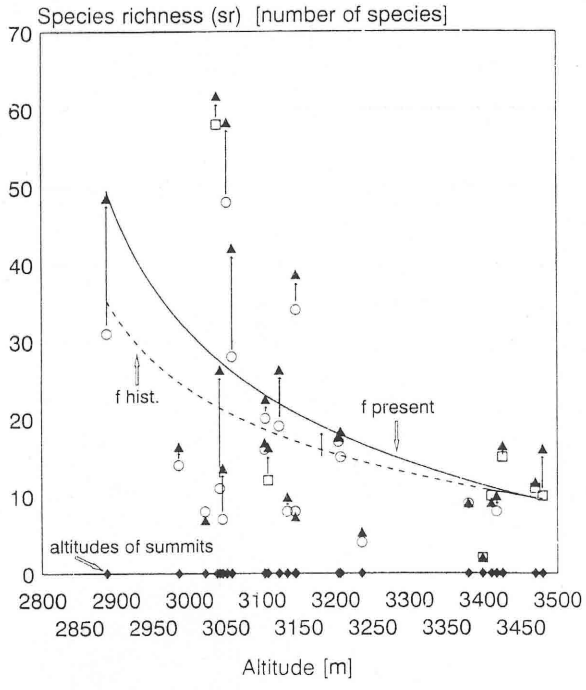
Climate effects on mountain plants

SIR — Temperature-limited environments such as boreal regions, arctic regions and high mountains are thought to be very sensitive to greenhouse warming[1]. As a result of such warming, for example, plant species and communities in high mountains will be pushed upwards in elevation and may be eliminated if already at mountain summits[2,3]. If evidence were to be found of a continuing change of summit floras, this would indicate that global warming is already having a significant ecological impact. Although preliminary observations have recently been presented[4], no conclusive evidence has yet been reported.

During the summer of 1992, we collected data on the state of the flora at 26 summits exceeding 3,000 m in the middle part of the Alps (western Austria, eastern Switzerland) and compared the actual records on cover and abundance of vascular plant species with historical records[5–10]. Species richness has increased during the past few decades (see figure), and is more pronounced at lower altitudes. However, upward movement of the alpine-nival flora is an overall trend, as indicated by the comparison of the fitted regression lines for species-richness with altitude. Although the presented data are not corrected for age of the historical record or for the expansion of the considered belt, the difference between the two regression lines is obvious. The exponential decrease of species rich ness with altitude is a general feature of the nival vegetation above the closed alpine grasslands.



Species richness of historical and our present-day records at nival summits in the Alps plotted against altitude. Rare species are downweighted (0.25), species of moderate abundance were given the weight 0.5, frequent species the weight 1.0. Rare species were downweighted due to the comparatively high probability that these were overlooked by the original authors. Displayed are 24 summits with siliceous bedrock. Age of the historical records is 40 to 90 years (circles, 1895–1918; squares, 1947–53; triangles, present-day). Arrows, increase in species richness, which is pronounced at lower altitudes and low to moderate at higher altitudes. Most summits considered are climbed only occasionally, so the effect of humans is negligible.

On the basis of 12 very precise historical records [8–10], we calculated moving rates for nine typical nival plant species. The maximum values approached 4 m per decade, although most of the values were below 1 m per decade. The old records used for this calculation were collected about 70–90 years ago. According to the records from meteorological stations in Austria, the mean annual temperature has increased since that time by 0.7 °C (ref. 11). Taking into account an average decrease of 0.5 °C per 100 m of increasing altitude, this warming should theoretically lead to a shift in the altitudinal vegetation belts at a rate of 8–10 m per decade. The empirical values are clearly far lower than this.

In conclusion, there is no doubt that even moderate warming induces migration processes, and that this process is under way. The example from the limits of plant life at high alpine summits is of general importance and suggests that global warming is already having a significant effect on alpine plant ecology. Even in situations where plants must move upwards, the warming is sufficient to stimulate migration, and may cause disastrous extinctions in these environments.

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