Abstract: Most mountain ungulates exist in semiisolated populations that are at risk of extinction because they are small. Consequently, the preservation of traditional travel routes allowing connectivity within metapopulations is an important conservation goal. Many mountain ungulates, however, are also threatened by introduced diseases and parasites carried by domestic livestock. In the presence of exotic diseases, connectivity among populations may increase rather than lessen extinction risk.
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Patchy Habitats, Fragmented Populations
Mountain-dwelling ungulates (Caprinae), including wild sheep, goats, ibex and chamois move over long distances. These movements may involve seasonal migrations to search for mates or food, exploit mineral licks or to avoid predators. Individuals can move distances of over 80 km, and animals from one population can range over more than 2000 km² of valleys and mountains. Neighbouring populations often overlap in part of their yearly distribution, but typically each individual returns to its native winter range [1,2]. The patchy distribution of winter habitats or of other critical habitats in mountain ecosystems is likely responsible for the metapopulation structure of most mountain ungulates [1]. Large, continuous tracts containing habitat suitable for year-round use are rare in most mountains, so that many Caprinae populations include only a few dozen to a few hundred individuals that use specific patches of seasonally critical habitat. Often patches of seasonally suitable habitat are separated by large tracts of unproductive or unsuitable habitat. Thus most mountain ungulates make seasonal migrations along altitudinal gradients to take advantage of differences in timing of vegetation green-up [3]. In some species, females move to cliffs or to high elevations to avoid predation on their young and not to seek the best forage.

Why Connectivity is Good
The knowledge of travel routes, particularly those through inhospitable habitat such as mature forest, is transmitted culturally; young individuals learn the location of travel routes by following older animals. Those cultural traditions may be lost after local extinctions, and thus a major challenge of reintroduction programs is to ensure that animals learn the location of seasonal ranges and of safe travel routes connecting those ranges [7]. Human developments in mountain areas, particularly residential areas, fences or major highways, can effectively block those travel routes and increase the risk of extinction of isolated populations. Consequently, the protection of travel routes is important to ensure connectivity among groups within a metapopulation.
Landscape-Level Movements of Mountain Ungulates: Carrying Genes and Pathogens between Populations

When Connectivity is Bad
Because of their long-distance movements, mountain ungulates are also very effective at carrying pathogens over large areas. Exotic diseases from domestic livestock are a major conservation challenge for mountain ungulate populations worldwide [Table 1,4,6]. Contact with domestic livestock at a single site can transmit pathogens that are then carried to a very large metapopulation. Pneumonia in bighorn sheep (Ovis canadensis) and mange in chamois (Rupicapra rupicapra), for example, can spread far beyond the initial contact point with infected domestic livestock, particularly when males move among groups of females during the rut. Animals in wilderness areas or in National Parks are therefore put at risk by conservation and agricultural policies existing outside the boundaries of inaccessible or protected areas. In the presence of these threats, managing to increase connectivity may be counterproductive. The risks of disease transmission must be evaluated in each case against the risks of increasing inbreeding and stochastic extinctions by isolating populations. In particular, the health status of mountain ungulates destined for transplants must be carefully evaluated. More importantly, policies aimed at removing the risk of contact between domestic livestock and wild Caprinae are key to the conservation of mountain ungulates.

An Example: Alpine Ibex
Consider for example the conservation status of Alpine Ibex (Capra ibex) (Fig. 1). Ibex almost went extinct in the Alps in the 19th century, and only survived in the Gran Paradiso area, a Royal Hunting Reserve that later became Italy’s first National Park. Ibex have now been reintroduced in many areas, number in the tens of thousands and are hunted in several countries. In much of the current range, however, they exist in small and isolated populations with varying degrees of genetic diversity. Current conservation strategies aim at establishing connectivity among reintroduced populations. Ibex, however, are susceptible to various diseases carried by domestic livestock, such as brucellosis and keratoconjunctivitis. Connectivity among populations, while maintaining greater genetic diversity, also allows for disease transmission. Clearly, ibex conservation is complex and requires long-term planning over a large geographical scale. That requirement is made more difficult by the fine-scale jurisdictional subdivision of the Alps, where a single ibex metapopulation may range over several countries and subnational administrative units, including areas with widely different land-use practices. Similar conservation problems face large mammals in many other mountainous areas of the world. In the conservation of mountain ungulates, as in human medical philosophy, an ounce of prevention is worth a pound of cure.

Table 1. Some infectious diseases transmitted from domestic livestock to wild mountain ungulates.

<table>
<thead>
<tr>
<th>Wild mountain ungulate species infected</th>
<th>Infection</th>
<th>Source of infection</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bighorn sheep (Ovis canadensis)</td>
<td>Pneumonia</td>
<td>Domestic sheep</td>
<td>North America</td>
</tr>
<tr>
<td>Ibex (Capra ibex)</td>
<td>Brucellosis</td>
<td>Domestic sheep</td>
<td>Alps</td>
</tr>
<tr>
<td>Ibex, chamois (Rupicapra rupicapra)</td>
<td>Keratoconjunctivitis</td>
<td>Domestic sheep</td>
<td>Alps</td>
</tr>
<tr>
<td>Pyrenean chamois (R. pyrenaica)</td>
<td>Sarcoptic mange</td>
<td>Domestic sheep</td>
<td>Pyrenees</td>
</tr>
<tr>
<td>Ibex</td>
<td>Foot rot</td>
<td>Sheep and cattle</td>
<td>Alps</td>
</tr>
</tbody>
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References

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