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J. E. McCosker, California Academy of Sciences, San Francisco, CA 94118 USA E-mail: jmccosker@calacademy.org. R. Bustamante, CSIRO Marine Research, Queensland 4163, Australia. E-mail: rodrigo.bustamante@csiro.au. G. M. Wellington, Unversity of Houston, Houston, TX 77204 USA E-mail: wellington@uh.edu.

FERAL ROCK DOVES IN THE GALÁPAGOS ISLANDS: BIOLOGICAL AND ECONOMIC THREATS

By: R. Brand Phillips, Howard L. Snell, and Hernan Vargas

INTRODUCTION

Rock doves (*Columba livia*) have been introduced worldwide and are found in most major cities (Reinke 1959, Simms 1979, Robbins 1995). They inhabit urban, suburban, and rural environments (Jobin *et al.* 1996, Henderson *et al.* 2000). In many areas, rock doves roost and nest in natural areas, but make daily flights of several kilometers to forage in cities and agricultural zones (Earle and Little 1993, Baldaccini *et al.* 2000). Rock doves often cause problems, such as fouling structures, contaminating food, and transmitting diseases (Haag 1995, Weber 1979). Behavioral traits related to the domestication of this species permit rock doves to exist at unnaturally high population densities in these environments (Haag 1995). This ability to tolerate high population densities is a major factor contributing to the social and environmental impacts of rock doves.

In the Galápagos, little is known about rock dove populations. The entire population of rock doves in the Galápagos is reported to be the descendents of four captive rock doves introduced to the islands in 1972 or 1973 (Harmon *et al.* 1987); however, previous introductions probably occurred. By the early 1980s, rock doves occurred on four of the five Galápagos islands with resident human populations (Santa Cruz, Isabela, San Cristóbal, and Floreana; Baltra appears to have escaped introduction or invasion of rock doves). In the mid-1980s, the owner of the Floreana birds abandoned his flock, which presumably then died off or emigrated. In 1985, the entire population of rock doves for Galápagos was estimated at approximately 200 (Harmon *et al.* 1987). The majority of the birds were kept in lofts in the towns of Puerto Baquerizo Moreno, San Cristóbal (112), Puerto Ayora, Santa Cruz (30), and Villamil, Isabela (50). A flock of 20 feral rock doves was observed using a gorge near Puerto Ayora.

During 2000 and 2001, preliminary surveys for rock doves on San Cristóbal, Santa Cruz, and Isabela yielded population estimates of 220, 200, and 130, respectively (Phillips and Snell in preparation). The rock dove populations were still concentrated in and around the 3 principal towns; however, in contrast to the mid-1980s, the majority of rock doves are now feral. In addition, captive flocks were present in the rural areas of the highlands on San Cristóbal and Santa Cruz. On Santa Cruz, the majority of the population nests, and roosts, in Galápagos National Park lands bordering Puerto Ayora.

The data from the recent surveys and those from the 1980s, indicate that rock dove populations are increasing rapidly (annual rate of approximately 5 to 10%), despite human consumption and occasional control programs by the Galápagos National Park Service (GNPS). If the rock dove population continues to increase at the present rate, urban and suburban habitat will soon become filled.

Thus, we can expect further expansion of the rock dove's distribution into parklands and the agricultural zone, as well as to other islands. With an expanding distribution will come greater chances for interaction between rock doves and the native fauna.

Feral rock doves have not been linked to impacts on human health or the native fauna in the Galápagos. However, rock doves harbor a wide range of human and avian pathogens (Weber 1979, Shivaprasad 2001), with the potential to infect and impact Galápagos's human residents and avifauana. To prevent impacts to and extinctions of the Galápagos's native fauna, the Charles Darwin Research Station (CDRS), in cooperation with the GNPS, has initiated a pro-active campaign to eradicate rock doves from the islands. An essential first step in this campaign is to educate and inform the local public of the negative aspects associated with rock doves. Fostering public support for this project will not only facilitate eradication efforts, but more importantly, it should reduce the chance of subsequent intentional reintroductions of rock doves after eradication is completed. The objective of this paper is to provide information on the potential impacts of rock doves for use in educational programs.

In addition to the education and eradication campaigns, the CDRS began a cooperative project with the GNPS, the University of Missouri, and the Saint Louis Zoo aimed at studying the diseases of native and introduced birds. Feral rock doves and chickens from Santa Cruz and San Cristóbal were necropsied and samples of tissues, saliva and blood for detection and diagnosis of several avian diseases. Results from this preliminary survey are expected within one year and additional sampling will be conducted on Isabela next year.

NEGATIVE ASPECTS OF FERAL ROCK DOVES

Human Health Effects

For the general public in Galápagos and elsewhere, feral rock dove populations present serious concerns for human health. Rock doves are reservoirs and vectors for over 40 human pathogenic bacteria, viruses, fungi, and parasites (Weber 1979, Long 1981, Haag and Gurdan 1990, Shivaprasad 2001, Dautel *et al.* 1991). Human infection can occur from consuming contaminated food or water (Alexander *et al.* 1997, Ricca and Cooney 1998, AVMA 2001). Human dwellings in close proximity to rock doves, their perch sites, and nests facilitate transmission of diseases by inhalation of aerosolized dried feces and the transfer of arthropod parasites (Dautel *et al.* 1991).

Most of the diseases transmitted to humans by rock doves have only minor health effects. For example, *Salmonella* spp. poisoning normally causes cramping and diarrhea in the 2 million persons infected yearly in the U.S.; however, even normally mild diseases can have serious effects (CDC 2001). Approximately 1000 persons die each year in the U.S. from salmonellosis, and rock doves are known to transmit this disease to man (Weber 1979). Toxoplasmosis, an infection caused by the parasitic protozoan (*Toxoplasma gondii*), is another very common disease transmitted by rock doves (Weber 1979). It occurs world-wide and infects more than 60 million people in the U.S. Normally, toxoplasmosis only causes flu-like symptoms, but permanent brain and eye damage can result in immuno-compromised individuals, and infected fetuses can be born retarded or with other serious mental or physical problems.

Psittacosis is another serious disease caused by the bacterium (*Chlamydia psittaci*; Martinov *et al.* 1997). Rock doves are linked to the transmission of *C. psittaci* to humans (Williams 1989, Gherman *et al.* 1995, Martinov *et al.* 1997). In 1025 cases of psittacosis reported to the Center for Disease Control from 1975 to 1984, 70% occurred in pet shop employees and bird owners, including those of rock doves (Williams 1989). In untreated cases, mortality from psittacosis can be as high as 20%. Mortality for persons treated with antibiotics is <1%, but serious complications can still occur, including pneumonia, hepatitis, arthritis, encephalitis, and fetal death.

Histoplasmosis and cryptococcosis are two fungal diseases found in many parts of the world, including South America (Ricca and Cooney 1998, Mattsson *et al.* 1999). The reservoir for the disease-causing agent is soil contaminated with bird feces (primarily rock dove). In areas where the histoplasmosis is endemic, 80% of the people test positive to skin tests. Most people who contract histoplasmosis only develop flu-like symptoms, but chronic lung damage can occur. For the general population, the risk of contracting cryptococcosis is low (<1/100,000), but 12% of all cases are fatal.

Several ectoparasites, such as ticks, fleas, and mites, infest rock doves and their nests, causing health problems for humans (Dautel *et al.* 1991). The soft tick (*Argas reflexus*) occurs in active and abandoned nesting sites of rock doves in West Berlin. Several people bitten by the tick suffered severe symptoms, including urticaria, bronchial obstruction, and loss of consciousness.

Figure 1. Rock doves in town of Puerto Villamil, Isabela.

Although we do not have medical records to document it, the risk of rock doves transmitting diseases to people is probably higher in the Galápagos than elsewhere due to several social and environmental factors. It is a common practice to collect rainwater from roofs for drinking. In many locations rock doves roost and defecate on these roofs. Rock doves harbor dozens of endoparasites (Ritchie *et al.* 1991), with many occurring in the feces. These parasites would be deposited in the cisterns and subsequently ingested. Many dove owners in the Galápagos feed their birds by broadcasting seed in their yards, which are generally dirt and shared by children, pets, and poultry. In this environment, many pathogens could easily become airborne and transmitted to humans, as well as to pets and livestock (Ritchie *et al.* 1999). Moreover, houses in Galápagos are often poorly constructed, lacking windows or well-sealing doors, thus increasing exposure to pathogenic organisms. Finally, the high humidity and mild temperatures of the islands provide favorable conditions year-round for pathogens.

There are additional health concerns associated with rock doves aside from disease transmission. We have encountered people that consume rock doves in Puerto Ayora and Villamil. Rock doves accumulate large quantities of toxic metals, such as lead, cadmium, and zinc in their tissues (Hutton 1980, Hutton and Goodman 1980, Garcia *et al.* 1988). In fact, rock doves are being considered as monitors of manganese pollution in urban environments (Loranger *et al.* 1994).

Economic and Social Impacts

In addition to direct impacts on human health, rock doves can cause significant agricultural loss. Rock doves serve as a reservoirs and vectors for several avian bacterial, viral, fungal, and parasitic pathogens (Shivaprasad 2001). More than 20 diseases in domestic poultry (chicken and turkey) are also found in rock doves (Macpherson *et al.* 1983, Saif *et al.* 1997, Shivaprasad 2001). This commonality of diseases between rock doves and poultry is considered a disease transmission threat (Johnston and Key 1992). During 1991 to 1994, rock doves were responsible for epizootic outbreaks of Newcastle disease, an avian paramyxovirus, in domestic chickens in the European Union (Alexander *et al.* 1997). Newcastle disease is the principal factor limiting chicken production in many developing countries (Alexander 1991, Spradbrow 1988), where mortality from Newcastle disease can be as high as 100% in unprotected flocks.

Rock doves foraging on stored grain are considered a causative factor in the transmission of diseases to livestock. This behavior also results in contaminated food stores and associated economic losses (Long 1981, Smith 1992, Little 1994, Alexander *et al.* 1997). Municipalities and private individuals incur monetary costs from rock doves. Their feces foul and damage buildings, statues, and cars, requiring cleanup and repair (Haag 1995). In United States cities, they are considered the most serious pest bird, causing an estimated $1.1 billion damage per year in urban areas (Pimentel *et al.* 1999).

The principal economic threat to the Galápagos from rock doves may be the potential decrease in revenues resulting from a decline or extinction of native avifauna (see Ecological Concerns). Tourism is a key component of the Galápagos economy, with the majority of the local workforce employed in tourism and commerce (Anonymous 2001). In 1999, tourism accounted for $78 million in the local economy (Anonymous 2000). In comparison, fisheries contributed only $6.4 million (J. C. Murillo, CDRS, Marine Biology, pers. comm.). The Galápagos are noted for several species of wildlife, such as tortoises (*Geochelone* spp.) and marine iguanas (*Amblyrhynchus cristatus*). Famous as well are several endemic species of birds, including finches (Fringillidae), penguins (*Spheniscus mendiculus*), and cormorants (*Nannopterum harrisi*). Several tourist sites are specifically visited for the avifauna (*e.g.*, Española and Genovesa). The extinction of one or more species of endemic avifauna could have devastating economic consequences.

Ecological Concerns

As conservation and natural resource management organizations, the CDRS and the GNPS are concerned about the potential ecological impacts of rock doves, with transmission of diseases to endemic avifauna the principal threat. Rock doves often forage in mixed avian species flocks. In Cape Town, South Africa, feral rock doves fly, nest, and roost with native rock pigeons (*C. guinea*; Earle and Little 1993, Little 1994). In the Galápagos, rock doves are frequently seen feeding with finches in Puerto Ayora and Puerto Baquerizo Moreno. Finches and warblers (*Dendrocia petechia*) have been observed sharing artificial water sources.

The tendency of rock doves to associate with other avian species, in combination with their gregarious behavior, facilitates inter-specific disease transmission. Rock doves have apparently introduced the avian pathogen, *Trichomonas gallinae*, into wild bird populations wherever they have been introduced (Stabler 1954, Honigberg 1978). Because of the relatively close phylogenetic relationship between native doves and rock doves, the chance of disease transmission is even more likely (Stabler 1954). In South Africa, feral rock doves and native rock pigeons were found to share three blood parasites (Earle and Little 1993). Harmon *et al.* (1987) identified *T. gallinae* in the Galápagos dove (*Zenaida galapagoensis*), an endemic species with several populations that appear to be declining sharply, and rock doves are suspected of transmitting the pathogen.

The threat of disease transmission from rock doves is not only limited to members of the Columbidae. Newcastle disease, which was recently documented in the Galápagos's rock dove population (unpublished data),

caused widespread death in double-crested cormorants (*Phalacrocorx auritus*) in Canada and the U.S. (Kuiken *et al.* 1999). Juvenile mortality in cormorants infected with Newcastle disease is as high as 64% (Kuiken *et al.* 1998). Newcastle disease has also been isolated from Adelie penguins (*Pygocelis adeliae*) and falcons (Austin and Webster 1993, Wernery *et al.* 1992). The presence of feral rock doves infected with Newcastle disease is cause for concern considering the Galápagos has endemic species of cormorants, penguins, and raptors. The threat to Galápagos's cormorant and penguin populations is especially heightened because of their small, restricted populations.

In addition to Newcastle disease, rock doves are reservoirs for more than 20 wild avian pathogens, which infect taxa including, seabirds, penguins, raptors, and passerines (Shivaprasad 2001). The Galápagos harbor endemic species in each of these avian groups. Among this suite of pathogens found in rock doves is the protozoan responsible for causing avian malaria. Avian malaria has yet to be detected in the Galápagos, but *Culex quinquefasciatus* mosquitoes, the vector responsible for transmitting the disease, now occur in the Galápagos (Peck *et al.* 1998).

Avian malaria (and similar diseases) may be one of the most potentially serious threats facing the Galápagos's avifauna. The introduction of avian malaria to the Hawaiian islands, in conjunction with habitat destruction and introduced predators, is attributed with the extinction or decline of >75% of Hawaii's native avifauna (Atkinson *et al.* 1995). The impact of avian malaria on Hawaii's native avifauna, is such that, many species of birds now survive only in the mosquito-free high altitude zones (Atkinson *et al.* 2000).

CONCLUSION

Clearly feral rock dove populations in Galápagos have the potential to influence human health and impact the economic livelihood of citizens. Equally important is the serious risk of disease transmission from rock doves to Galápagos avifauna. Rock dove eradication is the only long-term solution to these problems. In most areas worldwide, eradication of rock doves is not an option; the Galápagos situation is different. In the Galápagos, rock dove populations exist in localized areas, and because it is an island ecosystem, the chances of reintroduction are greatly reduced and more easily managed. The latter aspect is aided by the recent passage of the Special Law of Galápagos, which makes it illegal to import alien species into the Galápagos. From a technological standpoint, rock doves are a relatively easy species to eradicate; the social and political obstacles to eradication pose difficult challenges. Despite the challenges, the eradication of rock doves is desirable to safeguard the health and economic viability of the local populace and to protect Galápagos's unique avifauna.

ACKNOWLEDGEMENTS

Fieldwork and support during writing of this paper was supported by grants from the United Nations Foundation via the UNESCO World Heritage Committee, Frankfurt Zoological Society, and the Global Environmental Facility via Fundación Natura.. Partial support was also provided by the Charles Darwin Foundation and the University of New Mexico. We want to thank M. Anderson (CDRS), F. Azuero, E. Cadena, W. Espinosa, C. Gaona, F. Gaona, and R. Jimenez (GNPS/CDRS) for field assistance. V. Carrión provided valuable logistical support. H. Jeffcoat reviewed an earlier draft of this paper.

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R. Brand Phillips, Biology Department, University of New Mexico, Albuquerque, New Mexico, 87131-1091 USA E-mail: rbrand@unm.edu. Howard L. Snell, Charles Darwin Research Station, Galápagos Islands, Ecuador and Biology Department, University of New Mexico, Albuquerque, New Mexico, 87131-1091 USA E-mail: howard@fcdarwin.org.ec or snell@unm.edu. Hernan Vargas, Charles Darwin Research Station, Galápagos Islands, Ecuador and Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Oxford, OX1 3PS, UK E-mail: hernan.vargas@zoology.oxford.ac.uk.

Opuntia echios echios, Isla Plaza Sur.

EVIDENCE FOR LOW GENETIC DIVERGENCE AMONG GALÁPAGOS *OPUNTIA* CACTUS SPECIES

By: Robert A. Browne, David J. Anderson, Mark D. White and Michele A. Johnson

INTRODUCTION

Islands are often showplaces of dramatic examples of evolutionary divergence and adaptive radiation. A combination of factors, including reproductive isolation from mainland populations, founder effect, limited competition, and freedom from predation can result in rapid evolution. Among the best-known examples of morphological divergence in the Galápagos are tortoises, finches, and prickly pear cacti (*Opuntia*) with markedly different forms on different islands.

Cacti are a prominent, and often dominant, component of the Galápagos flora. During the driest period of the year in the lowlands, they are virtually the only green vegetation to be found. Of the three cactus genera in the islands, *Brachycereus* and *Jasminocereus* are each represented by a single species (Dawson 1962a, 1962b). In contrast, prickly pear (*Opuntia*) are both widespread and highly diverse, growing on all of the major islands and most islets. Six species are currently recognized, with three of these further divided into varieties, yielding a total of fourteen taxa (Anderson and Walkington 1971). A long-standing debate has revolved around how many taxa deserve species status versus recognition as subspecies or varieties. Pronounced morphological variation in such traits as degree of spines, seed size, and height are the basis for taxonomic designation. *Opuntia* in the Galapagos can occur as large arboreal (tree-like) forms up to 12 m in height and as low-growing, shrubby forms. This variation could result from various genetic factors such as genetic drift and selection, but could also be due to environmental influences.

The origins of *Opuntia* in the Galápagos are not well understood. Two methods of colonization have been proposed. One theory suggests that parts of cacti may have rafted to the islands on the Humboldt Current which flows northward along the west coast of South America, turning west as it nears the equator, and proceeding to the Galápagos Islands (Dawson 1962b). Alternatively, cactus seeds may have been carried by birds flying across the ocean from the mainland (Porter 1983).

Cacti are an important resource in the Galápagos because of the extensive use of pads, flowers, and fleshy fruits as a food source by reptiles, birds, and insects. Tortoises on some islands appear to be highly dependent upon *Opuntia* during the dry season for both food and water. This resource may be in jeopardy since populations of *Opuntia* have been greatly reduced or eliminated on a number of islands. Photographs from the early twentieth century show areas occupied by numerous large cacti where none exist today. The most apparent reason for this reduction is damage inflicted upon the cacti by goats which were introduced to the islands (Grant and Grant 1989). Goat populations have been eradicated or reduced on several islands, hopefully allowing for the recovery of *Opuntia* populations, but are at high densities and even expanding on other islands. It appears that even in areas with large numbers of fruits and seeds, germination frequency is low, perhaps due in part to the low density or absence of tortoises. Tortoises may aid seed