Climate change and the potential for hybridization-mediated extinction of endemic high-mountain plants: the case of Sierra Nevada

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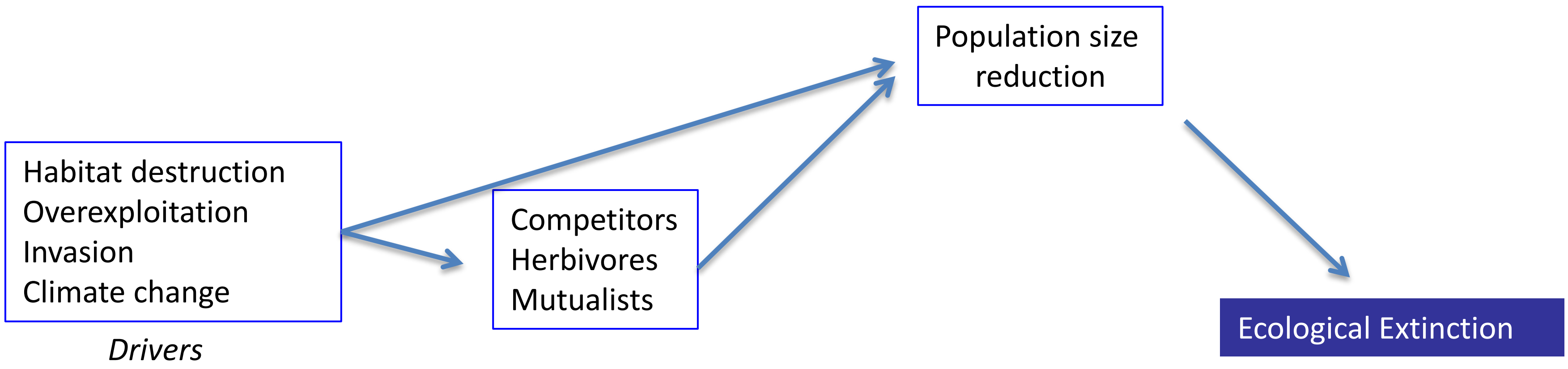
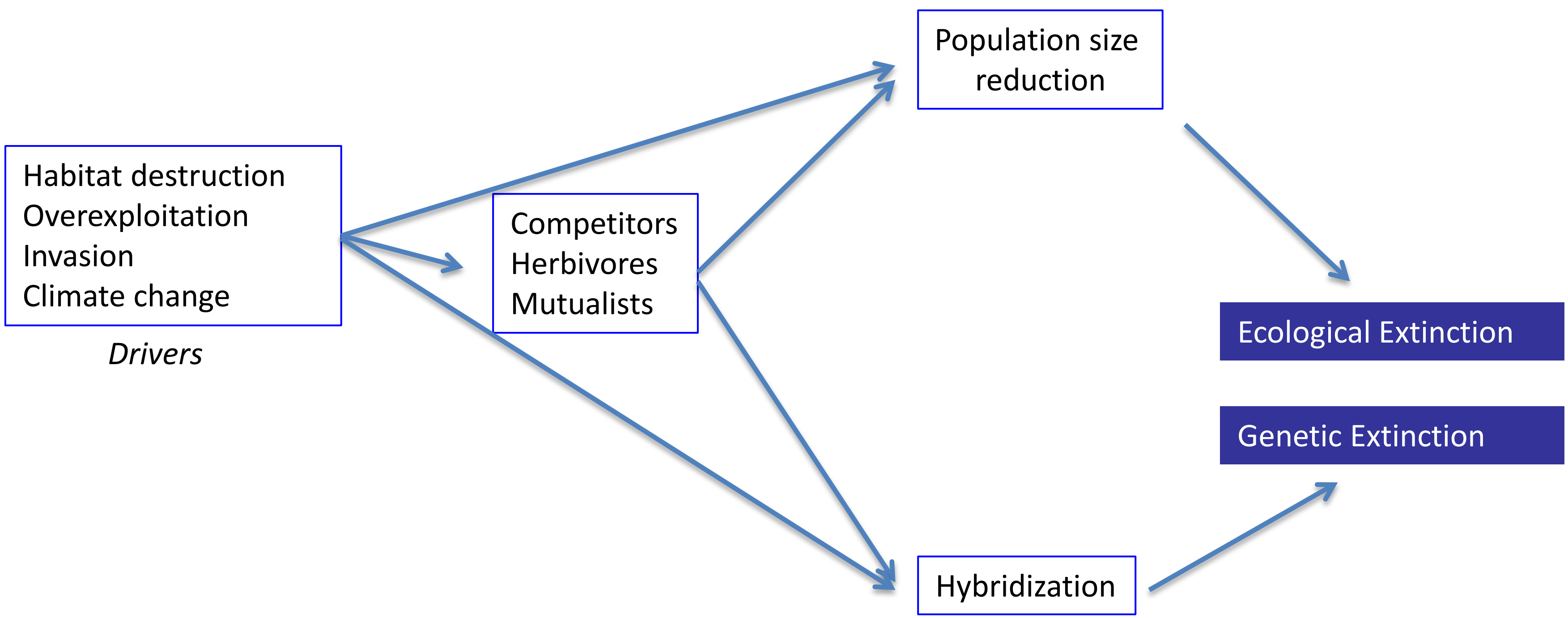
Climate change and hybridization



Climate change and hybridization

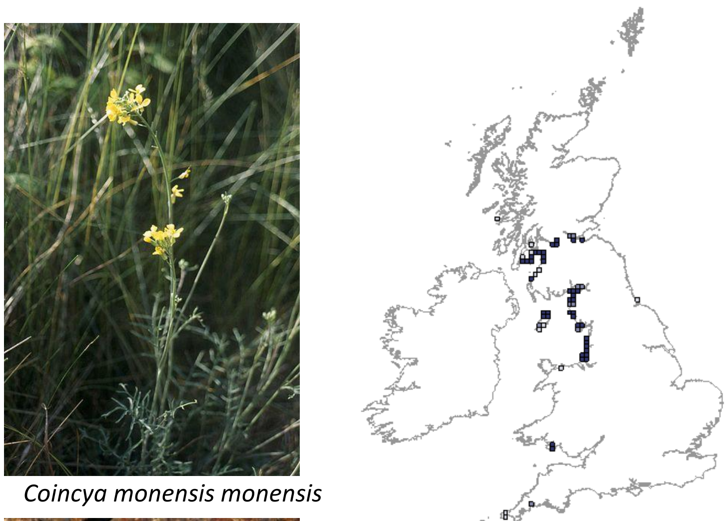


Climate change and hybridization

Anthropogenic Hybridization

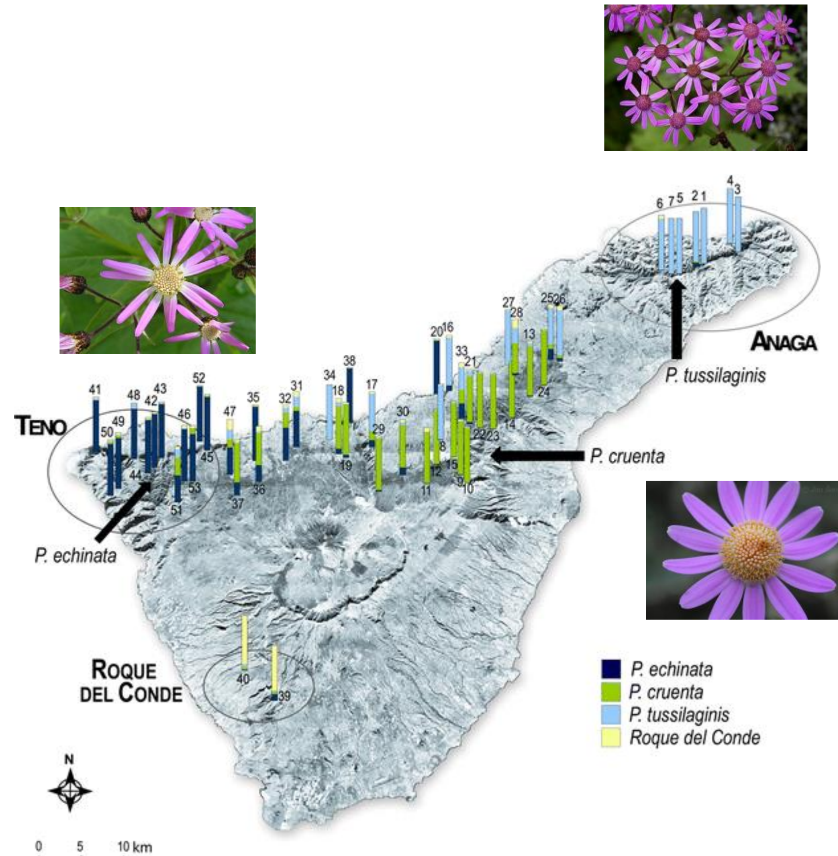
Invasion and Hybridization

Habitat destruction and Hybridization



Coincya monensis monensis

Coincya monensis cheiranthos



Facey et al. 2007, van Hengstum et al. 2012

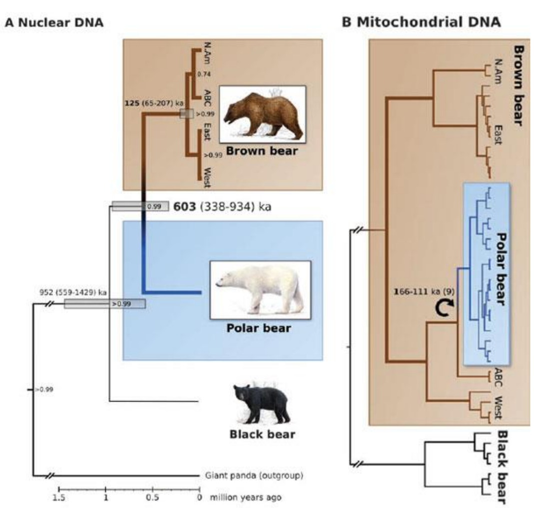
Climate change and hybridization

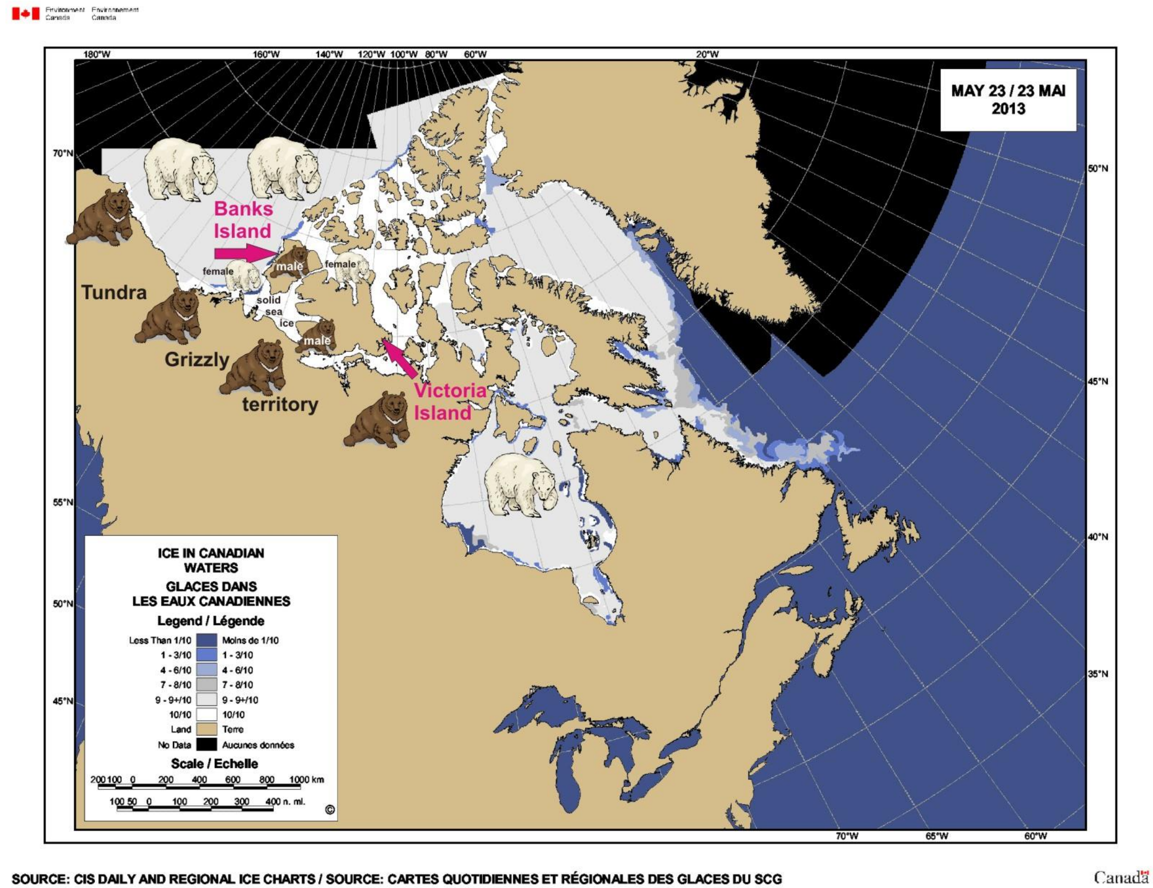
Climate-change and Hybridization

Climate change will come together closely-related allopatric species

Grolar bears

Ursus arctos horribilis *Ursus maritimus*





Pots et al. 2013.Science

Climate change and hybridization

Climate-change and Hybridization

Climate change will change altitudinal distribution faster than latitudinal distribution

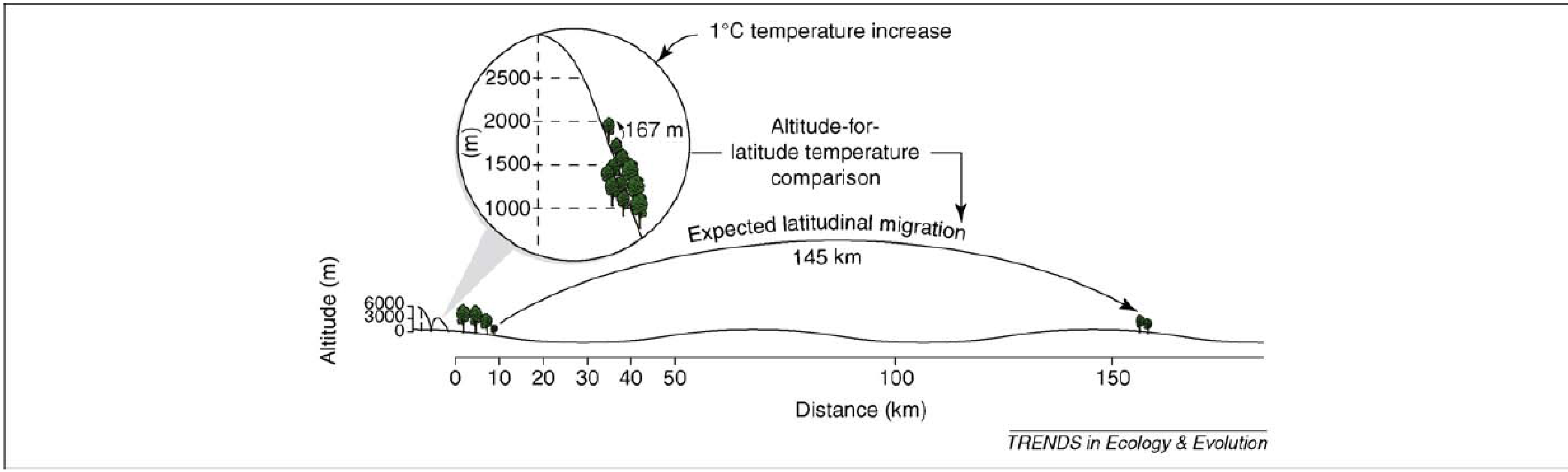


Figure 1. Equivalent migrations in lowland and mountain regions predicted based on an altitude-for-latitude model of temperature similarity. A 1 °C increase in mean annual temperature results in a range change of ~167 m in altitude but ~145 km in latitude (based on a temperature lapse rate of -6 °C km^{-1} altitude and -6.9 °C 1000 km^{-1} latitude from data in Refs [3,14]). Trees are not to scale.

Jump et al. 2009

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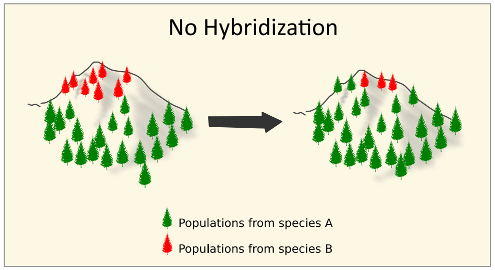
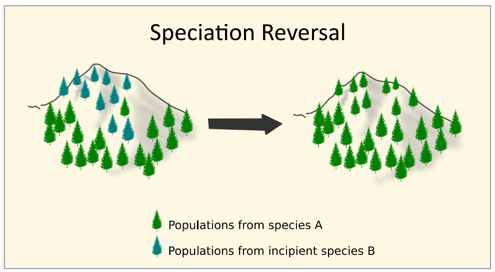
Climate-change and Hybridization

A



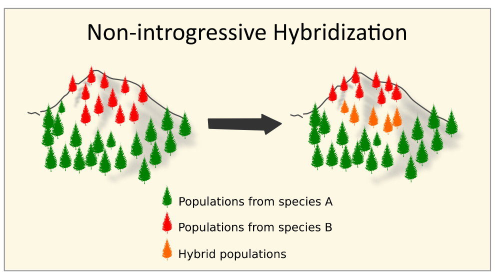
No hybridization occurs when two species with strong intrinsic reproductive barriers contact. The outcome is the demographic decline of the less competitive species

B



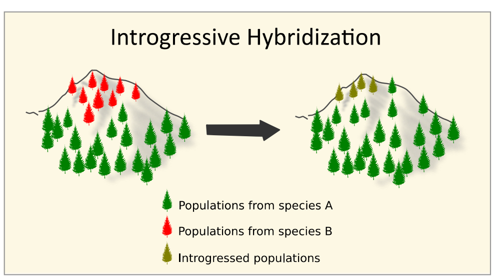
Speciation reversal occurs after the primary contact between an incipient species and the widespread species. The result is a single, genetically homogeneous, species.

C



Non-introgressive hybridization occurs when two species contact and hybridize without between-species transfer of genes. The outcome is a hybrid zone in the contact area

D



Introgressive hybridization occurs when two species contact and there is a net transfer of genes from one species to the other. When the two species in contact differ markedly in their abundance, the rarer may be completely replaced by hybrids.

Climate change and hybridization

Effect of climate change in Sierra Nevada plants

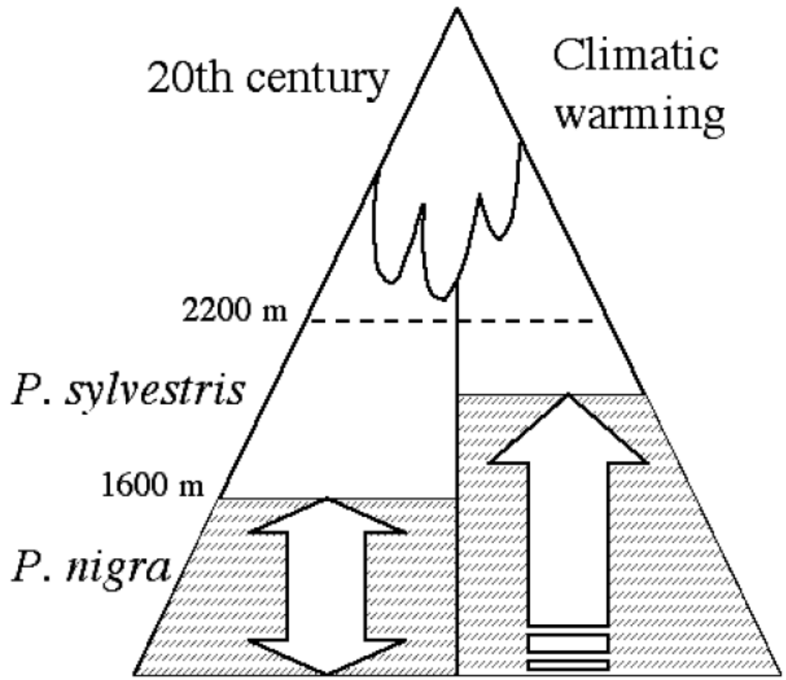


Figure 1. Schematic diagram of the *Pinus* spp. distribution in the mid-high mountain of Sierra Nevada (southeastern Spain), and the altitudinal range at which *T. pityocampa* lives. Until now (20th century, left), *P. sylvestris* was out of the activity range of *T. pityocampa* (double arrow), which lived mainly upon *P. nigra* at lower altitudes, below 1600 m (the old interaction area, stripped). In the current and future scenario (climatic warming, right), optimal climatic belts for all species will move upwards, but the speed of this movement will be quicker for insects (arrow upwards) than for plants. The interaction area of *T. pityocampa* with *Pinus* spp. will move uphill (emerging interaction area, stripped), but in the upper part the host plant will be *P. sylvestris* instead of *P. nigra*, then establishing a new plant–insect interaction.

Hódar & Zamora 2004

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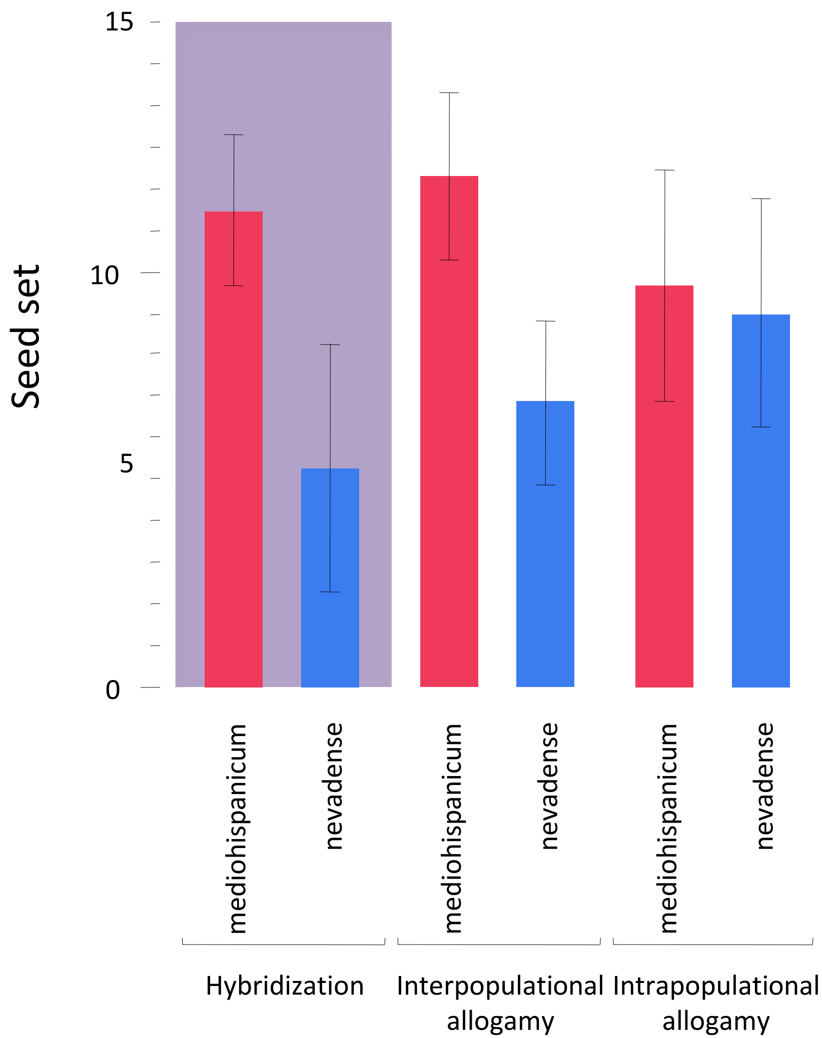

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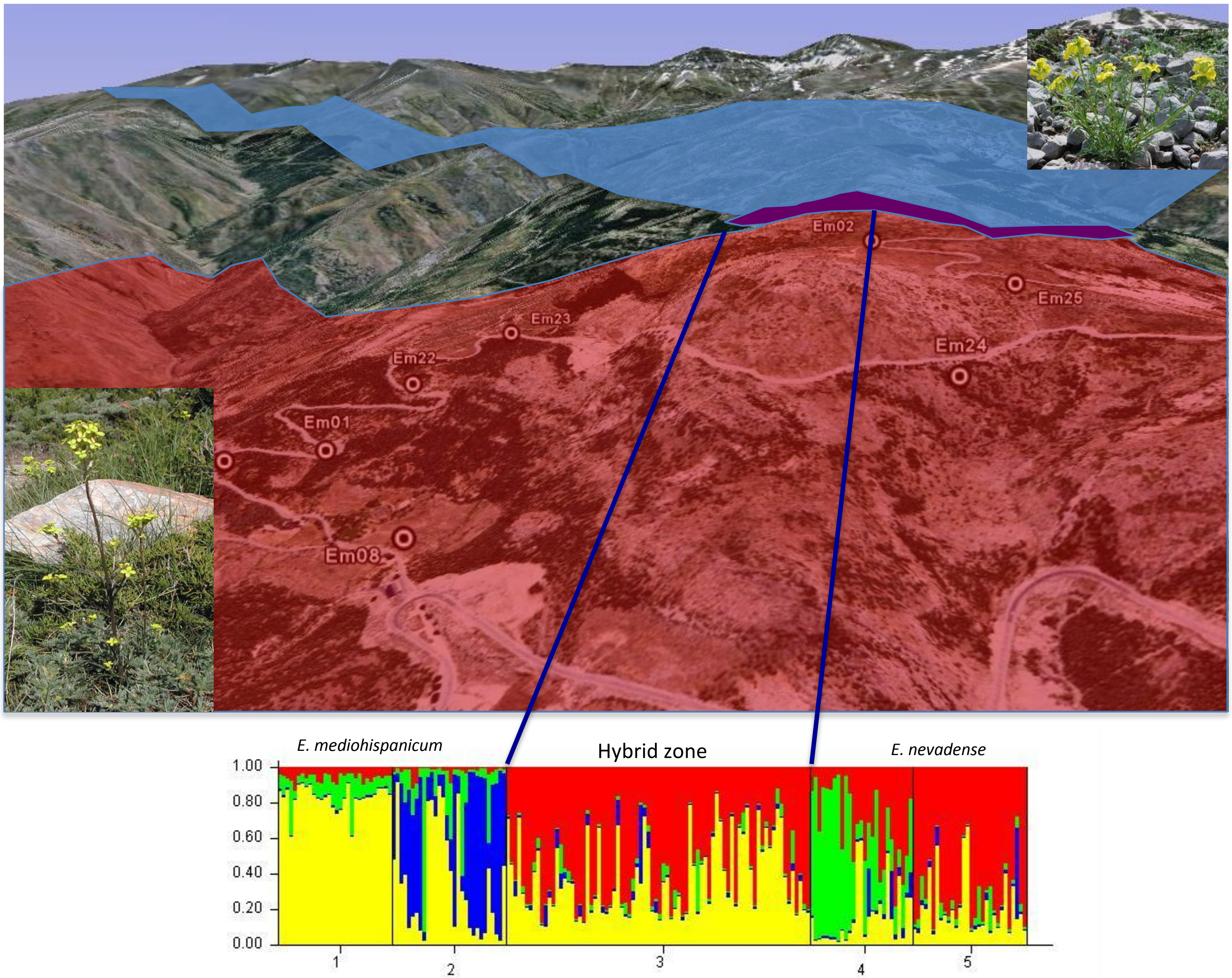
Effect of climate change in Sierra Nevada plants



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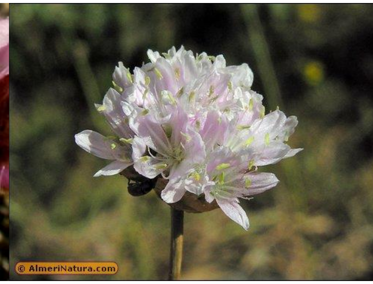
Armeria filicaulis filicaulis



Armeria filicaulis nevadensis

Armeria splendens

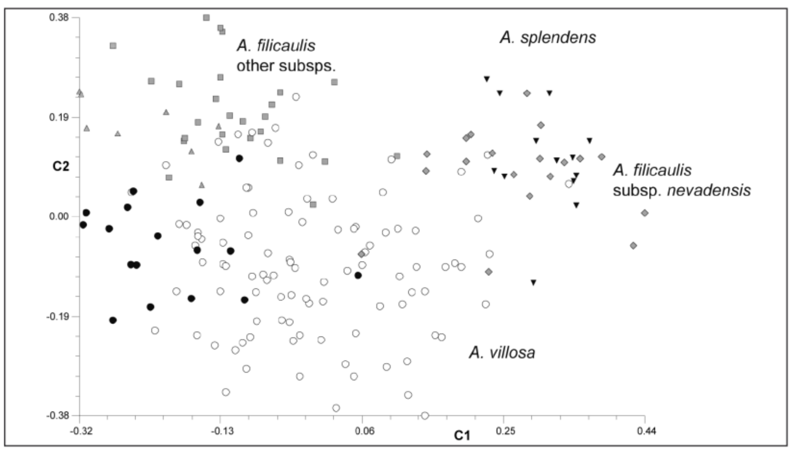


Fig. 2. Genetic variation among 197 studied individuals of *Armeria* spp. as displayed by a bi-dimensional scatter-plot using the two first coordinates of a principal coordinates analysis based on a Dice similarity matrix of RAPD's phenotypes. Symbols as in Fig. 1.

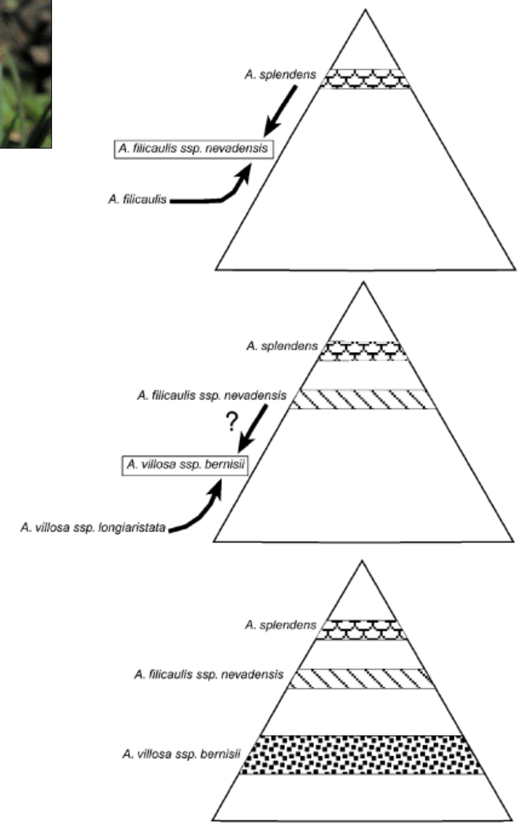


Fig. 4 Scheme representing a likely scenario for altitudinal migrations of *Armeria* in the Sierra Nevada massif, during glacial and interglacial Pleistocene periods, that resulted in horizontal transfer and possibly in the origin of hybrid taxa (see text).

Gutierrez Larena et al. 2002

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Endemic taxa			Hybridizing with			
Name	**Altitudinal Distribution**	**Relict**	**Name**	**Geographical Distribution**	**Altitudinal Distribution in Sierra Nevada**	**Relative altitudinal location**
Agrostis canina granatensis	2000-2900	No	*Agrostis canina* s. sl.	Eurasia	600-2200	Lower altitudinal belt
Agrostis nevadensis	2000-3300	No	*Agrostis canina* s. sl.	Eurasia	600-2200	Lower altitudinal belt
Anthyllis vulneraria pseudoarundana	2200-3200	No	*Anthyllis vulneraria* s.sl.	Eurasia	50-2000	Lower altitudinal belt
Armeria filicaulis nevadensis	2300-3000	Yes	Hybrid species			
Armeria filicaulis trevenqueana	1700-2000	Yes	*Armeria villosa bernisii*	Baetic mountains	900-2200	Same altitudinal belt
Armeria splendens	2400-3000	Yes	*Armeria filicaulis*	Baetic mountains	900-1900	Lower altitudinal belt
Artemisia granatensis	2500-2700	Yes	*Artemisia umbelliformis*	Alpine mountains	2800–3000	Same altitudinal belt
Centaurea bombycina xeranthemoides	1000-1500	No	*Centaurea bombycina* s. sl.	Baetic mountains	200-1600	Lower altitudinal belt
Centaurea gadorensis	1300-1700	No	*Centaurea pulvinata*	Sierra Nevada	1200-2000	Same altitudinal belt
Centaurea pulvinata	1500-1900	No	*Centaurea gadorensis*	Penibaetic mountains	1100-1900	Lower altitudinal belt
Cerastium alpinum aquaticum	2500-3300	Yes	*Cerastium alpinum nevadense*	Sierra Nevada	2700-3300	Same altitudinal belt
Cerastium alpinum nevadense	2700-3300	Yes	*Cerastium alpinum aquaticum*	Sierra Nevada	2500-3300	Same altitudinal belt
Dactylis glomerata juncinella	2000-3300	No	*Dactylis glomerata* s.sl.	Eurasia	600-1500	Lower altitudinal belt
Draba hispanica laderoi	2500-3200	Yes	*Draba hispanica hispanica*	Western Mediterranean	1000-2200	Lower altitudinal belt
Erigeron frigidus	3000-3400	No	*Erigeron major*	Baetic mountains	1800-3000	Lower altitudinal belt
Eryngium glaciale	2400-3400	No	*Eryngium bourgatii*	Western Mediterranean	1500-3000	Lower altitudinal belt
Erysimum baeticum	1600-2600	No	*Erysimum mediohispanicum*	Iberian Peninsula	700-1900	Lower altitudinal belt
Erysimum nevadense	2000-2800	No	*Erysimum mediohispanicum*	Iberian Peninsula	700-1900	Lower altitudinal belt
Helianthemum apenninum estevei	1300-1800	No	*Helianthemum apenninum* s. sl.	Baetic mountains	0-1800	Lower altitudinal belt
Nepeta boissieri	1700-2200	No	Hybrid species			
Pinus sylvestris nevadensis	1700-2200	Yes	*Pinus sylvestris* s. sl.	Eurasia	700-1900	Lower altitudinal belt
Santolina elegans	1700-2000	No	*Santolina rosmarinifolia*	Western Mediterranean	300-2100	Lower altitudinal belt
Saxifraga trabutiana	1600-2400	No	*Saxifraga granulata*	Eurasia	200-2800	Lower altitudinal belt
Sideritis arborescens luteola	1000-1600	No	*Sideritis arborescens* s.sl.	Western Mediterranean	500-1000	Lower altitudinal belt
Sideritis glacialis	2000-3000	No	*Sideritis hirsuta*	Western Mediterranean	50-2000	Lower altitudinal belt
Thymus serpylloides serpylloides	2000-3000	No	*Thymus serpylloides gadorensis*	Iberian Peninsula	1500-2200	Lower altitudinal belt

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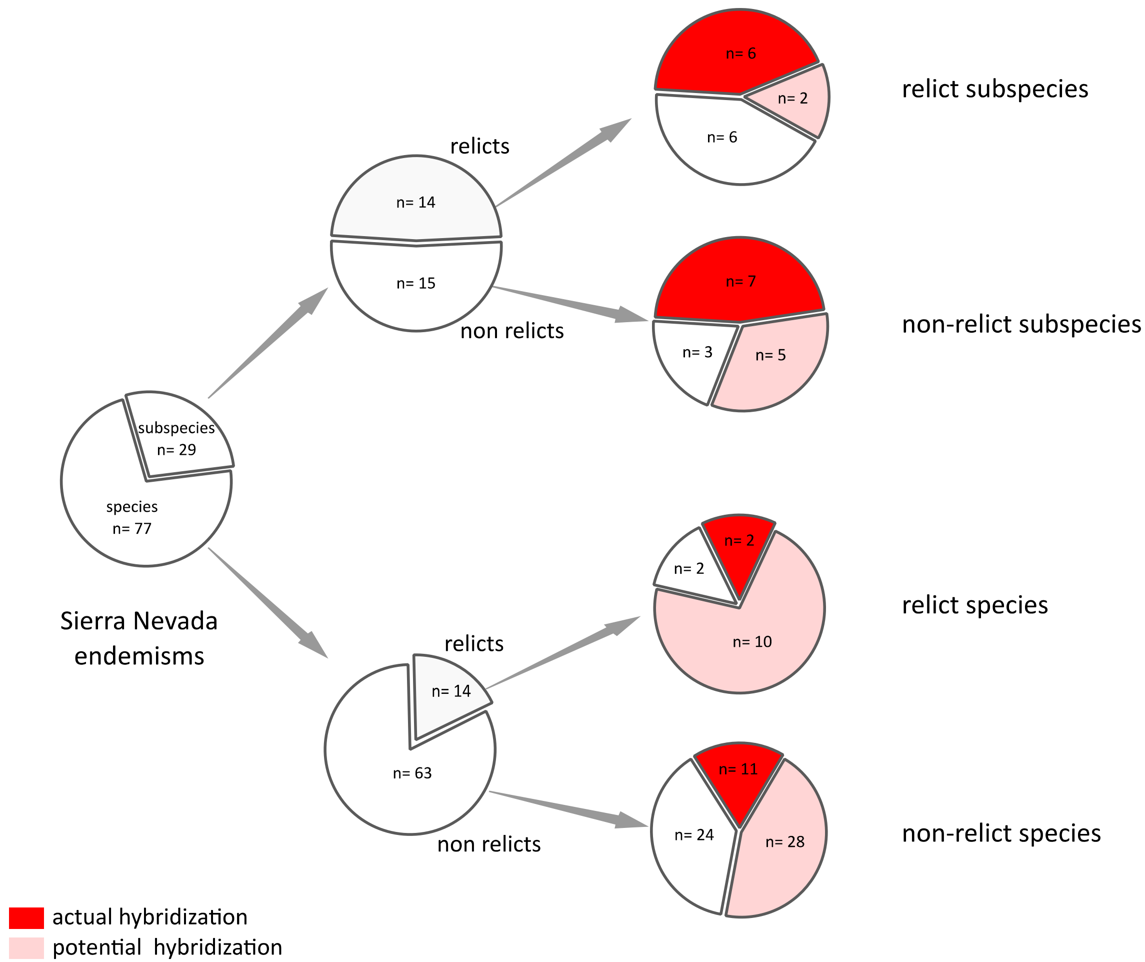

Climate change and hybridization

Conclusions

- Natural hybridization has been reported in 25% of the Sierra Nevada endemic high-mountain flora
- Although hybrid speciation has occurred, we presume that most hybridization is introgressive, provoking the genetic assimilation of the rarer, alpine species.
- Time has come to include in future conservation agendas a protocol for the surveillance and monitoring of potential genetic swamping in endemic high-mountain plants.
- This will provide precious knowledge that will help to preserve these unique environments.