Threats to Biodiversity: A Case Study of Hawaiian Birds

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Background Reading

What is biodiversity? Defining biodiversity is a difficult and complex task that depends on the level of analysis used to categorize a region. At the ecosystem level, biodiversity may be defined as the number of biomes in a given region. Biomes are large ecosystems that are characterized by vegetation, precipitation gradients, moisture gradients, elevation, and latitude. At the organism level, biodiversity is the number of species in a given area. This would include not only the number of species, but also the number of populations of each species in a given area as well as information about the size of these populations. A third definition of biodiversity is based on genetic diversity. Genetic diversity refers either to the number of alleles in a given population or to the number of rare alleles present in the population. Yet another way to conceptualize biodiversity is to think of it as evenness. Evenness can be applied at multiple levels of analysis (biomes, species, or alleles). For example, evenness may consider the number of species in a given area relative to the total number in that area. A region with five species found in equal abundances is more diverse than a region with five species where only one of those species is abundant and the other four species are encountered less often. Because biodiversity is defined in different ways and at different levels in biology, monitoring the biodiversity of a particular region can be a difficult task. The integration of all levels of analysis leads to complex and often conflicting descriptors of biodiversity.

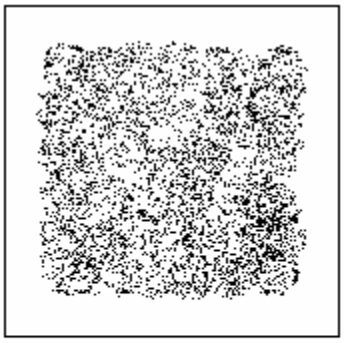
Regardless of how biodiversity is defined, there is little question that it is declining. Though most of the public's attention is focused on a few charismatic endangered species, such as the Northern spotted owl, the gray wolf, and the giant panda, these are only a miniscule fraction of the number of species that are threatened, endangered, or already extinct. The North Carolina Natural Heritage Program, an affiliate of The Nature Conservancy, the world's premier data collector on biodiversity, is tracking the populations of one bird, two salamander, four fish, seven mollusk, six insect, and 35 plant species in Durham County, North Carolina, alone. Not all of these species are in immediate danger of going totally extinct. In fact, only two plants, the smooth coneflower and Michaux's sumac, are federally protected as "Endangered Species." Some of these species are rare in North Carolina but common elsewhere. However, the process of extinction begins with the extirpation of local populations, and it usually happens without our knowledge.

Biodiversity is threatened by disruptions to the natural ecosystem that limit the resources needed by an organism (e.g., light, water, food, or space) or alter how that organism interacts with other organisms (e.g., competition and predation). Two phenomena that create these types of disruptions include the establishment of **exotic**, or **introduced species**, and **habitat fragmentation**.

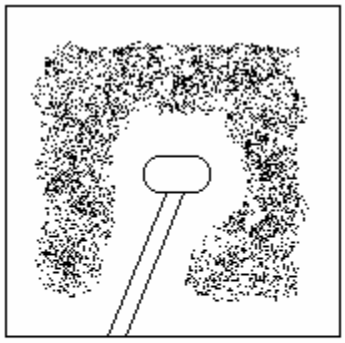
The establishment of introduced species threatens indigenous biota. Introduced species are brought to an area either intentionally or by accident and are not part of the native ecosystem. Although most introduced species fail to survive in a new habitat, some actually thrive and can out-compete native species, prey on native species, transmit exotic diseases, facilitate the spread of native diseases, hybridize with natives, and alter habitats.

Some of these effects are observed with the salt cedar, a tree that derives its name from the fact that it concentrates salts in its leaves. This drought-tolerant tree was introduced into the western United States in the early part of the last century to control erosion. It spread rapidly, and now many streams, particularly in the southwest, are lined with nothing but salt cedar. The leaf litter causes the soil to become too saline for native cottonwood and willow seedlings to establish. Given that the native vegetation along southwestern rivers and streams is possibly the most productive habitat for breeding birds in North America, it is not surprising that bird populations have been affected, including the endangered southwestern willow flycatcher and Bell's vireo (cowbirds are also a problem for these species).

Along with introduced species, habitat fragmentation may disturb native ecosystems. When people alter natural areas, for example, through agriculture or urban sprawl, the habitats needed to sustain native species are often eliminated. The remaining natural areas are left isolated. This process is referred to as habitat fragmentation. This problem is one of the major concerns of conservation biologists. With habitat fragmentation, the direct loss of suitable habitat is not the only problem. Other, less obvious effects can also be important. For example, breaking up large populations into smaller ones that cannot remain self-sustaining may result in loss of genetic exchange among different populations, or increased edge effects. In the take-home exercise, you'll learn how the introduction of ungulates such as cattle, goats, or pigs by humans has led to habitat fragmentation.



Unfragmented forest. Shaded areas represent forest areas where breeding birds are NOT vulnerable to nest parasites like cowbirds.



Forest following fragmentation by a road and pasture. Notice the disproportionate decrease in habitat suitable for deep-forest birds.

But why should humans worry about introduced species, habitat fragmentation, or even extinction? Practically speaking, numerous species fulfill crucial ecological roles in our biosphere by recycling nutrients, producing oxygen, or pollinating plants, while other species are actual or potential natural resources that can be used for crops, fibers, and medicine. Reservoirs of genes for disease resistance can be found in the wild relatives of crop plants or domestic livestock. When the value of biodiversity is assessed in terms of ecology and resources, its importance to human health, the economy, social justice, and national security can be appreciated (for a review, see Lubchenco 1998). Others argue that biodiversity should be preserved for ethical and aesthetic reasons.

Over the next two weeks you will examine the biodiversity crisis using the Hawaiian Islands as a case study. This archipelago is geographically diverse in size, elevation, and habitat type and is historically rich in biodiversity. Hawaii's flora and fauna is an example of how isolation can lead to adaptive radiation (the emergence, from a common ancestor, of numerous species to fill underused niches). This has produced many very specialized species, most of which are endemic, meaning they are found nowhere else on Earth. However, these species are particularly vulnerable to the effects of introduced species, habitat loss and fragmentation. To put the magnitude of the problem in perspective, the Hawaii Natural Heritage Program tracks 30 vertebrates, 102 invertebrates, and 515 plants that are considered to be "critically imperiled globally" (1-5 occurrences and/or fewer than 1,000 individuals remaining, or more abundant but facing extremely serious threats range-wide) or "imperiled globally" (6-20 occurrences and/or 1,000-3,000 individuals remaining, or more abundant but facing serious threats range-wide). For comparison, in New Jersey, which is approximately the size of Hawaii, the Natural Heritage Program tracks 3 vertebrates, 14 invertebrates, and 21 plants that are "critically imperiled globally" or "imperiled globally." We will attempt to understand some of the reasons why, over the last several centuries, there has been a massive decline in Hawaii's biodiversity.

References:

- Hawaii Natural Heritage Program. 2002. Natural Diversity Database. University of Hawaii at Manoa. 3050 Maile Way, Gilmore 409, Honolulu, Hawaii 96822.
- Lubchenco, J. 1998. Entering the century of the environment: a new social contract for science. *Science* 279:491-497.
- NatureServe. 2001. The New Jersey Natural Heritage Program. http://www.natureserve.org/nhp/us/nj/index.html
- The North Carolina Natural Heritage Program. 2002. http://www.ncsparks.net/nhp/county.html
- Robinson, S.K., F.R. Thompson, III, T.M. Donovan, D.R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* 267:1987-1990.
- Wilson, E.O. 1992. *The Diversity of Life*. Cambridge, MA: The Belknap Press of Harvard University Press.

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In-Class Exercise

1. Examine the data presented in Table 1. How many of these species are currently extinct? What other trends do you notice? What factors might contribute to these trends?

Table 1. Status of native birds breeding in the Hawaiian Islands.

Group	Species Known to Have Existed	Current Species	Endangered or Threatened Species	Number of Extinct Species
Seabirds	22+	22	2	
Herons	1	1	0	
Ibises	2	0	-	
Waterfowl	11	3	3	
Hawks	3	1	1	
Rails	11	2	2	
Stilts	1	1	1	
Owls	4	1	0	
Crows	3	1	1	
Honeyeaters	6	2	2	
Old World Flycatchers	1	1	0	
Old World Warblers	1	1	1	
Hawaiian Thrushes	6	3	2	
Honeycreepers	45	20	9	
Totals	117+	59	24	

Table 1 modified from Scott, J.M., C.B. Kepler, C. van Riper III, and S.I. Fefer. (1988). Conservation of Hawaii's vanishing avifauna. *Bioscience* 38(4):238-253.

2. One factor that leads to a decline in biodiversity is the introduction of non-native species. However, most species that are introduced to an area do not become established. What are some characteristics of species that might make them more likely to thrive in a new habitat?

3. Several species of large rats arrived to Hawaii as stowaways on ships. These rats live in a variety of habitats and eat a variety of foods, both plants and animals. Speculate about how these introduced rats could directly and indirectly affect native bird species.

4. Researchers hypothesize that several factors may affect the extent of predation by rats on birds. These factors include bird size, nesting site, and the amount of time young spend in the nest (duration of egg incubation and nestling period). Formulate one hypothesis and its accompanying null hypothesis about how one of these factors might affect predation.

    a. Bird size:
        - H1 (hypothesis):
        - H0 (null hypothesis):

    b. Nesting site:
        - H1 (hypothesis):
        - H0 (null hypothesis):

    c. Incubation and nestling period:
        - H1 (hypothesis):
        - H0 (null hypothesis):

5. Examine the data given to you (Table 2a, 2b, or 2c). Does the data support or refute your hypothesis?

Table 2a. Predation by rats (*R. rattus* and *R. exulans*) on birds. Included in this table are the typical stages of life at which rats prey upon the species of bird listed, the population trends of each bird species since rats were introduced, and the size of each bird measured as the average length of male and female birds.

Bird Species	Stage of Life-Cycle Preyed Upon	Effect on Population	Size (cm)
Diomedea immutabilis (Laysan Albatross)	Chicks	Continuing coexistence with rats	81
Diomedea nigripes (Black-footed Albatross)	Chicks	Minor	81
Pterodroma hypoleuca (Bonin Petrel)	Eggs, chicks	Major decline	30
Pterodroma phaeopygia sandwichensis (Hawaiia Dark-rumped Petrel)	Chicks	Nearly 40% of eggs and chicks destroyed during 2-year study	43
Phaethon rubricauda (Red-tailed Tropicbird)	Eggs, chicks	Up to 65% and 100% losses of eggs and chicks respectively in some years	102
Puffinus pacificus (Wedge-tail Shearwater)	Eggs, ?chicks	Minor	43
Fregata minor (Great Frigatebird)	Adults	Minor	94
Porzana palmeri (Laysan Rail)	Unknown	Extinction	15
Sterna fuscata (Sooty Tern)	Eggs, chicks	Continuing coexistence with rats	43
Sterna lunata (Grey-backed Tern)	Eggs, chicks	All young destroyed in one year	38
Telespyza cantans (Laysan Finchbill)	Unknown	Extinction	19

Table 2a modified from:

° Atkinson, I. A. E. 1985. The spread of commensal species of *Rattus* to oceanic islands and their effects on island avifaunas. In P. J. Moors (ed.), *Conservation of Island Birds*. pp. 35-81. ICBP Technical Publication No. 3.

° Pratt, D. H., Bruner, P. L., and Berrett, D. G. 1987. *A Field Guide to the Birds of Hawaii and the Tropical Pacific*. Princeton, NJ: Princeton University Press.

Table 2b. Predation by rats (*R. rattus* and *R. exulans*) on birds. Included in this table are the typical stages of life at which rats prey upon the species of bird listed, the population trends of each bird species since rats were introduced, and the usual nest location for each species.

Bird Species	Stage of Life-Cycle Preyed Upon	Effect on Population	Usual Nest Situation
Diomedea immutabilis (Laysan Albatross)	Chicks	Continuing coexistence with rats	Ground surface
Diomedea nigripes (Black-footed Albatross)	Chicks	Minor	Ground surface
Pterodroma hypoleuca (Bonin Petrel)	Eggs, chicks	Major decline	Burrows
Pterodroma phaeopygia sandwichensis (Hawaiia Dark-rumped Petrel)	Chicks	Nearly 40% of eggs and chicks destroyed during 2-year study	Burrows
Phaethon rubricauda (Red-tailed Tropicbird)	Eggs, chicks	Up to 65% and 100% losses of eggs and chicks respectively in some years	Ground surface
Puffinus pacificus (Wedge-tail Shearwater)	Eggs, ?chicks	Minor	Burrows
Fregata minor (Great Frigatebird)	Adults	Minor	Branches < 3m high
Porzana palmeri (Laysan Rail)	Unknown	Extinction	Ground surface
Sterna fuscata (Sooty Tern)	Eggs, chicks	Continuing coexistence with rats	Ground surface
Sterna lunata (Grey-backed Tern)	Eggs, chicks	All young destroyed in one year	Ground surface
Telespyza cantans (Laysan Finchbill)	Unknown	Extinction	On or near ground

Table 2b modified from Atkinson, I. A. E. 1985. The spread of commensal species of *Rattus* to oceanic islands and their effects on island avifaunas. In P. J. Moors (ed.), *Conservation of Island Birds*. pp. 35-81. ICBP Technical Publication No. 3.

Table 2c. Predation by rats (*R. rattus* and *R. exulans*) on birds. Included in this table are the typical stages of life at which rats prey upon the species of bird listed, the population trends of each bird species since rats were introduced, incubation and nestling periods for bird species. The incubation period is determined as the number of days from egg laying to hatching. Nestling period is determined as the number of days from hatching to fledging.

Bird Species	Stage of Life-Cycle Preyed Upon	Effect on Population	Incubation Period (Days)	Nestling Period (Days)
Diomedea immutabilis[1,4] (Laysan Albatross)	Chicks	Continuing coexistence with rats	62-67	140
Diomedea nigripes[1,4] (Black-footed Albatross)	Chicks	Minor	62-67	165
Pterodroma hypoleuca[2,3] (Bonin Petrel)	Eggs, chicks	Major decline	48.7	Unknown
Pterodroma phaeopygia sandwichensis[1] (Hawaiia Dark-rumped Petrel)	Chicks	Nearly 40% of eggs and chicks destroyed during 2-year study	50-55	115
Phaethon rubricauda[3,4] (Red-tailed Tropicbird)	Eggs, chicks	Up to 65% and 100% losses of eggs and chicks respectively in some years	40-50	Unknown
Puffinus pacificus[1,4] (Wedge-tail Shearwater)	Eggs, ?chicks	Minor	48-63	60-90
Fregata minor[1,4] (Great Frigatebird)	Adults	Minor	51-57	166
Porzana palmeri (Laysan Rail)	Unknown	Extinction	Unknown	Unknown
Sterna fuscata[3,4] (Sooty Tern)	Eggs, chicks	Continuing coexistence with rats	27-33	16
Sterna lunata[4] (Grey-backed Tern)	Eggs, chicks	All young destroyed in one year	24-35	Unknown
Telespyza cantans (Laysan Finchbill)	Unknown	Extinction	Unknown	Unknown

Table 2c modified from Atkinson, I.A.E. 1985. The spread of commensal species of *Rattus* to oceanic islands and their effects on island avifaunas. In P. J. Moors (ed.), *Conservation of Island Birds*. pp. 35-81. ICBP Technical Publication No. 3.

[1]Berger, A.J. 1972. *Hawaiian Birdlife*. Honolulu: The University Press of Hawaii.

[2]Grant, G.S., J. Warham, T.N. Pettit, and G.C. Whittow. 1983. Reproductive behavior and vocalizations of the Bonin Petrel (*Pterodroma hypoleuca*). *Wilson Bulletin* 95(4):522-539.

[3]Harrison, C.S. 1990. *Seabirds of Hawaii: Natural History and Conservation*. Ithaca, NY: Cornell University Press.

[4]Niethammer, K.R., J.I. Megyesi, and D. Hu. 1992. Incubation periods for 12 seabird species at French Frigate Shoals, Hawaii. *Colonial Waterbirds* 15(1):124-127.

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Group 1—Take-Home Assignment

As you discovered in class, introduced small mammals like the black rat have devastated the bird populations of Hawaii through predation. However, grazing mammals such as pigs, cows, and goats also have contributed to the decline and extinction of Hawaiian birds. In 1778 and the years following, large numbers of these mammals were brought to the Hawaiian Islands for agricultural reasons on expeditions led by Captain James Cook and other sea captains. Since that time, many of these mammals have become feral (i.e., though once domesticated, they no longer depend on humans).

Your assignment, as a class, is to develop an understanding of the problems associated with the introduction of these ungulates (hoofed mammals) to the Hawaiian biota, specifically to native birds. We can categorize these problems as follows: (1) how ungulates affect the habitat of native birds, (2) how ungulates facilitate the spread and establishment of other introduced species, and (3) why Hawaii's birds are particularly susceptible to introduced species. During the next week, each group in your class will examine one of these aspects of the problem using information you get from the list of references below. Next week, groups will share their findings with the entire class.

Group 1: How might the ungulates introduced to Hawaii affect the habitats of native birds?

Use the following references to generate your response:

- Drost, C.A., and G.M. Fellers. 1999. Non-native animals on public lands. http://biology.usgs.gov/s+t/noframe/x180.htm.
- Scott, J.M., C.B. Kepler, C. van Riper III, and S.I. Fefer. 1988. Conservation of Hawaii's vanishing avifauna. *BioScience* 38(4):238-253.
- Scott, J.M. 11/30/1999. Hawaii—Overview. http://biology.usgs.gov/s+t/noframe/t283.htm
- Stone, C.P. 1989. Non-native land vertebrates. In: C.P. Stone and D.B. Stone (eds.). *Conservation Biology in Hawaii*. Honolulu: University of Hawaii Cooperative National Park Resources Studies Unit. pp88-95.
- Stone, C.P., and L.L. Loope. 1987. Reducing negative effects of introduced animals on native biotas in Hawaii: What is being done, what needs doing, and the role of national parks. *Environmental Conservation* 14:245-258.
- Vitousek, P.M., L.L. Loope, and C.P Stone. 1987. Introduced species in Hawaii: Biological effects and opportunities for ecological research. *Trends in Ecology and Evolution* 2(7):224-227.

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Group 2—Take-Home Assignment

As you discovered in class, introduced small mammals like the black rat have devastated the bird populations of Hawaii through predation. However, grazing mammals such as pigs, cows, and goats also have contributed to the decline and extinction of Hawaiian birds. In 1778 and the years following, large numbers of these mammals were brought to the Hawaiian Islands for agricultural reasons on expeditions led by Captain James Cook and other sea captains. Since that time, many of these mammals have become feral (i.e., though once domesticated, they no longer depend on humans).

Your assignment, as a class, is to develop an understanding of the problems associated with the introduction of these ungulates (hoofed mammals) to the Hawaiian biota, specifically to native birds. We can categorize these problems as follows: (1) how ungulates affect the habitat of native birds, (2) how ungulates facilitate the spread and establishment of other introduced species, and (3) why Hawaii's birds are particularly susceptible to introduced species. During the next week, each group in your class will examine one of these aspects of the problem using information you get from the list of references below. Next week, groups will share their findings with the entire class.

Group 2: How might the ungulates introduced to Hawaii aid in the establishment and spread of other introduced species?

Use the following references to generate your response:

- Scott, J.M., C.B. Kepler, C. van Riper III, and S.I. Fefer. 1988. Conservation of Hawaii's vanishing avifauna. *BioScience* 38(4):238-253.
- Scott, J.M. 11/30/1999. Hawaii—Overview. http://biology.usgs.gov/s+t/noframe/t283.htm
- Stone, C.P. 1989. Non-native land vertebrates. In: C.P. Stone and D.B. Stone (eds.). *Conservation Biology in Hawaii*. Honolulu: University of Hawaii Cooperative National Park Resources Studies Unit. pp88-95.
- Stone, C.P., and L.L. Loope. 1987. Reducing negative effects of introduced animals on native biotas in Hawaii: What is being done, what needs doing, and the role of national parks. *Environmental Conservation* 14:245-258.
- Vitousek, P.M., L.L. Loope, and C.P Stone. 1987. Introduced species in Hawaii: Biological effects and opportunities for ecological research. *Trends in Ecology and Evolution* 2(7):224-227.

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Group 3—Take-Home Assignment

As you discovered in class, introduced small mammals like the black rat have devastated the bird populations of Hawaii through predation. However, grazing mammals such as pigs, cows, and goats also have contributed to the decline and extinction of Hawaiian birds. In 1778 and the years following, large numbers of these mammals were brought to the Hawaiian Islands for agricultural reasons on expeditions led by Captain James Cook and other sea captains. Since that time, many of these mammals have become feral (i.e., though once domesticated, they no longer depend on humans).

Your assignment, as a class, is to develop an understanding of the problems associated with the introduction of these ungulates (hoofed mammals) to the Hawaiian biota, specifically to native birds. We can categorize these problems as follows: (1) how ungulates affect the habitat of native birds, (2) how ungulates facilitate the spread and establishment of other introduced species, and (3) why Hawaii's birds are particularly susceptible to introduced species. During the next week, each group in your class will examine one of these aspects of the problem using information you get from the list of references below. Next week, groups will share their findings with the entire class.

Group 3: What characteristics of Hawaii's endemic birds make them more vulnerable than other birds in Hawaii to species invasions like that of the ungulates described above?

Use the following references to generate your response:

- Campbell, N.A., J.B. Reece, and L.G. Mitchell. Angiosperms and animals have shaped one another's evolution. In: *Biology*. 5th ed. Menlo Park, CA: Benjamin/Cummings. p570.
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- Olson, S.L., and H.F. James. 1982. Fossil birds from the Hawaiian islands: Evidence for wholesale extinction by man before western contact. *Science* 217:633-635.
- Stone, C.P. 1989. Non-native land vertebrates. In: C.P. Stone and D.B. Stone (eds.). *Conservation Biology in Hawaii*. Honolulu: University of Hawaii Cooperative National Park Resources Studies Unit. pp88-95.
- Stone, C.P., and L.L. Loope. 1987. Reducing negative effects of introduced animals on native biotas in Hawaii: What is being done, what needs doing, and the role of national parks. *Environmental Conservation* 14:245-258.
- Warner, R.E. 1968. The role of introduced disease in the extinction of the endemic Hawaiian avifauna. *The Condor* 70:101-120.