

Historical Policy Goals for Fish Management in Northern Continental Patagonia Argentina: A Structuring Force of Actual Fish Assemblages?

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Abstract.—Early in the 20th century, the fish fauna of Patagonia consisted of 20 native fish species. In 1904, exotic species, mostly salmonids from North America and Europe, were introduced, giving rise to an extensive sport fishery. Scientific literature, stocking and catch logbooks, and registries of organizations in charge of enforcing management practices were searched in relation to effects of probable policy goals upon actual fish assemblage structure of two major river basins of northern Patagonia. Policy goal history in this region can be divided into three periods. Between 1904 and 1910, goals were focused on increasing diversity and sport fishery opportunities through salmonid introductions. From 1910 to 1970, goals shifted towards development of both commercial and sport fisheries, increasing diversity by introducing and restocking salmonids and native fish species and preserving both through fishing regulations. In these two periods, policies were centralized under the federal government. From 1970 on, policy has been characterized by decentralization in relation to provincial and national park jurisdictions. The former fosters the development of sport fisheries, while the latter focuses on the protection of native fish species and opposes new introductions. However, Patagonia's isolated environments, lack of road infrastructure, particular management circumstances, biological capacities of released species, and great dispersion capacity of salmonids were fundamental factors that shaped the artificial and natural dispersion in both the Negro and Manso River drainages.

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Introduction

Many of the studies pertaining to the introduction of exotic species have focused on the impacts upon native species and the ecosystems into which they were introduced. However, understanding the invasion processes is as important (Dunham et al. 2002). Salmonids have both a great capacity of adaptation and of dispersion (Gowan et al. 1994) and they also constitute the freshwater fish family with the greatest world distribution (Welcomme 1988).

Introduction and dispersion of salmonids in Patagonia in general and on its northern region in particular have been a process strongly influenced by shifting and sometimes capricious management policies, both in Argentina and in Chile (Pascual et al. 2002). Not all species of this family were introduced at the same time, nor were all the environments stocked with the same intensity or at the same time. (Marini 1936; González Regalado 1945; Baigún and Quirós 1985). Today, the entire process looks very much like a trial and error route without a template. Decisions were, and still are, made without considering the invasive capacity of different species, the competition among different introduced species that could follow, or their potential impacts upon native biota.

The objectives of the present work are (1) to analyze the introduction of salmonids into northern Patagonia in relation to historical and present data, (2) to evaluate both natural and artificial dispersion of each of the introduced species, (3) to characterize the variation in distribution and abundance of each one of these species, and (4) to determine the degree of success of each species in different water bodies of the Negro and Manso River basins from a historical perspective.

Material and Methods

Study Area

The present work is based on the Negro and Manso River drainage basins, which were chosen because salmonid stocking records and presence-absence data are the most complete of Patagonia. Also, the Negro has been the river basin in Patagonia most strongly and actively affected by plantings with exotic fish. Because of its 70,000-km² area, the Negro (Figure 1) drainage basin is one of the most important drainage basins of Argentina and the largest of Patagonia. The effective drainage area is triangular in shape, having been formed by the 36,400 km² of the Limay River drainage subbasin in the south and the 32,450 km² of the Neuquén River subbasin in the north. They unite at latitude 39° south and longitude 68° west to form the Negro River subbasin with a drainage area of 1,000 km² (HIDRONOR, 1978) and a maximum flow of 1,600 m³/s. The entire basin, fed by rain, snowfall, and ice melting from the Andean range in the west, drains after crossing the Patagonian steppe into the Atlantic Ocean. Climate varies from west to east from cold humid in the Andean range to arid in the steppe, with precipitation decreasing from 4,000 mm to less than 300 mm per year in just 50–100 km and only 200 mm by the seashore (De Aparicio and Difrieri 1958; Mermoz and Martín 1988). The hydrological pattern is characterized by two peak flows, one driven by rainfall rains and the other one by spring snow melting. All lakes and rivers in the basin are well oxygenated and mainly neutral or slightly alkaline with calcium bicarbonate, becoming enriched with sulfates and sodium when they get closer to the ocean (Bonetto and Wais 1995). Conductivity varies among subbasins from 30 to 67 μ S/cm in the Limay and from 75 to 250 μ S/cm in the



Figure 1. Study area. Negro River drainage basin and Manso River drainage basins. Rivers: 2. Pulmari, 3. Ruca Choroi, 4. Quillén, 5. Malleo, 6. Aluminé, 7. Catan Lil, 9. Quilquihue, 10. Chimehuín, 11. Quemquemtreu, 14, Caléufu, 15. Collon Curá, 16. middle Limay, 17. Neuquén, 18. Negro, 19. and 21. Upper Limay, 20. Pichi Leufú, 22. Traful, 23. Correntoso, 26. Ñiriguau, 29. Middle Manso, 30. Lower Manso. Lakes: 1. Aluminé, 8. Huechulafquen, 12. Meliquina, 13. Filo Hua Hum, 24. Nahuel Huapi, 25. Gutiérrez, 27. Mascardi, 28. Guillermo.

Neuquén, with a maximum of 3,600 $\mu\text{S}/\text{cm}$ in Lake Pellegrini.

The fish fauna has a low number of species (Pascual et al. 2002), with three siluriforms (otuno *Diplomistes viedmensis*, *Hatcheria macraei*, and *Trichomycterus areolatus*), two Galaxids (inanga *Galaxias maculatus* and *G. platei*), three Percichthids (creole trout *Percichthys colhuapensis*, creole perch *P. trucha*, and *P. vinciguerrai*), two Cyprinodontiformes (onesided livebearer *Jenynsia lineata* and *Cnes-*

terodon decenmaculatus), a silverside (*Odonesthes hatcheri*) and a lamprey (pouched lamprey *Geotria australis*). Also, mullet (liza *Mugil liza*) can be found in the lower Negro River subbasin area influenced by tides (Arratia et al. 1983; Milano and Vigliano 1997; Cussac et al. 1998; Bello 2002; Pascual et al. 2002). Besides salmonids, other species introduced into the basin by man are Buenosairean pejerrey *Odontesthes bonaerensis*, *Corydoras* sp., *Cheirodon eigenmanniorum*, and common carp *Cyprinus carpio*, which are found only in the

Negro River subbasin. (Pascual et al. 2002; Alvear et al., in press).

The Manso River basin (Figure 1) is formed by three sections: upper, middle, and lower Manso. Fed by the Tronador mountain glaciers (Gallopín 1978), the upper Manso waters are murky, with a high load of sediments. Upon flowing and forming Mascardi lake, sediments deposit and the water becomes clear. The middle Manso connects a series of lakes (Los Moscos, Hess, Fonck Grande, Fonck Chico, Julio A. Roca, Felipe, Martín, and Steffen). The lower Manso flows southeast, from Lake Stephen, joining the Villegas and Foyel rivers and then turning westward across the Andes into Chile. It then flows into the Puelo River, which drains into Pacific Ocean (De Aparicio and Difrieri 1958). The hydrological pattern is characterized by two peak flows, one driven by rainfall and the other one by spring snow melting. The average discharge is 65.2 m³/s at the end point of the middle Manso (Secretaría de Recursos Naturales y Desarrollo Sustentable. Subsecretaría de Recursos Hídricos 1997). The climate is cold and humid with an annual average rainfall of 1,500 mm (De Aparicio and Difrieri 1958; Drago 1974). In general, the waters, which are near oxygen saturation levels, have a conductivity ranging between 36 and 44.9 μ S/cm and a neutral pH (Pedrozo et al. 1993). The vegetation cover corresponds mostly to sub-Antarctic forest of *Nothofagus* sp., *Fitzroya cupresoides*, and *Austrocedrus chilensis* (Dimitri 1972). The native fishes are represented only by inanga and *G. platei* (Alonso et al. 1997; Milano et al. 2002), salmonids being the only exotic fish introduced to the basin (Alonso et al. 1997).

For this work, data of both drainage basins were subdivided into strata, which mainly coincide with the natural subbasins (Figure 1).

Data Gathering and Analysis

We compiled a database that covers the 1904–2002 period by using a variety of sources, including historical archives of fish hatcheries and fisher associations, particular log books, and refereed and gray literature, as well as data from our own research projects. Data on stocking and distribution for all species were organized on electronic databases and divided in time periods according to objectives.

Historical Stocking Analysis

We analyzed different official records, of the Aquaculture Division of the Ministerio de Agricultura, Ganadería y Pesca de la República Argentina, MAGPRA (Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina. Piscicultura Nahuel Huapi 1908–1933; Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina 1938–1979; Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina. Piscicultura Nahuel Huapi 1914–1917; Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina 1938–1979; Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina. Piscicultura Río Limay 1950–1979; Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina 1938–1979; Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina. Centro de Salmonicultura Bariloche 1971–1986). We found that records collected at different times had different degrees of reliability, with the oldest information being the most detailed and systematically collected one. Therefore, we used data on stocking site, species, and numbers stocked only up to 1986. Based on this information, we looked at the numbers stocked per species per year, the total number stocked in each basin and the numbers stocked in each subbasin. The 82 years cov-

ered by the official records were divided arbitrarily into three periods according to stocking intensity and spread (1) from 1904 to 1930, (2) from 1931 to 1946, and (3) from 1947 to 1986.

Presence–Absence Data

The dispersion of salmonids in both drainage basins was analyzed based on existing data for three periods: 1908–1924, 1937–1943, and 1996–2002 (Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina, Piscicultura Nahuel Huapi 1908–1933; Valette 1924; Bruno Videla 1938, 1941, 1944; GonzÁlez Regalado 1941a, 1941b, 1941c, 1945; Marini 1936, 1942). Pre-1996 presence–absence data were obtained through a variety of sampling methods and interviews conducted by MAGPRA. Data for the 1996–2002 period were obtained from samplings conducted by the “Grupo de Evaluación y Manejo de Recursos Ícticos CRUB-UNC, GEMARI.” All analyses were performed by subbasin.

Salmonid Abundance

For this analysis, we compared commercial and exploratory catches in some lakes of both drainage basins conducted between 1937 and 1942, with those conducted in the same environments between 1996 and 2002 (Table 1).

In 1937–1942, catches were made between October and March (Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina. Piscicultura Bariloche 1938–1942), using multifilament gill nets of 45 m in length by 2.5 m in height. Mesh sizes were 52 and 60 mm between knots. Gill nets were set perpendicular to the coastline, operating from dusk to dawn. (Bruno Videla 1938; Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina. Piscicultura Bariloche 1939–1942.). On each occasion species, numbers, and total weight (kg) of fish caught were recorded (Oficial Archives Ministerio de Agricultura y Ganadería de la República Argentina. Piscicultura Bariloche 1938–1942).

Table 1. National Nahuel Huapi Park Lakes for which salmonid catches of the periods 1937–1942 and 1996–2002 were compared. **a:** 1937–1942 period; **b:** 1996–2002 period. masl = meters above sea level.

Subbasin	Lake	Location	Altitude (masl)	Depth (m)	Sampling date	
					a	b
Lake Nahuel Huapi	Moreno	41°05'S–71°32'O	764	112	11/26/40	11/16/97
	Gutiérrez	41°14'S–71°28'O	750	111	11/29/40	11/23/96
	Espejo	40°37'S–71°46'O	772	245	02/20/41	01/20/98
Limay River	Nahuel Huapi	40°55'S–71°30'O	764	438	03/09/41	03/15/02
	Traful	40°25'S–71°27'O	800	339	04/18/40	04/13/02
Upper Manso River	Mascardi	41°19'S–71°35'O	750	218	02/17/41	02/21/97
Middle Manso River	Los Moscos	41°21'S–71°35'O	790	50	01/15/40	02/14/97
	Hess	41°22'S–71°43'O	735	24	02/21/40	02/12/97
	Fonck	41°19'S–71°47'O	780	85	01/28/41	01/29/97
	J. A. Roca	41°22'S–71°46'O	725	38	02/07/41	02/11/97

Fish catches between 1996 and 2002 were obtained using the methodology described by Vigliano et al. (1999), using similar nets and setting procedures as in 1938–1942. The specific composition and the catch per unit of effort in numbers (CPUEN) for each species were estimated for each period. In all cases, the unit effort was defined as 100 m² of net and 24 h of operation. Differences in catches between periods and between different basins were compared by one way variance analysis (analysis of variance [ANOVA]), when normality and homoscedasticity of data were proven, or with a Mann-Witney (M-W) test when normality assumptions were not met.

Results

Policy Goals Throughout the Years

It is clear from official documents that the introduction of salmonids in northern Patagonia changed over time. Between 1904 and 1910, the main goals were to increase diversity and sport fishing opportunities. From 1910 to 1970, goals shifted towards the development of both commercial and sport fisheries: fishing regulations were established, new species were introduced, and restocking included both salmonids and native fish species. In these two periods, policies were dictated by the federal government, which also undertook management actions. From 1970 on, there was a decentralization of freshwater management in Patagonia, with the provincial governments and the National Park Administration taking the lead. While provincial governments typically foster the development of sport fisheries, the National Park Administration focuses on the protection of native fish and opposes new introductions (Pascual et al. 2002).

Origin of Salmonids Introduced to Northern Patagonia.

While it is difficult to establish the specific rivers from which original salmonids were brought into Patagonia, it has been possible to establish the country of origin of the initial imports with certain confidence (Table 2), as well as the likely varieties from which actual populations derive.

Brook trout *Salvelinus fontinalis* were introduced in 1904 from the United States (Marini 1936), adapting quickly to the different environments in the region. By 1907, local reproductive stocks were available so as to not require further imports. Therefore, all stocks in both the Negro and Manso River basins are descendants of the fish introduced between 1904 and 1905.

All brown trout *Salmo trutta* inhabiting North Patagonia are descendants from embryos imported from Chile in 1931 (Marini 1936), which in turn descended from eggs brought at the beginning of the 20th century from Hamburg, Germany (de Buen 1959).

The first batches of Atlantic salmon *S. salar* were brought in 1904 from the Great Lakes (MacCrimmon and Gots 1979), and in 1931, more specimens, originally from Germany, were imported from Chile (de Buen 1959).

Rainbow trout *Oncorhynchus mykiss* eggs arrived from the United States for the first time in 1904 (Tulian 1908). These first batches probably came from the McCloud River, California (Pascual et al. 2001). These were sent to hatcheries in the Santa Cruz river, La Cumbre in the Cordoba province and a small number to the Nahuel Huapi hatchery (Marini 1936). The fish in the La Cumbre hatchery were sent to the river Cicerone hatchery in the Tucuman province (Valette 1915),

Table 2. Species introduced in the Negro and Manso river drainage basins since 1904. In the case of established species years of introduction corresponds to the first recorded stocking. On the case of *C. clupeaformis* dates on the three introduction attempts are reported.

Negro River drainage basin				
Species	Introduction year	Origin	Total no. fish introduced	Actual status
<i>Coregonus clupeaformis</i>	1904, 1940, 1965	USA	1,700,000	Nonestablished
<i>Salvelinus fontinalis</i>	1904	USA	4,329,998	Established
<i>S. namaycush</i>	1904	USA	53,000	Nonestablished
<i>Salmo salar</i>	1904	USA, Chile	844,543	Established
<i>Onchorhynchus mykiss</i>	1924	Pisc. Cicerone Argentina, Chile	3,032,092	Established
<i>Salmo trutta</i>	1931	Chile	431,398	Established
Manso River drainage basin				
Species	Introduction Year	Origin	Total no. fish introduced	Actual status
<i>Salvelinus fontinalis</i>	1916	Pisc. Nahuel Huapi, Argentina	480,520	Established
<i>Salmo salar</i>	1931	Chile	47,650	Nonestablished*
<i>Onchorhynchus mykiss</i>	1938	Pisc. Bariloche Argentina, Chile	348,693	Established
<i>Salmo trutta</i>	1931	Chile	341,890	Established

* Presence detected until the 1960s.

from which most of the rainbow introductions at the beginning of the 20th century came (Valette 1924). In 1931, rainbow trout were imported from Chile (Marini 1936). These specimens were descendants from specimens originally imported in 1905 from Hamburg, Germany (de Buen 1959). It is also possible that these rainbow trout were originally from the McCloud River (Pascual et al. 2001). In 1969, rainbow trout from Denmark were brought to the hatchery in Bariloche (Baiz 1973), from where they were extensively distributed to commercial aquaculture facilities throughout Argentina. Even though these were not used to stock natural environments (M. Baiz, Head of Centro de Salmonicultura Bariloche 1971–1993, personal communication), intentional or unintentional releases to

water bodies in the region cannot be discarded (Alonso 2003).

Historical Analysis of Salmonid Stocking

Six species of salmonids were introduced in northwestern Patagonia starting in 1904, four of which were able to establish self-sustainable populations (Table 2). Number of species and specimens and dates of introductions and origin were different for the Manso and the Negro basins (Table 2) While introductions in the Negro basin started in 1904 and ended in 1964, those in the Manso basin started 12 years later and ended in 1938. Numbers stocked in both basins differed widely throughout the 82 years (Table 2). Annual stocking rate of all species in the Negro basin

was 92,625 fish, while that of the Manso basin was of 17,410 fish. In both basins, the species most intensively stocked were brook trout and rainbow trout. On the Manso basin, as many brown trout were stocked as the other two species. The species that was least intensively stocked was Atlantic salmon (Table 2).

From 1907 to 1930 (Figure 2), brook trout were continuously stocked, and it was the only species disseminated until 1924 when rainbow trout was introduced into the Neuquén drainage basin. Rainbow trout started to be frequently stocked from 1937 on, becoming the preferred species in 1950. Salmon stocking ended in 1906, and in 1931, it was again regularly introduced in small numbers until 1973. Brown trout was sporadically stocked from 1931 to 1958; dissemination was intensified until 1969 and then decreased until 1981 when the last stocking took place.

In the Manso River basin, stocking was more irregular. Brook trout was introduced in 1916 and 1918 and then annually between 1937

and 1971. Rainbow trout was discontinuously propagated for 39 years, since its first introduction in 1938. Stocking of brown trout was more or less regular between 1931 and 1969, usually at numbers similar to those of brook trout. Only seven introductions of Atlantic salmon were identified throughout the 63-year-record for this basin (Figure 3).

Introductions and Presence–Absence Data over Time

During the 1904–1986 period, a total of 603 stocking events of all species were recorded for the Negro and Manso River basins combined. Of these, 371 were in the Negro River subbasins of the Nahuel Huapi, Triful, Pichileufú, and Limay rivers, 134 were in the rest of the Negro river basin, and only 98 were in the Manso River basin.

Brook trout was introduced to all subbasins at different periods, except for the middle and lower Limay subbasins (Figure 4). Presence data throughout the different periods show

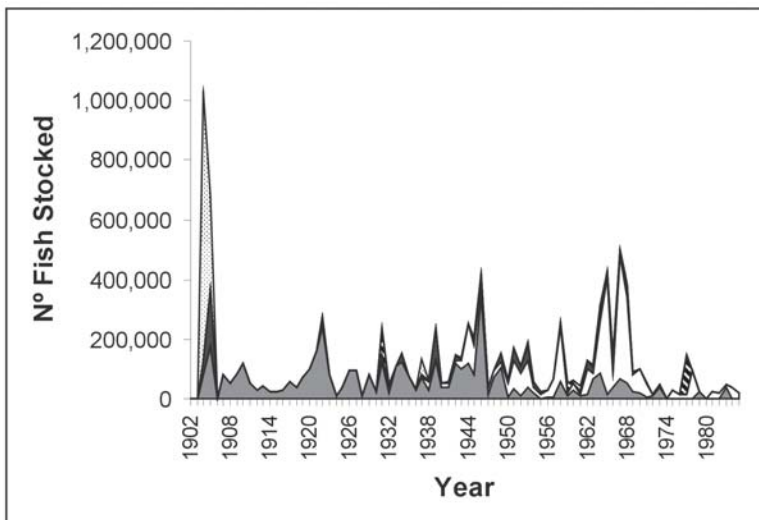


Figure 2. Numbers of fish officially stocked on the Negro River drainage basin between from 1904 to 1986.  brook trout,  rainbow trout,  Atlantic salmon,  brown trout,  others

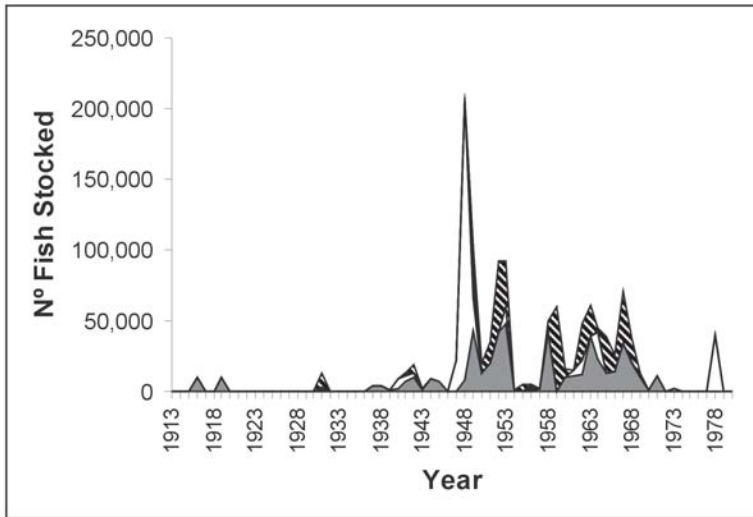


Figure 3. Numbers of fish officially stocked on the Manso River drainage basin from 1916 to 1979. brook trout, rainbow trout, Atlantic salmon, brown trout

that this species retracted towards western environments of the Andean range (Figure 4). Salmon was introduced during all three analyzed periods, but in a geographically more restricted fashion. No stockings have been recorded of this species for the middle and lower Limay or the Neuquén and Negro rivers (Figure 5). After an initial expansion, which lasted approximately until 1945, this species retracted to a small number of water bodies, all of them in the Negro River basin (Figure 5). Before 1930, rainbow trout had been introduced only into Pellegrini Lake in the Negro River basin. Between 1931 and 1945, this species was widely disseminated in locations on all subbasins (Figure 6). A similar scenario is found for brown trout, which after their initial 1931 stocking were introduced to all subbasins (Figure 7). These two last species quickly adapted and dispersed in all considered subbasins (Figures 6–7).

Historic Variation of Salmonid Abundance

An important variation per species catches was detected for both drainage basins between

study periods (Table 3). Global CPUEN (all lakes, all species) did not differ significantly between river basins during the 1937–1942 period (ANOVA, $P > 0.05$) or during the 1997–2002 period (ANOVA, $n = 10$, $P > 0.05$).

Even though the numbers of fish caught varied between periods, significant differences were only found for catches at lake Espejo, where catches were higher for the period of 1937–1942 (M-W, $n = 8$, $P < 0.05$).

Important differences were found between periods for particular species. Brook trout catches in the period 1937–1942 did not differ between drainages (ANOVA, $n = 10$, $P > 0.05$), a period where this species was dominant all throughout both river basins. A strong drop in CPUEN values for this species was observed in 1996–2002 (ANOVA, $n = 20$; $P < 0.05$), to the extent that it is absent today in several environments where it occurred and virtually has disappeared from all lakes, while rainbow and brown trout populations increased consider-

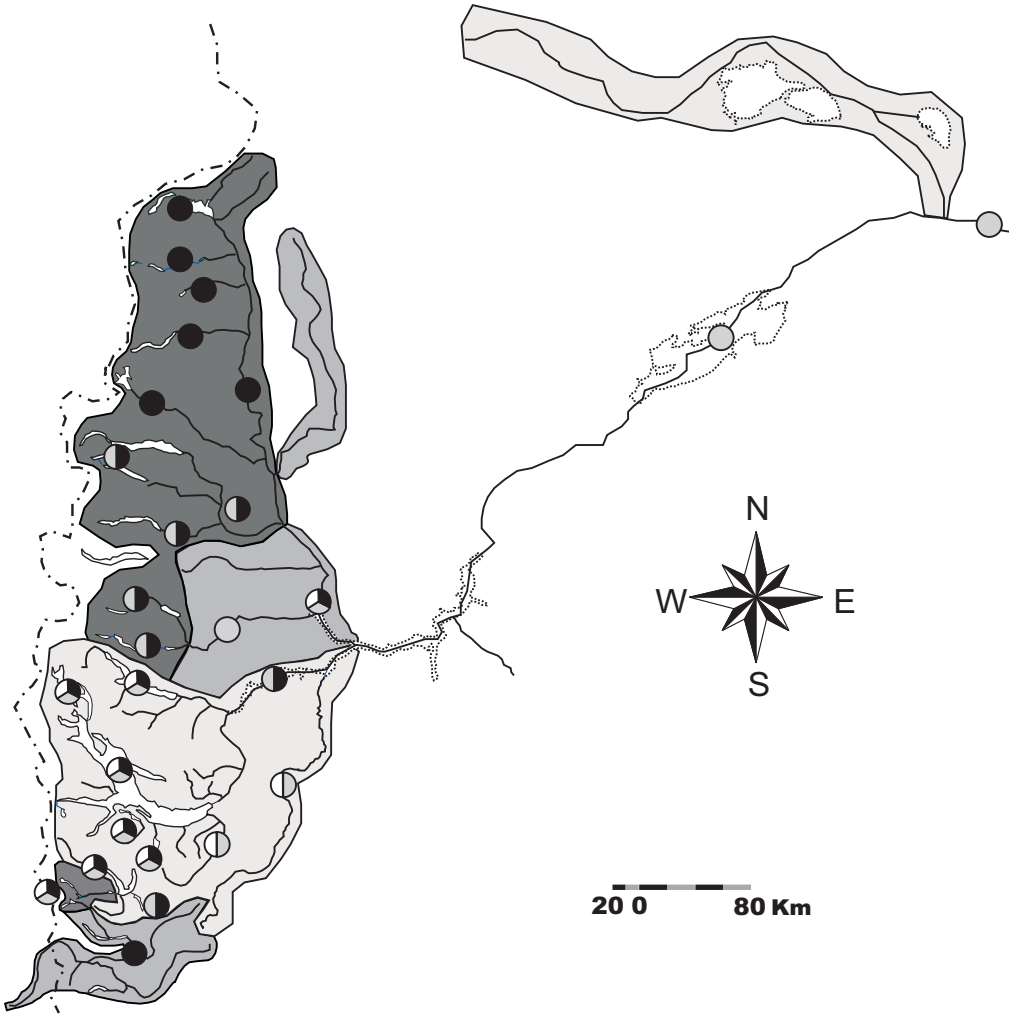


Figure 4. Brook trout stocking distribution and historic presence map. Stocking periods: 1. light gray areas 1904–1930, 2. dark gray areas 1931–1945, 3. medium gray areas 1946–1986. Presence data: white circles 1904–1930, gray circles 1937–1945, black circles 1990–2002.

ably between periods in all studied water bodies. In summary, there has been a replacement of brook trout in both drainage basins by these two species. Thus, in the Manso drainage, brook trout went from representing 100% of the catches on the first period to only 33% of the catches in the second (Table 3).

Discussion

The introduction and acclimatization of salmonids into the Negro and Manso River

basins implied a long and complex process, characterized by shifting management goals and species preferences over space and time. Of all species introduced into northern Patagonia, brook, rainbow, and brown trout, as well as Atlantic salmon, managed to adapt successfully to different water bodies in the region. Only lake whitefish *Coregonus clupeaformis*, introduced in 1904, 1937, and 1964, and lake trout *Salvelinus namaycush*, introduced in 1904 and 1905 (Tulian 1908; Marini 1936; Oficial Archives Ministerio de

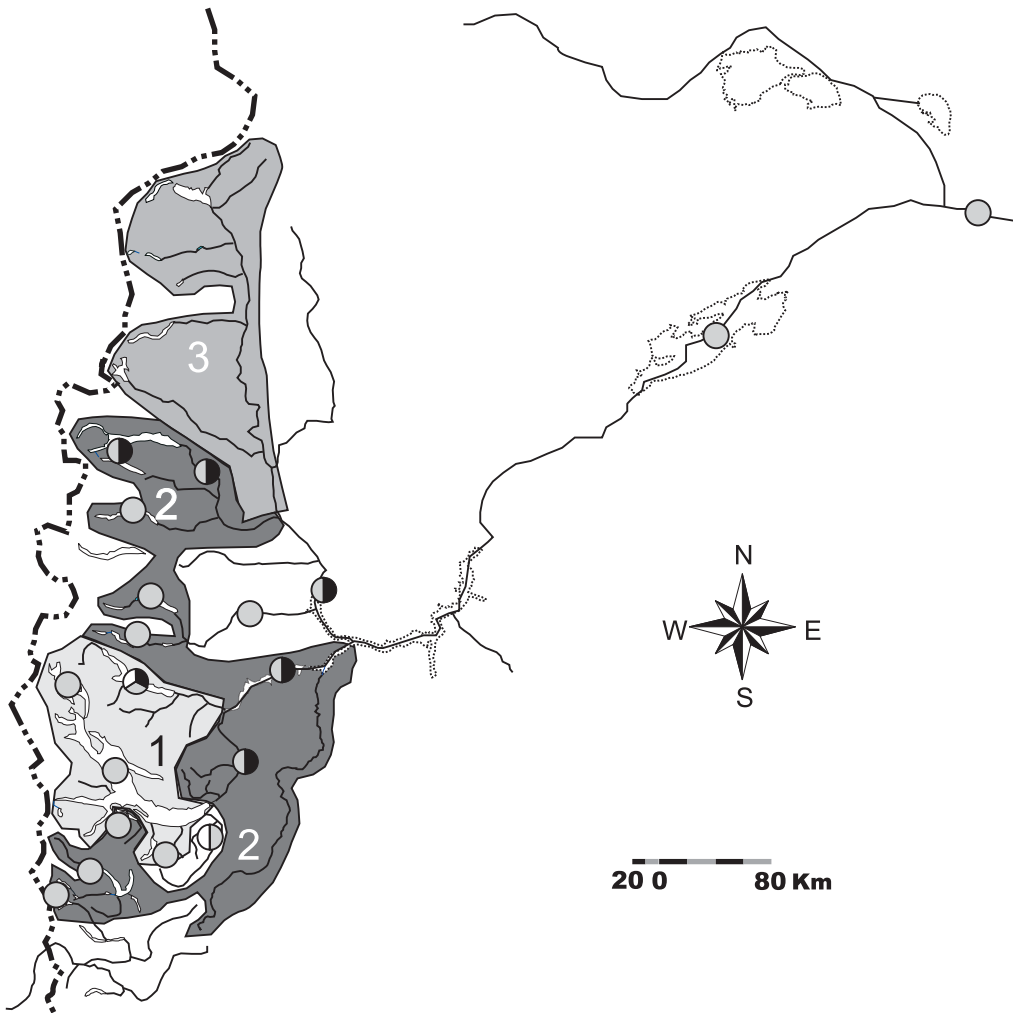


Figure 5. Atlantic salmon stocking periods: 1. light gray areas 1904–1930, dark gray areas 1931–1945, medium gray areas 1946–1986. Presence data: white circles 1904–1930, gray circles 1937–1945, black circles 1990–2002.

Agricultura y Ganadería de la República Argentina. Piscicultura Bariloche 1934–1970), failed to produce self-sustaining populations.

The six species introduced to Patagonia have different success records as introduced species around the world. Lake whitefish was introduced to only seven countries, failing in all of them (Welcomme 1988). Lake trout was introduced into 11 countries in Europe, Oceania, and South America, adapting only

to environments in the Alps, New Zealand, and Argentina (Welcomme 1988). In Patagonia, self-sustaining populations exist in the Santa Cruz and Chico basins (Pascual et al. 2002). Atlantic salmon has been the subject of numerous worldwide introductions during the past two centuries, but it has adapted only in New Zealand and Argentina (MacCrimmon and Gots 1979). A new round of dissemination of this species is occurring through escapes from fish farming facilities in Chile (Pascual et al. 2002) that cross the Andes

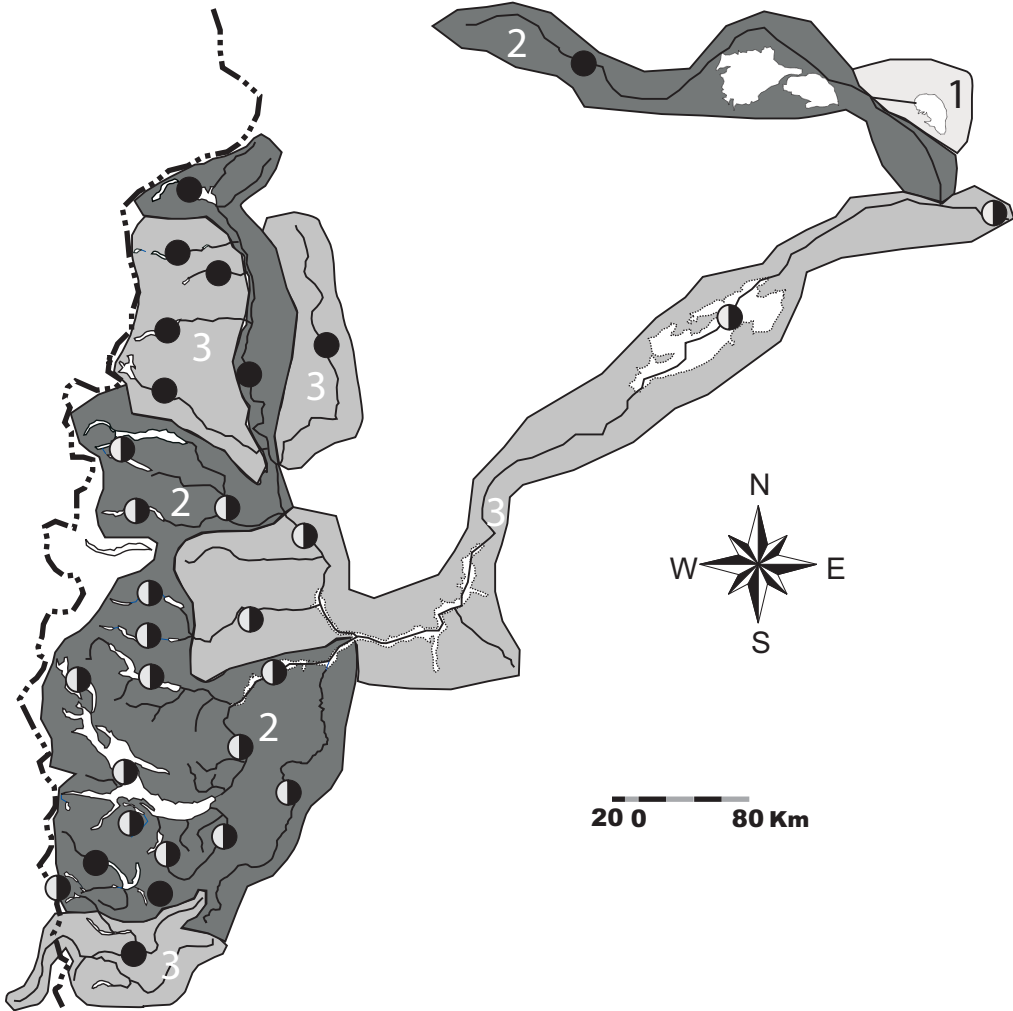


Figure 6. Rainbow trout stocking periods: 1. light gray areas 1904–1930, dark gray areas 2. 1931–1945, 3. medium gray areas 1946–1986. Presence data: gray circles 1937–1945, black circles 1990–2002.

through Pacific river basins of Argentina. Brook, rainbow, and brown trout have widely spread on the five continents with different results (Welcomme 1988). Brook trout established scattered populations in several countries (MacCrimmon and Campbell 1969). Rainbow trout and brown trout are the two salmonid species with the widest world distribution, establishing permanent populations in many countries (MacCrimmon and Marshall 1968; MacCrimmon et al. 1970; MacCrimmon 1971). In Patagonia, these two

species have prospered the most among salmonids (Pascual et al. 2002), with anadromous and land-locked populations all throughout their range (Pascual et al. 2001).

Specific policy goals in 1904–1910, 1910–1970, and 1970–2002 undoubtedly influenced the introductions' outcomes. Thus, meanwhile, on the first two periods, four different salmonid species and some native species were introduced. The third period is characterized by provincial administrations focus-



Figure 7. Brown trout stocking periods: 1. dark gray areas, 1904–1930; 2. dark gray areas, 1931–1945; 3. medium gray areas, 1946–1986. Presence data: gray circles 1937–1945, black circles 1990–2002.

ing on restocking of primarily rainbow trout with sport fishing benefits in mind.

Other factors that contributed to shape the artificial and natural dispersion of salmonids in the Manso and Negro basins were the degree of isolation of different locations, with lack of road infrastructure well into the 20th century (Bustillo 1968); a trial and error management route without a template (Marini 1936, 1941); and the biological plasticity of released specimens, including their great dis-

persive capacity (Gowan et al. 1994; Sakai et al. 2001). Stocking was conducted in all environments, but while western environments were stocked with four species, eastern ones were stocked with only rainbow and brown trout. In 1986, different national and provincial fishing related agencies were closed down and stocking activities continued in the hands of different nongovernmental organizations. The number of fish stocked, as well as the number of stocking events in the different drainage basins, may have influenced the ac-

Table 3. Records of salmonid catch per unit effort in numbers (CPUEN) on lakes of the Andean Range of the Negro river drainage basin (upper Limay subbasin) and Manso river drainage basin (upper and middle Manso subbasins). Catches were compared between same months (see Table 2), of 1937–1942(a) and 1995–2002 period (b).

Negro River drainage basin						
Lake		CPUEN				Total
		Brook trout	Atlantic salmon	Rainbow trout	Brown trout	
Moreno este	a	2,00	0,66	0,66		3,32
	b	2,00		4,00		6,00
Gutiérrez	a	5,33				5,33
	b	1,00		0,50	0,50	2,00
Espejo	a	23,85				23,85
	b	0,52		0,42		0,94
N. Huapi (B. Rincon)	a	5,63	0,15	-		5,78
	b			1,33	4,00	5,33
N. Huapi (Dina Huapi)	a	11,85	0,30			12,15
	b			1,33	0,67	2,00
Traful (Pto. Arrayan)	a	1,33	0,33			1,66
	b	1,00		2,00	2,00	3,00
Manso River drainage basin						
Lake		CPUEN				Total
		Brook trout	Atlantic salmon	Rainbow trout	Brown trout	
Mascardi	a	8,70	0,35			9,05
	b	1,66		1,66	5,33	8,65
Los Moscos	a	10,47	0,15			10,62
	b			0,54	0,54	1,80
Hess	a	1,33				1,33
	b			2,00	2,67	4,67
Fonck	a	16,22				16,22
	b	12,00		8,00	7,00	27,00
J. A. Roca	a	12,17				12,17
	b	2,00		2,25		4,25

tual dispersion of different species, but it is still not clear how these two variables influenced probability of success of both colonization and posterior dispersion of invasive species. Thus, while total stocking of brown trout until 1986 was one order of magnitude less than that of brook trout, its present distribution is much more extended, being also more numerous in several environments.

The different stocking periods have played a key role in the historic distribution of the four adapted species. During the first 30 years, brook trout and salmon were the only salmonids caught in the region. Brook trout was stocked in higher numbers, but both adapted quickly (Ormsby 1908a, 1908b) and initially dispersed naturally in both drainages (Valette 1924; Marini 1942). Brook trout dominated

the scene at least until 1945 in most of the Negro River basin and in practically all of the Manso basin (Bruno Videla 1944; González Regalado 1945).

Introduction of rainbow and brown trout produced a dramatic shift in species composition of freshwater bodies in northern Patagonia. Sampling between 1939 and 1942 started to yield rainbow trout in all lakes of the Nahuel Huapi subbasin and upper and middle Manso River. There is also evidence that these changes proceeded fast. Bruno Videla (1944) states that rainbow trout was not dominant in 1941 in the subbasin of the Nahuel Huapi Lake, but by 1944, it had displaced brook trout in all connected water bodies. In short, rainbow trout became dominant in just 8 years from its first report in 1939.

Exotic rainbow trout has been able to displace brook trout in several locations of its endemic range (Larson and Moore 1985). There is, therefore, a great interest to study their interaction to derive management actions for brook trout (reviewed in Fausch 1988). These studies have included field work (Larson and Moore 1985), field removal experiments (Moore et al. 1986), and laboratory experiments (Cunjak and Green 1983, 1984, 1986), which have attempted to reveal those factors that affect coexistence of these two species. In general, rainbow trout appears to be a superior competitor, but the dominance of one or the other species is apparently modulated by several physical factors. Some studies in the Appalachians also indicate that the relative size that the fish have during their first growing season determines the outcome of the interaction (Larson and Moore 1985), but this hypothesis has not been assessed for other environments. The success of rainbow trout and the demise of brook trout in northern Patagonia appear to have followed the same scenario observed in North America. It, therefore, pro-

vides a fantastic opportunity to explore the interaction between these species.

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