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Conservation of the freshwater fauna of Patagonia: an alert to the urgent need for integrative management and sustainable development

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Patagonia is considered one of the last pristine biomes of the world; however, its freshwater ecosystems face several pressures, which threaten the maintenance of their ecosystem services. The native freshwater fish fauna of Patagonia is unique (Aigo *et al.*, 2008), and has experienced severe damage since the early 20th Century due to the introduction of salmonids [*Salmo trutta* L. 1758, *Salmo salar* L. 1758, *Oncorhynchus mykiss* (Walbaum 1792), *Oncorhynchus masou* (Brevoort 1856), *Oncorhynchus kisutch* (Walbaum 1792), *Oncorhynchus tshawytscha* (Walbaum 1792), *Salvelinus fontinalis* (Mitchill 1814) and *Salvelinus namaycush* (Walbaum 1792)]. Moreover, in addition to the continual invasion of salmonids, this fauna currently faces new threats of additive and synergistic effects as yet neither well understood nor well studied. Here, based on scientific evidence, the main current and future effects affecting this fauna are summarized as good indicators of the health of freshwater ecosystems.

First of all, aquaculture based on salmonid production is a severe stressor in Patagonia. In Chile, this activity is advancing dramatically southward, increasing the input of nutrients, antibiotics and other drugs into aquatic ecosystems, as well as extending the propagule pressure of salmonid invasion due to the escape of millions of individuals from farms every year (Cussac *et al.*, 2014). Similar to aquaculture, hydropower development is an additional major stressor in Patagonia. Several large rivers have been dammed in Argentina (Neuquén, Limay and Futaleufú), with the consequent loss of connectivity (fragmentation) and severe disturbance of the flow regime downstream of the dams. This scenario is highly probable in the near future for more Argentinean and Chilean rivers which have high hydropower potential (*e.g.* Santa Cruz, Yelcho, Cuervo, Baker and Pascua Rivers). The balance between cost and benefit remains a matter of controversy (www.icold-cigb.org/GB/Dams/dams_environment.asp).

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These two large-scale stressors, salmonid aquaculture and river damming, act together with a variety of other local pressures. One is deterioration of the water quality caused by an increase in urbanization and farmland acreage, and the massive numbers of livestock throughout Patagonia. Trampling and grazing due to the increasing number of cattle and sheep have provoked habitat degradation both on the riverbanks and along the littoral zone of lakes. In turn, all these local effects on water and habitat quality are bringing about a reduction in the value of salmonid fisheries.

Sport fishing itself has led to a number of cascade effects, in addition to salmonid effect (Habit *et al.*, 2012). For example, the use of live bait has permitted the dispersal of several species. This is the case of the common carp *Cyprinus carpio* L. 1758, which has advanced up to the Limay River basin and towards the south and west, from the Colorado River basin to the Negro River basin (Aigo *et al.*, 2008). In Patagonia, although live bait is illegal, native galaxiids are commonly used for this purpose, mainly *Galaxias maculatus* (Jenyns 1842). Moreover, in Argentina, species stocked for sports fishing not only include salmonids, but also other species such as the bonaerensean pejerrey *Odontesthes bonariensis* (Valenciennes 1835), which has led to genetic introgression with populations of Patagonian pejerrey *Odontesthes hatcheri* (Eigenmann 1909). Finally, all these current or future changes must be seen in an overall global change scenario, in which temperature and precipitation patterns are expected to alter species distribution and abundance throughout Patagonia (Cussac *et al.*, 2009).

With this note, the aim is to urge the authorities, citizens and scientists of Chile and Argentina to work together in supporting new integrative policies for the entire region, based on catchment management. The available scientific information shows that the current damage could have been prevented if a holistic view based on transdisciplinary work had been employed in decision-making.

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