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Review Article

A global review of the American mink (*Neovison vison*) removal techniques – Patagonia as a case study for their potential application

Una revisión global de las técnicas de eliminación del visón americano (*Neovison vison*) – La Patagonia como estudio de caso para su posible aplicación

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ABSTRACT

American mink (*Neovison vison*) represents a threat to both biodiversity and economy in various regions of the world, including Patagonia. This invasive species has been successfully removed from many areas of Europe. In Chile and Argentina there have been only patchily distributed attempts of local control to date and large-scale removal has been considered unfeasible. We analyzed available scientific information, to determine best-fit strategies and improved methodologies that increase efficiency (capture per unit of effort) in American mink control. We reviewed published papers about programs that aimed at local control, functional or total eradication of minks in the Web of Science (WoS) database. Based on accessible information, the influence of some field variables on capture efficiency was determined through a General Lineal Model. From 1525 results in the WoS search, 51 papers refer to mink control action carried out in 28 areas of Europe and South America since 1992. Trapping has been the most used and efficient capture method. Short trapping periods that cover larger lineal distances per control program, and the use of attractants, specifically pheromones, have led to improved control efficiency. Chilean, Scottish and English experiences showed among the highest trapping efficiency values. We identify areas of research needed on mink ecology and behavior and trapping techniques that could improve trapping efficiency. A control program that incorporates the outcomes of this data assessment has the potential to improve feral mink removal. But further research is required to ensure that these efficiency measures result in cost-effective control in Patagonia.

Keywords: bait, control, management, trapping.

RESUMEN

El visón americano (*Neovison vison*) representa una amenaza para la biodiversidad y para la economía de muchas regiones del mundo, Patagonia incluida. Este invasor ha sido removido exitosamente en muchas zonas de Europa, sin embargo, en Argentina y Chile solo ha habido intentos de control aislados y la eliminación a gran escala se considera inviable. Basándonos en experiencias anteriores mundiales, nuestro objetivo fue determinar las estrategias y metodologías más adecuadas que aumenten la eficiencia (capturas por unidad de esfuerzo) en el control de visones. A través de la Web of Science (WoS) se buscaron artículos publicados acerca de proyectos que persiguieran el control, la eliminación o la erradicación de la especie. Se determinó la influencia de algunas variables de terreno en la Eficiencia de captura empleando un Modelo Lineal Generalizado. De 1525 publicaciones, solo 51 refieren acciones de control en 28 áreas de Europa y Sudamérica desde 1992. El trampeo ha sido el método de captura más empleado. Breves periodos de captura, trampas potenciadas con atrayentes, específicamente feromonas; y abarcar una mayor longitud de la cuenca; han incrementado la eficiencia del control de visones. Las experiencias en Chile, Escocia e Inglaterra mostraron los más altos valores de eficiencia en el trampeo. Un programa de manejo que incluya los resultados de esta evaluación, tendría el potencial de mejorar la eliminación de visones y controlarlos con éxito en la Patagonia chilena, aunque se requiere más investigación para garantizar que estos indicadores de eficiencia resulten en un control rentable en la Patagonia.

Palabras clave: cebo, control, manejo, trampeo.

INTRODUCTION

American mink (*Neovison vison* Schreber, 1777, recently discussed as belonging to the genus *Neogale* [Patterson *et al.* 2021]), is considered one of the most widely distributed and publicized invasive carnivores in the world (Bonesi & Palazon, 2007; Liu *et al.* 2020; Tedeschi *et al.* 2022). Native to North America, extant feral populations can be found in more than 30 countries in Europe, Asia and South America (Fasola *et al.* 2021). Its worldwide spread was a direct consequence of fur farming development during the past century (Bonesi & Palazon 2007). The "mink menace" (Sheail, 2004) in many regions continues because many of those farms are still operating (Fasola & Valenzuela, 2014; Roy *et al.* 2009). Argentina, Chile and more recently, Uruguay, are the only territories in the southern hemisphere that face the consequences of mink presence (Jaksic *et al.* 2002; Laufer *et al.* 2022; Ojeda, 2016). Minks are generalist voracious predators, feeding on fish, mammals, birds, amphibians, lizards and invertebrate prey. Their negative impacts on native wildlife have been well documented around the world, particularly predating ground-nesting birds and small mammals and as a competitor with native species for resources (Fasola *et al.* 2021; MacDonald & Harrington, 2003; Stefansson *et al.* 2016). The decline in the Coot (*Fulica atra*) breeding population in north-eastern Poland have been a consequence of mink invasion since mid-1980s (Brzeziński *et al.* 2012). During the first half of the 1990s, feral North American Mink caused the reduction of more than 30% of breeding bird colonies in the Finnish Baltic Archipelago as well as the disappearance of many colonies of terns and gulls (Craik 1993; Nordström & Korpimäki 2004). Fasola & Roesler (2018) reported that a single mink event downsized the grebe population by 4%, over just 2-3 days. American mink has been implicated in the local extinction of the British water vole (*Arvicola amphibius*) during the past century (Strachan *et al.* 2010). In continental Europe, American mink caused negative effects on native European mink (*Mustela lutreola*) through interspecific competition, direct aggression included (Sidorovich *et al.* 1999). A drastic reduction in the distribution range of native mink coincided with the arrival of the invasive one in 1988, although invasion was not the only cause of decline. The roles of minks in transmission and as a reservoir of diseases have also been described as a negative impact on native species (Barros *et al.* 2014; Knuuttila *et al.* 2015; Barros *et al.* 2018; Barros *et al.* 2022). This mustelid is recognized as natural reservoirs for pathogens such as Aleutian virus, Leptospira, Toxoplasma and Canine Distemper Virus (Hammer *et al.* 2007; Knuuttila *et al.* 2015; G. Medina-Vogel, 2010). Sepúlveda *et al.* (2014) proposed the role of mink as a bridging host between domestic and wild mammals in the transmission of Canine Distemper Virus in Chile. In addition to ecological consequences, economic losses due to direct impact on livestock activity i.e. poultry and farmed fish, and those involved in the species' control; should be added to the list of undesirable effects (Kelly *et al.* 2013; Cerda *et al.* 2017). This species represents an ecological and economical problem, which is why some actions of control or eradication have been implemented to mitigate those impacts.

To deal with biological invasion, it is important to know first which will be the main goal: total eradication or 'functional eradication' defined by Green & Grosholz (2021) as population suppression (control) to a level that achieves an acceptable level of damage mitigation. The main difference between total eradication and functional eradication lies in the possibility of recolonization of the previously cleared area in the latter (Robertson *et al.* 2017). While there is a general consensus on the need to control mink invasions in all territories, there has been some skepticism with regards to the likelihood of achieving even functional eradication, especially in large areas (Zabala *et al.* 2010). Both approaches will require the most efficient control methods possible.

Patagonia is one of the main regions of South America impacted by the American mink invasion. The species might be found in almost all Chilean water bodies and islands between latitudes 38° and 55° S (Mora *et al.* 2018) and it was estimated that its expansion covered an area of 450 thousand km^2 of Argentina Patagonia (Fasola & Valenzuela 2014). Some research on the ecological and economic consequences of the presence of the mink in this area allows us to understand some of the impacts of this species (Cerda *et al.* 2017; Fasola & Roesler 2018; Ramírez-Pizarro *et al.* 2019; Schüttler *et al.* 2008). Flightless steamer duck and upland goose nest survival have been severely reduced by mink predation on Navarino Island (Schüttler *et al.* 2009). Likewise, critically endangered Hooded Grebe (*Podiceps gallardoi*) has been severely impacted by mink attacks (Fasola & Roesler 2018). The inclusion of bird species that do not nest on the ground like Passerines and woodpeckers in the invaders diet is alarming as well (Jiménez *et al.* 2014). Valenzuela *et al.* (2013) found some preferential predation of small native rodents over exotic species. The role of the mink as a vector in parvovirus transmission between domestic pets and the endangered native southern river otter has been proven (Barros 2022). The impacts of minks on the Chilean economy have been estimated at nine and a half million US dollars per year and a loss of 416 million US dollars is projected for the next two decades (Cerda *et al.* 2017). These numbers are probably underestimated due to the lack of information about damages on local livestock activity, tourism and disease transmission. That is why some local feral mink removal efforts have been carried out in the country, but most of them have been temporarily and geographically discontinuous (CECPAN 2020; Davis *et al.* 2012; Medina-Vogel *et al.* 2015). Because there are functioning fur farms located in Argentine Patagonia, and the Andes Mountains do not seem to represent an effective barrier to the dispersal of juveniles during summer (Fasola *et al.* 2021), the risk of recolonization of previously cleared areas remains. However, properly implemented, mink removal has been shown to be effective, both to drastically reduce invader populations and in native fauna recovery (Korpimäki & Nordström 2004; Nordström *et al.* 2002; Reynolds *et al.* 2013). Fasola *et al.* (2021) concluded that there was a great need for site-specific "pre-defined trapping designs", which must be as efficient as possible. Thus, our present review aims to select the best-fit strategies and improved methodologies that would increase efficiency for a large-scale mink control program in Patagonia, based on a bibliographic analysis of previous experiences worldwide.

METHODOLOGY

Literature review and analysis

Scientific literature was reviewed to identify American mink management programs around the world from 1992 to 2022. To do that, an exhaustive search was made on Web of Science Database, checking not only its Core Collection, but also KCI-Korean Journal Database, Russian Science Citation and SciELO Citation Indexes. Keywords: "*Neovison vison* or *Mustela vison* or American mink" and "Management or Control or Removal or Eradication" were explored in all fields of the database. One initial revision of titles was made to eliminate spurious results. Later, a final selection was made by to filter the studies that refer to any mink management action.

Impacts on culled populations of minks were evaluated based mainly on project outcomes provided by authors in their manuscripts. GBIF database was used as an additional tool to analyze mink occurrences and trends before and after each project was implemented (https://www.gbif.org). This analysis could not be done for South America because of the lack of information on the area in the GBIF data bank. The objectives of the projects are reported; and usually included a decrease in the mink population and/or a stabilization or increase in the native species threatened by mink over time (Bonesi & Palazon 2007).

All publications that referred to any management action on invasive mink populations, regardless of whether it was reported as successful or not, were analyzed to assess the best elimination strategy. Where the information was available, details of the goals, technique(s) applied, capture timing, area and lineal distance covered, captures effort, costs and outcomes of each program were extracted. When the available data (i.e. distance between consecutive traps or trapping time) was given in a range, the mean value was selected for the analyses. Capture rates (calculated as the ratio between the number of minks removed and total effort given in trap-night units) was the indicator of Efficiency that was analyzed. Where live-trapping techniques were applied, trapping efficiency was compared between countries and season with a Kruskal-Wallis test, since the data did not meet the premise of homogeneity of variance. The Capture Rate dependence on some explanatory variables, including season of the year, trapping time (period when traps remained active), use of rafts, the type of traps (lethal or live) and bait (food or scent gland) used on capture; was analyzed by applying a Simple Linear Regression. The models were fitted via maximum likelihood estimation in SPSS V.20. In addition, control or removal recommendations provided by some authors are mentioned.

RESULTS

Techniques employed

From 1525 results in the WoS search, only 51 published papers refer to any mink control action, in 28 areas or localities of Europe and South America since 1992. Mink control actions in nine additional localities in United Kingdom have been only mentioned and no published results were found. Both trained hounds and floating rafts have been used as methods to detect mink presence and/or to locate their dens (Table 1). Trapping has been the most widely used technique to remove minks (in 24 of the 28 localities), although some culling efforts still concentrate on direct hunting (8 localities). In fact, trapping is often the most widely used method of small mammals control worldwide, except in countries and situations where a lack of non-target mammals allows the use of toxins (Byrom *et al.* 2016; Prakash 2018; Tobin & Fall 2004). Among those approaches where mink traps were used, live types were more often used than lethal ones (77% vs. 21%). In addition, live trapping has been the main technique used to remove mink in all successful attempts carried out on larger land masses (Table 2). Combination of both kinds of trap were included only in the Buenos Aires Plateau Project, Argentina. Few cases mentioned the bycatch of non-target species (only 6 of the 28 localities). While lethal traps are used in alien species control (Parkes & Murphy 2004; Nordström *et al.* 2003; Brown *et al.* 2015; Fasola & Roesler 2018), there are ethical reasons to avoid the use of this method (Mason & Littin 2003; Meerburg *et al.* 2008). Indeed, non-target species deaths resulting from the 1998 Danish experience must be taken into account when planning the use of lethal traps (Hammershøj 2004). On the contrary, the use of live traps is a publicly accepted successful technique (Moore *et al.* 2003). These devices also possess fewer undesired ecological long-term effects or "collateral damage" compared with other invasive species control techniques, such as poisoning, immunocontraception or biological control (Bomford & O'Brien, 1992; Capdevila *et al.* 2006). Live trapping has the nuisance of bycatch of non-target species, but they can be released with no harm. In addition, live traps demand daily examination and humane disposal of trapped individuals, factors that have been considered handicaps (Fasola & Roesler 2016) but ensure humaneness (Iossa *et al.* 2007). Hunting with firearms has been demonstrated to be ineffective as a culling technique for minks (Zalewski *et al.* 2016).

Efficiency assessment

Only 11 small- and large-scale mink management projects could be classified as successful based on their outcomes. Other than programs on Baltic Sea Islands started in the 1990s, most of the effective programs have been carried out during the current century (Table 2). Total eradication goals have been pursued mostly on islands, where functional eradication appears to be more feasible than in continental areas. Information data on trapping campaigns carried out in 40 sites, in six countries (published in 17 journals) was used in the GLM analysis. Only the food bait used, and the distance covered during a trapping period showed any significative influence on the dependent variable Capture Efficiency (X^2 = 3-141; $p < 0.05$) and there is no evidence of any significant difference in efficiency among the seasons of the year amongst the few studies that trapped year round (Table 3). The use of an olfactory lure did not show a statistically significant effect on efficiency in our analysis, but it is fair to mention that this attractant was used on very few occasions (six percent of trapping attempts) and in five of those attempts, they were used in conjunction with the food bait. Plotting capture-rates related to average trapping period and the effort (traps-nights) involved indicates better removal results during short trapping periods (Fig. 1). Indeed, the best efficiency values have been obtained when trapping was conducted in an area for a week or two. Watershed removals carried out in Chile, England and Scotland exhibited the best efficiency results (Fig. 2). Furthermore, efficiency among approaches in different countries exhibit highly significant differences ($KW\text{-}H_{5\text{-}114}$=43.2; $p < 0.001$).

Table 1. American mink removal attempts obtained from literature review. 0/1 values refer to nonuse or use of each technique, respectively. Empty cells mean there is no information available in the consulted literature. Nontarget species data is mentioned as number of individuals: number of different species. / Proyectos de eliminación del visón americano obtenidos en la búsqueda bibliográfica. Los valores 0/1 se refieren al no uso o uso de cada técnica respectivamente. Las celdas vacías implican que no hay información disponible en la literatura consultada. Los datos de las especies no objetivo se dan en número de individuos: número de especies.

Programmes, Country	Years	Technique				Type of Traps		Type of Bait		Non-target Species Report	References
		Hunting	Hounds	Traps	Rafts			Scent Gland	Food		
Finnish Islands, Finland	1992-1998	1	1	0	0	0	0	0	0		Nordström & Korpimäki 2004; Fey *et al.* 2009
Finnish Archipelago, Baltic Sea	1992-2001	1	1	1	0	0	1	1	1		Nordström & Korpimäki 2004
Thy, Denmark	2004	1	0	1	0	0	1	0	0	106ind:4spp	Hammershøj 2004
Norway	2012	1	0	0	0	0	0	0	0		Stien & Hausner 2018
Thingvallavatn, Iceland	1958-1986	1	0	1	0	0	0	0	0		Hersteinsson 1992
Iceland	2007-2009	1	1	1	0	1	0	0	0		Stefansson *et al.* 2016
Gorodok, Belarus	1992-1993	1	0	1	0	0	0	0	0		MacDonald & Harrington 2003
Lovat, Belarus	1992-2002	1	0	0	0	0	0	0	0		Sidorovich 2011
Mazurian Lakeland, Poland	1995-2000	0	0	1	0	1	0	0	1		BrzezińSki *et al.* 2010
Sinkhote Alin, Russia	2003-2018	1	0	0	0	0	0	0	0		Oleynikov 2019
Ceskomoravská, Czech Republic	2005	0	0	1	0	1	0	0	1		Padyšákov *et al.* 2009
Hebridean Mink Project, Scotland	2001-2013	0	1	1	0	1	0	1	1		Moore *et al.* 2003; Roy *et al.* 2006; Bodey *et al.* 2010; Roy 2011; Lambin *et al.* 2014; Roy & Robertson 2017
Cairngorms National Park, Scottish Mink Initiative, Scotland	2006-present	0	0	1	1	1	0	0	0		Bryce *et al.* 2011; Melero *et al.* 2018
Wester Islands, Scotland	1997-2006	0	0	1	0	1	0	0	0		Craik 2008
Mull Isle, Scotland	2004	0	0	1	0	1	0	0	0		Roy & Robertson 2017
Itchen, England	2003	0	0	1	1	1	0	0	0	11ind:5spp	Porteus *et al.* 2012
Thames Catchment, England	2004-2005	0	0	1	1	1	0	0	0		Harrington *et al.* 2009
Monnow River, England	2006-2010	0	0	1	1	1	0	0	1	32ind:7spp	Reynolds *et al.* 2013
Hiiumaa Island, Estonia	1998-2000	0	0	1	0	1	1	1	1		MacDonald & Harrington 2003
Alava-Burgos-Catalonia, Spain	1998-2011	0	0	1	0	1	0	0	0		Mañas *et al.* 2016
Catalonia, Spain	2002-2006	0	0	1	0	1	0	0	0		Melero *et al.* 2010
Galicia Islands, Spain	2009-2014	0	0	1	0	1	0	0	0		Velando *et al.* 2017

Continuación Table 1.

Programmes, Country	Years	Technique				Type of Traps		Type of Bait		Non-target Species Report	References
		Hunting	Hounds	Traps	Rafts			Scent Gland	Food		
Butron River, Spain	2007	0	0	1	0	1	0	0	1		Zabala *et al.* 2010; Zuberogoitia *et al.* 2010
Buenos Aires Plateau, Argentina	2013-2015	0	0	1	1	1	1	1	1	3ind:1sp	Fasola & Roesler 2016, 2018
Navarino Island, Cape Horn, Chile	2007-2008	0	0	1	0	0	1	0	1	25ind:6spp	Davis *et al.* 2012
Magdalena Fiord-Cisnes River-Maullin-Todos los Santos, Chile	2009-2013	0	0	1	0	1	0	0	1		Medina-Vogel *et al.* 2015
Toltén-Valdivia-Bueno-Maullín, Chile	2018-2020	0	0	1	0	1	0	1	1	47ind:5spp	Medina-Vogel *et al.* 2022
Chiloé, Chile	2013-present	0	0	1	0	1	0	1	1		CECPAN 2020

Table 2. Mink management projects: their scope, outcomes and sustainability in time. ER: Eradication. FE: Functional Eradication. / Proyectos de manejo de visones en base a sus resultados y sostenibilidad en el tiempo. ER: Erradicación. CR: Remoción Completa. CO: Control.

Project	Country	Scale	Period	Covered Area (Km^2)	Captured Mink	Technique	Aim	Success Indicator	References
Hebridean Mink Project Phase I: Uist	Scotland	Islands	2001-2006	1 009	532	Live Traps Trained Hounds	ER	No further mink records since 2006. Bird successful nesting increased.	Moore *et al.* 2003 Roy 2011 gbif.org
Hebridean Mink Project Phase II: Harrys and Lewis	Scotland	Islands	2007-2013	2 611	1 514	Live Traps	ER	Mink population decline 80 % in 2014.	Lambin *et al.* 2014 gbif.org
Finnish Archipelago	Finland	Islands	1992-2001	197	148	Lethal Traps Trained Hounds	ER	No further mink records. Increased breeding densities of bird species.	Nordström *et al.* 2003 gbif.org
Hiiumaa Island	Estonia	Islands	1998-2000	1000	50	Lethal Traps Leg-hold traps	ER	Successful reintroduction of European mink	MacDonald & Harrington 2003

Continuación Table 2.

Project	Country	Scale	Period	Covered Area (Km^2)	Captured Mink	Technique	Aim	Success Indicator	References
Cairngorm Water Vole Conservation Project	Scotland	Mainland	2006-2009	10 570	376	Live traps Rafts	FE	Sustainable mink population decline. Mink Detection Rate reduced ten times.	Bryce *et al.* 2011
North West Highlands Mink Control Project	Scotland	Mainland	2009-2011	29 500	1 224	Live traps Rafts	FE		Oliver 2015
Scottish Mink Initiative	Scotland	Mainland	2011-			Live traps Rafts	FE		Oliver 2015 Robertson *et al.* 2017
River Monnow Project	England	Mainland	2006-2010	420	115	Live traps Rafts	FE	Persistence of reintroduced water vole populations	Reynolds *et al.* 2013
Atlantic Islands of Galicia	Spain	Islands	2009-2014	6.2	90	Live traps	ER	No further mink records.	Velando *et al.* 2017
Buenos Aires Lake Plateau	Argentina	Mainland	2013 -2015	3 000	67	Live traps Lethal Traps Firearms	FE	No further mink predation records on Hooded Grebe colonies	Fasola & Roesler 2016

Table 3. General Lineal Model statistical analysis of the collected data from 126 trapping areas in six countries. Efficiency (number of minks captured per trap night) is the Response variable. (*) Denotes statistical significance (≤ 0.05) compared with null model. / Estadígrafos del Modelo Lineal Generalizado de los datos recopilados de 126 áreas de trampeo en seis países. La eficiencia (número de visones capturados por noche de trampa) es la variable respuesta. (*) Denota significación estadística (≤ 0,05) en comparación con el modelo nulo.

Independent Variables	Variable Type	N	Chi-square Likelihood ratio	Significance p
(Intersection)			35.671[a]	< 0.001*
Bait_Fish	Binomial	65	4.008	0.045*
Bait_Scent_Gland	Binomial	17	3.388	0.066
Distance_between_traps (meters)	Discrete	126	11.614	0.169
Distance_Covered (kilometers)	Discrete	101	141.943	< 0.001*
Season	Categorical	81	2.827	0.419
Trapping_Period (days)	Discrete	126	17.643	0.090
Trap_night	Continuous	126	3.160	0.075

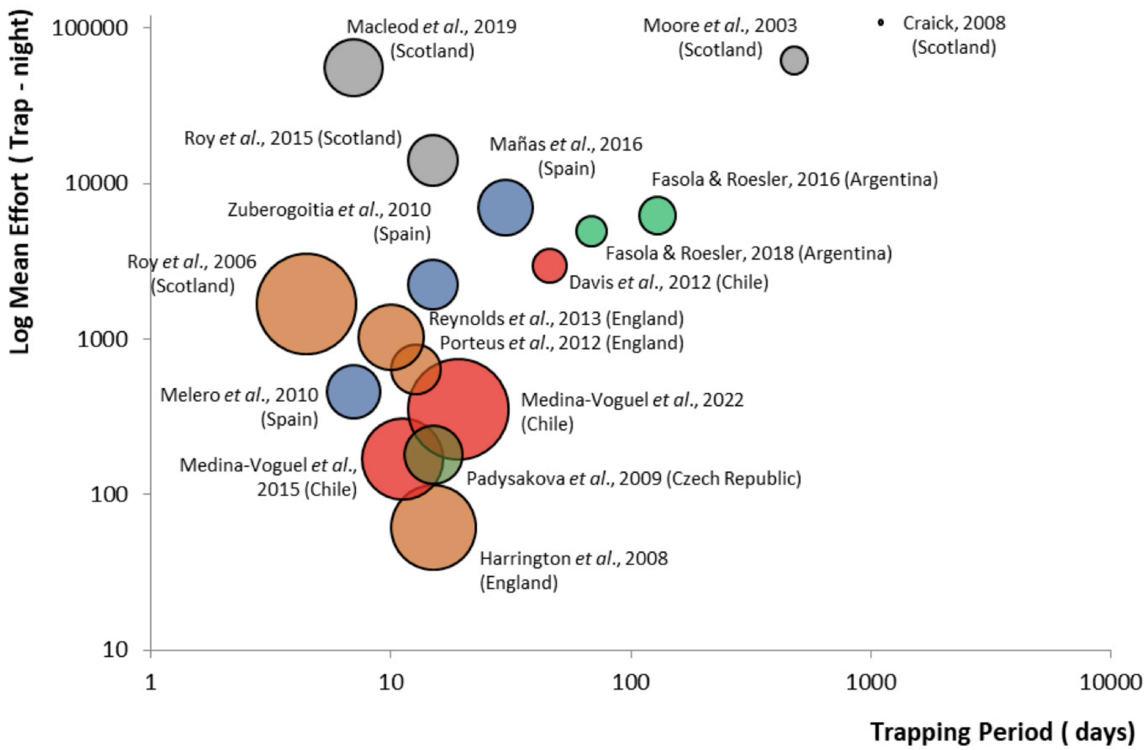

Figure 1. Effort – Trapping period – Capture Rates relationship of trapping approaches carried out in six countries of Europe and South America. Effort is given in Trap-Night unit. Size of the dots is proportional to the number of minks per unit of effort. Each plot is labeled with the reference article. / Relación entre Esfuerzo - Período de trampeo y Tasa de Captura de los proyectos de trampeo realizados en seis países de Europa y América del Sur. La unidad de esfuerzo es Trampas-Noche. El tamaño de los puntos es proporcional a la eficiencia (número de visones por unidad de esfuerzo). Cada círculo está etiquetado con el artículo de referencia.

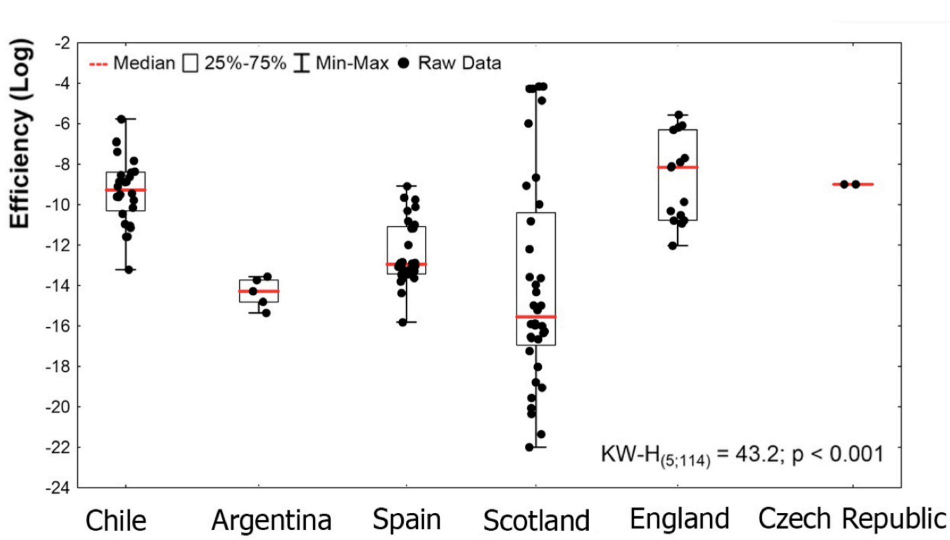

Figure 2. Mink captures Efficiency comparison among six European and South American countries that reported the application of trapping techniques. Efficiency is given in number of minks captured by unit of effort (Trap-Night). / Comparación de las eficiencias en la captura de visones entre seis países de Europa y Sudamérica que han aplicado la técnica de trampeo. La Eficiencia se expresa en número de visones capturados por unidad de esfuerzo (Trampas-Noche).

Baits and olfactory lures

Trap efficiency will depend on the selection of lures and trapping techniques (Medina-Vogel *et al.* 2022). Food, mainly canned or fresh fish or chicken, has been the most common bait employed during mink trapping campaigns (Bryce *et al.* 2011; CECPAN 2014; Davis *et al.* 2012), although traps have been operated without any lures, especially in the United Kingdom (Craik 2008). Although the use of an olfactory lure did not show a statistically significant effect on efficiency in our analysis, there is a general consensus that pheromones are the best attractants since mustelids are olfactory animals. It has been proved that baits based on pheromones extracted from minks subcaudal scent glands can increase trapping efficiency from two to four and a half fold (Roy *et al.* 2006; Roy 2011; Roy & Robertson 2017). Anal gland and body odour lures have proved to be at least as effective as food-based lures at attracting ferrets (*Mustela furo*) and stoats (*M. erminea*) to traps and monitoring stations (Clapperton *et al.* 1989, 1999; Murphy *et al.* 2022). Even the scent of previously captured minks is considered to improve capture probability (Nordström *et al.* 2003). There is evidence of additional advantages of using scents: capture rates of non-targets are reduced so a greater proportion of traps remain available for mink capture (Medina-Vogel *et al.* 2022). In addition, a little quantity of scent is required, which makes transport easier. Besides, these glands can be surgically removed during the same campaign which decrease costs associated. Moreover, scent viability remains effective for many days whereas food baits typically decompose (Roy *et al.* 2009) and new formulations may enhance attractiveness (Murphy *et al.* 2019, 2022) and extend scent lure longevity. Finally, Roy *et al.* (2006) suggested that olfactory attractants are more effective in the later stages of the campaigns, counteracting the lowered capture rates and possible reductions in trappability typical of low-density culled populations.

Genetic techniques

Molecular genetic techniques have proved to be valuable for defining genetic structure of invader populations and migration rates (Mora *et al.* 2018; Velando *et al.* 2017). Genetic tools have allowed eradication units to be defined, allowing control efforts to be targeted effectively (Robertson & Gemmell 2004). For instance, mountains in northeast Scotland restrain gene flow between south-western and north-eastern mink populations. Resulted genetic structure would allow management efforts to be carried out independently (Zalewski *et al.* 2009). In addition, the genetic approach enables the identification of sink areas, therefore we are able to assess the probability of recolonization (Dlugosch & Parker 2008). Fraser *et al.* (2013) proposed a management plan based on genetic clusters for mink control in Scotland. This plan pointed out which populations need to be eradicated first and the direction of the mink control progression in order to minimize the probability of recolonization and to avoid gene flow between the east-west stocks. Bifolchi *et al.* (2010) investigated the mink population structure in France and found three genetically distinct units at the regional scale. Those clusters were congruent with the establishment and spread of American mink in that country. Authors suggested a recent admixture among populations, which increases the genetic diversity of the species and could lead to an increase of adaptive potential (Kolbe *et al.* 2004). Culling efforts should thus focus on the inferred contact areas aiming to disrupt gene flow. Other ecological studies on invasive minks have linked DNA information to support some of their hypotheses about the origin of feral populations (Hammershøj 2004; Zalewski *et al.* 2011; Velando *et al.* 2017). In southern Chile, three different mink lineages have been identified (Mora *et al.* 2018). In addition to genetic structure, molecular approaches also bring important information about effective population size and immigration rates of invaders (Schwartz *et al.* 2007). Zalewski *et al.* (2009) proved that continuous culling reduces genetic variability and increases genetic structuring of invading mink on Swedish islands. Velando *et al.* (2017) demonstrated that the mink population on Galician Atlantic islands might be considered almost isolated and only two individuals were candidates as immigrants during ten years of campaign. On the contrary, in mainland populations variability remained due to the continuous entrance of new individuals from neighboring zones. Thus, genetic monitoring provides useful information to evaluate and improve control programs of invasive vertebrates.

Seasonal effects

In the current analysis, season seems to have no effect on efficiency. This is likely an artefact as most studies were concentrated in only certain seasons. Moreover, 36% of the removal areas reported in the literature could not be included in the seasonal analysis because of the lack of accessible information. A seasonal effect can be observed in those cases where annual effort was kept constant during the whole year (Harrington *et al.* 2009; Moore *et al.* 2003). Seasonal effects on capture results might be the consequence of changes in weather, food availability and social behavior (Gehrt & Fritzell 1996; Craik 2008). While animals may be attracted more to baits in winter when there is less food available (Zabala *et al.* 2001), climatic conditions may make trapping at that time of year impractical. Most authors found higher captures during the mating and juvenile dispersal seasons, so they mostly concentrate efforts during those months (Fasola & Roesler

2016; Roy *et al.* 2015). It is also in those periods when the probability of capturing females is higher. Craik (2008) caught more females during a short period in late summer, when they are free from young kits. Roy *et al.* (2015) found that the female:male ratio of captures in South Harris and the Uists was highest in spring and/or summer. Medina-Vogel *et al.* (2015) showed similar results capturing females. It is important that removal efforts target females because the abundance of females has a larger impact on population growth than that of males (Oliver 2015). For the same purpose, the spatial ecology of the species is relevant when capturing females. In watersheds in northern Spain, females tended to use smaller streams, while males controlled major river areas (Zabala *et al.* 2007). We thus support the previous recommendations that advocate limited trapping periods of mink control, focused on seasons and areas of highest trappability (Medina-Vogel *et al.* 2015; Roy *et al.* 2015; Harrington *et al.* 2009). Care must be taken, however, to ensure that the timing of trapping of resident individual minks does not just provide enhanced survival and breeding success of younger members of the population and immigrants (Bodey *et al.* 2011).

Control efficacy

Many of the studies in the review reported measures of control success — either in terms of percentage of the mink population removed or the responses of species at risk from predation or competition by minks. On islands, permanent removal seems a reasonable objective and some examples have been successfully carried out (Moore *et al.* 2003; Nordström *et al.* 2002). Robertson *et al.* (2017) mentioned the most important factors influencing effectiveness of mink control on islands are: superficial area, remoteness, season and previous experience. The Hebridean Mink Project (HMP) could be considered a reference point for successful management on islands. Started in 2001, after a previous study of feasibility (Moore *et al.* 2000), this project aimed to protect ground nesting birds through the removal of feral mink on the Western Islands of Scotland (Moore *et al.* 2003). Roy (2011) concluded that detection of sprung traps is improved using solid metal doors; accessible trapping sites near roads save time and efforts; rotation of expert trappers around different areas improves quality of settings; seasonal patterns of behaviors influence mink vulnerability to traps; and the use of scent gland as lure increased trap efficiency by 50% compared with fish-baited traps. It is important to highlight other contributions of the HMP such as: the use of hounds to detect mink, especially during denning periods when minks are less mobile; and the continuity of trapping efforts even when no further animals were caught. The HMP second phase (2006-2013) doubled the covered area in the Hebridean islands (Lambin *et al.* 2014). The effect of mink removal on bird communities in Hebrides has not been described yet, although Moore *et al.* (2003) provide a baseline for monitoring them. Following a similar approach, American minks were removed from certain islands in the Baltic Sea, Southern Finland, between 1992 and 2001 (Nordström *et al.* 2003). While it might be classified as a small-scale project (covered area 72 to 125 km^2), it had been considered successful as well. The increased density of breeding birds on some islands of the archipelago was an indicator of the positive effect of mink removal. The peculiar method applied to force minks to abandon their refuges is noteworthy. Once a trained hound detected dens, minks were flushed out using an air-blasting leaf-blower device and killed with a shotgun. Lethal traps were also used, especially during winters. Estonian Hiiumaa Islands, located in the Baltic Sea as well, should be included in the list of successful eradication of invasive mink. Leg-hold traps proved more effective than lethal ones (Conibear type) in this program. Success is undeniable, more than 160 captive-bred European minks *Mustela lutreola* were released onto the islands (MacDonald & Harrington 2003), with an estimated 65 individuals present in 2016 (Maran *et al.* 2018)

Current alien mink populations in Spain are patchily distributed in the northern half of the country (Bravo 2007), included some islands in Galicia (Velando *et al.* 2017). Since 1999, Spanish experiences have been aimed at controlling the American mink and to protect the European mink at the same time. This represents a challenge because the species are sympatric in some areas. Although the eradication attempt carried out in Catalonia between 2002 and 2006 was not achieved, it contributed a lesson: sustained culling efforts reduce both population abundance and juvenile spread to new areas (Melero *et al.* 2010). Eradication was successfully achieved on the Spanish islands (Velando *et al.* 2017) albeit the scales were much smaller (6.2 km^2).

Unlike on islands, complete mink eradication from larger land masses is still often considered an unrealistic goal (Zabala *et al.* 2010). Most managers prefer to keep the status quo rather than pursue a permanent solution (King *et al.* 2009). This is despite examples like the success in eradicating Norway rats *Rattus norvegicus* from Alberta, Canada, demonstrating that the goal is feasible (Simberloff *et al.* 2003). Reynolds *et al.* (2004) listed many simultaneous conservation actions carried out in different Natural Reserves of mainland United Kingdom that contemplated or included mink control programs. Although scale should not be considered a barrier (Martin *et al.* 2019), larger areas introduce new challenges like the continuous risk of reconquest of the cleared area and the high expenses of control. The uncertainty in the knowledge of the real and changing spread of the invasive population also mitigates against the goals of the programs. Zabala *et al.* (2010) demonstrated that after eradication from small continental areas, the removed population could be considered as closed to immigration in the short term. Approaches on continents must therefore consider controlling neighboring buffer zones or ongoing surveillance and intermittent control to prevent the establishment of new populations (Robertson *et al.* 2017).

The Cairngorm Water Vole Conservation (CWVC) Project has been the largest mainland invasive mink removal attempt worldwide (Reynolds *et al.* 2013). This successful program was carried out in Cairngorms National Park, East Scotland to promote water vole (*Arvicola amphibius*) conservation (Bryce *et al.* 2011). These authors mentioned that the project relied heavily upon three key aspects: (1) the formal partnership between national and local organizations with an interest in mink control; (2) the participation of volunteers from local communities without any financial reward; and (3) use of an adaptive management approach with information gained in the early stages, to optimize the project's conservation benefit, sustainability and cost-effectiveness. It should be noted that the CWVC project was initiated with only partial knowledge of upland mink populations. The Scottish Mink Initiative, started in 2009 as the continuity of the Cairngorms project, extended the covered area to 29 000 km^2. One of the aims of this initiative was to keep the area free of established adult female mink during spring (Oliver 2015). The CWVC Project worked on the hypothesis that increasing contiguous coverage in a downstream direction should be more effective for mink removal. So, the recolonization rate from source lowland populations of mink is suppressed. The influence of lineal covered area found in the current analysis supports the idea of the removal to watershed level and seems to influence in on efficiency as well. Similarly, a short-term methodology was applied by Zuberogoitia *et al.* (2010) along 174 km^2 of the Butron River System in Spain. The total basin area was partitioned into sections and trapping efforts were conducted in turns. The idea was to concentrate culling efforts in each section, starting in the upper section of the waterway and developing in subsequent sections downstream. During the final stage, cage-traps were spread over the whole catchment area to capture elusive minks. To evaluate the success of the program once the trapping period finished, searching for mink traces and camera traps continued to operate for another month (Zabala *et al.* 2010). The same authors mentioned that the removal programs carried out following juvenile dispersal diminish immigration risk and reduce trapping time, and hence management costs. At the same time the CWVC has been running, two parallel mink control schemes were carried out in Monnow River and Upper Thames, western and southern mainland Britain (Harrington *et al.* 2009; Reynolds *et al.* 2013). The applied methodology in the Monnow Catchment case included the use of track-recording rafts to monitor continuously for invader presence. Raft use continued even after mink populations declined. Live traps were only set when mink presence was confirmed. Thus, trapping effort was reduced and a fast response guarantied (Reynolds *et al.* 2013). The same combination of seasonal reactive trapping and good monitoring technique were followed in a larger area of the Thames Catchment (Harrington *et al.* 2009). In this case, monitoring for immigrating individuals once the population was lowered was critical. Traps have been set on shore or on rafts (Bryce *et al.* 2011) depending on the area of management and the staff´s experience. These rafts were designed to act both as a monitoring device and as a trapping site for American mink. They have the inconvenience of duplicating costs of conventional systems, which makes management in large areas very expensive but this cost may be offset by decreased manpower requirements (Reynolds *et al.* 2004). However, the use of these devices is limited on inland rivers, particularly in rocky spates or where the water level is highly variable (Harrington *et al.* 2009). The same authors reported that rafts failed to detect mink at low population levels. New technologies like self-reporting or self-resetting cages have been added to traditional trapping for other species, but their application to a large-scale eradication project seems to be unlikely due to the high associated costs (Jones *et al.* 2015; Medina-Vogel *et al.* 2015). Nevertheless, animal welfare was the motive behind these technologies, and still needs to be taken into account. The idea is to minimize the period animals are held in traps through a rapid response, thus reducing risk of stress, hypo- or hyperthermia, dehydration and injuries (Larkin *et al.* 2003).

Previous mink control experiences have shown that management can be achieved at several spatial scales and using different approaches (Fasola & Valenzuela 2014; Roy & Robertson 2017; Zuberogoitia *et al.* 2010). Some of those attempts might be classified as successful, but some others fail. Adams *et al.* (2014) mentioned two main causes of control failure: lack of research about spatial ecology and population genetics of the target species. Reinvasion of controlled areas by target species is one of the main causes of some project failures (Adams *et al.* 2014). Based on Hein & Jacob (2015), the recovery of previously depleted populations might result in two possible ways: survival and multiplication of a small remaining fraction of the population and/or immigration from nearest buffer zones. The population recovery mechanism and time will depend on the species itself. Based on that assumption, control efforts focus, on one hand, on the detection and removal of small numbers of survivals and, on the other hand, the control of the target species in the neighboring areas. Once the target population has been diminished, individuals are not detected. This might be due to the true absence of the species or the inability to detect it (Medina-Vogel *et al.* 2015). Russell *et al.* (2005) and Zuberogoitia *et al.* (2006) demonstrated for *Rattus norvegicus* and American mink, respectively, how the traditional methods of capture and detection fail when a small number remains. This situation causes an increment in the effort needed to remove those few remaining minks as well as the use of alternatives like sniffers dogs, camera traps or searching for DNA traces (Martin & Lea 2020; Moore *et al.* 2003; Zuberogoitia *et al.* 2010). As discussed before, immigration is the second mechanism involved in the recovery of a previously depleted population. It will depend on the dispersal behavior of the species (Hein & Jacob 2015) so it is important to know its life history strategies. In addition, recognition of the population boundaries in terms of connectivity helps to prevent reentry of new individuals (Adams *et al.* 2014). In this sense, the adoption of an "eradication unit" concept (Robertson & Gemmell 2004) maximizes the efficiency of control. The understanding of the genetic structure of target population reduces reconquest risk during management (Velando *et al.* 2017). Thomson *et al.* (2000) demonstrated short-term effectiveness in eradication of foxes (*Vulpes vulpes*) in a large area by controlling buffer zones as well. Thus, it is appropriate to extend control to adjacent areas and to conduct ongoing surveillance of mink-free zones, in this way reducing the risk of introduction of new individuals. To create virtual barriers all around the cleared space by setting control devices at a high density could be an additional measure to guarantee eradication success in time (Bell *et al.* 2019).

Despite its achievements, The Cairngorm Water Vole Conservation Project (2006-2009) and its successor the Scottish Mink Initiative showed a weakness, the temporal and spatial variation in project funding. The interims of low funding resulted in diminished culling efforts. The subsequent increase in fecundity as a compensatory effect in the remaining mink population limited the project's success (Melero *et al.* 2015). Mink eradication campaigns in the 1960s in UK failed because of the same reasons: the lack of sufficient effort and the rapid spread of this species, including escapees from mink farms, the latter a continued risk (Robertson *et al.* 2017). The "Special Mink Trapping Operations" started in 1964 was not completely accepted from the very beginning, even though the species was considered a dangerous pest in England. The failure of this program was not admitted, but it is known that more than 5000 minks were removed from 180 thousand km^2 during a quinquennium (Sheail 2004).

Argentinian and Chilean experience

There have been no coordinated plans or management efforts between Argentina and Chile for the control of the American mink invasion in Patagonia (Valenzuela *et al.* 2016). Nevertheless, a few localized small-scale attempts have been carried out (Cerda 2008; Davis *et al.* 2012; Valenzuela *et al.* 2016) — they have been patchy and unsynchronized. Buenos Aires Lake Plateau is considered the first program to control American mink in Argentina and Patagonia (Chile and Argentina). Started in 2013, it was implemented with a tangible conservation purpose: conservation of the critically endangered Hooded Grebe (*Podiceps gallardoi*) (Fasola & Roesler 2016). Rather than using a single methodology, this control program relied on a combination of lethal traps, spotlights and firearms to address local peculiarities. Lethal traps, set on rivers and streams on areas where daily access was not possible, were responsible for 94.3% of captures. Floating raft devices were used to avoid bycatch. Additional to food bait, scent from female mink anal glands was used as attractant. An important factor in this program was the reliance on knowledge of the species' life history. As mink are found at low elevations throughout the year but are not present in the highlands until the late summer when the young males disperse (Fasola & Roesler 2018), mink removal occurred first in upper parts and later in the lower areas, in order to keep dispersing juveniles near the source. Success of this project is based on the absence of grebe predation events.

Despite the presence of mink on South American islands reported since 2001 (Crego *et al.* 2018; Rozzi & Sherriffs 2003), no proper invader expansion control strategies have been carried out for ten years. In 2013, mink spread reached Chiloé Archipelago in the Los Lagos Region (Vergara & Valenzuela 2014). This led to the implementation of the "Action plan for monitoring and early eradication of the American mink on the island of Chiloé" (CECPAN 2014). This control effort, although needing to be improved, has been maintained to date, covering 9.1 km^2 of the major island of Chiloé Archipelago (CECPAN 2020). Since 2009, continued culling efforts have been made in continental areas of southern Chile (Medina-Vogel *et al.* 2015, 2022). The main goal of those campaigns has been to improve trapping efficiency through the designing of new techniques and selection of strategies that fit better to the Patagonian scenario. Indeed, the efficiency values of these trials are among the highest and consequently, those improvements might be applied in future large-scale management programs on the continent. The conclusions of Medina-Vogel *et al.* (2022) agree with previous studies on trap spacing effect in mustelids (King 1980; Melero *et al.* 2008) that showed the best capture rates, especially the concurrent capture of females and males were with traps set at 200-meter intervals Some other remarkable conclusions have been short trapping periods in each site; and the design of a smaller, cheaper and species-specific trap variant GMV-13. These studies also confirm that the use of scent gland lures increases mustelid trap efficiency (Clapperton *et al.* 2017; Roy *et al.* 2006) and agree with Zuberogoitia *et al.* (2010) that trapping efforts should be focused in certain seasons of the year (Medina-Vogel *et al.* 2022).

Expenses

While trapping efficiency in terms of capture per unit effort may be improved over small areas by the techniques described here, ensuring that a control or eradication program is cost-effective will require a clear understanding of the costs of the operation. Management of alien invasive species is a costly process and requires large short-term investments (Pimentel *et al.* 2005; Zabala *et al.* 2010). Pascal *et al.* (2008) considered the eradication of a predator as the most cost-effective management option. There are a few examples of how expensive it can be. American mink removal in Outer Hebrides totaled 1.65 million pounds sterling in a period of 5 years (Moore *et al.* 2003). In Spain, the control of the species was estimated at 175 thousand euros during only three months of the campaign (Zuberogoitia *et al.* 2010). Eradication of mink from 1000 km^2 Estonian Hiiumaa Island cost between 47 to 66 thousand pounds sterling (Genovesi 2000). Based on Robertson *et al.* (2017), the most important factors influencing expenses of mink control are the same that modulate effectiveness: superficial area, isolation, season of the year and previous trapper experience. Authors found an inverse relationship between the cost of removal per unit area and the land area to manage; relative cost decreases 10% when controlled zone is doubled. The selection of proper control techniques should also be included in the list of items that influence costs (Medina-Vogel *et al.* 2015). Zabala's *et al.* (2010) model considered that the number of traps operated per trapper was the most influential variable on the final costs of one project. Based on these authors, a qualified trapper payment is the biggest expense (70 euros per day of service) and it should be able to manage 40 traps each day in an optimistic scenario. Some practical issues reduce the number of traps that one person can operate, like area complexity and the presence of sympatric species susceptible to being trapped. This reduction leads to a local increase in eradication costs beyond estimates. There are several ways to reduce the costs associated with alien species control. To develop new baits (Roy *et al.* 2006), to consider basic information about mink ecology when planning (Medina-Vogel *et al.* 2015), recruitment of volunteers (Bryce *et al.* 2011) or the use of trained dogs to detect mink dens (Moore *et al.* 2003) can enhance trapping efficiency, reducing overall management expenses as well. This has important implications when planning large programs (Robertson *et al.* 2017) because lack of funding has been the main reason of some campaign failures (Melero *et al.* 2015).

DISCUSSION

Complete mustelid eradication remains particularly challenging because of their elusiveness, neophobia to objects such as traps and high mobility (Craik 2008; King *et al.* 2009). So, the challenge is to identify the best strategic use of traps and optimal solutions will depend on the spatial, ecological, social and financial context (Parkes & Murphy 2004; Gormely & Warburton 2020). Our analysis of the available literature identified a range of factors that contributed to the efficacy of various mink control projects around the world. It also allowed us to identify areas of research needed on mink ecology and behavior and trapping techniques that could improve trapping efficacy in larger land masses and islands in Patagonia.

Despite the wide range of distribution of the American mink and the negative consequences that the presence of this species implies, there is still little scientific information about the control and management of this invader. We are aware that much of the information remains in the gray literature, so basing the analysis exclusively on articles published in journals is biased in principle. This is one of the reasons statistical analyses should not be considered defining and the influence of variables like season, trapping period and lures on efficacy needs to be re-evaluated. Another of the limitations of the current analysis is basing the effectiveness solely on the number of minks caught per unit of effort, since as mentioned before, there are other indicators. However, if properly interpreted, it could be considered a valid estimator of efficiency, but not of the success of a program.

Research needs for the Patagonian scenario

Despite the progress achieved in Chile in the development of new and more efficient trapping techniques (Medina-Vogel *et al.* 2015, 2022), the role of minks as reservoirs of diseases and their transmission to other species (Barros *et al.* 2014; Sepúlveda *et al.* 2014; Barros *et al.* 2018; Barros *et al.* 2022), the analysis of the impact of this invasive mustelid on some native fauna and the economy (Leone *et al.* 2014; Cerda *et al.* 2017) and genetic structure of the species (Mora *et al.* 2018); several topics remain unknown. To comprehend spatial ecology of American mink in Patagonia is a pending topic. Further studies about home ranges, habitat use and juvenile dispersal mechanisms are needed in order to understand species distribution and to improve removal strategies. Furthermore, it is well known juvenile dispersal during summer seasons in the northern hemisphere (Fasola *et al.* 2021; Hein & Jacob 2015) but, how fast it might occur in Patagonia remains unknown. Medina-Vogel *et al.* (2015) reported an increment in the mink population during the third year of campaigns. The speed of this re-occupancy, and the continuity and efficiency of the removal efforts will determine whether our control goals will be achieved or not. In addition, to decrease trap evasion by minks, our knowledge of some other topics needs be improved, like mink responses to traps, their elusiveness and the influence of prior experience. The use of camera traps will help us to understand this issue, and should lead to enhanced trapping efficiency (King *et al.* 2009; Zuberogoitia *et al.* 2010).

Efficiency should be taken into account when planning removal programs. Thus, the goals might be geared towards increasing the number of minks trapped in time or to diminish trapping effort involved during control. Many factors that increase efficiency have been highlighted in this review like the use of attractants, mainly olfactory ones, short trapping periods or increasing lineal coverage. In addition, there are some others that have been proposed previously like the new traps variant design and to concentrate culling only during certain seasons (Medina-Vogel *et al.* 2022), the use of spatial and genetic knowledge about local mink populations (Adams *et al.* 2014; Fraser *et al.* 2013) or to employ sniffers dogs and techniques to flush out (as mentioned on page 44) resident mink in some stages or areas (Moore *et al.* 2003). The selection of the most efficient techniques and protocols not only helps to achieve management proposals efficiently, but also reduces the associated costs, making control sustainable. And as discussed above, reducing the recolonization rate and providing long-term financial support are recognized as two of the most importance main cause for eradication succeeds.

The ultimate end for the mink removal campaigns is the conservation of native biodiversity. García-Díaz *et al.* (2021) capsulated this idea, stating that management should be "addressing the impact rather than the species". Thus, to assess effectiveness of any control programs, some ecological indicator of recovery of Patagonian biodiversity needs to be evaluated. Native threatened species populations are good candidates to consider. For instance, water vole *Arvicola amphibius* population recovery has been the main one in mainland Britain projects (Reynolds *et al.* 2013). Projects in Spanish Catalonia and Estonian Hiiumaa Islands have evaluated the recovery of native European mink *Mustela lutreola* (MacDonald & Harrington 2003; Maran *et al.* 2018; Melero *et al.* 2010). Increases in ground nesting bird colonies has been the focus of some projects that were carried out in Western Islands of Scotland (Moore *et al.* 2003), Finnish Islands (Nordström *et al.* 2003) and Argentinian Patagonia (Fasola & Roesler 2016). In Chile, some experiences have involved the protection of another sympatric mustelid, the River Otter *Lontra provocax*. Commonly known as "huillín", this species of mustelid is native to South America. Their populations have been decimated by the destruction of their natural habitats and uncontrolled hunting and trade (Medina 1996). Its critical situation is exacerbated by the introduction of invasive species in Patagonia such as trout, minks and feral cats and dogs (Calvo-Mac *et al.* 2020; Chehébar 1985). Otter population recovery could be considered a proper gauge of success, along with trends in species of ground nesting aquatic birds.

Finally we need to understand the motivations of Patagonian people as well as their opinions on pest removal programs (Ballari *et al.* 2016). That is what Pearson *et al.* (2019) named the "feasibility phase". It is important to explain to local residents their role in the projects as well as the benefits they might obtain. In this sense, surveys, talks and training workshops need to be carried out with the aim to engage with and to educate people as well as to gain information about the status of mink populations in each locality. Furthermore, public support guarantees access to private properties, greater coverage, volunteers recruitment where it is needed and reduces risk of vandalism of traps (Bryce *et al.* 2011).

CONCLUSION

Although the aim of this analysis was not to give a unique recipe for how to remove minks, some of our findings might help to achieve this control efficiently. Although the initial purpose was to find strategies applicable to the Patagonian landscape, the results may well be useful in other regions of the world. We strongly recommend strategies that uses the most efficient methods based on an understanding of local mink ecology, behavior and genetics structure. The key findings of our review include: (1) to use live traps and to enhance them with baits or olfactory lures, (2) short-trapping periods (a week or two) and rapidly moving from one area to another in the same watershed and (3) removal efforts should cover as much distance as possible within the basin and its tributaries, including both the area of invasion and buffer zones. We recommend further studies on the spatial ecology and activity patterns of minks to ensure that the findings of this review, based mainly on work conducted in Europe, are applicable to Patagonia. To ensure that these efficiency provisions convert into cost-effective long-term mink control, information is required on the density, social organization, breeding cycle, genetics and activity patterns of the local mink population. What else do we need to consider? The control program should include independent ecological measures of effectiveness and should be conducted in consultation with local communities.

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