Systematics and endangered species

Why worry about systematics?

Systematics is the science of diversity, and if we are concerned about the loss of diversity one might think that it would be a major contributor to the theory and practice of conservation biology. After all, before you can conserve anything, you have to be able to identify what it is you intend to conserve. The U.S. Endangered Species Act (`http://www.fws.gov/endangered/laws-policies/esa.html`) specifies, for example, that

> §3(16) The term "species" includes any subspecies of fish or wildlife or plants, and any distinct population segment of any species or vertebrate fish or wildlife which interbreeds when mature.

We've already seen some important ways that ecology and genetics contribute to conservation biology, and we'll see many more through the remainder of this course. But we won't see as many contributions from systematics. In fact, we won't say a whole lot about systematics after this lecture and the case study that follows next Wednesday.

Nonetheless, systematics plays an important role, and there are some important ways in which it should contribute more in the future. Soltis and Gitzendanner [12] identify four of them.

1. Species concepts
2. Identifying lineages worthy of conservation
3. Setting conservation priorities
4. The effects of hybridization on the biology and conservation of rare species

Species concepts

Biologists have been arguing about what species are for as long as they have been grouping organisms into species, and I don't propose to solve the problem. Fortunately, we don't necessarily have to agree with one another. The "hybrid policy" proposed by the U.S. Fish & Wildlife Service in 1996 (`http://www.fws.gov/filedownloads/ftp_DJCase/endangered/federalregister/1996/s960207a.html`)[1] notes that

> The [Endangered Species] Act does not attempt to define "species" in biological terms, and thus allows the term to be applied according to the best current biological knowledge and understanding of evolution, speciation, and genetics.

The biological species concept[2] has been the most widely accepted and influential species definition for most of the last sixty years. In the last twenty years, however, systematists are increasingly inclined to define species in phylogenetic terms, either as minimal (or at least very small) monophyletic clades (the history-based conception) or as population systems with fixed, diagnosable differences (the character-based conception).

In one sense, it might not seem to matter how we define species. In fact, many conservation biologists are now focusing on the protection of "evolutionarily significant units"[3] precisely because systematists can't agree on how to define what species are. Remember, however, that the U.S. Endangered Species Act states specifically that

> the term "species" includes any subspecies of fish or wildlife or plants, and any distinct population segment of any species or vertebrate fish or wildlife which interbreeds when mature.

That means that "evolutionarily significant units" without a formal latinized name can be protected only if they are vertebrates, e.g., grizzly bear, timber wolf, and certain salmon runs in the Pacific northwest. Plants and invertebrates can be protected *only* if they have latinized names that can be applied to them. Of course, it doesn't matter whether they are recognized as subspecies (or varieties in plants), so long as they are formally recognized. It does mean, however, that if you work with plants or invertebrates and identify an evolutionarily significant unit worthy of protection, you (or a systematist friend of yours) will have to put a formal name on it if you want it to receive protection under the U.S. Endangered Species Act.

Moreover, Collar [3] points out that the species concept we adopt could have a large impact on the conservation decisions we make. In birds, whose taxonomy is better understood than that of any other group of animals or plants, using a phylogenetic species concept

[1] If you visit the Fish & Wildlife Service's page on "Laws & Policies | Regulations and Policies" (`http://www.fws.gov/endangered/laws-policies/regulations-and-policies.html`), you won't find any mention of the hybrid policy. That's because the policy was proposed, but never adopted. You can find a mention of an early version of it in [8].

[2] "A species is a group of actually or potentially interbreeding natural populations that are reproductively isoated from other such groups" [7].

[3] More on that in a moment

instead of a biological species concept could double or triple the number of species recognized [3, p. 131]. The result would undoubtedly be a large increase in the number of bird species that we recognize as threatened, which may or may not be a good thing. To cite an even more extreme recent example, Witt et al. [14] used mtDNA barcoding to identify species within a group of sponges in the Great Basin. They distinguish two provisional species within the currently recognized *Hyatella sandra* and thirty-three within *Hyatella azteca*. Sequence divergence among the species was ten times greater than divergence among individuals belonging to the same species and ranged from 4.4% to 29.9%. Witt et al. argue that these results suggest that "diversity and endemism in the invertebrate faunas of Great Basin spring systems is far higher than previously realized. Clearly this 'cryptic fauna' merits consideration in conservation efforts." What do you think?

Evolutionarily significant units

Ryder [11] proposed the evolutionarily significant unit (ESU) as the minimal unit of conservation management. It is an attractive idea because it avoids problems associated with species definitions — or at least it seems to. An ESU is simply

- a set of populations that is morphologically and genetically distinct from other similar populations or
- a set of populations with a distinct evolutionary history.

This captures the idea that in most groups of plants and animals there are "units" of some sort above the level of individuals and populations that are the appropriate units of conservation concern. But you can probably see the difficulty with this definition already.

- How distinct morphologically or genetically do populations have to be to be regarded as different ESUs?
- How do we tell whether one set of populations has an evolutionary history distinct from another?

Well, the answer to the first question is: "It depends."[4]

[4]Sounds a lot like arguments about species definitions, doesn't it?

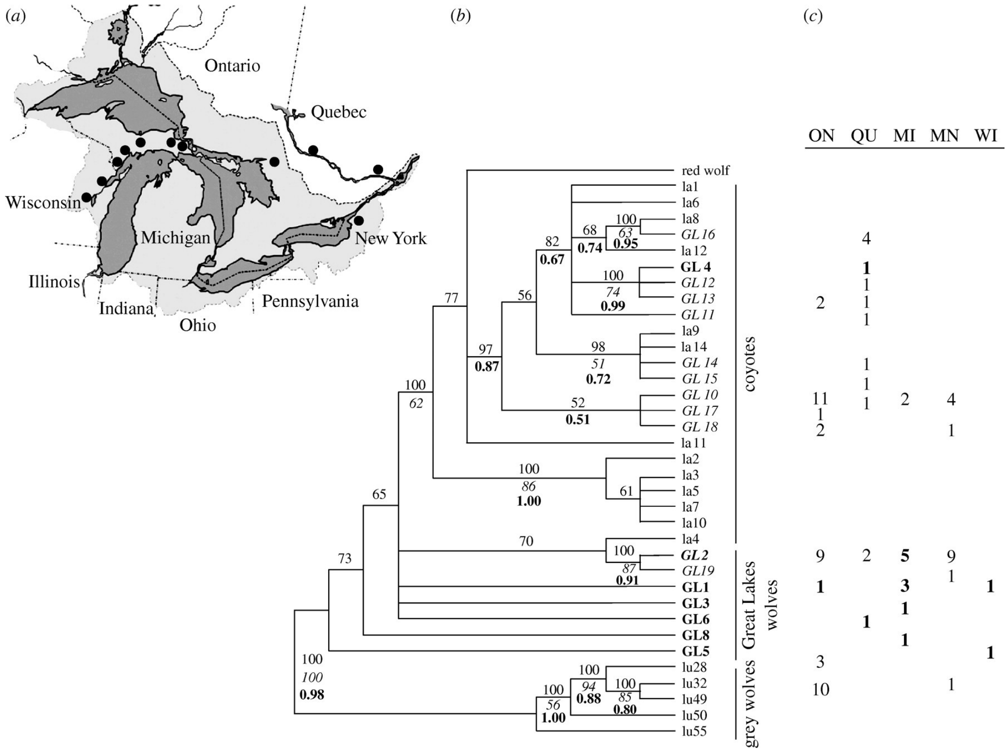

Figure 1: Genetic analysis of Great Lakes wolves (from [6]). Notice that haplotypes found in Great Lakes wolves, those with a GL prefix, are also found in Ontario and Quebec and that many of them are found in a clade that includes haplotypes from coyotes. Historic samples are in bold

ESUs and DPSs

Pennock and Dimmick [9] argue, for example, that many population segments of vertebrates currently protected under the ESA would not be protected if population segments were defined as ESUs. Protected populations of grey wolf and grizzly bear in northern Minnesota, for example, don't seem particularly different either genetically or morphologically from those just across the border in Canada (Figure 1), nor do they seem likely to have an independent evolutionary history. In fact, Leonard and Wayne [6] present data showing that western Great Lakes wolves may be hybrid derivatives of wolves present before the precipitous decline (*Canis lycaon*), coyotes (*Canis latrans*), and gray wolves (*Canis lupus*) and that haplotypes found in Michigan, Wisconsin, and Minnesota are also found in Ontario and Quebec.

Waples [13], on the other, hand argues that use of ESUs to define population segments in fish[5] is precisely what the ESA intends when it directs that listing decisions be based "solely on the basis of the best scientific and commercial data availabls" (§4(b)(1)(A)). Dimmick et al. [5] respond by arguing that "any unit of conservation defined solely in terms of adaptation is likely to underestimate biological diversity.

The U.S. Fish & Wildlife Service and the National Oceanic and Atmospheric Administration have agreed on a policy that they use to determine whether a distinct population segment should be listed under the Endangered Species Act (`http://www.fws.gov/endangered/laws-policies/policy-distinct-vertebrate.html`).

1. Discreteness of the population segment in relation to the remainder of the species to which it belongs.

2. The significance of the population segment to the species to which it belongs.

3. The population segment's conservation status in relation to the Act's standards for listing (i.e., is the population segment, when treated as if it were a species, endangered or threatened?).

The last standard is pretty straightforward. The first two require more specification.

Discreteness

To be considered discrete, a population segment must satisfy one of these conditions:

1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.

[5]Waples is an employee of the National Marine Fisheries Service, and the policy Pennock and Dimmick criticize arose, in part, from Waples' attempt to arrive at a method for identifying "distinct population segments" of Pacific salmon. That policy is codified in Federal regulations for conservation of salmonid species native to the Pacific (56 CFR 58612–58618; November 20, 1991). Current policy for recognizing distinct population segments of vertebrates (61 CFR 4722–4725; February 7, 1996; `http://endangered.fws.gov/policy/pol005.html`) is less restrictive. Its definition of discreteness requires either that "It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors" or that "It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act," i.e., existing regulatory mechanisms are inadequate for protection.

2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.[6]

Significance

Significance is considered only if a population segment is discrete. Its significance "will consider available scientific evidence ... of the discrete population segment's importance to the taxon to which it belongs." Those considerations may include, but are not limited to, the following list:

1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon.
2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon.
3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range.
4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

ESUs and DPSs revisited

What about wolves in the western Great Lakes? Are they an evolutionarily significant unit? Does your answer to that question affect your answer to the question of whether they are a distinct population segment worthy of protection under the Endangered Species Act?

Identifying ESUs

What about determining whether populations are historically distinct from one another? That's a little more straightforward, at least in principle. Consider the case of the dusky seaside sparrow.

- A single popualtion in Brevard County, Florida (see Figure 2)

[6]§4(a)(1)(D) refers to "the inadequacy of existing regulatory mechanisms" as a factor that would allow listing of a species as endangered or threatened.

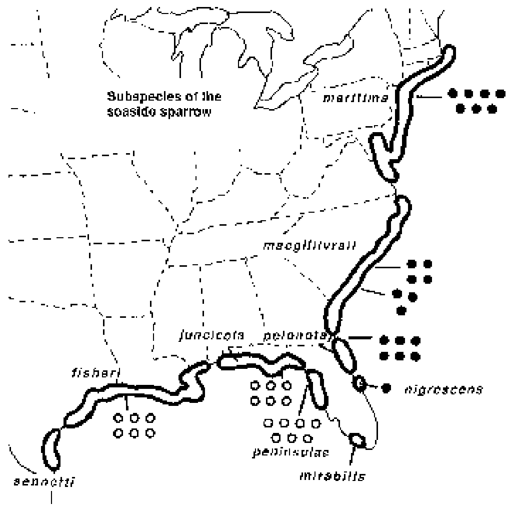

Figure 2: Distribution of seaside sparrow (*Ammodramus maritimus) subspecies in eastern North America. The dusky seaside sparrow is subspecies nigrescens (from [1], © 1989 American Association for the Advancement of Science).*

- Avise and Nelson [1] extracted mtDNA from the last surviving male after it died in the late 1980's and compared it with mtDNA extracted from other seaside sparrows collected from the Atlantic and Gulf coasts.
- Many different haplotypes identified.
- Major division between haplotypes on Atlantic and Gulf coasts.
- Dusky seaside sparrow haplotype a small twig on the Atlantic coast branch. (see Figure 3)
- Their conclusion: conservation efforts directed at the dusky seaside sparrow were misguided. The major evolutionary disjunction is between Atlantic and Gulf coasts.
- **PROBLEM**: mtDNA is maternally inherited. Hybridization between dusky seaside sparrow and other seaside sparrows was documented. A single non-dusky maternal ancestor of the last remaining male would produce this result even if the dusky were actually very different for all or nearly all of its nuclear genes. Multiple haplotypes from within populations would lessen concern about this problem.

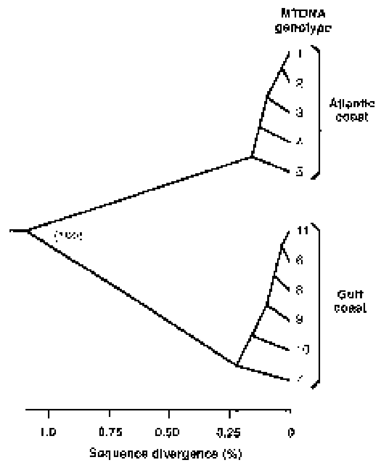

Figure 3: Haplotypes found in analysis of seaside sparrow DNA. The haplotype of the last male dusky seaside sparrow is 1. That haplotype is also found in subspecies *maritima* and *macgillivraii* (from [1], © 1989 American Association for the Advancement of Science).

Setting conservation priorities

We'll come back to this topic and discuss it in more detail later in the course. For now just notice that it might make more sense to devote more conservation attention to taxa that are the last surviving representative of their lineage than to those that are part of a large and speciose group.

- Tuatara *versus* other lizards
- Species in a monotypic genus (*Franklinia alatamaha*, last seen in wild in 1803) *versus* a species in a speciose genus (*Carex polymorpha*, ca. 2000 spp. in genus worldwide)

Clark and May [2] argue that the allocation of research effort is very uneven. Based on a review of 32,000 entries in the Zoological Record, invertebrates account for about 79% of known species worldwide, but only 11% of research articles on conservation while vertebrates account for only about 3% of known species and about 69% of conservation research articles. While this suggests a considerable bias in research effort, Czech et al. [4] argue that allocation of benefits by the U.S. Endangered Species Act follows what would be expected from a political science model based on a combination of public attitudes toward particular taxa (favorable: plants, birds, mammals, fish; unfavorable: reptiles, amphibians, invertebrates) and the number of non-governmental organizations (NGOs) with an interest in those particular taxa. The large amount of resources devoted to birds, mammals, fish, and tortoises reflects both positive public attitudes and a lot of NGO interest.

Hybridization

The "hybrid policy"[7] proposed by the U.S. Fish & Wildlife Service in 1996 specifically notes that hybrids may be worthy of protection.

> The Services believe the responsibility to conserve endangered and threatened species under the Act extends to those intercross progeny if (1) the progeny share the traits that characterize the taxon of the listed parent, and (2) the progeny more closely resemble the listed parent's taxon than an entity intermediate between it and the other known or suspected non-listed parental stock. The best biological information available, including morphometric, ecological, behavioral, genetic, phylogenetic, and/or biochemical data, can be used in this determination.

The questions involving identification and protection of hybrids are fundamentally in the domain of systematics

- What are the relationships of this presumed hybrid? Is it distinct from other taxa?
- Does it closely resemble a non-listed taxon?

In the end the question of whether to protect the product of becomes the question, "Is this entity an evolutionarily significant unit?" In that sense, hybrids pose no particular problem for endangered species protection. For example, the U.S. Fish and Wildlife determined

> Recent evidence indicates that Lloyd's hedgehog cactus is not a distinct species but rather a hybrid or cross which is not evolving independently of its parental species. Therefore, *E. lloydii* no longer qualifies for protection under the Act.[8]

In that case a taxonomic decision led to delisting of a species. In another case taxonomic work confirmed that a species of hybrid origin was distinct and worthy of protection.

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[7] `http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1996_register&docid=fr07fe96-16`

[8] `http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1999_register&docid=fr24jn99-12`

Heiser was able to produce hybrids between Pecos sunflower and both common sunflower and prairie sunflower, but these hybrids were of low fertility. These results support the validity of Pecos sunflower as a true species. In 1990, Rieseberg et al. published the results of molecular tests on the hypothesized hybrid origin of Pecos sunflower, using electrophoresis to test enzymes and restriction-fragment analysis to test ribosomal and chloroplast DNA. This work identified Pecos sunflower as a true species of ancient hybrid origin with the most likely hybrid parents being common sunflower and prairie sunflower.[9]

Hybridization can, however, threaten the persistence of endangered species. Of the eleven individuals of Catalina Island mountain mahogany that remained in the wild in 1995, five were hybrids [10].

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