of working agreements and instilling local ownership of the problems, the decisions required, and their management during the workshop process. As participants appreciate the complexity of the problems as a group, they take more ownership of the process as well as the ultimate recommendations made to achieve workable solutions. This is essential if the management recommendations generated by the workshops are to succeed.

Participants have learned a host of lessons in more than 120 CBSG workshop experiences in nearly 50 countries. Traditional approaches to endangered species problems have tended to emphasize our lack of information and the need for additional research. This has been coupled with a hesitancy to make explicit risk assessments of species status and a reluctance to make immediate or non-traditional management recommendations. The result has been long delays in preparing action plans, loss of momentum, and dependency on crisis-driven actions or broad recommendations that do not provide useful guidance to the managers.

CBSG's interactive and participatory workshop approach produces positive effects on management decision-making and in generating political and social support for conservation actions by local people. Modeling is an important tool as part of the process and provides a continuing test of assumptions, data consistency, and of scenarios. CBSG participants recognize that the present science is imperfect and that management policies and actions need to be designed as part of a biological and social learning process. The workshop process essentially provides a means for designing management decisions and programs on the basis of sound science while allowing new information and unexpected events to be used for learning and to adjust management practices.

Workshop Processes and Multiple Stakeholders

Experience: The Chairman and Program Staff of CBSG have conducted and facilitated more than 260 species and ecosystem workshops in 50 countries. Reports from these workshops are available from the CBSG Office or at *www.cbsg.org*. We have worked on a continuing basis with agencies on specific taxa (e.g., Florida panther, Atlantic Forest primates in Brazil, black-footed ferret) and have assisted in the development of national conservation strategies for other taxa (e.g., Sumatran elephant, Sumatran tiger, Mexican wolf).

Scientific Studies of Workshop Process: The effectiveness of these workshops as tools for eliciting information, assisting the development of sustained networking among stakeholders, impact on attitudes of participants, and in achieving consensus on needed management actions and research has been extensively debated. We initiated a scientific study of the process and its long-term aftermath four years ago in collaboration with an independent team of researchers (Westley and Vredenburg, 2003). A survey questionnaire is administered at the beginning and end of each workshop. They have also conducted extensive interviews with participants in workshops held in five countries. A book detailing our experiences with this expanded approach to Population and Habitat Viability Assessment workshops (Westley and Miller, 2003) will provide practical guidance to scientists and managers on quantitative approaches to threatened species conservation. The study also is undertaking follow up at one and two years after each workshop to assess longer-term effects. To the best of our knowledge there is no comparable systematic scientific study of conservation and management processes. *We would apply the same scientific study tools to the workshops in this program and provide an analysis of the results after the workshop.*

CBSG Workshop Toolkit

Our basic set of tools for workshops include: small group dynamic skills; explicit use in small groups of problem restatement; divergent thinking sessions; identification of the history and chronology of the problem; causal flow diagramming (elementary systems analysis); matrix methods for qualitative data and expert judgments; paired and weighted ranking for making comparisons between sites, criteria, and options; utility analysis; stochastic simulation modeling for single populations and metapopulations; and deterministic and stochastic modeling of local human populations. Several computer packages are used to assist collection and analysis of information with these tools. We provide training in several of these tools in each workshop as well as intensive special training workshops for people wishing to organize their own workshops.

Stochastic Simulation Modeling

Integration of Biological, Physical and Social Factors: The workshop process, as developed by CBSG, generates population and habitat viability assessments based upon in-depth analysis of information on the life history, population dynamics, ecology, and history of the populations. Information on demography, genetics, and environmental factors pertinent to assessing population status and risk of extinction under current management scenarios and perceived threats are assembled in preparation for and during the workshops. Modeling and simulations provide a neutral externalization focus for assembly of information, identifying assumptions, projecting possible outcomes (risks), and examining for internal consistency. Timely reports from the workshop are necessary to have impact on stakeholders and decision makers. Draft reports are distributed within 3-4 weeks of the workshop and final reports within about three months.

Human Dimension: We have collaborated with human demographers in several CBSG workshops on endangered species and habitats. They have utilized computer models incorporating human population characteristics and events at the local level in order to provide projections of the likely course of population growth and the utilization of local resources. This information was then incorporated into projections of the likely viability of the habitat of the threatened species and used as part of the population projections and risk assessments. We are preparing a series of papers on the human dimension of population and habitat viability assessment. It is our intention to further develop these tools and to utilize them as part of the scenario assessment process.

Risk Assessment and Scenario Evaluation: A stochastic population simulation model is a kind of model that attempts to incorporate the uncertainty, randomness or unpredictability of life history and environmental events into the modeling process. Events whose occurrence is uncertain, unpredictable, and random are called stochastic. Most events in an animal's life have some level of uncertainty. Similarly, environmental factors, and their effect on the population process, are stochastic - they are not completely random, but their effects are predictable within certain limits. Simulation solutions are usually needed for complex models including several stochastic parameters.

There are a host of reasons why simulation modeling is valuable for the workshop process and development of management tools. The primary advantage, of course, is to simulate scenarios and the impact of numerous variables on the population dynamics and potential for population extinction. Interestingly, not all advantages are related to generating useful management recommendations. The side-benefits are substantial.

- Population modeling supports consensus and instills ownership and pride during the workshop process. As groups begin to appreciate the complexity of the problems, they have a tendency to take more ownership of the process and the ultimate recommendations to achieve workable solutions.
- Population modeling forces discussion on biological and physical aspects and specification of assumptions, data, and goals. The lack of sufficient data of useable quality rapidly becomes apparent

and identifies critical factors for further study (driving research and decision making), management, and monitoring. This not only influences assumptions, but also the group's goals.

- Population modeling generates credibility by using technology that non-biologically oriented groups can use to relate to population biology and the "real" problems. The acceptance of the computer as a tool for performing repetitive tasks has led to a common ground for persons of diverse backgrounds.
- Population modeling explicitly incorporates what we know about dynamics by allowing the simultaneous examination of multiple factors and interactions - more than can be considered in analytical models. The ability to alter these parameters in a systematic fashion allows testing a multitude of scenarios that can guide adaptive management strategies.
- Population modeling can be a neutral computer "game" that focuses attention while providing persons of diverse agendas the opportunity to reach consensus on difficult issues.
- Population modeling results can be of political value for people in governmental agencies by providing support for perceived population trends and the need for action. It helps managers to justify resource allocation for a program to their superiors and budgetary agencies as well as identify areas for intensifying program efforts.

<u>Modeling Tools:</u> At the present time, our preferred model for use in the population simulation modeling process is called *VORTEX*. This model, developed by Bob Lacy (Chicago Zoological Society), is designed specifically for use in the stochastic simulation of the extinction process in small wildlife populations. It has been developed in collaboration and cooperation with the CBSG PHVA process. The model simulates deterministic forces as well as demographic, environmental, and genetic events in relation to their probabilities. It includes modules for catastrophes, density dependence, metapopulation dynamics, and inbreeding effects. The *VORTEX* model analyzes a population in a stochastic and probabilistic fashion. It also makes predictions that are testable in a scientific manner, lending more credibility to the process of using population-modeling tools.

There are other commercial models, but presently they have some limitations such as failing to measure genetic effects, being difficult to use, or failing to model individuals. *VORTEX* has been successfully used in more than 100 PHVA workshops in guiding management decisions. *VORTEX* is general enough for use when dealing with a broad range of species, but specific enough to incorporate most of the important processes. It is continually evolving in conjunction with the PHVA process. *VORTEX* has, as do all models, its limitations, which may restrict its utility. The model analyzes a population in a stochastic and probabilistic fashion. It is now at Version 9.5 through the cooperative contributions of dozens of biologists. It has been the subject of a series of both published and in-press validation studies and comparisons with other modeling tools. More than 2000 copies of *VORTEX* are in circulation and it is being used as a teaching tool in university courses.

We use this model and the experience we have with it as a central tool for the population dynamic aspects of the Workshop process. Additional modules, building on other simulation modeling tools for human population dynamics (which we have used in three countries) with potential impacts on water usage, harvesting effects, and physical factors such as hydrology and water diversion will be developed to provide input into the population and habitat models which can then be used to evaluate possible effects of different management scenarios. No such composite models are available.

CBSG Resources as a Unique Asset

<u>Expertise and Costs:</u> The problems and threats to endangered species everywhere are complex and interactive with a need for information from diverse specialists. No agency or country encompasses all of the useful expert knowledge. Thus, there is a need to include a wide range of people as resources and analysts. It is important that the invited experts have reputations for expertise, objectivity, initial lack of local stake, and for active transfer of wanted skills. CBSG has a volunteer network of more than 800

experts with about 250 in the USA. More than 3,000 people from 400 organizations have assisted CBSG on projects and participated in workshops on a volunteer basis contributing tens of thousands of hours of time. We will call upon individual experts to assist in all phases of this project.

Indirect cost contributions to support: Use of CBSG resources and the contribution of participating experts provide a matching contribution more than equaling the proposed budget request for projects.

Reports: Draft reports are prepared during the workshop so that there is agreement by participants on its content and recommendations. Reports are also prepared on the mini-workshops (working groups) that will be conducted in information gathering exercises with small groups of experts and stakeholders. We can print reports within 24-48 hours of preparation of final copy. We also have CD-ROM preparation facilities, software and experience.

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Simulation Modeling and Population Viability Analysis

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Bob Lacy – Chicago Zoological Society / IUCN CBSG
Phil Miller – Conservation Breeding Specialist Group (IUCN / SSC)

A model is any simplified representation of a real system. We use models in all aspects of our lives, in order to: (1) extract the important trends from complex processes, (2) permit comparison among systems, (3) facilitate analysis of causes of processes acting on the system, and (4) make predictions about the future. A complete description of a natural system, if it were possible, would often decrease our understanding relative to that provided by a good model, because there is "noise" in the system that is extraneous to the processes we wish to understand. For example, the typical representation of the growth of a wildlife population by an annual percent growth rate is a simplified mathematical model of the much more complex changes in population size. Representing population growth as an annual percent change assumes constant exponential growth, ignoring the irregular fluctuations as individuals are born or immigrate, and die or emigrate. For many purposes, such a simplified model of population growth is very useful, because it captures the essential information we might need regarding the average change in population size, and it allows us to make predictions about the future size of the population. A detailed description of the exact changes in numbers of individuals, while a true description of the population, would often be of much less value because the essential pattern would be obscured, and it would be difficult or impossible to make predictions about the future population size.

In considerations of the vulnerability of a population to extinction, as is so often required for conservation planning and management, the simple model of population growth as a constant annual rate of change is inadequate for our needs. The fluctuations in population size that are omitted from the standard ecological models of population change can cause population extinction, and therefore are often the primary focus of concern. In order to understand and predict the vulnerability of a wildlife population to extinction, we need to use a model which incorporates the processes which cause fluctuations in the population, as well as those which control the long-term trends in population size (Shaffer 1981). Many processes can cause fluctuations in population size: variation in the environment (such as weather, food supplies, and predation), genetic changes in the population (such as genetic drift, inbreeding, and response to natural selection), catastrophic effects (such as disease epidemics, floods, and droughts), decimation of the population or its habitats by humans, the chance results of the probabilistic events in the lives of individuals (sex determination, location of mates, breeding success, survival), and interactions among these factors (Gilpin and Soulé 1986).

Models of population dynamics which incorporate causes of fluctuations in population size in order to predict probabilities of extinction, and to help identify the processes which contribute to a population's vulnerability, are used in "Population Viability Analysis" (PVA) (Lacy 1993/4). For the purpose of predicting vulnerability to extinction, any and all population processes that impact population dynamics can be important. Much analysis of conservation issues is conducted by largely intuitive assessments by biologists with experience with the system. Assessments by experts can be quite valuable, and are often contrasted with "models" used to evaluate population vulnerability to extinction. Such a contrast is not valid, however, as *any* synthesis of facts and understanding of processes constitutes a model, even if it is a mental model within the mind of the expert and perhaps only vaguely specified to others (or even to the expert himself or herself).

A number of properties of the problem of assessing vulnerability of a population to extinction make it difficult to rely on mental or intuitive models. Numerous processes impact population dynamics, and many of the factors interact in complex ways. For example, increased fragmentation of habitat can make it more difficult to locate mates, can lead to greater mortality as individuals disperse greater distances across unsuitable habitat, and can lead to increased inbreeding which in turn can further reduce ability to attract mates and to survive. In addition, many of the processes impacting population dynamics are intrinsically probabilistic, with a random component. Sex determination, disease, predation, mate acquisition -- indeed, almost all events in the life of an individual -- are stochastic events, occurring with certain probabilities rather than with absolute certainty at any given time. The consequences of factors influencing population dynamics are often delayed for years or even generations. With a long-lived species, a population might persist for 20 to 40 years beyond the emergence of factors that ultimately cause extinction. Humans can synthesize mentally only a few factors at a time, most people have difficulty assessing probabilities intuitively, and it is difficult to consider delayed effects. Moreover, the data needed for models of population dynamics are often very uncertain. Optimal decision-making when data are uncertain is difficult, as it involves correct assessment of probabilities that the true values fall within certain ranges, adding yet another probabilistic or chance component to the evaluation of the situation.

The difficulty of incorporating multiple, interacting, probabilistic processes into a model that can utilize uncertain data has prevented (to date) development of analytical models (mathematical equations developed from theory) which encompass more than a small subset of the processes known to affect wildlife population dynamics. It is possible that the mental models of some biologists are sufficiently complex to predict accurately population vulnerabilities to extinction under a range of conditions, but it is not possible to assess objectively the precision of such intuitive assessments, and it is difficult to transfer that knowledge to others who need also to evaluate the situation. Computer simulation models have increasingly been used to assist in PVA. Although rarely as elegant as models framed in analytical equations, computer simulation models can be well suited for the complex task of evaluating risks of extinction. Simulation models can include as many factors that influence population dynamics as the modeler and the user of the model want to assess. Interactions between processes can be modeled, if the nature of those interactions can be specified. Probabilistic events can be easily simulated by computer programs, providing output that gives both the mean expected result and the range or distribution of possible outcomes. In theory, simulation programs can be used to build models of population dynamics that include all the knowledge of the system which is available to experts. In practice, the models will be simpler, because some factors are judged unlikely to be important, and because the persons who developed the model did not have access to the full array of expert knowledge.

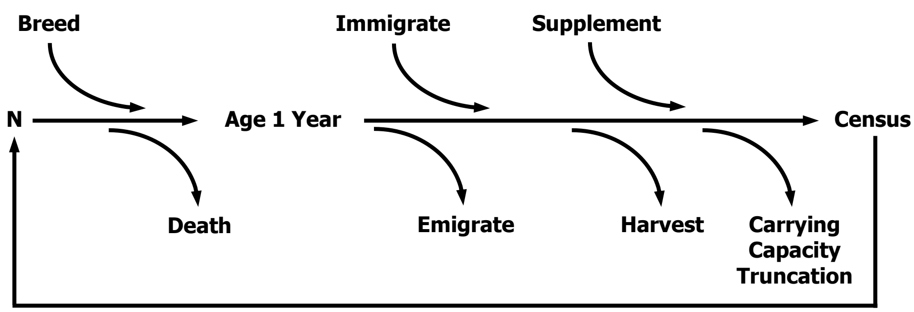
Although computer simulation models can be complex and confusing, they are precisely defined and all the assumptions and algorithms can be examined. Therefore, the models are objective, testable, and open to challenge and improvement. PVA models allow use of all available data on the biology of the taxon, facilitate testing of the effects of unknown or uncertain data, and expedite the comparison of the likely results of various possible management options.

PVA models also have weaknesses and limitations. A model of the population dynamics does not define the goals for conservation planning. Goals, in terms of population growth, probability of persistence, number of extant populations, genetic diversity, or other measures of population performance must be defined by the management authorities before the results of population modeling can be used. Because the models incorporate many factors, the number of possibilities to test can seem endless, and it can be difficult to determine which of the factors that were analyzed are most important to the population dynamics. PVA models are necessarily incomplete. We can model only those factors which we understand and for which we can specify the parameters. Therefore, it is important to realize that the models probably underestimate the threats facing the population. Finally, the models are used to predict the long-term effects of the processes presently acting on the population. Many aspects of the situation could change radically within the time span that is modeled. Therefore, it is important to reassess the data and model results periodically, with changes made to the conservation programs as needed (see Lacy and Miller (2002), Nyhus *et al*. (2002) and Westley and Miller (2003) for more details).

The *VORTEX* Population Viability Analysis Model

For the analyses presented here, the *VORTEX* computer software (Lacy 1993a) for population viability analysis was used. *VORTEX* models demographic stochasticity (the randomness of reproduction and deaths among individuals in a population), environmental variation in the annual birth and death rates, the impacts of sporadic catastrophes, and the effects of inbreeding in small populations. *VORTEX* also allows analysis of the effects of losses or gains in habitat, harvest or supplementation of populations, and movement of individuals among local populations.

VORTEX Simulation Model Timeline



Events listed above the timeline increase N, while events listed below the timeline decrease N.

Density dependence in mortality is modeled by specifying a carrying capacity of the habitat. When the population size exceeds the carrying capacity, additional morality is imposed across all age classes to bring the population back down to the carrying capacity. The carrying capacity can be specified to change linearly over time, to model losses or gains in the amount or quality of habitat. Density dependence in reproduction is modeled by specifying the proportion of adult females breeding each year as a function of the population size.

VORTEX models loss of genetic variation in populations, by simulating the transmission of alleles from parents to offspring at a hypothetical genetic locus. Each animal at the start of the simulation is assigned two unique alleles at the locus. During the simulation, *VORTEX* monitors how many of the original alleles remain within the population, and the average heterozygosity and gene diversity (or "expected heterozygosity") relative to the starting levels. *VORTEX* also monitors the inbreeding coefficients of each animal, and can reduce the juvenile survival of inbred animals to model the effects of inbreeding depression.

VORTEX is an *individual-based* model. That is, *VORTEX* creates a representation of each animal in its memory and follows the fate of the animal through each year of its lifetime. *VORTEX* keeps track of the sex, age, and parentage of each animal. Demographic events (birth, sex determination, mating, dispersal, and death) are modeled by determining for each animal in each year of the simulation whether any of the events occur. (See figure below.) Events occur according to the specified age and sex-specific probabilities. Demographic stochasticity is therefore a consequence of the uncertainty regarding whether each demographic event occurs for any given animal.

VORTEX requires a lot of population-specific data. For example, the user must specify the amount of annual variation in each demographic rate caused by fluctuations in the environment. In addition, the frequency of each type of catastrophe (drought, flood, epidemic disease) and the effects of the catastrophes on survival and reproduction must be specified. Rates of migration (dispersal) between each pair of local populations must be specified. Because *VORTEX* requires specification of many biological parameters, it is not necessarily a good model for the examination of population dynamics that would result from some generalized life history. It is most usefully applied to the analysis of a specific population in a specific environment.

Further information on *VORTEX* is available in Miller and Lacy (1999) and Lacy (2000).

Dealing with Uncertainty

It is important to recognize that uncertainty regarding the biological parameters of a population and its consequent fate occurs at several levels and for independent reasons. Uncertainty can occur because the parameters have never been measured on the population. Uncertainty can occur because limited field data have yielded estimates with potentially large sampling error. Uncertainty can occur because independent studies have generated discordant estimates. Uncertainty can occur because environmental conditions or population status have been changing over time, and field surveys were conducted during periods which may not be representative of long-term averages. Uncertainty can occur because the environment will change in the future, so that measurements made in the past may not accurately predict future conditions.

Sensitivity testing is necessary to determine the extent to which uncertainty in input parameters results in uncertainty regarding the future fate of the pronghorn population. If alternative plausible parameter values result in divergent predictions for the population, then it is important to try to resolve the uncertainty with better data. Sensitivity of population dynamics to certain parameters also indicates that those parameters describe factors that could be critical determinants of population viability. Such factors are therefore good candidates for efficient management actions designed to ensure the persistence of the population.

The above kinds of uncertainty should be distinguished from several more sources of uncertainty about the future of the population. Even if long-term average demographic rates are known with precision, variation over time caused by fluctuating environmental conditions will cause uncertainty in the fate of the population at any given time in the future. Such environmental variation should be incorporated into the model used to assess population dynamics, and will generate a range of possible outcomes (perhaps represented as a mean and standard deviation) from the model. In addition, most biological processes are inherently stochastic, having a random component. The stochastic or probabilistic nature of survival, sex determination, transmission of genes, acquisition of mates, reproduction, and other processes preclude exact determination of the future state of a population. Such demographic stochasticity should also be incorporated into a population model, because such variability both increases our uncertainty about the future and can also change the expected or mean outcome relative to that which would result if there were no such variation. Finally, there is “uncertainty” which represents the alternative actions or interventions which might be pursued as a management strategy. The likely effectiveness of such management options can be explored by testing alternative scenarios in the model of population dynamics, in much the same way that sensitivity testing is used to explore the effects of uncertain biological parameters.

Results

Results reported for each scenario include:

<u>Deterministic r</u> -- The deterministic population growth rate, a projection of the mean rate of growth of the population expected from the average birth and death rates. Impacts of harvest, inbreeding, and density dependence are not considered in the calculation. When $r = 0$, a population with no growth is expected; $r < 0$ indicates population decline; $r > 0$ indicates long-term population growth. The value of r is approximately the rate of growth or decline per year.

The deterministic growth rate is the average population growth expected if the population is so large as to be unaffected by stochastic, random processes. The deterministic growth rate will correctly predict future population growth if: the population is presently at a stable age distribution; birth and death rates remain constant over time and space (i.e., not only do the probabilities remain constant, but the actual number of births and deaths each year match the expected values); there is no inbreeding depression; there is never a limitation of mates preventing some females from breeding; and there is no density dependence in birth or death rates, such as a Allee effects or a habitat "carrying capacity" limiting population growth. Because some or all of these assumptions are usually violated, the average population growth of real populations (and stochastically simulated ones) will usually be less than the deterministic growth rate.

<u>Stochastic r</u> -- The mean rate of stochastic population growth or decline demonstrated by the simulated populations, averaged across years and iterations, for all those simulated populations that are not extinct. This population growth rate is calculated each year of the simulation, prior to any truncation of the population size due to the population exceeding the carrying capacity. Usually, this stochastic r will be less than the deterministic r predicted from birth and death rates. The stochastic r from the simulations will be close to the deterministic r if the population growth is steady and robust. The stochastic r will be notably less than the deterministic r if the population is subjected to large fluctuations due to environmental variation, catastrophes, or the genetic and demographic instabilities inherent in small populations.

<u>P(E)</u> -- the probability of population extinction, determined by the proportion of, for example, 500 iterations within that given scenario that have gone extinct in the simulations. "Extinction" is defined in the *VORTEX* model as the lack of either sex.

<u>N</u> -- mean population size, averaged across those simulated populations which are not extinct.

<u>SD(N)</u> -- variation across simulated populations (expressed as the standard deviation) in the size of the population at each time interval. SDs greater than about half the size of mean N often indicate highly unstable population sizes, with some simulated populations very near extinction. When SD(N) is large relative to N, and especially when SD(N) increases over the years of the simulation, then the population is vulnerable to large random fluctuations and may go extinct even if the mean population growth rate is positive. SD(N) will be small and often declining relative to N when the population is either growing steadily toward the carrying capacity or declining rapidly (and deterministically) toward extinction. SD(N) will also decline considerably when the population size approaches and is limited by the carrying capacity.

<u>H</u> -- the gene diversity or expected heterozygosity of the extant populations, expressed as a percent of the initial gene diversity of the population. Fitness of individuals usually declines proportionately with gene diversity (Lacy 1993b), with a 10% decline in gene diversity typically causing about 15% decline in survival of captive mammals (Ralls *et al*. 1988). Impacts of inbreeding on wild populations are less well known, but may be more severe than those observed in captive populations (Jiménez *et al*. 1994). Adaptive response to natural selection is also expected to be proportional to gene diversity. Long-term conservation programs often set a goal of retaining 90% of initial gene diversity (Soulé *et al*. 1986). Reduction to 75% of gene diversity would be equivalent to one generation of full-sibling or parent-offspring inbreeding.

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