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PhD Dissertation 07/2009 I Elke Schüttler I Population ecology, impact and social acceptance of American mink ...

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Population ecology, impact and social acceptance of American mink (*Mustela vison*), a recent invasive species on Navarino Island, Cape Horn Biosphere Reserve, Chile

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Population ecology, impact and social acceptance of American mink (*Mustela vison*), a recent invasive species on Navarino Island, Cape Horn Biosphere Reserve, Chile

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Mustela vison

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Contents

Summary

The earth's biota is greatly altered by the increasing shifting of species distributions. Biological invasions and their impacts are of major conservation concern particularly in island ecosystems. Despite its geographic isolation the pristine sub-Antarctic Cape Horn Archipelago is replete with non-native species. Among these, the most recently arrived mammal is the American mink (*Mustela vison*), a North American mustelid that is currently establishing its southernmost feral population on Navarino Island within the young Cape Horn Biosphere Reserve. Here, mink represent a new guild of terrestrial mammalian predators, among which the island lacks native species. This thesis aims at broadening the basic knowledge of the population ecology and impacts of the mink on Navarino Island. It specifically addresses relative abundance and habitat use of mink, their diet, the ecological impacts on the nest survival of ground-nesting waterbirds, as well as public perceptions and acceptance of control measurements. Thus, a broad and interdisciplinary approach is attempted that offers results of practical relevance for an integrative management of invasive species in the Cape Horn region.

Sign surveys and trapping detected that mink had spread to adjacent islands (Navarino, Hoste) from its source population on Argentine Tierra del Fuego, but its presence in other parts of the biosphere reserve was not proved. Sign surveys on Navarino Island revealed that mink have colonized the entire island only one decade after it had been first registered. 79 % of surveys in 68 sites in different semi-aquatic habitats (marine coasts, river, lake and pond margins) contained scats of mink. The relative abundance of mink measured with capture-mark-recapture was estimated to be 0.75 mink/km of marine shoreline. Habitat models revealed that mink preferred shrubland over meadows and forested habitat, coastal areas with rocky outcroppings over flat beaches and interestingly, mink avoided habitats strongly modified by invasive beavers (*Castor canadensis*).

Regarding the potential ecological impact of mink, the main prey groups were defined through diet analysis. On average, these were mammals (37 % of the biomass), birds (36 %) and fish (24 %). During spring and summer, however, the consumption of birds at marine coasts was twice as much compared to the cool season when migratory birds had left the region. Adult Passeriformes, and offspring of Anseriformes and Pelecaniformes were a frequent prey. Regarding mammals, mink basically preyed upon muskrats (*Ondatra zibethicus*, invasive) and yellow nosed grass mice (*Abrothrix xanthorhinus*, native). Mink predation on ground-nesting waterbirds was evaluated for different breeding strategies, habitats and nest characteristics by monitoring nests of (i) solitary nesting birds (*Chloephaga picta, Tachyeres pteneres*, n=102 nests), (ii) colonial birds (*Larus dominicanus, Larus scoresbii, Sterna hirundinaceae*, n=361), and (iii) of 558 artificial nests. Discriminant analyses revealed that solitary nesting waterbirds breeding at rocky outcrop shores in concealed nests were most vulnerable to predation by mink.

Knowledge, attitudes, values and acceptance of control of mink and also beavers were explored through qualitative interviews (n=37) with members of different socio-cultural groups on Navarino. Using content analysis (following Mayring), the results indicated that the public had complex knowledge of mink and beavers and that people were concerned at their impacts. The attitudes and values associated with native and invasive species were species-specific, and most interviewees favored the control of invasive species, but were skeptical towards their eradication. While positions toward the controlling of beavers were ambiguous, the control of mink was widely accepted.

The results of this research are relevant for the management of invasive species in the Cape Horn Biosphere Reserve. Besides the consideration of scientific research, managers should also include public views in the process of designing and implementing control programs. This integration can

help to avoid conflicts arising from information gaps or from management plans that disregard attitudes and values. Based on the findings of the ecological research, rocky outcrop marine coasts should be used as priority sites for a more intensive control of mink, for two reasons. First, these habitats were most populated by mink, and second, these habitats harbored most vulnerable bird species to predation by mink. However, the attention paid to the mink should not overshadow vigilance against other factors contributing to the vulnerability of bird and other species in the region.

Zusammenfassung

Die zunehmende Ausbreitung von Arten verändert die globale Biodiversität tiefgreifend und nachhaltig. Besonders in Ökosystemen auf Inseln rufen biologische Invasionen und ihre Auswirkungen große Besorgnis unter Naturschützern hervor. Trotz der geographischen Isolation beherbergt das sub-antarktische Kap-Hoorn-Archipel zahlreiche nicht-heimische Arten. Das als letzte dorthin gelangte Säugetier ist der Amerikanische Mink (*Mustela vison*), eine nordamerikanische Marderart, die derzeit ihre südlichste wildlebende Population auf der Insel Navarino im vor kurzem eingerichteten Kap-Hoorn-Biosphärenreservat etabliert. Hier stellt der Mink eine neue Gilde von terrestrischen Raubsäugern dar, da die Insel keine einheimischen beherbergt. Diese Arbeit zielt darauf ab, das Grundlagenwissen über die Populationsökologie und die Auswirkungen des Minks auf der Insel Navarino zu erweitern. Konkret werden relative Abundanz und Habitatvorlieben des Minks, sein Beutespektrum, die Auswirkungen auf den Nisterfolg bodenbrütender Küstenvögel, sowie die öffentliche Wahrnehmung und Akzeptanz von Kontrollmaßnahmen untersucht. Damit wird ein breiter und interdisziplinärer Ansatz angewandt, der Ergebnisse von praktischer Relevanz für ein integratives Management invasiver Arten in der Kap-Hoorn-Region zur Verfügung stellt.

Mit Hilfe von Spurensuche und Lebendfang konnte gezeigt werden, dass sich der Mink von seiner Ursprungspopulation auf dem argentinischen Teil von Tierra del Fuego auf benachbarte Inseln (Navarino, Hoste) ausbreiten konnte; sein Vorkommen in anderen Teilen des Biosphärenreservats wurde jedoch nicht nachgewiesen. Die Spurensuche auf der Insel Navarino ergab, dass der Mink in nur einem Jahrzehnt, nachdem er erstmals registriert wurde, die gesamte Insel besiedelt hatte. 79 % aller Begehungen in 68 Untersuchungsflächen verschiedener semiaquatischer Habitate (Meeresküstenufer, Flussufer, See- und Teichufer) enthielten Losungen des Minks. Das relative Vorkommen der Art wurde mit der Fang-Wiederfang-Methode auf 0.75 Minke/km Küstenlinie geschätzt. Die Ergebnisse von Habitatmodellen zeigen, dass der Mink strauchige Vegetation Wiesen und bewaldeten Habitaten vorzieht, ebenso felsige Küstenabschnitte flachen Stränden. Interessanterweise mied der Mink Habitate, die stark von ebenfalls invasiven Bibern (*Castor canadensis*) verändert worden waren.

Die potentiellen ökologischen Auswirkungen des Mink wurden anhand einer Untersuchung seines Nahrungsspektrums erfasst. Im Durchschnitt waren die Hauptbeutegruppen Säuger (37 % der Biomasse), Vögel (36 %) und Fische (24 %). Im Frühling und Sommer stieg der Anteil von erbeuteten Vögeln in Küstengebieten aber um das Doppelte an, verglichen mit der kalten Jahreszeit, während der Zugvögel die Region verlassen hatten. Adulte Passeriformes und Küken von Anseriformes und Pelecaniformes waren dabei eine häufige Beute. Was Säuger betrifft, so erbeutete der Mink hauptsächlich Bisamratten (*Ondatra zibethicus*, invasiv) und die südamerikanische Feldmaus (*Abrothrix xanthorhinus*, heimisch). Die Prädation von bodenbrütenden Küstenvögeln durch den Mink wurde für unterschiedliche Brutstrategien, Habitate und Nesteigenschaften an (i) einzeln nistenden Vögeln (*Chloephaga picta, Tachyeres pteneres*, n=102 Nester), in Kolonien brütenden Vögeln (*Larus dominicanus, Larus scoresbii, Sterna hirundinaceae*, n=361) und (iii) an 558 künstlichen Nestern untersucht. Mit Hilfe von Diskriminanzanalysen konnte gezeigt werden, dass einzeln nistende Küstenvögel, die an felsigen

Küstenabschnitten nisten und ihre Nester verstecken, am stärksten durch eine Prädation des Minks gefährdet waren.

Untersucht wurden auch Wissen, Einstellungen, Wertzuschreibungen und die Akzeptanz der Kontrolle des Minks und auch des Bibers mittels qualitativer Interviews (n=37) mit Angehörigen unterschiedlicher soziokultureller Gruppen auf Navarino. Unter Verwendung der Inhaltsanalyse (nach Mayring) ergab sich, dass das Wissen über diese beiden Arten ausgeprägt und die Sorge um ihre Auswirkungen vorhanden waren, dass Einstellungen und Werte, die mit heimischen und invasiven Arten assoziiert wurden, artspezifisch waren und dass die meisten Befragten sich für eine Kontrolle von invasiven Arten aussprachen, einer Ausrottung aber eher skeptisch gegenüber standen. Während die Meinungen zur Kontrolle des Bibers auseinander gingen, wurde die Kontrolle des Minks weithin akzeptiert.

Die Ergebnisse dieser Untersuchungen sind relevant für ein Management von invasiven Arten im Kap-Hoorn-Biosphärenreservat. Neben der Berücksichtigung von wissenschaftlichen Untersuchungen sollten Naturschutzbehörden auch die Ansichten der Bevölkerung in den Prozess der Planung und Durchsetzung von Kontrollprogrammen einbeziehen. Diese Integration kann dazu beitragen, dass Konflikten entgegengesteuert wird, die durch Informationslücken entstehen oder durch Managementpläne, die Einstellungen und Werte nicht berücksichtigen. Basierend auf den ökologischen Untersuchungen sollten felsige Meeresküsten aus zwei Gründen als Prioritätszonen für eine verstärkte Kontrolle des Minks eingerichtet werden: Erstens waren diese Habitate am dichtesten vom Mink besiedelt, und zweitens beheimateten sie die am stärksten durch Prädation seitens des Minks gefährdeten Vogelarten. Die Aufmerksamkeit auf den Mink sollte jedoch nicht von anderen Ursachen ablenken, die zur Gefährdung von Vögeln und anderen Arten in der Region beitragen.

Resumen

La biota de la tierra se encuentra sustancialmente alterada por el creciente movimiento de especies. A su vez, las invasiones biológicas y sus impactos son de gran interés para la conservación si ocurren en ecosistemas insulares. A pesar de su aislamiento geográfico, el prístino archipiélago sub-Antártico de Cabo de Hornos se encuentra fuertemente invadido por especies no nativas. El mamífero más reciente llegado es el visón norteamericano (*Mustela vison*), un mustélido que en este momento está estableciendo su población asilvestrada más austral en Isla Navarino, parte de la recientemente declarada Reserva de Biosfera Cabo de Hornos. Aquí, el visón representa un nuevo tipo de depredador mamífero terrestre ya que la isla carece carnívoros terrestres nativos. Esta tesis tiene como objetivo ampliar el conocimiento básico de la ecología y del impacto del visón norteamericano en Isla Navarino. En específico, se investigan la abundancia relativa y el uso de hábitat del visón, su dieta, el impacto sobre el éxito de nidificación de aves costeras nidificando en el suelo, tal como la percepción pública y la aceptación de medidas de control. Se utiliza un enfoque amblio e interdisciplinario que ofrece resultados de relevancia práctica para un manejo integrativo de especies invasoras en la región de Cabo de Hornos.

Mediante muestreos de señales y trampeo directo se detectó que el visón se ha extendido desde su población fuente en Tierra del Fuego, Argentina, a islas adyacentes (Navarino, Hoste). Sin embargo, su abundancia en otras zonas de la Reserva de Biosfera no ha sido comprobada. Muestreos de señales en Isla Navarino revelaron que el visón ha colonizado toda la isla una década después de que el primer visón fue registrado. 79 % de los muestreos en 68 sitios en diferentes hábitats semi-acuáticos (costa marina, riberas de ríos, lagos y lagunas) registraron heces de visón. La abundancia relativa del visón fue estimada en 0.75 visones/km de ribera de costas marinas usando la técnica de marcaje y recaptura. Modelos de hábitat permitieron señalar que el visón prefiere vegetación arbustiva por sobre las praderas o bosques, áreas costeras rocosas por sobre las

playas llanas y, lo que es interesante, que el visón evitó hábitats fuertemente modificados por otra especie invasora, el castor canadiense (*Castor canadensis*).

Respecto al impacto ecológico potencial del visón, se definieron sus grupos principales de presa mediante el análisis de heces. La dieta consistió principalmente en mamíferos (37 % biomasa), aves (36 %) y peces (24 %). Sin embargo, durante la primavera y el verano el consumo de aves en las costas marinas era el doble comparado a la estación fría cuando las aves migratorias han abandonado la región. Passeriformes adultos y crías de Anseriformes y Pelecaniformes constituyeron una presa frecuente entre las aves. Respecto a los mamíferos, el visón básicamente depredó ratas almizcleras (*Ondatra zibethicus*, invasora) y el ratón de hocico bayo (*Abrothrix xanthorhinus*, nativo). La depredación del visón sobre aves acuáticas que nidifican en el suelo se evaluó según diferentes estrategias de reproducción, hábitats y características del nido mediante un monitoreo de nidos (i) de aves nidificantes en solitario (*Chloephaga picta, Tachyeres pteneres*, n=102 nidos), (ii) de aves nidificantes en colonias (*Larus dominicanus, Larus scoresbii, Sterna hirundinaceae*, n=361), y (iii) de 558 nidos artificiales. Análisis discriminatorios revelaron que aves acuáticas que nidifican solitarias en costas rocosas y en nidos cubiertos fueron las más vulnerables a la depredación por el visón.

Se exploró el conocimiento, las actitudes y valores y la aceptación de control de visones y castores a través de entrevistas cualitativas (n=37) con miembros de diferentes grupos socio-culturales en la Isla Navarino. El método de análisis de contenido (según Mayring) mostró que el conocimiento acerca del visón y del castor y la preocupación por sus impactos eran complejos, que las actitudes y valores asociadas a las especies nativas e invasoras dependían de la especie y que la mayoría de los entrevistados era a favor de un control de especies invasoras, pero escéptico de su erradicación. Las posiciones acerca del control del castor eran ambiguas, pero el control del visón era mucho más aceptado.

Los resultados de esta investigación son relevantes para la gestión de especies invasoras en la Reserva de Biosfera Cabo de Hornos. Además de considerer la investigación científica, los servicios encargados deberían también incluir la opinión pública en el proceso de diseño e implementación de programas de control. Esta integración puede evitar la generación de conflictos que surgen al existir vacíos de información, o de actitudes y valores no respetados por los planes de manejo. Basado en las investigaciones ecológicas, las costas marinas rocosas podrían ser utilizadas como sitios de prioridad para un control reforzado del visón, por dos razones: Primero, por ser los hábitats con un mayor número de visones, y segundo, por que hospedan las especies de aves más vulnerables ante la depredación del visón. Sin embargo, la atención hacía el visón no debe eclipsar los otros factores que contribuyen a la vulnerabilidad de las aves y otras especies en la región.

CHAPTER ONE
General introduction

Biological invasions

Human trade and travel around the globe are causing increases in species shifting (Elton 1958). Many introduced species are a significant component of the global economy, typically those which are managed or cultivated. Negative effects are often associated with those species that become successfully naturalized (Sax et al. 2007). However, most introductions, except for vertebrates, actually fail to (rapidly) establish permanent populations (Williamson 1996, Jeschke & Strayer 2005). Regardless, some invasive species can have serious ecological and socio-economic consequences (e.g. Parker et al. 1999, D'Antonio & Hobbie 2005, Pimentel et al. 2005). It is by virtue of those species that biological invasions are seen as one of the most important drivers and consequences of global anthropogenic change, together with global warming and land-use change (Vitousek et al. 1997, Sala et al. 2000).

Regarding the ecological effects of biological invasions, invasive animal species can cause reductions in population sizes of native species through direct and indirect mechanisms. Direct mechanisms include predation, grazing, competition, and interbreeding. Indirectly, populations are reduced through habitat change, transmission of diseases, and cascading trophic interactions. Plant invaders can entirely modify, for example, the fire regime, nutrient cycling, and hydrology in native ecosystems (Mack et al. 2000). Among the most serious invasions are those of carnivores introduced to island biotas (Elton 1958, Courchamp et al. 2003, Sax et al. 2007). This is also one of the few accepted generalizations concerning the success of invaders (Mack et al. 2000). The survival of intentionally or accidentally introduced species on islands and the significance of their ecological impacts seem to be less a matter of the comparatively low insular biodiversity (Levine & D'Antonio 1999); rather it most probably depends on the nature of those species that are present or those groups of species that are absent from the islands (Goodman 1975, Simberloff 1995). When terrestrial mammalian predators were absent before, the impacts of introduced carnivores often include local extinctions of native species, especially of bird populations or even complete extinctions, in the case of endemic species on oceanic islands (e.g. Macdonald & Thom 2001, Sax et al. 2007).

A major focus of invasion biology lies in applied conservation oriented research, striving to explain, manage or prevent the impacts of invasive species as outlined above. Yet, invasive species are also used for addressing basic research questions in ecology, evolutionary biology, and biogeography (Sax et al. 2007). In comparison, economic questions have been less studied and socio-cultural questions seldom. Some authors contributed important studies on the economic costs of biological invasions (e.g. Perrings et al. 2002, Pimentel et al. 2005), or addressed the impacts associated with invasive species that are threats to human health (e.g. McMichael & Bouma 2000, Juliano & Lounibos 2005). Rather recently, social sciences and humanities have become involved with studies on public viewpoints or on the ethics of invasive species (e.g. Eser 1998, Körner 2000, Fitzgerald et al. 2005, Fischer & van der Wal 2007, Haider & Jax 2007, Shackleton et al. 2007).

In the increasing and already very extensive literature on invasion biology, terms on the concepts on invasive species are diverse and lack common agreement (Coulatti & MacIsaac 2004). One reason for this is probably the strong intersection of research, public policy, and media maintaining a debate partially based on values and emotions often not clearly expressed (Lodge & Shrader-Frechette 2003, Brown & Sax 2004). Several researchers have proposed classification schemes to clarify invasion terminology (e.g. Davis & Thompson 2000, Heger & Trepl 2003, Heger 2004, Coulatti & MacIsaac 2004). In this dissertation, I use the definition provided by Heger (2004, p. 12, translation E. Schüttler) for plant invaders, referring to an *alien* (in this work also exotic, naturalized, non-native) organism as "any species that occurs at a location outside its area of origin; the occurrence of the species must have been prevented in the past by a barrier to dispersal, and not by the unsuitable conditions in the new habitat". *Invasive* species are "alien species spreading in the new area. They are appreciated as invasive no matter how fast or far they spread, and no matter whether they exert any cultural or economic negative effects on native ecosystems or not". As a neutral term that is free of any value judgment, this ecological definition does not imply that invasive species are harmful from a conservationist perspective. This latter assertion is often made by policy institutions (Heger & Trepl 2008).

The complications the dubiety of the native/non-native framework induces for policy interpretation is described by Schullery & Whittlesey (2001) in a fascinating example of mountain goat policy in the U.S. Yellowstone National Park. The dilemma conservation managers faced in the 1990s was a policy that required resisting mountain goats migrating north into Yellowstone because they were descendants of human-introduced populations. But at the same time, mountain goats moving in from the west had to be welcomed as natives because they were part of a non-human caused colonization. Hettinger (2001) provides many more examples of species that do not fit the criteria often used to distinguish native from non-native species. Prime doubts about this framework refer to the relativity of space and time criteria and the exclusion of humans as vectors for species (reviewed in Warren 2007).

These criticisms indicate that the use of the concept of 'native' and 'non-native' and the policies grounded on it are embedded in specific value systems (Körner 2000, Warren 2007). Research on biological invasions should recognize that it unavoidably implies values (Hettinger 2001), which is, after all, legitimate in conservation biology (Shrader-Frechette & McCoy 1993, Barry & Oelschlaeger 1996). These values however should be explicitly stated and not "sold" to the public as force scientific conclusions. The consideration of a more balanced array of values and perspectives is urged, on the one hand, for a broader acceptance of local or national biodiversity policies (Fischer & Young 2007, Berghöfer et al. 2008), and on the other hand, as part of the international strategy on the conservation of biological diversity as claimed in the Malawi Principles (principle 1) of the Ecosystem Approach of the Convention on Biological Diversity: "the objectives of management of land, water and living resources are a matter of societal choice" (UNEP/CBD 2000, p. 104).

Against this background, in the present study I investigate and discuss the need for action with respect to a new invasive species, the American mink (*Mustela vison* Schreber, 1777), on Navarino Island within the Cape Horn Biosphere Reserve in southern Chile.

The American mink

The American mink is a member of the family *Mustelidae*. As many species of mustelids the mink has also been hunted throughout its native range on the North American continent on account of its coat. Wild mink in North America and millions of farm animals worldwide are of economic importance for fur trade (Dunstone 1993). Escapes or intentional releases of farm mink have led to the establishment of feral populations of the species throughout Eurasia and in southern South America.

The mink was imported as a fur bearer from North America to mink farms in Chile and Argentina from the 1930s. On the Argentine part of Tierra del Fuego Island, American mink reportedly escaped into the wild during the 1960s (Jaksic et al. 2002). It is from this feral population that mink on Navarino Island most probably originate. This island is located in the

Chilean Antarctic Province (pertaining to Region XII) south of Tierra del Fuego, from which it is separated by the Beagle Channel (ca 5 km wide). American mink might have swum across the Beagle Channel reaching Navarino and adjacent islands during the mid-1990s. The first mink was officially registered in 2001 (Rozzi & Sherriffs 2003).

American mink are medium-sized carnivores with a body weight of about 1 kg and a total length of approximately 50-60 cm (Larivière 1999). They are semi-aquatic animals inhabiting marine shore habitats, flowing waters, lake shores, freshwater and saltwater marshes. As den sites, mink occupy shelters located under tree roots, rock piles, dense vegetation, and burrows of rabbits or muskrats in close vicinity to the water's edge (Birks & Linn 1982). Mink are generalist predators and their diet includes prey from both aquatic and terrestrial sources, strongly reflecting the local and seasonal availability of prey (Dunstone 1993). Their average linear measured home ranges vary between two to four km/shoreline depending on sex, age, and habitat (Larivière 1999). Normally, mink exhibit no inter-sexual overlap and low intra-sexual overlap, but in marine coastal habitats inter-sexual overlap is higher (Dunstone & Birks 1985). Mink activity largely occurs within 100-200 m from water (Dunstone 1993). The mating season ranges from February to April (northern hemisphere) and litter size averages four (range 2-8) after a gestation period of about 50 days (Sidorovich 1993).

Being highly adaptable and opportunistic predators, numerous studies in Europe have shown that feral populations of introduced mink can be detrimental to native species (see reviews in Macdonald & Harrington 2003, Bonesi & Palazon 2007). Impacts include reductions of prey populations as has been well documented for seabird colonies on islands (Clode & Macdonald 2002, Nordström & Korpimäki 2004), ground-nesting inland water birds (Ferreras & Macdonald 1999), fish and crustaceans (Delibes et al. 2004), rodents (Jefferies 2003), amphibians (Ahola et al. 2006); and competition to native mustelid species (Maran et al. 1998, Sidorovich et al. 2001, but see Bonesi et al. 2006a). In South America, mink have caused reductions in waterbird populations (Lizarralde & Escobar 2000). They are also considered to have caused the decline of the river otter *Lontra provocax* in Argentinean Patagonia (Previtali et al. 1998), although Medina (1997) and Fasola et al. (2009) found little support on competition for space and food. The impacts of mink on economic activities such as fish or poultry farming or on the ecotourism industry are less studied (e.g. Sheail 2004). The overall economic impact seems to be rather small, but can be significant in specific regions (Bonesi & Palazon 2007).

Essential knowledge about the population ecology and the impacts of American mink on Navarino Island and in the Cape Horn Biosphere Reserve is lacking. As the recent invasion of the mink on Navarino leads to high concern among nature conservationists, the interest in an evaluation of the need for action is strong (Rozzi et al. 2006a, Soto & Cabello 2007). On Navarino Island the situation is different from most other areas in Europe and South America where mink populations became established. The native mammal assemblage on Navarino is extremely scarce and lacks mustelids or other carnivores (Anderson et al. 2006a). Therefore, on Navarino Island mink represent a new guild (Root 1967) of terrestrial mammalian predators. This situation is expected to have significant consequences on the population ecology of mink and on their ecological impacts.

The study area

The thesis was conducted in the austral region of Cape Horn within the Magellanic Sub-Antarctic Forest Biome in the very south of the American continent (Fig. 1.1). It is the southern hemisphere latitudinal equivalent of Denmark. The region is characterized by numerous fjords and islands. Recently, it was identified as one of the 24 most pristine wilderness areas of the world Forest Biome due to the extensive size of intact native vegetation remaining and the low human population density (Mittermeier et al. 2003). Cape Horn is also of cultural importance. It is home to the world's southernmost pre-Columbian human population, the Yaghan indigenous people (McEwan et al. 1997).

Although this region remained protected from extensive modern human impact due to its geographic isolation and the presence of the Chilean Navy (Rozzi et al. 2006a), today the local biological and cultural diversity has been subjected to the growing influences of the global economy and culture (Berghöfer et al. 2008). Since the 20th century, invasive species introduced for economic interests (e.g. trout, livestock) are impacting the natural ecosystems (Anderson et al. 2006a), international companies dominate the fisheries industry (Pollack et al. 2008), and the Yaghan language and traditions have been widely lost (Rozzi et al. 2003). One initiative to address the global change was the declaration of the Cape Horn Biosphere Reserve (54°-56°S) by UNESCO in 2005 with the aim of incorporating the area's biodiversity and traditional activities into a plan for long-term sustainable development through ecotourism (Rozzi et al. 2006a).

The research in the framework of this dissertation was mainly carried out on Navarino Island (55°S, 2,500 km^2), a Chilean island within the Cape Horn Biosphere Reserve. The island is located south of Tierra del Fuego Island. Transport to the next Chilean city, Punta Arenas, takes at least 30 hours by boat or 1.5 hours by plane. Only 2,300 people live in the Biosphere Reserve, most in Puerto Williams, the only town and capital of the Chilean Antarctic Province, on the northern coast of Navarino. A few people live on isolated farms and navy stations, which mostly rely on shipping. Only one dirt road connects the northern coast of the island. The main habitat types include Magellanic subpolar evergreen rainforests dominated by *Nothofagus betuloides* and *Drimys winteri*, Magellanic deciduous forests of *Nothofagus pumilio*, Magellanic Tundra bog communities (*Sphagnum* spp.), thickets and shrublands, and high-Andean vegetation (Pisano 1977, Rozzi et al. 2006a). On Navarino Island elevations are not higher than 1,000 m a.s.l. The climate is characterized by short and cool summers (mean temperature 9.6°C), and long and moderate winters (mean temperature 1.9°C). The seasonal distribution of precipitation is relatively uniform and averages annually 467.3 mm (Rozzi et al. 2006a). Glaciers covered the entire region until approximately 15,000 B.C. (McCulloch et al. 1997); but no glaciers exist on Navarino Island today.

The native vertebrate fauna on Navarino Island is restricted to birds, mammals, and fish. Amphibians and reptiles are absent. With approximately 154 species, birds represent the most diverse and abundant group of terrestrial vertebrates on the island (Couve & Vidal 2003). Terrestrial mammal species are scarce with only two species of rodents, two species of bats, and one species of ungulates (Olrog 1950, Anderson et al. 2006a). In the marine zone, mammals include fur seals, dolphins, and occasionally whales. Sea otters (*Lontra felina*) are mainly associated with the Wollaston and Cape Horn Islands (Rozzi et al. 2006a). As far as freshwater fish are concerned, Navarino hosts only three native species, but the marine fish fauna in the Beagle Channel is rich with over 50 species (López et al. 1996). The assemblage of exotic and native vertebrate species is described in further detail in chapter two.

Aims of the dissertation

With this thesis I aim to contribute to the research on invasive species of high conservation concern with an approach that is integrative in three ways: first, an interdisciplinary vision on the problem is attempted, considering both the ecological and social perspectives; second, a connection between science and management in a parallel process is sought; and third, the relationships established between different invasive species are considered. The American mink is an invasive species of high conservation concern in its initial phase of invasion on Navarino Island and in the Cape Horn Biosphere Reserve. The specific purpose of this dissertation is to broaden the basic knowledge for decision-making for the management of the mink. I examined the distribution of American mink in the Cape Horn Biosphere Reserve, its relative abundance and habitat preferences on Navarino Island, its ecological impact with a special focus on ground-nesting coastal waterbirds, and public views on the American mink and the North American beaver as contrasting invasive species regarding arrival times and impact.

Methods

As mink are semi-aquatic mustelids, study sites included shorelines of coasts, rivers, lakes, and ponds. To determine the presence of mink in the Cape Horn Biosphere Reserve, I participated in an eight-day expedition in May 2005 during which eight locations on the Chilean part of Tierra del Fuego Cape were visited. I collected presence/absence data using trapping and signs surveys at coastal and riverine shorelines. All other research was carried out on Navarino Island during 2005-2007. Twelve 4 km long coastal sites along the northern coast of the island were selected, all separated by at least 3 km, the approximate home range length of mink (Dunstone 1993). The main habitat was shrubland predominated by species of *Berberis buxifolia*, *Pernettya mucronata* and *Chiliotrichum diffusum*. Six sites were dominated by steep coasts with rocky outcroppings, while the other six shorelines were flat beaches with pebbles, sand, and mud as the predominant substrate. At all of these sites, I carried out sign surveys of mink, and monitored the nest survival of artificial nests. At nine of these coastal sites, I also monitored natural nests of solitary nesting and colonial waterbirds. Bird censuses were conducted two to four times during the breeding season. Nest characteristics (e.g. concealment by vegetation) relevant for different search strategies of predators were measured at both artificial and natural nests. In order to survey for predation of nests by mink in the interior of the island, artificial nests were also laid out at three lakes at a distance of 5-8 km from the northern coast. At three coastal sites I collected capture-mark-recapture data during the four seasons. Live-trapping was also performed once along three rivers in the northern part of the island. Apart from the coastal sites, scats and tracks were also searched all over the island, but surveys were concentrated in the northern part. In total, scats and tracks were recorded at 68 sites in four different semi-aquatic habitats: along coastal shores (n=15), river banks (n=9), lake margins (n=31, perimeter > 1 km), and pond margins (n=13, perimeter < 1 km). During the surveys, I recorded small-scale habitat features such as vegetation cover or bottom material of the coast, in order to later relate them to mink presence/absence data. Scats (n=512) collected during those surveys were consecutively analyzed by classifying the hard remains into different prey groups (e.g. mammals, birds, fish) with the objective of determining the diet of mink in different semi-aquatic habitats and seasons. Fig. 1.1 and 1.2 show the sampling locations of the thesis. Beside these ecological investigations, I conducted thirty-seven semi-structured qualitative face-to-face interviews with local people residing in Puerto Williams. Themes covered in an open questionnaire guide ranged from their knowledge of mink and beavers, and the evaluation of exotic and native species to the acceptance of the control of invasive species.

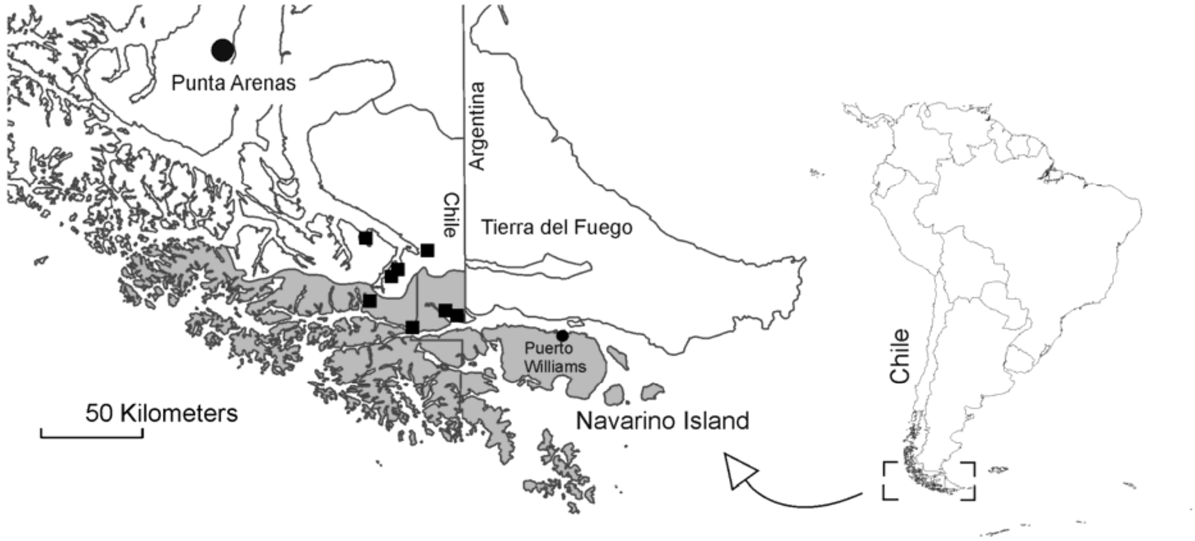

Fig. 1.1 Overview of the study area. Navarino Island with Puerto Williams as the capital of the Chilean Antarctic Province, is located within the Cape Horn Biosphere Reserve (shaded in gray) in southern South America. Black squares indicate sites visited during the expedition in May 2005 where live trapping and sign surveys of mink were applied.

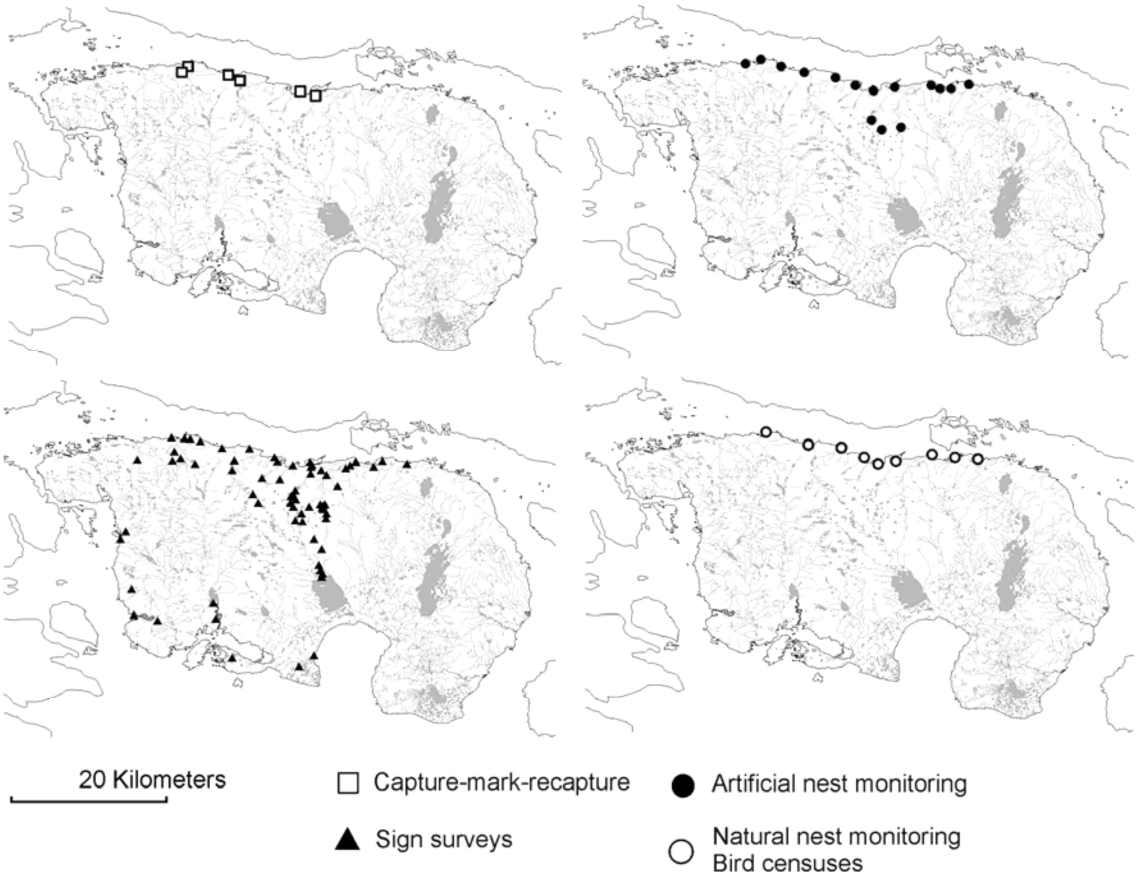

Fig. 1.2 Overview of the study sites and the methods applied on Navarino Island during 2005-2007.

Integrating science with management

A control program on invasive species has been recently implemented in the Cape Horn Biosphere Reserve, and currently new management plans are being designed (Soto & Cabello 2007, Choi 2008). The regional control program residing with the Ministry of Agriculture, specifically the Agriculture and Livestock Service (SAG), has promoted the hunting of detrimental invasive species in the Magallanes and Chilean Antarctic Region from 2004-2007 (Soto & Cabello 2007). Eight species were included in the program; these were beavers (*Castor canadensis*), muskrats (*Ondatra zibethicus*), and mink, but also feral domestic animals of dogs, cats, pigs, cattle, and horses. Interested hunters were trained, provided with traps, and they were paid for delivered furs (beavers, mink, muskrats) and meat (beavers). Handicraft courses for furs were offered to the local communities. The program was designed as a process of on-going evaluation and adaptation, and therefore SAG desired and promoted the discourse with scientists, as well as with public and private stakeholders.

From the beginning of this dissertation, I cooperated with the coordinators of the control program and information was continuously exchanged between both sides. We agreed upon the communication of data on trapped mink on Navarino Island, i.e.,date, location, habitat type, sex, etc. Further, we defined an exclusion area of approximately 10 km along the northern coast of Navarino Island where mink should not be hunted in order to provide a basis for a comparison between mink removal and mink inhabited sites. I communicated the cooperation requirements in a meeting of hunters in Puerto Williams. However, the foreseen scientific comparison and the use of data of trapped mink was not applicable due to the low trapping success on Navarino Island.

After the completion of the first year of the control program, SAG sent out invitations to an evaluation workshop in which researchers, non-governmental nature conservation organizations, forestry and sanctuary public agencies from both Chile and Argentina discussed the success of the program. The hunters' trapping success for mink was very low in comparison to beavers: in the end, the control program recorded in total 11,700 dead beavers, but only 234 dead mink, with the majority being trapped in Tierra del Fuego Island by a professional Canadian trapper (Soto & Cabello 2007). Therefore, a special workshop on the mink was organized during the last year of the program in Puerto Williams aiming to reinforce efforts to hunt mink (see Fig A.1, Appendix, for a press release). The workshop included both exchange of experiences between researchers and trappers, and practical training in trapping. Within this framework, a film of the Helmholtz Centre for Environmental Research-UFZ about the invasion of mink on Navarino Island was broadcast on local television (see Fig A.2, Appendix, for the DVD cover). Finally, I communicated own preliminary results to SAG in a mid-term report and as recommendations for management. The final report of the control program (Soto & Cabello 2007) includes a chapter on diet analysis and interview citations.

Structure of the thesis

This thesis is composed of seven chapters. This first chapter introduces the background, the aims and methodology of the study. Chapters two to six present the results of the research carried out, written in the form of scientific papers (chapters two and four are already published). Chapter seven completes the thesis by giving a synthesis of the main findings and their implications for the management of invasive species in general, but particularly of the mink in the Cape Horn Biosphere Reserve (Fig. 1.3 provides a schematic outline). In the following, I give a brief overview of the aims and relevance of the research chapters.

Chapter Two

This chapter (published as Anderson et al. 2006a) gives an overview on the assemblage of exotic vertebrate species found in the Cape Horn Biosphere Reserve. Field research was carried out by a team of investigators on Navarino Island and on various expeditions throughout the archipelago over a period of five years. Existing information on exotic and native species was synthesized and completed with monitoring data. My contribution to this work was the assessment of the distribution of the American mink in the Cape Horn Biosphere Reserve. The results presented here provide the most detailed survey to date of the assemblage and distribution of exotic vertebrate species in the Cape Horn Biosphere Reserve.

Chapter Three

The aim of this chapter (paper submitted to *Biodiversity and Conservation*) is to quantify abundance and habitat preferences of American mink as a new carnivorous species on Navarino Island. I assumed that the absence of other native mustelids or predators would favor the establishment of mink on the island. Firstly, direct (live-trapping) and indirect (sign surveys) methods were used to estimate the abundance of mink in different semi-aquatic habitats (coastal shores, river, lake and pond margins). Secondly, the influence of small-scale habitat features on mink abundance was modeled (e.g. coarseness of shoreline, vegetation cover). And thirdly, the influence of habitats engineered by invasive beavers was related to mink abundance. The results of this study offer the basic information needed for designing an integrative management plan on invasive species.

Chapter Four

The fourth chapter (published as Schüttler et al. 2008) contains an overall assessment of the ecological impact of American mink as predators through an analysis of their diet. I used over five hundred scats collected during the sign surveys (chapter three), sorted the hard remains into six categories (mammals, birds, fish, insects, crustaceans, and mollusks) and assessed variations in the diet of mink between habitats and seasons. For a subset of scats collected at marine coasts, birds were identified to the order level and mammals to the species level. Again, a relationship between two invasive species was assessed: the importance of invasive muskrats, which form an important prey for mink in its original distribution range, as a food item for mink on Navarino Island. This work provides an initial baseline diagnosis about the potential impact of mink on native and exotic fauna of Navarino Island.

Chapter Five

The goal of this chapter (published as Schüttler et al. 2009) is to give a scientific answer on concerns expressed by investigators and public agencies at the reduction of nest survival of "naïve" ground-nesting waterbirds by the mink (e.g. Rozzi & Sherriffs 2003, Soto & Cabello 2007). Therefore, I designed a study aimed at deriving a vulnerability profile for birds as a function of different breeding strategies, habitat, and nest characteristics. Nest predation by mink was examined on nests of solitary nesting birds (*Chloephaga picta, Tachyeres pteneres*), species nesting in colonies (*Larus dominicanus, Larus scoresbii, Sterna hirundinaceae*), and on artificial nests imitating geese nests. Nest characteristics were also recorded, such as nest concealment by vegetation or the habitat type around the nest, and these variables related to the predator type (autochthonous birds or invasive mink). The results allow the identification of high priority species of ground-nesting waterbirds for conservation.

Chapter Six

How do local people perceive invasive species in their environment? In this chapter (paper submitted to *Environmental Management*) a social dimension on the traditionally ecological research on invasive species is added. The focus was on two contrasting invasive species on Navarino Island: the mink as a recently arrived predator and the beaver as an established herbivore. Through qualitative interviews this study explores what knowledge, conceptual thoughts, and impact perceptions of these invasive species and invasive species in general exist among the community members of Puerto Williams; what values regarding native and exotic species are at stake; and how the controlling of mink and beaver is accepted by the general public. The results provide steps towards an inclusion of a broader public in the process of designing and implementing management responses to biological invasions.

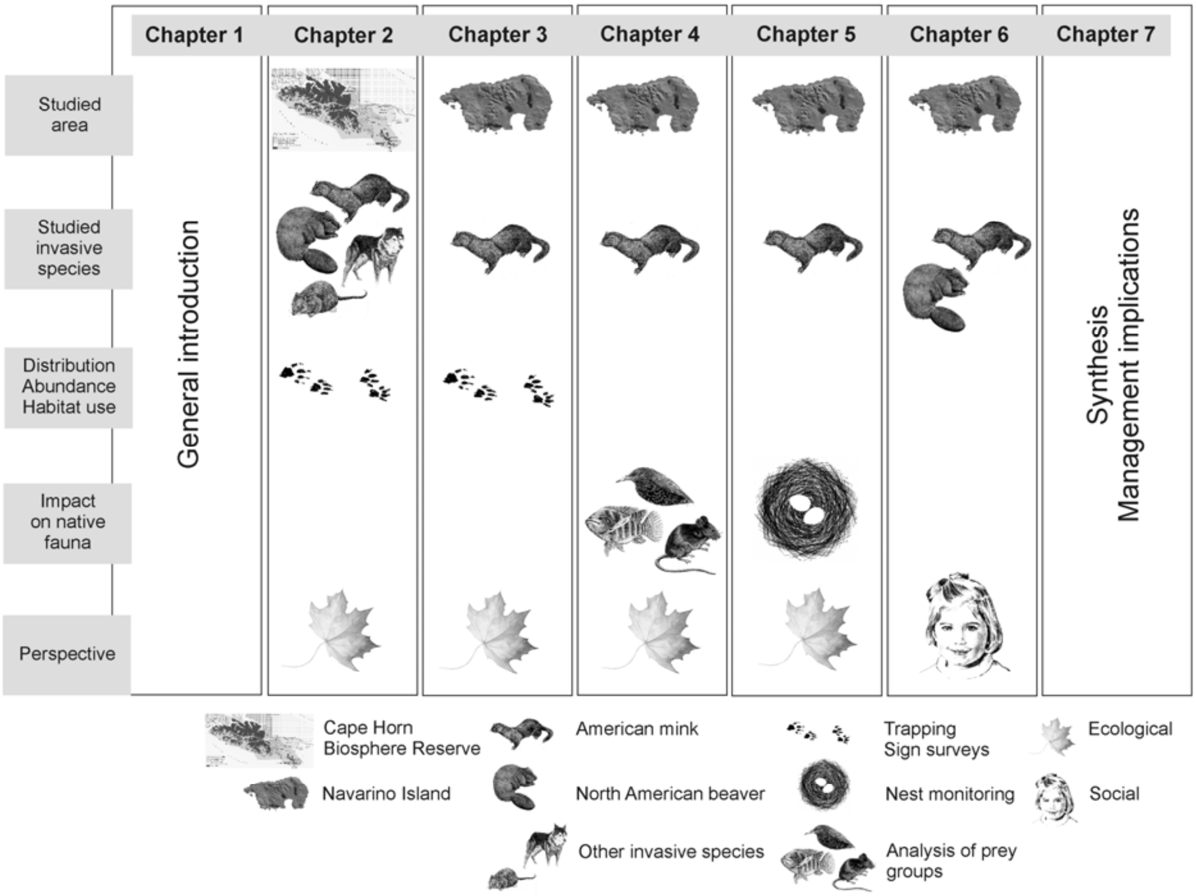

Fig. 1.3 Schematic outline of the dissertation. Chapter one provides the general introduction. Chapters two to six contain the investigation on the American mink, written in the form of research papers. Chapter seven completes the thesis with a synthesis of the main findings and management implications of the study (animals were painted by Jimena Saiter, courtesy of UNESCO Montevideo).

CHAPTER TWO

Exotic vertebrate fauna in the pristine sub-Antarctic Cape Horn Archipelago[1]

Abstract

Pristine wilderness is a scarce global resource, while exotic species are so common that they constitute a principal component of worldwide ecological change. The relationship between these two topics, invasion and remoteness, was the impetus behind five years of fieldwork aimed at identifying the assemblage and range of exotic vertebrates in Cape Horn, Chile, identified as one of the world's most pristine wilderness areas. While the archipelago has extremely low human population density and vast tracts of undisturbed land, we discovered that several terrestrial vertebrate groups were dominated by exotic species. Native birds were diverse (approximately 154 spp.), and only 1.3 % (or two spp.) were introduced. In contrast, exotic terrestrial mammals (twelve spp.) and freshwater fish (three spp.) outnumbered their native counterparts, constituting 55 % and 75 % of the assemblages. Using GIS, we found that not all areas were impacted equally, largely due to intensity of human occupation. Human settled islands (Navarino and Tierra del Fuego) hosted the greatest number of exotics, but humans alone did not explain observed patterns. Remote islands also had introduced species. North American beavers (*Castor canadensis*), American minks (*Mustela vison*) and feral domestic dogs and cats were particularly widespread, and their range in isolated parts of the study area raised important ecological and management questions. In conclusion, the Cape Horn Archipelago retained areas free of exotic vertebrates, particularly parts of the Cape Horn and Alberto D'Agostini National Parks, but at many sites introduced species were overwhelming native biota and altering these previously remote natural ecosystems.

Key words: Cape Horn, Chile, exotic species, invasive, global change, sub-Antarctic forests, Tierra del Fuego, wilderness

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[1] A slightly modified version of this chapter has been published as Anderson CB, Rozzi R, Torres-Mura JC, McGehee SM, Sherriffs MF, Schüttler E, Rosemond AD (2006) Exotic vertebrate fauna in the remote and pristine sub-Antarctic Cape Horn Archipelago, Chile. Biodiversity and Conservation 15: 3295–3313.

My contribution: I carried out trapping and sign surveys of mink in an eight-day expedition in May 2005 in the Cape Horn archipelago. My trapping data on Navarino Island (autumn and winter 2005) was also included in this paper. All other field work was carried out by a team of investigators. Christopher Anderson analyzed the data and wrote the paper. I made comments on the manuscript.

Introduction

The impact and distribution of exotic species is today a major area of scientific interest and conservation concern (Courchamp et al. 2003). Together with habitat fragmentation and global warming, species introductions constitute a principal cause of current global ecological change (Vitousek et al. 1997). As a country, Chile hosts proportionally few exotic vertebrates. Introduced species represent only 3.9 % of the Chilean vertebrate assemblage (Jaksic 1998). However, within the Patagonian ecoregion of southern South America, exotics constitute a higher proportion of vertebrate fauna. For example, in the Argentine portion of Tierra del Fuego 67 % of mammal species were found to be exotic (Lizarralde & Escobar 2000), and a study of freshwater fish in the Chilean portion of Tierra del Fuego Island described two exotics and only one native species (Vila et al. 1999).

The political unit of Cape Horn County is the world's southernmost forested ecosystem and encompasses all of the islands south of the Beagle Channel, in addition to the Chilean portion of Tierra del Fuego Island located south of the highest peaks in the Darwin Mountain Range (Fig. 2.1). The area belongs biogeographically to the Magellanic Biome (Pisano 1981), and more specifically to the Magellanic Sub-Antarctic Forest Ecoregion (Rozzi 2002). It recently has been classified as one of the world's most pristine remaining wilderness areas due to its extensive size, the intact nature of its native vegetation and its low human population density (Mittermeier et al. 2003). Mittermeier et al. (2003) also point out that the Magellanic Sub-Antarctic Forests have a very high percentage of protected area (75 % in Cape Horn County and 51 % for the whole region), compared to the world's other remaining wilderness areas, and consequently merit special recognition. Cape Horn County almost encompasses the limits of the Cape Horn Biosphere Reserve (which was nominated after the publication of this chapter in 2005).

Based on these criteria, this region is apparently remote from direct human influence, but in fact the Yahgans first settled the ecosystems of southern Chile 7,500 years ago (Ocampo & Rivas 2000). European explorations began in the 1500s, and colonization commenced in earnest in the late 1800s, provoking the first major landscape changes and introductions of exotic vertebrate fauna, principally associated with livestock grazing (Martinic 1973). The first record of a deliberate introduction of vertebrates to the islands south of the Beagle Channel was in 1867, when goats were brought to Lewaia Bay on Navarino Island by Anglican missionaries (Martinic 1973). During the 20^{th} century the number of introductions increased and expanded from domestic animals, including invasive species that expanded throughout the archipelago and others that did not become established at all. The realization that non-native biota can reach even the most remote areas left on the planet poses a conservation challenge for southern Chile, particularly given that a large portion is also classified by the Chilean environmental commission (CONAMA) as a priority area for national biodiversity conservation (Rozzi & Massardo 2002).

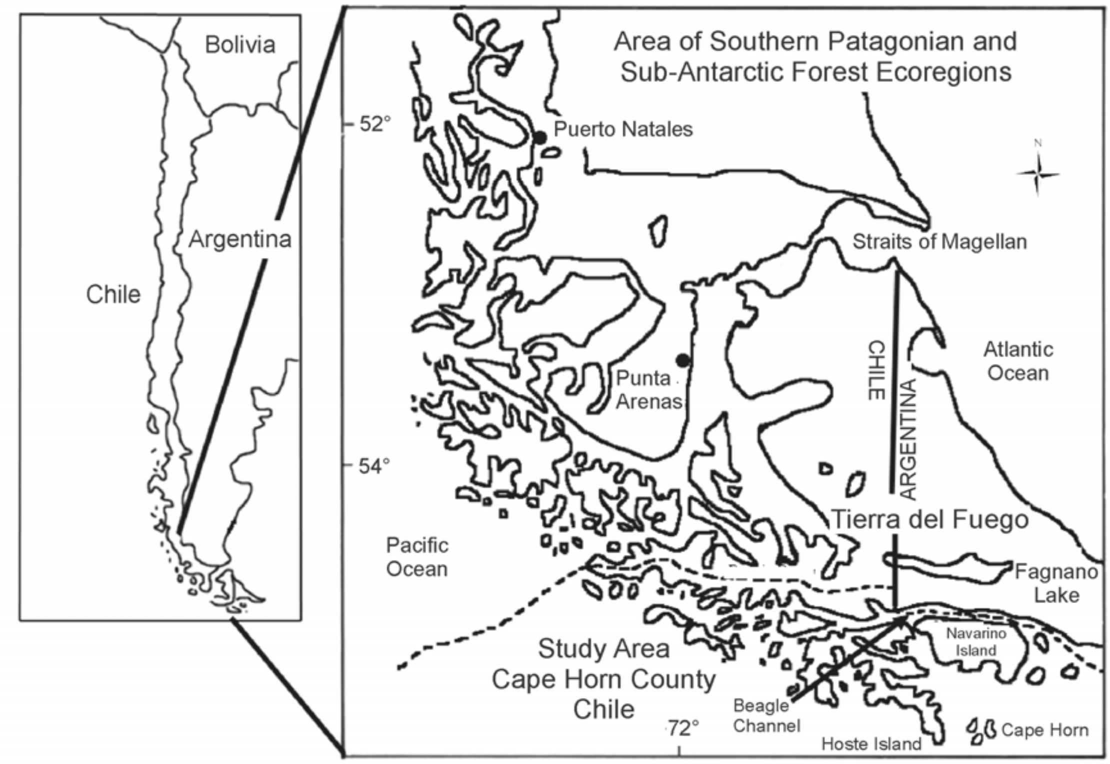


Fig. 2.1 Map of southern South America with inset of the area that includes the Southern Patagonian and Sub-Antarctic Ecoregions. South of the dashed line lies the biogeographic and administrative territory of Cape Horn County, Chile.

Despite the area's importance, detailed and precise information about exotic species in this area is currently lacking. Effective management of the extant National Parks (Cape Horn and Alberto D'Agostini) and the UNESCO Cape Horn Biosphere Reserve requires up-to-date knowledge of the assemblage and distribution of exotics, as well as their associated impacts. In order to achieve this goal, this paper (i) synthesizes existing information of native and non-native vertebrate fauna in the Cape Horn Archipelago; (ii) uses five years of monitoring and survey information to describe in greater detail the exotic vertebrate assemblage and distribution patterns; and (iii) analyzes three taxa identified as particularly harmful or widespread: the North American beaver (*Castor canadensis*), the American mink (*Mustela vison*) and feral domestic predators (dogs and cats). These species further are used to highlight the implications of invasion, demonstrating the effect of ecological barriers, the potential rapidity of establishment and the possibility for changing positive ecosystem feedback loops to negative. While providing relevant information for local managers, our information also serves to better comprehend the global context of species invasion dynamics.

Material and Methods

Study area

Cape Horn County is located within the administrative district known as the Chilean Antarctic Province, which in turn is itself part of the Magallanes and Chilean Antarctic Region (Fig. 2.1). The study area consists of an archipelago with hundreds of islands that cover approximately 15,488 km^2. The political boundaries also correspond largely to biogeographic barriers created by the icecap found towards the north in the Darwin Mountain Range on Tierra del Fuego Island and the sea barriers on all other sides. The area is part of the Magellanic Sub-Antarctic Forest Biome (for a detailed site description see Rozzi et al. 2004a).

Data collection and analysis

The data presented here were collected by a team of investigators over five years of fieldwork associated with the Omora Ethnobotanical Park's long-term ecological research efforts in the sub-Antarctic ecoregion. A total of forty sites on nineteen islands were surveyed over the course of five years (Table A.3, Appendix). Sampling included systematic and opportunistic mistnetting, point-count transects and checklists for birds, which were conducted in alpine, shrub, pasture and forested habitats between January 2000 and January 2005. Avian sampling has been carried out systematically six days per month on Navarino Island since 2000. In addition during January and April 2002, April 2003, January and May 2004, January and May 2005 bird surveys were conducted during boating expeditions throughout the archipelago. Data concerning fish presence and absence were based on at least one day of rod-and-reel fishing per surveyed water body on Navarino, Hoste and Tierra del Fuego Islands, as well as opportunistic observational evidence and interviews with fishermen.

Sherman traps for small mammals were deployed on Navarino Island in quarter hectare grids in shrub, rush wetlands, cushion bog, pasture and evergreen, deciduous and mixed forest habitats. In addition, traps were placed around human settlements. Traps were baited with oats and checked twice daily. In January and May 2004 and January and May 2005 expeditions were conducted by boat through the archipelago in order to access remote and difficult portions of the county, and qualitative Sherman trap sampling for small rodents was conducted from one to two nights per site on Hoste, Herschel and Horn Islands.

Live traps (20 x 20 x 70 cm) were used in April and May 2005 at Pia Sound, Olla Cove and Yendegaia Bay (Tierra del Fuego Island) and on Navarino Island to sample for mink. A total effort of 420 trap nights was carried out on Navarino Island and twenty-five trap nights for Tierra del Fuego (TDF). Visual surveys were conducted at each site for a distance of 0.5 to 2 km of stream or coastline and divided into 200 m sections that were classified as positive or negative detection of mink evidence. Detection surveys were made of the places where tracks were likely to be found, such as sandy or muddy ground, and scats were searched for on exposed marking places, such as rocks and fallen trees for territorial scent marking (Dunstone 1993).

At each stop during expeditions, visual transects and surveys were also used to detect evidence (spoor, rooting, disturbance and tracks) of larger exotic species, such as beavers, muskrats and feral domestic animals, throughout the archipelago during stays of one to three days. Locations where observational transects were conducted during expeditions included: London Island; Romanche Bay (Gordon Island); Ventisquero Sound, Pía Sound, Olla Cove and Yendegaia Bay (TDF); Islotes Holger; Parque Omora, Inútil Bay, Wulaia Bay and Douglas Bay (Navarino); Jemmy Button Island; Orange Bay and Ponsonby Sound (Hoste Island); Mascart Island; Kendall Cove (Wollaston Island); Puerto Dillon (Grevy Island); Victoria and Washington Channels (Bayly Island); Puerto Maxwell and Saint Martin Cove (Hermite Island); Martial Cove (Herschel Island); and Cape Horn Island (for details see Table A.3, Appendix).

All survey and observational information was geo-referenced in order to utilize GIS to produce distribution maps. Maps were then used to identify areas free of exotics and also recognize the species that were particularly widespread and independent of human association. In addition, collected field data were supplemented with a bibliographic review and questionnaires of local residents, sailors, fishermen and scientists. Non-native species under domestic or animal husbandry practices, such as sheep or chickens, were not considered in the analysis because they are kept exclusively in enclosures. On the other hand, pigs, cows, dogs, cats and horses were examined because many also have become feral or are free ranging.

Results

Human inhabited islands – Navarino and Tierra del Fuego

We identified a total of seventeen exotic vertebrate species, including mammals, birds and freshwater fish, inhabiting Cape Horn County, Chile (Table 2.1). No native or introduced amphibians or reptiles were discovered in the study area. The twelve recorded exotic mammal species represented a majority (55 %) of the total mammalian assemblage (22 total spp.) (Table 2.2). Rodents and carnivores contributed the most introduced species with four non-native species each.

Two typically associated human rodents, *Rattus norvegicus* and *Mus musculus*, were found only in Puerto Williams on Navarino Island. Likewise, the only wild exotic birds detected in the whole study area were the rock dove (*Columba livia*) and the house sparrow (*Passer domesticus*), which were confined to Puerto Williams. The rock pigeon (*C. livia*) was introduced deliberately by residents of Puerto Williams during the past decade, while *P. domesticus* probably crossed from the Argentine portion of Tierra del Fuego (TDF). These two exotic birds made up only 1.3 % of the approximately 154 native bird species that inhabit terrestrial and coastal areas of the archipelago (Couve & Vidal 2003). The introduced grey fox (*Pseudalopex griseus*), which is native to the continental mainland of South America, was only found in the study area at Yendegaia Bay on TDF.

Table 2.1 Summary of introduced vertebrate fauna recorded for Cape Horn County, Chile with their mode of arrival and source of information. 1. Omora database 2. Canclini 1999, 3. Rozzi & Sherriffs 2003, 4. Sielfeld & Venegas 1980, 5. Sielfeld 1977, *indicates reliable fisherman report.

Introduced vertebrate species of Cape Horn County, Chile			
Order	***Scientific name***	**Common name**	**Source(s)**
	MAMMALS		
Artiodactyla	*Sus scrofa*	Feral pig	1
	Bos tarus	Feral cow	1
Carnivora	*Canis lupus familiaris*	Feral dog	1, 2
	Felis domesticus	Feral cat	1
	Mustela vison	American mink	1, 3
	Pseudalopex griseus	Patagonian grey fox	1
Lagomorpha	*Oryctolagus cuniculus*	European rabbit	1
Perissodactyla	*Equus caballus*	Feral horse	1
Rodentia	*Castor canadensis*	North American beaver	1, 4, 5
	Ondatra zibethica	Muskrat	1, 5
	Mus musculus	House mouse	1
	Rattus norvegicus	Norway rat	1
	FRESHWATER FISH		
Salmoniformes	*Salmo trutta*	Brown trout	1
	Oncorhynchus mykiss	Rainbow trout	1
	Salvelinus fontinalis	Brook trout	1*
	BIRDS		
Passeriformes	*Passer domesticus*	House sparrow	1
Columbiformes	*Columba livia*	Rock pigeon	1

Among freshwater fishes, we identified three exotic species, which represented 75 % of the archipelago's total assemblage. Only one native species (*Galaxias maculatus*) was confirmed within the county, while three more were described for the adjacent area of Argentina by Cussac et al. (2004). The exotic freshwater fish fauna in the study area were all Northern Hemisphere trout (Salmoniformes), including brown (*Salmo trutta*), rainbow (*Oncorhynchus mykiss*) and reliable fishermen accounts of brook (*Salvelinus fontinalis*) (Table 2.3). No exotic fish were found in the western portion of the county on Hoste or Tierra del Fuego Islands. The only water bodies found to have trout were on Navarino Island and included: 1) Windhond watershed (brown and rainbow), 2) Robalo River below the dam (rainbow), 3) Navarino Lake (brook), 4) Mejillones River (rainbow), 5) Faraónes River (rainbow), 6) Lum River (rainbow), 7) Pilushejan River (rainbow) and 8) Douglas River (brown). In addition, several bog lakes along the north coast of the island, which are unconnected to adjacent water courses, contained brown and rainbow trout.

Table 2.2 Native and exotic mammals of Cape Horn County, Chile. TDF indicates Tierra del Fuego and the other names refer to islands in the archipelago. 1. Omora database, 2. Allen 1905, 3. Cabrera 1961, 4. Olrog 1950, 5. Patterson et al. 1984, 6. Peña & Barría 1972, 7. Reise & Venegas 1987, 8. Sielfeld 1977, 9. Sielfeld 1984, 10. Thomas 1916.

Mammals order	**Native species**		**Site**	**Exotic species**		**Site**
	Scientific name	**Common name**		***Scientific name***	**Common name**	
Artiodactyla	*Lama guanicoe*	Guanaco	TDF & Navarino[1]	*Sus scrofa*	Feral pig	Navarino, Hoste & Gordon[1]
				Bos tarus	Feral cow	TDF & Navarino
Carnivora	*Lontra provocax*	Large river otter	TDF, Grevy, Picton, Lennox, Wollaston, Hermite[4], Grevy & Gordon[9]	*Canis lupus familiaris*	Feral dog	TDF, Navarino, Hoste & Horn[1]
	Lontra felina	Sea otter	TDF, Hoste, Grevy, Picton, Wollaston[1], Bayly, Hermite, Herschel[4], Grevy & Gordon[9]	*Felis domesticus*	Feral cat	Navarino & Horn[1]
	Pseudalopex culpaeus lycoides	Fuegian red fox	TDF & Hoste[4]	*Mustela vison*	American mink	Navarino, Hoste & Argentine TDF[1]
				Pseudalopex griseus	Grey fox	Yendegaia, TDF[1]
Lagomorpha				*Oryctolagus cuniculus*	European rabbit	Yendegaia, TDF & Navarino[1]
Perissodactyla				*Equus caballus*	Feral horse	TDF & Navarino[1]
Chiroptera	*Histiotus montanus*	Eared bat	TDF, Navarino[4,6] & Wollston[4]			
	Myotis chiloensis	Chiloé bat	TDF, Navarino[4,6] & Grevy[4]			

Table 2.2. *continued.*

Mammals order	Native species		Site	Exotic species		Site
	Scientific name	**Common name**		***Scientific name***	**Common name**	
Rodentia	*Abrothrix xanthorhinus*	Yellow-nosed mouse	TDF, Navarino1 & Hoste[3,8]	*Castor canadensis*	North American beaver	TDF, Navarino, Hoste, Picton, Nueva & Lennox[1]
	Akodon hershkovitzi	Cape Horn mouse	Herschel, Hermite & Horn[1, 5]	*Ondatra zibethica*	Muskrat	TDF, Navarino, Hoste, Picton, Nueva & Lennox[1]
	Euneomys chinchilloides	Fuegian chinchilla mouse	TDF, Wollaston, Hermite & Hoste[1]	*Mus musculus*	House mouse	Puerto Williams, Navarino[1]
	Oligoryzomys longicaudatus	Long-tailed mouse	TDF[7], Wollaston[1], Hermite[3,10]	*Rattus norvegicus*	Norway rat	Puerto Williams, Navarino[1]
TOTAL	10			12		

Table 2.3 Native and exotic freshwater fish fauna found in Cape Horn County, Chile. *G. maculatus* is the only native fish confirmed for the study area: 1. Omora database, 2. Jenyns (1842), 3. Vila et al. (1999), 1*indicates species only cited for areas adjacent to Cape Horn County, Chile in the Argentine portion of Tierra del Fuego (Cussac et al. 2004). When not otherwise noted, sites are located on Navarino Island.

Freshwater fish order	Native species		Site(s)	Exotic species		Site(s)
	Scientific name	**Common name**		***Scientific name***	**Common name**	
Osmeriformes	*Galaxias maculatus*	Common galaxia	Navarino I.[1], Hardy Peninsula (Hoste I.)[2] & TDF[3]			
	*Galaxias platei**		Roca, Escondido, Fagnano, Yehuín & Margarita Lakes(Argentine TDF)			
	*Aplochiton taeniatus**		Argentine coast of Beagle Channel on TDF			
	*Aplochiton zebra**		Area near Fagnano Lake (Argentine TDF)			
Salmoniformes				*Salmo trutta*	Brown trout	Pilushejan, Mejillones, Windhond and Douglas Rivers[1]
				Oncorhynchus mykiss	Rainbow trout	Lum, Guanaco, Mejillones, and Róbalo Rivers[1]
				Salvelinus fontinalis	Brook trout	Navarino Lake
TOTAL	1 (3*)			3		

Feral animals

While feral domestic animals were most abundant on Navarino and Tierra del Fuego, they were not strictly confined to those human-inhabited islands. We discovered, for example, scat and rooting disturbance from *Sus scrofa* at Romanche Bay on uninhabited Gordon Island in the western portion of the county and on Hoste Island. Pet dogs and cats likewise are being kept at isolated military outposts and ranches throughout the archipelago, such as Hoste, Horn, Lennox, Picton and Wollaston Islands. A similar native terrestrial predator (the Fuegian red fox, *Pseudalopex culpaeus*) only inhabited Hoste and Tierra del Fuego Islands.

On Navarino Island, dogs were found in all types of habitats, ranging from sea-level to above tree line. Cats, likewise, were observed even in remote forests. On several occasions they were seen preying upon songbirds in the Omora Ethnobotanical Park, Puerto Inútil and the small Holger Islands off the northwest coast of Navarino Island. *Sus scrofa*, the feral hog, was detected mostly around the northern and western coastlines of Navarino Island, especially in coastal, shrub and mixed forest habitats. Human-inhabited Navarino and Tierra del Fuego Islands were also the only locations where the European rabbit (*Oryctolagus cuniculus*) was seen. At Yendegaia Bay, they were commonly found along river and coastal shorelines. Rabbits were once common on Navarino Island, as well, but they were virtually eliminated with the viral control program conducted in the 1950s. In 2004, however, we observed rabbits on several occasions on the northwestern tip of the island, and they may be a new introduction from an adjacent ranch.

Mink, beaver and muskrat

Based on surveys and mapping, we determined that three of the most widespread or potentially harmful exotic vertebrate species found in the archipelago were the North American beaver (*Castor canadensis*), the American mink (*Mustela vison*) and the muskrat (*Ondatra zibethica*). All three were brought from North America by the Argentine government in the 1940s and 1950s as part of an effort to introduce economically valuable furbearers. Once survey information was geo-referenced and mapped, it was also realized that these species had the widest distributions of any exotic species in the archipelago and were the least associated with human settlements.

We first confirmed the presence of mink in Cape Horn County in 2001 on Navarino Island (Rozzi & Sherriffs 2003). During transects conducted in the austral summer of 2004 and 2005, we sighted mink or their tracks along the major watercourses of Navarino Island (Fig. 2.2). Surveys and trapping also found them in the town of Puerto Williams and Omora Ethnobotanical Park, and one was observed on Hoste Island. On Navarino Island their densities ranged from 0.79 to 1.32 individuals per kilometer along coastal shoreline habitat, which river riparian habitat had a lesser density of 0.26/km. Minks are known also for the Argentine portion of Tierra del Fuego (Massoia & Chebez 1993, Lizarralde & Escobar 2000), but were not detected during our trapping and surveys in the Chilean portion of the island at Pia Sound, Olla Cove and Yendegaia Bay. Residents of the national police outpost at Yendegaia Bay reported never having seen them.

Beaver were detected easily given their dam building and foraging activities. They were found in every watershed on Navarino, Picton, Nueva and Lennox Islands. On Tierra del Fuego and Hoste Islands, their distribution is limited towards the western and southern portions of the study area (Fig. 2.3). Overall, their distribution extended in the east from Nueva Island to the western tip of Hoste Island (see eastern and western extremes in Fig. 2.3). Parts of the western portion of the Beagle Channel and the extreme, marginal islands along the Pacific Ocean have yet to be invaded. The distribution currently reaches its southern terminus at Orange Bay on Hoste Island, and the Wollaston Island group, which makes up part of Cape Horn National Park, has not yet been colonized.

Fig. 2.2 Distribution of American mink (*M. vison*) in Cape Horn County, Chile. The shaded portion shows the county's area. Black dots indicate confirmed mink presence; white squares with black dots indicate their confirmed absence.

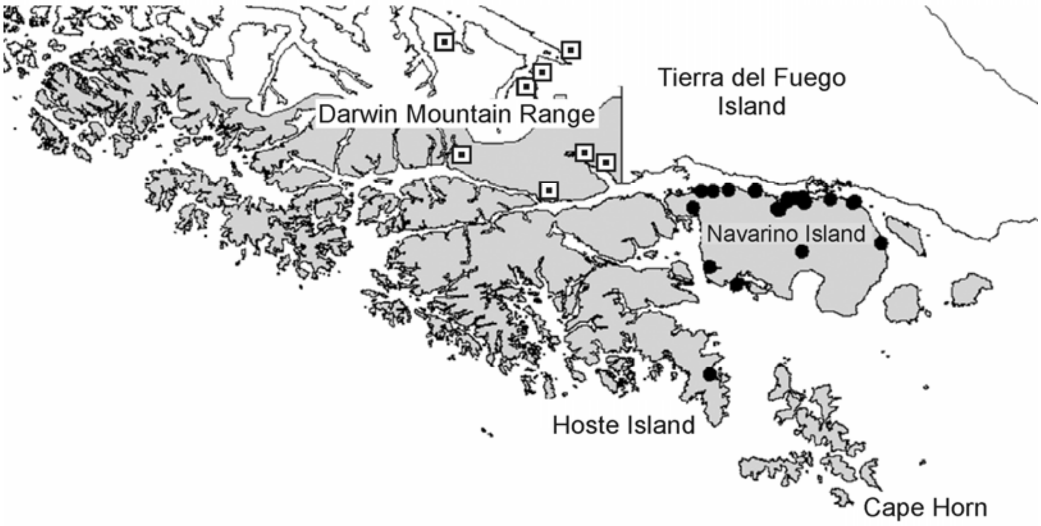
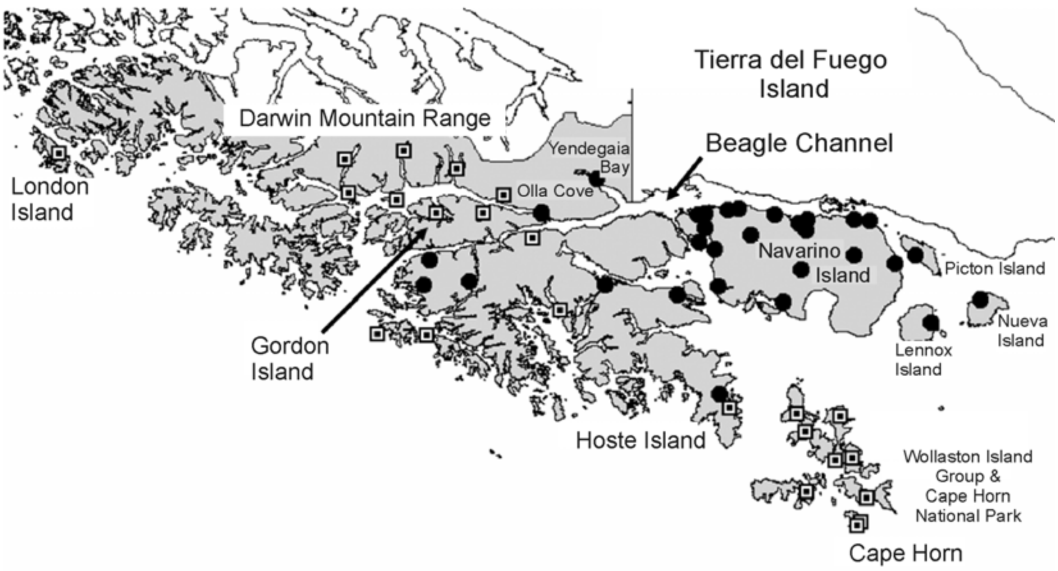


Fig. 2.3 Distribution of beaver (*C. canadensis*) in Cape Horn County, Chile. The shaded portion shows the county's area. Black dots indicate confirmed beaver presence; white squares with black dots indicate their confirmed absence.



Burrowing activity by muskrats (*O. zibethica*) and skeletal remains were evident in peat lands (*Sphagnum* spp.) and cushion bogs on Navarino and Hoste Islands. However, muskrats, like beavers, were not found to inhabit the western portion of the survey area, such as the southwestern portion of TDF, or the far southern Cape Horn National Park.

Finally, an important bibliographic review concerning exotic species in Chile reported that reindeer (*Rangifer tarandus*) were brought to Navarino Island in 1972 (Jaksic 1998), but we confirmed that this record was erroneous. A plan did exist to introduce reindeer, but the Chilean navy suspended the project. The individuals remained on the continent, eventually dying there (N. Soto, Wildlife Division Chief, Regional Agriculture and Livestock Service, personal comment).

Discussion

Lessons and implications of invasion

Lesson 1: barriers to invasion

Beavers have been able to colonize much of the county and at very high densities (Skewes & Olave 1999). The lack of native predators, combined with their relatively high reproductive rates (up to eight offspring per year, Long 2003), allowed beaver populations to grow explosively after initial introduction in the 1940s. In addition, the habitat of the sub-Antarctic forests is very similar to the beaver's native range, and their ability to swim up to 5 miles across water bodies (Long 2003) has facilitated their expansion throughout the archipelago.

In terms of their impacts, "naïve" vegetation in southern Chile lacks a common evolutionary history with the beaver and, therefore, appears be more vulnerable to herbivory and flooding. While in North America some plants, such as the trembling aspen (*Populus tremuloides*), produce defensive chemicals in response to beaver foraging that in turn deters future impacts and allows regeneration (Basey et al. 1988), sub-Antarctic forests are totally suppressed and do not regenerate for at least a couple of decades, if at all (Lencinas et al. 2001). In addition, we have found that the herbaceous community assemblage associated with beaver meadows actually increases the number of exotic plants present in the riparian assemblage, which presents a case of one exotic species facilitating others (C.B. Anderson, unpublished data).

The ability of this species to disperse across the Fuegian Archipelago is well documented (Skewes & Olave 1999). Therefore, it is informative to note where we did not find them six decades after the initial introduction. Fig. 2.3 showed the sites where we have confirmed the beaver's presence and absence in Cape Horn County. To the west and southwest they have not been successful at colonizing, while farther north in Tierra del Fuego they have been able to travel far greater distances and even arrive to the Brunswick Peninsula on the continental mainland (Skewes & Olave 1999). In addition, beaver have not been found in Cape Horn National Park (the Wollaston Island group), even though they were present on adjacent Hoste Island and as far east as Nueva Island.

These characteristics of the beaver's geographic distribution indicated that the colonization of certain parts of Cape Horn County is not due to a lack of dispersal ability, but rather intrinsic local conditions that do not permit establishment of viable populations. The uncolonized portion of the county typically receives greater precipitation and has steeper topography. The vegetation community is Magellanic rainforest, typical of the western channels, where the floral assemblage is dominated by *Nothofagus betuloides* and *Drimys winteri* (Rozzi et al. 2004a). Often these forests are also stunted by the strong, constant winds that buffet the seaward side of the county. Physical parameters, such as rainfall and geomorphology, and biological characteristics, such as vegetation assemblage, could act together to create an ecological barrier that would explain why this habitat has not proven suitable for beaver establishment.

Lesson 2: passing undetected

The case of the mink is somewhat different than that which was previously described for the beaver, but demonstrates another lesson of species invasions. Mink began to be introduced to Tierra del Fuego in the 1940s (Lizarralde & Escobar 2000), but even as recently as the early 1990s, Massoia & Chebez (1993) still classified it as a "species of hypothetical or doubtful presence" on Tierra del Fuego Island. Since then, it has not only been confirmed on Tierra del Fuego, but today it is also frequently sighted on adjacent islands in the archipelago (Rozzi & Sherriffs 2003).

Like the beaver, mink have a relatively high fecundity rate (Long 2003). As carnivores introduced onto islands that often lack native predators (only Tierra del Fuego and Hoste Islands have native populations of the fox *Pseudalopex culpaeus* and native otter populations were brought to near extinction due to over-hunting), minks are flourishing in the abundant shoreline and freshwater ecosystems. While *M. vison* is known to utilize aquatic habitats to forage, its dispersal across large, marine water bodies, such as the Beagle Channel (average width approximately 5 km), was an unexpected discovery. We would have predicted that while it may have become an invasive species on Tierra del Fuego, where it was directly introduced, its limited dispersal ability to other islands would have restricted its overall distribution.

The fact that it has been able to establish itself without early detection by scientists and managers and to colonize several islands adjacent to its Tierra del Fuego source population in only a few years, therefore, is quite striking and alarming. This exotic carnivore raises particularly acute conservation concerns. In the Aysén Region of Chile detrimental impacts on bird diversity and abundance have been recorded after the arrival of mink, and consequently it is considered a harmful species (SAG 2001). The islands of the Cape Horn area host an abundant and diverse marine, coastal and terrestrial avifauna that evolved without significant terrestrial predators. Many songbird species, such as the austral thrush (*Turdus falcklandii*) and rufous-collared sparrow (*Zonotrichia capensis*), as a result use ground nests in the austral archipelago (S. McGehee, unpublished data), while in other parts of Chile the same species nest in trees. Therefore, the impacts of mink on birdlife in Cape Horn County could be even more dramatic, than those experienced in other parts of Chile. Also, mink presence has been shown to affect the distribution of the rare native river otters (*Lontra provocax*) in Argentine lakes (Aued et al. 2003), and Delibes et al. (2004) found that an introduced mink's ecological niche can extend to the intertidal zone, where it would directly compete with sea otters and establish a new top predator throughout the archipelago.

Lesson 3: converting positive feedback loops to negative

In the past, domestic pets have been allowed to be kept by residents stationed in the Cape Horn National Park. The fact that we found dogs and cats at many isolated outposts throughout the archipelago is significant. These introduced predators, for example, caused the extermination of Cape Horn Island's colony of Magellanic penguins (*Spheniscus magellanicus*). However more significantly, this impact may not be limited to one population, but rather could extend to an entire community and ecosystem via an intricate feedback system.

The presence of a penguin nesting colony means the accumulation of penguin feces, which in turn elevates levels of nitrogen in the soil. The tundra soils of Cape Horn are naturally nutrient poor, and it is only in these enriched, penguin-modified areas that the grass species *Poa flabellata* are able to exist (Pisano 1982). *P. flabellata* itself further changes soil characteristics and structure, such as organic content and depth, which in turn permits the establishment of Graminae tundra formations (Pisano 1982). The interrelation of these ecosystem components becomes even more complex when we consider that penguin nesting success is also a product of habitat quality, which includes vegetation cover and the height and density of grasses that protect eggs from predation, temperature extremes and wind (Gandini et al. 1997).

This natural positive feedback loop between penguin presence, Graminae vegetation patches and nesting success for the penguin itself in the Cape Horn Archipelago may become a negative feedback that prohibits the recolonization of the island if steps are not taken to remedy this exotic species impact in Cape Horn National Park. The introduction of an exotic species to Cape Horn Island has the potential to alter an entire biotic assemblage and ecosystem, which is consequently a major economic opportunity vis-à-vis ecotourism, and demands prompt action.

These results together demonstrate the diverse reasons to better understand and more effectively manage the exotic species in Cape Horn County, Chile.

Conclusions

While Jaksic (1998) found that overall Chile hosts few exotic vertebrates (3.9 % of the total), this general trend was not the case in the Cape Horn area, where we discovered seventeen introduced vertebrate species. As a total number, this non-native richness could appear rather minor, when compared to more heavily impacted parts of Chile and the rest of the world. However, when the comparison is made in relation to the quantity of native species richness, the proportional domination of exotic mammals and freshwater fish was striking, 55 % and 75 %, respectively.

Most introduced species were found on human inhabited islands. Those that were associated with human perturbed areas also generally did not appear to greatly affect native populations and ecosystems away from human settlements. On the other hand, several important species did not have distributions closely tied to humans (e.g. beaver, muskrats and mink). Significantly, though, we did find a portion of Cape Horn County that was still unimpacted by exotics. The unimpacted areas largely corresponded to the Cape Horn and Alberto D'Agostini National Parks, but our further finding that some species' ranges, such as the North American beaver, the mink and feral domestic predators, are increasing into the parks serves to underline the globalized threat of exotic species, even in remote areas, when management and control programs are lacking (Rozzi et al. 2004b, Anderson et al. 2005).

These results present us with lessons on how species become invasive and what their new role becomes within non-native ecosystems. Future work should expand on the information presented here to test the underlying ecological mechanisms for the distributions we have discovered. Finally, we hope that our findings serve to re-enforce the case that management and protection of this area is greatly needed. Care should be taken to prevent future introductions, and controlling the dispersal of those already present must be a priority for local and regional authorities.

CHAPTER THREE

Abundance and habitat preferences of the American mink on Navarino Island[2]

Abstract

Since 2001 invasive American mink has been known to populate Navarino Island, an island located in the pristine wilderness of the Cape Horn Biosphere Reserve, lacking native carnivorous mammals. As requested by scientists and managers, our study aims at understanding the population ecology of mink in order to respond to conservation concerns. We studied the abundance of mink in different semi-aquatic habitats using live-trapping (n=1,320 trap nights) and sign surveys (n=68 sites). With generalized linear models (GLMs) we evaluated mink abundance in relation to small-scale habitat features including habitats engineered by invasive beavers (*Castor canadensis*). Mink have colonized the entire island and signs were found in 79 % of the surveys in all types of semi-aquatic habitats. Yet, relative population abundance (0.75 mink/km of coastline) was still below densities measured in other invaded or native areas. The habitat model accuracies indicated that mink were generally less specific in habitat use, probably due to the missing limitations normally imposed by predators or competitors. The selected models predicted that mink prefer to use shrubland instead of open habitat, coastal areas with heterogeneous shores instead of flat beaches, and interestingly, that mink avoid habitats strongly modified by beavers. For the management of mink, we suggest the establishment of rocky coastal shores as priority sites deserving special conservation efforts. Further research is needed with respect to the immigration of mink from adjacent islands and to examine facilitating or hampering relationships between the different invasive species present, especially if an integrative management is sought.

Key words: exotic species, capture-mark-recapture, *Castor canadensis*, management, *Mustela vison*, population size, sign surveys, trapping, wetlands

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[2] This chapter has been submitted as Schüttler E, Ibarra JT, Gruber B, Rozzi, R, Jax K „Abundance and habitat preferences of the southernmost population of American mink, a recent invasive species on Navarino Island, Chile“, in Biodiversity and Conservation.

My contribution: I carried out field work concerning trapping and sign surveys in semi-aquatic habitats, analyzed the data, and wrote the paper. Tomás Ibarra contributed with additional data of sign surveys at lakes and ponds, including the seasonal monitoring at lakes. Bernd Gruber guided the statistical analysis. Ricardo Rozzi and Kurt Jax supervised the study.

Introduction

In the past 200 years, the numbers of species that have entered new ranges through human agency have increased enormously. Although many exotic species are an integral component of our global economy, biotic invasions can cause fundamental changes in native biodiversity (Vitousek et al. 1997, Sala et al. 2000). The largest part of biodiversity loss occurs on islands, where indigenous species have often evolved in the absence of competition, herbivory, parasitism or predation (Elton 1958, Courchamp et al. 2003, Sax et al. 2007). Therefore, predatory mammal invaders on islands are seen particularly as a major factor for reducing populations of native species, and thus often provoke high conservation concern (Macdonald & Thom 2001, Krajik 2005).

The American Mink (*Mustela vison*) is a semi-aquatic carnivorous mustelid native of North America and introduced to South America as a fur bearer, with feral populations still restricted to the southern parts of Chile and Argentina (Jaksic et al. 2002). The mink represents a recent invasion on Navarino Island within the Cape Horn Biosphere Reserve (Rozzi et al. 2006a). Liberated or escaped animals from mink farms on the Argentine side of Tierra del Fuego might have swum across the Beagle Channel (ca 5 km wide) probably reaching Navarino Island during the mid-1990's, and first registered by scientists in 2001 (Rozzi & Sherriffs 2003). The native mammal assemblage on the island is extremely low in its number of species and lacks mustelids or other carnivores (Anderson et al. 2006a); sea otters (*Lontra felina*) are mainly associated with the Wollaston and Cape Horn Islands (Rozzi et al. 2006a). This situation has two consequences: firstly, mink have no natural enemies on the island (apart from anecdotes of predation by feral dogs), and secondly, mink have no competitors.

Among the biotic factors regulating populations are direct (e.g. predation, interference competition) and indirect (e.g. trophic webs, exploitative competition) interactions. Predation can be excluded for mink on Navarino Island, and therefore we assume the establishment of mink to be facilitated. Interspecific competition that plays a predominant role in carnivores leading to direct aggressive interactions (Palomares & Caro 1999) is also missing for mink on the island. As one of the factors determining habitat use of mink is inference from competitors (Dunstone & Ireland 1989, Sidorovich et al. 1996, Bonesi & Macdonald 2004) the absence of other mustelids on Navarino should influence its habitat requirements, i.e.,allowing the mink to be less specific. The aim of this study was to quantify and discuss these two parameters, abundance and habitat preferences, in the initial phase of the invasion of mink representing a new guild of terrestrial mammalian predators on Navarino Island.

Although the ecology of mink as an invasive species is well studied in some European countries, especially the UK (e.g. Yamaguchi et al. 2003, Reynolds et al. 2004, Bonesi et al. 2006a, b), systematic data on its population ecology in the Cape Horn region are still missing. The need for these data has been expressed by scientists and public agencies currently supporting the implementation of control strategies for invasive mammals in the Cape Horn Biosphere Reserve (Anderson et al. 2006a, Rozzi et al. 2006a, Soto & Cabello 2007). Specific requests are population estimations in order to define target numbers to be removed, data helping to improve the trappability success (e.g. season-dependent effectiveness of trapping), habitat preferences, and relationships between different introduced mammal species (invasional meltdown hypothesis by Simberloff & Von Holle 1999). Among the latter relationships there is a particular interest in whether beaver engineering (*Castor canadensis*) would improve habitats for the mink, by creating slow-flowing ponds and burrows (as shown by Żurowski & Kammler 1987, Sidorovich et al. 1996). The interest also arises from the current plans for total eradication of beavers from Chilean and Argentine Tierra del Fuego Island and adjacent islands within the Cape Horn Archipelago (Choi 2008).

Major conservation concerns are derived from studies on the impact of mink conducted in Europe (see review in Bonesi & Palazon 2007). The authors report reductions in populations of ground-nesting waterbirds (Craik 1997, Ferreras & Macdonald 1999, Nordström & Korpimäki 2004), water voles (*Arvicola terrestris*, Jefferies 2003), fish and crustaceans (Delibes et al. 2004), and amphibians (Ahola et al. 2006). In South America, studies on the impact of mink are still scarce, but mink are considered to be detrimental to waterbirds (Lizarralde & Escobar 2000, Rozzi & Sherriffs 2003), and perhaps to southern river otters *Lontra provocax* (Previtali et al. 1998, but see Medina 1997, Fasola et al. 2009). Studies on the diet of mink on Navarino Island (Schüttler et al. 2008, Ibarra et al. 2009) confirm those concerns, demonstrating relatively high numbers of birds in the spring and summer diet of mink, a possible result of prey naivety to the new terrestrial predator (e.g. ,Nordström et al. 2004, Schüttler et al. 2009).

In this paper, we describe (1) the relative abundance of *Mustela vison* in different semi-aquatic habitats of Navarino Island; (2) the relationship between mink abundance and small-scale habitat features; and (3) the relation between beaver habitats and mink abundance. The study will provide practical information indispensable for the design of a management plan. Finally, the results can be used to predict habitats favoring the invasion of American mink in the Cape Horn Biosphere Reserve and elsewhere.

Study area

The study was carried out on Navarino Island (2,528 km^2), located at the extreme southern tip of South America. The island forms part of the Cape Horn Biosphere Reserve (54°-56°S) and belongs to the Magellanic Sub-Antarctic Evergreen Rainforest ecoregion, recently identified as one of the 24 most pristine wilderness areas of the world (Mittermeier et al. 2003). The main habitats include (i) evergreen rainforests dominated by *Nothofagus betuloides* and *Drimys winteri*, (ii) Magellanic deciduous forests of *Nothofagus pumilio*, (iii) peatlands, moorlands and bogs, (iv) high-Andean vegetation communities dominated by cushion plants and lichens, (v) streams and lakes, and (vi) thickets or shrublands in naturally or anthropogenically disturbed areas (Pisano 1977, Rozzi et al. 2006a). The climate type is oceanic, with a low annual thermic fluctuation (< 5°C), a mean annual temperature of 6°C, and an annual precipitation of 467.3 mm (Pisano 1977). During winter, streams and lakes are ice-bound. The human population of approximately 2,300 people is concentrated in the settlement of Puerto Williams, capital city of the Chilean Antarctic Province, on the northern coast of Navarino Island. A small fishing village, Puerto Toro, exists on the eastern coast of the island. Outside these towns, human settlements are limited to rural houses, and some Navy stations. Access to the settlements and other areas relies mostly on shipping, except for a dirt road that connects the northern coast of Navarino Island. Therefore, our research was concentrated in the northern part of the island.

As mink are semi-aquatic mustelids, our study sites comprised shorelines of marine coasts, river banks, lake and pond margins. The habitat adjacent to the water's edge included meadow communities, shrubland dominated by *Berberis buxifolia*, *Pernettya mucronata* and *Chiliotrichum diffusum* (Moore 1983), peatlands (*Sphagnum* spp.), evergreen and deciduous forests dominated by the genus *Nothofagus* (basically found in the northern part of the island), and habitats modified by beavers. Beaver foraging for both food and construction activities in *Nothofagus* forests clears trees and alters the riparian community structure (Anderson et al. 2006b). This results in greater understory species richness, particularly of exotic plants, and productivity (Martínez et al. 2006, Anderson et al. 2009).

Methods

Capture-mark-recapture

We applied capture-mark-recapture with the aim of estimating the relative abundance of mink. Trapping took place at three sites on the northern coast of Navarino Island: Robalo at the Omora Ethnobotanical Park (54°56'S, 67°39'W), Guerrico (54°54'S, 67°51'W), and Mejillones (54°53'S, 67°58'W), where we selected 4 km of riverside and 4 km of coastline within each study site (n=6 sites). Each trapping session lasted 4-5 nights. Trapping was repeated during all four seasons for coastal sites (April 2005-September 2007), but at rivers we trapped only once during autumn and early winter in 2005 (N=1,320 trap nights during 15 trapping sessions). For each trapping session we used 20 camouflaged Tomahawk traps set at approximately 200 m intervals. Traps were baited with fresh fish and placed at a maximal distance of 10 m from the waters edge. Traps along rivers were placed on one side of the river facing downstream, because presumably animals are more likely to use an overland route when moving up river (Dunstone 1993). Traps were checked every morning. Captured mink were lightly anaesthetized with Ketamine (Drag Pharma Chile), weighed, sexed, measured, and marked with AEG-ID microchips that were injected directly under the skin. Mink were classified as juveniles or adults by their body weight, wearout of teeth, facial characteristics, and presence of grey hair following Halliwell & Macdonald (1996). However, only post-mortem determination of age is an objective method (Dunstone 1993). After full recover the animals were released at the same spot where captured.

Sign surveys

Trapping is a time-consuming estimate of mink abundance and when recapture rates are low sound analysis of capture-recapture data is difficult (Bonesi & Macdonald 2004). Therefore, we complemented abundance estimates with an indirect method, namely sign surveys. Sign surveys are an appropriate way to efficiently estimate distribution and relative abundance of vertebrate carnivores, which are often cryptic, nocturnal and may have large home ranges (review in Wilson & Delahay 2001, Gruber et al. 2008). For American mink sign surveys are recommended when carried out in comparable seasons, and when the aim is to monitor mink populations over large areas (Bonesi & Macdonald 2004). Indirect survey methods based on scats, however, can be seriously problematic due to the possibility of misidentification (Davison et al. 2002, Harrington et al. 2008). For the identification of mink scats and tracks on Navarino Island, this does not represent a challenge as the mammal assemblage does not include other mustelids (Anderson et al. 2006a); and sea otters (*Lontra felina*) are restricted to the Wollaston and Cape Horn Islands (Rozzi et al. 2006a), being only rarely seen in the southern parts of Navarino Island (Yaghan indigenous people, personal communication). We searched for scats and tracks in four different semi-aquatic habitats (n=68 sites): along coastal shores (n=15), river banks (n=9), lake margins (n=31) and pond margins (n=13) (Fig. 3.1) 124 times. In the absence of depth measurements, we classified wetland habitats into lakes when the perimeter was > 1 km and into ponds when ≤1 km. Coastal sites comprised 1.8-4 km shoreline (median 4 km), rivers 1.4-4 km (median 4 km), lakes 1.1-5.8 km (median 2 km), and ponds 0.3-1 km (median 0.8 km). The majority of sites (n=59) were located in the northern part of Navarino Island. The southern part of the island (> 54°06'S, beneath Lake Windhond) was accessed by boat. Lakes and ponds in the interior of the island (including Lake Windhond) were mainly reached through the three trekking trails existing on the island. Study sites were divided into 200 m contiguous sections (Bonesi & Macdonald 2004). Shores and river banks (one bank only) were surveyed up to 5 m from the waters edge. A team of three trained surveyors conducted the surveys. We repeated sign surveys during different seasons at ten lakes each (spring, summer, autumn, winter, 2006), and at twelve coastal sites (autumn 2005 n=3, spring 2005 n=7, spring 2006 n=9, summer 2006 n=7, summer 2007 n=12). For rivers and ponds we relied on summer surveys (2006/07) only.

Systematic errors can arise from the probability of signs being detected by the surveyor in different habitats exhibiting either a consistent positive or negative influence on the results (Thompson et al. 1998, Bonesi & Macdonald 2004). These errors should be particularly avoided when coinciding with a research question. In our case we aimed to investigate habitat preferences of mink on Navarino Island. It is apparent that detectability of scats might correlate with the type of habitat. In order to quantify whether this represented a source of systematic error we used "artificial scats" in a small exemplary experimental design. We distinguished between coastal sites characterized by steep shorelines, cliffs, and rocks (rocky outcrop, n=6 sites), and sites characterized by a basically flat shore and the presence of pebbles, sand or mud (beaches, n=6 sites). We placed 50 artificial scats (pack-twine, 1 cm diameter, 10 cm long) in each 1.5 km rocky outcrop coastal habitat (n=6) and along beaches (n=6), imitating mink habits in the choice of marking places. A second trained surveyor then searched for artificial scats in the twelve study sites, annotating the number of scats found. Our results indicate that the surveyor detected scats independently of the coast type (Man-Whitney-Test: $U=7.5$, $p=0.1$).

During each sign survey 9-15 habitat variables were recorded depending on the semi-aquatic habitat type (Table 3.1). Variables for all sites concerned habitat type, vegetation cover of three different strata, distance to the forest, coarseness of the shoreline and incline, presence of dogs and humans. For rivers, lakes and ponds, we also recorded the influence of beavers, altitude, and distance to the coast; for rivers we additionally estimated water depth, water flow and river width.

Table 3.1 Habitat variables recorded in all sites (coast, rivers, lakes, ponds) and in selected habitats.

Habitat variables	Recorded in	Description and *categories*
HABITAT	All sites	Predominant habitat type 10x5 m^2: *1. Bare: earth/rock* *2. Uniform: pasture, peatland, wetland* *3. Simple: shrubs, grasses, but no mature trees* *4. Complex: evergreen, mixed, deciduous forest*
STRATA 1 STRATA 2 STRATA 3	All sites	Vegetation cover for vegetation strata 1,2 and 3 (0-1 m, 1-5 m, >5 m): *0-20 %, 20-40 %, >40 %*
DIST_FOREST	All sites	Distance to the forest: *<10 m, 10-50 m, 50-100 m, >100 m*
COARSE	All sites	Percentage of cliff, rock, pebbles, sand, mud, vegetation within 10x1 m of the shoreline, merged into one continuous index of coarseness (range 1-6)
INCLINE	All sites	Incline of shore within 10 m from water shed: *Flat, medium, steep*
DOGS	All sites	Presence/absence of dogs
HUMANS	All sites	Presence/absence of human settlement within 500 m
INFL_BEAVERS	Rivers Lakes Ponds	Influence of beavers within 100 m *1. None (absence of beavers)* *2. Low (signs of beaver activity)* *3. Medium (signs of beaver activity and destroyed dams)* *4. Strong (signs of beaver activity and intact dams)*
ALTITUDE	Rivers Lakes Ponds	Altitude [m] measured with GPS

Table 3.1. *continued*.

Habitat variables	Recorded in	Description and *categories*
DIST_COAST	Rivers Lakes Ponds	Direct distance to coast [m] measured with GPS
DEPTH	Rivers	Water depth at 1 m from river bank *<1 m, >1 m*
FLOW	Rivers	Water flow of rivers *None, low, medium, strong*
WIDTH	Rivers	River width *0.5-2 m, 2-5 m, >5 m*

Statistics

Relative abundance of mink was measured as the number of sections (200 m) containing signs per survey. During our sign surveys we searched for tracks and scats and recorded sightings. As the detection of tracks is rather dependent on ground composition and weather conditions (Wilson & Delahay 2001), we used Spearman's rank correlation tests to check whether the combined set of signs was different from surveys that relied on scats only. Seasonal differences were tested with Kruskal-Wallis rank sum tests and Spearman's rank correlations.

The effect of small scale habitat features on mink abundance was examined using generalized linear models (GLMs). Our response variable was mink abundance (presence/absence of scats in 200 m sections). This was a binary variable and thus presumed to follow a binomial distributional family with a logit link function in the GLMs. We designed three different candidate models (Table 3.2) guided by the following hypotheses: (1) mink should favour a high vegetation cover (Previtali et al. 1998, Yamaguchi et al. 2003); (2) they should be most commonly associated with heterogeneous rocky shorelines (Allen 1984, Bonesi et al. 2000, Moore et al. 2003, Fasola et al. 2009); (3) beavers should improve the habitat quality for mink (Żurowski & Kammler 1987, Sidorovich et al. 1996); and (4) the more suitable riverine habitats should be shallow, slow-moving bodies of water (Dunstone 1993). The first and second hypothesis could be tested by the full data set of the four semi-aquatic habitats, the third one excluded coasts from our data set, and the fourth hypothesis concerned merely river characteristics. In order to build models containing as few parameters as possible (Crawley 2007), in the second and third models (M2, M3) we only included variables that had proved significant in the previous models (M1, M2). We primarily performed principal component analysis (PCA) as an explanatory tool to identify suitable variables. Thus, we excluded variables with a strong correlation (Spearman's rho > 0.6) (Fielding & Haworth 1995) and less biological relevance for mink. To perform the PCA we used the ade4 package rewritten for the R environment (R Development Core Team 2008). The model selection procedure was based on Akaike's Information Criterion (AIC), a statistical method that rewards parsimony by penalizing the maximum likelihood for the number of model parameters (Akaike 1973). The predictive model accuracy was assessed by constructing relative operating characteristics (ROC) curves (e.g. Mason & Graham 2002). The area under the ROC curve is expressed as an AUC value (Area Under the ROC Curve) that characterizes the quality of a forecast system by describing the system's ability to anticipate correctly the occurrence or non-occurrence of pre-defined events. When the model (forecast system) has some skill, the AUC value will exceed 0.5. For the interpretation of AUC values we can use the following categories (Hosmer & Lemeshow 2000): $0.7 \leq AUC \leq 0.8$ = acceptable; $0.8 \leq AUC \leq 0.9$ = excellent; $0.9 \leq AUC < 1.0$ = outstanding. Analyses of variance tables were used to present significant model terms.

To evaluate which of the categories of the significant habitat variables was preferred by mink, we calculated the ratio of mink presence and the availability of the habitat feature. For example, the availability of shrubland (the "simple" habitat type, see Table 3.1) was 209 out of 611 cases with a mink presence of 59 out of 124 cases (presence only) yielding a ratio of 1.39. We tested for significance with two-sample tests for equality of proportions with Bonferroni corrections. All statistical analyses were performed using the R statistical software 2.7.1. (R Development Core Team 2008), p-values were considered as significant when < 0.05.

Table 3.2 Candidate models for predicting mink habitat preferences corresponding to different hypotheses. An explanation of the habitat variables is given in Table 3.1.

Candidate models GLM	Data set	n	Variables of fitted models
Null model			Intercept only
M1	Coast, lakes, rivers, ponds	611	HABITAT + STRATA1 + DIST_FOREST + COARSE + INCLINE + DOGS
M2	Lakes, rivers, ponds	333	HABITAT + COARSE + INCLINE + ALTITUDE + DIST_COAST + INFL_BEAVERS
M3	Rivers	139	HABITAT + COARSE + INCLINE + INFL_BEAVERS + DEPTH + FLOW + WIDTH

Results

In total, 21 individual mink were trapped 25 times during 15 trapping sessions (N=1,320 trap nights) in six study sites. All captured mink were of the normal wild type, i.e.,dark-brown in color. Adults (n=10) were mainly captured during autumn (n=8), and juveniles (n=11) during summer (n=8). The overall sex ratio of the catches was 2.5 males (n=15) to one female (n=6). Females usually weighed 0.5-0.7 kg, and males 0.5-1.3 kg.

Trappability in coastal sites was highest during autumn and summer yielding in a median relative mink abundance of 0.75 individuals/km (ranges 0.5-1.25 for autumn, and 0.0-1.25 for summer) (Table 3.3). Although we set traps at rivers during autumn when mink were frequently trapped in coastal sites, the relative abundance of mink was low with 0.0 and 0.25 individuals/km along riparian shores. Due to the presence of raptors (e.g. *Milvago chimango*, *Caracara plancus*) in our study sites traps were frequently disturbed (e.g. bait missing, closed door). When excluding disturbed traps from our analysis median trapping success was 4.0 (2.17-6.25) captures/100 trap nights compared to 3.0 (2.0-5.0) (all traps set) at coastal habitats during autumn, and 3.9 (0.0-8.47) compared to 3.75 (0.0-6.25) at coastal habitats in summer. For rivers, the exclusion of disturbed traps made no big difference (0.52, range 0.0-1.06 with disturbed traps excluded versus 0.5, range 0.0-1.0 with all traps set).

Table 3.3 Results of live trapping in three sites of costal habitat with seasonal repetitions, and three sites along river banks during autumn/winter in the northern part of Navarino Island (n=15 trapping sessions). ROB=Robalo, GUE=Guerrico, MEJ=Mejillones.

Site	Total length (km)	Habitat	Year	Season	Month	Trap nights	Captures	Re-captures	Mink/km
ROB	4	coast	2005	autumn	April	100	3	1	0.75
GUE	4	coast	2005	autumn	April	100	5	2	1.25
MEJ	4	coast	2005	autumn	May	100	2	1	0.5
ROB	4	river	2005	autumn	May	100	1	0	0.25
GUE	4	river	2005	autumn	June	100	0	0	0
MEJ	4	river	2005	winter	July	100	0	0	0
ROB	4	coast	2005	spring	December	80	0	0	0
GUE	4	coast	2005	spring	December	80	0	0	0
MEJ	4	coast	2005	spring	December	80	1	0	0.25
ROB	4	coast	2007	summer	March	80	0	0	0
GUE	4	coast	2007	summer	February	80	3	0*	0.75
MEJ	4	coast	2007	summer	February	80	5	0*	1.25
ROB	4	coast	2007	winter	August	80	0	0	0
GUE	4	coast	2007	winter	September	80	1	0	0.25
MEJ	4	coast	2007	winter	September	80	0	0	0
TOTAL	60 km					1320	21	4	

*4 dead juvenile mink in traps lowered the recapture probability (GUE 1, MEJ 3)

Seventy-nine per cent of all surveys conducted once during summer (2006/07, n=68) contained signs of mink (n=403) (Fig. 3.1). The results show that mink have been able to colonize the whole island starting from their theoretical arrival point in the northern part of the island and reaching the very South of Navarino. From the eastern part of the island where we lacked sign surveys we included a record of a captured mink in the fishing town of Puerto Toro. Scats were also found at high altitudes (577 m) at the lower edge of the high-Andean zone. Surveys relying on scats and surveys recording scats, tracks, and sightings highly correlated with each other, for coastal habitat (S=272.7, n=41, $p < 0.001$, rho=0.98), lake shores (S=2413.4, n=61, $p < 0.001$, rho=0.94), and pond margins (S=0, n=13, $p < 0.001$, rho=1). However, for rivers it made a difference whether surveyors were collecting only scats or additionally tracks (S=73.9, n=9, p=0.31, rho=0.38). Mink sightings occurred only five times in 124 surveys and can therefore be neglected. For further analysis we refer to scat surveys only, assuming that this method is more reliable for comparisons between different types of semi-aquatic habitats (Bonesi & Macdonald 2004).

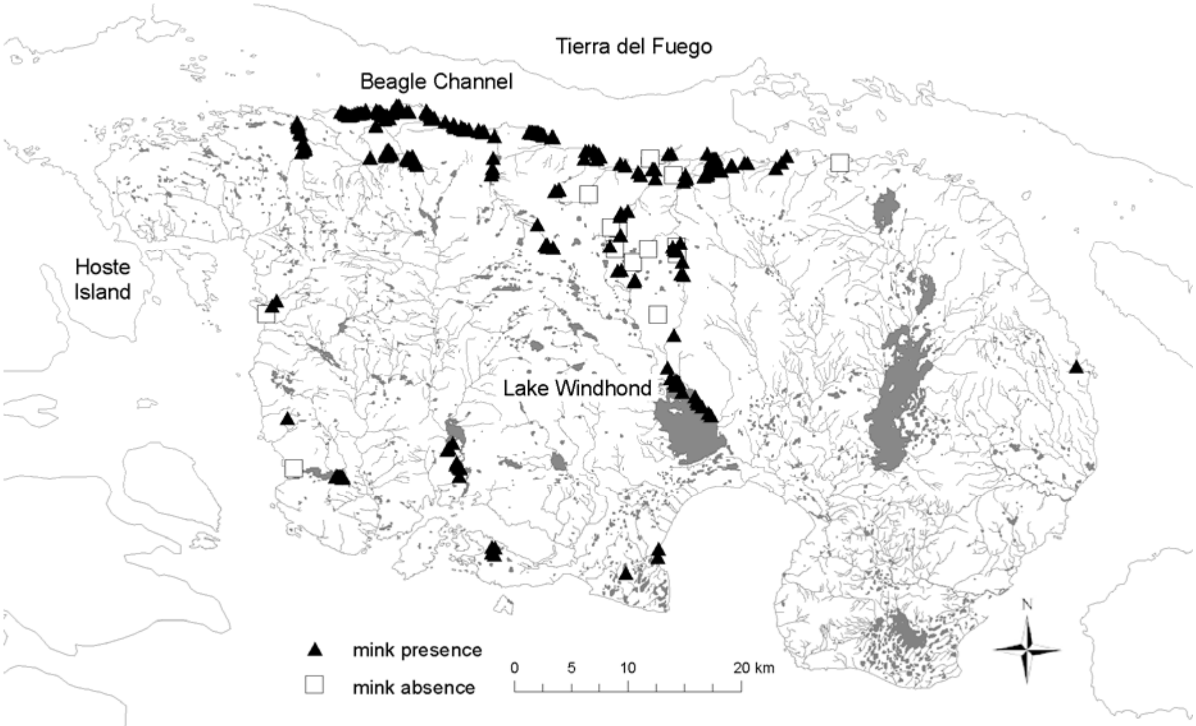

Fig. 3.1 Sign surveys of mink (scats, tracks, sightings, n=68) in different semi-aquatic habitats (coast, rivers, lakes, ponds) during summer 2006/07 on Navarino Island. Mink presence refers to each sign found during the sign surveys (n=403, overlapping triangles due to enlarged size). Minimum transect length was 300 m, maximum transect length 4 km. Mink presence in the eastern part of the island refers to a captured mink in Puerto Toro.

Relative abundance of mink did not differ significantly between the four semi-aquatic habitats (Kruskal-Wallis rank sum test, n=68, λ^2=1.06, df=3, p=0.79) (Fig. 3.2). For coastal habitats we estimated a median of 10 % sections (200 m) with scats (1st Qu.=7.5, 3rd Qu.=40), for rivers 14.3 % (5.6-25), for lakes 15.4 % (3.3-25), and for ponds 20 % (0-50). Ponds and coastal sites showed an especially high variance between different sites of the same semi-aquatic habitat ranging from min. 0 to max. 75 % sections found positive by searching for scats.

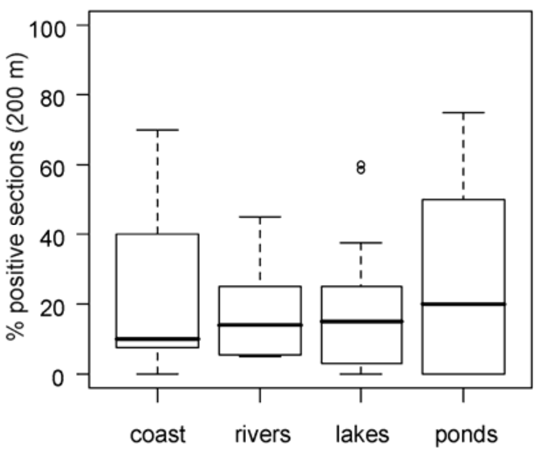

Fig. 3.2 Percentage of 200 m sections found positive by searching for mink scats during summer 2006/07 in different semi-aquatic habitats: coastal (n=15), riparian (n=9), lake shores (n=31), and pond margins (n=13).

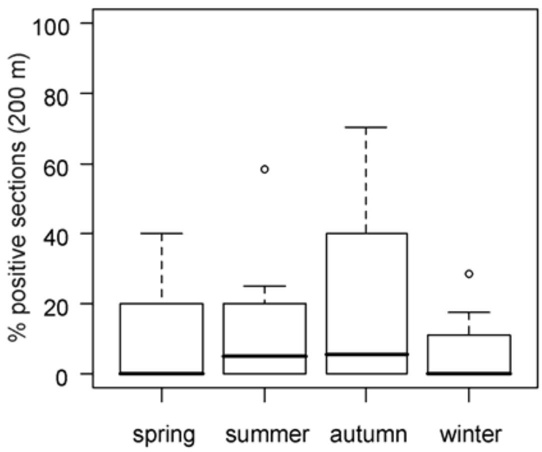

Fig. 3.3 Percentage of 200 m sections found positive by searching for mink scats at lakes (n=10) during different seasons in 2006.

We conducted repetitive sign surveys at ten lakes located in the northern part of Navarino Island and checked whether the proportion of sections with signs of mink varied between seasons. No significant differences between seasons were found (Kruskal-Wallis rank sum test, n=40, $\lambda^2=1.14$, df=3, p=0.77) (Fig. 3.3). Neither did we find evidence for variation between spring and summer surveys at nine coastal sites (North) during 2006/07 (Spearman correlations, S=38.0, n=9, p=0.04, rho=0.68), nor during 2005/06, where correlations were not significant, but showed a positive trend (S=14.8, n=7, p=0.06, rho=0.74).

In order to evaluate small-scale habitat preferences of mink, we built a first Model M1 (Table 3.2), which covered summer presence/absence data (n=611) from all semi-aquatic habitats studied (coast, rivers, lakes, ponds). The first two axes of the PCA explained 50.1 % of the variance. Variables with high loadings (> |0.7|) on the first principal component were habitat type (0.85), vegetation cover of strata two (0.79) and three (0.76), and distance to forest (-0.71), whereas dogs (0.87) and humans (0.86) reached high loadings on the second component. We excluded two variables from the model procedure: humans correlating with dogs, which are possible direct predators and therefore the more proximate variable for mink, and vegetation cover of strata two and three correlating with habitat, the biologically more relevant variable for mink as prey availability depends on the type of habitat. Model accuracy of the most parsimonious model was at the limit of acceptance (AUC=0.65). It included three significant variables: incline, habitat, and coarseness of shoreline (Table 3.4, M1). Dogs, distance to forest and vegetation cover of strata one (0-1 m) did not have a significant effect on mink abundance and were removed by stepwise AIC selection. Thus, among the habitat types available, the simple habitat (shrubs, grasses, but no mature trees) was preferred. Two-sample tests for equality of proportions (all df=1) proved this to be significant (simple versus uniform: $\chi^2=6.24$, $p < 0.05$; simple versus complex: $\chi^2=9.56$, $p < 0.01$). Mink favored steeper shorelines, a difference we found significant (flat versus medium: $\chi^2=10.73$, $p < 0.01$; flat versus steep: $\chi^2=7.28$, $p < 0.05$). Mink also preferred shorelines characterized by a higher degree of coarseness, i.e.,a higher percentage of cliffs and rocks, in contrast to beaches with sand, mud or vegetation as the main substrate ($\chi^2=5.34$, p=0.02) (Fig. 3.4).

Table 3.4 Analysis of variance table for the effects of habitat variables on the abundance of mink modelling summer presence/absence data for three candidate models M1, M2 and M3 (Table 3.1).

Model		Df	Deviance Resid.	Df	Resid. Dev	P(>|Chi|)
M1	*Intercept*			610	616.45	
	INCLINE	1	9.66	609	606.79	0.002**
	HABITAT	3	12.55	606	594.23	0.01**
	COARSE	1	4.45	605	589.79	0.03*
M2	*Intercept*			332	295.20	
	DIST_COAST	1	0.01	331	295.19	0.92
	ALTITUDE	1	4.47	330	290.72	0.04*
	INFL_BEAVERS	1	12.84	329	277.88	<0.001***
M3	*Intercept*			138	121.43	
	INFL_BEAVERS	1	11.76	137	109.67	0.001***
	WIDTH	1	1.03	136	108.64	0.29
	DEPTH	1	5.37	135	103.27	0.02*

*significant at 0.05, ** significant at 0.01, *** significant at 0.001

Model M2 (Table 3.2) was fitted with the three significant variables of the first model and the three additional variables: influence of beavers, altitude, and distance to the coast, valid for rivers, lakes and ponds only (n=333 cases). The first two components of the PCA explained 63.1 % of the variance, and high loading variables for the first component were altitude (-0.85) and distance to coast (-0.78). All variables were entered in this model. The best model reached an AUC value of 0.67. Significant variables of this model were influence of beavers and altitude (Table 3.4, M2). The former significant variables from M1 did not contribute to explain the presence of mink in this scenario, neither was distance to coast of importance. Interestingly, mink preferred habitats without beaver influence. Thus, mink presence was significantly higher where beavers were absent (none versus medium influence: $\chi^2=8.61$, $p < 0.05$). Mink presence was slightly greater in habitats at lower altitudes (< 100 m), but not significantly ($\chi^2=1.52$, $p=0.2$) (Fig. 3.4).

The last model M3 was built for river data only (n=139) containing the significant variables of models M1 and M2, and the additional variables river depth, river flow and river width. The first two axes of the PCA explained 51.8 % of the variance. Variables with high loadings on the first axis were coarseness (-0.85), incline (-0.77), and river flow (-0.77); on the second axis river depth (-0.71). As neither of the variables strongly correlated with each other, we included all variables into the model (Table 3.2). The accuracy of the most parsimonious model was very acceptable (AUC=0.79). M3 again revealed the effect of beaver influence on mink abundance, and river depth as one of the new river variables (Table 3.4, M3). Although mink tended to prefer deeper rivers (Fig. 3.4), this difference was not significant ($\chi^2=0.06$, $p=0.81$).

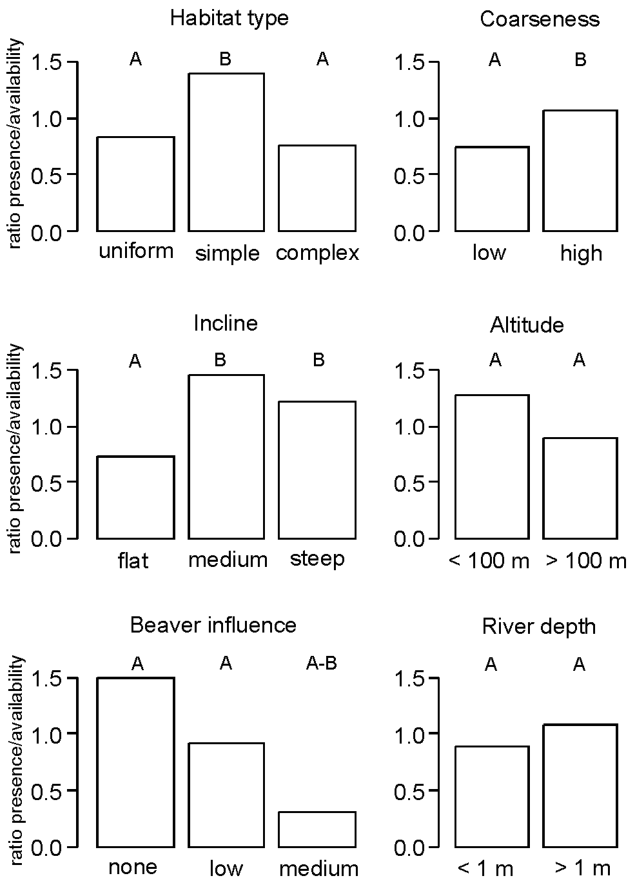

Fig. 3.4 Differences in the preference of different habitat categories of the significant habitat features from model M1, M2 and M3. For each graph different letters above the bars indicate significant differences ($p < 0.05$ with 2-sample tests for equality of proportions) in the ratios of presence of mink versus the habitat availability. Low coarseness refers to indices 1-3, high coarseness to indices 4-6. The categories "bare" habitat type and "high" beaver influence had to be excluded from this analysis due to low sample sizes (≤ 5 % available).

Discussion

Abundance estimations

Our results show that mink have colonized a high proportion of semi-aquatic habitats throughout the island only ten years after the first mink was registered. We used trapping and sign surveys to answer two questions: what type of habitats do mink prefer and how many of them are there? Our data on relative mink abundances along coastal shores (median: 0.75 mink/km for both, autumn and summer, range 0.0-1.25) were lower than studies in Canada, Scotland or Argentina revealed (summary in Table 3.5). Repetitive trapping also lowered the abundance of our preliminary trapping data (0.79-1.32 mink/km at coasts, and 0.26 at rivers) given in Anderson et al. (2006a). Our low relative abundances of maximal 0.25 mink/km along rivers trapped in autumn somehow seem in line with the generally lower densities of mink along rivers and inland lakes in comparison to coastal shores measured in other regions. Here, abundances usually did not exceed one mink/km (Table 3.5), with some exceptions (Smal 1991). As Dunstone & Ireland (1989) argued, the density of mink appears to vary with the productivity of the habitat, i.e., mink occupy larger home ranges when associated with prey-impoverished habitats. This was shown for oligotrophic rivers where home range lengths for male mink reached 2.5 km, in comparison to 1.5 km in coastal habitat (Dunstone & Birks 1985).

Our estimations of relative mink abundances based on sign surveys, however, did not reveal significant differences between rivers and coastline; on the contrary, mink were shown to be rather equally present in different semi-aquatic habitat types. On the one hand, these contradicting results may be based on the low trapping efforts performed at rivers. On the other hand, studies have shown that the proportion of sections with mink signs were only loosely correlated with mink abundance estimated from live trapping (Bonesi & Macdonald 2004, Harrington et al. 2008). Bonesi & Macdonald (2004) recommended that sign surveys at low mink densities might be a better way to estimate the relative density of mink than trapping. In this context, sign surveys might also control seasonal differences as our seasonal surveys at ten lakes were not significantly different in terms of percentages of positive sections (see also Harrington et al. 2008). Yet, trapping success in the same study sites was highly variable, and was dependent on seasonal factors, i.e., reproduction. Maximum abundance was measured during autumn, the mating season, when adult males prevailed, and during late summer, when juveniles predominated (see also Dunstone 1993, Bartoszewicz & Zalewski 2003, Moore et al. 2003). A male bias as in our case is commonly found in mustelid trapping studies (Buskirk & Linstedt 1989). This bias probably arises from the greater home range size (Yamaguchi et al. 2003 measured a male's home range to be 1.73 times larger than that of a female) and increased mobility of males, especially during the mating period (Dunstone 1993). In general, live trapping of American mink likely underestimates population densities as authors report trap avoidance (e.g. Smal 1991, Yamaguchi et al. 2003). Taken together, our results suggest that the population of mink on Navarino Island seemed not to be saturated yet. Comparing our trapping data with data from other areas (see Table 3.5), mink abundance is low, and especially in the light of lacking competitors and predators the carrying capacity on Navarino Island might even be higher.

Table 3.5 Summary of relative mink densities measured as individuals/km by trapping in different semi-aquatic habitats in invaded and native (Canada, USA) areas sorted by ascending mink densities.

Mink density [mink/km]	Habitat	Study site	Source
1.35-2.27	Coast	Canada	Hatler (1976)
2.0	Coast	Scotland	Birks & Dunstone (1991)
1.5	Coast	Argentina	Previtali et al. (1998)
1.1	Coast	Scotland	Moore et al. (2003)
0.48-1.37	Rivers	Ireland	Smal (1991)
0.57-0.92	Swamps, marshes	USA	Mitchell (1961)
0.1-0.7	Rivers	England	Halliwell & Macdonald (1996)
0.26-0.53	Rivers	England	Birks & Dunstone (1991)
0.15-0.51	Rivers	England	Harrington et al. (2009)
0.46	Rivers	Belarus	Sidorovich et al. (1996)
0.35-0.43	Lakes	Ireland	Smal (1991)
0.17-0.33	Rivers	England	Bonesi & Macdonald (2004)
0.18	Lakes	Scotland	Moore et al. (2003)

Habitat requirements

Patterns of habitat use of mink have been mainly related to the availability and distribution of prey and dens, and to the interference or jeopardy from competitors or enemies (e.g. Halliwell & Macdonald 1996, Bonesi et al. 2000, McDonald 2002, Yamaguchi et al. 2003, Bonesi et al. 2006a). The fact that on Navarino Island mink has no competitors or enemies (as mentioned above, wild dogs might represent a danger for mink) should influence its habitat preferences in terms of being less specific. Our three habitat models had forecast quality, but the AUC-values of 0.65 (model M1) and 0.67 (model M2) were at the very limits of acceptability ($0.7 \leq AUC \leq 0.8$ = acceptable following Hosmer & Lemeshow 2000). This can be interpreted as the generalist habitat preferences we assumed. An invasive species that lacks natural enemies in its new environment can undergo niche shifts, i.e., it can extend the *realized* niche (Hutchinson 1957) that includes constraints arising from biotic interactions toward its *fundamental* niche that is merely genetically and physiologically determined (Fitzpatrick et al. 2007, review in Pearman et al. 2008).

As assumed in hypothesis (1), mink avoided open habitats, and instead used shrubland, a pattern previously described (Allen 1984, Previtali et al. 1998, Yamaguchi et al. 2003). This can be explained by the higher offer of dens and hiding places provided in heterogeneous landscapes (Dunstone 1993, Halliwell & Macdonald 1996). The availability of a wide diversity of prey also explains this pattern. Small mammals in Chile have been shown to use shrub microhabitat based on its profitability in terms of seed and arthropod availability (Simonetti 1989). The yellow nosed grass mouse (*Abrothrix xanthorhinus*), one of the most important mammal prey of mink together with introduced muskrats (*Ondatra zibethicus*) (Schüttler et al. 2008), was predominantly associated with dense shrubland (*Berberis buxifolia*, *Chiliotrichum diffusum*, *Pernettya mucronata*) or reed (*Marsippospermum grandiflorum*) (Gañan et al., unpublished data). Muskrat foods and feeding habits vary widely with habitat and season (Perry 1982) and remain to be investigated in our study region in order to better understand their importance for mink.

Secondly, we expected mink to be more abundant in rocky areas and boulder fields of coastlines, in contrast to beaches with pebbles or sand as the main substrate, hypothesis (2). Our results confirmed this hypothesis. As shown in previous studies, rockpools and boulder fields represented important feeding areas for mink in Alaska and Scotland (Ben-David et al. 1996, Bonesi et al. 2000). Although mink on Navarino Island consumed significantly more fish in marine habitats than along lake shores and rivers (Schüttler et al. 2008, Ibarra et al. 2009), fish as a prey group (with 17.4 % dominant items in the diet) was less important than were birds and mammals (40.7 %, and 37.6 %, respectively). Therefore, we suggest that the availability of birds and their offspring might also play a role in mink's preferences for rocky outcrops. Raya & Schiavini (2002) have shown that the presence of kelp beds presented the highest abundance of seabird species breeding in the Beagle Channel, coinciding with rocky coasts, where kelp forests typically monopolize (Steinberg & Kendrick 1999). The fact that mink were significantly associated with steeper shorelines might coincide with the fact that cliffs or rocks normally constitute steeper shorelines, although our indices for coarseness and incline did not reveal a strong correlation (Spearman's rho=0.43). Again, the association of bird species with steep shorelines might provide an explanation, as is the case for some species of Pelecaniformes (a bird order found in the diet of mink on Navarino Island, Schüttler et al. 2008), like for example rock or imperial shags (*Phalacrocorax magellanicus*, *P. atriceps*) (Couve & Vidal 2003).

Contradictory to hypothesis (3), we found mink to be more abundant in habitats without beaver presence or with low beaver influence, i.e., signs of beaver activity, but no dams. As in other invaded areas (Belarus, Poland) mink were shown to profit from the ice-free access to water around beaver lodges, and inclusively to use them as dens (Żurowski & Kammler 1987, Sidorovich et al. 1996), it is questionable why mink should not do this on Navarino Island. As beavers' impacts on habitat, community and ecosystem variables have been shown to have similar directions in their native range and in South America (Anderson et al. 2009), diverging conditions seem not to be a reason. One explanation might be the methodological challenge to survey for mink signs around the beaver lodges where plenty of fallen trunks and the muddy substrate might decrease the detectability of signs. Further studies including a mix of methodologies (e.g. search for mink dens, trapping etc.) are needed to concentrate on this relationship in order to further comment on the invasional meltdown hypothesis (Simberloff & Von Holle 1999, Simberloff 2006). The planned beaver eradication campaign (Choi 2008) represents a good possibility to design a study on mink abundance in beaver removal areas.

Regarding rivers, we predicted that suitable habitats would be large, slow-moving rivers, hypothesis (4). Although river depth was a significant variable in our habitat model, mink preference for deeper rivers had no significant relevance when tested with univariate statistics. Neither did river width and river flow play a role in the choice of riverine habitats. Although Dunstone (1993) suggested that mink's adaptation suit it for hunting in slow-moving rivers, Strachan & Jefferies (1993) reported its preference for fast-flowing rocky water courses. In Belarus, mink occurs in higher densities on larger, deeper rivers than on small rivers less than one metre deep (Sidorovich et al. 1996). Also in Argentinian Patagonia mink favored deeper water because of the availability of crustacean prey (Previtali et al. 1998). Thus, habitat requirements of mink for rivers seem to be less consistent, while prey availability might be of special importance.

Conclusions for management

During one decade, American mink has colonized the entire island of Navarino and signs were found in all types of semi-aquatic habitats, as well as under extreme conditions like in the high-Andean habitat. If managers decide to intensively control mink as a result of public concern and ecological studies on the vulnerability of the native fauna (e.g. Anderson et al. 2006a, Schüttler et al. 2008, Ibarra et al. 2009), this will be a challenging task. Our trapping data indicate that carrying capacity might not yet have been reached, making the recent invasion of mink an urgent topic (e.g. Simberloff 2003). Sound trapping data on population dynamics, however, would be desirable in order to better understand facts important for a long-term management design such as estimations of the carrying capacity, or immigration of mink from adjacent islands. Our data on habitat preferences confirmed the rather generalist qualities of mink in terms of habitat selection, especially under the premise that mink constitute a new guild of terrestrial predators on Navarino Island. Yet, we were able to predict that mink should live at higher abundances in coastal areas with heterogeneous shores. Thus, for the design of a management plan, steep rocky coasts might represent priority sites with intensive trapping efforts, at the same time protecting the habitats that harbour most vulnerable bird species (Schüttler et al. 2009). Previous studies showed that trapping can effectively reduce the local abundance of mink from islands (e.g. Macdonald & Harrington 2003, Moore et al. 2003, Nordström et al. 2004) and from areas on the UK mainland (e.g. Reynolds et al. 2004, Harrington et al. 2009). If management is planned in an integrative manner, i.e., considering various introduced mammal species (Soto & Cabello 2007), then the relationships between those species should be considered. As shown here, the removal of beavers will probably not necessarily result in a decrease of mink habitat quality. Ideally, control efforts will follow a conjoint strategy together with scientists and the local community in order to guarantee the most accepted and cost-effective management implications.

CHAPTER FOUR

Diet of the American mink and its potential impact on the native fauna[3]

Abstract

Invasive exotic species of mammalian predators represent a major cause of vertebrate animal extinctions on islands, particularly those that lack native mammalian carnivores. In 2001, the American mink (*Mustela vison*) was recorded for the first time on Navarino Island, in the Cape Horn Biosphere Reserve (55°S) in Chile, representing the southernmost population of mink worldwide. In order to assess its potential impact on native fauna, we studied its diet on Navarino Island, as part of an integrative management program on invasive species. Over a three-year period (2005-2007) we collected 512 scats in semi-aquatic habitats: marine coasts, riparian and lake shores. Overall, the main prey was mammals (37 % biomass), and birds (36 %), followed by fish (24 %). Over the spring and summer, mink consumed significantly more birds, whereas mammals constituted the main prey over the autumn and winter when migratory birds had left the area. Among birds, the mink preyed mainly on adult Passeriformes, followed by Anseriformes and Pelecaniformes, caught as chicks. Among mammals, the exotic muskrat (*Ondatra zibethicus*) was the most important prey, and together with the native rodent *Abrothrix xanthorhinus* it accounted for 78 % of the biomass intake. For an integrated management of invasive exotic mammal species on Navarino Island and in the Cape Horn Biosphere Reserve it is important to further research interactions established here among the various introduced mammals, and to initiate immediate control of the mink population in its initial stage of invasion.

Key words: conservation, exotic mammals, management, mustelids, waterbirds

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My contribution: I carried out the field work and diet analysis in the laboratory; I analyzed the data, wrote and submitted the paper. Field assistants helped during several sign surveys. In the laboratory I was supported by an assistant and by Jaime Cárcamo who facilitated all the laboratory needs, reference collections and establishment of the methods used. Ricardo Rozzi and Kurt Jax supervised the study.

Introduction

Invasive exotic species and their impacts are currently regarded as one of the major causes of anthropogenic global change (Sala et al. 2000) and biodiversity loss (Vitousek et al. 1997). In particular, invasive predators can have severe impacts on native prey populations, especially on remote islands due to prey naivety or a lack of their natural predators or competitors that would have otherwise limited their success (Elton 1958, Macdonald & Thom 2001). In the case of evolutionary isolation of native species, introductions of carnivore species to island ecosystems can even lead to local extinctions, as it has been documented for several bird species (Courchamp et al. 2003).

The American mink (*Mustela vison*) is a successful alien predator in most European countries, where it has established feral populations following its introduction from North America for the purpose of fur farming (reviews in Macdonald & Harrington 2003, Bonesi & Palazon 2007). In South America the mink was introduced to Chile and Argentina in the 1930s (Jaksic et al. 2002), where populations established in southern Chile (Sandoval 1994, Rozzi & Sherriffs 2003, Anderson et al. 2006a) and Argentina (Pagnoni et al. 1986). Mink are medium-sized mustelids with a body weight of about 1 kg. They are semi-aquatic mammals found associated with marine shore habitats, river banks, lake shores, freshwater and saltwater marshes. As generalist predators their diet includes prey from both aquatic and terrestrial sources in variable proportions and strongly reflects local and seasonal availability of prey (Dunstone 1993).

Being a highly adaptable and opportunistic predator various studies in Europe have shown that mink can be detrimental to native species (Macdonald & Harrington 2003). The most apparent impact of the mink is a reduction in the range or population size of native prey as has been well documented for seabird colonies on islands (Clode & Macdonald 2002, Nordström et al. 2004), ground-nesting inland water birds (Ferreras & Macdonald 1999), intertidal marine communities (Delibes et al. 2004), rodents (Jefferies 2003) and amphibians (Ahola et al. 2006). Negative impacts due to competition are subject to discussion for the European mink (Maran et al. 1998, Sidorovich et al. 2001). In South America mink have caused reductions in waterbird populations (Lizarralde & Escobar 2000). They are also considered to be responsible for the decline of the river otter *Lontra provocax* (Previtali et al. 1998), although Medina (1997) found little support on competition for space and food.

The case of Navarino Island represents a recent invasion of the mink, where it was first recorded in 2001 (Rozzi & Sherriffs 2003). Navarino Island is located south of Tierra del Fuego, from which it is separated by the Beagle Channel. At numerous points this channel is less than 5 km wide. Mink that escaped or were released from mink farms on Tierra del Fuego might have swum across the Beagle Channel, reaching Navarino Island, and other islands of the Cape Horn Biosphere Reserve (Rozzi & Sherriffs 2003). Here, they represent a new guild because Navarino Island lacks native terrestrial mammalian predators. Thus among the mechanisms by which introduced carnivores affect the local biota (competition, disease, interbreeding, predation, Macdonald & Thom 2001) predation is the most expected mechanism for mink on Navarino, with possible indirect effects on trophic webs.

On Navarino Island the most diverse and abundant group of vertebrates are birds (Rozzi et al. 2006a). Many of them are ground-nesting, and expected to be especially vulnerable to predation from introduced mink as behavioral adaptations to terrestrial predators might lack (Anderson et al. 2006a, Soto & Cabello 2007). Although the Cape Horn region is part of one of the most pristine areas in the world (Mittermeier et al. 2003), this archipelago has not only been invaded by mink, but also by feral domestic animals, rodents and two more North American wild fur mammals: the beaver (*Castor canadensis*) and the muskrat (*Ondatra zibethicus*). In total, the assemblage of exotic terrestrial mammals on the island outnumbers their native counterparts (Anderson et al. 2006a). Some of these exotic species of rodents might represent prey for the mink, thereby generating possible predator-prey interactions among exotic species.

The prime purpose of this study is to quantify the composition of the diet of the southernmost population of American mink in its initial stage of colonization, considering seasonal and habitat variations, in order to provide an initial baseline diagnosis about its potential impact on native and exotic fauna of Navarino Island, and the Cape Horn Biosphere Reserve. Our hypotheses are as follows: first, given that birds are the most abundant group of terrestrial vertebrates on Navarino, birds could represent the main prey group in the diet of the mink. Second, given that in Cape Horn several bird species and/or populations are winter migrants, we expect birds to be the main prey especially during the breeding season and in marine coastal habitats where bird populations are particularly abundant and diverse. Third, given that the exotic muskrat is an important prey for mink in its original distribution range; this rodent species could also constitute an important prey for mink populations in the area of Cape Horn, thus facilitating the arrival of the newcomer mink (i.e., invasional meltdown hypothesis by Simberloff & Von Holle 1999). We will try to estimate the absolute number of birds, mammals, and fish that mink remove monthly and discuss these results in the context of conservation and management with a special focus on the potential impact that the recently introduced mink might have on native bird, especially ground-nesting, and mammal populations.

Material and methods

Study area

The study was carried out on Navarino Island (2,528 km^2), located at the extreme southern tip of South America. The island forms part of the Cape Horn Biosphere Reserve (54°-56°S) and belongs to the Magellanic Sub-Antarctic Evergreen Rainforest ecoregion, recently identified as one of the 24 most pristine wilderness areas of the world (Mittermeier et al. 2003). The main habitats include (i) evergreen and deciduous forests dominated by the genus *Nothofagus*, (ii) peatlands, moorlands, and bogs, (iii) alpine communities dominated by cushion plants, and lichens, (iv) streams and lakes, and (v) thickets or scrublands in naturally or anthropogenically disturbed areas (Pisano 1977, Rozzi et al. 2006a). The climate is oceanic, with a low annual thermic fluctuation (< 5°C), a mean annual temperature of 6°C, and an annual precipitation of 467.3 mm (Pisano 1977). During the winter, streams and lakes are ice-bound. The human population is concentrated in the town of Puerto Williams, the capital city of the Chilean Antarctic Province, on the northern coast of Navarino. Access to the town, rural settlements and navy stations relies mostly on access from the sea, except for a dirt road that connects the entire northern coast of Navarino Island.

Potential vertebrate prey on Navarino Island

With 154 species, birds represent the most abundant and diverse group of terrestrial vertebrates on the island (Couve & Vidal 2003, Rozzi et al. 2006a). Native mammals include only five species: one Artiodactyla, two Chiroptera, and two Rodentia. At present, exotic mammals include eleven species, therefore outnumbering native species. They include four species of rodents: *Castor canadensis*, *Mus musculus*, *Ondatra zibethicus*, and *Rattus norvegicus* (Anderson et al. 2006a). *Ondatra zibethicus* is an important native prey to mink in North America (Dunstone 1993). As far as freshwater fish are concerned, Navarino Island only hosts one common native species (*Galaxias maculatus*), two extremely rare native species (*Aplochiton* spp.) and two exotic species of trout, *Salvelinus fontinalis* and *Oncorhynchus mykiss* (Moorman 2007). However, the marine fish fauna in the Beagle Channel is rich and includes more than 50 species (López et al. 1996). There are no amphibians or reptiles present on Navarino Island (Anderson et al. 2006a).

Dietary analysis

Diet was analyzed by examining 512 feces (=scats) collected from 36 sites on Navarino Island between April 2005 and March 2007. The sites included different semi-aquatic habitats: 13 marine coastal sites, 14 sites along lake shores, and nine sites along riparian shores. The majority of the sites (28 sites) were located at the northern margin of Navarino Island due to the limited accessibility of the southern areas. To ensure that collected scats represented different individuals we sampled sites that were separated by at least three km (the average linear territory size described for the American mink, Dunstone 1993). We searched for scats at all sites over the summer. Due to climatic conditions and accessibility, we only conducted scat searches over the spring, autumn and winter seasons at coastal sites. All scats were frozen for long-term storage. Collected scats were thawn and soaked in water overnight prior to sieving (0.3 mm). The washed scats were then dried at 50°C (24 h) and stored in paper bags. We sorted the undigested prey remains into six categories (mammals, birds, fish, insects, crustaceans, mollusks) using a binocular microscope. Seeds and plant material were excluded from the analysis as we suspected that this was a result of secondary prey, accidental intake or adhesion after defecation. We estimated the percentage volume of each prey category per scat to the nearest 10 % and weighed it to 0.01 g.

For the identification of mammals and birds we used the reference collections of the Instituto de la Patagonia, Universidad de Magallanes, complemented by our own additional collections and local keys (Reise 1973, Chehébar & Martín 1989, Reyes 1992, Rau & Martínez 2004). Mammals were identified to the species level by examining hair samples; birds were identified to the order level, the taxonomic level a microscopic examination of feathers permits (Day 1966). To address the question of which age category birds are preferably consumed by mink we classified birds that had been identified taxonomically into adults and chicks. We assigned the sample to chicks if at least three of the following features applied: long slender barbs at short rhachis, presence of papillae, truncated feather shape, lack of coloration, lack of pennaceous barbs, and a small amount of bones in the sample (Ewart 1921, Busching 2005). Insects were identified by a local entomologist to the species level, and where this was impossible to the next higher taxonomic level (order, subclass).

To quantify the relative contribution of prey groups to mink's diet we applied three indices; the first two are commonly used (Jędrzejewska & Jędrzejewski 1998):

(1) Percentage of relative frequency of occurrence of each food item (RFO), calculated as the number of occurrences of a prey category divided by the number of occurrences of all prey categories. With this index, small prey items tend to be overrated in terms of importance.

(2) Percentage biomass of a given prey item (BIO) estimated by multiplying its dry mass by its empirically determined coefficients of digestibility. This coefficient is measured as the ratio of fresh mass of a given prey to the dry mass of its remains in scats (Jędrzejewska et al. 2001). We applied the following correction factors: mammals (17.3), birds (17.2), eggs (687.5), fish (30.8), crustaceans and mollusks (14.8), provided by Brzeziński & Marzec (2003). For insects we used the value (5.0) provided by Lockie (1961). Calculating the biomass reflects the real intake of prey as it takes into account different sizes and digestibility of prey (Brzeziński & Marzec 2003).

(3) Percentage occurrence of the dominant item (POD) with the item constituting the largest volume class considered as the dominant one (Hammershøj et al. 2004). This method can compensate for the disadvantage of secondary prey intake.

Statistics

We conducted Spearman's rank correlations between the corresponding prey groups of different indices (RFO, BIO, POD) in order to evaluate whether those indices were comparable with each other. We assessed differences in the diet composition between habitats and seasons using chi-squared tests with Yates' continuity and Bonferroni corrections, Fisher's exact tests when expected values were less than five, and two-sample tests for equality of proportions, all two-sided, running the R version 2.7.1. (R Development Core Team 2008).

In order to measure the degree of specialization of mink in different habitats and seasons we calculated its food-niche breadth for the six defined food categories using Hurlbert's standardization of Levins' B index (Levins 1968, Hurlbert 1978, Krebs 1999):

$$B_s = \frac{(B-1)}{(n-1)}$$

with B_s=standardized niche breadth, B=Levins' index, n=number of food categories,

$$B = \frac{1}{\sum p_i^2}$$

where p_i is the proportion of items in the diet that are of food category i. The proportion was calculated for each of the three indices used in this study (RFO, BIO, POD). The range of Levins' B index is 1 to n. Therefore it depends on the number of food categories. The standardized niche breadth B_s is independent of n and has a range from 0 to 1, with 1 indicating the broadest niche.

We estimated the intake of prey groups by the mink in order to evaluate its impact on prey populations where abundances are known. To assess how many birds, mammals and fish a single mink might consume during a warm month, we followed the approach developed by Jędrzejewska & Jędrzejewski (1998) in Bartoszewicz & Zalewski (2003). Accordingly, the number of a given prey group eaten per day per mink (N_{pd}) was calculated as:

$$N_{pd} = \frac{DFC \times B_p}{Wt_p}$$

where DFC is the average daily food consumption of mink (app. 190 g, 153 ± 48 g for females, 231 ± 72 g for males, estimated from Dunstone 1993), B_p is the fraction of given prey biomass in the mink diet, and Wt_p is the wet mass of a given prey: 75 g for small birds, 35 g for small rodents, 1100 g for the muskrat, and 113 g for fish (Dunstone 1993, Bartoszewicz & Zalewski 2003). We used an overall index of 75 g for birds as our results indicated that bigger birds (e.g. Anseriformes) were almost exclusively consumed as chicks.

Results

The analysis of scat content showed that the mink diet consisted mainly of mammals and birds (Fig. 4.1). Combined, both taxonomic groups accounted for more than half of the mink diet using the relative frequency of occurrences index (59.3 % RFO), for 68.0 % when estimated by the biomass index (BIO), and for 80.1 % with the dominant item method (POD). In the overall diet, mammals were more important than birds using RFO (χ^2=7.79, df=1, p < 0.01), but not significantly different form birds in biomass intake (χ^2=0.73, p=0.394). Fish were the third most important component in the mink diet accounting for 14.1-23.7 %. Overall, we found that terrestrial food (72.5-83.2 % mammals, birds, insects) provided a much more important source of food for mink than did aquatic prey (16.8-27.5 % fish, crustaceans, mollusks) (for all indices $\chi^2 \geq 375.35$, all df=1, all $p < 0.001$).

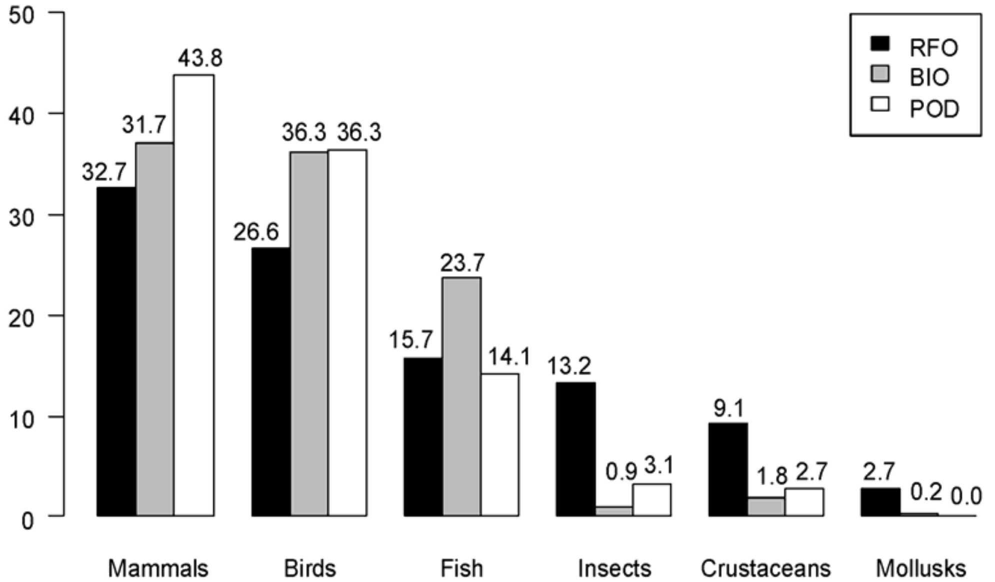

Fig. 4.1 Overall occurrence of prey categories in scats of American mink on Navarino Island. Percentages are based on data from all scats (N=512) collected from three types of semi-aquatic habitats (marine, riparian, lake) over the four seasons during a three-year period (2005-2007). RFO=relative frequency of occurrences of each prey category, BIO=percentage of biomass consumed, POD=percentage of occurrence of each prey category as the dominant item.

Variations in mink diet among habitats

All three indices correlated significantly with each other (Spearman rank correlations, all n=6 prey groups: RFO with BIO, $r_s=0.94$, p=0.017; RFO with POD, $r_s=1.0$, $p < 0.01$; BIO with POD, $r_s=0.94$, p=0.017). For this reason, we focused on the most conservative index, the dominant item method (POD), to evaluate differences in prey composition between scats collected in different habitat types. Mink diet in the summer varied significantly among different habitats types (Fig. 4.2). The dominant item index differed between riparian and marine coastal habitats (Fisher's exact test, df=5, $p < 0.001$), and riparian and lake habitats (df=5, $p < 0.001$) Differences between marine coastline and lakes were also significant (df=5, p=0.031), but the contrast in values was less pronounced. In lake habitats, the proportion of birds (58.0 %) exceeded the proportion of mammals (34.1 %) significantly ($\chi^2=9.15$, df=1, $p < 0.01$). In contrast, in riparian habitats bird prey was much less frequent than mammal ones (22.4 vs. 55.1 %, $\chi^2=9.67$, $p < 0.01$). Indeed, in riparian habitats the consumption of birds by the mink was significantly lower than in marine ($\chi^2=6.62$, p=0.01) and lake habitats ($\chi^2=10.67$, $p < 0.01$). Regarding the other taxonomic groups, fish was only found to be frequent prey in marine coastal habitats (17.4 %). Thus the consumption of fish by the mink was significantly higher in marine habitats compared to lake ($\chi^2=5.78$, p=0.016), and riparian habitats ($\chi^2=6.19$, p=0.013). Regarding other prey (insects, crustaceans, mollusks), insects were found to be the dominant item in riparian habitats occurring in 20.4 % of the analyzed scats, while crustaceans were the most important prey in marine coastal habitat accounting for 5.2 %.

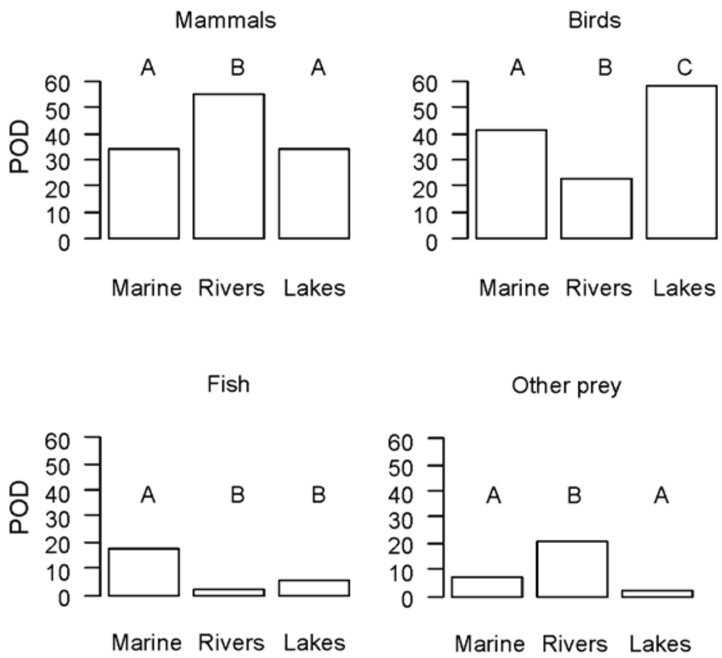

Fig. 4.2 Differences in the consumption of mammals, birds, fish and other prey (insects, crustaceans, mollusks) by mink over the summer in different habitat types (N=292 scats). For each graph different letters above the bars indicate significant differences ($p < 0.05$ with 2-sample tests for equality of proportions) in the percentage of occurrence of the dominant item (POD) in a prey group among habitat types.

Variations in mink diet among seasons

We assessed seasonal differences in the diet of the mink in marine coastal habitats focusing on the POD index as done for differences between habitats. Diet composition between spring-summer and autumn-winter, respectively, was insignificant (Fisher's exact test, df=5, p=0.12, and p=0.23, respectively) so that data were pooled for the warm season (spring-summer) and the cool season (autumn-winter). However, the diet of the mink in warm and cool seasons varied significantly (df=5, $p < 0.001$) (Fig. 4.3). Scats collected during the warm season at marine coastal sites were approximately equally dominated by mammals and birds (37.6 vs. 40.7 %, $\chi^2=0.4$, df=1, p=0.53). In contrast, during the cool season, scats collected in marine habitats were dominated by mammal items (59.8 % POD), while birds, which were dominant items in only 16.2 % of analyzed scats, were significantly less consumed ($\chi^2=45.33$, df=1, $p < 0.001$). Fish represented the dominant item in 16.7-19.7 % of scats in warm and cool seasons, and no significant temporal variation could be determined. Furthermore, no significant seasonal fluctuations for the other prey groups could be found, which made up less than 5 % of the dominant items in warm and cool seasons.

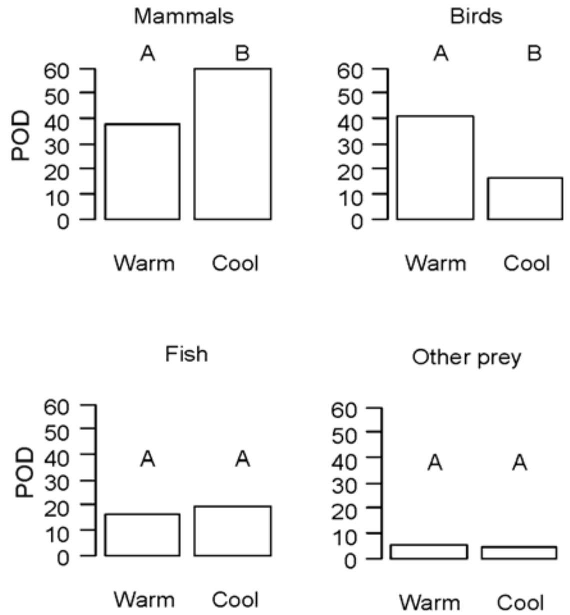

Fig. 4.3 Differences in the consumption of mammals, birds, fish and other prey (insects, crustaceans, mollusks) by mink during warm (spring-summer) and cool (autumn-winter) seasons in marine coastal habitat (N=375 scats). For each graph different letters above the bars indicate significant differences ($p < 0.05$ with 2-sample tests for equality of proportions) in the percentage of occurrence of the dominant item (POD) in a prey group among seasons.

Trophic niche breadth

The standardized trophic niche breadths during the summer season were highest for mink inhabiting marine coastal habitats (Table 4.1). Lake habitats exhibited low values of trophic niche breadth. Mink diet in lake habitats concentrated on birds (58 % POD); fish and other prey groups were almost absent (Fig. 4.2). In marine habitats, mink diet showed the highest variation during summer, and the lowest during winter when mink relied essentially on mammals (63.6 % POD), and entire prey groups (insects, crustaceans, mollusks) lacked in its diet. For spring and autumn the trophic niche breadths were intermediate.

Table 4.1 Levins' standardized niche breadth for mink on Navarino Island, estimated on the basis of scats collected in marine coastal, riparian and lake habitats over the summer (N=292), and for scats collected from marine habitats over different seasons of the year (N=375).

Index	Habitats (summer)			Seasons (marine coast)			
	Marine	Rivers	Lakes	Spring	Summer	Autumn	Winter
RFO	0.78	0.45	0.47	0.64	0.78	0.52	0.35
BIO	0.43	0.18	0.17	0.39	0.43	0.31	0.40
POD	0.42	0.30	0.24	0.35	0.42	0.28	0.21

Taxonomic identification

We identified prey groups from 193 scats collected during the warm season (spring-summer) in marine coastal habitat. We focused on this sample as food niche breadth was broadest in marine habitats, and in order to coincide with the breeding season of birds. Birds were the most diverse group of prey on Navarino Island. Seven of the twelve orders of birds breeding on the island were present in the scats analyzed (Table 4.2). Passeriformes were the most abundant order in the diet, with indices from 10.2-14.8 % (RFO, BIO, POD). However, Pelecaniformes, Anseriformes and eggs also played an important role in terms of biomass intake. Together these four groups accounted for 76.2 % of the bird biomass consumed by mink. Passeriformes were mainly caught as adults, whereas all other bird orders were caught as chicks, with the difference being highly significant (χ^2=37.9, df=1, $p < 0.001$).

As far as mammals are concerned, the two dominant species were the native rodent *Abrothrix xanthorhinus* and the exotic muskrat (*Ondatra zibethicus*), with 8.9-14.8 %, and 8.7-15.2 % (RFO, BIO, POD), respectively (Table 4.2). Together *A. xanthorhinus* and *O. zibethicus* represented 78.2 % of the mammal biomass consumed by the mink on Navarino Island. The relative importance of *Oligoryzomys longicaudatus*, the second native rodent species on the island, was modest. Its relative frequency of occurrence, biomass and dominance as a prey item were less than a third of the values determined for *A. xanthorhinus* and *O. zibethicus*. The presence of the house mouse (*Mus musculus*) in the diet was negligible. It was found only in three samples collected in the vicinity of houses. Noticeably, the two other exotic rodent species, namely the beaver (*Castor canadensis*) and the Norway rat (*Rattus norvegicus*), were not found in any of the scats collected in marine coastal habitats over the spring and summer. The occurrence of mink hair in some of the scats was ascribed to grooming. In summary, the proportion of exotic mammals in terms of biomass was 49.9 %, a proportion that exceeds the value of 43.2 % estimated for native mammals (the other 6.9 % correspond to non identified mammal prey). The contribution of invertebrates to the mink's biomass intake (2.9 %) was negligible (Table 4.2). In spite of this however, mink seem to actively search for insects because all of the insect taxa identified, except for the coleoptera *Microplophorus magellanicus,* were flightless, and therewith easier to catch. Hence, insects were probably consumed directly by mink (although we cannot exclude consumption by other active hunters).

Table 4.2 Diet composition of American mink over the warm season (spring-summer) in marine coastal habitat on Navarino Island (N=258 scats, 2005-2007). RFO=relative frequency of occurrences, BIO=percentage of biomass, POD=percentage of occurrence of dominant item.

Prey group	RFO	BIO	POD
Abrothrix xanthorhinus	8.9	10.1	14.8
Mus musculus	0.6	0.1	0.3
Mustela vison	2.4	1.3	3.8
Oligoryzomys longicaudatus	2.6	3.2	4.8
Ondatra zibethicus	8.7	13.9	15.2
Unident. Mammals	6.1	2.1	2.8
Total mammals	**29.2**	**30.8**	**41.7**
Anseriformes	3.9	5.1	6.9
Ciconiformes	1.3	1.7	2.4
Coraciiformes	0.4	0.3	0.7
Gruiformes	0.2	0.4	0.3
Passeriformes	10.2	11.3	14.8
Pelecaniformes	3.7	7.5	6.2
Podicipediformes	0.9	1.0	1.7
Eggs	3.9	6.6	-
Unident. Birds	6.3	6.2	6.6
Total birds	**30.7**	**40.0**	**39.7**
Fish	**15.5**	**26.3**	**14.8**
Arachnida, Acari	0.4	-	-
Coleoptera	0.9	-	-
Hemiptera, Heteroptera	0.2	-	-
Aegorhinus vitulus	0.2	-	-
Microplophorus magellanicus	1.5	0.1	0.3
Pycnosiphorus femoralis	1.7	0.1	0.3
Sinopla perpunctatus	0.2	-	-
Unident. Insects	5.7	-	0.3
Total insects	**10.7**	**0.3**	**1.0**
Crustaceans	**10.9**	**2.4**	**2.8**
Mollusks	**3.0**	**0.2**	**-**
Food niche breadth	0.68	0.42	0.36
Total N items or biomass (g)	541	2566.6 g	290

Monthly food consumption of mink

How hungry are mink? On average the daily food consumption of a mink is approximately 190 g (estimated from Dunstone 1993). Following our biomass fractions (BIO) of prey groups over the spring and summer we can estimate an extrapolated monthly (30 days) consumption, which does not take into account varying energy demands of the animal. Accordingly, a single mink would consume monthly on average: nine Passeriformes, four Anseriformes, six Pelecaniformes, 13 other birds (total birds: 32), 17 *Abrothrix xanthorhinus*, five *Oligoryzomys longicaudatus*, one muskrat, three other small rodents (total mammals: 26), and 13 fish. The small proportion of remaining prey groups (2.9 % BIO) was neglected in this estimation. Based on trapping data of mink on Navarino Island, mink relative densities ranged from 0.79-1.32 individuals/km along marine coastal habitat (Anderson et al. 2006a). Applying these densities to a 10 km stretch of coastline eight to thirteen mink living there could roughly consume about 248-415 small birds, 205-343 mammals, and 105-175 fish in one month during the warm season.

Discussion

Mammals as a reliable source, birds welcome when available

Diet composition showed that mink relied principally on mammalian and avian prey with significant variations over habitats and seasons. In marine coastal habitat and in particular at lakes birds were the principal prey group. Over the warm season mink preyed on both vertebrate groups almost equally, but relied mainly on mammals over the cool season. These results suggest that mammals represent a stable base in the diet compensating for periods with lower bird availability.

Compared to other studies on mink diet worldwide, the proportion of birds in scats from marine coastal habitat on Navarino Island over the summer was exceptionally high. Further north, in Argentinean Patagonia coastal mink predominantly prey on crustaceans and insects (Previtali et al. 1998). In Eurasia fish and crustaceans seem to be the most important prey for mink in marine habitat (Jędrzejewska et al. 2001, Delibes et al. 2004), although mammals can also play an important role (Dunstone & Birks 1987). In riparian habitats, fish, mammals and amphibians are reported as principal prey groups in the diet of introduced mink (Medina 1997, Ferreras & Macdonald 1999, Jędrzejewska et al. 2001, Hammershøj et al. 2004). Noticeably, few studies report a high consumption of birds, which only occurred in productive waterbird breeding habitats and areas with large wildfowl populations in inland wetlands, especially during the warm season (Ward et al. 1986, Arnold & Fritzell 1987, Bartoszewicz & Zalewski 2003). Therefore, the opportunistic diet habits of the mink (Dunstone 1993) seem to reflect the abundance and diversity of prey available in each region.

The exceptionally high abundance of birds in the diet of mink at the southern end of the Americas might be explained by at least three factors: (i) in the insular austral environment amphibians and reptiles as possible prey groups are absent, (ii) aquatic prey might play a minor role due to the climate conditions in combination with the greater level of energy expenditure used to catch it (Stephenson et al. 1988), and (iii) during the warm season, the density of birds returning from migration is high, the mobility of birds during incubation, brood rearing or moulting is reduced (Bartoszewicz & Zalewski 2003), and many ground-nesting birds on Navarino supply vulnerable offspring.

Impact on native prey populations

In order to assess the direct ecological impact of mink on prey populations we must identify "sensitive species", i.e., species with low abundances, low hunting effort for mink and high energy content (Dunstone 1993). Our identification of bird remains in mink scats is reliable to the level of orders. Consequently, we attempted to identify potentially sensitive species among the main orders we found in the diet of mink on Navarino Island. Passeriformes were the most abundant bird order in the diet, and furthermore affected as being caught as adults, i.e., as individuals contributing to the reproduction of the population. Although we don't know whether these passerines were ground or tree-nesting, we suggest that potentially sensitive species might be those that breed in open nests at low height, and present low abundances in the Cape Horn archipelago region. Based on avian censuses for Navarino Island (Anderson & Rozzi 2000, Anderson et al. 2002, McGehee et al. 2004) these criteria target three species: the ground nesting Magellanic tapaculo (*Scytalopus magellanicus*), the Patagonian tyrant (*Colorhamphus parvirostris*), and in particular the fire-eyed diucon (*Xolmis pyrope*) (S. Ippi, personal communication). In inland wetlands bird species that are locally rare, such as the Fuegian snipe (*Gallinago stricklandii*)

(Couve & Vidal 2003) might be threatened because in comparison to marine coastal habitats, inland wetlands on Navarino Island seem to harbor less potential prey for mink (lack of crustaceans, marine fish etc.).

With respect to large ground-nesting birds (e.g. Anseriformes, Pelecaniformes) our results confirm that mink predominantly caught their chicks. Among Anseriformes, two species endemic to the subantarctic archipelago region of southwestern South America (41-56°S, including the Falklands) have small populations that might be particularly vulnerable to mink predation of their offsprings: the flightless steamer duck (*Tachyeres pteneres*) and the kelp goose (*Chloephaga hybrida*). Both species are strictly coastal, and they inhabit the area all year round (Couve & Vidal 2003). Their population densities along the coasts of the Beagle Channel (0.74, and 0.46 birds/km for *T. pteneres* and *C. hybrida*, respectively, estimated by Raya & Schiavini 2002) are very low in the light of the numbers of birds consumed by mink in our numeric example (25-42/month/km).

Regarding native mammals, mink hunted native rodents in proportion to their availability. In the spring-summer diet we found three times more *Abrothrix xanthorhinus* than *Oligoryzomys longicaudatus*. This proportion resembles the relative abundances obtained for these two species through censuses with Sherman traps on the study sites on Navarino Island (Gañan et al., unpublished results). *A. xanthorhinus* was trapped six times more frequently than *O. longicaudatus*. For *A. xanthorhinus* Gañan et al. estimated mean relative densities of 8-39 individuals/ha (per 100 trap nights, depending on the habitat type: forest, pasture, reed, shrubland), and 0-6 individuals/ha for *O. longicaudatus*, respectively, during spring to autumn (N=3,800 trap nights). Hence, based on our estimations for the consumption of native rodents from our biomass fractions in mink diet (17-29/month/km), it seems that *Mustela vison* does not represent a threat to these mammal species, although these rough estimates have to be treated with caution. The indirect impact of mink on changes in the prey offer for autochthonous bird predators requires further analysis.

Exotic mammals as prey for mink

Our results from marine coastal scats over the warm season show a considerable proportion of muskrat among mammal biomass consumed by mink on Navarino Island. Interestingly, this result coincides with studies from North America, where muskrats are the largest and probably most important mammalian prey for mink (Dunstone 1993). Over the winter months in particular young muskrat are vulnerable to mink predation (Errington 1954). Thus, populations of these two North American invasive mammals have reestablished their predator-prey interactions at the southern end of the continent. We lack systematic abundance data of the muskrat, but SAG's Control Program of Exotic Species in Magallanes (Soto & Cabello 2007), reports that 250 muskrat were captured in Tierra del Fuego and the Cape Horn Region by a single trapper working in lake and riparian habitats over 2005/2006. We therefore assume that muskrat is a reliable and highly energetic source for mink. This result adds one more example of facilitatory interactions between an invasive species already present, the muskrat (arrival in the fifties, Jaksic et al. 2002), aiding a new species to establish (Simberloff & Von Holle 1999), although not in a mutual way.

As far as the other species of North American introduced rodents are concerned, we did not find any beaver remains in the diet of mink in marine habitats. This might be due to the fact that beavers are mostly associated with riparian habitats (Anderson et al. 2006b). Studies on mink scats (n=235) collected in inland wetlands on Navarino Island have shown that only 2 % contained beaver remains (Ibarra 2007). Again, these results for Navarino Island coincide with those found in North America (Dunstone 1993) and Europe (e.g. Brezeziński & Żurowski 1992) where beavers are not reported as prey species. A probable explanation is that beavers are too large as prey for mink (their body weight ranges from 18-23 kg, Aleksiuk 1968), and that young beavers are sufficiently guarded by their parents (Brezeziński & Żurowski 1992). However, mink might profit from the coexistence with beavers, since their engineering activities provide denning facilities for the mink (Żurowski & Kammler 1987).

Concluding remarks

Birds constituted an important prey group for the introduced mink on Navarino Island, especially in marine coastal habitat and lakes during the breeding season. Studies in other insular ecosystems have shown that the introduction of mink can lead to severe reductions of bird populations (Ferreras & Macdonald 1999, Nordström & Korpimäki 2004). We identified two Anseriformes (*Tachyeres pteneres* and *Chloephaga hybrida*) endemic to southern South America, which might be seriously threatened by the presence of mink on Navarino Island. For these reasons we advise governmental agencies (Iriarte et al. 2005) to start controlling mink populations immediately. In order to increase trapping success, control should take place mainly during periods of high activity of mink (spring and autumn, Moore et al. 2003), and with particular intensity at nesting habitats of sensitive bird species during their breeding periods (under the consideration of the trapper's influence).

For an integrated management of exotic species on Navarino Island and the Cape Horn Biosphere Reserve it is important to undertake further research on the direct and indirect interactions established here among the various introduced mammal species (Silva & Saavedra 2008). The muskrat might protect native species from being preyed upon the opportunistic predator, but on the other hand it represents a reliable food source for the mink. Finally, we recommend that long-term monitoring of bird populations should accompany the mink management strategies that are currently being implemented in this remote region of the world. The critical need for conserving the avifauna and ecosystem integrity of the Cape Horn Biosphere Reserve is especially relevant for ecotourism, which currently represents the main option for achieving both economic and environmental sustainability at the southern end of the Americas (Rozzi et al. 2004a).

CHAPTER FIVE

Vulnerability of ground-nesting waterbirds to predation by invasive American mink[4]

Abstract

Biological invasions constitute one of the most important threats to biodiversity. This is especially true for “naïve” birds that have evolved in the absence of terrestrial predators in island ecosystems. The American mink (*Mustela vison*) has recently established a feral population on Navarino Island (55°S), southern Chile, where it represents a new guild of terrestrial mammal predators. We investigated the impact of mink on ground-nesting coastal waterbirds with the aim of deriving a vulnerability profile for birds as a function of different breeding strategies, habitat, and nest characteristics. We compared rates of nest survival and mink predation on 102 nests of solitary nesting species (*Chloephaga picta*, *Tachyeres pteneres*), on 361 nests of colonial birds (*Larus dominicanus*, *Larus scoresbii*, *Sterna hirundinacea*), and on 558 artificial nests. We calculated relative mink and bird densities at all nest sites. Nests of colonial species showed the highest nest survival probabilities (67-84%) and no predation by mink. Nest survival rates for solitary nesting species were lower (5-20%) and mink predation rates higher (10-44%). Discriminant analyses revealed that mink preyed upon artificial nests mainly at shores with rocky outcroppings where mink were abundant. High nest concealment increased the probability for predation by mink. Conservation planning should consider that invasive mink might severely affect the reproduction success of bird species with the following characteristics: solitary nesting, nesting habitat at rocky outcrop shores, and concealed nests. We recommend that work starts immediately to control the mink population with a priority in the nesting habitats of vulnerable endemic waterbirds.

Key words: artificial nests, breeding birds, management, *Mustela vison*, nest characteristics, nest survival

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My contribution: I designed the study, conducted the field work, analyzed the data, wrote and submitted the paper. Steven McGehee aided in the search of natural nests and and conducted several bird surveys. Artificial nest monitoring was strongly supported by various field assistants. Reinhard Klenke guided the statistical analyses and gave scientific advice while preparing the manuscript. Ricardo Rozzi and Kurt Jax supervised the study.

Introduction

The earth's biota is greatly altered by invasive plant and animal species producing concern and discussion about their ecological consequences (Elton 1958, Vitousek et al. 1997, Gobster 2005, Vellend et al. 2007). Biodiversity on islands is particularly vulnerable to biotic exchange (Courchamp et al. 2003, Sax and Gaines 2008). The survival of introduced species on islands and the significance of their ecological impacts are less a matter of low insular biodiversity (Levine & D'Antonio 1999); rather it depends on the nature of those species that are present or those groups of species that are missing from the islands (Goodman 1975, Simberloff 1995). This is especially true for alien carnivore invasions on islands where terrestrial mammalian predators were absent before. Their impact on insular bird populations can cause extensive population reductions and even local extinctions (King 1985, Atkinson 1996, Macdonald & Thom 2001).

Bird populations are regulated by natural limiting factors like predation, food supply, nest sites, parasites, pathogens, competition; and human-induced factors like hunting, pesticides or pollutants (Newton 1998). The effects of predation depend on the extend to which it is additive to compensation by other losses. In some ground-nesting waterbirds, however, predation can not only reduce egg and chick stages (Opermanis et al. 2001, Kauhala 2004, Nordström & Korpimäki 2004), but actually also their breeding numbers (Côté & Sutherland 1997, Newton 1998). Hence, bird species are assumed to develop their own strategies to minimize predation (Martin 1993). It is widely accepted that prey naïvety plays a significant role in the confrontation with the threat of an introduced predator, because native fauna often lack those strategies to minimize predation as behavioral or evolutionary adaptations (Berger et al. 2001, Short et al. 2002, Nordström et al. 2004). Critical factors among those adaptations are (i) social factors like coloniality (Inman & Krebs 1987, Siegel-Causey & Kharitonov 1990), (ii) area-specific factors like habitat (Willson et al. 2001, Whittingham & Evans 2004) or nest density (Ackerman et al. 2004), and (iii) site-specific factors like nest height (Martin 1995) or nest concealment (Butler & Rotella 1998, Rangen et al. 2000). Those factors have been investigated separately or in combination, with artificial and/or natural nests, often with contradictory results (Major & Kendal 1996). Finally, nest predation processes cannot fully be understood without knowledge of the predator community, i.e., abundance and searching behavior of predators (Angelstam 1986, Miller & Knight 1993).

The American mink (*Mustela vison*) is a carnivorous species from North America that has recently established its southernmost reproducing population in the world on Navarino Island, Cape Horn Biosphere Reserve (southern Chile, 54-56°S). It was first registered on the island in 2001 (Jaksic et al. 2002, Rozzi & Sherriffs 2003), but arrived earlier in Tierra del Fuego on the other side of the Beagle Channel in the 1940s and 1950s (Lizarralde & Escobar 2000). Therefore, it is most probable that some individuals crossed the Beagle Channel after escaping from fur farms in Tierra del Fuego (Rozzi & Sherriffs 2003). On Navarino Island, mink represent a new guild (Root 1967) because the island lacks native terrestrial mammalian predators. In this pristine ecoregion the most diverse and abundant group of vertebrates are birds (Rozzi et al. 2006a). Many of them are ground-nesting, including two songbird species (*Turdus falcklandii*, *Zonotrichia capensis*) that use ground nests in the Cape Horn region (S. McGehee, unpublished data), while in other parts of Chile the same species nest in trees. Therefore, scientists and public agencies have expressed strong concerns about the impact of mink on the island's avifauna, especially ground-nesting birds (Rozzi & Sherriffs 2003, Anderson et al. 2006a, Soto & Cabello 2007).

American mink are semi-aquatic mustelids inhabiting marine coasts, flowing waters, and banks with a generalist diet including prey from both aquatic and terrestrial sources (Dunstone 1993). Birds are most exposed to the risks of opportunistic predation by mink during their reproductive period due to the birds' limited mobility (Arnold & Fritzell 1987, Bartoszewicz & Zalewski 2003) in combination with the higher energy requirement of the breeding mink (Dunstone 1993). In Europe, introduced mink have successfully established feral populations (reviews in Macdonald & Harrington 2003, Bonesi & Palazon 2007), which prey significantly upon ground-nesting wetland birds (Ferreras & Macdonald 1999) and seabirds (Antolos et al. 2004, Nordström & Korpimäki 2004). Also some cases of surplus-killing of chicks and adults within a colony have been reported (e.g. Craik 1997). In South America, wild mink populations in the southern part of Chile and Argentina also include birds in their diets (Medina 1997, Previtali et al. 1998, Schüttler et al. 2008, Fasola et al. 2009, Ibarra et al. 2009). However, studies on the impact of mink on waterbirds in the southern hemisphere are scarce.

The main purpose of our study was to understand the impact of the American mink as a recently introduced terrestrial predator on the nest survival of "naïve" ground-nesting waterbirds on Navarino Island. We aim to draw an overall vulnerability profile of bird species to predation by mink as a function of their breeding strategy (colonial vs. solitary nesting), as well as area-specific (habitat), and site-specific (nest concealment) factors. Based on this profile, we discuss high priority species of ground-nesting waterbirds for conservation and implications for the management of mink populations in the southernmost tip of the Americas.

Methods

Study area

The study was carried out on Navarino Island (2,528 km^2), Chile, located at the extreme southern tip of South America (Fig. 5.1). The island forms part of the Cape Horn Biosphere Reserve (Rozzi et al. 2006a) and belongs to the Magellanic Sub-Antarctic Forest Ecoregion, recently identified as one of the 24 most pristine wilderness areas of the world Forest Biome (Mittermeier et al. 2003). The main habitats include (i) evergreen rainforests dominated by *Nothofagus betuloides* and *Drimys winteri*, (ii) Magellanic deciduous forests of *Nothofagus pumilio*, (iii) peatlands, moorlands, and bogs (*Sphagnum* spp.), (iv) high-Andean communities dominated by cushion plants and lichens, and (v) thickets or scrublands in naturally or anthropogenically disturbed areas (Pisano 1977, Rozzi et al. 2006a). The climate type is oceanic, with a low annual thermic fluctuation (< 5°C), a mean annual temperature of 6°C, and an annual precipitation of 467.3 mm (Pisano 1977). During winter, streams and lakes are ice-bound. Human population is concentrated in Puerto Williams (ca 2,300 inhabitants), the capital city of the Chilean Antarctic Province, on the northern coast of Navarino. Due to the extremely limited infrastructure on Navarino Island - only one dirt road connects the northern coast - our research was mainly restricted to this accessible coast of the island. The interior of the island must be reached by the three existing trekking trails, and western, southern and eastern coasts rely on water transport.

Our study sites comprised twelve 4 km long transects of marine shoreline and three lakes at a distance of 5.3-7.7 km from the coast and an altitude of 387-510 m. All study sites were separated by more than 3 km in order to cover distinct territories of mink, which occupy on average linear territories of 3 m (Dunstone 1993). We conducted natural and artificial nest monitoring, bird counts, and mink surveys in the same coastal study sites and during the same breeding seasons. At lakes, we only focused on artificial nest monitoring and mink surveys.

Species studied

We concentrated our study on solitary nesting and colonial species that are resident, common, or endemic in the region. The solitary nesting species studied were the upland goose (*Chloephaga picta*) and the flightless steamer duck (*Tachyeres pteneres*). The upland goose occurs as a resident on coasts and in wet grasslands of Patagonia and the Falkland Islands (Couve & Vidal 2003). It usually breeds close to water (up to 200 m), along the coast, river valleys, and around ponds

(Summers & McAdam 1993). On Navarino Island, upland geese were found breeding close to water mainly in scrublands dominated by *Berberis buxifolia*, *Pernettya mucronata* and *Chiliotrichum diffusum* (Moore 1983), and less frequently in forested habitats or meadow communities. The flightless steamer duck is a strictly coastal species endemic to western Patagonia and Tierra del Fuego (Couve & Vidal 2003). The flightless species nests on rocky outcrops, but access to uplands and to the sea must be easy (Weller 1976). This pattern was observed on Navarino Island, too. Among colonial seabirds, we focused on kelp gulls (*Larus dominicanus*), dolphin gulls (*Larus scoresbii*), and South American terns (*Sterna hirundinacea*). Only the dolphin gull is endemic to Patagonia and the Falkland Islands (Couve & Vidal 2003). Kelp gulls nest in a wide variety of environments along the sea coast and at continental wetlands (Yorio et al. 1999, Yorio & Borboroglu 2002), whereas dolphin gulls and South American terns are more restricted to breeding habitats on bare rocks close to the water's edge or on small offshore islands (Scolaro et al. 1996, Yorio et al. 1996). On Navarino Island, these three species nested in close vicinity (< 20 m) to each other on an exposed marine peninsula composed of bare gravels with marine deposits and meadow patches, the latter were used for nesting by the terns (Fig. 5.1). Potential autochthonous predators of eggs include the southern crested caracara (*Caracara plancus*), chimango caracara (*Milvago chimango*), Chilean skua (*Catharacta chilensis*), and kelp gull (Johnson 1965). Among the mammal species introduced to the Cape Horn Biosphere Reserve, the American mink and feral domestic dog (*Canis familiaris*) prey upon bird eggs. Predation by Norway rats (*Rattus norvegicus*) and feral pigs (*Sus scrofa*) was assumed to be uncommon as rats are only associated with the one town on the island, Puerto Williams (Anderson et al. 2006a), and tracks of pigs were absent along our transect walks. Humans occasionally take eggs from the nests of upland geese and gulls.

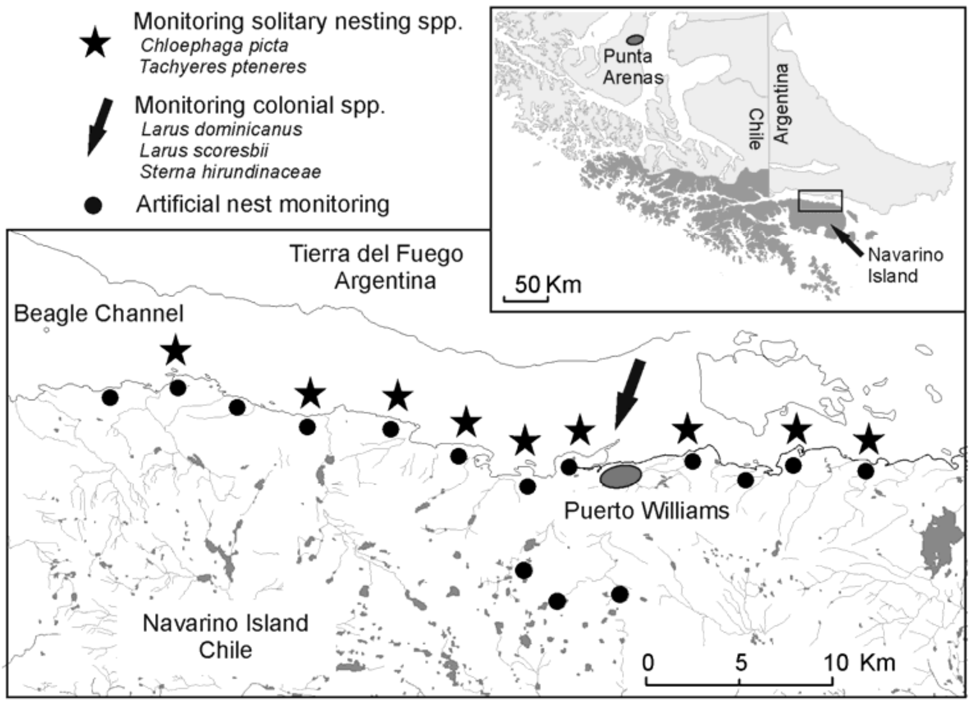

Fig. 5.1 Map of the nest monitoring study sites. Navarino Island is located within the Cape Horn Biosphere Reserve (54°-56°S, shaded in dark grey, top right) in southern South America.

Natural nests

Breeding activity of single and colonial bird species was monitored along the northern coast of Navarino Island during 74 days of the nesting season of 2005/06 and during 88 days of the nesting season of 2006/07 starting on 1st November on each year. We monitored 463 nests: upland goose (n=79), flightless steamer duck (n=23), kelp gull (n=204), dolphin gull (n=83), and South American tern (n=74). Study sites comprised seven (2005/06) and nine transects (2006/07) of 4 km shoreline. In order to detect nests of solitary nesting species, we walked the transects and recorded territorial behavior or presence of a guarding male. Dolphin gulls and South American terns were only found breeding in 2006/07 and in close vicinity to the kelp gull colony. Typically, eight days (8.16 d, SD=1.91 d) elapsed between successive visits to the same nest. At each visit we recorded the number of eggs until hatching, abandonment, or predation occurred. In order to minimize positive or negative observer effects on nest survival as a result of human tracks, nest attendance or behavior (Götmark 1992), we chose a moderate frequency of nest visits, flagged shrubs decently with short orange and yellow tapes at a distance of 5 m from the nest and reduced nest visit time to the minimum (< 1 min). We use the term nest survival to refer to the probability that a nest will hatch at least one young over the entire nesting period (Dinsmore et al. 2002, Jehle et al. 2004). This definition does not take into account predation events affecting only some eggs of a surviving nest; therefore, it overestimates offspring's survival. However, in our nest data, predation or unknown loss of some eggs in successful nests only happened in 9 % of all successful nests (n=318). These nests concerned seven nests of upland geese, 16 nests of kelp gulls, two nests of dolphin gulls, and three nests of South American terns. We guess that possible predators for upland geese were autochthonous bird predators or humans rather than the mink, since it destroys many or all eggs at once (Ferreras & Macdonald 1999). In the colonies the gulls themselves were probably responsible for scavenging or removing eggs.

Artificial nests

Although artificial nests are widely used in avian field studies (Moore & Robinson 2004), they have been criticized as not reliably reflecting predators and predation rates of natural nests (e.g. Faaborg 2003). This is because artificial nests differ from real nests in a number of important ways such as nest type, egg type, concealment, nest spacing, odor, missing adults etc. (Major & Kendal 1996). In order to maximize the external validity of experimental design, authors recommend using artificial nests primarily in conjunction with active nests, and identifying the predators at both types of nest (Mezquida & Marone 2003, Moore & Robinson 2004). So far, a direct comparable context (same data taken at the same time and location, and with the same methods) has been achieved in only a few studies (review in Moore & Robinson 2004). Here, we combined natural nest monitoring with artificial nests in a comparable context as a way to effectively investigate the influence of habitat and nest characteristics on the predator type. Yet, we are aware that the interpretation of our data derived from artificial nests has to be treated with caution.

Artificial nests were constructed to imitate geese nests and were baited with one domestic chicken egg and one clay egg. Artificial ground nests were of approximately 20 cm in diameter, lined with dry plant material and upland goose down. In order to reduce olfactory cues that might influence predators, we washed the chicken eggs and used gloves when handling eggs and nests. The nests were marked with flagging tape in the same manner as for the natural nests.

Five hundred and seventy-five artificial nests were installed at twelve study sites in marine coastal habitats (n=500) and at three sites along lakes (n=75). These sites included two different types of shore: (1) "rocky outcrop" (n=225 nests), and (2) "beaches" (n=350 nests). These two shore types were assigned as follows: within each study site, we measured the percentage of cliff, rock, pebbles, sand, mud, and vegetation (leaf litter, grasses, mosses) each 200 m within 10x1 m of the shoreline, as well as the incline of the shore within 10 m from the water shed (flat: 0-1 m, medium: 1-2 m, steep: < 2 m). The first shore type, rocky outcrop, was assigned when over the half of these measurements were predominated by cliffs, rocks, and steep shores, whereas beaches were characterized by over 50% pebbles, sand, mud, vegetation, and flat shores. The adjacent vegetation in the twelve study sites were majorly shrubs of *Berberis buxifolia* and *Chiliotrichum diffusum*, but also forested habitats (*Nothofagus* spp.) and meadows (Pisano 1977, Moore 1983, Rozzi et al. 2006a). In coastal habitats, 200 nests were placed in a 71 day nesting season starting on 29th December 2005, and 300 nests were placed in a 69 day nesting season starting on 4th December 2006. At the lakes, 75 nests were installed starting on 6th January 2007 in order to survey for mink predation in the interior of the island where upland geese use wetlands for breeding (Summers & McAdam 1993, S. McGehee, unpublished data).

Each of the twelve artificial nest sites comprised a stretch of 1.25 km, where 25 nests were distributed with a distance of 50 m in between each nest. Nests were placed up to 30 m from the water's edge in different vegetation types, cover and different degrees of nest concealment defined by the vegetation found at each 50 m mark. We monitored nests at 5 day intervals (5.12 d, SD=0.41 d) for 29-30 days, which is the incubation period of upland geese after completing the clutch (Summers & McAdam 1993). We considered a nest to have been preyed upon when at least one egg was found preyed on or marked with bills or teeth. Humans destroyed 17 nests in the marine coastal habitat. These nests were excluded from our analysis (total n=558).

Predator identification

We categorized predators into five groups: American mink, domestic dogs, humans, birds and "unknown" for uncertain cases caused by multi-predator visits or the lack of clues. The identification of predators was based on a detailed examination of eggshells and their location, nest material dislocation, and other signs, such as the presence of hairs or scats. Although some authors preclude the identification of nest predators from nest remains (e.g. Larivière 1999), we believe that we classified predators in an unbiased manner. The predator community on Navarino Island is remarkably small and overlaps in predator patterns are rare. However, for the three species nesting in colonies, it was difficult to identify predators, mostly due to the disappearance of egg shells, which were exposed to strong winds and bird activity in the colony. To diagnose mink predation, we followed Craik (1995) and Opermanis et al. (2001). Mink predation signs were: canine marks, typically 1-2 mm wide and, if paired, ca 10 mm apart, eggshells often hidden under vegetation, eggs might be untouched, and nests little damaged. Bird predation signs were: small egg fragments, eggshells in nest or vicinity, eggs missing, nest material lifted or spread to the nearby surroundings. Dog predation signs were: egg punctures 4-5 mm wide and, if paired, > 3 cm apart, egg fragments > ½ egg, widespread, and nest remains spread out. If all eggs disappeared without signs of fragments, and downy feathers still covered the nest, this pattern was attributed to humans (but only for solitary nesting species). Employing comparison with beak imprints in the clay eggs taken from specimens, 42.3 % of artificial clay eggs preyed upon by birds could further be classified into species. A small number of imprints of rodent incisors on artificial clay eggs (2.5 %, n=14 nests) were attributed to mice (either *Abrothrix xanthorhinus* or *Oligoryzomys longicaudatus*).

Area and nest site characteristics

We examined the effect of area and site characteristics of nests on the type of predator (mink vs. birds) they attracted. We chose variables that were important for different search tactics (e.g. Butler & Rotella 1998) (Table 5.1). We took measurements at all nest sites of solitary nesting species (n=102) and at all artificial nests set in the nesting period 2006/07 (n=375). Area-specific variables were taken for all artificial nests (n=558). Measurements were conducted on the day a nest was found or constructed.

Table 5.1 Area and nest site variables measured at artificial nests and natural nests of solitary nesting species.

Area variables	Definition	Measurement/categories
Age	Age of the nest at hatching/failure counted from the first day of the breeding season	Continuous [days]
Aquatic	Type of aquatic habitat defined for each site	Coast and lakes
Mink	Relative abundance of mink signs measured as percentage of positive 500 m sections	Continuous [%]
Shore	Type of shore defined for each site (slope and composition of shore)	Rocky outcrop and beaches
Temperature	Median temperature with 4 daily measurements across survival period of each nest	Continuous [°C]
Site variables	Definition	Measurement/categories
Cover	Area covered by vegetation in a 5x5 m^2 square around nest	1. 0-20 % 2. 20-40 % 3. >40 %
Distance	Shortest distance of nest to shore, measured with GPS	Continuous [m]
Habitat	Predominant habitat type in a 10x10 m^2 square around nest	Bare: earth/rock Uniform: pasture, peatland, wetland Simple: shrubs, grasses, but no mature trees Complex: evergreen, mixed, deciduous forest
Height	Height of shrubs and bushes at nest, estimated by hand palm	Continuous [m]
Side	Percentage lateral coverage of nest, taken adjacent to the nest from the 4 cardinal directions	1. 0-25 % 2. 25-50 % 3. 50-75 % 4. >75 %
Top	Percentage overhead nest concealment, quantified looking from above down to nest	1. 0-25 % 2. 25-50 % 3. 50-75 % 4. >75 %

Bird and mink abundance

We censused bird populations two to four times during each breeding season at seven (2005/06) and nine (2006/07) coastal study sites. We counted the target species and avian predators (together eight species) using binoculars (8x25) while walking 4 km transects along the shorelines during the morning. We recorded all observations of adult and juvenile animals on both sides of the transect, up to 50 m away (1 transect=40 ha). Line transects are favored over point counts if targeted species are relatively easy to identify, but mobile, and occurring at low densities (Bibby et al. 2000). Gulls and terns occupying large colonies were counted from a larger distance to prevent flushing and were cross-checked by a second observer. However, we are aware that our estimations of colonial birds are approximate. For our analysis we pooled data over study sites, although the abundance of solitary nesting species and predatory birds (colonies excluded) differed significantly between sites (Kruskal-Wallis-Test: $\chi^2=224.7$, df=6, $p < 0.001$). However, further investigation of the causes of these differences is beyond the scope of this paper.

We systematically surveyed for mink signs (scats, tracks, sightings) twice each breeding season (spring and summer) at seven (2005/06) to twelve (2006/07) marine coastal study sites and at three lakes (2006/07). At three marine sites and at lakes, we relied on data from one survey only (summer 2007). The 4 km transects and lake perimeters (1 km) were divided into 500 m contiguous sections and the proportion of positive sections (with signs) for each transect was calculated (e.g. Bonesi & Macdonald 2004).

Statistical analysis

For estimates of nest survival of natural and artificial nests, we used the Mayfield estimator (Mayfield 1961) with the standard error developed by Johnson (1979). The Mayfield method estimates the daily survival rate (DSR) as DSR=1–DPR (daily predation rate). DPR is calculated as the number of failed nests divided by the number of exposure days. For the calculation of the number of exposure days of failed nests, we assumed that failure occurred at the midpoint between the final nest checks. The nest survival rate over the nesting period t (days) is calculated as $(DSR)^t$, which can be expressed as a percentage. The durations of egg-laying and incubation periods were taken from the literature (see caption Fig. 5.2). As we lacked literature for flightless steamer ducks, we used the periods described for upland geese. Data for both breeding periods were pooled. As data from the egg-laying period was sparse, we could not stratify by stages (as recommended by Jehle et al. 2004) and thus had to assume constant nest survival.

We used principal component analysis (PCA) and linear discriminant analysis (DA) in order to check for the compatibility of artificial nests with natural nests, and to check for differences in site-specific nest variables (six variables, Table 5.1) between nests of the single-breeding species (classes=species). This first data set (DA 1) combined artificial and natural nests (n=475). In a second data set (DA 2), we investigated the combination of area-specific and site-specific nest variables (eleven variables, Table 5.1), which best separates the type of predator (classes=predators) using artificial nests (n=375, 2006/07). We performed a DA based on the results of the PCA using the ade4 package rewritten for the R environment (R Development Core Team 2008) of the ADE-4 software (Thioulouse et al. 1997, Dray & Dufour 2007). For DA 2, we applied a reduced set of variables based on the PCA results in order to prevent redundancy of information. The significance of the DA was tested by a Monte-Carlo permutation test. Continuous variables that were not normally distributed were transformed. We log transformed distance and height, and arcsine square-root transformed mink density. The PCA routine of the ade4 library applies variables standardized to zero mean and unit variance.

We used nonparametric statistics for comparing proportions (2-sample tests for equality of proportions), sample medians (Wilcoxon's rank sum test), and for testing for independence in contingency tables (Fisher's exact and chi-square tests) with Yates' continuity and Bonferroni corrections, all two-sided. The statistical analyses conducted in R version 2.7.1. (R Development Core Team 2008) were considered significant when p-values were < 0.05. The discriminant analysis DA 2 was documented in R source code and submitted as supplemental material.

Results

Nest survival probabilities

Mayfield constant nest survival rates were comparatively high for species nesting in colonies: 84.2 % for dolphin gulls, 76.3 % for South American terns, and 67.2 % for kelp gulls. In contrast, nest survival rates were low for the solitary nesting upland goose (20.0 %), and very low for the solitary nesting flightless steamer duck (5.2 %) (Fig. 5.2). Artificial nests had the lowest survival rates with only 0.4 % surviving. As the 95 % confidence intervals of Mayfield nest survival probabilities of species nesting in colonies did not overlap with those of solitary nesting species, differences in the nest survival of these two breeding strategies were significant.

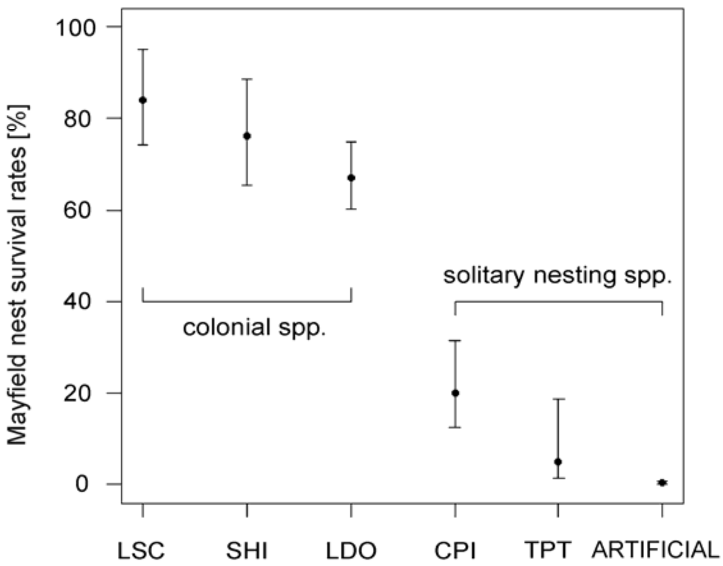

Fig. 5.2 Nest survival estimates for colonial and solitary nesting species. Survival probabilities followed Mayfield (1961) with 95 % confidence intervals (Johnson 1979). Breeding periods were pooled. LSC=*Larus scoresbii*[a], SHI=*Sterna hirundinacea*[b], LDO=*Larus dominicanus*[c], CPI=*Chloephaga picta*[d], TPT=*Tachyeres pteneres*[e], ARTIFICIAL=Artificial nests[f]. Egg-laying and incubation periods (*t*) applied in DSR$^{\wedge t}$ [a]26 days (Yorio et al. 1996), [b]26 (Scolaro et al. 1996), [c]28.5 (Yorio & Borboroglu 2002), [d]36 (Summers & McAdam 1993), [e]36 (as *C. picta*), [f]30.

Identified predators

We found different patterns of predation for solitary nesting species, colonial species, and the artificial nests (Table 5.2). Minks were the most important predators of nests of flightless steamer ducks accounting for 52.6 % of preyed nests (successful and abandoned nests excluded). On the contrary, mink were responsible for only 18.2 % of the preyed nests of upland geese, the difference being significant between the two solitary nesting species (2-sample test for equality of proportions: χ^2=6.1, p=0.01). The predation rate of mink on artificial nests (pooled over breeding periods as there were no significant differences) was 17.3 % and thus comparable with values of predation by mink on upland geese nests. Predation on artificial nests in rocky outcroppings, however, yielded a significantly higher predation rate (36.4 % of total predators) than along beaches (6.2 %, 2-sample tests for equality of proportions: χ^2=77.9, $p < 0.001$). The same trend was detected for upland geese, whose nests were preyed upon by mink to a higher proportion at rocky outcrop shorelines (27.3 % or 3 out of 11 preyed nests) than at beaches (15.2 % or 5 out of 33 preyed nests). This was not true for flightless steamer ducks, though (46.7 % or 7 out of 15 at rocky outcrops versus 75.0 % or 3 out of 4 at beaches). We did not find any predation by mink in the three colonial species, but they had a quite high rate of unknown nest failure of 84.6-100 % (14.9-24.0 % of total nests found). Thus predation by introduced mink coincided with those species characterized by rather low Mayfield nest survival probabilities.

Birds as autochthonous predators were greatly responsible for lowering the nest survival of artificial nests (68.8 %). We identified bird predators of 236 clay eggs: the southern crested caracara was the most common avian predator with 62.7 % predation on 236 clay eggs, followed by the chimango caracara (31.3 %). *Larus* spp. (5.1 %) and the Chilean skua (0.9 %) did not play a major role in the predation of artificial nests. For the natural nests, birds accounted for 31.8 % of preyed nests in upland geese, 26.3 % in flightless steamer ducks, and only 7.6 % in colonial species. Finally, humans were identified as an important predator for upland geese, causing 25.0 % of failed nests.

Table 5.2 Nest fate of natural and artificial nests. Numbers indicate the percentage of total nests found and, in parenthesis, the percentage of total preyed nests (successful and abandoned nests excluded).

Nest fate	*Chloephaga Picta*	*Tachyeres pteneres*	*Larus dominicanus*	*Larus scoresbii*	*Sterna hirundinacea*	Artificial nests
Successful*	36.7	8.7	74.0	90.4	82.4	0.0
Abandoned	7.6	8.7	0.0	0.0	0.0	-
Mink	**10.1 (18.2)**	**43.5 (52.6)**	**0.0 (0.0)**	**0.0 (0.0)**	**0.0 (0.0)**	**17.3 (17.3)**
Bird	17.7 (31.8)	21.7 (26.3)	2.0 (7.5)	0.0 (0.0)	0.0 (0.0)	68.6 (68.6)
Human	13.9 (25.0)	4.4 (5.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Dog	1.3 (2.3)	8.7 (10.5)	0.0 (0.0)	0.0 (0.0)	2.7 (15.4)	0.0 (0.0)
Mouse	-	-	-	-	-	2.6 (2.6)
Unknown	12.7 (22.7)	4.3 (5.3)	24.0 (92.5)	9.6 (100.0)	14.9 (84.6)	11.5 (11.5)
Total nests	79	23	204	83	74	558

* no. of successful nests/ no. of total nests found yields into the naïve nest survival estimator which is positively biased (Jehle et al. 2004)

Factors influencing mink predation

Using discriminant analysis on PCA results, we tested the representativeness of artificial nests ("artificial"), and the explanatory nest site variables which best separated the species classes of upland goose ("CPI") and flightless steamer duck ("TPT") (n=475, DA 1). The first principal component explained 37 % of the variance, the second component 19 %. Variables with high loadings (> |0.7|) on the first component was height of shrubs around the nest (0.82). Two discriminant functions (the axes) were generated (in general n-1, n=number of classes), and the first axis accounted for 85 % of total inertia. The Monte-Carlo permutation test showed that discrimination was significant ($p < 0.001$, based on 1000 permutations). The centroid of artificial nests strongly overlapped with the centroids of solitary nesting species (Fig. 5.3).

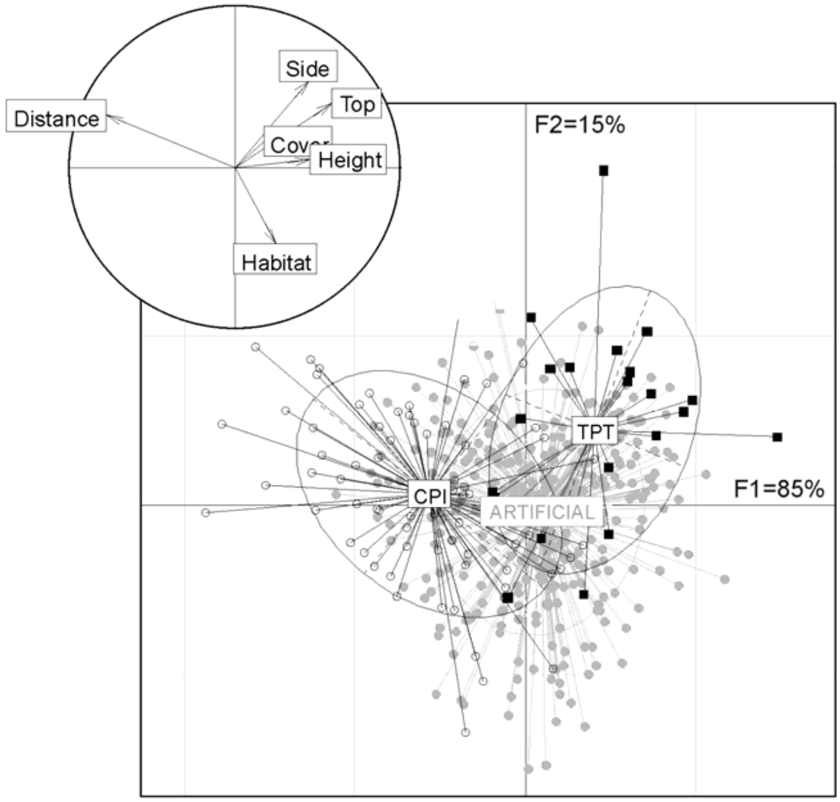

Fig. 5.3 Results of the discriminant analysis 1. DA 1 was based on PCA results of 6 site-specific nest variables classified by artificial nests and natural nests of solitary nesting species (n=475). ARTIFICIAL=Artificial nests, CPI=*Chloephaga picta*, TPT=*Tachyeres pteneres*. Eigen values F1: 0.26 (85 % total inertia), F2: 0.05 (15 % total inertia). The circle represents the cosines between the variables and the canonical scores. Direction and length of the arrows are a metric of the discriminatory power of the variables.

However, the chosen set of variables discriminated very well between the nests of both "real" species. The first (horizontal) axis was mainly determined by distance to the shore (cosines=-0.77) and top nest cover (0.58, all other cosines< |0.46|) (Fig. 5.3 circle). Along the second axis (15 % of total inertia), side nest cover (0.54, all other cosines< |0.47|) contributed to the separation of classes. Thus upland geese built their nests at a greater distance from the shore, whereas nests of flightless steamer ducks were characterized by a high overhead and lateral concealment (see Table 5.3 for empirical values).

Table 5.3 Empirical values for variables with discriminatory power in discriminant analysis 1. The variables are described in Table 5.1.

Discriminant variables DA 1	*Chloephaga Picta*	*Tachyeres pteneres*	Artificial nests
Distance [m] (mean, SD, median, range)	35.8±47.6 6 (1-236)	8.5±6.5 17 (1-24)	9.1±6.1 7 (2-32)
Top (median, range)	1 (1-4)	4 (1-4)	2 (1-4)
Side (median, range)	2 (1-4)	4 (1-4)	3 (1-4)
Total nests	77	23	375

The same multivariate analysis was performed on 375 artificial nests with four predator classes "mink", "bird", "mouse", "unknown", and a fifth class containing "successful" nests (DA 2). The first principal components explained 27 % of the variance, the second 23 %. High loading variables (> |0.7|) for the first component were lakes (1.3), top nest cover (-0.75), and height of shrubs around the nest (-0.71). This time, we out sorted redundant variables such as relative abundance of mink signs as it highly correlated with the type of shore (Spearman's rho=0.86). Other redundant variables were Temperature, Cover and Side. We then performed the discriminant analysis with seven main variables. Accordingly, the predator classes were significantly separated ($p < 0.001$, Monte-Carlo test based on 1000 permutations) along four discriminant functions. The first function accounted for 50 % of total inertia, the second for 38 %, and the following axes for 10 % and 2 %, respectively. The centroid of successful nests was very well separated from the centroids of preyed nests (Fig. 5.4).

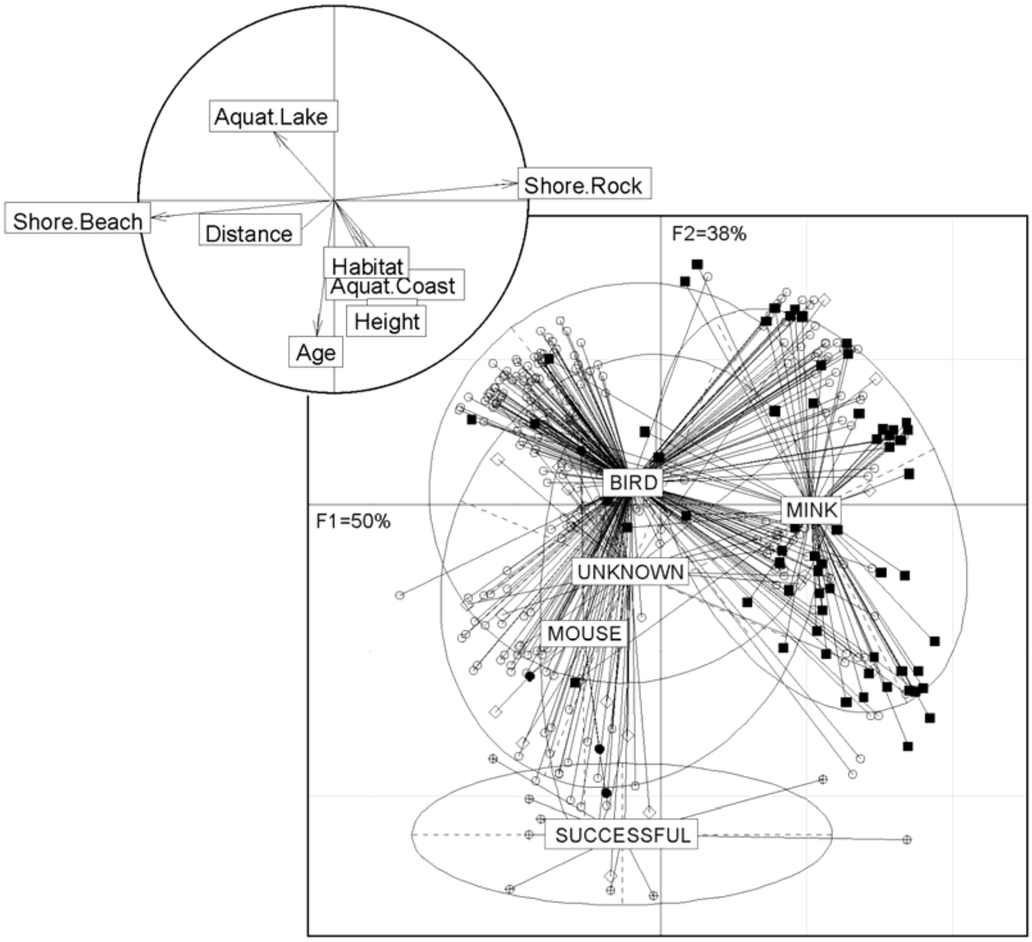

Fig. 5.4 Results of the discriminant analysis 2. DA 2 was based on PCA results of seven area-specific and site-specific nest variables of artificial nests (n=375), classified by nest fate ("successful", "mink", "bird", "mouse", "unknown"). Mice can either refer to *Abrothrix xanthorhinus* or *Oligoryzomys longicaudatus*. The variable Top is covered by Height. Eigenvalues F1: 0.22 (50 % total inertia), F2: 0.17 (38 % total inertia). The circle represents the cosines between the variables and the canonical scores. Direction and length of the arrows are a metric of the discriminatory power of the variables.

Of the four predator classes, mink formed the most distinct class, although overlapping with the three remaining classes, which were located close together. Nests with unknown reasons for failure were more probably preyed upon by birds and mice rather than by mink, although multi-predator visits cannot be excluded. Along the first axis, the type of shore (cosines=0.94 for rocky outcrop, and -0.94 for beaches, all other cosines < |0.32|) was the variable contributing most to separating the predator classes (Fig. 5.4 circle). Along the second axis, nest age (-0.70), height of vegetation at the nest (-0.54), and top nest cover (-0.50, all other cosines < |0.36|) were the three variables contributing most discriminatory power. Thus mink mainly preyed on nests at coastal habitats with rocky outcroppings where relative mink abundance was also higher than along beaches (Wilcoxon rank sum test: W=114, $p < 0.001$, n=22 sites). At rocky outcrops 68.8 % 500 m sections contained signs (median, range 25-100 %, n=9), whereas at beaches only 12.5 % of the sections were positive (0-43.8 %, n=13). Nests built towards the end of the breeding season were apparently more successful (see Table 5.4 for empirical values).

Table 5.4 Empirical values for variables with discriminatory power in discriminant analysis 2. The variables are described in the Table 5.1. The main focus of DA 2 was to assess differences between predation patterns of invasive mink and autochthonous birds. Sample sizes for artificial nests preyed on by mice and for successful nests were small, but included into the analysis for reasons of integrity.

Discriminant variables DA 2	Mink	Bird	Mouse	Unknown	Successful
Shore, rocky outcrop (# nests)	55	85	0	8	2
Shore, beaches (# nests)	8	183	5	22	7
Age [days] (mean, SD, range)	28.1±20.8 (5-57)	28.5±18.8 (5-58)	31.4±23.2 (6-49)	31.7±20.4 (5-59)	68.4±0.73 (67-69)
Height [m] (mean, SD, range)	0.47±0.44 (0-2)	0.38±0.31 (0-2)	0.38±0.08 (0.3-0.5	0.39±0.39 (0.1-1.7)	0.28±0.08 (0.2-0.4)
Top (median, range)	2 (1-4)	1 (1-4)	4 (2-4)	3 (1-4)	3 (1-4)
Total nests	63	268	5	30	9

Navarino Island's bird community

As the abundance patterns are different for colonial species, which occur clumped, individual numbers per colony were used, whereas for the other species studied individuals/km was employed. Kelp gulls as a predatory species on search flights were also counted along our transects. The kelp gull colony had a size of 315 individuals (range 168-433, both breeding seasons pooled), dolphin gulls of 150 individuals (132-200) and South American terns of 90 individuals (64-320). Among the predatory birds, kelp gulls had a relative abundance of 4.5 individuals/km (median, range 0.5-19.3) per transect, a significantly higher abundance than estimated for the three raptor species (all Wilcoxon-tests: W=820, $p < 0.001$) (Fig. 5.5). Abundances for raptors ranged from 0-0.75 individuals/km for crested caracara, 0-3.75 for the Chilean skua, and 0-3.25 for chimango caracara. Among solitary nesting species, we estimated 4.75 individuals/km (0.5-31.75) for the upland goose and 1.75 individuals/km (0.5-13.75) for flightless steamer ducks. Although we made our counts in the same sites where nests were monitored, these counts refer to resting and feeding birds as well as guarding males (cryptic incubating females could not be included) (Fig. 5.5).

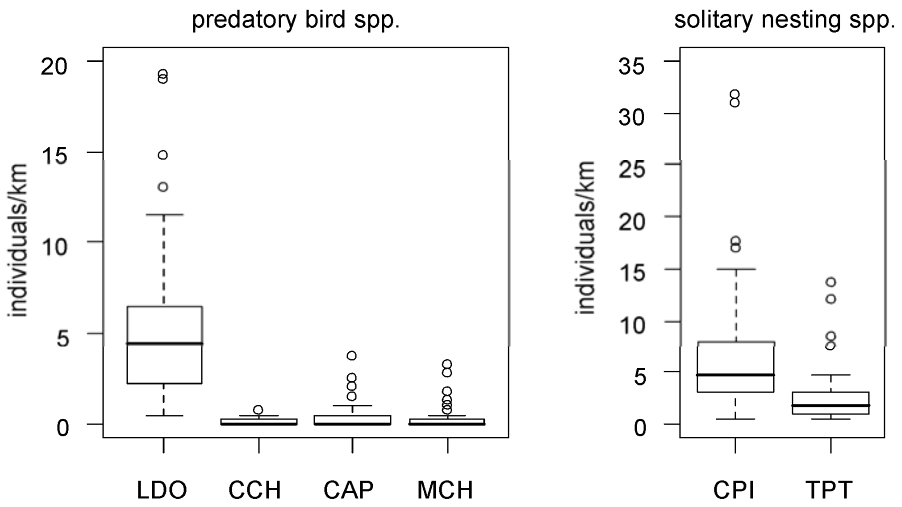

Fig. 5.5 Bird counts of solitary nesting species and predatory birds. Predatory birds refer to kelp gulls on search flights and raptors. Counts were made along the northern coast of Navarino Island and cover all study sites and breeding periods (2005-2007). LDO=*Larus dominicanus*, CCH=*Catharacta chilensis*, CAP=*Caracara plancus*, MCH=*Milvago chimango*, CPI=*Chloephaga picta*, TPT=*Tachyeres pteneres*.

Discussion

Vulnerability profile

With a combined approach of natural and artificial nests a vulnerability profile was drawn for ground-nesting waterbirds under mink invasion on Navarino Island. We found patterns of nest predation by mink among social nesting strategies, habitat, and nest characteristics. Thus, the ground-nesting waterbirds that are especially vulnerable to predation by mink are those that are (i) solitary nesting, (ii) breeding in coastal habitats with rocky outcrop shores, and (iii) concealing their nests. This profile is best illustrated by a high predation rate of mink (44 %) on flightless steamer ducks, a species with very low densities (1.75 individuals/km), which perfectly match all the characteristics of our vulnerability profile. Other ground-nesting species to which most of these characteristics apply are: flying steamer duck (*Tachyeres patachonicus*), crested duck (*Lophonetta specularioides*) and kelp goose (*Chloephaga hybrida*). In consequence, these represent bird species vulnerable to mink predation, and might require special conservation efforts.

How can these patterns characteristic for predation by mink be explained? We start with the first pattern, solitary nesting (i). Depending on group size, nest densities, predator type, and predator size, colonial breeding can lead to a decrease in predation risk due to earlier predator detection and/or higher nest defense efficiency (reviews in Wittenberger & Hunt 1985, Siegel-Causey & Kharitonov 1990). For example, gull colonies successfully show aggressive behavior towards predators (Kruuk 1964), a reason why some bird species are found associated with gull colonies during nesting, e.g. tufted ducks (Opermanis et al. 2001). The second pattern, the association with rocky outcrop marine shore habitats (ii), apparently is a function of habitat requirements of mink. Dunstone (1993) stated that in coastal habitats sheltered rocky shores are ideal for mink. Our results agree with this. Mink abundance was significantly higher along steep and rocky coastal shores than along beaches. Our results also revealed the importance of concealed nests (iii) as predictors for predation by mink. Many researchers agree about the differences between avian and mammalian predators with respect to the importance of nest concealment (e.g. Butler & Rotella 1998, Opermanis et al. 2001). Thus, avian predators appear to visualize nests, whereas mammalian predators primarily depend on olfactory cues and therefore prey upon nests irrespective of concealment (Guyn & Clark 1997). This explains why mink were preying upon both types of nests; open nests (predominantly upland geese) and concealed nests (flightless steamer ducks). However, our results on natural and artificial nests indicate that concealed nests in surroundings with dense vegetation were more vulnerable to predation by mink. We suggest two reasons. First, concealing nests requires a minimum amount of dense vegetation, which is a habitat preference of mink (e.g. Yamaguchi et al. 2003), and second, concealment is limiting the view of the surroundings of the nest and thus might prevent appropriate response if predators are not detected in time (trade-off hypothesis by Götmark et al. 1995).

Vulnerability and "naïvety"

Behavioral decisions under the risk of predation include escaping from predators, inspecting predators, and mobbing predators depending on the encounter situation and type of prey, i.e., adults or offspring (Lima & Dill 1990). Defense strategies against potential avian predators on their clutches have been described for upland geese (Quillfeldt et al. 2005) and flightless steamer ducks (Livezey & Humphrey 1985). However, assuming that a mammalian predator will induce different encounter situations than avian predators, this requires different behavioral decisions than those for avian predators. On Navarino Island, bird species were not confronted with a terrestrial mammalian predator until the arrival of mink during the mid-1990s (Rozzi & Sherriffs 2003). There is no evidence for evolutionary isolation from native terrestrial predators as Navarino Island does not harbor endemic bird species (Couve & Vidal 2003). Bird species endemic for Patagonia have been evolved together with native predators like the Fuegian red fox (*Pseudalopex culpaeus lycoides*) in Tierra del Fuego. Although bird species on Navarino Island should have developed evolutionary adaptations to terrestrial predators, we believe that they might lack behavioral adaptations to the recently arrived mink. Animals have the ability to behaviorally influence their risk of being preyed upon in ecological time, i.e., during their lifetime (reviewed in Lima & Dill 1990). Missing confrontation with a terrestrial predator therefore should result in behavioral naïvety for resident bird species as shown for arctic terns in mink removal areas (Nordström et al. 2004).

Validity of predicting vulnerability

We have been investigating predation of mink in its early colonization stage at the beginning of the 2000s. Since then, mink sightings have been increasing, suggesting a rapid increase in the mink population (Rozzi & Sherriffs 2003). However, trapping and sign surveys in different semi-aquatic habitats of Navarino Island (Anderson et al. 2006a, E. Schüttler, unpublished data) have shown that the density of mink is still below densities measured in other invaded regions (e.g. Previtali et al. 1998, Moore et al. 2003). Although we lack knowledge of the carrying capacity for mink on Navarino Island, we assume that the population of mink will grow further. The consequences this might have for bird populations have to be investigated by long-term research and cannot be extrapolated from our short-term results. One possible divergence from our suggested vulnerability profile could be that species nesting in colonies will also be affected by a future increasing population of mink. The higher defense behavior of colonies does not always protect them from predation by mink as various studies have demonstrated (e.g. Craik 1997, Antolos et al. 2004, Nordström et al. 2004).

Concerns about the validity of inferences made about nest survival of natural nests from artificial nests basically originate from the differences in parental presence, odor, egg characteristics, and location of these two nest types (Butler & Rotella 1998). In our study, artificial nests had significantly lower survival rates than natural nests. We assume that the main draw-back of artificial nests, "no cryptic female sitting on the eggs" (Angelstam 1986, p. 370), could have attracted more avian predators to the more visible nests. A possible solution for this draw-back could be to cover the eggs of artificial nests with down, just like geese and ducks in our study area do when leaving their nests. Despite these difficulties and possibilities to improve our study design, we think that our data is sufficiently reliable, for three reasons. First, as we were primarily interested in predation by mink, we think that our artificial nests provided sufficient olfactory cues (downy feathers) to attract mammalian predators irrespective of concealment (see the comparable predation rates of mink between artificial nests and upland geese). Second, the internal validity of our artificial nest design was maintained carefully in order to accurately measure predator behavior (see Moore & Robinson 2004); and third, an extrapolation of our results to real nests might be justified to a certain degree as we maximized comparability, for example nest characteristics of artificial nests matched well with those of natural nests (results of DA 1) indicating that they were quite "truly" built.

Management implications

The observed vulnerability patterns are valuable for decision-making and priority setting in the management of invasive mink on Navarino Island. We identified ground-nesting waterbirds under risk from a conservationist point of view. Control programs should focus on preventing mink from establishing territories near breeding areas of vulnerable ground-nesting species and bird colonies. The assessment of coastal breeding habitats can be facilitated by using Geographical information systems (GIS) and existing digital data archives (Rönkä et al. 2008). Predator removal programs have been shown to have a positive effect on hatching success and post-breeding population size of target bird species (reviews in Newton 1994, Côté & Sutherland 1997). Targeted removal of mink from particular areas, particularly rocky outcrop coasts, during the breeding season (e.g. Clode & Macdonald 2002, Banks et al. 2008, Ratcliffe et al. 2008) could therefore represent a first task of conservationists. The design of a long-term management plan should include clear objectives, participation of local stakeholders, careful consideration of costs vs. benefits, possible negative effects of target and non-target species, and prevention efforts (e.g. Moore et al. 2003, Nordström et al. 2003, Baxter et al. 2008). However, mink control should not overshadow vigilance against other human induced factors contributing to mortality in ground-nesting waterbirds, such as dog predation or egg-stealing by humans.

CHAPTER SIX

Do you like the mink? Public perceptions of invasive mammals in the Cape Horn Biosphere Reserve[5]

Abstract

Biological invasions and their management are complex and often controversial issues reflecting a diversity of values. Research and public policy on invasive species have concentrated on their ecological and economic impact, most frequently overlooking the social component. Yet, the exploration of public views on invasive exotic species represents an urgent need for any societal discourse on this cross-cutting issue. We conducted qualitative semi-structured interviews to explore the knowledge, range of values, and acceptance of control of invasive species in a socio-culturally heterogeneous community within the Cape Horn Biosphere Reserve in southern Chile. Our questions focused on two contrasting invasive species of high conservation concern: (1) the American mink (*Mustela vison*), a recently introduced carnivore impacting waterbirds and poultry farming; and (2) the North American beaver (*Castor canadensis*), an established herbivore with strong impacts on subantarctic forests. We found that public knowledge, conceptualization of exotic species and concern at their impacts were complex and basically acquired in a non-formal way. Value attribution was species-specific, impeding generalizations concerning exotic and native species. In contrast to the recently arrived mink, the beaver had become interconnected with the community (utilitarian, symbolic values), suggesting a socially dynamic conceptualization of the native/non-native framework. With respect to the management of invasive species, the local community revealed multi-faceted positions and provided numerous suggestions. The general consensus was in favor of control, but skeptical towards total eradication. We conclude that in our case study the local community revealed a wide range of positions around the complex issue of biological invasions. Further steps towards an inclusion of a broader public in the process of finding responses to invasive species are proposed.

Key words: acceptance, attitudes, *Castor canadensis*, eradication, management, *Mustela vison*, non-native species, policy, qualitative interviews, values

[5] A modified version of this chapter is intended for publication as Schüttler E, Rozzi R, Jax K „Towards a societal discourse of invasive species management: a case study on public perceptions of mink and beaver in Cape Horn“, in Human Ecology.

My contribution: I designed the study together with Uta Berghöfer, Kurt Jax and Ricardo Rozzi. I conducted the interviews, analyzed the data, wrote and submitted the paper. Kurt Jax contributed single paragraphs to the discussion. Ricardo Rozzi and Kurt Jax supervised the study.

Introduction

There is widespread concern among nature conservationists and policy institutions about invasive exotic species "progressively replacing biodiversity with biosimilarity" (Warren 2007, p. 428). Biological invasions are not only considered as one of the major threats to the earth's biota, but some also degrade human health and wealth (Sala et al. 2000, Pimentel et al. 2005). As a consequence of such impacts, "native only" policies (Kendle & Rose 2000) have widely been promoted and implemented (e.g. McNeely et al. 2001, Krajik 2005).

Scientists are increasingly questioning the native/non-native dichotomy (a review of the key criticisms can be found in Warren 2007). Among the criticisms it has been pointed out that "native" and "exotic" are socially constructed labels and highly dependent on spatial and temporal scales (e.g. Townsend 2005). Additionally, the implementation of this construct is related to non-static value systems, not only to science (e.g. Hopkins 2001); there are some parallels to xenophobia (e.g. Olwig 2003, but see Hettinger 2001); and the dichotomy is valid only when humans as vectors for the movement of species are excluded from nature (e.g. Warren 2005).

Not only scientists are confused given that the debate also involves conflicting value systems and public policies (Lodge & Shrader-Frechette 2003). In this study, we investigate how the public might also hold an array of different perspectives on exotic species. Compared to a large body of literature on the negative ecological impacts of invasive species (Vitousek et al. 1997, Parker et al. 1999, D'Antonio & Hobbie 2005), and some important contributions on their economic costs (e.g. Perrings et al. 2002, Pimentel et al. 2005), little attention has been paid to the public's perceptions of invasive species (García-Llorente et al. 2008). An increasing number of studies on social components of invasive species are beginning to explore knowledge, values, ecosystem services, and ethical viewpoints regarding the control of these species (Robinson et al. 2004, Fitzgerald et al. 2005, Meech 2005, Fraser 2006, Binimelis et al. 2007, Bremner & Park 2007, Fischer & van der Wal 2007, Haider & Jax 2007, Shackleton et al. 2007, García-Llorente et al. 2008). These studies have addressed the positions of different stakeholders, including indigenous people and the general public, and have disclosed a contrasting diversity of perspectives.

What does this mean for the management of invasive species? According to the Malawi Principles (here: principle 1) of the Ecosystem Approach of the Convention on Biological Diversity, "the objectives of management of land, water and living resources are a matter of societal choice" (UNEP/CBD 2000, p. 104). Decision-making through societal discourse, i.e., connecting scientific knowledge and societal choices, however, still remains a major challenge (Berghöfer & Berghöfer 2006). The consideration of a broader array of perspectives, knowledge, cultures, values and relationships with nature represents a critical step for gaining a broader socio-ecological understanding and reducing conflicts in biodiversity policy (Jax & Rozzi 2004, Binimelis et al. 2007, Fischer & Young 2007, Rozzi 2007, Berghöfer et al. 2008). The previous step might help to prioritize the allocation of scarce resources available for management and conservation (Hobbs et al. 2006). In the field of invasive species, the consideration of public viewpoints represents an important asset for the development and acceptance of new management approaches.

Our study assesses the social dimension of invasive species in one of the most remote and pristine areas remaining on the planet: the Cape Horn Biosphere Reserve (CHBR) in the Sub-Antarctic Magellanic Ecoregion (Rozzi et al. 2006a). Our aim is to offer a novel approach to the global discussion on exotic species, and to provide insights for the regional design and implementation of management plans for invasive mammals in the CHBR. Here, awareness of the impacts of invasive species had led to a regional control program residing with the Ministry of Agriculture, specifically the Agriculture and Livestock Service (SAG) (Iriartre et al. 2005, Soto & Cabello 2007). The hunting of mink, beavers, and other declared detrimental invasive species was promoted in the Magallanes and Chilean Antarctic Region from 2004-2007. This program has resulted in 11,700 dead beavers, and 234 dead mink (Soto & Cabello 2007). With respect to the beaver, Chilean and Argentinean scientists and government officials are currently planning the largest eradication project ever attempted: "The beavers must die" (Choi 2008). This plan has, however, been driven almost exclusively by the efforts of conservationists and state agencies, but giving little attention to the values, knowledge, and interests of the local community.

We conducted qualitative interviews with members of different socio-cultural groups within the CHBR. First, we explored the knowledge, conceptual thoughts and perceptions of the impacts with respect to invasive species. Second, we investigated the range of attitudes and values regarding native and exotic species. Third, we assessed the attitudes toward controlling invasive species. These general issues were addressed through distinct examples. We focused on the recently arrived (a decade ago) carnivorous American mink (*Mustela vison*), and the long established (< 5 decades ago) herbivorous North American beaver (*Castor canadensis*). These are the two invasive species of highest nature conservation concern in the CHBR (Anderson et al. 2006a, Rozzi et al. 2006a, Soto & Cabello 2007). As examples of native species, we chose a conspicuous, almost charismatic, though locally rare mammal species, the guanaco (*Lama guanicoe*), and the upland goose (*Chloephaga picta*) as representative of the rich and abundant coastal avifauna in the area (Couve & Vidal 2003). This study thus provides insights into the spectrum of viewpoints about different invasive and native species among those people who are most concerned about management decisions as they live in closest vicinity of these new species.

Methods

Study site

Our study took place on Navarino Island (55°S) within the Cape Horn Archipelago, Chile, at the southernmost tip of the American continent. The area belongs to one of the earth's 24 most pristine wilderness ecoregions (Mittermeier et al. 2003), harboring a diverse mosaic of landscapes, habitat types and different terrestrial, freshwater and marine ecosystems (Rozzi et al. 2006a, b). Cape Horn is the homeland of the world's southernmost pre-Columbian human population, the Yaghan indigenous people (McEwan et al. 1997). Although this region remained protected from extensive modern human impact due to its geographic isolation and the presence of the Chilean Navy (Rozzi et al. 2006a, b), the local biological and cultural diversity has been subjected to the growing influences of the global economy and culture (Berghöfer et al. 2008). Since the mid 20th century, an ensemble of invasive mammal species originally introduced for economic purposes has been altering the natural ecosystems (Anderson et al. 2006a); fisheries are dominated by international companies (Pollack et al. 2008); and the Yaghan indigenous language and ecological practices have been widely displaced (Rozzi et al. 2003). The creation of the UNESCO Cape Horn Biosphere Reserve in 2005 aimed to counterbalance these pressures on the austral biological and cultural diversity (Rozzi et al. 2006a).

Approximately 2,300 residents live in Puerto Williams, capital of the Chilean Antarctic Province on Navarino Island, which is the largest human settlement in the CHBR. Puerto Williams was founded in 1953 as a military base and is the southernmost permanent settlement in the world. In spite of its small size, it involves a complex societal structure, including contrasting socio-cultural groups: the Yaghan indigenous people, Chilean Navy members and their families, temporary and permanent civilian residents (Rozzi et al. 2003). Among the latter, fishing and public services figure as most important activities. The Naval Base population is characterized by continuous turnover, given that most Navy families are stationed in the Cape Horn region for only two to three years.

The recent invader mink

The American mink is a North American semi-aquatic mustelid, which was introduced to Argentine Tierra del Fuego Island in the 1940 and 1950s for fur farming (Jaksic et al. 2002). Only recently, in 2001, mink were officially registered for the first time on Navarino Island, located south of Tierra del Fuego (Rozzi & Sherriffs 2003). Escaped farm animals are believed to have swum across the Beagle Channel (ca 5 km wide), which separates the Chilean island from the main island of Tierra del Fuego. A Yaghan indigenous described his first experience with the mink:

> "*I think that all the elder people here confused it* [the mink] *with the otter, only the color was different. I was surprised when I saw it for the first time, because I saw it in the sea…and the color attracted my attention; it was darker, and smaller*." (Interview 24-08-2005)

Among invasion biologists, the mink is considered a successful invasive species widely distributed throughout Europe with detrimental impacts on native species, including ground-nesting birds, rodents, amphibians and mustelids (reviews in Macdonald & Harrington 2003, Bonesi & Palazon 2007). Perhaps the most severe reduction of native species caused by mink occurred in Britain: water vole populations have declined by 97 % since 1900 (Jefferies 2003), and the depredation of ground-nesting waterbirds by mink, including surplus-killing, have provoked almost complete breeding failure amongst colonies of gulls and terns (Craik 1997, Nordström et al. 2004). In South America, where wild populations of mink exist in southern Chile and Argentina, they have also been reported to affect the native fauna (Medina 1997, Previtali et al. 1998, Lizarralde & Escobar 2000). The impact of mink on economic activities such as fish or poultry farming or on the ecotourism industry is less studied (e.g. Sheail 2004). The overall economic impact seems to be rather small, but can be significant in specific regions (Bonesi & Palazon 2007).

The mink's invasion of Navarino Island has given rise to concerns by nature conservationists and public officials. As it represents a new guild of terrestrial mammalian predators, it was suspected of having negative effects on ground-nesting birds (Rozzi & Sherriffs 2003, Anderson et al. 2006a, Soto & Cabello 2007). Indeed, chicks of coastal waterbirds and adult passerines form a principal part of the mink's diet on Navarino Island (Schüttler et al. 2008, Ibarra et al. 2009), and mink have been shown to depredate considerably on the eggs of solitary nesting species (Schüttler et al. 2009).

The "old" invader beaver

Twenty-five mating pairs of the North American beaver were released as furbearers into Argentine Tierra del Fuego Island in 1946 (Jaksic et al. 2002). The densities of this semi-aquatic rodent species rapidly increased to very high levels (Lizarralde 1993), probably driven by natural enemy escape and resource opportunity (Wallem et al. 2007). Already in 1962 beavers had reached Navarino Island, after having crossed the Beagle Channel without human aid (Sielfeld & Venegas 1980). An old fisherman reported his first experience with (the effects of) beavers:

> "*So, I was surprised and as I was feared I went back to the camp, because I didn't want to continue walking there, I was like scared…Because it was like if there had been people who had logged the trees with knifes and axes, I have never thought that these animals would have done this. You could see that they were taking the trunks to their den, and I thought that this was someone, a person, that some person had been there*." (Interview 08-07-2005)

Today, beavers have colonized the archipelago of Tierra del Fuego, parts of the Cape Horn Biosphere Reserve (Anderson et al. 2006b, Skewes et al. 2006), and of the Chilean mainland (Brunswick Peninsula) (Wallem et al. 2007, Anderson et al. 2009). As ecosystem engineers (Jones et al. 1994), beavers have caused the largest alteration to the subantarctic forests since the recession of the last ice age (Anderson et al. 2009), with ecological, economic, and social consequences. Among the ecological consequences are alterations in the habitat (e.g. reduction of the canopy cover), biotic communities (e.g. facilitation of introduced plant species establishment), and ecosystem variables (e.g. reduction of tree biomass) of riparian and stream ecosystems (Anderson & Rosemond 2007, Anderson et al. 2009). Social and economic effects include impacts on forestry and livestock management, and damage to the infrastructure (Skewes & Olave 1999). On the other hand, use has been made of beavers by hunting them for their meat and fur, or as a tourist attraction.

Survey methods

We used a qualitative approach to explore the different concepts, values and attitudes related to selected invasive and native species in the socio-culturally heterogeneous community of Puerto Williams. The choice of a qualitative research method allowed topics to emerge that went beyond the researcher's perspective, leaving more space for the expression of diverse perceptions (Mayring 2003, Kuckartz 2005). Between 2005 and 2007 we performed 37 semi-structured qualitative face-to-face interviews with local people. All interviewees were adults and had lived at least one year up to 77 years on Navarino Island. The participants were randomly chosen from different representative sectors of the population on Navarino Island, and from an interest group, namely nature conservationists. The interviewees were recruited by personal approach and were grouped according to their socio-cultural background or principal activity. Intersections between groups were only given among Yaghan indigenous people and fishermen, as indicated. This classification has to be regarded as flexible and served to cover a broad spectrum of perspectives rather than to analyze differences between those groups (which would require a quantitative approach). The backgrounds of the interviewees were as follows:

- *Chilean Navy members*, consisting of eight persons of mixed gender, aged 26-43, for professional reasons their residence on Navarino Island was normally less than four years.
- *Yaghan indigenous people*, consisting of five local residents of mixed gender, aged 28-77, all having grown up on Navarino Island or on adjacent islands (except for the youngest participant). Fishing was not their principal activity.
- *Fishermen,* consisting of seven men, three of them Yaghan, aged 28-74, most had been long resident on Navarino Island.
- *Public service employees*, consisting of three men, aged 38-53, 6-14 years of residence on Navarino Island.
- *Civil residents* with a variety of economic activities (not fishing), consisting of ten local residents of mixed gender, aged 31-71, and with the broadest spectrum of residence on the island (2-71 years).
- *Nature conservationists*, consisting of four persons of mixed gender, partly academic, partly administrative professionals; two were foreigners; aged 30-48, 1-7 years of residence in the region.

The interviews were conducted in Spanish and took between half and one and a half hour, depending on the interview situation (on average 48 min). With an open interview guide, we aimed at talking about three main topics in a personal and exploring manner: knowledge of mink and beaver, evaluation of exotic and native species, and attitudes towards control of invasive species (Table 6.1). All interviewees were asked all questions, but the order was adapted to the course of conversation; we allowed other related topics to be raised during the interview.

Table 6.1 Themes covered in the interview guide using semi-structured open questions.

Theme 1: knowledge of mink and beaver
- *Which animals are typical for you on Navarino Island?*
- *Which native and exotic (non-native) animal species do you know on Navarino Island?*
- *What do you know about mink and beaver?* (arrival, ecology, impacts on the island and on inhabitants, and reasons for their survival on Navarino Island)
- *How do you estimate the quantities of mink/beaver* (today and in ten years)?
- *Which personal experiences do you have with the mink/beaver?*
- *How did you acquire your knowledge about the animals on the island?*
- *What is an exotic (non-native) species for you? Which general characteristics do exotic species have?*
Theme 2: evaluation of exotic and native species
- *Is there an important animal for you on Navarino Island? Why?*
- *Is there an animal you don't like on Navarino Island? Why?*
- *What does the mink/beaver mean to you?*
- *What does the guanaco/upland goose mean to you?*
- *Do you evaluate differently exotic and native species?*
Theme 3: attitudes towards controlling invasive species
- *Does nature need human aid with respect to exotic species?*
- *What does the term "control program of exotic species" mean to you?*
- *What do you think about a control program of exotic species on Navarino Island?*
- *What should this control program contain?*
- *Do you think that the mink/beaver could be used? How?*
- *Would you personally participate in a control program of exotic species on Navarino Island?*

Interview coding and analysis

The interviews were digitally recorded and subsequently transcribed verbatim. Our text analysis was guided by the qualitative content analysis strategy following Mayring (2003). In this approach, the reduction of the text material is achieved by developing inductive categories, i.e., categories arising from the raw data, not pre-determined categories. The performance of this process is theory-driven following analytical rules (generalization and reduction of paraphrases). However, content analysis does not aim at developing or verifying theories; rather it is a descriptive method to interpret systematically linguistic material as for example arising from qualitative interviews, focus group discussions, or participant observation (Kuckartz 2005). The coding procedure was carried out separately for our three main themes (Table 6.1). We will keep this classification throughout our results section, although the topics strongly intersect. It is obvious that questions on the characteristics of invasive species, their impacts, and attitudes towards their control often imply an evaluation.

The theoretical approach we used as an orientation for our coding procedure was based on the knowledge forms developed by Matthiesen (2005). This approach emphasizes the diversity and overlapping character of different knowledge forms ("knowledgescapes"), instead of reducing knowledge into traditional dichotomous categories (e.g. indigenous versus non-indigenous knowledge). We also refer to Berghöfer et al. (2008), who applied Matthiesen's approach and described the transfer processes of knowledge found among the population of our study area (e.g. formal education or families as teachers or "learning facilitators"). Thirdly, we use the nine basic values of living diversity defined by Kellert (1996). We explicitly refer to these values in our evaluation section. A short description of Kellert's values is given in the following:

(1) The *utilitarian* value emphasizes that humans derive material benefit from the diversity of life including food, medicine, clothing, and other products.

(2) The *naturalistic* value refers to the many satisfactions people obtain from the direct experience of nature and wildlife. The naturalist experiences find their expression through formally organized recreation such as birding, fishing, or hunting. These natural experiences can bring people relaxation, calm, and peace of mind and even enhanced intellectual growth, creativity, and imagination.

(3) The *ecologistic-scientific* value puts emphasis on the systematic study of the structure, function, and relationships in nature.

(4) The *aesthetic* value refers to the aesthetic impact of nature on people. The experience of nature can provoke feelings of intense pleasure, even awe at the physical splendor of the natural world.

(5) The *symbolic* value expresses the use of nature for communication and thought. People have employed nature for expressing ideas and emotions.

(6) The *humanistic* value emphasizes that wildlife and nature give people an avenue for expressing and developing the emotional capacities for attachment, bonding, intimacy, and companionship.

(7) The *moralistic* value grows out of discerning a basic kinship binding all life together. An ethic emerges directing humans to minimize harm to other creatures viewed as fundamentally like ourselves.

(8) The *dominionistic* value refers to the confrontation of people by wildlife and nature with significant challenges, which test and refine people's capacities to endure and even master in order to survive.

(9) The *negativistic* value refers to the negative feelings including aversion, fear, and dislike that nature evokes. Certain animals and landscapes provoke acute passions and avoidance response in many people.

While we do not share Kellert's idea (related to the "biophilia-hypothesis") that these values are inborn tendencies of all human beings, we think that his classification is useful for many purposes and specifically for the questions of this study. In contrast to, for example, the philosophically more sophisticated typology of values presented by Norton (1987), Kellert's empirically derived categories also include negative values (*domionistic, negativistic*), which is of special relevance with respect to evaluating species that some people view as undesirable.

Results

Theme 1: knowledge of mink and beaver

Knowledge and conceptualization

We started our interviews with a general question on the participants' knowledge and experience of mink and beaver. Most interviewees classified them as introduced animals, apart from three navy members who either thought that mink and beaver were native or had not yet heard about the mink. Almost half of the participants stated that they did not know much about the mink; in contrast, beavers were well known and people often had experienced these animals.

Local knowledge (addressing locally situated forms of knowledge-based competencies, Matthiesen 2005) about animals played a predominant role over all groups. Learning facilitators were "settlers", "the old", locals, or own family members. As knowledge sources, personal experience acquired through work in nature (fishing, farming, hunting) was especially relevant for fishermen, Yaghan people and civil residents related to outdoor activities. A formal acquisition of knowledge (university, school, books, courses, contact with scientists) existed among nature conservationists, public service employees, civil residents, and navy members. This source of knowledge related to an intellectual relationship with nature and also included global perspectives (Berghöfer et al. 2008).

In order to explore the conceptualization people had of exotic animals, we asked them about their own definitions and the characteristics they associated with exotic species. Most interviewees agreed that exotic species were species introduced to a place they did not originally belong to. For some it made a difference whether those species arrived with human aid or on their own. Time played a minor role when talking abstractly; however, the beaver was regarded as "*already belonging to us*" by five interviewees. Some Yaghan people used their life time experience as a reference: "*I was accustomed to seeing those animals that I have seen since my childhood, and suddenly seeing a new animal is a novelty*." Other rather infrequent descriptions included: not typical for Chile, extraordinary, useful, and upgrading Chile. Interestingly, interviewees among fishermen and civil residents attributed to exotic animals a settler's spirit: the "*new neighbors*" emigrated in search of new habitats, adapting themselves to their new harsh environment "*like us*". Two interviewees were not convinced of the native/exotic concept. One navy member would not make a difference between animals, and one civil resident criticized the concept as xenophobic.

Among the reasons why the mink and beaver could survive on Navarino Island over two-thirds of the interviewees agreed upon the similar (climate) conditions on the island compared to their native range, the abundant offer of nourishment, as well as the lack of natural enemies (apart from wild dogs). Some civil residents and navy members were convinced that the absence of civilization favored the establishment of mink and beavers. Exotic species were also seen as superior to native species as the latter were not well adapted to them (nature conservationists, public service, civil residents). Finally, interviewees from all groups assigned exotic species a negative impact on their new environment. Exotic species were threatening the equilibrium of the invaded ecosystem. "*An animal that is not from here can mix up the cycle of the ecosystem, the way they* [the native animals] *are in peace among themselves. That another* [animal] *is arriving in order to eat their brood…disorganizes the chain, the life chain they have*", (fisherman). Interestingly, negative impacts were also mentioned among those interviewees that had "welcomed" the arrival of exotic species; those contradicting statements were sometimes acknowledged as such.

Impacts of mink and beaver

The mink. There was little direct experience of the impact of mink; and by the majority of the interviewees it was perceived as an invisible predator. However, inferences were made based on its status as a predator, on a perceived decline of geese during recent years, and on reports about the failure of family-run chicken farming due to mink. Table 6.2 shows the spectrum of impacts mentioned in the interviews. The decline of birds and the negative consequences for tourism were perceived as the predominant impact of mink by most interviewees. Only five people thought that mink were not a pest. Several interviewees, however, acknowledged a limited knowledge of the mink and its impacts, as well as an indifference towards it: "*…there is no effect* [of mink], *because the people don't know it…they don't talk a lot about the mink*", (civil resident).

Table 6.2 Impacts of mink mentioned in 37 qualitative interviews.

Impact description	Values* affected	Dimension
Threat for native animals, especially ground-nesting birds with the possibility of species becoming extinct	Naturalistic Aesthetic Symbolic Humanistic Moralistic	Ecological/ Social
Identity and rootedness of local people at risk as a consequence of species extinctions	Symbolic Humanistic Moralistic	Social
Possible invasion of settlement, attacks on humans		Social
Negative impact on farm animals, especially chicken farming	Utilitarian	Economic
Negative impact on fishermen by destruction of fishing nets	Utilitarian	Economic
Threat for sustainable/bird watching tourism	Utilitarian Naturalistic	Economic

* categories according to Kellert (1996)

The beaver. The most perceived impact of exotic species was the damage to the forests by beavers, and in most cases this impact was directly experienced. Other impacts were more specifically mentioned following the perspectives of the particular group; for example, ecological impacts were predominantly perceived by nature conservationists. Table 6.3 summarizes the impacts of beavers referred to in the interviews. Although the great majority attested these impacts to the beaver, about a third of the interviewees among all groups (except for nature conservationists) were less convinced of the severity of their impacts. They simply doubted that beavers were as destructive as people were telling: loggers were seen as more destructive than beavers, beavers were perceived at rather low numbers due to hunting efforts, wild dogs, and mink, and some were pointing to the regeneration of the forest: "*…they* [the beavers] *don't do big damage, more damage is done by the motor saws, twice that of the beavers. The beaver is eating what is good for him, never a whole area*", (Yaghan).

Table 6.3 Impacts of beavers mentioned in 37 qualitative interviews.

Impact description	Values* affected	Dimension
Destruction of the forest	Utilitarian Naturalistic Aesthetic Moralistic	Ecological
Changes in the ecological communities due to engineering habits	Naturalistic Aesthetic Moralistic	Ecological
Disruption of nutrient cycles	Utilitarian	Ecological
Prevention of the aquisition of scientific knowledge of pristine ecosystems	Ecologistic-scientific	Ecological
Destruction of bridges due to changed watercourses	Utilitarian	Economic
Deformation of the aesthetics of the landscape	Aesthetic	Social

Table 6.3 *continued.*

Impact description	Values* affected	Dimension
Threat for tourism	Utilitarian	Economic
Disturbance of hiking	Utilitarian Naturalistic Aesthetic	Economic/ Social
Contamination of potable water	Utilitarian	Economic/ Social
Disturbance of grazing land for farm animals	Utilitarian	Economic
Disturbance of the extraction of fire wood	Utilitarian	Economic
Prevention of the cultivation of crops	Utilitarian Naturalistic	Economic
Negative impacts on reed extraction for traditional handicrafts	Utilitarian	Economic/ Social
Negative impact on natural heritage	Moralistic	Social

* categories according to Kellert (1996)

Theme 2: evaluation of exotic and native species

General viewpoints

Values were, of course, already present in the results of theme 1 (see tables 6.2 and 6.3). Theme 2, however, covered more direct questions on the evaluation of different exotic and native species, leaving space for positive value assignments, too. We identified three different general viewpoints regarding the evaluation of native and invasive species in general. Firstly, native species were considered more important (context is given below) than exotic species; secondly, all animals were considered of equal importance; thirdly, exotic species were perceived as positive (but statements whether they were also perceived as more important than native species were not explicitly made). All positions were quite well represented among all groups of interviewees. The first viewpoint assigned native species (but not exotic species) an intrinsic value, a cultural reference, a symbolic value for the region, as well as qualities like uniqueness, rarity, better commercial uses, and harmlessness. The second viewpoint was principally based on the intrinsic value, goodness, equal rights, and sense of being inherent in all organisms. The third viewpoint valued the extraordinary property of exotic species, the contribution of exotic species to species richness and to the attractiveness of the region. Yet, the interviewees made differentiated statements about specific species.

Specific viewpoints on selected species

To acquire an overall idea of which species were seen as typical for the island, personally important, or unwelcome, we asked participants to name those animals that first came to their mind (the first five named per interviewee were then selected for the analysis). A total of thirty-one species were named plus eight groups of animals (e.g. petrels or gulls). The interviewees selected typical animals among exotic and native species (Fig. 6.1). The beaver, along with the guanaco was named a typical species by 19 of the interviewees from all groups except for public service employees, while the guanaco was rather named by groups with a longer residence (Yaghan, fishermen, civil residents, public service employees). Interestingly, the "newcomer" mink was already perceived as a quite typical species (5 interviewees). Among the important animals chosen, native animals figured prominently (again chosen by interview groups with a longer residence); and vice versa the disliked animals were particularly the exotic species. Native animals, especially the guanaco (15 interviewees), gained much more importance than did exotic animals, of which feral dogs (13 interviewees) were particularly disliked. However, nine interviewees thought that all animals were important, irrespective of the native/non-native dichotomy (Fig. 6.1). In the following, we give the background for such general statements assigning the nine wildlife values defined by Kellert (1996) to invasive mink and beavers, and, as a comparison, to two exemplary native species, the guanaco and the upland goose. Table 6.4 summarizes the values associated with these four species.

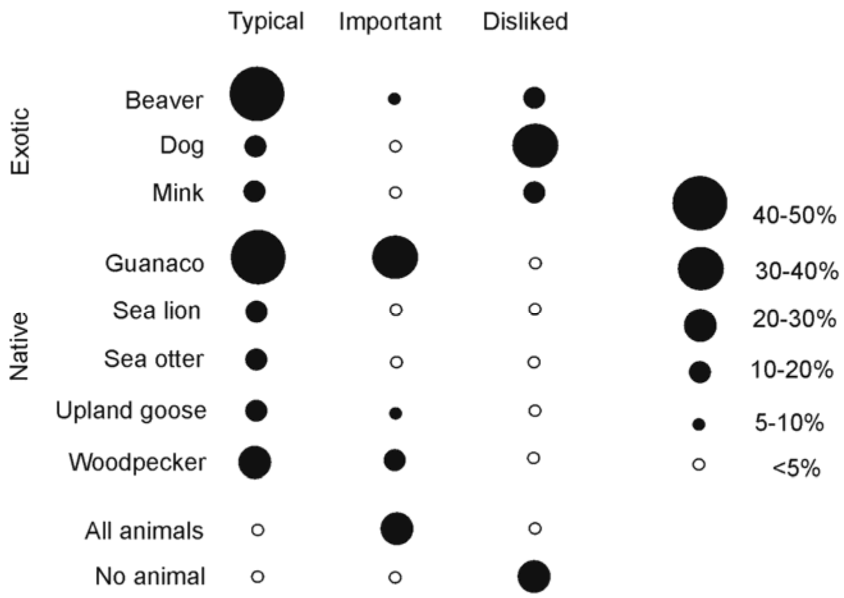

Fig. 6.1 Nomination of typical, important, and disliked animals on Navarino Island (up to 5 per interviewee per category, only animals that at least 15 % of the interviewees (n=6) had named either as typical, important, or disliked animals, n=37 interviewees). The woodpecker refers to *Campephilus magellanicus*, the sea otter to *Lontra felina*, different species exist among sea lions.

The mink. The great majority of the interviewees agreed that a direct use (and thus the utilitarian value) of the mink was limited; as carnivorous animals their meat would not be suitable. It was generally acknowledged that a control program would generate incomes on the island and that mink furs might become a source of income; precious mink coats were also seen as a status symbol by some interviewees. Yet, hunting mink was regarded as quite difficult, because it was well-known that many hunters had not been successful.

Mink were generally perceived as cryptic animals and thus personal experiences with mink were rare. Only one fisherman described the mink as tame when feeding it with fish bait (naturalistic value). An aesthetic value was rarely attributed to mink: only a few interviewees believed mink to be physically attractive. "*From my point of view it has a vivacity, very animated, it is a very animated animal*", (nature conservationist). Some emotional bonding (humanistic value) towards mink was expressed by various interviewees of different groups who found them affectionate, friendly, playful, entertaining, charismatic, and more intelligent than others: "*I am a hunter and I have no problems* [with killing], *but this creature* [the mink] *was, was like charismatic...it was like killing a cat more or less, an animal with a superior intelligence to the others*", (nature conservationist).

Ethical concern was expressed for the decline of birds, which some attributed to mink, but others to humans as a consequence of overhunting and pollution in general. Among the negative wildlife values, the mink as one of the invasive "pest" animals provoked the desire to control (domionistic value): "*...the only adverse conditions we can impose on them* [the mink and beaver] *is the human predator*", (public service employee). Fear was another emotion related to mink (negativistic value): the "*aggressive*" mink were perceived as a personal threat by a third of the interviewees except for nature conservationists. "*The mink attacks you, also the dogs…It attacks. I don't know whether this is true, because I haven't seen them. But now I am afraid when hiking in nature*", (Yaghan).

The beaver. The great majority of interviewees knew about direct use of beavers for meat and for fur provision (utilitarian value). Most had tried beaver dishes, either as an exclusive regional specialty or as a rather common meal after hunting (some older settlers). Interest in the beaver's fur has been expressed, although few were actually making use of it. Some mentioned the provision of firewood by beavers. As for economic uses, people of all groups (except for fishermen) mentioned the touristic appeal of beavers, either as a regional dish in restaurants, or as an outdoor wildlife activity. "*…the tourist loves it; he wants to see the beaver swimming…*", (civil resident). Most people interviewed also mentioned the economic incentives linked with hunting beavers in the context of a control program. As for medicinal uses, one Yaghan woman imagined the extraction of oils from exotic animals.

Throughout all groups the observation of beavers was mentioned as an impressive nature experience (naturalistic value). "*…you see a beaver and suddenly you feel happy…especially in winter times when there is an ice cap, and you see them swimming underneath*", (navy member). Many interviewees have searched out direct contact with beavers, whether to admire their engineering activities, or to shoot a photo or to paint it. The hunting of beavers was also seen as a sports activity by some interviewees (fishermen, a nature conservationist), or as a possibility to connect oneself to nature (a public service employee). Most groups conceived beavers as physically nice, but further aesthetic values were not related to it. For some civil residents, beavers were a symbolic species for the island: "*It is like our mascot*", (civil resident). As a spiritual dimension of the symbolic value, a local civil resident also acknowledged that mystical stories had been circulating about beavers. Beavers had been kept as pets by two interviewees and were described as tamable, lovely animals when young (but incidentally damaging the furniture when adults). The sense of affiliation (humanistic value) may also be found in humanized characterizations of animals. Some interviewees identified themselves with the beaver. "*The beaver already belongs here. It is similar to oneself, one came from outside and got accustomed to here…Not the mink…it doesn't provide much confidence to me*", (civil resident). An analogy was also drawn to humans with respect to the construction of their dens, the storage of a winter stock, and their healthy nutrition. Throughout, the beaver was admired for its engineering skills and intelligence. They were also described as sympathetic, affectionate, and defenseless.

With respect to the destruction of the forest, the question of the responsibility was a source of disagreement among the interviewees. On the one hand, the beaver was seen as an "*enemy of the forest*", but on the other hand loggers were made responsible for the exploitation of the forest. Although appreciated in many ways, the beaver was also perceived as a "*pest*" animal, which justified its control (domionistic value). Disgust towards the beaver as a big water-loving rodent was particularly felt by two navy members (negativistic value).

Table 6.4 Summary of the values associated with two invasive species (mink, beaver) and two native species (guanaco, upland goose, i.e., birds in general).

Values according to Kellert (1996)	Mink	Beaver	Guanaco	Upland goose/ birds
Utilitarian	✓	✓	✓	✓
Naturalistic	✓	✓		✓
Ecologistic-scientific				
Aesthetic	✓	✓	✓	✓
Symbolic		✓	✓	✓
Humanistic	✓	✓	✓	✓
Moralistic			✓	✓
Domionistic	✓	✓		
Negativistic	✓	✓		

The guanaco. Among the native animal species on Navarino Island, versatile uses were ascribed to the guanaco by all groups interviewed apart from nature conservationists: fur, meat, wool, "*it's an animal that can save your life…*", (fisherman), important in traditional uses in Yaghan culture and in tourism (utilitarian value). However, direct uses were rather of a traditional and cultural character as laws have prohibited the hunting of guanacos. The Yaghan people and fishermen especially complained about this, as they only partly knew or accepted the reasons for those laws.

The aesthetic values of guanacos were their beauty and attractiveness, their calm charisma and nice shape. The guanaco was also named as symbolic for the region. Beyond this, native animals played an important role for the identity of the Yaghan people: the guanaco, for example, as "*most ancient animal on the island*" appeared in their traditional legends. But also residents of the civilian population identified themselves with the guanaco. They were regarded as free spirits, as settlers of the region (humanistic value). Regarding moralistic sentiments, a great majority of the local community expressed their concerns about the missing responsibility of people residing only a few years on the island, who then abandoned their dogs when leaving the island. Wild dogs were often seen as a reason for the declining population of guanacos.

Negative values were only associated in one case with the guanaco. Its negative impact on the forest provoked mistrust in a nature conservationist.

Upland goose/birds. The upland goose had importance in providing meat and eggs, as well as being attractive for hunting as a sports activity. Again, these uses were of a rather traditional character as hunting has been restricted by law.

Although directly asking about upland geese, birds in general often arose in the conversation. The contact with birds was generally enjoyed and was of importance for recreation (naturalistic value). "*It is beautiful to see it* [the Magellanic woodpecker], *to hear it picking or to hear its songs, beautiful*", (civil resident). Among the most appreciated aesthetic elements of nature were birds (aesthetic value). The interviewees admired their beautiful colors and elegance (wild geese, Magellanic woodpecker), impressive flight and size (Andean condor), and their ornamental character in the landscape (upland goose). Birds were widely used for communication (symbolic value); as symbols for the region: "*…here, the birds are the protagonists, the dominating beings, they are the kings…as is the lion in another area*", (public service employee); as umbrella species (Magellanic woodpecker); or indicators for seasons (upland goose). In a spiritual-cultural sense, birds were mentioned by Yaghan indigenous people with respect to their belief in rebirth and the meaning of birds within this religion. In former times, birds were also traditionally imitated in ritual dances. Overall, birds played a predominant role for people's company (humanistic value): "…*they* [the gulls] *are with you in the sea, they come to your boat, they always talk to you…*", (fisherman); "…*I was alone in this place, but the animals* [geese] *there were with me with their calls, their songs…*", (Yaghan). Upland geese were also a subject of identification. They were characterized as a faithful, moral monogamous species, with a family likeness. The perceived decline of birds was an issue of special concern among many groups (moralistic value). A Yaghan woman narrated that traditional customs of nourishment are not possible any more: "*Today it is more difficult to find it* [a nest of an upland goose] *and when you find it, it's a pity to take them* [the eggs], *because we will stay without birds, this would be so sad*."

No negative values (domionistic, negativistc) were ascribed to birds.

Theme 3: attitudes towards the management of exotic species

When asking what the participants understood by the term "control program of exotic species", the great majority of the interviewees clearly recognized that it was about reducing the population of mink and beaver (those were incorporated into the following section). Few had other associations. For them, a control program meant, for example, counting the animals and vaccinating them (a navy member), or, more in the sense of a closed hunting season, regulating their population numbers in order to assure their survival (a fishermen, a civil resident, both elderly settlers).

Acceptance of controlling

The interviews revealed a spectrum of different attitudes towards the management of exotic species (Table 6.5). All positions were present in almost all groups, but the general consensus was estimated as in favor of "*doing something*", while voices expressing the contrary presented rather individual perspectives. People, however, were cautious in approving total eradication, especially of beavers (an exception were nature conservationists). Rather, they proposed control; not only to maintain the versatile uses associated with beavers, but also because it seemed to be difficult to pass a definite judgment on such a complex issue (uncertainty about numbers, impacts, moral issues, feasibility, and consequences of control).

Table 6.5 Public acceptance of the management of invasive species on Navarino Island. Main perspectives revealed from 37 qualitative interviews.

Perspective	Quotes
Pro	
Native species in danger	"*…hunt them…or try to ensure that the exotics are not overpopulated, overwhelming the natives, because the natives can be lost and then we will have to look at them in a book*."
Creation of income	"[A control program] *will make the local community work*."
Ambivalent	
Control yes, eradication no	"*…the beaver should not be eliminated in its totality, but a certain number of the species should be respected, because it is also striking for touristic marketing*."

Table 6.5 *continued.*

Perspective	Quotes
Ambivalent	
Control yes, other methods than killing	"*It makes me sad to see them* [the beavers] *hanging*[6]*…It would be good if they would find another way to extinguish them, not by killing them in such a crude way.*"
Decisions from above	"*…the voice of the local people doesn't really count. One thing is that they don't speak a lot, and the other thing is that all things are imposed.*"
Contra	
Species' right to exist	"*They are talking of exterminating it* [the beaver]. *Something that also makes me concerned, because we will exterminate one more species.*"
Exotics not responsible	"*…we are charging the mink for a crime that basically is the responsibility of the human being.*"
Exotics as scapegoats	"*I would prefer that the mink would eat something different from the eggs of…the upland goose. But I also think there are people who are killing upland geese, because it's an exotic dish. So why don't we also talk about what humans do…?*"
Let nature take its course	"*Nature is taking care of itself.*"

Suggestions for managing

The interviewees from all groups had many ideas and suggestions on how to treat the topic. We summarize the main findings: (1) ways should be found to better accept exotic species: "*One should also search for the benefits of mink and beaver…*," (navy member) or "*…finding another way to make them* [the exotics] *being liked*," (fisherman); (2) as many interviewees among navy members and civil residents had problems with the killing of animals, they wished that other "humane" methods of control would be found, for example, castration or the establishment of a reserve for exotics; (3) although not directly asked, a great majority included feral dogs in their statements, agreeing upon the necessity that local authorities had to recognize and combat the problem of domestic dogs being abandoned; (4) rapid action was seen as essential for the mink as a recent predatory invasive species in order to prevent irreparable damage; (5) civil residents and nature conservationists thought that informing and awareness raising about invasive species were necessary assets for a control program; (6) a few participants mentioned the importance of preventing the introduction of new species to Chile; and (7) the creation of an "artificial" market for products of exotic species as a financial instrument of a control or eradication strategy was seen as critical, especially by nature conservationists.

Finally, when asking the interviewees whether they had a personal interest in supporting a control program on Navarino Island, most of them spontaneously said yes. Some fishermen, Yaghan people and civil residents wanted to actively hunt the animals. However, many interviewees could not imagine killing them (especially navy members and the public service employees), but would consider support in monitoring, education, organization or processing furs. Few participants disagreed with a management of mink and beavers and therefore refused their personal participation in a control program.

[6] Beavers are mostly killed by traps of the type *Coniber* (Soto & Cabello 2007), and then hung.

Discussion

This study demonstrates that public perceptions of exotic species indeed can be diverse. In the following we discuss our main findings, with a focus on how they can deliver productive and challenging input for policy makers. These findings are: (1) public knowledge and concerns for biodiversity issues can be complex and deserve further efforts to acknowledge them; (2) different values are assigned to different exotic and native species, which is relevant for generalizations in dealing with exotic species in policy; and (3) if high public awareness and active interest in the management of invasive species can be identified, this suggests good preconditions for the participation of the local public in management issues.

Complex public knowledge and concern

Remarkably, the local community knew many animal species inhabiting the Cape Horn region, mostly without formal education, rather through "knowledge facilitators" or their own personal experiences (see also Berghöfer et al. 2008). The importance of local knowledge and its non-formal acquirement is not only relevant for a further understanding of the construction of values (Kellert 1996, Rozzi et al. 2003), but also for the success or failure of educational programs currently being developed in the region.

Regarding the interviewees' understanding of the native/non-native concept, we found that many issues discussed by the scientific community such as time scale of invasions, human influence, or critique of the concept, were also present in the answers. In most cases, the participants' definitions were in concordance with the definitions guided by policy objectives, which emphasize the negative impacts of invasive species (Binimelis et al. 2007, Heger & Trepl 2008). Similarly, the scientifically contested concept of the balance of ecosystems as the classical "big idea" of environmental thought (Botkin 1990, Pickett & Ostfeld 1995) was a predominant understanding of nature among the interviewees. Ideas allowing nature more dynamism and variability were less frequently expressed. As often observed in the public environmental discourse, this represents a time lag, as ecological sciences have been offering non-equilibrium ideas of ecosystem processes for over three decades now (Wallington et al. 2005, Fischer & Young 2007). They are, however, rather difficult to communicate.

A broad array of ecological, economic and social impacts of mink and beavers were mentioned. Although the strength and significance of these impacts were subjects of discussion and uncertainty, the multi-faceted array of statements demonstrates awareness of the topic – keeping in mind that most interviewees based their statements on local knowledge and not on scientific literature. A differentiated perception of the impacts, however, needs the input of science (e.g. mink are not threatening all birds per se, but specific species, Schüttler et al. 2008, 2009). Altogether, it is essential that biodiversity policies develop ways to better accredit public knowledge, rather than just classifying it into "correct" or "incorrect" in relation to scientific definitions (Hunter & Brehm 2003, Berghöfer et al. 2008). On the one hand, using local knowledge in policy represents a further source of the often cost-intensive acquirement of information and, on the other hand, it contributes to mutual respect and better acceptance of management issues. Not least it can form an entry point for a more balanced discourse between social groups with different educational backgrounds, softening the still prevalent dominance of scientific knowledge. This has also been acknowledged in the Ecosystem Approach of the CBD, which urges in principle 11 to: "consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices" (UNEP/CBD 2000, p. 107). More than factual knowledge (scientific or local) as such, however, the explicit consideration of values into conservation management is strongly desired (Jepson & Canney 2003, Jax & Rozzi 2004).

Species-specific attitudes and values

Values are generally understood as higher-order evaluative standards that guide people in their behavior. As such, values are assumed to be determinants of preferences and attitudes[7] (Rokeach 1973, Olson & Zanna 1993). Conservation and management of biodiversity are not only driven by science, but also by attitudes and values (Soulé 1985, Jepson & Canney 2003, Jax & Rozzi 2004), a reason why they should be explicitly integrated into policies. In our study we chose two eye-catching invasive species and two representative native species hoping that this would give us some insight on values related to invasive species on the one hand and native species on the other hand.

In comparison to the beaver, the recent invader mink received less value assignments, a possible result of ignorance or indifference. In those cases where value assignments were provided, it was rather poorly associated with positive wildlife values, i.e., emotional attachment (friendly animals). Negative values included the negativistic value (aggressive animals) and domionistic value (control because it threatened birds). Those negative values might also arise from rejection due to foreign origin (e.g. Olwig 2003). In contrast, the beaver having been present for nearly 50 years covered the whole spectrum of positive and negative values, pointing to the ambivalent relationship that the local community had with beavers. Mixed sentiments towards the beaver were also quite often expressed, for example: "*although the beavers are detrimental, they are lovely*". Noticeably, the beaver had become interconnected with the community, not only as a typical and symbolic species, but also with respect to versatile uses. As described in other studies, invasive species are often integrated into the rural communities and exploited (Robinson et al. 2004, de Neergaard et al. 2005, Shackleton et al. 2007).

The values ascribed to the two selected native species, the guanaco, and the upland goose (but in a wider sense birds in general), were entirely positive values. The guanaco was significant in terms of use, and its cultural and symbolic meaning for the region; birds were especially important with respect to recreation, aesthetics, identification, and companionship. The symbolic value seemed to be of general importance: the native species were a striking reference for the rootedness of the local community with their land and culture. However, generalizations in terms of a general positive evaluation of native species cannot be made on this basis alone. If, for example, we would have chosen an inconspicuous native species (e.g. a species of bats) or a dangerous toxic animal (which does not exist on Navarino), value assignments probably would have been rather different. If such a generalization is desired, studies should incorporate a broader array of species. It may, though, be questioned if such a generalization is useful at all. A more specific evaluation based on specific species or species traits is certainly more appropriate, from a conceptual, pragmatic, and ethical perspective.

We conclude that generalizations in the value assignments of native species, on the one hand, and exotic species on the other hand, are hard to draw. Yet, we confirm two general trends previously described for exotic species. Firstly, "old" invasive species are likely to receive a broader spectrum of values, including positive values. For example, the symbolic dimension that clearly figured among native species might be claimed for invasive species when time scales are long enough. Other studies showed similar findings, i.e., species introduced in the past were not recognized as non-native, while recent invasive species effectively were perceived as "new" species (Fischer & van der Wal 2007, García-Llorente et al. 2008). These results support the idea that the native/non-

[7] The discussion about the stability of values is beyond the scope of this paper. Here, we did not attempt to distinguish between the long-term character of values and the short-term character of attitudes, opinions or interests.

native concept is a socially dynamic concept[8]. Secondly, invasive predators are likely to be less positively judged. The negative evaluation of the mink might not only be based on its recent appearance, but on its nature of being a predator. Negative attitudes towards carnivores typically figure among groups whose economic interests are threatened by these animals, in which case systems of compensation might represent solutions (Kaltenborn et al. 1998). Nevertheless, the contribution of conservationists (in this specific case the non-governmental organization Omora Foundation) in shaping public opinion towards the mink, might also have provoked a rather negative perception of the mink, especially because direct experience of this rather inconspicuous and "hidden" animal is uncommon for local people as compared to the beaver. Omora was the institution that communicated the arrival of the mink to the scientific community (Rozzi & Sherriffs 2003); and which supported the creation of the control program.

The assessment of values is one thing, but the priority setting of values is another. In most instances, management decisions involve trade-offs between different values. No generally accepted rules for balancing conflicting values exist, and actual negotiating of different values and goods affected will remain a matter of ethical societal discourse (Gorke 2007, Haider & Jax 2007). Specifically, identifying the conflicting values and their importance, and then asking for explicit trade-offs represents a first important step (e.g. Shackleton et al. 2007). Our tables 2 and 3 show values affected by the impact of mink and beavers. This qualitative approach might be extended using quantitative methods (e.g. Fitzgerald et al. 2005). But already in their current form and under the consideration of the scientifically proved impacts (Anderson et al. 2006a, Schüttler et al. 2008, Anderson et al. 2009, Ibarra et al. 2009), this approach can be used as a starting point for a societal discourse about the objectives of a management of exotic species.

High awareness of management issues

Attitudes towards the management of mink and beavers were multi-faceted. Nevertheless, the majority of the local community supported controlling strategies for two reasons: firstly, to reduce the perceived negative impacts of invasive species; and secondly, to create income. While the first point reflects a common sense between the community and nature conservation interests, the second point might imply some sort of conflict. Benefits from the management of invasive species for the community can be either achieved by the employment of hunters, or by the profit from the products of scarificed animals (fur, meat, oils, handcrafts). As the control program of the Agriculture and Livestock Service (SAG) initially paid for animal products (Soto & Cabello 2007), most people referred to this type of benefit. However, nature conservationists in our interviews, and later the SAG control program itself, agreed that the creation of a market was a rather unsuccessful strategy, unprofitable in remote areas and contradicting in objectives (a successful market would avoid losing its product). Hence, if managers want to confide on the "support for income" argument, policies should clearly communicate how benefit will be generated and who will benefit from the initiative (for example, local hunters or external hunters).

Disagreement existed about the degree (control or eradication) and the specific methods for the management of exotic species. An approach of "co-management" could start with issues where there is greatest agreement among groups (Robinson et al. 2004). In our study, this would concern the relative negative perceptions of mink and feral dogs. Further, objections to extreme actions (total eradication) should be taken serious (see also Robinson & Whitehead 2003); and ambivalent perceptions should be respected. The idea of maintaining or recreating a "pristine" nature or "wilderness" by eradicating exotic species, popular among conservationists (e.g. Choi 2008), is a legitimate value statement but by no means the only possible one, nor in any way inescapable, or scientifically more legitimate than other goals, even from a conservation

[8] In Europe, for example, often a distinction is made between archeophytes (plants that have arrived before 1492, the year of the discovery of America), and neophytes (those that arrived later).

perspective. Here suggestions made by the local community could represent a means to achieve compromises in conflicting issues. In our case study, this would mean, for example, taking up the idea of establishing a small reserve for beavers.

While value decisions can and should profit from being informed by scientific research (e.g. in cases of possible misperceptions as to the impact of an exotic species on other species or its direct danger to humans), the still highly privileged role of expert knowledge in shaping management decisions should be reduced in favor of a more balanced perspective on the full spectrum of values and interests involved. Otherwise there is clearly the danger that the values of particular groups (those of scientists and conservationists) are sold to the public as objective and force scientific conclusions. This may often not result from conscious advocacy but from a neglect to recognize the individual and collective values also included in scientific work, especially in conservation biology. Values – also among scientists and in the process of scientific work – are unavoidable and legitimate (Shrader-Frechette & McCoy 1993), but they should be made explicit and not be transported under the disguise of scientific authority. In consequence, we thus think that community members are necessary contributors in the ongoing debate to guide and support management actions and decisions about invasive species. Future work is needed, however, to implement such advanced discourse processes, i.e., in the development of the still scarce participatory approaches and frameworks (Robinson & Whitehead 2003, Berghöfer & Berghöfer 2006, Binimelis et al. 2007, Shackleton et al. 2007).

Conclusions

This paper had the objective of exploring the social perspective in a setting where management plans for invasive species are forming. In general, our approach can be seen as an example of how to gather insight into the conditions that mangers will meet in local communities concerned with exotic species with respect to their knowledge, awareness, values at stake, and the level of acceptance of control. In our case study, the awareness of the local community and its active interest represent perfect conditions for a further discourse on management options for invasive species for the region. This is probably the case for many other communities facing the same challenges. In our eyes, further steps to include local communities in a mutual enriching process of designing and implementing management responses to biological invasions are:

- Providing information on empirical data of impacts and gaps in knowledge.
- Providing information on feasible methods of control and different scenarios for management as a basis for further discussions.
- Favoring specific contexts over general issues, i.e., being as specific as possible with respect to single species and their resident times, rather than discussing management options for invasive species in general.
- Identifying potential conflicting values and finding ways to employ trade-offs, i.e., rules allowing the balancing of conflicting values (Meech 2005, Haider & Jax 2007, Shackleton et al. 2007).
- Clarifying the short- and long-term economic perspectives of management for the community.
- Using the full spectrum of methodology to support a participatory process like in-depth interviews (e.g. Berghöfer et al. 2008), focus group discussions (e.g. Fitzgerald et al. 2002, Fischer & Young 2007), quantification of views (e.g. Fitzgerald et al. 2005, García-Llorente et al. 2008); rather than educational programs that reflect universal paradigms (Fischer & Young 2007).

In the case of Navarino, we summarize our main findings for the management of invasive species:

- Better information on the local community (as explicitly wished) is a precondition for a participative process to design a management plan.
- Control of mink and feral dogs most probably do not have conflict potential.
- Total eradication of beavers as currently aspired (Choi 2008) might produce conflicts among the local community; the consideration of compromises (e.g. control instead of eradication, establishment of a beaver reserve) might provide solutions.
- Personal participation in a management program is of interest to the local community, but a clarification of the economic incentives from a management program is needed.

We hope that our paper provides an example of the lessons gained when listening to the local voice. Interdisciplinary research, as the consideration of various perspectives on the same topic, can help to stimulate the debate on how we want to live with the increasing shifting of species distributions. It is then the task of biodiversity policy, both on the global but especially on the local level, to include those elements, thereby creating management decisions that are most widely accepted.

CHAPTER SEVEN

Synthesis

Taken together, the research described in five independent chapters provides a broader picture of the ecological and social role the recently arrived American mink plays on Navarino Island. This final chapter consists of two parts. In the first part I summarize the key findings of this study. In the second part I discuss the significance of the results with regard to the management of invasive species, particularly the mink, at the southern end of the Americas.

Key findings

Distribution, abundance and habitat use of American mink in the Cape Horn Biosphere Reserve

This work is a contribution to the field of biological invasions as a driver and a consequence of global anthropocentric change, studied on the basis of the example of the spread of a non-native species in a remote wilderness area. In spite of its extreme isolation and relatively low human impact, the Cape Horn Biosphere Reserve harbors a rich non-native vertebrate fauna, which includes more exotic terrestrial mammals and freshwater fish than corresponding native taxa. In only a few years, mink have been able to colonize several islands adjacent to Argentine Tierra del Fuego Island from which feral populations originate – long undetected by investigators or managers. However, in eight locations visited on the Chilean part of Tierra del Fuego Island I could not prove mink presence in the Cape Horn Biosphere Reserve (chapter two).

On Navarino Island, American mink has colonized a high proportion of semi-aquatic habitats throughout the island (79 % of all surveys contained signs); only one decade after the first mink was registered (chapter three). Trapping data, however, revealed that relative mink densities at coastal shores (0.75 mink/km) were lower than in other areas where mink are native or where it got established (Hatler 1976, Birks & Dunstone 1991, Previtali et al. 1998, Moore et al. 2003). But as mink on Navarino lack competitors from the same guild as well as predators (with the possible exception of feral dogs), its establishment is likely to be facilitated. Therefore, the findings indicate that the population of mink might not yet have reached the limit of the carrying capacity of the ecosystem (assuming that mink are sufficiently provided with food). With respect to habitat use, mink were probably less restricted than in other areas, again, possibly due to the lack of competitors or other enemies, which normally influence the habitat requirements of mink (e.g. McDonald 2002, Bonesi et al. 2006a). Among the habitat preferences identified were (1) shrubland as preferred to forested habitat or meadows (see also Previtali et al. 1998, Yamaguchi et al. 2003) probably due to the better conditions for building dens (Halliwell & Macdonald 1996) and the higher availability of small mammals, (2) steep, rocky coastlines as preferred to flat beaches (see also Ben-David et al. 1996, Bonesi et al. 2000), and (3) interestingly, mink avoided habitats strongly modified by beavers. This finding was contradictory to other studies conducted in areas where beavers were native (Żurowski & Kammler 1987, Sidorovich et al. 1996). Further studies are needed to better explain why beavers could hamper habitat use by mink.

Ecological impacts

As a non-native predator on an island where native terrestrial mammalian predators are absent, the mink can contribute to the reduction of its prey populations. So, on what food does it rely? By analyzing its diet I showed that the main prey groups were mammals (37 % of the biomass), and birds (36 %), followed by fish (24 %) (chapter four). While during autumn and winter mammals played an important role as prey, birds were consumed more than twice as much during spring and summer compared to the cool season, when migratory birds had left the area. The consumption of birds at coastal sites over the warm season was exceptionally high in relation to reports from Europe (Ferreras & Macdonald 1999, Jędrzejewska et al. 2001), or other parts of Patagonia (Medina 1997, Previtali et al. 1998), but comparable to the results of studies on mink diet in other productive waterbird breeding habitats (Arnold & Fritzell 1987, Bartoszewicz & Zalewski 2003). The often described opportunistic diet habits of the mink (Dunstone 1993) are therefore valid also for the Cape Horn Biosphere Reserve. Among the birds identified from the scats were adult passerines and large ground-nesting birds (Anseriformes, Pelecaniformes) caught as chicks. Regarding mammals, the native yellow nosed grass mouse (*Abrothrix xanthorhinus*), together with the non-native muskrat (*Ondatra zibethicus*), were the most important prey species. At this stage, native mammals, however, were not rated as sensitive species based on abundance estimations and their biomass fractions in the diet. The fact that mink and muskrat re-established their predator-prey interactions at the southern end of the continent supports the invasional meltdown hypothesis (by Simberloff & Von Holle 1999). Thus, it is assumed that muskrat facilitate the establishment of mink as it represents a reliable and highly energetic source for mink, especially when birds and small mammals are less abundant during the cool season (Ibarra et al. 2009).

In the diet analysis I could show that chicks of large ground-nesting coastal waterbirds were consumed by mink, but egg shells can be underrepresented in its diet as mink eat the contents of eggs without necessarily eating the shell (Ferreras & Macdonald 1999). By directly studying its predation on natural and artificial nests, it was possible to derive a vulnerability profile for ground-nesting waterbirds (chapter five). According to the patterns found, mink might strongly affect the reproduction success of (1) solitary nesting waterbirds compared to colonial species, (2) waterbirds breeding in coastal habitats with rocky outcrop shores compared to flat beaches, and (3) waterbirds concealing their nests compared to open nests. The first pattern is related to the earlier predator detection and/or higher nest defense efficiency found in colonial breeding strategies (Wittenberger & Hunt 1985, Siegel-Causey & Kharitonov 1990). Although this pattern seems to be obvious, studies from Scotland and Finland have shown that breeding in colonies does not always protect them from predation by mink (Craik 1997, Nordström & Korpimäki 2004). Therefore, mink predation on colonies should be further investigated in the future. The second pattern is in line with the mink's habitat preferences for steep and rocky coastal shores (chapter three). The third pattern has to do with the olfactory cues used by mammalian predators to detect their prey (Guyn & Clark 1997) plus the limited view the incubating female has from its concealed nest of the surroundings (trade-off hypothesis by Götmark et al. 1995). Here, missing confrontation with a terrestrial predator before the arrival of mink might prevent bird species from the adequate behavioral response (see also Nordström et al. 2004).

Social acceptance

Qualitative interviews with the local community of Puerto Williams on Navarino Island revealed three main findings (chapter six), all relevant especially for policy makers. (1) Knowledge of and concern for biodiversity issues were widely present in the community. The interviewees addressed the complexity and criticisms of the native/non-native concept and the effects associated with mink and beavers included a broad array of ecological, economic, and social impacts. (2) Value assignments were species-specific, but two previously described trends were confirmed for exotic species: first, long-established invasive species that have become interconnected with the community (e.g. use, recreation, see also Shackleton et al. 2007, García-Llorente et al. 2008) receive a broader spectrum of values, including positive ones (the case of the beaver). Second, invasive predators are generally less positively judged (Kaltenborn et al. 1998) (the case of the mink). (3) The majority of the interviewees was in favor of controlling invasive species, but skeptical towards total eradication.

Practical significance of the thesis

This study was conducted within a framework that is promising for the application of its scientific results to management plans. First, the study forms part of a research line on invasive species hosted by the Omora foundation in Puerto Williams. Thus, research on various invasive species, particularly beavers, freshwater fish, and mink is informing the Chilean Agriculture and Livestock Service (SAG) responsible for the management of invasive species in the Magallanes and Chilean Antarctic Region (Region XII). Second, since the beginning of the study, SAG has been implementing a control program on beavers, mink and other invasive species (Soto & Cabello 2007), and information on my research on the mink was continuously exchanged (see chapter one). As mink were rather unsuccessfully trapped, Soto & Cabello (2007) explicitly state in their final report that they see an urgent need to augment control efforts for mink in order to prevent negative impacts on biodiversity. At the moment, beavers - and not mink - are in the focus of a large management plan currently been designed (Choi 2008). I hope that the results of this thesis and its implications for managing invasive species, but particularly American mink, will re-enforce and shape management initiatives in the Cape Horn Biosphere Reserve.

I start with the most important recommendation arising from this research: including public views into management plans on invasive species. The community of Puerto Williams is highly aware of and interested in the problem of biological invasions (chapter six). These are convenient conditions for a further societal discourse on management options for invasive species in the region. Researchers and managers currently dominating the debate around management plans (see Choi 2008) should include a broader public in the process of designing and implementing a control program. This approach does not only contest the international urge for participation (UNEP/CBD 2000), but it also helps to raise the acceptance of biodiversity policies (e.g. Fischer & Young 2007, Rozzi 2007, Berghöfer et al. 2008). Although from a conservationist perspective, the sense of the planned eradication of beavers (Choi 2008) is hardly discussed, the consideration of the social dimension may lead to other solutions as more attitudes and values are at stake. The persons responsible for management plans should therefore see community members as necessary contributors in the whole process of management decisions on invasive species.

What practical advice can be derived for the American mink, specifically? Since the majority of community members of Puerto Williams were in favor of a control program for mink, I estimate the conflict potential of such a program to be low. Also from a conservationist perspective, the ecological impacts of mink lead to the recommendation “pro management”. Birds constitute an important prey group during their breeding season in marine coastal habitat and at lakes (chapter four, and Ibarra et al. 2009). Particularly vulnerable ground-nesting waterbirds are solitary nesting species concealing their nests and breeding along rocky marine coastal shores (chapter five). Given that studies in other insular ecosystems have shown that the introduction of mink can lead to severe reductions in bird populations (e.g. Craik 1997, Ferreras & Macdonald 1999, Nordström et al. 2003, Antolos et al. 2004), this might become true in the near future on Navarino Island, too. The critical need for conserving the avifauna of the Cape Horn Biosphere Reserve is especially relevant for ecotourism, which currently represents the main option for achieving both economic and environmental sustainable development for this remote wilderness area (Rozzi et al. 2006a).

Therefore, starting a control program of the probably still growing population of mink is seen as an urgent task for managers. A first step towards a long-term management plan should be the establishment of priority sites for a more intensive control at rocky marine coasts. Mink abundance was higher in this type of habitat than at beaches (chapter three) allowing gathering experience with different trapping techniques (Moore et al. 2003). As mink have been colonizing marine coasts, rivers, lakes, and ponds on the entire island of Navarino, i.e., areas with very difficult access, the feasibility of control has to be carefully checked. Exchange with successful control campaigns of mink (e.g. Moore et al. 2003, Nordström et al. 2003) or consulting with international invasive species specialist groups (e.g. of the World Conservation Union, IUCN) can support the choice of effective strategies. Beside the control of mink, further conservation measurements for vulnerable bird species should be evaluated (e.g. nesting aids). Eight potentially sensitive bird species were identified. All have rather small populations on Navarino Island or along the Beagle Channel (Anderson & Rozzi 2000, Anderson et al. 2002, Raya & Schiavini 2002, McGehee et al. 2004), and breed at low height or at the ground. These species are: Magellanic tapaculo (*Scytalopus magellanicus*), Patagonian tyrant (*Colorhamphus parvirostris*), fire-eyed diucon (*Xolmis pyrope*), Fuegian snipe (*Gallinago stricklandii*), flightless steamer duck (*Tachyeres pteneres*), flying steamer duck (*Tachyeres patachonicus*), crested duck (*Lophonetta specularioides*), and kelp goose (*Chloephaga hybrida*). Five of these species are also endemic to Patagonia (41°-56°S); those are the Magellanic tapaculo, Fuegian snipe, flightless and flying steamer duck, and kelp goose.

The attention on the mink should not, though, overshadow vigilance against other factors contributing to the vulnerability of bird and other species in the region, such as habitat destruction or direct exploitation by humans.

References

Ackerman JT, Blackmer AL, Eadie JM (2004) Is predation on waterfowl nests density dependent? - Tests at three spatial scales. Oikos 107: 128-140.

Ahola M, Nordström M, Banks PB, Laanetu N, Korpimäki E (2006) Alien mink predation induces prolonged declines in archipelago amphibians. Proceedings of the Royal Society B 273: 1261-1265.

Akaike H (1973) Information theory as an extension of the maximum likelihood principle. Paper presented at the Second International Symposium on Information Theory, Akademiai Kiado, Budapest, Hungary.

Aleksiuk M (1968) Scent mound communication, territoriality, and population regulation in the beaver. Journal of Mammalogy 49: 759-762.

Allen AW (1984) Habitat suitability index models: Mink. U.S. Fish Wildlife Service, Washington, DC., USA.

Allen JD (1905) Mammalia of Southern Patagonia. Princeton University, Princeton, New Jersey, USA.

Anderson CB, Rozzi R (2000) Bird assemblages in the southernmost forests in the world: methodological variations for determining species composition. Anales del Instituto de la Patagonia 28: 89-100.

Anderson CB, Rozzi R, Elphick C, McGehee S (2002) El programa Omora de anillamiento de aves en los bosques subantárticos: la estandardización del tamaño de anillos apropiados para las aves de la región de Magallanes. Boletín Chileno de Ornitología 9: 2-11.

Anderson CB, Cienek MC, Gutiérrez A, Rozzi R (2005) Biota terrestre y dulceacuícola – Expedición enero 2005. Informe Técnico: Proyecto Diagnóstico, Diseño y Gestión del Parque Regional Tierra del Fuego. Chile Sustentable. Ministerio de Bienes Nacionales, Santiago de Chile.

Anderson CB, Rozzi R, Torres-Mura JC, McGehee SM, Sherriffs MF, Schüttler E, Rosemond AD (2006a) Exotic vertebrate fauna in the remote and pristine sub-Antarctic Cape Horn Archipelago, Chile. Biodiversity and Conservation 15: 3295–3313.

Anderson CB, Griffith CR, Rosemond AD, Rozzi R, Dollenz O (2006b) The effects of invasive North American beavers on riparian plant communities in Cape Horn, Chile. Do exotic beavers engineer differently in sub-Antarctic ecosystems? Biological Conservation 128: 467-474.

Anderson CB, Rosemond AD (2007) Ecosystem engineering by invasive exotic beavers reduces in-stream diversity and enhances ecosystem function in Cape Horn, Chile. Oecologia 154: 141-153.

Anderson CB, Pastur GM, Lencinas MV, Wallem PK, Moorman MC, Rosemond AD (2009) Do introduced North American beavers *Castor canadensis* engineer differently in southern South America? An overview with implications for restoration. Mammal Review 39: 33-52.

Angelstam P (1986) Predation on ground-nesting birds' nests in relation to predator densities and habitat edge. Oikos 47: 365-373.

Arnold TW, Fritzell EK (1987) Food habits of prairie mink during the waterfowl breeding season. Canadian Journal of Zoology 68: 2322-2324.

Atkinson IAE (1996) Introductions of wildlife as a cause of species extinctions. Wildlife Biology 2: 135-141.

Aued MB, Chéhebar C, Porro G, Macdonald DW, Cassini MH (2003) Environmental correlates of the distribution of southern river otters *Lontra provocax* at different ecological scales. Oryx 37: 413-421.

Banks PB, Nordström M, Ahola M, Salo P, Fey K, Korpimäki E (2008) Impacts of alien mink predation on island vertebrate communities of the Baltic Sea Archipelago: review of a long-term experimental study. Boreal Environment Research 13: 3-16.

Barry D, Oelschlaeger M (1996) A science for survival: values and conservation biology. Conservation Biology 10: 905-911.

Bartoszewicz M, Zalewski A (2003) American mink, *Mustela vison* diet and predation on waterfowl in the Słońsk Reserve, western Poland. Folia Zoologica 52: 225-238.

Basey JM, Jenkins SH, Busher PE (1988) Optimal central-place foraging by beavers: Tree-size selection in relation to defensive chemicals of quaking aspen. Oecologia 76: 278-282.

Baxter PWJ, Sabo JL, Wilcox C, McCarthy MA, Possingham HP (2008) Cost-effective suppression and eradication of invasive predators. Conservation Biology 22: 89-98.

Ben-David M, Bowyer RT, Faro JB (1996) Niche separation by mink and river otters: coexistence in a marine environment. Oikos 75: 41-48.

Berger J, Swenson JE, Persson I-L (2001) Recolonizing carnivores and naïve prey: Conservation lessons from Pleistocene extinctions. Science 291: 1036-1039.

Berghöfer U, Berghöfer A (2006) 'Participation' in development thinking - coming to grips with a truism and its critiques. In: Stoll-Kleemann S, Welp M (eds) Stakeholder dialogues in natural resource management. Theory and practice: 79-116. Springer Verlag, Berlin Heidelberg, Germany.

Berghöfer U, Rozzi R, Jax K (2008) Local versus global knowledge: Diverse perspectives on nature in the Cape Horn Biosphere Reserve. Environmental Ethics 30: 271-292.

Bibby C, Burgess ND, Hill DA, Mustoe SH (2000) Bird Census Techniques, 2nd edn. Academic Press, London, UK.

Binimelis R, Monterroso I, Rodríguez-Labajos B (2007) A social analysis of the bioinvasions of *Dreissena polymorpha* in Spain and *Hydrilla verticillata* in Guatemala. Environmental Management 40: 555-566.

Birks JDS, Linn IJ (1982) Studies on the home range of feral mink (*Mustela vison*). Symposia of the Zoological Society of London 49: 231-257.

Birks JDS, Dunstone N (1991) Mink. In: Corbet GB, Harris S (eds) The handbook of British mammals: 212-218. Blackwell Scientific Publications, Oxford, GB.

Bonesi L, Dunstone N, O'Connell M (2000) Winter selection of habitats within intertidal foraging areas by mink (*Mustela vison*). Journal of Zoology 250: 419-424.

Bonesi L, Macdonald DW (2004) Evaluation of sign surveys as a way to estimate the relative abundance of American mink (*Mustela vison*). Journal of Zoology 262: 65-72.

Bonesi L, Strachan R, Macdonald DW (2006a) Why are there fewer signs of mink in England? Considering multiple hypotheses. Biological Conservation 130: 268-277.

Bonesi L, Harrington LA, Maran T, Sidorovich VE, Macdonald DW (2006b) Demography of three populations of American mink *Mustela vison* in Europe. Mammal Review 36: 98-106.

Bonesi L, Palazon S (2007) The American mink in Europe: Status, impacts, and control. Biological Conservation 134: 470-483.

Botkin DB (1990) Discordant harmonies. A new ecology for the 21th century. Oxford University Press, Oxford, UK.

Bremner A, Park K (2007) Public attitudes to the management of invasive non-native species in Scotland. Biological Conservation 139: 306-314.

Brezeziński M, Żurowski W (1992) Spring diet of the American mink *Mustela vison* in the Mazurian and Brodnica Lakelands, northern Poland. Acta Theriologica 37: 193-198.

Brezeziński M, Marzec M (2003) Correction factors used for estimating prey biomass in the diet of American mink *Mustela vison*. Acta Theriologica 48: 247-254.

Brown JH, Sax DF (2004) An essay on some topics concerning invasive species. Austral Ecology 29: 530-536.

Busching W-D (2005) Einführung in die Gefieder- und Rupfungskunde. AULA-Verlag GmbH, Wiebelsheim, Germany.

Buskirk SW, Linstedt SL (1989) Sex biases in trapped samples of Mustelidae. Journal of Mammalogy 70: 88-97.

Butler MA, Rotella JJ (1998) Validity of using artificial nests to assess duck-nest success. Journal of Wildlife Management 62: 163-170.

Cabrera A (1961) Catálogo de los mamíferos de América del Sur. Tomos I & II. Revista del Museo Argentino de Ciencias Naturales Bernardino Rivadavia, Ciencias Zoológicas IV: 1-732.

Canclini A (1999) Los indios del Cabo de Hornos: La vida de Susan y Henry Burleigh entre los aborígenes más primitivos del planeta. Zagier & Urruty Publications, Ushuaia, Argentina.

Chehébar C, Martín S (1989) Guía para el reconocimiento microscópico de los pelos de los mamíferos de la Patagonia. Doñana, Acta Vertebrata 16: 247-291.

Choi C (2008) Tierra del Fuego: the beavers must die. Nature 453: 968.

Clode D, Macdonald DW (2002) Invasive predators and the conservation of island birds: the case of American mink *Mustela vison* and terns *Sterna* spp. in the Western Isles, Scotland. Bird Study 49: 118-123.

Antolos M, Daniel D, Collis K (2004) Breeding ecology of Caspian terns at colonies of the Columbia Plateau. Northwest Science 78: 303-312.

Côté IM, Sutherland WJ (1997) The effectiveness of removing predators to protect bird populations. Conservation Biology 11: 395-405.

Coulatti RI, MacIsaac HJ (2004) A neutral terminology to define 'invasive' species. Diversity and Distributions 10: 135-141.

Courchamp F, Chapuis J-L, Pascal M (2003) Mammal invaders on islands: impact, control and control impact. Biological Reviews 78: 347-383.

Couve E, Vidal C (2003) Birds of the Beagle Channel and Cape Horn. Ediciones Fantástico Sur, Punta Arenas, Chile.

Craik JCA (1995) Effects of North American mink on the breeding success of terns and smaller gulls in west Scotland. Seabird 17: 3-11.

Craik JCA (1997) Long-term effects of North American Mink *Mustela vison* on seabirds in western Scotland. Bird Study 44: 303-309.

Crawley MJ (2007) The R Book. John Wiley & Sons, Ltd, Chichester, England.

Cussac V, Ortubay S, Iglesias G, Milando D, Lattuca ME, Barriga JP, Battini M, Gross M (2004) The distribution of South American galaxiid fishes: the role of biological traits and post-glacial history. Journal of Biogeography 31: 103-121.

D'Antonio CM, Hobbie SE (2005) Plant species effects on ecosystem processes. Species Invasions. In: Sax DF, Stachowicz JJ, Gaines SD (eds) Insights into Ecology, Evolution, and Biogeography: 65-84. Sinauer Associates, Sunderland, USA.

Davis MA, Thompson K (2000) Eight ways to be a colonizer; two ways to be an invader: A proposed nomenclature scheme for invasion ecology. Bulletin of the Ecological Society of America 81: 226-230.

Davison A, Birks JDS, Brookes RC, Braithwaite TC, Messenger JE (2002) On the origin of faeces: morphological versus molecular methods for surveying rare carnivores from their scats. Journal of Zoology 257: 141-143.

Day MG (1966) Identification of hair and feather remains in the gut and faeces of stoats and weasels. Journal of Zoology 148: 201-217.

Delibes M, Clavero M, Prenda J, del Carmen Blásquez M, Ferreras P (2004) Potential impact of an exotic mammal on rocky intertidal communities of northwestern Spain. Biological Invasions 6: 213-219.

de Neergaard A, Saarnek C, Hill T, Khanyile M, Martinen-Berzosa A, Birch-Thomsen T (2005) Australian wattle species in the Drakensberg Region of South Africa - An invasive alien or a natural resource? Agricultural Systems 85: 216-233.

Dinsmore SJ, White GC, Knopf FL (2002) Advanced techniques for modeling avian nest survival. Ecology 83: 3476-3488.

Dray S, Dufour A-B (2007) The ade4 Package: Implementing the Duality Diagram for ecologists. Journal of Statistical Software 22: 1-20.

Dunstone N (1993) The Mink. T & AD Poyser Ltd, London, UK.

Dunstone N, Birks JDS (1985) The comparative ecology of coastal, riverine and lacustrine mink *Mustela vison* in Britain. Zeitschrift für Angewandte Zoologie 59: 59-70.

Dunstone N & Birks JDS (1987) The feeding ecology of mink (*Mustela vison*) in coastal habitat. Journal of Zoology 212: 69-83.

Dunstone N & Ireland M (1989) The mink menace? A reappraisal. In: Putman RJ (ed) Mammals as pests: 225-241. Chapman & Hall, London, UK.

Elton CS (1958) The ecology of invasions by animals and plants. Methuen and Company, London, UK.

Errington PL (1954) An analysis of mink predation upon muskrats in north-central United States. Iowa State Coll. Agricultural Experimental Station Research Bulletin 320: 798-924.

Eser U (1998) Werturteile im Naturschutz: ökologische und normative Grundlagen am Beispiel der Neophytenproblematik. Ph.D. thesis. Fakultät für Biologie, Universität Tübingen, Germany.

Ewart CJ (1921) The nestling feathers of the Mallard, with observations on the composition, origin, and history of feathers. Proceedings of the Zoological Society of London 2: 609-642.

Faaborg J (2003) Truly artificial nest studies. Conservation Biology 18: 369-370.

Fasola L, Chehébar C, Macdonald DW, Porro G, Cassini MH (2009) Do alien North American mink compete for resources with native South American river otter in Argentinean Patagonia? Journal of Zoology 277: 187-195.

Ferreras P, Macdonald DW (1999) The impact of American mink *Mustela vison* on water birds in the upper Thames. Journal of Applied Ecology 36: 701-708.

Fielding AH, Haworth PF (1995) Testing the generality of bird-habitat models. Conservation Biology 9: 1466-1481.

Fischer A, van der Wal R (2007) Invasive plant suppresses charismatic seabird - the construction of attitudes towards biodiversity management options. Biological Conservation 135: 256-267.

Fischer A, Young JC (2007) Understanding mental constructs of biodiversity: Implications for biodiversity management and conservation. Biological Conservation 136: 271-282.

Fitzgerald G, Fitzgerald N, Wilkinson R (2002) Social acceptability of stoats and stoat control methods. In: Science for conservation 207. Department of Conservation, Wellington, New Zealand.

Fitzgerald G, Fitzgerald N, Wilkinson R (2005) Social acceptability of stoats and stoat control methods: A survey of the New Zealand public. In: Science for Conservation 253. Department of Conservation, Wellington, New Zealand.

Fitzpatrick M, Weltzin JF, Sanders NJ, Dunn RR (2007) The biogeography of prediction error: why does the introduced range of the fire ant over-predict its native range? Global Ecology and Biogeography 16: 24-33.

Fraser A (2006) Public attitudes to pest control: A literature review. Science & Technical Publishing, Wellington, New Zealand.

Gandini P, Frere E, Boersma D (1997) Efectos de la calidad de habitat sobre el éxito reproductivo del pinguino de Magallanes (*Spheniscus magellanicus*) en Cabo Vírgenes, Santa Cruz, Argentina. Ornitologia Neotropical 8: 37-48.

García-Llorente M, Martín-López B, González JA, Alcorlo P, Montes C (2008) Social perceptions of the impacts and benefits of invasive alien species: Implications for management. Biological Conservation 141: 2969-2983.

Gobster PH (2005) Invasive species as ecological threat: is restoration an alternative to fear-based resource management? Ecological Restoration 23: 261-270.

Götmark F (1992) The effects of investigator disturbance on nesting birds. Current Ornithology 9: 63–104.

Götmark F, Blomqvist D, Johansson OC, Bergkvist J (1995) Nest site selection: A trade-off between concealment and view of the surroundings? Journal of Avian Biology 26: 305-312.

Goodman D (1975) The theory of diversity-stability relationships in ecology. Quarterly review of Biology 50: 237-266.

Gorke M (2007) Eigenwert der Natur. Ethische Begründung und Konsequenzen. Habilitation thesis. Institut für Botanik und Landschaftsökologie, Ernst Moritz Arndt Universität Greifswald, Germany.

Gruber B, Reineking B, Calabrese JM, Kranz A, Poledníková K, Polenik L, Klenke R, Valentin A, Henle K (2008). A new method for estimating visitation rates of cryptic animals via repeated surveys of indirect signs. Journal of Applied Ecology 45: 728–735.

Guyn KL, Clark RG (1997) Cover characteristics and success of natural and artificial duck nests. Journal of Field Ornithology 68: 33-41.

Haider S, Jax K (2007) The application of environmental ethics in biological conservation: a case study from the southernmost tip of the Americas. Biodiversity and Conservation 16: 2559–2573.

Halliwell EC, Macdonald DW (1996) American mink *Mustela vison* in the Upper Thames catchment: relationship with selected prey species and den availability. Biological Conservation 76: 51-56.

Hammershøj M, Thomsen EA, Madsen AB (2004) Diet of free-ranging American mink and European polecat in Denmark. Acta Theriologica 49: 337-347.

Harrington LA, Harrington AL, Macdonald DW (2008) Estimating the relative abundance of American mink *Mustela vison* on lowland rivers: evaluation and comparison of two techniques. European Journal of Wildlife Research 54: 79-87.

Harrington LA, Harrington AL, Moorhouse T, Gelling M, Bonesi L, Macdonald DW (2009) American mink control on inland rivers in southern England: An experimental test of a model strategy. Biological Conservation, doi: 10.1016/j.biocon.2008.12.012

Hatler DF (1976) The coastal mink of Vancouver Island, British Columbia. Ph.D. thesis. University of British Columbia, Vancouver, Canada.

Heger T (2004) Zur Vorhersagbarkeit biologischer Invasionen. Entwicklung und Anwendung eines Modells zur Analyse der Invasion gebietsfremder Pflanzen. Ph.D. thesis. Neobita 4, 197 pp.

Heger T, Trepl L (2003) Predicting biological invasions. Biological Invasions 5: 313–321.

Heger T, Trepl L (2008) What are invasive alien species? Concepts and definitions (in German). Natur und Landschaft 83: 399-401.

Hettinger N (2001) Exotic species, naturalization and biological nativism. Environmental Values 10: 193-224.

Hobbs RJ, Arico S, Aronson J, Baron JS, Bridgewater P, Cramer VA, Epstein PR, Ewel JJ, Klink CA, Lugo AE, Norton D, Ojima D, Richardson DM, Sanderson EW, Valladares F, Vilà M, Zamora R, Zobel M (2006) Novel ecosystems: theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography 15: 1-7.

Hopkins J (2001) Exotic species, science and society. Glasgow Naturalist 23: 84-90.

Hosmer DW, Lemeshow S (2000) Applied Logistic Regression. John Wiley & Sons, New York, USA.

Hunter LM, Brehm J (2003) Brief comment: Qualitative insight into public knowledge of, and concern with, biodiversity. Human Ecology 31: 309-320.

Hurlbert SH (1978) The measurement of niche overlap and some relatives. Ecology 59: 67-77.

Hutchinson GE (1957) Concluding remarks. Cold Spring Harbour Symposia on Quantitative Biology 22: 415-427.

Ibarra JT (2007) El visón en Upushwaia: Variaciones estacionales de la avifauna en ambientes de humedal y de su depredación por la especie exótica invasora *Mustela vison* (Schreber) en Isla Navarino, Reserva de Biosfera Cabo de Hornos, Chile. Master thesis. Facultad de Agronomía e Ingeniería Forestal, Pontificia Universidad Católica de Chile, Santiago, Chile.

Ibarra JT, Fasola L, Macdonald DW, Rozzi R, Bonacic C (2009) Invasive American mink *Mustela vison* in wetlands of the Cape Horn Biosphere Reserve, southern Chile: what are they eating? Oryx 43: 1-4.

Inman AJ, Krebs J (1987) Predation and group living. Trends in Ecology & Evolution 2: 31-32.

Iriarte JA, Lobos GA, Jaksic FM (2005) Invasive vertebrate species in Chile and their control and monitoring by governmental agencies. Revista Chilena de Historia Natural 78: 143-154.

Jaksic FM (1998) Vertebrate invaders and their ecological impacts in Chile. Biodiversity and Conservation 7: 1427-1445.

Jaksic FM, Yáñez JL (1983) Rabbit and fox introductions in Tierra del Fuego: history and assessment of the attempts at biological control of the rabbit infestation. Biological Conservation 26: 367-374.

Jaksic FM, Iriartre JA, Jiménez JE, Martínez DR (2002) Invaders without frontiers: cross-border invasions of exotic mammals. Biological Invasions 4: 157-173.

Jax K, Rozzi R (2004) Ecological theory and values in the determination of conservation goals: examples from temperate regions of Germany, United States of America, and Chile. Revista Chilena de Historia Natural 77: 349-366.

Jędrzejewska B, Jędrzejewski W (1998) Predation in vertebrate communities. The Białowieża Primeval Forest as a case study. Ecological Studies Vol. 135. Springer, Berlin, Heidelberg, New York.

Jędrzejewska B, Sidorovich VE, Pikulik MM, Jędrzejewski W (2001) Feeding habits of the otter and the American mink in Białowieża Primeval Forest (Poland) compared to other Eurasian population. Ecography 24: 165-180.

Jefferies DJ (2003) The water vole and mink survey of Britain 1996-1998 with a history of the long term changes in the status of both species and their causes. The Vincent Wildlife Trust, Ledbury, UK.

Jehle G, Adams AAY, Savidge JA, Skagen SK (2004) Nest survival estimation: a review of alternatives to the Mayfield estimator. The Condor 106: 472-484.

Jenyns L (1842) The zoology of the H.M.S. Beagle during the years 1832 to 1836. Fisches 53: 1-172.

Jepson P, Canney S (2003) Values-led conservation. Global Ecology & Biogeography 12: 271–274.

Jeschke JM, Strayer DL (2005) Invasion success of vertebrates in Europe and North America. Proceedings of the National Academy of Sciences of the United States of America 102: 7198–7202.

Johnson AW (1965) The birds of Chile and adjacent regions of Argentina, Bolivia and Peru. Vol 2. Platt, Buenos Aires, Argentina.

Johnson DH (1979) Estimating nest success: the Mayfield method and an alternative. The Auk 96: 651-661.

Jones CG, Lawton JH, Shachak M (1994) Organisms as ecosystem engineers. Oikos 69: 373-386.

Juliano SA, Lounibos LP (2005) Ecology of invasive mosquitoes: effects on resident species and on human health. Ecology Letters 8: 558–574.

Kaltenborn BP, Bjerke T, Strumse E (1998) Diverging attitudes towards predators: do environmental beliefs play a part? Human Ecology Review 5: 1-9.

Kauhala K (2004) Removal of medium-sized predators and the breeding success of ducks in Finland. Folia Zoologica 53: 367-378.

Kellert SR (1996) The value of life: biological diversity and human society. Island Press, Washington, D.C., USA.

Kendle AD, Rose JE (2000) The aliens have landed! What are the justifications for 'native only' policies in landscape plantings? Landscape and Urban Planning 47: 19-31.

King WB (1985) Island birds: will future repeat the past? Technical Publication 3. International Council for bird preservation, Cambridge, UK.

Körner S (2000) Das Heimische und das Fremde. Die Werte Vielfalt, Eigenart und Schönheit in der konservativen und in der liberal-progressiven Naturschutzauffassung. Lit-Verlag, Münster, Germany.

Krajik K (2005) Winning the war against island invaders. Science 310: 1410-1413.

Krebs CJ (1999) Ecological Methodology. Benjamin/Cummings, Menlo Park, California, USA.

Kruuk H (1964) Predators and anti-predator behaviour of the black-headed gull (*Larus ridibundus L.*). Behaviour Supplement 11: 1-130.

Kuckartz U (2005) Einführung in die computergestützte Analyse qualitativer Daten. 1.ed. VS Verlag für Sozialwissenschaften, Wiesbaden, Germany.

Larivière S (1999) Reasons why predators cannot be inferred from nest remains. The Condor 101: 718-721.

Lencinas MV, Escobar J, Martínez Pastur G, Quiroga P, Malmierca L (2001) Dinámica de vegetación de bosques de *Nothofagus* en áreas impactadas por *Castor canadensis* en Tierra del Fuego. XXVIII Jornadas Argentinas de Botánica. Boletín de la Sociedad Argentina de Botánica 36: 94.

Levine JM, D'Antonio CM (1999) Elton revisited: a review of evidence linking diversity and invasibility. Oikos 87: 15-26.

Levins R (1968) Evolution in changing environments: some theoretical explorations. Princeton University Press, Princeton, USA.

Lima SL, Dill LM (1990) Behavioral decisions made under the risk of predation: a review and prospectus. Canadian Journal of Zoology 68: 619-640.

Livezey BC, Humphrey PS (1985) Territoriality and interspecific aggression in Steamer-Ducks. The Condor 87: 154-157.

Lizarralde MS (1993) Current status of the introduced beaver (*Castor canadensis*) population in Tierra del Fuego, Argentina. Ambio 22: 351-358.

Lizarralde MS, Escobar JM (2000) Mamíferos exóticos en la Tierra del Fuego. Ciencia hoy 10: 52-63.

Lockie JD (1961) The food of the pine marten *Martes martes* in West Ross Shire, Scotland. Proceedings of the Zoological Society of London 136: 187-195.

Lodge DM, Shrader-Frechette K (2003) Nonindigenous species: Ecological explanation, environmental ethics, and public policy. Conservation Biology 17: 31-37.

Long JL (2003) Introduced mammals of the world: their history, distribution and influence. CSIRO Publishers, Collingwood, Australia.

López HL, García ML, San Román NA (1996) Lista comentada de la ictiofauna del Canal Beagle, Tierra del Fuego, Argentina. CADIC, Ushuaia, Argentina.

Macdonald DW, Thom MD (2001) Alien carnivores: unwelcome experiments in ecological theory. In: Gittleman JL, Funk SM, Macdonald DW, Wayne RK (eds) Carnivore Conservation: 93-122. Cambridge University Press, Cambridge, UK.

Macdonald DW, Harrington LA (2003) The American mink: the triumph and tragedy of adaptation out of context. New Zealand Journal of Zoology 30: 421-441.

Mack RN, Simberloff D, Lonsdale WM, Evans H, Clout M, Bazzaz FA (2000) Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications 10: 689-710.

Major RE, Kendal CE (1996) The contribution of artificial nest experiments to understanding avian reproductive success: a review of methods and conclusions. Ibis 138: 298-307.

Maran T, Kruuk H, Macdonald DW, Polma M (1998) Diet of two species of mink in Estonia: displacement of *Mustela lutreola* by *M. vison*. Journal of Zoology 245: 218-222.

Martin TE (1993) Nest predation among vegetation layers and habitat types: revising the dogmas. American Naturalist 141: 897-913.

Martin TE (1995) Avian life history evolution in relation to nest sites, nest predation, and food. Ecological Monographs 65: 101-127.

Martínez Pastur G, Lencinas MV, Escobar J, Quiroga P, Malmierca L, Lizarralde M (2006) Understorey succession in areas of *Nothofagus* forests in Tierra del Fuego (Argentina) affected by *Castor canadensis*. Applied Vegetation Science 9: 143-154.

Martinic M (1973) Crónica de las Tierra del Sur del Canal Beagle. Editorial Francisco de Aguirre S.A., Buenos Aires, Argentina.

Mason SJ, Graham NE (2002) Areas beneath the relative operating characteristics (ROC) and relative operating levels (ROL) curves: Statistical significance and interpretation. Quarterly Journal of the Royal Meteorological Society 128: 2145-2166.

Massoia E, Chebez JC (1993) Mamíferos silvestres del Archipiélago Fueguino. L.O.L.A., Buenos Aires, Argentina.

Matthiesen U (2005) KnowledgeScapes. Pleading for a knowledge turn in socio-spatial research. Leibniz-Institute for Regional Development and Structural Planning (IRS), Erkner, Germany.

Mayfield H (1961) Nesting success calculated from exposure. The Wilson Bulletin 73: 255-261.

Mayring P (2003) Qualitative Inhaltsanalyse. Grundlagen und Techniken. 8. ed. Beltz Verlag, Weinheim and Basel, Germany.

McCulloch RD, Clapperton CM, Rabassa J, Currant AP (1997) The glacial and post-glacial environmental history of Fuego-Patagonia. In: McEwan C, Borrero LA, Prieto A (eds) Patagonia: natural history, prehistory and ethnography: 12-31. University Press, Princeton, New Jersey, USA.

McDonald RA (2002) Resource partitioning among British and Irish mustelids. Journal of Animal Ecology 71: 185-200.

McEwan C, Borrero LA, Prieto A (1997) Patagonia: natural history, prehistory and ethnography at the uttermost end of the earth. British Museum, London.

McGehee S, Rozzi R, Ippi S, Anderson CB, Vásquez R, Woodland S (2004) Late-Summer presence of the Patagonian Tyrant, *Colorhamphus parvirostris* (Darwin) in Navarino Island, Cape Horn County. Anales del Instituto de la Patagonia 32: 25-33.

McMichael AJ, Bouma MJ (2000) Global changes, invasive species and human health. In: Mooney HA, Hobbs RJ (eds) Invasive species in a changing World: 191–210. Island Press, Washington, D.C., USA.

McNeely JA, Mooney HA, Neville LE, Schei PJ, Waage JK (2001) A global strategy on invasive alien species. IUCN, Gland, Switzerland.

Medina G (1997) A comparison of the diet and distribution of southern river otter (*Lutra provocax*) and mink (*Mustela vison*) in Southern Chile. Journal of Zoology 242: 291-297.

Meech H (2005) Eradicating non-native mammals from islands: facts and perceptions. ECOS 26: 72-80.

Mezquida ET, Marone L (2003) Are results of artificial nest experiments a valid indicator of success of natural nests? Wilson Bulletin 115: 270-276.

Miller CK, Knight RI (1993) Does predator assemblage affect reproductive success in songbirds? The Condor 9: 712-715.

Mitchell JL (1961) Mink movements and populations on a Montana river. Journal of Wildlife Management 25: 48-54.

Mittermeier RA, Mittermeier CG, Brooks TM, Pilgrim JD, Konstant WR, da Fonseca GAB, Kormos C (2003) Wilderness and biodiversity conservation. Proceedings of the National Academy of Sciences of the United States of America 18: 10309–10313.

Moore D (1983). Flora of Tierra del Fuego, Anthony Nelson, England. Missouri Botanical Garden, USA.

Moore NP, Roy SS, Helyar A (2003) Mink (*Mustela vison*) eradication to protect ground-nesting birds in the Western Isles, Scotland, United Kingdom. New Zealand Journal of Zoology 30: 443-452.

Moore RP, Robinson WD (2004) Artificial bird nests, external validity, and bias in ecological field studies. Ecology 85: 1562-1567.

Moorman MC (2007) The conservation implications of introduced trout and beaver on native fish in the Cape Horn Biosphere Reserve, Chile. Master thesis. North Carolina State University, USA.

Newton I (1994) Experiments on the limitation of bird breeding densities - a review. Ibis 136: 397-411.

Newton I (1998) Population limitation in birds. Academic Press, London, UK.

Nordström M, Högmander J, Laine J, Nummelin J, Laanetu N, Korpimäki E (2003) Effects of feral mink removal on seabirds, waders and passerines on small islands in the Baltic Sea. Biological Conservation 109: 359-368.

Nordström M, Korpimäki E (2004) Effects of island isolation and feral mink removal on bird communities on small islands in the Baltic Sea. Journal of Animal Ecology 73: 424-433.

Nordström M, Laine J, Ahola M, Korpimäki E (2004) Reduced nest defence intensity and improved breeding success in terns as responses to removal of non-native American mink. Behavioral Ecology and Sociobiology 55: 454-460.

Norton, BG (1987) Why preserve natural variety? Princeton University Press. Princeton, New Jersey, USA.

Ocampo C, Rivas P (2000) Nuevos fechados ^{14}C de la costa norte de la isla Navarino, costa sur del canal Beagle, Provincia Antártica Chilena, Región de Magallanes. Anales del Instituto de la Patagonia 28: 23-35.

Olrog CC (1950) Notas sobre mamíferos y aves del archipiélago de Cabo de Hornos. Acta Zoológica Lillonana IX: 505-532.

Olson JM, Zanna MP (1993) Attitudes and attitude change. Annual Review of Psychology 44: 117-154.

Olwig KR (2003) Natives and aliens in the national landscape. Landscape Research 28: 61-74.

Opermanis O, Mednis A, Bauga I (2001) Duck nests and predators: interaction, specialisation and possible management. Wildlife Biology 7: 87-96.

Pagnoni GO, Garrido JL, Marín MR (1986) Impacto económico y ambiental del visón, *Mustela vison* (Schreber, 1777) en el norte de la Patagonia. CENPAT-CONICET, Dirección de Fauna Silvestre, Provincia de Chubut, Argentina.

Palomares F, Caro TM (1999). Interspecific killing among mammalian carnivores. American Naturalist 153: 492-508.

Parker IM, Simberloff D, Londsdale WM, Goodell K, Wonham M, Kareiva PM, Williamson MH, Von Holle B, Moyle PB, Byers JE, Goldwasser L (1999) Impact: toward a framework for understanding the ecological effects of invaders. Biological Invasions 1: 3-19.

Patterson BD, Gallardo MH, Freas KE (1984). Systematics of mice of the subgenus *Akodon* (Rodentia: Cricetidae) in southern South America, with the description of a new species. Fieldiana Zoology, New Series 23: 1-16.

Pearman PB, Guisan A, Broennimann O, Randin CF (2008) Niche dynamics in space and time. Trends in Ecology & Evolution 23: 149-158.

Peña LF, Barría G (1972) Presencia de *Histiotus montanus magellanicus* Philp. y *de Myostis ch. chiloensis* Waterhouse (Chiroptera) al sur del Estrecho de Magallanes. Anales del Museo de Historia Natural Valparaiso 5: 202-202.

Perrings C, Williamson M, Barbier EB, Delfino D, Dalmazzone S, Shogren J, Simmons P, Watkinson A (2002) Biological invasion risks and the public good: an economic perspective. Conservation Ecology 6 [online] URL: www.consecol.org/vol6/iss1/art1.

Perry HR, Jr. (1982) Muskrats. In: Chapman JA, Feldhammer GA (eds) Wild mammals of North America: biology, management, and economics: 282-325. John Hopkins University Press, Baltimore, USA.

Pickett STA, Ostfeld RS (1995) The shifting paradigm in ecology. In: Knight RL, Bates SF (eds) A new century for natural resources management: 261-278. Island Press, Washington, D.C., USA.

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52: 273-288.

Pisano E (1977) Fitogeografía de Fuego-Patagonia chilena. I. Comunidades vegetales entre las latitudes 52° y 56°S. Anales del Instituto de la Patagonia 8: 121-250.

Pisano E (1981) Bosquejo fitogeográfico de Fuego-Patagonia. Anales del Instituto de la Patagonia 12: 159-171.

Pisano E (1982) Comunidades vegetales vasculares de la isla Hornos. Anales del Instituto de la Patagonia 13: 125-143.

Pollack G, Berghöfer A, Berghöfer U (2008) Fishing for social realities - Challenges to sustainable fisheries management in the Cape Horn Biosphere Reserve. Marine Policy 32: 233–242.

Previtali A, Cassini MH, Macdonald DW (1998) Habitat use and diet of the American mink (*Mustela vison*) in Argentinian Patagonia. Journal of Zoology 246: 482-486.

Quillfeldt P, Strange IJ, Masello JF (2005) Escape decisions of incubating females and sex ratio of juveniles in the Upland Goose *Chloephaga picta*. Ardea 93: 171-178.

R Development Core Team (2008) R: A language and environment for statistical computing. In: R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/ [Cited: 03/02/2009].

Rangen SA, Clark RG, Hobson KA (2000) Visual and olfactory attributes of artificial nests. The Auk 117: 136-146.

Ratcliffe N, Craik C, Helyar A, Roy S, Scott M (2008). Modelling the benefits of American Mink *Mustela vison* management options for terns in west Scotland. Ibis 150: 114-121.

Rau J, Martínez DR (2004) Identificación de los órdenes de aves chilenas a través de la microestructura de sus plumas. In: Muñoz A, Rau J, Valenzuela J (eds) Aves rapaces de Chile: 229-234. CEA Ediciones, Validiva, Chile.

Raya Rey AR, Schiavini A (2002) Distribution and density of Kelp Geese and Flightless Steamer Ducks along the Beagle Channel, Tierra del Fuego, Argentina. Waterbirds 25: 225-229.

Reise D (1973) Clave para la identificación de los cráneos de marsupiales y roedores chilenos. Gayana 27: 1-20.

Reise D, Venegas W (1987) Catálogo de registros localidades y biotopos del trabajo de investigación acerca de los pequeños mamíferos de Chile y Argentina. Gayana, Zoología 51: 103-130.

Reyes CF (1992) Clave para la identificación de los órdenes de aves chilenas: microestructura de los nodos de las bárbulas. Thesis. Instituto profesional de Osorno, Osorno, Chile.

Reynolds JC, Short MJ, Leigh RJ (2004) Development of population control strategies for mink *Mustela vison*, using floating rafts as monitors and trap sites. Biological Conservation 120: 533–543.

Robinson CJ, Whitehead P (2003) Cross-cultural management of pest animal damage: a case study of feral buffalo control in Australia's Kakadu National Park. Environmental Management 32: 445-458.

Robinson CJ, Smyth D, Whitehead PJ (2004) Bush tucker, bush pets and bush threats: cooperative management of feral animals in Australia's Kakadu National Park. Conservation Biology 19: 1385-1391.

Rönkä M, Tolvanen H, Lehikoinen E, von Numers M, Rautkari M (2008) Breeding habitat preferences of 15 bird species on south-western Finnish archipelago coast: Applicability of digital spatial data archives to habitat assessment. Biological Conservation 141: 402-416.

Rokeach M (1973) The nature of human values. Free Press, New York, USA.

Root RB (1967) The niche exploitation pattern of the blue-gray gnatcatcher. Ecological Monographs 37: 317-350.

Rozzi R (2002) Biological and cultural conservation in the archipelago forest ecosystems of southern Chile. Ph.D. thesis. Department of Ecology and Evolutionary Biology, University of Connecticut, USA.

Rozzi R (2007) Future environmental philosophies and their biocultural conservation interfaces. Ethics and the Environment 12: 142-145.

Rozzi R, Massardo F (2002) Antecedentes de biodiversidad y sitios prioritarios en la Comuna Cabo de Hornos: Recopilación de información sobre los ecosistemas subantárticos en apoyo a la Estrategia Nacional y Plan de Acción para la biodiversidad. Informe Técnico. Comisión Nacional del Medio Ambiente XII Región, Punta Arenas, Chile.

Rozzi R, Sherriffs M (2003) El visón (*Mustela vison* Schreber, Carnivora: Mustelidae), un nuevo mamífero exótico para la isla Navarino. Anales del Instituto de la Patagonia 31: 97-104.

Rozzi R, Massardo F, Silander Jr. J, Anderson C, Marin A (2003) Conservación biocultural y ética ambiental en el extremo austral de América: oportunidades y dificultades para el bienestar ecosocial. In: Figueora E, Simonetti J (eds) Biodiversidad y globalización: 51-85. Editorial Universitaria, Santiago, Chile.

Rozzi R, Massardo F, Anderson C (eds) (2004a) The Cape Horn Biosphere Reserve: A proposal for conservation and tourism to achieve sustainable development at the southern end of the Americas. Bilingual English-Spanish edition. Ediciones Universidad de Magallanes, Punta Arenas, Chile.

Rozzi R, Charlin R, Ippi S, Dollenz O (2004b) Cabo de Hornos: un Parque Nacional libre de especies exóticas en el confín de América. Anales del Instituto de la Patagonia 32: 55-62.

Rozzi R, Massardo F, Berghöfer A, Anderson CB, Mansilla A, Mansilla M, Plana J, Berghöfer U, Araya P, Barros E (2006a) Cape Horn Biosphere Reserve: Nomination Document for the incorporation of the Cape Horn Archipelago Territory into the Word Biosphere Reserve Network. MaB Program-UNESCO. Ediciones de la Universidad de Magallanes, Punta Arenas, Chile.

Rozzi R, Massardo F, Anderson CB, Heidinger K, Silander J (2006b) Ten principles for biocultural conservation at the southern tip of the Americas: The approach of the Omora Ethnobotanical Park. Ecology and Society 11: 43 [online]. Available from: www.ecologyandsociety.org/vol11/iss1/art43/.

SAG (2001) Cartilla para cazadores. Departamento de Protección de los Recursos Naturales Renovables, Servicio Agrícola y Ganadero, Santiago, Chile.

Sala OE, Chapin III FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH (2000) Global biodiversity scenarios for the year 2100. Science 287: 1770-1774.

Sandoval RJ (1994) Estudio ecológico del visón asilvestrado (*Mustela vison*, Schreber) en la XI Región. Thesis. Universidad Austral de Chile, Valdivia, Chile.

Sax DF, Stachowicz JJ, Brown JH, Bruno JF, Dawson MN, Gaines SD, Grosberg RK, Hastings A, Holt RD, Mayfield MM, O'Connor MI, Rice WR (2007) Ecological and evolutionary insights from species invasions. Trends in Ecology & Evolution 22: 465-471.

Sax DF, Gaines D (2008) Species invasions and extinction: The future of native biodiversity on islands. Proceedings of the National Academy of Sciences of the United States of America 105: 11490-11497.

Schüttler E, Cárcamo J, Rozzi R (2008) Diet of the American mink *Mustela vison* and its potential impact on the native fauna of Navarino Island, Cape Horn Biosphere Reserve, Chile. Revista Chilena de Historia Natural 81: 599-613.

Schüttler E, Klenke R, McGehee S, Rozzi R, Jax K (2009) Vulnerability of ground-nesting waterbirds to predation by invasive American mink in the Cape Horn Biosphere Reserve, Chile. Biological Conservation, doi: 10.1016/j.biocon.2009.02.013.

Schullery P, Whittlesey L (2001) Mountain goats in the Greater Yellowstone Ecosystem: a prehistoric and historical context. Western North American Naturalist 61: 289-307.

Scolaro J, Laurenti S, Gallelli H (1996) The nesting and breeding biology of the South American Tern in northern Patagonia. Journal of Field Ornithology 67: 17-24.

Shackleton CM, McGarry D, Fourie S, Gambiza J, Shackleton SE, Fabricius C (2007) Assessing the effects of invasive alien species on rural livelihoods: Case examples and a framework from South Africa. Human Ecology 35: 113-127.

Sheail J (2004) The mink menace: the politics of vertebrate pest control. Rural History 15: 207–222.

Short J, Kinnear JE, Robley A (2002) Surplus killing by introduced predators in Australia - evidence for ineffective anti-predator adaptations in native prey species? Biological Conservation 103: 283-301.

Shrader-Frechette KS, McCoy ED (1993) Method in ecology. Strategies for conservation. Cambridge University Press, Cambridge.

Sidorovich VE (1993) Reproductive plasticity of the American mink *Mustela vison* in Belarus. Acta Theriologica 38: 175-183.

Sidorovich VE, Jędrzejewska B, Jędrzejewski W (1996) Winter distribution and abundance of mustelids and beavers in the river valleys of Białowieża Primeval Forest. Acta Theriologica 41: 155-170.

Sidorovich VE, Macdonald DW, Pikulik MM, Kruuk H (2001) Individual feeding specialization in the European mink, *Mustela lutreola* and the American mink, *M. vison* in north-eastern Belarus. Folia Zoologica 50: 27-42.

Siegel-Causey D, Kharitonov SP (1990) The evolution of coloniality. In: Power DM (ed) Current ornithology 7: 285-330. Plenum, New York, USA.

Sielfeld W (1977) Reconocimiento macrofaunístico terrestre en el área de Seno Ponsonby (Isla Hoste). Anales del Instituto de la Patagonia 8: 275-296.

Sielfeld W (1984) Alimentación de las nutrias *L. felina* y *L. provocax* en el medio marino al sur del Canal de Beagle. Primera Reunión de trabajo de experiencias en mamíferos acuáticos de América del Sur, Buenos Aires, Argentina.

Sielfeld W, Venegas C (1980) Poblamiento e impacto ambiental de *Castor canadensis* Kuhl, en Isla Navarino, Chile. Anales del Instituto de la Patagonia 11: 247-257.

Silva CA, Saavedra B (2008) Knowing for controlling: ecological effects of invasive vertebrates in Tierra del Fuego. Revista Chilena de Historia Natural 81: 123-136.

Simberloff D (1995) Why do introduced species appear to devastate islands more than mainland areas? Pacific Science 49: 87-97.

Simberloff D (2003) How much information on population biology is needed to manage introduced species? Conservation Biology 17: 83–92.

Simberloff D (2006) Invasional meltdown 6 years later: important phenomenon, unfortunate metaphor, or both? Ecology Letters 9: 912-919.

Simberloff D, Von Holle B (1999) Positive interactions of nonindigenous species: invasional meltdown? Biological invasions 1: 21-32.

Simonetti JA (1989) Microhabitat use by small mammals in central Chile. Oikos 56: 309-318.

Skewes O, Olave R (1999) Investigacíon, aprovechamiento y control del castor en islas Tierra del Fuego y Navarino. Servicio Agrícola y Ganadero, XII Región, Punta Arenas, 185 pp + appendices.

Skewes O, González F, Olave R, Ávila A, Vargas V, Paulsen P, Konig HE (2006) Abundance and distribution of American beaver, *Castor canadensis* (Kuhl 1820), in Tierra del Fuego and Navarino Islands. European Journal of Wildlife Resources 52: 292–296.

Smal CM (1991) Population studies on feral American mink *Mustela vison* in Ireland. Journal of Zoology 224: 233-249.

Soto N, Cabello J (2007) Informe final: Programa control de fauna dañina en la XIIa Región 2004-2007. SAG-FONDEMA. Servicio Agrícola y Ganadero, Magallanes y Antártica Chilena, Punta Arenas, Chile.

Soulé ME (1985) What is conservation biology? BioScience 35: 727-734

Steinberg PD, Kendrick GA (1999) Kelp forests. In: Andrew N (ed) Under Southern Seas. The ecology of Australia's rocky reefs: 61–71. University of New South Wales Press, Sydney, Australia.

Stephenson R, Butler PJ, Dunstone N, Woakes AJ (1988) Heart rate and gas exchange in freely diving American mink (*Mustela vison*). Journal of Experimental Biology 134: 435-442.

Strachan R, Jefferies DJ (1993) The water vole *Arvicola terrestris* in Britain 1989-1990: its distribution and changing status. Vincent Wildlife Trust, London, UK.

Summers R, McAdam J (1993) The Upland Goose. A study of the interaction between geese, sheep and man in the Falkland Islands. Bluntisham Books, Bluntisham, UK.

Thioulouse J, Chessel D, Dolédec S, Olivier J (1997) ADE-4: A multivariate analysis and graphical display software. Statistics and Computing 7: 75-83.

Thomas O (1916) Notes on Argentina, Patagonia and Cape Horn Muridae. Annals and Magazine Natural History 8: 182-187.

Thompson WL, White GC, Gowan C (1998) Monitoring vertebrate populations. Academic Press, San Diego, USA.

Townsend M (2005) Is the social construction of native species a threat to biodiversity? ECOS 26: 3-9.

UNEP/CBD (2000) Ecosystem Approach. In: Decisions adopted by the Conference of the Parties to the Convention on Biological Diversity at its Fifth Meeting, Nairobi, 15-26 May 2000, pp. 103-109. http://www.cbd.int/doc/decisions/COP-05-dec-en.pdf [Cited: 08/01/2009].

Vellend M, Harmon LJ, Lockwood JL, Mayfield MM, Hughes AR, Wares JP, Sax DF (2007) Effects of exotic species on evolutionary diversification. Trends in Ecology & Evolution 22: 481-488.

Vila I, Fuentes LS, Saavedra M (1999) Ictiofauna en los sistemas límnicos de la Isla Grande, Tierra del Fuego, Chile. Revista Chilena de Historia Natural 72: 273-284.

Vitousek PM, D'Antonio CM, Loope LL, Rejmánek M, Westbrooks R (1997) Introduced species: a significant component of human-caused global change. New Zealand Journal of Ecology 21: 1-16.

Wallem PK, Jones CG, Marquet PA, Jaksic FM (2007) Identificación de los mecanismos subyacentes a la invasión de *Castor canadensis* (Rodentia) en el archipiélago de Tierra del Fuego, Chile. Revista Chilena de Historia Natural 80: 309-325.

Wallington TJ, Hobbs RJ, Moore SA (2005) Implications of current ecological thinking for biodiversity conservation: a review of the salient issues. Ecology and Society 10: 15. http://www.ecologyandsociety.org/vol10/iss1/art15/. [Cited 13/02/2009]

Ward DP, Smal CM, Fairley JS (1986) The food of mink *Mustela vison* in the irish midlands. Proceedings of the Royal Irish Academy Section B 86: 169-182.

Warren CR (2005) The concept of alien and native species: time for a rethink? ECOS 26: 10-18.

Warren CR (2007) Perspectives on the 'alien' versus 'native' species debate: a critique of concepts, language and practice. Progress in Human Geography 31: 427-446.

Weller MW (1976) Ecology and behaviour of steamer ducks. Wildfowl 27: 45-53.

Whittingham MJ, Evans KL (2004) The effects of habitat structure on predation risk of birds in agricultural landscapes. Ibis 146: 210-220.

Williamson M (1996) Biological invasions. Chapman & Hall, London, GB.

Willson MF, Morrison JL, Sieving KE, De Santo TL, Santisteban L, Díaz I (2001) Patterns of predation risk and survival of bird nests in a Chilean agricultural landscape. Conservation Biology 15: 447-456.

Wilson GJ, Delahay RJ (2001) A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. Wildlife Research 28: 151-164.

Wittenberger JF, Hunt GL (1985) The adaptive significance of coloniality in birds. Avian Biology 8: 1-78.

Yamaguchi N, Rushton S, Macdonald DW (2003) Habitat preferences of feral American mink in the Upper Thames. Journal of Mammalogy 84: 1356-1373.

Yorio P, Boersma PD, Swann S (1996) Breeding biology of the dolphin gull at Punta Tombo, Argentina. The Condor 98: 208-215.

Yorio P, Frere E, Gandini P, Conway W (1999) Status and conservation of seabirds breeding in Argentina. Bird Conservation International 9: 299-314.

Yorio P, Borboroglu G (2002) Breeding biology of Kelp Gulls (*Larus dominicanus*) at Golfo San Jorge, Patagonia, Argentina. Emu 102: 257–263.

Żurowski W, Kammler J (1987) American mink (*Mustela vison* Schreber, 1777) in beaver's sites. Przeglàd Zoologiczny 31: 513-521.

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List of tables

The captures are given in an abbreviated form.

Populärwissenschaftliche Zusammenfassung

Patagoniens exotische Fauna
Folgen der jüngsten Einwanderung des Minks auf der Insel Navarino

Als Darwin im Jahr 1832 mit der HMS Beagle den heutigen Beagle-Kanal im Süden Feuerlands entlang segelte, umkreisten ihn Riesensturmvögel und fluglose Dampfschiffenten flohen paddelnd vor dem Schiff. Die letzten Ausläufer der Anden mit ihren ausgedehnten Südbuchenwäldern zeigten sich schneebedeckt und in der Ferne vernahm man das Rufen der Guanakos.

Viel hat sich seitdem nicht verändert auf der chilenischen Insel Navarino, gelegen zwischen dem argentinischen Teil Feuerlands und dem berüchtigten Kap-Hoorn. Die Region zählt zu den letzten Wildnisgebieten der Erde und wurde 2005 von der UNESCO zum Kap-Hoorn-Biosphärenreservat erklärt. Doch wenn man genauer eindringt, findet man auch hier Spuren der Globalisierung.

Biologische Invasionen sind eine Konsequenz des weltweiten Handels und Reisens. Auch auf der Insel Navarino sind sie angekommen, die sogenannten invasiven Arten. Sie heissen so, weil sie sich in einer neuen Heimat etablieren, in die sie eigentlich nicht gehören. Ihre natürliche Ausbreitung blieb zuvor durch eine biogeographische Barriere, zum Beispiel einen Ozean, eingeschränkt. Zumeist mit Hilfe des Menschen konnten in den letzten hundert Jahren viele dieser Barrieren überwunden werden. So auch auf Navarino.

Der Marder Mink, ursprünglich aus Nordamerika stammend, wurde in den 30er Jahren zur Pelzzucht in Chile und Argentinien eingeführt. Auf Feuerland kamen manche Tiere frei oder wurden befreit. Von dort aus überquerten sie als ausgezeichnete Schwimmer den im Schnitt fünf Kilometer breiten Beagle-Kanal und gelangten so auf die Insel Navarino. Dort wurde der Mink als „seltsame Nutria“ gesichtet und 2001 offiziell registriert. Der Mink stellt so das jüngste invasive Säugetier im Kap-Hoorn-Biosphärenreservat dar.

Was aber bedeutet das Hinzukommen einer neuen Tierart für die heimische Fauna? Genau dies untersucht Elke Schüttler vom Helmholtz Zentrum für Umweltforschung in Leipzig: „Der Mink besetzt auf Navarino eine neue ökologische Nische, die des terrestrischen Raubsäugers.

Ausläufer der Anden
Blick auf den Beagle-Kanal, Südchile.

Vor der Einwanderung des Minks gab es hier nur Raubvögel. Diese erfordern am Himmel jagend andere Verhaltensanpassungen der Beutetiere als ein Bodenräuber. Damit könnten durch den Mink insbesondere solche Tiere in Gefahr geraten, die wenig an einen Bodenräuber angepasst sind, zum Beispiel bodenbrütende Vögel."

Nordamerikanischer Mink bei gefundenem Fressen: Nest der bodenbrütenden Magellangans.

Vögel stellen die artenreichste Gruppe unter den Wirbeltieren im Kap-Hoorn-Biosphärenreservat. „Mit 154 Arten, darunter endemische Arten wie die patagonische Dampfschiffente oder die Kelpgans, deren Federn bereits in den Zeremonien der Jaghan-Indianer verwendet wurden, sind die Vögel das Kapital unserer Insel", sagt Ricardo Rozzi von der dortigen Naturschutzorganisation Omora mit Sitz in Puerto Williams, der einzigen größeren Siedlung der Insel. Der Biologe und Philosoph setzt sich vor Ort wesentlich für die Entwicklung des Ökotourismus ein. „Wir müssen den Mink in seiner neuen Umgebung kennenlernen, um seine Auswirkungen einschätzen und Empfehlungen für ein Management geben zu können." Hier setzt Schüttlers Forschung an, die sie in enger Zusammenarbeit mit der lokalen Landwirtschaftsbehörde plant und diskutiert.

Zunächst ging es ans Fallenstellen in drei Untersuchungsflächen entlang der Nordküste. Alle 200 Meter eine Falle, insgesamt 20 Stück, bestückt mit frischem Fisch. Eine Woche lang bleiben die Lebendfallen offen und werden jeden Morgen kontrolliert. Befindet sich ein Mink darin, wird es spannend: „Ein bisschen nervös bin ich dann schon", sagt sie. „Ich muss den Mink betäuben, ihm einen Mikrochip mit individueller Nummer injizieren, vermessen und warten bis er aufwacht, um ihn wieder freizulassen." Fang-Wiederfang-Methode nennt sich das und dient zur Bestimmung der Populations-grösse. Knapp einen Mink pro Küstenkilometer fand Schüttler mit dieser Methode nachdem sie insgesamt 21 Individuen markiert hatte. Im Vergleich zu anderen Studien in Europa deutet dies jedoch auf eine noch anwachsende Population hin.

Doch obwohl der Mink erst vor kurzerm einwanderte, konnte er sich bereits auf der ganzen 40 x 60 km² großen Insel Navarino etablieren. Zusammen mit einheimischen Assistenten machte sich die Doktorandin auf mehrtägigen Wanderungen ins Innere der kaum erschlossenen Insel ein Bild von der Verbreitung des Minks entlang von Flüssen, Teichen und Seen. Wie Jäger auf der Pirsch nehmen sie dabei jede Spur des Vierbeiners auf und notieren die genaue Lage und das Habitat, der Kot wird dabei eingesammelt. „Der ist wertvoll!", erklärt José Llaipén, einer der mitforschenden Assistenten, „Eine Analyse der Hartteile gibt Aufschluss über das Nahrungsspektrum."

Die Spurensuche an insgesamt 53 Inlandgewässern und 15 Küstenflächen ergab: der Mink hat keine Vorlieben für ein bestimmtes Gewässerhabitat. Damit ist klar, welche Herausforderung die Kontrolle der Minkpopulation auf Navarino für die Landwirtschaftsbehörde bedeutet: Auf einer Insel, die kaum über Infrastruktur verfügt, muss sie praktisch jeden Fluss, Teich, See und Küstenabschnitt berücksichtigen.

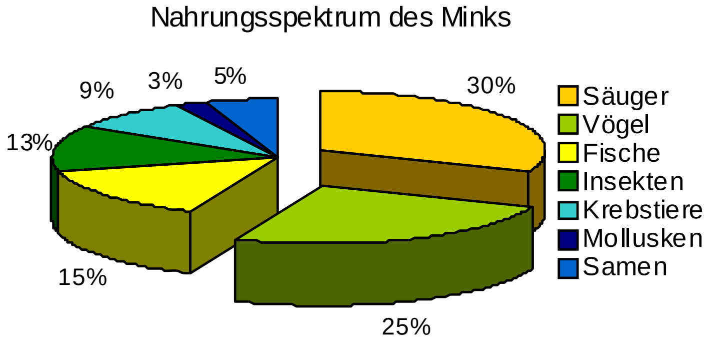
Inzwischen ist Elke Schüttler abgereist. Mit einem Rucksack voll wertvoller Indizien verbringt sie einige Monate im Labor des Patagonien-Instituts der Magallanes-Universität in Punta Arenas. Dort säubert sie den eingesammelten Kot und trennt unter dem Binokular Federn von Haaren, Schuppen von Chitinpanzern und Kalkschalen von Samen. So kann sie anhand der Häufigkeit des Vorkommens, des geschätzten Volumens und des Gewichts die Hauptbeutegruppen des Minks bestimmen. Mit Hilfe eines Abdrucks der Haarstruktur erschließt sich ihr unter dem Mikroskop sogar, welche Säugerarten der Mink gefressen hat. Jaime Cárcamo, der die kostbare Referenzsammlung des Patagonien-Instituts bestehend aus allerlei ausgestopften Tieren und Skeletten pflegt, unterstützt Schüttlers Doktorarbeit: „Die Nahrungsanalyse ist eine ausgezeichnete Methode, um Räuber-Beute-Beziehungen indirekt zu verstehen. Man kann sogar jahreszeitliche Schwankungen und Habitatvorlieben nachvollziehen“.

Schüttlers Hauptthese aber, der Mink könnte insbesondere bodenbrütende Vögel gefährden, erfordert einen direkte Prüfung. Sie möchte genau wissen, um welche Vogelarten es sich handelt. „Meine Lieblingsbeschäftigung sind die Nestbesuche. Es ist jedes Mal eine grosse Freude, ein Nest der Magellangans zu finden und bis zum Schlüpfen zu beobachten. Die Nester der patagonischen Dampfschiffente sind schwieriger zu entdecken, da sie versteckter brütet.“ Neben diesen beiden einzelnistenden Arten, besucht die Biologin auch Möwen- und Seeschwalbenkolonien. „Dazu ziehe ich immer meine ältesten Sachen an und arbeite so schnell wie möglich. Besonders die Blutschnabelmöwe regt sich sehr auf und wehrt sich mit einem „Regen“ aus der Luft!“, lacht sie. Häufig kommt es allerdings nicht zum Schlüpfen. Dann sammelt Schüttler die Eierschalen ein und bestimmt den Nesträuber. Auf Navarino kommen dazu in Frage: Möwen- und Raubvögel, verwilderte Hunde, der Mensch und schließlich der neue Räuber Mink.

Nach einem Monitoring von insgesamt 102 Gänse- und Entennestern und 361 Möwen- und Seeschwalbennestern fand sie heraus: Der Mink wagt sich nicht in die Kolonien, Eier aus vereinzelten Nestern jedoch verspeist er gerne. Dabei bevorzugt er insbesondere Eier der patagonischen Dampfschiffente. Von 23 untersuchten Nestern überlebten lediglich zwei, die Hälfte der ausgeraubten Nester ging auf das Konto des Minks.

Wie verhält es sich aber mit all den anderen Arten, die Schüttler nicht untersuchen konnte? Dazu fabriziert die Biologin sogenannte künstliche Nester und bestückt sie mit einem weißen Ei aus Knete und einem Hühnerei als Köder. Insgesamt 575 Kneteier formte sie zusammen mit vielen freiwilligen Händen und verteilte sie auf verschiedene Küstenhabitate, alle 50 Meter ein Nest. „Mit Hilfe der künstlichen Nester kann Elke den Prototyp des Nestes finden, das besonders vom Mink prädiert wird“, erklärt Doktorvater Jax aus der Naturschutzforschung des Helmholtz Zentrums für Umweltforschung und Professor an der Technischen Universität München. „Mit Erfolg: Ihr abgeleitetes Gefährdungsprofil zeigt, dass Küstenvögel, die einzeln nisten, als Brutgebiet felsige Küstenabschnitte auswählen und ihre Nester gut in der Vegetation verstecken, besonders verwundbar sind. Damit können nun auch nicht untersuchte Arten beim Schutzmanagement berücksichtigt werden.“

Dass aber nicht nur Eier der Küstenvögel auf dem Speiseplan des Minks stehen, sondern auch Singvögel, zeigt ein Blick auf die Nahrungsanalysen. Unter den verzehrten Vögeln traten zur Hälfte Federn von Singvögeln zu Tage, zumeist als Altvögel erbeutet, aufgestockt mit Küken von Gänse- und Entenvögeln, sowie Kormoranen. Als Nahrungsgeneralist jedoch bezieht der Mink auch auf der Insel Navarino alle vorhandenen Nahrungs-quellen: Neben den Vögeln setzt sich seine Ernährung aus Kleinsäugern



zusammen, den beiden Hauptbeutegruppen, gefolgt von Fischen, Insekten, Krebstieren, Mollusken und Samen (siehe Graphik). „Der Mink wird im allgemeinen als Nahrungsopportunist beschrieben, das heisst, er nutzt das jeweilige Nahrungsangebot voll aus“, erklärt Schüttler. “In der warmen Jahreszeit, wenn viele Wandervögel zurückkehren und beim Brüten verwundbar sind, steigt der Anteil an Vögeln in der Nahrung um das Doppelte! Im Winter hingegen werden vermehrt Kleinsäuger erbeutet, darunter auch die aus Nordamerika stammende Bisamratte, eine weitere invasive Art auf Navarino.“

Neben den rein biologischen Aspekten werden auch soziologische Fragen untersucht. Hierbei interessiert die Meinung der auf Navarino lebenden Bevölkerung. Die 2300 Seelen zählende Gemeinde setzt sich aus einer bunten Vielfalt von Menschen zusammen. Befragt wurden Jaghan-Indianer, die letzten Nachkommen der „Wassernomaden“, Militärangehörige, die in den 50er Jahren Puerto Williams als Militärbasis gründeten, Fischer, Naturschützer und Angestellte des öffentlichen Dienstes. Was wissen Sie über den Mink? Wie finden Sie ihn? Welche Bedeutung haben einheimische Arten für Sie? Was denken Sie über ein Kontrollprogramm der Mink-Population?

„Der Mink ist wie ein Elefant im Porzellanladen“, findet einer der Befragten, aber ein anderer meint: „Es scheint mir nicht ethisch, ein Tier zu töten, nur weil es exotisch ist.“ Die große Mehrheit allerdings nimmt den Mink als versteckt lebendes Tier kaum wahr. Fischer und Jaghan-Indianer schätzen den Mink aufgrund seiner Lebensweise als Räuber des Fischbestandes und der einheimischen Gänse nicht. Genauso die fünf Familien, die ihre Hühnerzucht wegen des Minks aufgeben mussten. Daher befürworten die meisten eine Kontrolle des Exoten, wenn auch mit möglichst „humanen“ Methoden, zum Beispiel Kastration.

Parallel zu Schüttlers Forschungen hat die Landwirtschaftsbehörde bereits mit der Jagd auf den Mink begonnen. Noch sind die Methoden nicht ausgereift, viele Minke gehen bislang nicht in die Falle. Doch die Forschungsergebnisse helfen, Prioritäten zu setzen. Man sollte die Fallen zunächst da einsetzen, wo sie dringend gebraucht werden. Zum Schutz der patagonischen Dampfschiffente. Langfristig kann aber nur ein sorgsam geplantes und finanzstarkes Kontroll-programm dazu beitragen, diese letzte Wildnisregion so zu erhalten, wie Darwin sie kennenlernte.“

Autorin: Elke Schüttler

Jaghan-Indianer Eugenio Calderón arbeitet als Fischer in Puerto Williams, Navarino.

APPENDIX

10/ El Magallanes, domingo 3 de diciembre de 2006

Crónica

Cabo de Hornos

Impulsan plan para controlar al visón

Un trabajo cohesionado entre representantes de organismos públicos y privados apunta a controlar la influencia del visón sobre la fauna nativa de la reserva de la biósfera Cabo de Hornos, en la Provincia Antártica.

Uno de los pasos preliminares de este accionar conjunto se concretó en un taller práctico de control del visón, realizado durante noviembre en Puerto Williams. De esta manera se quiso integrar la investigación científica con la toma de decisiones sobre los recursos naturales, a través del "Programa de difusión de la ciencia" del Instituto de Ecología y Biodiversidad (Ieb) y el Parque Omora-Umag, en conjunto con el Servicio Agrícola y Ganadero (Sag).

En el encuentro participaron investigadores de Omora-Umag, como José Tomás Ibarra y Elke Schüttler; del centro de investigación de Ushuaia Cadic, Alejandro Valenzuela; dos representantes del Sag, José Luis Cabello y Luis Llaipén; y potenciales cazadores del visón en la isla Navarino.

Con gran interés se están realizando investigaciones sobre el efecto del visón en el ecosistema de Puerto Williams.

El visón fue introducido en Tierra del Fuego en la década de los '50, como una alternativa para la actividad peletera.

Especie dañina

El visón es una especie emparentada con la nutria. Los especialistas estiman que cruzó el canal Beagle durante el año 2001 y así llegó a la reserva de la biósfera Cabo de Hornos. El roedor no es propio de esa zona, ya que fue introducido desde Norteamérica a Tierra del Fuego, a mediados de los años '50, con el objetivo de favorecer la actividad peletera y para "mejorar" el ecosistema, dada la carencia de mamíferos terrestres en el sector. Sin embargo, no se consideró el impacto negativo que este nuevo habitante tendría en el entorno. Su aparición se ha transformado en un fenómeno biológico importante, ya que se trata de un depredador de aves y roedores que ha invadido una zona en la que antes no había depredadores terrestres.

Las metas del trabajo apuntan a estudiar el impacto del visón sobre la fauna nativa (en particular las aves que acostumbran nidificar en el suelo, porque antes no tenían depredadores) y, en segundo término, al desarrollo de un plan de control de la especie, que incluya su caza.

En el taller introductorio efectuado en Puerto Williams se realizó una presentación pública de los resultados de las investigaciones sobre el tema en ambos lados del canal Beagle (Chile y Argentina), además de iniciativas de similares característica aplicadas en la región de Aisén (Undécima). También el encuentro incluyó un taller práctico de ensayo de métodos de trampeo para capacitar a cazadores.

Como los caiquenes no tenían depredadores naturales, solían nidificar en el suelo. Ahora son presa fácil de los visones.

La conclusión más relevante del taller estuvo en la importancia de aumentar la difusión de la información sobre la biología del visón y su impacto sobre la fauna. Tampoco se descarta la posibilidad de ingresos obtenidos con su caza, en el control del "Programa de control de la fauna dañina", dependiente del Sag, que cuenta con financiamiento del gobierno regional.

Con todo esto se espera que se fortalezca la cooperación entre investigadores chilenos y argentinos y funcionarios del Sag, para favorecer el intercambio de resultados, recomendaciones y el desarrollo de propuestas para establecer un programa de control del visón a largo plazo.

Fig A.1 Press release about a workshop on the control of American mink on Navarino Island integrating science and management.

Fig A.2 DVD cover of a 24 min film on the invasion of mink on Navarino Island prepared for educational purposes by the Helmholtz Centre for Environmental Research-UFZ.

Table A.3 Sampling for exotic vertebrates was conducted at forty sites on nineteen islands. The table includes the site name, island, coordinates, sampling regime and date surveyed for each study site.

Location	Island	Latitude & Longitude	Type of Sample	Date
Mount Horacio	London	54°40’28”S; 71°56’43”W	Transect	Jan and April 2004
Basket Cove	Basket	54°41’49”S, 71°35’51”W	Transect	April 2004
Courney Sound	TDF	54°37’12”S, 71°20’33”W	Transect	April 2004
Ventisquero Sound	TDF	54°46’54”S, 70°19’10”W	Transect	Jan 2004
Pía Sound	TDF	54°47’16”S; 69°37’23”W	Transect and mink trapping	Jan 2004 and May 2005
Italy Glacier	TDF	54°55’36”S, 69°14’02”W	Transect	April 2004
Olla Cove	TDF	54°56’29”S; 69°09’22”W	Transect and mink trapping	Jan 2004 and May 2005
Yendegaia Bay	TDF	54°50’S, 68°48’W	Transect, rodent and mink trapping	May 2005
Romanche Bay	Gordon	54°57’13”S; 69°29’37”W	Transect	Jan 2004 and May 2005
Group of islets off NE coast of Navarino	Holger		Transect	Jan 2004
Piedra Cove	Picton		Transect	Oct 2003
	Nueva		Helicopter flyover	May 2003
	Lennox		Helicopter flyover	May 2003
Navarino Lake	Navarino		Fishing	2004
Windhond River & Lake	Navarino		Transect, rodent trapping, fishing and mistnetting	Mar and Nov 2003
Omora Park, lower elevation areas	Navarino	54°57’S; 67°39’W	Transect, rodent and mink trapping, fishing and mistnetting	2000-2005
Omora Park, Bandera Mountain	Navarino		Transects, rodent trapping and mistnetting	2000-2005
Omora Park, Róbalo Lake	Navarino		Transect, rodent and mink trapping and mistnetting	2000-2005
Guerrico Bay and Hill	Navarino	54°54’43”S; 67°51’09”W 54°55’S; 67°54’W	Transect, rodent and mink trapping and mistnetting	2000-2005
Mejillones Bay and River	Navarino	54°57’S; 67°39’W	Transect, rodent and mink trapping, fishing and mistnetting	2000-2005

Table A.3 *continued*.

Location	Island	Latitude & Longitude	Type of Sample	Date
Lum River	Navarino		Fishing	2004
Pilushejan River	Navarino		Fishing	Mar 2002
Wulaia Bay	Navarino	55°03'S; 68°09'W	Transect, rodent trapping and mistnetting	2002 and Jan 2004
Puerto Inútil	Navarino	54°58'32"S; 68°12'49"W	Transect, rodent trapping and mistnetting	Jan 2000 and Jan 2004
Douglas Bay	Navarino	55°10'28"S; 68°06'18"W	Transect, rodent trapping, fishing and mistnetting	Jan 2000 and Jan and May 2004
14th of July Bay	Jemmy Button	55°01'25"S; 68°13'45"W	Transect, rodent trapping and mistnetting	Jan 2004
Isla Grande Bay	Hoste		Transect	May 2004
Punta San Bernardo	Hoste	55°30'05"S, 68°04'15"W	Transect	May 2004
Misiones Cove	Hoste	55°31'18"S, 68°05'49"W	Transect	May 2004
Orange Bay	Hoste	55°31'18"S; 68°05'49"W	Transect, rodent trapping and mistnetting	Jan 2004
In Ponsonby Sound	Mascart		Transect	May 2004
In Ponsonby Sound	Quemada		Transect	May 2004
Kendall Cove	Wollaston	55°45'59"S; 67°25'04"W	Transect	Jan 2004
Lientur Cove	Wollaston		Transect	May 2004
Washington Channel	Bayly	55°40'39"S; 67°35'18"W	Transect	Jan 2004
Victoria Channel	Bayly		Transect	Jan 2004
Dillon Port	Grevy		Transect	Jan 2004
Martial Cove	Herschel	55°49'23"S; 67°18'01"W	Transect and rodent trapping	Jan 2004
Saint Martin Cove	Hermite		Transect and rodent trapping	Jan 2004
Maxwell Port	Hermite		Transect and rodent trapping	Jan 2004
SE Peninsula	Cape Horn	55°57'46"S; 66°13'29"W	Transect and rodent trapping	Jan and May 2004