Background

Description

Part of unit 5 of the Course on Genomics, Ethics and Society, this section provides a background on the ethics of genomics and wildlife.

Body

Nature Conservation and Genomics/Genetics

Humans significantly influence wildlife and plant abundance and distribution globally. This unit focuses on both intended and unintended impacts of human actions on wildlife, and on how genomics might assist in tackling certain human transmissible diseases, mitigate past extinctions, and be used to manage and conserve global biodiversity more effectively. The International Union for the Conservation of Nature (IUCN) recognizes three scales of biodiversity conservation: 1) ecosystem, 2) species, and 3) gene; conservation genomics aims at protecting all three levels of diversity. While you read through this module, keep in the back of your mind that from an evolutionary perspective, high genetic variation (diversity) generally allows populations more opportunity to adapt naturally or through assisted processes than small populations with reduced genomic variation.

One of the central issues for conservation genomics is human-caused global environmental change, which has the potential to alter plant and animal distributions and assemblages spectacularly worldwide. Factors that contribute to human-caused global environmental change include the rising threat of climate change, resource exploitation (eg hunting),the introduction of invasive species, habitat fragmentation, pollution, and extensive changes in landscape composition. For instance, it has become quite clear that many organisms have migrated to higher elevations and latitudes in response to changes in climate in a span of less than 100 years (Chen *et al.*, 2011, Colwell *et al.*, 2008, Lenoir *et al.*, 2008, Root *et al.*, 2003, Walther, 2003). Furthermore, shifting patterns in seasonal plant phenology (when, for instance, plants come into leaf or flower) have been found to correspond to changes in the length of the growing season (Menzel & Fabian, 1999, Parmesan & Yohe, 2003). The specific response of organisms to global environmental change will depend on their ability to disperse, evolve, or adapt through phenotypic plasticity (the ability to produce a different phenotype in different environmental and climatic conditions) (Aitken *et al.*, 2008, Gienapp *et al.*, 2008, Hoffmann & Sgro, 2011, Reusch & Wood, 2007). When a species or population is unable to respond by dispersal, evolution, or adaptation by phenotypic plasticity, it will likely become geographically and genetically isolated, resulting in its eventual extinction, and a corresponding loss in biodiversity.

One of the main causes of loss of genetic diversity, as mentioned above, is small population size. Small populations may suffer from inbreeding depression, where fitness is reduced due to inbreeding and random genetic drift, meaning that infrequently occurring alleles are at risk of being lost (Frankham, 1995). These genetic effects tend to reduce genetic variation, and to fix harmful genes in their homozygous state, drastically impairing the species' ability to respond to ecosystem changes. As ecosystems become fragmented and resources become depleted, therefore, the ability of populations to respond via dispersal and gene flow becomes restricted, as populations become separated from one another. The density of propagules (materials used to propagate an organism, eg a spore or seed) dispersed from a given individual is normally expected to decrease with increasing geographic distance from the source. Because of this, the further apart individuals are, the lower the probability of them reproducing with one another. Thus, populations that are in close geographic proximity will be more genetically similar than those far away. This pattern of genetic relatedness is called isolation by distance (IBD) (Wright, 1943), and is commonly observed in nature (Meirmans, 2012, Slatkin, 1993). It's worth noting, though, that IBD assumes uniform dispersal ability, and this isn't always the case. The landscape can impose other limitations, such as rivers and mountains acting as barriers to movement.

Isolation by distance is not the only process that can lead to DNA differences between individuals of the same species. Other explanations for genetic differences include Isolation by Resistance (McRae, 2006), Isolation by Adaptation (Nosil *et al.*, 2008), Isolation by Environment (Sexton *et al.*, 2014, Wang & Bradburd, 2014), or Isolation by Colonization (Orsini *et al.*, 2013). McRae (2006) suggested Isolation by Resistance (IBR) as an alternative to IBD when geographically close individuals have different genotypes. Specifically, barriers to gene flow and dispersal may lead geographically close populations to have a greater degree of genetic differentiation than more distant populations. Barriers to movement can be physical geographic barriers such as rivers, urban environments or a mountain range, or they can be ecological, including reliance on mutualist pollinators or the continuous distribution of temperature and precipitation in heterogeneous systems. If barriers result in genetic isolation than small population size will result in reduced genetic variation, weak natural selection, inbreeding depression and an average reduction in overall individual fitness (Ouborg *et al.*, 2010).

Conservation genomics is a field which aims at assessing how genomic biodiversity is impacted by human activity, and is primarily concerned with maintaining genetic diversity in dwindling populations and potentially restoring genetic diversity from extinct populations. As we'll note below, though, and as our speaker for this unit describes, the tools of conservation genomics can also be used to reduce, remove or replace particular wildlife populations that can transmit diseases to people.

There are many reasons why it's argued that we should conserve genomic biodiversity, developed in more detail below. Biodiversity is important for economic reasons, in terms of ecosystem services and functions, and in some cases for aesthetic reasons. It's also argued (see below) that species, ecosystems, and perhaps populations, have some kind of intrinsic (non-instrumental) value, or that they have moral status. Aldo Leopold, sometimes called one of the "fathers" of conservation, said "…To keep every cog and wheel is the first precaution of intelligent tinkering" (Leopold, 1966). He may be suggesting that given our incomplete knowledge of how ecological systems function, we need to preserve every part of them.

Conservation genomic technologies are currently used in a variety of ways to conserve living organisms, species, populations, and systems, and to protect biodiversity; and there are prospects for new uses. Some examples of these various uses are:

(a) Captive breeding programs

Breeding members of threatened populations or species outside their native habitat in zoos or other conservation facilities, with the intention of subsequently reintroducing them to the wild, has long been a significant conservation tool. Since threatened populations are small in number, they generally have a correspondingly small gene pool. This creates the risk that captive breeding programs will produce inbred individuals with significantly reduced fitness. Genetic technology allows the gene pool of both wild and captive populations to be tracked, providing information that can be used to breed for genetic diversity. Genetic information can also be used to prevent selection for “captivity adaptation” – selection for genes (such as for tameness) that may be good for living in captivity, but not for re-introduction into the wild.

(b) Monitoring and managing species populations in the wild

Much conservation work involves wild, not captive bred populations, and here genetic technologies are also significant. Tracking genes in particular populations can help identify units of conservation interest; distinguish different species and subspecies; identify barriers between populations that lead to lack of gene flow; assist in understanding how genetically viable particular populations might be; and uncover whether hybridization is ongoing or has happened in the past. It can also identify disease risks in populations, and help in understanding adaptations to human and other selection pressures, such as the effects of climate change.

(c) De-extinction

The idea of reviving species that have become extinct, either in the recent or the deep past, has recently been widely discussed. This could be done by cloning and selective breeding, using recovered DNA from members of extinct species. Candidate species for de-extinction include passenger pigeons and woolly mammoths, among many others. Strictly speaking, since the species is already extinct, this is not conservation; but motivations for some proposed de-extinctions include contribution to the conservation of existing ecosystems.

(d) Transgenics

Transgenics is a technique that introduces a piece of DNA, conferring a specific phenotype, into a target organism. The transgenic species will then convey the transgene into its offspring. There are a variety of reasons to use transgenics in conservation genomics. In particular, there are cases where assisted migration (deliberately moving an organism to a new habitat when the climate changes in its current habitat) of an organism is untenable, and the modification will allow the species to exist *in situ* while the environment changes around them. This form of assisted adaptation may be important especially in species with important ecosystem functions or those species that provide important human services.

(e) Biological Control

Genomics can also be used in different ways as a form of biological control; some of these controls use genomics to eradicate perceived pests, as well as to conserve desirable organisms/ biodiversity. For instance, a species can be bred to be resistant to some pest or abiotic stress (eg drought). Populations bred in this way will have higher fitness than those lacking the trait, and will thus be at a competitive advantage. An additional method of biological control is the use of transgenics (discussed above). In our "Selected Issues in Depth" section, we see a different aspect of biological control: using transgenics to fight human infectious diseases, for example malaria and dengue fever. This form of biological control is still in its infancy, but recent advances in technology are likely to make it more viable soon.

Social and Ethical Issues Raised

Cloning and genetically modifying organisms generate a number of ethical concerns (see modules on GM crops and domesticated animals). However, one might imagine that the use of genetic technologies in wildlife conservation could be seen as wholly positive. Most people regard wildlife conservation—in terms of protecting species, ecosystems, and biodiversity—as good, even though there are occasions when human interests may be argued to outweigh such concerns. But this isn't entirely correct. Different aspects of these technologies have raised a number of social and ethical questions – both about their effect on “nature,” and certain conservation goals.

1. Wildness and Naturalness

As has been noted in previous modules, genetic technologies are often seen as threatening the value of “naturalness,” interpreted either in terms of interfering or changing an organism’s nature or imposing human influence where it was previously absent. The use of genetic technologies in nature conservation is no exception. One concern is that captive breeding influences, and to some degree determines, the genetic composition of species (especially if, for instance, strains or subspecies are bred for a particular feature, such as disease resistance). This means that the genetic “nature” of these organisms is no longer independent of human intention; on some views, this makes such organisms less wild, and in that respect, less valuable. A second, more general, concern is that human intervention into and control over the non-human world with genetic technologies is deeper and potentially more permanent in comparison to other forms of human intervention. So while one goal of conservation genomics may be to preserve “Nature,” at the same time one of "Nature's" most valued characteristics—its wildness, that it’s *not* human—may be lost. As one commentator says of such conservation attempts involving Lesser Geese:

> “The risk here is that misguided conservation might destroy the Lessers [the geese], in the very gesture that saved them: that the birds would cease to be “wild” or rather cease to be themselves in some vital and fundamental sense, that they might be taken from the wild, or have their wildness taken from them…Fail to intervene and the object is lost; intervene and the object may also be lost, although in other ways…” (Reinert 2013).

2. Species values

One key reason for conservation genomics/genetics is to prevent species extinctions. People value species for many reasons. Some species have significant cultural or historical value, or are highly charismatic—such as the polar bear. More generally, species can be valued because of future potential uses they may have (such as for medicines). They may be valued ecologically (in particular, they may be protected for the sake of ecosystems). They may be valued for their aesthetic qualities: beauty, strangeness, their sounds or songs, their scents, even their ugliness. In addition, people may value some or all species in themselves, independently of any uses they may have for us. For instance, they might deeply prefer to live in a world in which particular species, or all existing species, continue to exist.

A further claim that's sometimes made about species is that they have "moral status," independently of their usefulness to us or to ecosystems. On this view, we can have duties or responsibilities directly to species (such as not to make them extinct). A number of different arguments have been made to defend this controversial view – for instance, that species are coherent genetic lineages with morally relevant interests, and that it makes sense to say that they can be "benefited" and "harmed". The environmental ethicist Holmes Rolston (1986) argues that species are living forms embodying valuable evolutionary and generative processes, and that as such they should be regarded as having moral status. He maintains that making a species extinct should be seen as a "superkilling," since it not only kills an individual organism, but all future organisms of that type. However, arguments that species have moral status are controversial. Those who reject this view deny either that it makes sense to say that species have interests and can be harmed (while individual members of the species may have interests, the species as a whole does not); or maintain that if species do have interests, these interests do not matter morally. It's perfectly possible, they maintain, to say that something has interests, but not to think that these interests are relevant to whether something matters morally. After all, they might maintain, we could say that it's in the interests of a bacterium not to be killed (it can be harmed), but that doesn't mean we need to take the bacterium into account in our moral decision-making.

3. Value of Biodiversity

It's often argued that the use of genomics/genetics in conservation protects biodiversity (however biodiversity is interpreted), and that, since protecting biodiversity is good, there's a strong ethical reason to adopt these technologies. This raises the question that forms the title of a recent controversial book: What's so good about biodiversity? (Meier 2012). Obviously, "biodiversity" is not the kind of thing that could have moral status. And it's unlikely that anyone straightforwardly assigns biodiversity existence value. After all, most people would strongly prefer that some kinds of biodiversity, such as disease viruses, did not exist; and no-one argues that biodiversity should be increased by artificial means, for instance by rapidly extending synthetic biology. So it seems as though what's valued is only some biodiversity of the right kind.

The most frequent reason it's claimed that biodiversity is so important is that it's needed to provide ecosystem services for human beings. While this seems very plausible, Meier (2012) argues that the vast majority of our food comes from a very small number of organisms, and that, more generally, we could get the services we need with much less biodiversity than we currently have. So while some biodiversity is necessary, this doesn't give us a good reason to protect a very high proportion of it. (This issue was discussed at a conference in Oxford in January 2015 - here's the conference website, which you might find interesting: http://www.biodiversity.ox.ac.uk/events/biosymposium-2015-the-functions-and-values-of-biodiversity/)

This debate merges with more general current discussions about the nature and goals of conservation—and in particular, biodiversity protection—in what's come to be called the "Anthropocene," an era where human activities on the Earth are having effects on a geological scale. While many in this debate continue to argue that the protection of biological diversity – especially genetic diversity – remains highly ethically significant, these claims are, nonetheless, contested.

4. Restitutive Justice

In Unit 1, we noted that genetics and genomics impact justice concerns in various ways. One reason it's sometimes argued that species conservation (and de-extinction) is important, is that it can serve as *restitutive justice*. That is, where humans have caused some past harm – in this case endangering or destroying species – species conservation (and de-extinction) are a form of restitution, a way of "making good" past harms. However, this argument is problematic. It looks as though to defend this argument, you'd need to think that species have moral status – that species could both be harmed and owed duties. As we've seen, this claim is widely rejected. Second, like many reparation-type arguments, it's not clear who would have the duty of restitution. For instance, no one now alive contributed to the extinction of mammoths, dodos, or passenger pigeons, so no individual, at least, obviously has a duty to try to "make good." The best kinds of argument here depend on the idea that we have some kind of collective moral responsibility towards species that humans made extinct in the past. But this is a difficult argument to defend.

Alternative arguments might claim that justice is owed not to species themselves but rather to the ecosystems that are "harmed" by the endangerment or extinction of species they contain. However, this seems to rest on the idea that ecosystems have moral status, and that's at least as problematic as claiming it for species! Another possibility is to claim that there's a duty to future *human* generations to conserve endangered species, and to bring back extinct ones. This argument hasn't been very fully developed, but if it were widely accepted, it would certainly impose a significant burden of responsibility on people who currently exist.

In a recent paper in *Conservation Biology*, the philosopher Ron Sandler expressed considerable skepticism about restitutive justice arguments in the context of de-extinction, rejecting the argument that species as wholes can be harmed, such that we do not owe them anything.

> "Species, such as *E. migratorius* and *T. cynocephalus*, cannot be owed a debt of restorative justice [because they do not have aims or welfares distinct from those of the organisms that comprise them. Moreover, the individual organisms that were harmed and perhaps wronged during the extinction process are no longer alive. Nor are those who caused the extinctions. Therefore, it is not possible for a debt of restorative justice, even if there were one, to be paid by those who owe it to those who are due it." (Sandler 2014)

5. Animal Welfare

Some uses of conservation genetics have implications for animal welfare, in terms of causing discomfort, distress or suffering to individual animals, or ending their lives prematurely. Animals involved in captive breeding programs may suffer stress from human contact and handling, from unsuitable housing, and from the use of various reproductive technologies. In addition, sufficient genetic diversity to prevent inbreeding depression (which can cause significant health issues) is required. Individual animals with unwanted genetic sets – in particular animals that lack sufficient genetic diversity – may be culled, even if they are members of sentient and charismatic species. An example of this occurred in Denmark in 2014, when a giraffe was culled at Copenhagen Zoo because its genetic profile was similar to other male giraffes, and so it was unsuitable for use in the breeding program. Although euthanizing genetically-unwanted animals in this way is very unlikely to cause suffering, those who argue that sentient animals have a right not to be killed maintain that it's wrong to kill any animal just because its genes can't be used. This is, rights defenders maintain, to see animals not as living beings with moral status and lives in their own right, but as vehicles to be used to pass on appropriate genes.

For a link to the story on the Copenhagen Zoo giraffe, see:

http://www.decodedscience.com/marius-giraffe-killed/43172 and http://www.bbc.com/news/science-environment-26118748

6. Ethical issues raised by de-extinction

Resurrecting extinct species raises many of the same ethical issues already discussed (in this unit and in others). For instance, advocates for de-extinction often claim that bringing back extinct species can correct previous injustices, increase biodiversity, and serve various ecosystem functions. Opponents, meanwhile, argue that de-extinction is unnatural and contributes to human arrogance and domination over nature.

Perhaps the most critical issue raised by de-extinction, however, is its potential negative impact on animal welfare (most discussions of de-extinction have concerned vertebrate species). The ultimate goal of de-extinction is for species to be brought back. Many advocates for de-extinction admit, however, that successful de-extinction entails significant suffering for the first individuals brought into existence through genomics technologies. The techniques currently planned for de-extinction projects have been borrowed largely from cloning research. As discussed in the module on domesticated animals, stillborn births are still quite common in cloning, as are various health problems and deformities. Though successful de-extinction may be achieved eventually, it will require a great deal of trial-and-error, and will entail suffering for individual animals.

This is especially problematic when we consider that much of the rhetoric around de-extinction refers to the interests and the good of the *species*. As discussed above, it’s not clear that species, as such, have any morally relevant interests. It is instead sentient individual members of a species that have morally relevant interests. De-extinction projects that claim suffering for sentient individuals is necessary for the good of the species would therefore seem to be ethically problematic.

References

- Aitken SN, Yeaman S, Holliday JA, Wang T, Curtis-Mclane S (2008) Adaptation, migration or extirpation: climate change outcomes for tree populations. *Evolutionary Applications,* **1**, 95-111.
- Chen IC, Hill J, Ohlemuller R, Roy D, Thomas C (2011) Rapid range shifts of species associated with high levels of climate warming. *Science,* **333**, 1024-1026.
- Colwell RK, Brehm G, Cardelús CL, Gilman AC, Longino JT (2008) Global warming, elevational range shifts, and lowland biotic attrition in the wet tropics. *Science,* **322**, 258-261.
- Frankham R (1995) Conservation Genetics. *Annual Review of Genetics,* **29**, 305-327.
- Gienapp P, Teplitsky C, Alho JS, Mills JA, Merilä J (2008) Climate change and evolution: disentangling environmental and genetic responses. *Molecular Ecology,* **17**, 167-178.
- Hoffmann AA, Sgro CM (2011) Climate change and evolutionary adaptation. *Nature,* **470**, 479-485.
- Lenoir J, Gégout JC, Marquet PA, Ruffray PD, Brisse H (2008) A significant upward shift in plant species optimum elevation during the 20th century. *Science,* **320**, 1768-1771.
- Leopold A (1966) *A sand county almanac: With other essays on conservation from Round River,* New York, NY, Oxford University Press.
- Manel S, Holderegger R (2013) Ten years of landscape genetics. *Trends in Ecology & Evolution*.
- Manel S, Schwartz MK, Luikart G, Taberlet P (2003) Landscape genetics: combining landscape ecology and population genetics. *Trends in Ecology and Evolution,* **18**, 189-197.
- Mcrae BH (2006) Isolation by resistance. *Evolution,* **60**, 1551-1561.
- Meier, Don. 2012. *What's so good about biodiversity?* Dordrecht: Springer.
- Meirmans PG (2012) The trouble with isolation by distance. *Molecular Ecology,* **21**, 2839-2846.
- Menzel A, Fabian P (1999) Growing season extended in Europe. *Nature,* **397**, 658-659.
- Nosil P, Egan SP, Funk DJ (2008) Heterogeneous genomic differentiation between walking-stick ecotypes:"Isolation by Adaptation" and multiple roles for divergent selection. *Evolution,* **62**, 316-336.
- Orsini L, Vanoverbeke J, Swillen I, Mergeay J, De Meester L (2013) Drivers of population genetic differentiation in the wild: isolation by dispersal limitation,

isolation by adaptation and isolation by colonization. *Molecular Ecology,* **22**, 5983-5999.
- Parmesan C, Yohe G (2003) A globally coherent fingerprint of climate change impacts across natural systems. *Nature,* **421**, 37-42.
- Reinert, Hugo. (2013) The Care of Migrants - Telemetry and the fragile wild. *Environmental Humanities* 3: 1-24
- Reusch TBH, Wood TE (2007) Molecular ecology of global change. *Molecular Ecology,* **16**, 3973-3992.
- Rolston, Holmes. 1986. Duties to Endangered Species. *Bioscience* 35/11: 718-726
- Root TL, Price JT, Hall KR, Schneider SH, Rosenzweig C, Pounds JA (2003) Fingerprints of global warming on wild animals and plants. *Nature,* **421**, 57-60.
- Sandler, Ron. 2014. "The Ethics of Reviving Long Extinct Species." *Conservation Biology* 28/2 354-360
- Sexton JP, Hangartner SB, Hoffmann AA (2014) Genetic isolation by environment or distance: Which pattern of gene flow is most common? *Evolution,* **68**, 1-15.
- Slatkin M (1993) Isolation by distance in equilibrium and nonequilibrium populations. *Evolution,* **47**, 264-279.
- Sork V, Waits LP (2010) Contributions of landscape genetics approaches, insights, and future potential. *Molecular Ecology,* **19**, 3489-3495.
- Storfer A, Murphy MA, Evans JS *et al.* (2007) Putting the 'landscape' in landscape genetics. *Heredity,* **98**, 128-142.
- Walther G-R (2003) Plants in a warmer world. *Perspectives in Plant Ecology, Evolution and Systematics,* **6**, 169-185.
- Wang IJ, Bradburd GS (2014) Isolation by environment. *Molecular Ecology,* **23**, 5649-5662.
- Wright S (1943) Isolation by distance. *Genetics*, **28:** 14-138.

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