Have Patagonian waterfowl been affected by the introduction of the American mink *Mustela vison*?

Salvador J. Peris, Javier Sanguinetti and Moisés Pescador

Abstract The American mink *Mustela vison* has spread widely beyond its native North American range and is associated with problems for the conservation of native species because of its impact as both predator and competitor. We investigated the impact of feral mink on waterfowl in Lanín National Park, south-west Neuquén, Patagonia, Argentina, an area in which the predator is currently expanding. Statistically significant differences were observed in the number of waterfowl species at lakes without mink (7.3 ± SE 0.7) compared to those with mink (4.0 ± SE 0.6). Overall abundance of birds observed per day was higher at lakes without (104.2 ± SE 20.6) than with mink (21.2 ± SE 22.3). The great grebe *Podiceps major*, speckled teal *Anas flavirostris*, Chiloe wigeon *Anas sibilatrix* and red-gartered coot *Fulica armillata* were more abundant on water bodies without mink, and flocks of the ashy-headed goose *Chloephaga poliocephala* were larger in areas without mink. Other species, such as the white-tufted grebe *Rollandia rolland*, coscoroba swan *Coscoroba coscoroba*, black-necked swan *Cygnus melanocoryphus*, cinnamon teal *Anas cyanoptera*, Andean duck *Oxyura jamaicensis* and Andean gull *Larus serranus* were never observed in areas harbouring mink. We conclude that at least 12 of the 25 waterfowl species observed are sensitive to the presence of the mink, either being absent or having a lower abundance where mink are present.

Keywords Argentina, mink, *Mustela vison*, Patagonia, population impact, waterfowl abundance

Introduction

After habitat loss, invasive species are the second greatest threat to biodiversity (Hulme, 2003). Diagnosis of their impact on native species is therefore a fundamental problem in conservation biology (Park, 2004). One such invasive species is the American mink *Mustela vison*, a predator introduced extensively into Europe, Asia and southern areas of South America (Macdonald & Strachan, 1999; MacDonald et al., 2007). In Argentina mink farms were started in the 1950s in the southern province of Chubut. There have been successive escapes, either accidental or through the abandonment of nurseries (Pagnoni et al., 1986), and the species has increased its range to the north and east, following the numerous river-beds and lakes of the Andean mountain range.

In North America, the original source of mink, the predator is responsible for 65–68% of predation on eggs and nestlings of waterfowl (Pietz et al., 2003; Krapu et al., 2004). In Europe the impact of the expansion of mink on native bird life is appreciable and has been documented in Central Europe and Scandinavia (Andersson, 1992; Craik, 1997; Nordström et al., 2002; Bartoszewicz & Zalewski, 2003; Bonesi & Palazon, 2007), Great Britain (Macdonald & Harrington, 2003) and the Mediterranean region (Bonesi & Palazon, 2007). In South America excreta sampling (Medina, 1997; Previtali et al., 1998) of the summer diet of mink shows that it consumes crustaceans, mollusc bivalves, and small mammals and birds but little is known, probably because of the sampling methods used, of any differential consumption of bird species.

The aim of the work reported here was to explore the possible effect of the recent presence and progressive expansion of mink on the waterfowl population during the reproductive season, the time of year when any such impact may be most significant (Brzezinski & Marzec, 2003), in the water bodies of an extensive area in Patagonia.

Study area

The study was carried out in the c. 412,013 ha Lanín National Park, created in 1937 in south-west Neuquén, Argentina, with Chile to the west and the Nahuel Huapi National Park at its southernmost tip (Fig. 1). The Park lies between the Andes and the Patagonian steppe. It preserves landscapes of the Andean–Patagonian forests, with tree species such as the pehuén or araucaria *Araucaria araucaria*, northern beech and oak–beech (*Nothofagus* spp.) and Austral cypress *Austrocedrus chilensis*.

The Park includes mountain ranges whose altitude falls towards the east, blending into a smoothly undulating topography with a large number of glacial lakes and short heavy-flowing rivers. The heads of nine of the rivers are located on the eastern side of the Andes and belong to the Negro river basin; another river belongs to the western Andean side, together with a series of locked basins known as *arreicas* and other closed lagoons. The Park is subdivided into a northern sector, with the basins of the Lakes Ñorquinco, Rucachoroi and Quillén, a northern central

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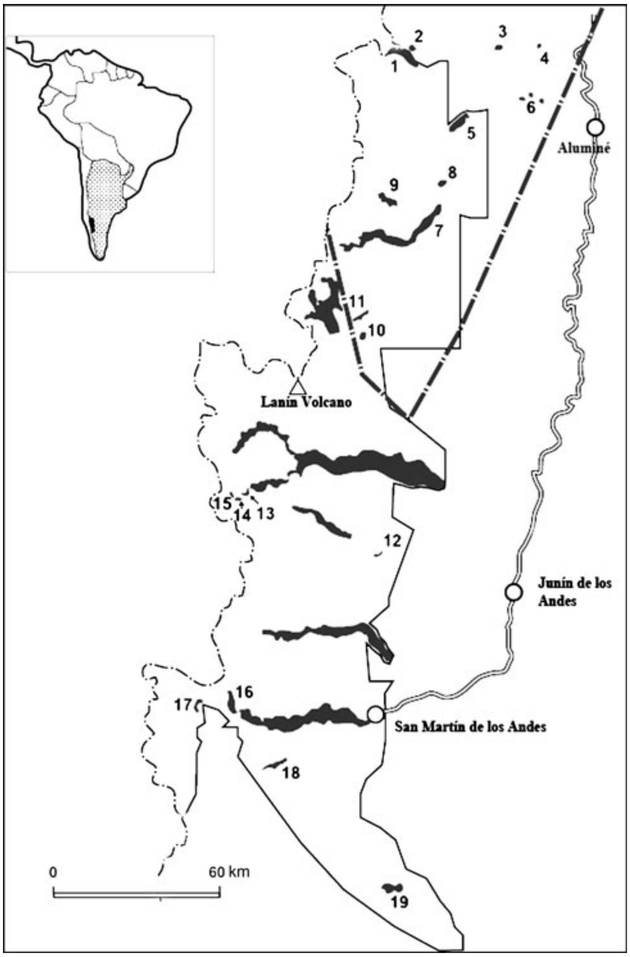

FIG. 1 Lanín National Park in Patagonia, Argentina. Numbers indicate the 21 water bodies surveyed (see Table 2 for names). The dashed line marks the northern limit of mink *Mustela vison* in 2007.

sector, including the basins of the Lakes Tromen, Huechulafquen and Curruhué, and a southern central sector that includes Lácar Lake, which flows to the Pacific Ocean, and Lolog Lake. The southern sector encompasses the basins of the Lakes Meliquina-Hermoso and Filo Hua-Hum, bordering the southern Nahuel Huapi National Park.

All the lakes are deep (e.g. the Quillén has a maximum depth of 155 m), and the water is moderately acidic in water bodies $>$ 50 ha (pH 6.1–5.5); lagoons $<$ 25 ha are alkaline, with a pH of 7.9–9.0 (S.J. Peris, J.Sanguinetti & M. Pescador, unpubl. data). Mean rainfall is $>$1,500 mm year^{-1}, with a maximum of 2,800 mm year^{-1} in the north central sector. The region has a low human density (1.84 inhabitants km^{-2}; Iglesias & Pérez, 1998).

Methods

Mink were first detected in Lanín National Park in 1994, although it was not until 1996–1997 that the species was commonly observed. Since then, it has colonized seven of the 12 river basins of the Park, occupying c. 208 km of lake edges and 900 km of the rivers and streams that flow into the Atlantic, i.e. an advance of 19–82 km year^{-1} (Funes et al., 2006). Since 1996 another invasion from Chile has been detected, affecting Lake Lácar. To detect mink, systematic sampling was carried out based on indications of the activity of the species (tracks, excreta, direct observations and occasional captures with traps) recorded by park rangers during 1996–2005. The method comprised 1,000-m transects that followed the edges of the lakes, ponds and main river-beds of the National Park.

The proportion of waterfowl in the diet of mink is related to waterfowl density, and is particularly high during the breeding season (Medina, 1997; Previtali et al., 1998). During 10–19 November 2005 (pre-reproductive season) and 16–23 January 2006 (post-reproductive season), in a total of 18 days of fieldwork, censuses of all waterfowl species (Podicipediformes, Ciconiiformes, Anseriformes, Gruiformes and Charadriiformes) were made at 21 lakes and lagoons that had a maximum area of 661 ha. The surface limit was adopted to allow us to survey all the birds at each site, something impossible to achieve at larger lakes (e.g. the 12,000 ha Huechulafquen). On each visit all species of birds were identified and, as far as possible, an exact count was made using optical devices of 8×40 to 20×60. Surveys were conducted by teams of 2–6 (mostly four) trained observers.

At each wetland 20–60 minutes were spent counting birds, depending on area, covering the whole perimeter with line transects along the bank or point counts. All censuses were on foot. Counts were not made on days or at times with strong wind, which creates swelling, or at times when poor light hindered observation. The data recorded included physical and botanical descriptions of each water body.

As surface area influences species composition and the abundance of waterbirds (Uresk & Severson, 1988; Guadagnin et al., 2005), the lakes and lagoons sampled were grouped in four size categories: (1) small, which included six ponds of 2–10 ha; (2) medium, which included six lakes of 42–78 ha; (3) large, which included five lakes of 296–347 ha; (4) very large, which included four lakes of 407–661 ha.

Differences in waterfowl populations between sites with respect to the presence or absence of mink were tested using χ^2 tests. Once checks of normality and homoscedasticity had been made, total bird abundances were analysed using one-way analysis of variance (Sokal & Rohlf, 1994). A logistic regression (Lewis, 2004) was used to examine the relative effects of waterfowl species, survey dates and category of water body on the presence of mink. Statistical analyses were performed using *SPSS v 15.0* (SPSS, Chicago, USA).

Results

A total of 27 species of waterfowl were observed at the 21 water bodies. Abundance of waterfowl and area of water

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TABLE 1 Variables selected, and not selected, by logistic regression as predictors of the presence/absence of mink *Mustela vison*.

Variable	β	SE	Wald's statistic	df	P
Variables in the regression					
Waterfowl abundance	0.694	0.167	17.225	1	<0.001
Lake size	−0.456	0.150	9.193	1	0.002
Constant	−1.201	0.269	19.953	1	<0.001
Variables not in the regression					
Survey dates	0.001	0.000	3.361	1	0.067

bodies were significant predictors in a logistic regression model of the presence/absence of mink (Table 1). On water bodies with a surface area of < 200 ha we observed a mean of 6–7 waterfowl species per day compared to 5–6 species on larger bodies, although the difference was not significantly different ($F_{3,35} = 0.23$, $P > 0.05$). The total number of waterfowl observed per day was, however, significantly different between water bodies ($F_{3,35} = 1.11$, $P > 0.05$; Table 2). There was a tendency towards a greater abundance of birds (mean 87.4–96.2 day^{-1}) on lakes < 100 ha than on larger lakes (28.3–53.5 day^{-1}; Fig. 2).

The mean number of species observed per day per water body was 6.3 ± SE 0.77 in November and 5.83 ± SE 0.84 in January but the difference between the two periods was not statistically significant ($F_{1,37} = 0.192$, $P > 0.05$). Similarly, the mean number of individuals observed per day per water body in November (64.5 ± SE 16) and January (81.5 ± SE 25.2) were not significantly different ($F_{1,37} = 0.34$, $P > 0.05$).

There was a significant difference ($F_{1,37} = 10.1$, $P = 0.003$) in the number of waterfowl species observed per day on water bodies without mink (7.3 ± SE 0.7) compared to those with mink (4.0 ± SE 0.6). Similarly, the mean number of individuals observed per day on water bodies without mink was significantly higher (104.2 ± SE 20.6) than with mink (21.2 ± SE 22.3; $F_{1,37} = 9.7$, $P = 0.004$; Fig. 2).

Ten waterfowl species were not observed on water bodies containing mink and four species were significantly more common on lakes without than with mink (Table 3): great grebe *Podiceps major* ($\chi^2 = 6{,}528$, $P = 0.013$), speckled teal *Anas flavirostris* ($\chi^2 = 7.769$, $P = 0.006$), Chiloe wigeon *Anas sibilatrix* ($\chi^2 = 6.310$, $P = 0.012$) and red-gartered coot *Fulica armillata* ($\chi^2 = 3.365$, $P = 0.046$). The ashy-headed goose *Chloephaga poliocephala* had mean flock sizes of 37.0 ± SE 11.48 and 3.38 ± SE 0.80 in areas without and with mink, respectively, and the difference was statistically significant ($F_{1,19} = 5.16$, $P = 0.03$).

Discussion

Of a total of 27 waterfowl species observed on water bodies where mink were absent only 17 were observed at water bodies where mink were present. In addition, there were significantly more individuals of four species on water bodies with

TABLE 2 Mean numbers of species and individuals per day (with SE) observed at each of the 21 water bodies surveyed (Fig. 1). Note that three water bodies close together are jointly labelled 6.

Water body	Surface (ha)	No. of species ± SE	No. of individuals ± SE
1, Ñorquinco	661	7.50 ± 0.71	45.50 ± 31.82
2, Nompehuen	81	8.00 ± 2.83	52.50 ± 43.13
3, Pulmari	178	13.00 ± 1.41	273.00 ± 19.41
4, Los Giles	10	8.50 ± 0.71	292.00 ± 53.76
5, Rucachoroi	347	13.00 ± 0	152.00 ± 31.75
6, Ñanco	2	9.00 ± 0	106.00 ± 40.51
6, Segunda laguna	2	4.50 ± 1.50	45.00 ± 23.84
6, Diaheu	2	8.50 ± 0.50	126.00 ± 19.57
7, Quillén*	49	6.00 ± 0	155.00 ± 32.58
8, Coipu	24	7.00 ± 0	64.00 ± 0
9, Hui-Hui	307	2.00 ± 1.41	5.00 ± 4.24
10, Laguna Chica	3	4.50 ± 0.71	30.00 ± 8.48
11, Huaca Mamuil	22	3.50 ± 0.71	14.50 ± 6.36
12, Curruhue Chico	42	6.50 ± 2.12	61.00 ± 14.14
13, Carilafquen	106	1.00 ± 1.00	1.00 ± 1.00
14, El Escorial	11	2.50 ± 0.50	10.00 ± 5.66
15, Laguna Verde	47	3.50 ± 0.71	16.50 ± 2.51
16, Nonthue	468	6.00 ± 1.41	15.50 ± 10.60
17, Queñi	412	2.50 ± 0.71	8.00 ± 4.24
18, Lago Escondido	296	1.50 ± 0.71	3.50 ± 3.53
19, Filo Hua-Hum	407	7.50 ± 2.12	44.50 ± 16.50

*Only for the north-eastern arm (total lake area is c. 2,400 ha)

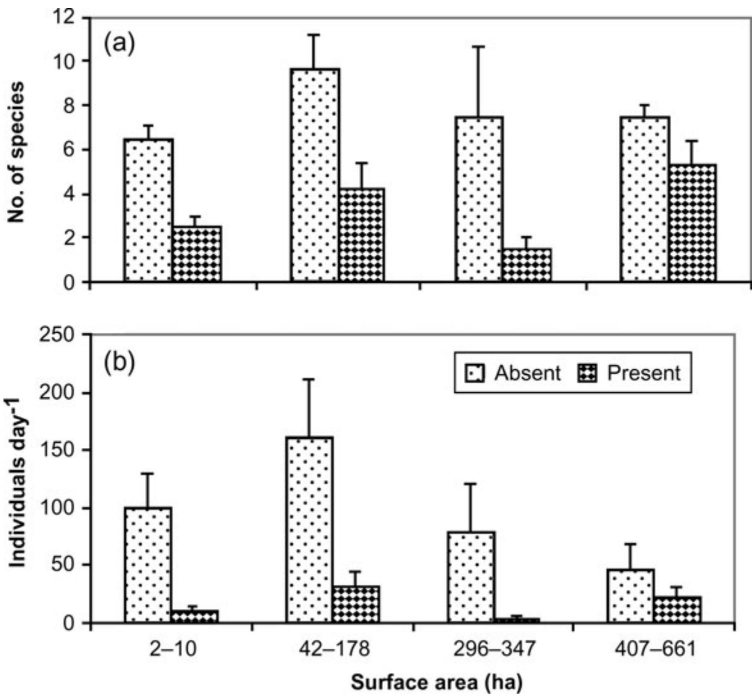

FIG. 2 (a) Mean number of species of waterfowl and (b) mean total number of waterfowl observed per day in water bodies (Fig. 1, Table 2) of four categories of surface area according to whether mink were present or absent. Vertical bars represent the standard error.

mink compared to water bodies without mink, and a greater overall abundance of waterfowl on mink-free water bodies.

For 13 of the waterfowl species observed the data are insufficient to allow us to test whether presence/absence or abundance of individuals has a relationship with the presence of mink. Nevertheless the relationship between the presence of mink and some waterfowl species was clear. The ashy-headed goose, for example, was present as only 1–2 pairs at some water bodies, such as Filo Hua-Hum, where mink have been present for 12 years. At the beginning of the 1990s they were counted there in groups of hundreds (data from Domingo and Jinny Taylor, owner of the Estancia Tres Lagos).

According to excreta analyses carried out in the UK, coots *Gallinula chloropus* and ducks (*Anas* spp.) comprise 15.3–16.4% and 2–4%, respectively, of the mink's diet (Macdonald & Strachan, 1999). However, in other areas of Europe, such as Poland, predation of mink on birds in spring and summer comprises 45–60% of breeding birds. Ducks (*Anas* spp.) and the European coot *Fulica atra* were the species most predated (11.2 and 7.8%, respectively), followed by grebes (*Podiceps* spp.; 1.8%). Only 13.6% of the nests of common geese *Anser anser* are successful in areas with mink (Nordström et al., 2002). In Chile birds comprise only 2.6% of mink diet (Medina, 1997), whereas in Argentina they form a higher proportion (30%; Previtali et al., 1998).

There is a debate about whether or not the presence of mink has decreased waterfowl populations (Brzezinski & Marzec, 2003; Bartoszewicz & Zaleswski, 2003), although in Finland the mink has limited the populations of small ducks (Nordström et al., 2002) and gulls (Banks et al., 2008). Adult birds of small and medium size could be more suitable prey for mink than larger species, probably because the latter are more successful at protecting their nest and young (Nordström & Korpimäki, 2004). Waterbird colonies may be effective at protecting themselves against diurnal predators but not against mainly nocturnal predators such as mink (Banks et al., 2008). Bird colonies are easier to locate, and attract predators. The ashy-headed goose, a colonial-breeding species, is one of the species most affected by mink in Patagonia (Schüttler et al., 2009).

In general, high predation by mink on aquatic birds can be explained by the relative abundance of birds in comparison to the availability of crustaceans, small mammals and fish (Chanin & Linn, 1980). In our study area, rivers such as Limay and Hua Hum are rich in crustaceans but other water bodies lack this prey and, although no data on crustaceans are available for the water bodies we surveyed, the diet of mink in nearby areas is most diverse in those basins with crustaceans (Fasola et al., 2009). In Sweden and North America, in habitats similar to those in Patagonia, the proportion of waterbirds in the mink's diet may increase to 78%, especially coots (70%), during the birds' breeding season (Gerell, 1967; Eberhardt & Sargeant, 1977). We do not know whether there is similarly high predation on coots in Patagonia, where *Fulica* spp. are able to produce up to two clutches per year, which could made them less sensitive to mink predation. In contrast, the two geese species, nesting at the edges of water bodies and in fields close to lakes, may be easy prey for mink, and as they have only one clutch per year they may be more sensitive to such predation. The lack of significant differences in abundance of some bird species between areas with and without mink could be because of lower predation by mink in the central zones of Lanín

TABLE 3 Mean numbers (with SE) of 27 species of waterfowl observed per day at water bodies (Fig. 1, Table 1) with and without mink.

Species	Mean no. without mink (± SE)	Mean no. with mink (± SE)
White-tufted grebe *Rollandia rolland*	1.80 ± 0.37	
Pied-billed grebe *Podilymbus podiceps*	1.00 ± 0	1.00 ± 0
Great grebe *Podiceps major*	2.83 ± 1.04	2.20 ± 0.39
Neotropic cormorant *Phalacrocorax olivaceus*	3.17 ± 0.87	7.00 ± 4.24
Great white egret *Egretta alba*	1.00 ± 0	
Cocoi heron *Ardea cocoi*	1.00 ± 0	
White-faced ibis *Plegadis chihi*	1.00 ± 0	
Black-faced ibis *Theristicus melanopis*	6.33 ± 2.55	4.00 ± 1.00
Chilean flamingo *Phoenicopterus chilensis*	2.00 ± 1.00	
Coscoroba swan *Coscoroba coscoroba*	2.67 ± 0.66	
Black-necked swan *Cygnus melanocoryphus*	15.67 ± 7.69	
Upland goose *Chloephaga picta*	12.75 ± 7.61	2.00 ± 1.00
Ashy-headed goose *Chloephaga poliocephala*	37.00 ± 11.48	3.38 ± 0.80
Flying steamer duck *Tachyeres patachonicus*	7.00 ± 2.53	1.67 ± 0.33
Spectacled duck *Anas specularis*	2.00 ± 0	2.00 ± 0
Yellow-billed pintail *Anas georgica*	7.13 ± 3.32	12.00 ± 7.00
Speckled teal *Anas flavirostris*	16.78 ± 5.20	7.00 ± 1.41
Chiloe wigeon *Anas sibilatrix*	11.18 ± 3.98	3.00 ± 2.30
Cinnamon teal *Anas cyanoptera*	2.00 ± 1.00	
Red shoveler *Anas platalea*	10.20 ± 4.64	2.00 ± 1.00
Andean duck *Oxyura jamaicensis*	5.18 ± 1.46	
Plumbeous rail *Pardirallus sanguinolentus*	30.00 ± 25.00	1.00 ± 1.00
Red-gartered coot *Fulica armillata*	40.14 ± 13.86	13.75 ± 5.40
White-winged coot *Fulica leucoptera*	16.38 ± 6.89	11.17 ± 5.59
Southern lapwing *Vanellus chilensis*	4.29 ± 0.95	2.50 ± 0.34
Kelp gull *Larus dominicanus*	3.20 ± 1.24	1.33 ± 0.33
Andean gull *Larus serranus*	5.75 ± 1.84	

National Park, where the abundance of the introduced European rabbit *Oryctolagus cuniculus*, another important mink prey, could reduce predation pressure on waterbirds.

Information on mink diet in Patagonia, with sporadic observations of its predation on waterbirds, is provided in Medina (1997) and Previtali et al. (1998). A mink was captured after hunting a Magellanic penguin *Spheniscus magellanicus* on the Guerrico seaboard (Tierra del Fuego). In the same region mink destroyed nests of Magellan geese *Chloephaga picta* (Rozzi & Sherriffs, 2003). Mink can birds nesting at lakes and ponds in a different way to birds nesting in rivers. Predation on nests of Canadian geese *Branta canadensis* and mallards *Anas platyrhynchos* has been reported to be < 48% on remote islands temporarily isolated from predators when strong river flows limit the arrival of predators, although mink is the predator least affected by such increases in river volume (Zoellick et al., 2004).

Birds choose nest sites where the risk of predation is smallest (Martin, 1993) and some waterfowl may be able to adapt to a new predator. In Europe the common moorhen *Gallinula chloropus*, which normally nests on the ground, builds nests in trees in areas where mink have been present for 15–20 years (Ferreras & Macdonald, 2001). In cases where nests are lost to predation other species, such as the coot, build a second nest in 47% of cases, and even a third (11%) in areas with mink (Macdonald & Strachan, 1999). It is possible that Patagonian species of *Fulica* may do the same. Our personal observations of *Chloephaga* indicate a preliminary anti-predator behaviour: in areas where mink have been present for 10–12 years the geese locate their nests away from lake edges.

An important finding of our study is that at least 12 of the total of 27 waterfowl species that we observed in Lanín National Park appear to be sensitive to the presence of mink, reflected either by their absence or lower numbers on water bodies where mink are present. Future issues that need to be researched are the relationship of the abundance of mink with that of waterbirds, and possible existence of anti-predator behaviour by birds such as has been observed in those European areas where the mink has been established from a long time.

The Patagonian landscape, with its richness of rivers and lakes draining to the Pacific coast of Chile and Atlantic coast of Argentina has some legal protection, with a number of national parks and other protected areas. However, this is a favourable habitat for mink, with mink farms in both countries. Although the relevant authorities are aware of the situation, effective anti-mink control is not yet available, at least not in Argentina. It is therefore likely that the range of mink will continue to increase in northern Patagonia, with concomitant effects on waterfowl.

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