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Recent Observation of a Proliferation of *Ranunculus trichophyllus* Chaix. in High-altitude Lakes of the Mount Everest Region: Comment

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Global High-altitude Limits for Aquatic Vascular Plants

The record altitudes at which organisms have been found are widely dispersed in the literature. Because of their anecdotal nature—a record altitude is often discovered by chance, rarely by specifically looking for it—such records often go unpublished, or are buried within publications dealing with wider subjects. However, the distributional limits at which organisms grow (maximum or minimum altitudes as well as other limits) are critical to our understanding of numerous basic biogeographic, ecological and physiological issues (Körner, 1999). With current awareness of global warming, records of maximum altitudes for organisms have taken on an even more pressing importance: variations in the actual maximum altitudes may indicate species responses to warming (Gottfried et al., 2002; Pauli et al., 2001; Parmesan and Yohe, 2003), and fragility of life at maximum altitudes has important management consequences (Halloy, 1989; Körner, 2000).

We therefore welcome Lacoul and Freedman's (2006) observations on *Ranunculus trichophyllus* at a maximum altitude of 4760 m (4750 m and 4780 m are also specified in the publication) in the Nepal Himalaya, which they quote as the highest altitude from which an aquatic angiosperm has been recorded. The authors consider this to represent a range expansion likely facilitated by climatic warming, given previous record altitudes quoted for the area of only around 4000 m.

However, it is worth complementing this information. The recorded altitude is considerably lower than those routinely surpassed by several vascular plants in numerous lakes in the South American Andes from latitudes 13°S to 27°S, and probably elsewhere along the cordillera, too. A few examples from above 4800 m are given here from our own experience and the literature to place the *Ranunculus trichophyllus* record from Nepal in perspective. Vouchers for the species cited are at LIL herbarium, Tucumán, Argentina; LPB herbarium, La Paz, Bolivia; and CUZ herbarium, Cuzco, Perú.

- Cerro Cóndor, Argentina, 5350–5400 m. On the border between Tucumán and Catamarca province, this lake harbors a dense population of *Zanichellia* sp. despite being partly ice covered, even in mid-summer (Halloy, 1981, 1983; Kühn and Rohmeder, 1943). As far as we are aware, this is the highest published record for an aquatic vascular plant.
- Lago Sibinacocha, Perú, 4880 m. This large high-altitude lake harbors diverse submerged communities, including *Potamogeton, Myriophyllum, Isoëtes*, and *Nitella* (an algae but with an almost vascular plant-like life form). Being largely unexplored, it is likely to harbor a number of other species known from lower lakes such as Titicaca. Upward range expansion in this area is being documented for diverse organisms from amphibians to plants (Halloy et al., 2005; Seimon et al., 2007).
- High Andean pools and tarns often linked to peat bogs harbor a variety of submerged vascular plants, e.g. *Callitriche* (4800 m, Sajama, Bolivia), *Myriophyllum* cf. *elatinoides* (4600–5244 m), *Potamotegon* cf. *pectinatus* (4600–5244 m), and *Isoëtes* spp. (4400–5030 m); the latter three are in the Sibinacocha lake region, Perú. A large number of semi-aquatic vascular plants also characterize these communities (*Carex* spp., *Distichia muscoides, Oxychloe andina,* and many more) throughout the Andes, often reaching well above 5200 m. Previously recognized altitudinal limits for other organisms (e.g. clams, amphibians) are also being breached in the Sibinacocha area (Krajick and Peter, 2006; Seimon et al., 2007).

Under the current global warming regime, which is amplified at high altitudes in low latitudes (Bradley et al., 2006), it is plausible that upward range extensions of aquatic vegetation and other organisms will continue to occur. To our knowledge, the highest elevation that a lake has been recorded is 6060 m on Ojos del Salado volcano in Argentina, where small ponds heated by volcanic activity have also been observed up to 6600 m (Halloy,

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1983); reports on possible lakes at 6200 and 6500 m on this mountain (Nucíforo, 1959) lack formal verification. Either way, this is considerably higher than previous quoted records of lakes from the Himalaya at 5300 m (Hutchinson, 1937; Troll, 1972) and 5600 m for the Mount Everest region (Lacoul and Freedman, 2006; Löffler, 1968), or from the Andes for lakes in summit craters of Volcán Tuzgle, Argentina (5400 m) photographed by Catalano (1926), and Volcán Licancabur on the border of Chile and Bolivia (5916 m; Cabrol et al., 2004). The lakes on Ojos del Salado did not have vascular plants either at 5750 or 6060 m when observed (1983). However, only some 15 lakes were visited, out of around 60 lakes higher than 5000 m. Such lakes seemed relatively recently ice-free, and the presence of migratory wader birds suggests that vascular plants may well be seeded there and prosper sooner rather than later. As climates warm, new lakes are probably being generated at ever-higher altitudes, but for any given lake newly reported, reasonable doubt must exist (in the absence of independent evidence) as to whether the lake is actually new, or is simply new to our records. An exception applies for lakes formed relatively recently in the wake of receding glaciers, as in the case of the ponds above Lago Sibinacocha in Perú, where both the timing of lake formation and establishment of aquatic plant communities can be determined within bracketed time periods (Seimon et al., 2007).

In this context, we recognize that any altitude record is subject to a threefold problem: (1) at any one time, a record is only due to the chance combination of observer, recorded organism, and the chance that that record will actually be published and reach the eyes of other researchers; (2) vertical range extensions, both upward and downward, in response to changing environmental conditions cause absolute limits to species distributions to change at decadal and longer time scales; and (3) in either case, precision of altitudinal records (particularly those from decades back) are sometimes erroneous by tens or even hundreds of meters; all records require careful screening for consistency and precision. Hence, our contributions here are only meant to add to the published knowledge, while recognizing that new altitudes will undoubtedly continue to appear. Inasmuch as awareness is part of the issue of recording, we hope this note will increase the likelihood of further altitudinal limits being recorded and published.

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