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Espèces végétales non-natives sur une île subantarctique chilienne : étude des perceptions des parties prenantes, modélisation des dynamiques de niches des espèces et cartographie des points chauds

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Résumé

La croissance des activités anthropiques au cours du dernier siècle a contribué à la dispersion et à l'établissement d'espèces végétales non-natives à travers le monde. Ces espèces sont des moteurs importants de changements environnementaux puisqu'elles ont la capacité de modifier les communautés végétales natives notamment à travers la compétition. Puisque les humains sont un des principaux moteurs d'introduction, d'établissement et de propagation d'espèces non-natives et que toute mesure de gestion, pour être efficace, dépend d'une acceptabilité sociale, il est nécessaire de comprendre les perceptions et les choix relatifs à leur utilisation et à leur gestion. La présente recherche a servi à : i) comprendre les perceptions des différentes parties prenantes envers les différentes espèces végétales non-natives de l'île Navarino, une zone tampon de la Réserve de la Biosphère du Cap Horn (RBCH) dans la région subantarctique chilienne ainsi qu'à ii) identifier les dynamiques de niches et les zones à haut potentiel d'établissement (i.e. points chauds) de quatre de ces espèces, qui serviront ensemble d'outils à la gestion de la RBCH. Pour répondre au premier objectif, sept groupes de parties prenantes ont été identifiés (i.e. résident-e-s, résident-e-s aîné-e-s, conservationnistes, membres de la marine, touristes, membres de la communauté autochtone yaghan, employé-e-s des services publics), à l'intérieur desquels 21 entrevues semi-dirigées ont été conduites. Pour répondre au deuxième objectif, les données de présence globales et régionales de quatre espèces végétales herbacées non-natives particulièrement abondantes i.e. *Bellis perennis*, *Cerastium fontanum*, *Taraxacum officinale* et *Trifolium repens* ainsi que les données climatiques associées ont servi à développer des modèles de distribution des espèces utilisant la méthode d'entropie maximale (MaxENT). En ce qui concerne le premier objectif, les résultats ont révélé des lacunes dans la compréhension du concept d'espèces non-natives parmi les différentes parties prenantes dans le contexte local. D'autre part, les analyses ont révélé de nombreuses valeurs positives associées aux espèces de plantes non-natives à Navarino, notamment la valeur esthétique. Aussi, cette recherche a montré que la plupart des parties prenantes étaient indifférentes à la gestion des espèces de plantes herbacées non-natives. En ce qui concerne le deuxième objectif, les résultats ont révélé un changement de niche habituellement utilisée par les espèces liée au climat moins favorable de Navarino ainsi qu'une forte plasticité pour les quatre espèces mentionnées ci-haut. Néanmoins, les quatre populations auraient atteint l'équilibre à Navarino. Finalement, la combinaison des modèles globaux et régionaux montre que les zones de points chauds se situent plus particulièrement sur la côte sud de l'île et s'étendent au Nord dépendamment des espèces. Basés sur les résultats obtenus, nous suggérons donc (i) de sensibiliser davantage les parties prenantes aux plantes non-natives, (ii) d'intégrer leurs valeurs dans les décisions de gestion futures et (iii) de surveiller les distributions des espèces végétales non-natives à Navarino à des fins de prévention en considérant l'emplacement stratégique de l'île de Navarino comme un tremplin potentiel pour la dispersion des espèces non-natives vers l'Antarctique.

Mots-clés : Espèces exotiques, perceptions, modélisation, niches, conservation, biodiversité, aires protégées, subantarctique

Abstract

The growth of human activities over the last century has contributed to the dispersal and establishment of non-native plant species around the world. These species are important drivers of environmental change since they have the capacity to modify native plant communities, especially through competition. Since human are the main drivers of introduction, establishment and spread of non-native species and since management strategies need to take into account public attitudes to be successful, it is necessary to understand the perceptions and choices regarding their use and management. The present study aimed to: i) understand the perceptions of different stakeholders towards the different non-native plant species of Navarino Island, a buffer zone of the Cape Horn Biosphere Reserve (CHBR) in the Chilean sub-Antarctic region and ii) identify niche dynamics and high potential establishment areas (i.e. hotspots) of four of these species, which together will serve as multidisciplinary tools for the CHBR management. To address the first objective, seven stakeholder groups were identified (i.e residents, elder residents, conservationists, marine members, tourists, Yaghan community members, public service employees), within which 21 semi-directed interviews were conducted. To address the second objective, global and regional occurrences of four of the most abundant species, i.e. *Bellis perennis*, *Cerastium fontanum*, *Taraxacum officinale* and *Trifolium repens* and associated climatic data were used to develop species distribution models using the maximum entropy method (MaxENT). Regarding the first objective, results of this study revealed shortcomings in the non-native concept understanding among stakeholders in a local context. On the other hand, the analyzes revealed many positive values associated with non-native plant species in Navarino, notably the aesthetic value. Nevertheless, this study showed that most stakeholders were indifferent to the management of non-native herbaceous plant species. Regarding the second objective, results revealed a niche shift usually used by species due to the less favorable climate of Navarino Island as well as high plasticity for the four plant species mentioned above. However, plant populations might have reached the equilibrium. Finally, the combination of global and regional models shows that hotspots areas are located more particularly on the south coast of the island and extend to the north depending on the species. Based on the results obtained in this study, we therefore suggest (i) increasing awareness of non-native plant among stakeholders, (ii) integrating their values into future decisions, and (iii) preventing dispersal of non-native plant species through Antarctica by monitoring species distribution on Navarino.

Keywords: Exotic species, perceptions, modelling, niche, conservation, biodiversity, protected areas, sub-Antarctic

Table des matières

Liste des tableaux

Liste des figures

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Introduction

La mondialisation, processus géo-historique d'extension progressive du capitalisme à l'échelle planétaire (Carroué, Collet & Ruiz, 2005), redéfinit actuellement les notions de territoires et d'espaces, en amenant même la substitution de ce terme par celui de *globalisation* (Dumont, 2001). Le déploiement accéléré de nouvelles dynamiques financières, culturelles, mais également écologiques à l'échelle de la planète entraîne de nouvelles problématiques mondiales (Chartier & Rodary, 2007). En effet, l'augmentation des échanges commerciaux internationaux ainsi que des transports humains contribuent notamment à un déplacement d'espèces important à travers le monde (Everett, 2000; Mullin & al. 2000). Certains milieux sont plus particulièrement vulnérables à ces espèces, notamment les milieux insulaires en raison de leur grande richesse écologique et de leur taux élevé d'endémisme (Lodge, 1993; Mueller-Dombois & Loope, 1990). L'introduction dans certains cas d'espèces non-natives pourrait changer radicalement les processus écosystémiques et influencer l'ensemble des assemblages biologiques (Vitousek, 1996; Mueller-Dombois, 1973).

On assiste, et participe, ainsi à une reconstruction du monde par les activités humaines, une période caractérisée par l'augmentation massive des émissions de gaz à effet de serre (GES) que Crutzen (2002) nommera Anthropocène. Par ailleurs, les changements climatiques induits par l'augmentation des GES pourraient affecter plus fortement les régions polaires et subpolaires ainsi que les régions insulaires (Frenot & al. 2006) et, parallèlement, une augmentation des températures pourrait favoriser l'établissement d'espèces introduites auparavant incapables de se reproduire dans un climat subantarctique (Frenot & al. 2001).

Cette imbrication des dynamiques limite alors la dissociation de l'humain et de la nature dans l'étude des phénomènes physiques et fait place à un nouvel écosystème social. On ne peut donc plus s'intéresser au milieu sans s'intéresser à l'humain qui l'occupe et qui le transforme. Ainsi, il est aujourd'hui majoritairement soutenu que la question des espèces non-natives est autant une question sociale, englobant les facteurs politiques et humains, qu'une question scientifique (Reaser, 2001). Néanmoins, bien que plusieurs études se soient penchées sur les conséquences biologiques, financières voir même sanitaires des espèces non-natives (Simberloff, 2005; Pimentel & al. 2001), peu d'études ont traité du rôle joué par le système social dans les différentes phases de la dynamique spatio-temporelle de ces dernières. Pourtant, tel que le soutiennent Udo et al. (2016, p.2) « chacune des grandes étapes du processus invasif d'une plante est profondément ancrée dans l'histoire particulière des milieux et de la société dans lesquels il s'opère, sous l'effet d'une composition inextricable d'éléments naturels et sociaux ».

À la lumière des informations présentées précédemment, ce mémoire se questionne sur l'enjeu des espèces végétales non-natives en contexte insulaire et a pour but principal d'intégrer les observations locales aux savoirs scientifiques dans une perspective multidisciplinaire. Plus précisément, le mémoire tente de répondre aux questions de recherche suivantes :

1. Comment se construisent et se façonnent les relations et interactions humains-plantes non-natives sur l'île Navarino, une île subantarctique de l'archipel du Cap Horn au Chili?
2. Comment évoluent les espèces végétales herbacées non-natives sur l'île et comment peut-on prédire leurs distributions?

Afin de répondre à ces questions de recherche, trois objectifs ont été poursuivis :

1. Déterminer la distribution actuelle des espèces végétales non-natives sur l'île Navarino.
2. Intégrer les perceptions et opinions locales associées à ces espèces.
3. Modéliser la distribution potentielle régionales et globales des espèces végétales non-natives les plus abondantes et distribuées localement.

Pour répondre aux questions de recherche et aux objectifs qui en découlent, différentes méthodes ont été préconisées. Je me suis d'abord appuyée sur une démarche conceptuelle et une revue du corpus scientifique traitant des espèces non-natives. Celle-ci a par la suite été conjuguée, en hiver 2018, à une démarche de terrain. Cette dernière s'est appuyée en premier lieu sur l'étude des perceptions des parties prenantes de l'île Navarino par le biais d'entrevues semi-dirigées avec les personnes appartenant aux différents groupes (i.e. résident-e-s, résident-e-s aîné-e-s, conservationnistes, membres de la marine, touristes, membres de la communauté autochtone yaghan, employé-e-s des services publics). Ensuite, la démarche de terrain s'est appuyée sur l'échantillonnage des espèces végétales non-natives sur l'île (Annexe 1) par le biais de transects, constituant une base de données nécessaires à la création des modèles de distribution potentielle des espèces.

Ce mémoire est divisé en trois chapitres. Le premier chapitre développe les concepts principaux cadrant l'analyse théorique du sujet et découlant de ma démarche conceptuelle. Les chapitres deux et trois sont développés sous formes d'articles et portent respectivement sur (i) la compréhension et la prise en considération des perceptions humaines quant aux espèces non-natives présentes localement et (ii) l'analyse des dynamiques de niches et la cartographie des zones de points chauds des espèces végétales non-natives sur l'île Navarino.

Chapitre 1 : Cadre conceptuel

Ce chapitre présente les principaux concepts qui ont été mobilisés dans le présent mémoire. Leur ordre dans la séquence de présentation a été sciemment choisi afin de briser les structures habituellement utilisées en sciences occidentales qui placent l'humain en dernier pan de la recherche. Bien que je ne puisse pas me défaire de mes privilèges intrinsèques à ma condition de blanche occidentale universitaire, le présent mémoire tente de défier la racialisation et la colonisation au sein des études environnementales. C'est en prenant conscience des enjeux de pouvoir et en les dénonçant que l'on contribue à la décolonisation de la science. L'humain doit être autre chose que le *post-scriptum* d'un article alimentant la bonne conscience.

1.1. Impérialisme socio-écologique

Les sciences de l'environnement ont historiquement été un espace blanc et colonial (Curnow & Helferty, 2018). Initialement, la conservation a été imbriquée dans des notions racistes, sexistes et classistes de la protection des étendues « sauvages » afin de servir le désir des hommes (n.b. comprendre ici le genre masculin) urbains et bourgeois de se projeter loin des conflits sociaux par le biais de la contemplation de paysages (Thorpe, 2011; Robic, 1992 :44). Ainsi, il importe de s'intéresser aux enjeux des aires protégées et des pratiques de conservation dans une perspective historique afin de mieux comprendre pourquoi certaines communautés locales considèrent les restrictions de gestion comme illégitimes (Wilshusen & al. 2002). En effet, la désignation d'aires protégées a conduit, et conduit encore, à la restriction d'accès des communautés locales aux ressources, au déplacement forcé des populations hors de leur territoire ancestral contribuant ainsi à une augmentation de la pauvreté ainsi qu'à une coupure culturelle et sociale (Hough, 1988 ; West, Igoe & Brockington, 2006). Longtemps, la nature telle qu'imaginée n'a pu être définie que par l'absence de l'humain et valorisée seulement à l'état « sauvage ». Cet impératif d'accroissement de la naturalité imprègnera la plupart des discours sur la conservation (Warren, 2007) et sera renforcé par la création des Réserves de la Biosphères, un concept développé par l'UNESCO en 1970 et reposant sur un zonage strict, comprenant un noyau entièrement protégé ainsi qu'une zone tampon environnante où n'est autorisé qu'une seule activité économique appropriée (Adams & Hutton, 2007). Les aires protégées et les réserves ont été largement critiquées, notamment sur les arguments intrinsèques menant à leur création, soutenant qu'elles sont en fait les instruments de projets politiques beaucoup plus vastes tels que le nationalisme, le colonialisme et le capitalisme et que leurs pratiques de conservation, qu'elles soient élaborées au sein de gouvernements ou d'ONG, sont structurées par rapport à des objectifs politiques plus larges, à plus long terme (Brockington & Duffy ; Holmes, 2015 ; MacDonald, 2010). Aussi, selon Balmford & Whitten (2003), les aires protégées génèrent également une injustice économique réelle sachant que leurs coûts naissent principalement localement, tandis que leurs avantages sont perçus globalement.

Ces préoccupations ont mené à un nouveau paradigme participatif dans la pratique de la gestion de la biodiversité (Reed, 2008) visant à intégrer mieux les différents groupes sociaux et partant du principe que si les communautés locales tirent des avantages de la conservation, elles seront plus susceptibles de contribuer à la conservation de la biodiversité (Brandon & Wells, 1992). Depuis les dernières années, la « cogestion adaptative » est donc devenue l'approche acceptée, voire même préférentielle, de gestion de la biodiversité en sciences occidentales (Nadasdy, 2005). La cogestion adaptative tente d'intégrer la participation de parties prenantes possédant différents types de connaissances écosystémiques (connaissances scientifiques, expérientielles, locales, traditionnelles et autochtones) et travaillant à différentes échelles écologiques (Charles, 2007). Oldekop et al. (2016, p.133) ont d'ailleurs fait l'évaluation globale des résultats sociaux et de conservation de 165 aires protégées (PA) et ont conclu que des « positive conservation and socioeconomic outcomes were more likely to occur when PAs adopted comanagement regimes, empowered local people, reduced economic inequalities, and maintained cultural and livelihood benefits ». Toutefois, plusieurs critiques ont été formulées à l'égard de ce type de gestion qui est susceptible d'utiliser les stéréotypes de « bon sauvage » ou encore de « l'indien écologique » en ignorant les processus complexes à l'intérieur des communautés locales (Agrawal & Gibson, 1999 ; Harkin & Lewis, 2007 ; Redford et al. 1998). En effet, les mouvements environnementaux ont souvent utilisé les peuples autochtones comme accessoires plutôt que comme partenaires (Curnow & Helferty, 2018). Wilshusen et al. (2002) rappellent d'ailleurs que les « sociétés traditionnelles » n'étant pas intrinsèquement « conservatrices naturelles » ne devraient en aucun cas limiter l'utilisation de stratégies participatives comme outil de gestion.

Les relations entre les individus, les sociétés, l'espace et les écosystèmes qui les soutiennent sont complexes et évoluent. Leur étude nécessite des approches inclusives et multidisciplinaires afin de mieux les comprendre. Le présent mémoire vise à mobiliser les concepts décris ci-haut afin de procéder à une étude inclusive des parties prenantes et de leurs perceptions vis-à-vis des plantes non-natives en contexte d'aire protégée afin de dégager des stratégies de gestion des zones protégées éventuelles de Navarino qui intègrent les aspects sociaux et écologiques.

1.2. Géographie des perceptions

Le succès de la conservation est grandement déterminé par le soutien local, lui-même fortement influencé par la perception des impacts sur les communautés locales et par les opinions sur la gestion et la gouvernance (Bennett & Dearden, 2014). Il est donc primordial que les perceptions de la communauté des impacts découlant de la conservation soient examinées afin que les processus de conservation puissent être adaptés et les résultats améliorés.

La perception est la fonction par laquelle une personne se représente des objets en leur présence (Grawitz, 1994) et constitue l'étape intermédiaire entre ceux-ci et leur représentation (Piaget & Inhelder, 1948). Elle permet donc de classifier un objet afin qu'il puisse être plus tard représenté, c'est-à-dire être évoqué sans qu'il ne soit perceptible (Auray et al., 1994). La représentation se présente ainsi comme un ensemble de valeurs (e.g. des croyances fondamentales), d'émotions qui résultent de l'expérience avec l'objet, mais également, qui détermine la relation et les attitudes de la personne avec ce dernier (Rokeach, 1973; Sauvé & Machabée, 2000). Les valeurs fournissent en ce sens des repères de jugement et permettent d'établir et de justifier des choix et prises de position (Mulkay, 2006). Berdoulay (1974, p. 187) avance ainsi que

> « Puisque la perception est à la fois une partie et une condition de la cognition, puisqu'elle relève de structures organiques héréditaires, de l'organisation immédiate de données sensorielles et de l'apprentissage, force est de considérer la perception comme un ensemble de processus constituant un nœud dans un réseau de relations animant l'individu, son comportement et son environnement ».

En ce sens, la géographie de la perception vise à s'interroger sur le « *sense of place* », le sentiment éprouvé pour des lieux, pour ce qui est spécifique à chacun (Claval, 1974).

La façon dont l'espace est représenté globalement (« sense of place ») a évolué de manière importante au cours des dernières décennies (Paulet, 2002). Loin d'être objectif, l'espace est qualifié par les valeurs qui lui sont conférées et qui lui donnent un sens (Cottet, 2013) et porte également les marques des codes culturels et des idéologies propres aux groupes sociaux auxquels appartiennent les sujets (Di Méo, 1998; Gilbert, 1986). En effet, si ces valeurs sont individuelles, elles possèdent aussi une composante collective (Cottet, 2013).

La prise en compte des perceptions et valeurs associées à la « nature » qu'ont les différentes parties prenantes qui interviennent dans la gestion des aires protégées et plus généralement des écosystèmes, tels que les conservationnistes, scientifiques, les résident-e-s ainsi que les touristes est particulièrement pertinente lors de toute initiative visant la gestion durable des ressources naturelles, la conservation de la biodiversité ou l'adaptation et l'atténuation des changements environnementaux (Vedwan, 2006; Weber, 2010). Non seulement apparaît-elle comme un moyen nécessaire pour lutter contre l'exclusion et favoriser un espace ouvert à la prise de parole dans un contexte de changements socio-environnementaux, mais elle peut aussi améliorer la compréhension des changements environnementaux et de leurs impacts sur les systèmes socio-écologiques (Pyhälä et al. 2016). Enfin, les perceptions déterminent les attitudes et sont donc un élément clé dans le développement de stratégies qui conviennent aux réalités locales (Patt et Weber 2014).

Le présent mémoire souscrit à ce courant cherchant à mieux comprendre la place qu'occupe les plantes non-natives dans l'univers émotif des parties prenantes de l'île Navarino et vise ainsi, par ses démarches, à approfondir le corpus littéraire de la géographie des perceptions.

1.3. Changements socio-environnementaux

Les activités humaines et les changements globaux que celles-ci amènent au système terrestre sont multiples, complexes et en interaction (Steffen et al. 2004). Bien qu'un nombre croissant de recherches fournisse une perspective sur la relation multiforme entre l'humain et le milieu naturel, le clivage entre les domaines « sociaux » et « physiques » persiste et rend l'applicabilité de solutions concrètes parfois difficiles (Hornborg & Crumley, 2007). Plus récemment, Sharp et Leshner (2014) ont fait appel à une science plus convergente intégrant des connaissances issues des sciences de la vie, des sciences sociales, physiques, économiques ainsi que de l'ingénierie. De nouveaux modèles de système-terre qui intègrent les actions et les réponses humaines aux changements environnementaux sont ainsi nécessaires et rendra la recherche sur les changements globaux plus pertinente pour les politiques d'atténuation et d'adaptation (Castree, 2015). On parle ainsi maintenant de « socioécosystèmes » (Berkes & Folke, 2000) dans lesquels s'observent des changements à la fois environnementaux, mais également sociaux qui ne peuvent plus être regardés comme des processus séparés (Folke, 2006).

Depuis quelques années, Navarino fait face à plusieurs changements socio-environnementaux, dont la croissance exponentielle de l'industrie du tourisme grâce aux navires de croisière (García, 2004), la construction de nouvelles routes et infrastructures (Sernatur, 2014) ainsi que la dispersion du castor d'Amérique (*Castor canadensis*) non-natif à travers l'île (Anderson et al. 2006).

1.3.1. Espèces non-natives: au cœur d'un débat polarisé

Les espèces non-natives sont des bons exemples, à la fois de résultantes de changements socio-environnementaux (e.g. augmentation de la mobilité), mais également de vecteurs de changements socio-environnementaux (e.g. modification des assemblages biologiques) (Hulme, 2009). Ainsi, la question des espèces non-natives est reconnue aujourd'hui dans les débats sur les changements environnementaux comme autant une question sociale qui englobe des facteurs politiques et humains, qu'une question strictement biologique (Reaser, 2001). Néanmoins, cette interconnexion a renforcé la polarisation de certains aspects fondamentaux et conceptuels des espèces non-natives. En effet, bien que la classification des espèces comme « natives » ou « non-natives » soit l'un des principes organisateurs de la conservation, la validité de ce dualisme est de plus en plus remise en question, suscitant des débats sur les concepts de lieu, d'espace, de nature et des interactions Humains-nature (Warren, 2007 ; également, voir Chapitre 2, section 1). Bien que plusieurs études aient proposé des définitions s'appuyant sur des principes géographiques (Richardson et al. 2000), biologiques (Colautti & MacIsaac, 2004) voire même philosophiques (Larson, 2011), les désaccords persistent.

Également, l'existence d'un grand nombre de terminologies utilisées, parfois de manière interchangeable, dans la littérature pour nommer une espèce non-native (e.g. : invasive, exotique, introduite, naturalisée) accentue la confusion autour du concept (Valéry et al. 2008). Par exemple, si au sein des ONG et des organismes gouvernementaux, une espèce non-native est dite « invasive » (ou « envahissante ») lorsqu'elle produit des impacts environnementaux ou socio-économiques négatifs, plusieurs études renvoient plutôt le terme « invasif » a une espèce ayant la capacité de se disperser et coloniser sans toutefois posséder le critère d'impact (Ricciardi & Cohen, 2007).

Dans le présent mémoire, le terme « non-native » sera utilisée pour référer à une espèce introduite par le biais de l'humain dans un nouvel environnement tandis que le terme « espèce à potentiel invasif » sera utilisé pour référer à une espèce non-native qui pourrait potentiellement se disperser et s'étendre de manière importante dans son nouvel environnement.

Le choix d'un langage le plus près de la neutralité possible contribue à déjouer les enjeux de pouvoir au sein des « Western sciences ». En effet, il est important de souligner la partialité du champ lexical appartenant aux espèces non-natives, notamment par l'utilisation de dichotomies fortes telles que : native-invasive, pur-contaminé, inoffensif-nuisible, naturel-dégradé et diversité-homogénéité (McNeely, 2001 ; Hattingh, 2001). En plus de conduire à une perception inexacte des espèces, l'utilisation d'un langage basé sur la peur ou sur la violence pour caractériser les espèces non-natives génère des malentendus et crée de la confusion vis-à-vis des espèces (Larson, 2005).

Dans la littérature scientifique, un nombre élevé d'études emploient inexorablement la formule « invasive alien species are a major threat to global biodiversity » (voir p.ex. Chornesky & Randall, 2003 ; Early et al. 2016; Mullin et al. 2000). S'il est vrai que plusieurs espèces non-natives interagissent négativement avec les espèces natives d'une communauté donnée, la majorité des espèces introduites n'ont peu ou pas d'effet sur leur environnement (Hulme, 2012). En ce sens, l'étude des traits permettant de prédire la survie, la dispersion et la propagation d'une espèce introduite dans un nouvel environnement a été au centre des études sur les « invasions biologiques » (Kleunen, Weber & Fischer, 2010). Tandis qu'il n'a pas été possible de dégager un profil-type applicable à toutes les espèces non-natives à potentiel invasif, des comparaisons interspécifiques ont permis de dégager quelques caractéristiques des plantes à potentiel invasif tels que de bonnes capacités de reproduction et de dispersion, un potentiel évolutif, une large distribution géographique et une forte abondance dans la zone native (Firn & al. 2011; Hayes & Barry, 2008; Richardson & Pyšek, 2006; Kolar & Lodge, 2001).

Néanmoins, plusieurs études relèvent la possibilité que le succès d'une espèce à s'établir, se disperser et s'étendre dépende plutôt de la correspondance entre des facteurs écologiques et évolutifs liés à l'espèce ainsi qu'à son environnement récepteur (Facon & al. 2006; Alpert, Bone & Holzapfel, 2000). En effet, plusieurs caractéristiques abiotiques semblent faciliter l'introduction, l'établissement et la dispersion d'espèces telles que la perturbation de l'environnement, la disponibilité en ressources, l'absence d'ennemis naturels (maladies, parasites et prédateurs) et un faible niveau de stress environnemental (Lake & Leishman, 2004; Alpert & al. 2000; Rejmanek, 1989). Ainsi, les espèces non-natives sont retrouvées plus particulièrement dans les milieux ouverts ou urbanisés, puisqu'il a été démontré que les activités humaines sont susceptibles de générer des opportunités d'installation en diminuant notamment les pressions de prédation, la concurrence et le parasitisme (Mooney & Cleland, 2001). Plusieurs études soutiennent également que les milieux insulaires, et plus particulièrement les îles subantarctiques, sont plus vulnérables vis-à-vis l'introduction d'espèces non-natives, notamment en raison de leur taux élevé d'endémisme (Rozzi & al. 2004; Lodge, 1993; Holdgate & Wace, 1961).

1.3.2. Changements socio-environnementaux dans les régions polaires et subpolaires

1.3.2.1. Climat

Certains des changements climatiques les plus importants sur Terre sont projetés pour les environnements polaires et subpolaires de hautes latitudes au cours des prochaines décennies (IPCC, 2014 ; Lee et al. 2017 ; Rintoul et al. 2018). Au cours des cinquante dernières années, des augmentations de température parmi les plus rapides au monde ont été enregistrées le long de la péninsule antarctique occidentale et des archipels insulaires associés (King et al. 2013 ; Vaughan et al. 2003). Des tendances au réchauffement ont également été observées dans plusieurs îles subantarctiques (Frenot, Gloaguen & Tréhen, 1997 ; Smith, 2002). En plus des hausses de température, des changements au niveau des précipitations ont également été documentés. Les caractéristiques des précipitations dépendent de diverses variables environnementales telles que la couverture nuageuse, la vitesse du vent et la température, particulièrement à l'échelle microclimatique (Convey, 2006) rendant ainsi difficile la détermination d'un patron général pour les régions polaires et subpolaires. En effet, une augmentation générale des précipitations a été prédite et observée dans la zone côtière antarctique (Turner, Colwell & Harangozo, 2012), tandis qu'une diminution des précipitations est évidente dans certaines parties de l'Antarctique (Chapuis, Frenot & Lebouvier, 2004 ; Chown & Smith, 1993). Bien que les introductions d'espèces non-natives ne soient pas liées directement au changement climatique, l'augmentation de la température pourrait faciliter la survie et réduire les obstacles au processus d'établissement (Frenot et al. 2005). En effet, le réchauffement climatique pourrait contribuer à l'expansion considérable des zones libres de glace en Antarctique, permettant à certaines espèces de s'étendre et même de franchir les anciennes divisions biogéographiques autrefois séparées par les glaces (Lee & al. 2017).

Dans le cadre de ce mémoire, la modélisation a été utilisée pour obtenir des données sur les niches potentielles qu'une espèce non-native peut occuper spécifiquement sur l'île subantarctique de Navarino en fonction de ses exigences climatiques.

1.3.2.2. Activités économiques

Depuis le début du XXe siècle, le paysage subantarctique a été transformé par l'humain, notamment par l'établissement de fermes qui ont contribué à l'introduction de nombreuses espèces herbacées pour la création de pâturages (Convey & Lebouvier, 2009 ; Rozzi, Charlin, Ippi & Dollenz, 2004). En plus de l'introduction intentionnelle, il a été démontré que le bétail sauvage tel que les chevaux (*Equus ferus caballus*) et les vaches (*Bos taurus*) ont le potentiel de disperser de grandes quantités de graines dans tout le paysage (Bartuszevige & Endress, 2008) en plus de contribuer à la création d'un sol à nu, facilitant l'établissement de plantes non-natives, ce qu'il est possible d'observer à Navarino (Valenzuela et al. 2014).

Outre l'élevage, c'est le tourisme qui est l'activité ayant connu la plus forte croissance dans la région subantarctique depuis son début dans les années 1960 (Frenot et al. 2005). Un nombre croissant de voyageuses et voyageurs s'intéressent en effet à visiter des endroits naturels qui restent « intouchés » (Hall & Wouters, 1994). Selon Hall (2015), le tourisme est maintenant reconnu comme étant profondément enraciné dans les processus de changements environnementaux globaux. En effet, il est d'ailleurs considéré comme l'un des plus grands vecteurs de déplacement et d'introduction d'espèces non-natives à travers le monde (Anderson, 2015). Aussi, l'industrie du tourisme contribue à la transformation du paysage, notamment par le développement d'infrastructures et de routes (Terkenli, 2004). Dans la région subantarctique chilienne, la croissance exponentielle du tourisme grâce aux navires de croisière dans des zones auparavant restreintes par la marine a entraîné un nombre croissant de touristes débarquant sur des îles inhabitées ainsi qu'un tourisme non réglementé dans des zones protégées, dépourvu d'informations, d'infrastructures et de guides (Rozzi et al. 2012). Également, des plans de développement sont en cours à Navarino, afin de construire des quais pour les paquebots de croisière, d'agrandir la piste d'atterrissage ainsi que le réseau routier pour stimuler l'économie locale (Sernatur, 2014), ce qui pourrait faciliter un transfert des espèces non-natives à travers l'île Navarino, mais également à travers tout le Cap Horn et l'Antarctique.

Plus récemment, dans les zones côtières de la Patagonie du sud, zone d'étude du présent mémoire, l'industrie de l'aquaculture intensive salmonicole est en expansion depuis la dernière décennie, car les mers intérieures, fjords et chenaux offrent des conditions environnementales idéales pour leur élevage (Soto & Norambuena, 2004). Néanmoins, il est bien établi que les déchets inorganiques dissous des fermes salmonicoles améliorent la croissance des algues, ce qui entraîne leur prolifération, pouvant par ailleurs avoir des effets encore mal compris sur le réseau trophique (Buschmann et al. 2006). De plus, ces choix politiques contreviennent avec les principales activités économiques de la région, soit la pêche artisanale, l'élevage à petite échelle ainsi que le tourisme (Schüttler et al. 2019). Bien que le présent mémoire ne se concentre pas sur l'environnement marin, une vision écosystémique, globale et intégrée des changements socio-environnementaux est pertinente pour en comprendre les dynamiques, particulièrement lorsque les activités économiques créent des conflits au sein des parties prenantes.

Chapitre 2: Public perceptions of non-native plant species on a Chilean sub-Antarctic island

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Abstract

Humans are the main drivers of the introduction, establishment and spread of non-native species worldwide but they have generally been excluded from management. Nevertheless, the social component of non-native species is now increasingly considered. In this paper, we investigated understanding, perceptions and attitudes towards management of non-native herbaceous plant species on Navarino, a remote Chilean sub-Antarctic island. Overall, our study showed a general understanding of the non-native species concept among the interviewees but revealed a lack of consciousness regarding non-native plants species in the local context. Interestingly, our study also revealed many positive values associated with non-native plants species on Navarino, among which the aesthetic value was the most highlighted. Whilst some non-native plants were strictly associated with positive values e.g. common daisy (*Bellis perennis*) and white clover (*Trifolium repens*), most species were associated with conflicting values. As a key result, our study lastly showed that most interviewees were indifferent about the management of the non-native herbaceous plant species. We therefore suggest (i) increasing the awareness of stakeholders with respect to non-native plants, (ii) incorporating stakeholder's values into future management decisions and (iii) considering the strategic location of Navarino Island as a potential stepping stone for the dispersion of non-native plants species towards the Antarctic.

Keywords: biological invasions; co-management; community; protected areas; subpolar regions; values

2.1. Introduction

The worldwide increase in commercial trade, transport, travel and tourism in recent years has contributed to the displacement of plant species around the world, some of which have successfully established in areas where they were formerly absent (Perrings, Mooney & Williamson, 2010; Westphal, Bowne, MacKinnon & Noble, 2008). Non-native plant species are key drivers of environmental changes since they might interact with native plant communities through competition (Pyšek et al. 2012; Vilà, Williamson & Lonsdale, 2004), alter pollination services (Vanbergen, Espíndola & Aizen, 2018), influence the soil nutrient cycle (Ehrenfeld, 2003), modify ecosystem carbon and nitrogen cycles (Liao et al. 2008) as well as change public perceptions of landscapes (Binimelis, Born, Monterroso & Rodríguez-Labajos, 2007).

Consequently, attempts to preserve nature and 'nativeness' from non-native plant species have traditionally focused on their eradication (Mack & Foster, 2009) which reinforced the idea that nature should remain pristine and separated from humans (Berghöfer, Rozzi & Jax, 2010). In addition to supporting a "bioxenophobic discourse" (Warren, 2007, p. 435), these policies of "strict-indigenism" contributed to a global depreciation of non-native species (Green, 2002; Kendle & Rose, 2000). Thus, the preferred typology to refer to non-native species often implied a negative meaning, e.g. "invasive", "weed", "alien", "pest", "disaster", "threat" (Colautti & MacIsaac, 2004; Chew & Laubichler, 2003; Early et al. 2016).

Although many studies on non-native species appear biased toward negative impacts and discourses (Colautti & MacIsaac, 2004; Pyšek et al., 2012), various of these species are also known to provide valuable benefits, e.g. aestheticism (Lindemann-Matthies, 2016), food supply (Shackleton et al. 2007) or medicinal remedies (Rao, Sagar & Sathyanarayana, 2012) which can contribute to their valorization. Nevertheless, when the benefits of a species are compared to the potential of the species to generate significant negative impacts, conflicts of interest often arise between stakeholders (Potgieter, Gaertner, O'Farrell & Richardson, 2019).

Therefore, a growing number of conservation practitioners, decision-makers and researchers recognize that non-native species management is as much a social issue as a scientific one (Novoa, Dehnen-Schmutz, Fried & Vimercati, 2017; Reaser, 2001; Stokes & al. 2006). As humans are the main drivers of the introduction, establishment, and spread of non-native species, it is necessary to understand perceptions and choices regarding their use and management (Bardsley & Edwards-Jones, 2006).

In recent years, an increasing effort to study public attitudes toward non-native species have been observed, but most of them employed either quantitative (e.g. Andreu, Vila & Hulme, 2009; Bremner & Park, 2007; García-Llorente, Martín-López, González, Alcorlo & Montes, 2008) or economic (e.g. Marshall, Friedel, van Klinken & Grice, 2011; Oreska & Aldridge, 2011) approaches. Moreover, studies on perception of non-native species have been largely animal-oriented (e.g. Aguirre-Muñoz et al. 2011; Cerri, Ferretti & Tricarico, 2016; Fleming & Bateman, 2016; Kapitza, Zimmermann, Martín-López & Wehrden, 2019; Schüttler, Rozzi & Jax, 2011). Instead, this study aims to improve our understanding of public perceptions on non-native herbaceous plant species, using the case of Navarino, a remote sub-Antarctic island of Chile, where, to our knowledge, no research of this kind has been carried out before.

To achieve this goal, we used a qualitative approach with semi-structured face-to-face interviews with members of different socio-cultural groups of Navarino Island. In the absence of biological data, we aimed to explore (1) conceptualization and knowledge, (2) values and (3) attitudes towards management of non-native plant species of the island.

Ultimately, this paper contributes to partly fill the knowledge gap on public perceptions of non-native herbaceous plant species and to provide important information for conservation managers. This is particularly relevant in face of a growing tourism and the national economic interests set in the region (Sernatur, 2014) that will likely contribute to the introduction of new and dispersion of existing non-native plant species. Lastly, this sub-Antarctic island represents a stepping stone between the South American continent and Antarctica and is therefore of particular interest for conservation efforts (Rozzi et al. 2007).

2.2. Materials and methods

2.2.1. Local setting

The study was carried out on Navarino (fig.1) a Chilean island (55 º S) located at the southern tip of the Tierra del Fuego region and within the Cape Horn Biosphere Reserve (CHBR). The vegetation of the region is composed of southern breech (*Nothofagus* spp.)

evergreen and deciduous forest, treeless Patagonian steppe dominated by fescues (*Festuca* spp.), low shrubs and hard-cushion species and Magellanic moorlands, a matrix of peatlands that include cushion bogs (Arroyo, Riveros, Peñaloza, Cavieres & Faggi, 1996; Godley, 1960; Pisano, 1981). The climate is dominated by its surrounding oceans and by permanent westerly winds that create a continuous stress factor for plant life throughout the area (Molina, Lumbreras, Benavent-González, Rozzi & Sancho, 2016).

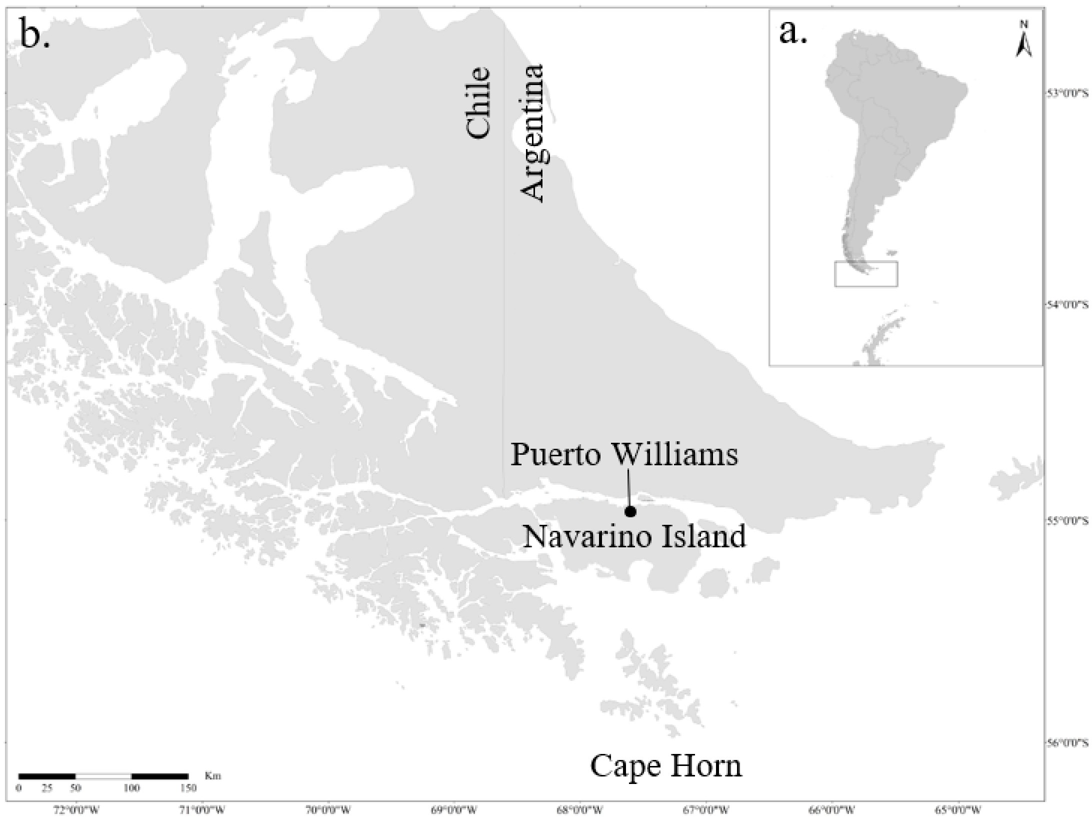

Figure 1. a. South America and Antarctica with focus on study site at the southern tip of Chile; b. Sub-Antarctic Navarino Island with Puerto Williams as the capital of the Chilean Antarctic Province.

The earliest records of non-native plants species in Tierra del Fuego date back to 1882, thirteen years after the first resident Europeans arrived, but there is evidence that some may have arrived earlier (Moore & Goodall, 1977). No such early records have been established specifically for Navarino, however the establishments of farms on Navarino in the early twentieth century contributed to the introduction of many herbaceous species for the creation of grazing meadows e.g. yorkshire fog (*Holcus lanatus*) and cock's-foot (*Dactylis glomerata*) (Rozzi, Charlin, Ippi & Dollenz, 2004). Currently, several species of non-native plants are found on Navarino Island, including the dandelion (*Taraxacum officinale*) and the sheep sorrel (*Rumex acetosella*), two species that are in the most distributed throughout the world (Frenot et al. 2005).

Since even widespread non-native species may have negligible effects (Hulme, 2012) and because most of the impacts from non-native species are context-dependent (Bartz & Kowarik, 2019), it cannot be alleged that these species will necessarily have an impact on Navarino. Nevertheless, as Simberloff et al. (2013) mentioned: "certain extremely consequential impacts, particularly at the ecosystem level, are not readily detected", which reinforces the need for a long-term monitoring of non-native species on Navarino island where little data on non-native plants are available.

Puerto Williams, capital of the Chilean Antarctic Province and located on Navarino Island, is the largest settlement in the CHBR with approximately 2 200 residents. The settlement includes the indigenous Yaghan community, the rotating personnel of the Chilean Navy, fishermen, public employees, and temporary residents (Berghöfer et al. 2010). The principal economic activities on Navarino are fishing, tourism, and small-scale livestock farming.

2.2.2. Data collection

A total of 21 semi-structured face-to-face interviews were carried out between December 2017 and March 2018 in Puerto Williams. The 21 participants were selected based on their belonging to the different targeted groups, namely: (i) Chilean navy members, (ii) indigenous Yaghan people, (iii) public services employees, (iv) civil residents of Puerto Williams, (v) elder residents who arrived before 1960 to Navarino, (vi) conservation practitioners and (vii) tourists. We interviewed three participants per group, totaling 7 women and 14 men. While it is true that a difference of status between the investigated groups (i.e., gender, ages, educational standard) may result in differences of non-native species perception (Bremner and Park 2007), our purpose here, based on an explorative methodology, was to assure to sample every group, independently from the individual characteristics. We used random sampling for tourists and snow-ball sampling for residents, elder residents, Yaghan people and Chilean navy members (see Atkinson & Flint, 2004). Interviews were conducted in Spanish or English, when the latter was the native language of the participant, and lasted between 20-90 min. The structure of the interviews was based on three main themes, namely (1) conceptualization, understanding and observations, (2) perceptions and values and (3) perception of management of non-native plant species (Table 1).

When we addressed the first theme, respondents were shown photographs of the non-native plant species present on Navarino (full list in Appendix 2) with their Latin and Spanish names and were asked to mention whether they had seen them on the island.

Table 1. Interview canvas on perceptions of participants of Navarino Island, southern Chile, towards non-native plant species, based on three main themes

Theme 1. General knowledge on non-native herbaceous plant species
How would you define an exotic species?
Can you name some exotic plant species present in Navarino?
To your knowledge, what are the reasons why these species have arrived here?
Do you know any potential impacts of exotic plant species?
Are you sufficiently informed about exotic plants?
Theme 2. Values associated with non-native herbaceous plant species
Between the exotic plants found in Navarino and showed in these photographs, which ones do you particularly appreciate and why?
Between the exotic plants found in Navarino and showed in these photographs, which ones do you like less and why?
Can you estimate the quantity in Navarino of each exotic plant that you recognize on these photographs (few, medium, many)?
Theme 3. Control of non-native herbaceous plant species
Have you ever tried to control/eradicate some of these plants in Navarino?
What would be the best way to prevent the introduction of other exotic plant species on the island?

2.2.3. Ethics

We obtained prior informed consent from each participant. We used written consent for public services employees and for conservation-practitioners and used verbal consent for the other groups described above. For each participant, we explained the project aims, the lack of risks in participating, the possibility of not answering to some questions, the information regarding the use and access of the results, and the anonymous and voluntary nature of their participation. We obtained ethics certificates from the Scientific Ethical Committee of the

University of Magallanes, Chile, and from the Ethics Committee for Arts and Science Research of the University of Montréal, Canada (CERAS-2016-17-203-D) (Appendix 3-4).

2.2.4. Data analysis

The interviews were digitally recorded and subsequently transcribed by a native Spanish speaker. We used a general inductive approach to content analysis which deduce categories from textual data (Bryman & Burgess, 2002; Hsieh & Shannon, 2005; Marying & Fenzl, 2014). We included information from across the whole interview into the coding procedure of our three main themes. After the exploration of the data, we searched for theories that matched our categories. Values toward non-native plants species found through the interviews were derived and classified according to a typology that we adapted for the local context from Alessa, Kliskey & Brown (2008) and Kellert (1996) presented in Table 2.

Table 2. Typology of values towards non-native plant species derived from the 21 interviews made with participants of Navarino Island, southern Chile and adapted from Alessa et al. (2008) and Kellert (1996) for the local context.

Values	Definition
Utilitarian	Species provide food and material to sustain people's lives Species can be exploited
Aesthetic	Species are attractive
Biological	Species provide places for other organisms Species have ecosystemic functions
Philosophical	Species are valued just because they exist Species deserve ethical relations
Negativistic	Species must be mastered and controlled Species are avoided because of fear or aversion
Indifference	Species bring no interest or concern

We employed the aesthetic value from both Alessa et al. and Kellert and we combined the subsidence value from Alessa et al. with the utilitarian value from Kellert. Additionally, we combined the biological and the life sustaining values from Alessa et al. and the ecological/scientific values from Kellert into one biological value. We also separated the indifference value initially combined into the negativistic value into two distinct values. Finally, a philosophical value was derived from the intrinsic value of Alessa et al. and from the moralistic value of Kellert.

2.3. Results

2.3.1. Conceptualization, knowledge and local observations

We first asked participants about their concept of the native/non-native framework in general. Many participants mentioned the North American beaver and the American mink (*Neovison vison*) as non-native species they knew, which have both colonized Navarino Island at different times. Also, more than half of the participants could describe a non-native species as “a species not from here”. However, about one third were not familiar with the framework, and classified, for example, native plants e.g. Lenga beech (*Nothofagus pumilio*) and Calafate (*Berberis microphylla*) as non-native. Nevertheless, half of the interviewees accurately named examples of non-native plants species they had seen before on Navarino before seeing the photographs, the most mentioned species being the common daisy (*Bellis perennis*) and the dandelion: “*I saw dandelions. They are everywhere. Walking to Williams and out”* (civil resident #2). Among the stakeholder groups who could cite examples, most came from conservation practitioners and civil residents. Interviewees were also asked to name factors related to the arrival and spread of non-native plants and about half said that humans were the main vector. Some specified further by pointing out that horticultural practices such as gardening: “*Residents bring in species from elsewhere, buying seeds and planting them in their gardens*” (civil resident #3), multiple movements from tourism: “*I presume it comes from the Europeans... The boats, the seeds under their feet ...*” (tourist #1) and colonization: “*colonization brought in many exotic plant species*” (Yaghan #3) were also important vectors of arrival and spread of non-native plants. Few participants also mentioned zoochory as a cause of arrival and dispersal: “*Plant dispersal may be related to birds when they eat the plants and disperse the seeds*” (Yaghan #3) and one participant mentioned wind as a natural factor of seed dispersion.

Participants were then asked if they knew potential impacts of non-native plants. Few participants could name examples, but when they could, the impact mentioned was generally "*a possible harm to the local flora*" (conservation practitioner #1). Nevertheless, tourists elaborated more on the potential impacts: "*The aggressiveness for the ecological niche could tip the balance in that type of ecosystem*" (tourist #2); "*They do things like beavers. If they do not have natural predators, or if the conditions are better than their normal habitat, they expand and everything else dies then*" (tourist #3). Some participants contrariwise argued that non-native plant species had no negative impacts on the environment: "*Each plant has its own space … It does not affect the other ones*" (Chilean navy member #1); "*I do not think that exotic plants have any influence in my sector, the forestry sector*" (conservation practitioner #3). On the other hand, one participant showed a clear interest in better understanding the potential impacts: "*I do not know if these plants occupy a large part of the island, if they cause harm to native plants or if they spread and I would like you to tell me*" (civil resident #2).

When presenting the photographs, the most frequently recognized species were the dandelion, the white clover (*Trifolium repens*), the common daisy, the common nettle (*Urtica dioica*) and the curly dock (*Rumex crispus*). For each recognized species, interviewees were asked their perception of its abundance (e.g. few, a lot) and were asked to name places where they had seen it on Navarino Island. Among all species, participants classified four species as "very abundant", namely the common daisy, the dandelion, the white clover and the curly dock (fig. 2). Regarding the spatial location of non-native plants, interviewees observed them mostly in human-impacted areas within Puerto Williams and in near vicinity of roads, the airport, farms, hiking trails, the Omora Ethnobotanical Park (a research, education and conservation center for the Cape Horn Biosphere Reserve), landfill, houses and gardens. Some participants also observed more specifically non-native species on shell middens, defined as cultural deposits of which the principal visible constituent is shell of mollusks and other invertebrates (Waselkov, 1987). Shell middens in Tierra del Fuego are archaeological remnants of the previous Yaghan presence and form, in coastal areas, a ring of intentional accumulations of shellfish food-waste around the presumably former hut (García-Piquer & Estévez-Escalera, 2018; Orquera & Piana, 2009). Very few interviewees mentioned areas not directly accessible by car or boat.

a. b. c. d.

Figure 2. Photographs of the four non-native plant species classified as "very abundant" by most of participants of Navarino Island: a. common daisy (*Bellis perennis*), b. dandelion (*Taraxacum officinale*), c. white clover (*Trifolium repens*) and d. curly dock (*Rumex crispus*)

2.3.2. Values attributed to species

2.3.2.1. Utilitarian value

A wide range of uses has been associated with non-native plant species by the interviewees (Table 3). An elder resident even told us that all plants could be used in one way or another. Uses were mentioned by the participants when the photographs of the non-native plant species were shown to them. Species with the greatest number of uses were the dandelion, the common nettle and the curly dock. Groups reporting the highest number of uses were elder residents of Puerto Williams, Yaghan people and conservation practitioners. One of the Yaghans interviewed mentioned that, in her memory, she had always seen and used dandelion: "*I have always been taught that the milk is used for injuries. I do not remember a time without* *dandelions*" (Yaghan #1). The perception of a higher utilitarian value of non-native plants as ornaments versus native plants was reported by a civil resident (#3): "*We had a brainstorming session on environmental issues in the community's environmental committee and one of the things I mentioned was promoting the use of native plants for our gardens, but they told me native plants are not useful for gardens since they take 30 years to grow*".

Table 3. Participant's reported uses of non-native plant species showed on photographs during the qualitative interviews made on Navarino Island, southern Chile.

Non-native plant	**Scientific name**	**Reported uses**
Broadleaf plantain	*Plantago major*	Medicinal properties
Common nettle	*Urtica dioica*	Remedies; Expectorant; Fever; Hair
Curly dock	*Rumex crispus*	Injuries; Tonsillitis; Burns
Dandelion	*Taraxacum officinale*	Milk against injuries; Edible; Minerals in petals and flowers; Stomach pains
Flowers species in general		Ornaments in gardens
Grasses		Urinary disorders
Mint	*Mentha* sp.	Repellent for insect and rats
Pineapple weed	*Matricaria discoidea*	Stomach pain; Medicinal properties
Spear Thistle	*Cirsium vulgare*	Edible
White clover	*Trifolium repens*	Improve soil

2.3.2.2. Biological value

This value was mostly found among nature practitioners and concerned interactions between species: "[Non-native] flowers, ecologically, contribute to more pollinizers, which helps to ensure that there is an important fauna. (...) I believe then that they constitute a major contribution" (conservation practitioner #3). More specifically, the dandelion has been named as a species providing food to birds by two different participants. There was also a concern raised by a participant about the ecosystem consequences that may result from the non-acceptance of exotic plants: "I imagine that the plants that are associated with the feeding of cows should be left no? Because if they disappear by whatever we do, the other animals will also go away, those we live with and need" (conservation practitioner #3). Indeed, white clover has been named by participants from different groups as being widely used by cattle for grazing.

2.3.2.3. Aesthetic value

Nearly half of the participants attributed an aesthetic value to the different non-native plants. People appreciated especially flowers for their beauty: "*Flowers in general are all beautiful*" (Chilean navy member #2); "*I do not find that [non-native] flowers are nuisances, in fact, I love flowers*" (public service employee #2). The common daisy was the most appreciated non-native plant species by interviewees: "*The daisy yes, it is beautiful, I know it well. In the Omora [Ethnobotanical] park there are many. It stays there because it's been a few years since it's a park, before it was a farm where I presume they planted all these species*" (civil resident #3). Some also valued dandelions: "*The dandelion has charisma because we can blow the seeds away and because it is very small*" (conservation practitioner #3). Many participants also named flowers they had in their gardens that we had not showed on our photographs or mentioned (e.g. lupines, fuchsias), which confirmed a strong general interest for ornamental plants in all groups, except for tourists.

2.3.2.4. Philosophical value

Two participants raised arguments within a more philosophical framework, the first one argued that we might need to rethink the concept of non-native species in the era of the Anthropocene:

> *The dynamics of vegetation is in constant change, it is not stable, so our intention to conserve may be part of one of our human whims. We want nothing to change because we like it as it is, for aesthetics itself… Perhaps there is an unconscious part of me in which I want nature in one way, as I know it, and even if life and nature go in another direction, I want to keep in mind that it will remain as it was ... If the temperature rises, I would think that it is the exotic plants that will eventually dominate, while native flora is accustomed here to the cold and more stable conditions and do not have the ability to acclimate in comparison to others. So sometimes, I do not like it, but I think it would be necessary to adapt to the change, because in the end, everything changes (conservation practitioner #3).*

The other participant brought nuances to the framework of native/non-native species:

> *The spread of exotic plants is something that has existed since man is man. Men have always sown. The speech saying that anything new to happen is a disaster, I do not agree. It could be, but I cannot say it, otherwise the world would not be as it is today. All plants that are used to eat, for example. It's a phenomenon that started so long ago. There are introduced species on Navarino Island that have been introduced for more than 100 years.*

It is not a disaster either, the island is not carpeted with curly docks or dandelions, to name only these plants. It is not necessary to exaggerate either (civil resident #1).

2.3.2.5. Negativistic value

Most of the participants expressed disgust and aversion for the curly dock, describing it as "*ugly*", "*horrible*" or even "*a disaster*". Some also mentioned the hardness in getting rid of it: "*They grow bizarrely and big and everywhere. It's universal, it's just everywhere! You must take the soil out completely and the seeds still disperse*" (civil resident #3). Dandelion was also characterized as a pest requiring control by most of the interviewees: "*I think it's impossible to eradicate dandelion. It's like a little demon. Every day in my greenhouse I have to remove the dandelion seeds that come in*" (civil resident #3). On the other hand, spear thistle was frequently described as physically unappealing by interviewees, but most have mentioned the danger related to its spines-tipped stem and spine-leaves. Similarly, many participants raised the danger associated with the common nettle, having caused skin rashes and contributing to a feeling of fear towards the plant and its effects: "*I gave it [common nettle] to my son once to fight a virus, but I will never do it again! It is itchy… Bad advice of alternative medicine*" (public service employee #1).

2.3.2.6. Indifferent value

Indifference towards non-native species was also noted for a few participants, mostly Chilean navy members. One participant did not mention any benefit or consequence of the plants shown while another did not believe that species could have an impact on anything. Further, two participants mentioned the lack of importance of the theme. One participant argued: "*I do not think it is a priority in terms of what we are currently experiencing at the political and social level*" (conservation practitioner #3) while another one claimed: "*The truth is that, here, nobody cares*" (civil resident #1).

2.3.3. Attitudes towards management of species

One third of the participants (including all interviewed tourists) were in favor of better control actions regarding non-native species on Navarino. Additionally, tourists expressed the wish to get more information about non-native species upon their arrival on the island and one suggested that: "*the way forward should also focus more on trails and not letting people avoid mud, for example, because afterwards, the trail is stepped everywhere*" (tourist #3). One tourist also believed that "*animals that contribute to the dispersion of seeds should be managed*" (tourist #2). On another side, one participant suggested that: "*it should start with prevention in the sea and air entry ways, and then generate means of control and mitigation*" (conservation practitioner #1). However, some participants had no interest in management: "*curly dock does not cause any economic harm to livestock. Our mission [at work] is to devote resources to invasive species or invasive plants that have political and economic consequences on the export or productivity of livestock, for example. In this case, the curly dock has no effect*" (public service employee #1). Some participants also believed control measures would be difficult, if not impossible to apply: "*I think it's a complex subject… I do not know what alternatives there are, how can this be controlled*" (conservation practitioner #2); "*I do not know how… So much seeds! I cut every curly dock in my garden and others appear, appear, appear*" (public service employee #3).

On the other hand, some participants wished they could pursue their use of non-native species despite control measures: "*How can you eradicate them, eliminate them, I do not know. But if you can take advantage of them, it would be fantastic, and it could also go along with the creation of control measures*" (conservation practitioner #1); "*I do not think it's necessary to make a management plan as such, and try to eradicate the curly dock, but I think we should still try to contain these plants in a small space to use them as medicine*" (Yaghan #1). While all civil residents mentioned their willingness to get involved in a control program, they also mentioned the lack of awareness and interest of other people: "*I would participate, I would be more than happy to participate, but, frankly spoken, that is science fiction. There is no culture, politically speaking. It is not profitable. Eradicate a couple of little plants. They spend millions of dollars to study, but to do concrete things, nothing…*" (resident #1); "*Yes, I am already involved in this topic in the environmental committee, but they consider exotic insects more of a priority. They seemed more concerned with the management of this type of species rather than plants*" (resident #3). One participant mentioned that control should not happen through public policy, but rather through citizen participation: "*Maybe we can do community campaigns in* *which children, people, could better manage their gardens. I believe this would be more effective than a public policy*" (conservation practitioner #2).

2.4. Discussion and conclusion

We investigated understanding, perceptions and attitudes towards management of non-native herbaceous plant species on a remote sub-Antarctic Chilean island. Overall, our study showed a general understanding of the non-native species concept among the participants but revealed a lack of consciousness regarding non-native plants species in the local context. Specifically, participants confounded native with non-native plants and were unaware of their potential impacts. These low levels of knowledge could be explained by a few underlying causes. Firstly, research on non-native species in southern Chile has been extensively focused on beavers and minks (e.g. Anderson, Griffith, Rosemond, Rozzi & Dollenz, 2006; Crego, Jiménez & Rozzi, 2018; Menvielle et al. 2010; Schüttler et al. 2011), while few studies have looked at plant species (Rozzi et al. 2004; Vidal et al. 2015). Secondly, impacts of non-native plants may be less visible than those of some animals (e.g. beavers as ecosystem engineers). Thirdly, local efforts on the management of non-native species have also only focused on animals e.g. beavers, minks and muskrats (*Ondatra zibethicus*) (Soto & Cabello, 2007). Lastly, it seems that media coverage or access to information does not allow people to obtain knowledge on non-native plants of the island. Fischer & van der Wal (2007, p. 256) pointed out that one common criticism is "that members of the general public might have insufficient knowledge and motivation to contribute to environment-related decision making in a valid and meaningful way".

Although the number of interviews by category of stakeholders is small and it is difficult to compare results across groups, the results indicate some trends that should be confirmed with more interviews.

Remarkably, our study revealed positive values associated with non-native plant species on Navarino Island. Overall, the aesthetic value of species, particularly flowers was the most highlighted. Positive interactions have also been mentioned by participants, such as feeding interactions between birds and seeds in general or between cattle, horses, common daisies and white clovers more specifically. Among the body of literature focusing on non-native species, positive ecosystem interactions remain under-researched (Kuebbing & Nuñez, 2015; Pyšek et al. 2012). While there are some studies on positive interactions between non-native and native species in other parts of the world (Fischer et van der Wal, 2007; Molina-Montenegro, Badano & Cavieres, 2008; Simberloff & Von Holle, 1999; Tecco, Gurvich, Díaz, Pérez-Harguindeguy & Cabido, 2006), those focusing on sub-Antarctic contexts are scarce, if not non-existent. This is crucial because interactions are scale and context-dependent and can develop and adapt over time. Indeed, some participants mentioned this challenge in a context of climate change (philosophical value). Interviewees questioned the forced claim on paralyzing nature in a changing world. In this spirit, Schlaepfer, Sax & Olden, (2011) argued that non-native species could fulfill important ecosystem and aesthetic functions, particularly in places where native species cannot persist due to environmental changes. In fact, the principal issue in valuing native species in conservation is that it commits us to appreciate a flora and fauna that reflects a specific environmental and climatic state which is under constant change (Kendle & Rose, 2000). This new ecology (i.e. "the new wild", Pearce, 2016) shows once more that the dichotomous concept of "good-natives" and "bad-aliens" as traditionally expressed in the invasion biology sub-discipline is a fractured concept.

Whilst some non-native plants were strictly associated with positive values (e.g. common daisy and white clover, two important species for livestock grazing), most species were associated with conflicting values. Specific species with conflicting values included the dandelion which, although some called it a pest, others rather called it a beauty of nature. Another example of conflicting values is the curly dock which most people characterized as a pest, but which also has medicinal properties that are used especially among Yaghans. Diaz (2010) found that 4% of the vascular plants used by the indigenous peoples of southern Patagonia are exotic species, such as curly dock and dandelion, two species that were naturalized early in the region due to the intentional introduction by settlers. Such values should undeniably be considered to avoid social conflicts in non-native species management (Estévez, Anderson, Pizarro & Burgman, 2015). Social conflicts are disagreements arising between individuals and groups who express incompatible beliefs, values, or goals (Crowley, Hinchliffe & McDonald, 2017). Conflict can result when both sides of the argument fail to assess the trade-offs between them (Dickie et al. 2014). Value-based conflicts are inherently difficult to resolve because management authorities must balance the needs of different stakeholders while still conserving the environment (Zengeya et al. 2017). Power issues are embedded in biological invasions and increased interest around this topic is likely to make conflicts more widespread in the future (Dickie et al. 2014). Generally, collaboration and levels of trust among stakeholders can be increased by an open and fair participation process (Novoa, Kaplan, Wilson & Richardson, 2016; Estévez et al. 2015). We believe that a fair participation process involves also promoting the plurality of opinions as well as disclosing the controversial nature of debate around the management of non-native species. We thus agree with Schüttler et al. (2011, p.181) that: "especially in settings with strong differences in power and education, as given on Navarino Island, the danger is great that an established dominant position will guide practice without any discussion, neglecting 'silent voices', not used to articulate themselves".

As a key result, our study nevertheless showed that most participants were indifferent about the management of non-native herbaceous plant species. This was probably a result of either absent impacts of non-native plant species, poor experiences on negative consequences of non-native plant species and/or few information. We therefore suggest implementing awareness campaigns in a way of promoting access to information and open discussion on non-native species since it is an essential tool for engaging different stakeholders. Similarly, Bardsley & Edward-Jones (2006, p. 207) highlighted that:

> *To prevent a considerable local backlash against environmental policies that inhibit the activities of agricultural and horticultural producers, nursery owners and local residents in general, it could be necessary to evolve invasive species management with substantial local input via participatory approaches, rather than imposing programs from above.*

On the other hand, the indifference of the stakeholders regarding the management of the non-native plant species may instead favor the status quo option among the different management strategies. Indeed, Kalnicky, Brunson & Beard (2014, p. 194) raised that "in the case where a non-native species is unlikely to have long-term detrimental effects on social or ecological systems, it is possible that a wait-and-see approach may be beneficial in reducing money spent attempting to control or eradicate the species".

On another side, the high interest of tourists on non-native species suggests that it could be particularly relevant to implement activities directed towards this stakeholder group to improve their awareness of the risks related to non-native species introduction and dispersal on Navarino Island and in the CHBR. As the increase in the movement of non-native species is directly related to the growth in international trade, tourism and human mobility (Anderson, Rocliffe, Haddaway & Dunn, 2015; Hall, 2015), reducing unintentional introductions through these vectors will require effective prediction, surveillance, awareness-raising and control (Tatem, 2009). On Navarino, the exponential growth of the tourism industry through cruise ships (García, 2004), the construction of new roads and infrastructures (Sernatur, 2014), the spread of introduced beaver (*Castor canadensis*), which create forest corridors and open habitats (Anderson et al. 2006), are all anthropogenic disturbance that could confer competitive advantages to non-native plant species and thus facilitate their establishment and dispersal (Byers 2002). Furthermore, an increase in temperature and precipitation is expected in the Tierra del Fuego area (IPCC, 2013) which could facilitate the establishment of non-native species (Lebouvier et al. 2011). Since it has been shown that human influence associated with rapid social and economic changes at different scales can significantly influence the fate of local and regional biological diversity (Cerda, Barkmann & Margrraf, 2014), it is particularly important to put non-native plant species onto the public agenda for Navarino. Inspections of visitor's footwear and luggage on arrival to pristine sites such as the Cape Horn Biosphere Reserve could be a way to substantially reduce propagule loads (Lee & Chown, 2009), as partially implemented in the Southern Ocean Islands (de Villiers et al. 2006) and in the Antarctic continent (Hughes et al. 2019). As previously said, this is particularly relevant since the island represents a stepping stone between the South American continent and the Antarctic and non-native propagules might be transported from the CHBR further south (Rozzi et al. 2007). Currently, several non-native species are found along the sub-Antarctic islands (Frenot et al. 2005; Lebouvier et al. 2011) which represents a significant challenge for the Antarctic, since some of them has yet been noticed in the peninsula (Cuba-Díaz, Troncoso, Cordero, Finot & Rondanelli-Reyes, 2013; Fuentes-Lillo, Cuba- Díaz, Troncoso-Castro & Rondanelli-Reyes, 2017; Olech & Chwedorzewska, 2011). Among the four species classified by participants as "very abundant" (dandelion, common daisy, white clover and curly dock), only the curly dock has been found further south than Navarino (i.e. Baily Island) (Rozzi et al. 2004). Despite the fact that most species perceived as most abundant on Navarino have no records in Cape Horn and the

Antarctic, we anticipate that they might reach out there shortly. This highlights the need of common conservation guidelines for the sub-Antarctic and Antarctic.

Our study therefore contains important points for decision-makers and managers of the Cape Horn Biosphere Reserve with respect to public perceptions on non-native plant species which will need to be considered if any control actions are required in the future.

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References

Aguirre-Muñoz, A., Samaniego-Herrera, A., Luna-Mendoza, L., Ortiz-Alcaraz, A., Rodríguez-Malagón, M., Félix-Lizárraga, M., … Latofski-Robles, M. (2011). Eradications of invasive mammals on islands in Mexico: the roles of history and the collaboration between government agencies, local communities and a non-government organisation. In E. C. R. Veitch, M. N. Clout, & D. R. Towns (Eds.), *Island Invasives: Eradication and Management Proceedings of the International Conference on Island Invasives* (pp. 386–394).

Alessa, L. (Naia), Kliskey, A. (Anaru), & Brown, G. (2008). Social–ecological hotspots mapping: A spatial approach for identifying coupled social–ecological space. *Landscape and Urban Planning*, *85*(1), 27–39. https://doi.org/10.1016/j.landurbplan.2007.09.007

Anderson, C. B., Griffith, C. R., Rosemond, A. D., Rozzi, R., & Dollenz, O. (2006). 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*(4), 467–474. https://doi.org/10.1016/j.biocon.2005.10.011

Anderson, L. G., Rocliffe, S., Haddaway, N. R., & Dunn, A. M. (2015). The Role of Tourism and Recreation in the Spread of Non-Native Species: A Systematic Review and Meta-Analysis. *PLOS ONE*, *10*(10), e0140833. https://doi.org/10.1371/journal.pone.0140833

Andreu, J., Vilà, M., & Hulme, P. E. (2009). An Assessment of Stakeholder Perceptions and Management of Noxious Alien Plants in Spain. *Environmental Management*, *43*(6), 1244–1255. https://doi.org/10.1007/s00267-009-9280-1

Arroyo, M. T. K., Riveros, M., Peñaloza, A., Cavieres, L., & Faggi, A. M. (1996). Phytogeographic Relationships and Regional Richness Patterns of the Cool Temperate Rainforest Flora of Southern South America. In R. G. Lawford, E. Fuentes, & P. B. Alaback (Eds.), *High-Latitude Rainforests and Associated Ecosystems of the West Coast of the Americas: Climate, Hydrology, Ecology, and Conservation* (pp. 134–172). https://doi.org/10.1007/978-1-4612-3970-3_8

Atkinson, R., & Flint, J. (2004). Snowball sampling. In M. Lewis-Beck, A. E. Bryman, & T. F. Liao (Eds.), *The SAGE Encyclopedia of Social Science Research Methods*. SAGE Publications.

Bardsley, D., & Edwards-Jones, G. (2006). Stakeholders' perceptions of the impacts of invasive exotic plant species in the Mediterranean region. *GeoJournal*, *65*(3), 199–210. https://doi.org/10.1007/s10708-005-2755-6

Bartz, R., & Kowarik, I. (2019). Assessing the environmental impacts of invasive alien plants: a review of assessment approaches. *NeoBiota*, *43*, 69–99. https://doi.org/10.3897/neobiota.43.30122

Berghöfer, U., Rozzi, R., & Jax, K. (2010). Many Eyes on Nature: Diverse Perspectives in the Cape Horn Biosphere Reserve and Their Relevance for Conservation. *Ecology and Society*, *15*(1). https://doi.org/10.5751/ES-03316-150118

Binimelis, R., Born, W., Monterroso, I., & Rodríguez-Labajos, B. (2007). Socio-Economic Impact and Assessment of Biological Invasions. In W. Nentwig (Ed.), *Biological Invasions* (pp. 331–347). https://doi.org/10.1007/978-3-540-36920-2_19

Bremner, A., & Park, K. (2007). Public attitudes to the management of invasive non-native species in Scotland. *Biological Conservation*, *139*(3), 306–314. https://doi.org/10.1016/j.biocon.2007.07.005

Bryman, A., & Burgess, B. (2002). *Analyzing Qualitative Data*. Routledge.

Byers, J. E. (2002). Impact of non-indigenous species on natives enhanced by anthropogenic alteration of selection regimes. *Oikos*, *97*(3), 449–458. https://doi.org/10.1034/j.1600-0706.2002.970316.x

Cerda, C., Barkmann, J., & Marggraf, R. (2014). Non-market economic valuation of the benefits provided by temperate ecosystems at the extreme south of the Americas. *Regional Environmental Change*, *14*(4), 1517–1531. https://doi.org/10.1007/s10113-014-0591-2

Cerri, J., Ferretti, M., & Tricarico, E. (2016). Are you aware of what you are doing? Asking Italian hunters about an invasive alien species they are introducing. *Journal for Nature Conservation*, *34*, 15–23. https://doi.org/10.1016/j.jnc.2016.08.003

Chew, M. K., & Laubichler, M. D. (2003). Natural Enemies--Metaphor or Misconception? *Science*, *301*(5629), 52–53. https://doi.org/10.1126/science.1085274

Colautti, R. I., & MacIsaac, H. J. (2004). A neutral terminology to define 'invasive' species: Defining invasive species. *Diversity and Distributions*, *10*(2), 135–141. https://doi.org/10.1111/j.1366-9516.2004.00061.x

Crego, R. D., Jiménez, J. E., & Rozzi, R. (2018). Potential niche expansion of the American mink invading a remote island free of native-predatory mammals. *PLOS ONE*, *13*(4), e0194745. https://doi.org/10.1371/journal.pone.0194745

Crowley, S. L., Hinchliffe, S., & McDonald, R. A. (2017). Conflict in invasive species management. *Frontiers in Ecology and the Environment*, *15*(3), 133–141. https://doi.org/10.1002/fee.1471

Cuba-Díaz, M., Troncoso, J. M., Cordero, C., Finot, V. L., & Rondanelli-Reyes, M. (2013). Juncus bufonius, a new non-native vascular plant in King George Island, South Shetland Islands. *Antarctic Science*, *25*(3), 385–386. https://doi.org/10.1017/S0954102012000958

de Villiers, M. S., Cooper, J., Carmichael, N., Glass, J. P., Liddle, G. M., McIvor, E., … Roberts, A. (2006). *Conservation Management at Southern Ocean Islands: towards the Development of Best-Practice Guidelines*. 19.

Díaz, E. D. (2010). *Flora de interés etnobotánico usada por los pueblos originarios: Aónikenk, Selk'nam, Kawésqar, Yagan y Haush en la Patagonia Austral*. *26*, 12.

Dickie, I. A., Bennett, B. M., Burrows, L. E., Nuñez, M. A., Peltzer, D. A., Porté, A., … van Wilgen, B. W. (2014). Conflicting values: ecosystem services and invasive tree management. *Biological Invasions*, *16*(3), 705–719. https://doi.org/10.1007/s10530-013-0609-6

Early, R., Bradley, B. A., Dukes, J. S., Lawler, J. J., Olden, J. D., Blumenthal, D. M., … Tatem, A. J. (2016). Global threats from invasive alien species in the twenty-first century and national response capacities. *Nature Communications*, *7*, 12485. https://doi.org/10.1038/ncomms12485

Ehrenfeld, J. G. (2003). Effects of Exotic Plant Invasions on Soil Nutrient Cycling Processes. *Ecosystems*, *6*(6), 503–523. https://doi.org/10.1007/s10021-002-0151-3

Estévez, R. A., Anderson, C. B., Pizarro, J. C., & Burgman, M. A. (2015). Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management: Confronting Invasive Species Conflicts. *Conservation Biology*, *29*(1), 19–30. https://doi.org/10.1111/cobi.12359

Fischer, A., & van der Wal, R. (2007). Invasive plant suppresses charismatic seabird – the construction of attitudes towards biodiversity management options. *Biological Conservation*, *135*(2), 256–267. https://doi.org/10.1016/j.biocon.2006.10.026

Fleming, P. A., & Bateman, P. W. (2016). The good, the bad, and the ugly: which Australian terrestrial mammal species attract most research? *Mammal Review*, *46*(4), 241–254. https://doi.org/10.1111/mam.12066

Frenot, Y., Chown, S. L., Whinam, J., Selkirk, P. M., Convey, P., Skotnicki, M., & Bergstrom, D. M. (2005). Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews*, *80*(1), 45–72. https://doi.org/10.1017/S1464793104006542

Fuentes-Lillo, E., Cuba-Díaz, M., Troncoso-Castro, J. M., & Rondanelli-Reyes, M. (2017). Seeds of non-native species in King George Island soil. *Antarctic Science*, *29*(4), 324–330. https://doi.org/10.1017/S0954102017000037

García, M. (2004). Ecotourism in Cape Horn. In R. Rozzi, F. Massardo, & C. Anderson (Eds.), *The Cape Horn Biosphere Reserve: A Proposal for Conservation and Tourism to Achieve Sustainable Development at the Southern End of the Americas.* (pp. 177–204). University of Magallanes Press.

García-Llorente, M., Martín-López, B., González, J. A., Alcorlo, P., & Montes, C. (2008). Social perceptions of the impacts and benefits of invasive alien species: Implications for management. *Biological Conservation*, *141*(12), 2969–2983. https://doi.org/10.1016/j.biocon.2008.09.003

García-Piquer, A., & Estévez-Escalera, J. (2018). The social use of space in a shell midden: Testing ethnoarchaeological data from Tierra del Fuego (Argentina) with intra-site spatial analyses. *Journal of Archaeological Science: Reports*, *18*, 1053–1065. https://doi.org/10.1016/j.jasrep.2017.12.028

Godley, E. J. (1960). The Botany of Southern Chile in Relation to New Zealand and the Subantarctic. *Proceedings of the Royal Society of London. Series B, Biological Sciences*, *152*(949), 457–475. Retrieved from JSTOR.

Green, P. (2002). Riparian alien plants: towards ecological acceptance? *ECOS*, *23*(2), 34–42.

Hall, C. M. (2015). Tourism and biological exchange and invasions: a missing dimension in sustainable tourism? *Tourism Recreation Research*, *40*(1), 81–94. https://doi.org/10.1080/02508281.2015.1005943

Hsieh, H.-F., & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research*, *15*(9), 1277–1288. https://doi.org/10.1177/1049732305276687

Hughes, K. A., Convey, P., Pertierra, L. R., Vega, G. C., Aragón, P., & Olalla-Tárraga, M. Á. (2019). Human-mediated dispersal of terrestrial species between Antarctic biogeographic regions: A preliminary risk assessment. *Journal of Environmental Management*, *232*, 73–89. https://doi.org/10.1016/j.jenvman.2018.10.095

Hulme, P. E. (2012). Weed risk assessment: a way forward or a waste of time? *Journal of Applied Ecology*, *49*(1), 10–19. https://doi.org/10.1111/j.1365-2664.2011.02069.x

IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* (T. F. F. Stocker, D. Quin, G.-K. Plattner, M. M.B. Tignor, S. Allen K., J. Boschung, … P. M. Midgley, Eds.).

Kalnicky, E. A., Brunson, M. W., & Beard, K. H. (2014). A social–ecological systems approach to non-native species: Habituation and its effect on management of coqui frogs in Hawaii. Biological Conservation, 180, 187–195. https://doi.org/10.1016/j.biocon.2014.09.044

Kapitza, K., Zimmermann, H., Martín-López, B., & Wehrden, H. von. (2019). Research on the social perception of invasive species: a systematic literature review. *NeoBiota*, *43*, 47–68. https://doi.org/10.3897/neobiota.43.31619

Kellert, S. R. (1996). *The Value of Life: Biological Diversity And Human Society*. Washington DC: Island Press.

Kendle, A. D., & Rose, J. E. (2000). The aliens have landed! What are the justifcations for "native only" policies in landscape plantings? *Landscape and Urban Planning*, 13.

Kuebbing, S. E., & Nuñez, M. A. (2015). Negative, neutral, and positive interactions among nonnative plants: patterns, processes, and management implications. *Global Change Biology*, *21*(2), 926–934. https://doi.org/10.1111/gcb.12711

Lebouvier, M., Laparie, M., Hullé, M., Marais, A., Cozic, Y., Lalouette, L., … Renault, D. (2011). The significance of the sub-Antarctic Kerguelen Islands for the assessment of the vulnerability of native communities to climate change, alien insect invasions and plant viruses. *Biological Invasions*, *13*(5), 1195–1208. https://doi.org/10.1007/s10530-011-9946-5

Lee, J. E., & Chown, S. L. (2009). Breaching the dispersal barrier to invasion: quantification and management. *Ecological Applications*, *19*(7), 1944–1959. https://doi.org/10.1890/08-2157.1

Liao, C., Peng, R., Luo, Y., Zhou, X., Wu, X., Fang, C., … Li, B. (2008). Altered ecosystem carbon and nitrogen cycles by plant invasion: a meta-analysis. *New Phytologist*, *177*(3), 706–714. https://doi.org/10.1111/j.1469-8137.2007.02290.x

Lindemann-Matthies, P. (2016). Beasts or beauties? Laypersons' perception of invasive alien plant species in Switzerland and attitudes towards their management. *NeoBiota*, *29*, 15–33. https://doi.org/10.3897/neobiota.29.5786

Mack, R.N., & Foster, S. K. (2009). Eradicating Plant Invaders: Combining Ecologically-Based Tactics and Broad-Sense Strategy. In Inderjit (Ed.), *Management of Invasive Weeds* (pp. 35–60). Dordrecht: Springer.

Marshall, N. A., Friedel, M., van Klinken, R. D., & Grice, A. C. (2011). Considering the social dimension of invasive species: the case of buffel grass. *Environmental Science & Policy*, *14*(3), 327–338. https://doi.org/10.1016/j.envsci.2010.10.005

Mayring, P., & Fenzl, T. (2014). Qualitative Inhaltsanalyse. In N. Baur & J. Blasius (Eds.), *Handbuch Methoden der empirischen Sozialforschung* (pp. 543–556). https://doi.org/10.1007/978-3-531-18939-0_38

Menvielle, M. F., Funes, M., Malmierca, L., Ramadori, D., Saavedra, B., Schiavini, A., & Soto Volkart, N. (2010). American beaver eradication in the southern tip of South America: main challenges of an ambitious project. *Aliens. The Invasive Species Bulletin*, *29*, 9–16.

Molina, J. A., Lumbreras, A., Benavent-González, A., Rozzi, R., & Sancho, L. G. (2016). Plant communities as bioclimate indicators on Isla Navarino, one of the southernmost forested areas of the world. *Gayana. Botánica*, *73*(2), 391–401. https://doi.org/10.4067/S0717-66432016000200391

Molina-Montenegro, M. A., Badano, E. I., & Cavieres, L. A. (2008). Positive interactions among plant species for pollinator service: assessing the 'magnet species' concept with invasive species. *Oikos*, *117*(12), 1833–1839. https://doi.org/10.1111/j.0030-1299.2008.16896.x

Moore, D. M., & Goodall, R. N. (1977). La flora adventicia de Tierra del Fuego. *Anales Del Instituto de La Patagonia*, *8*, 263–274.

Novoa, A., Dehnen-Schmutz, K., Fried, J., & Vimercati, G. (2017). Does public awareness increase support for invasive species management? Promising evidence across taxa and landscape types. *Biological Invasions*, *19*(12), 3691–3705. https://doi.org/10.1007/s10530-017-1592-0

Novoa, A., Kaplan, H., Wilson, J. R. U., & Richardson, D. M. (2016). Resolving a Prickly Situation: Involving Stakeholders in Invasive Cactus Management in South Africa. *Environmental Management*, *57*(5), 998–1008. https://doi.org/10.1007/s00267-015-0645-3

Olech, M., & Chwedorzewska, K. J. (2011). Short Note: The first appearance and establishment of an alien vascular plant in natural habitats on the forefield of a retreating glacier in Antarctica. *Antarctic Science*, *23*(02), 153–154. https://doi.org/10.1017/S0954102010000982

Oreska, M. P. J., & Aldridge, D. C. (2011). Estimating the financial costs of freshwater invasive species in Great Britain: a standardized approach to invasive species costing. *Biological Invasions*, *13*(2), 305–319. https://doi.org/10.1007/s10530-010-9807-7

Orquera, L. A., & Piana, E. L. (2009). Sea Nomads of the Beagle Channel in Southernmost South America: Over Six Thousand Years of Coastal Adaptation and Stability. *The Journal of Island and Coastal Archaeology*, *4*(1), 61–81. https://doi.org/10.1080/15564890902789882

Pearce, F. (2016). *The New Wild: Why Invasive Species Will Be Nature's Salvation*. Beacon Press.

Perrings, C., Mooney, H., & Williamson, M. (2010). *Bioinvasions and Globalization: Ecology, Economics, Management, and Policy*. OUP Oxford.

Pisano, V. E. (1981). Bosquejo fitogeográfico de Fuego-Patagonia. *Anales Del Instituto de La Patagonia*, *12*, 159–171.

Potgieter, L. J., Gaertner, M., O'Farrell, P. J., & Richardson, D. M. (2019). Perceptions of impact: Invasive alien plants in the urban environment. *Journal of Environmental Management*, *229*, 76–87. https://doi.org/10.1016/j.jenvman.2018.05.080

Pyšek, P., Jarošík, V., Hulme, P. E., Pergl, J., Hejda, M., Schaffner, U., & Vilà, M. (2012). A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. *Global Change Biology*, *18*(5), 1725–1737. https://doi.org/10.1111/j.1365-2486.2011.02636.x

Rao, R. R., Sagar, K., & Sathyanarayana, N. (2011). Resource Utilization and Beneficial Aspects of Invasive Alien Weeds with Special Reference to the Western Ghats, India. In J. R. Bhatt, J. S. Singh, S. P. Singh, R. S. Tripathi, & R. K. Kohli (Eds.), *Invasive alien plants: an ecological appraisal for the Indian subcontinent* (pp. 271–281). https://doi.org/10.1079/9781845939076.0000

Reaser, J. K. (2001). Invasive alien species prevention and control: the art and science of managing people. In J. A. McNeely (Ed.), *The Great Reshuffling: Human Dimensions of Invasive Alien Species* (pp. 89–104). Cambridge: IUCN.

Rozzi, R., Charlin, R., Ippi, S., & Dollenz, O. (2004). Cabo de Hornos: Un parque nacional libre de especies exoticas en el confin de America. *Anales del Instituto de la Patagonia*, *32*, 55–62.

Rozzi, R., Massardo, F., Mansilla, A., Anderson, C. B., Berghöfer, A., Mansilla, M., … Barros, E. (2007). La Reserva de Biosfera Cabo de Hornos: Un desafio para la conservacion de la biodiversidad e implementacion del desarollo sustentable en el extremo austral de America. *Anales del Instituto de la Patagonia*, 16.

Schlaepfer, M. A., Sax, D. F., & Olden, J. D. (2011). The Potential Conservation Value of Non-Native Species: Conservation Value of Non-Native Species. *Conservation Biology*, *25*(3), 428–437. https://doi.org/10.1111/j.1523-1739.2010.01646.x

Schüttler, E., Rozzi, R., & Jax, K. (2011). Towards a societal discourse on invasive species management: A case study of public perceptions of mink and beavers in Cape Horn. *Journal for Nature Conservation*, *19*(3), 175–184. https://doi.org/10.1016/j.jnc.2010.12.001

Sernatur. (2014). *Plan de Acción Región de Magallanes y Antarctica Chilena Sector Turismo 2014-2018*. Santiago de Chile: Sernatur.

Shackleton, C. M., McGarry, D., Fourie, S., Gambiza, J., Shackleton, S. E., & Fabricius, C. (2007). Assessing the Effects of Invasive Alien Species on Rural Livelihoods: Case Examples and a Framework from South Africa. *Human Ecology*, *35*(1), 113–127. https://doi.org/10.1007/s10745-006-9095-0

Simberloff, D., Martin, J.-L., Genovesi, P., Maris, V., Wardle, D. A., Aronson, J., … Vilà, M. (2013). Impacts of biological invasions: what's what and the way forward. *Trends in Ecology & Evolution*, *28*(1), 58–66. https://doi.org/10.1016/j.tree.2012.07.013

Simberloff, D., & Von Holle, B. (1999). Positive Interactions of Nonindigenous Species: Invasional Meltdown? *Biological Invasions*, *1*(1), 21–32. https://doi.org/10.1023/A:1010086329619

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

Stokes, K. E., O°FNeill, K. P., Montgomery, W. I., Dick, J. T. A., Maggs, C. A., & McDonald, R. A. (2006). The Importance of Stakeholder Engagement in Invasive Species Management: A Cross-jurisdictional Perspective in Ireland. *Biodiversity & Conservation*, *15*(8), 2829–2852. https://doi.org/10.1007/s10531-005-3137-6

Tatem, A. J. (2009). The worldwide airline network and the dispersal of exotic species: 2007–2010. *Ecography*, *32*(1), 94–102. https://doi.org/10.1111/j.1600-0587.2008.05588.x

Tecco, P. A., Gurvich, D. E., Díaz, S., Pérez-Harguindeguy, N., & Cabido, M. (2006). Positive interaction between invasive plants: The influence of Pyracantha angustifolia on the recruitment of native and exotic woody species. *Austral Ecology*, *31*(3), 293–300. https://doi.org/10.1111/j.1442-9993.2006.01557.x

Vanbergen, A. J., Espíndola, A., & Aizen, M. A. (2018). Risks to pollinators and pollination from invasive alien species. *Nature Ecology & Evolution*, *2*(1), 16. https://doi.org/10.1038/s41559-017-0412-3

Vidal, O. J., Aguayo, M., Niculcar, R., Bahamonde, N., Radic, S., San Martín, C., … Félez, J. (2015). Plantas invasoras en el Parque Nacional Torres del Paine (Magallanes, Chile): Estado del arte, distribución post-fuego e implicancias en restauración ecológica. *Anales Del Instituto de La Patagonia*, *43*(1), 75–96. https://doi.org/10.4067/S0718-686X2015000100006

Vilà, M., Williamson, M., & Lonsdale, M. (2004). Competition Experiments on Alien Weeds with Crops: Lessons for Measuring Plant Invasion Impact? *Biological Invasions*, *6*(1), 59–69. https://doi.org/10.1023/B:BINV.0000010122.77024.8a

Warren, C. R. (2007). Perspectives on the `alien' versus `native' species debate: a critique of concepts, language and practice. *Progress in Human Geography*, *31*(4), 427–446. https://doi.org/10.1177/0309132507079499

Waselkov, G. A. (1987). Shellfish Gathering and Shell Midden Archaeology. In M. B. Schiffer (Ed.), *Advances in Archaeological Method and Theory* (pp. 93–210). https://doi.org/10.1016/B978-0-12-003110-8.50006-2

Westphal, M. I., Browne, M., MacKinnon, K., & Noble, I. (2008). The link between international trade and the global distribution of invasive alien species. *Biological Invasions*, *10*(4), 391–398. https://doi.org/10.1007/s10530-007-9138-5

Zengeya, T., Ivey, P., Woodford, D. J., Weyl, O., Novoa, A., Shackleton, R., … van Wilgen, B. (2017). Managing conflict-generating invasive species in South Africa: Challenges and trade-offs. *Bothalia - African Biodiversity & Conservation*, *47*(2), 1–11. https://doi.org/10.4102/abc.v47i2.2160

Chapitre 3: Combination of global and regional models to assess niche dynamics, establishment stage and hotspots of four non-native species on a sub-Antarctic island of the Cape Horn Biosphere Reserve.

Le présent chapitre présente un article prêt à être soumis pour publication dans la revue Polar Biology et peut être cité comme suit :

Crête, G., Bizama, G., Herrmann, T.M., Schüttler & Vidal, O. (Unpublished) Combination of global and regional models to assess niche dynamics, establishment stage and hotspots of four non-native plant species on a sub-Antarctic island of the Cape Horn Biosphere Reserve.

Abstract

The combination of growing anthropic activities and climate change is facilitating the establishment of species in locations previously considered hostile, such as polar and subpolar regions, which has prevented their introduction in the past. In this paper, we investigated the niche dynamics, establishment stage and areas of potential occurrence (hotspot) of *Bellis perennis*, *Cerastium fontanum*, *Taraxacum officinale* and *Trifolium repens*, four non-native plants distributed on Navarino, a remote Chilean sub-Antarctic island. We used maxENT to construct global and regional species distribution models with their occurrences and climatic variables as well as to assess the establishment stages of the four species. We used principal component analysis methods to investigate potential shifts of the species niche. We found a strong evidence for a shift in the climatic niche of the four species across its non-native range and may suggest significant plasticity to survive in areas with diverse temperature ranges. Our results showed that annual temperature and precipitation were the most important variables determining the distribution of the species. Although our analyses suggest that most observed occurrences of the four species on Navarino represent stabilizing populations, the hotspots maps produced in this study can be useful in preventing species future spread and monitoring current areas of distribution.

Keywords: biological invasions; modelling; plasticity; maxENT; management; protected areas

3.1. Introduction

Global urbanization, mobility and market are currently transforming ecosystems through the worldwide introduction of non-native species. Non-native plant species are key drivers of environmental changes in their receiving ecosystem (Perrings, Mooney & Williamson, 2010; Westphal, Browne, MacKinnon & Noble, 2008), as they especially interact with native plant communities (Pyšek et al. 2012; Vilà, Williamson & Lonsdale, 2004) and native pollinators (Vanbergen, Espíndola & Aizen, 2018) through competition and as they have the capacity to modify the soil nutrient cycle (Ehrenfeld, 2003) and both carbon and nitrogen cycles (Liao et al. 2008). In sub-Antarctic ecosystems, although levels of endemism are high (Chown and Convey 2016), relatively simple community structure makes them vulnerable to the introduction of non-native species but directs effects in polar and subpolar regions remain understudied as studies have yet merely focused on the effects of non-native vertebrates (Frenot et al. 2005).

The spatial distribution of plant species depends on a range of abiotic and biotic factors, among which climate is one of the most important contributing factors (Andrewartha & Birch, 1986; Wharton & Kriticos, 2004; Woodward, 1987). As climate is changing globally, the establishment of species outside their native environment is facilitated in polar and subpolar regions (Faúndez & Carvajal, 2014). In the Arctic and sub-Arctic, the connectivity to more temperate regions is far greater than in the Antarctic and most species movements to higher latitudes are range expansions, rather than direct introductions by humans (Bennett et al. 2015). For their part, because of the isolation and hostile environmental conditions of the Antarctic and sub-Antarctic, non-native plant species traditionally needed special adaptation skills to establish (Ott et al., 2006). As human activities are now reducing Antarctica's biological isolation, accelerated climate change is increasing the number, extent, and effects of non-native species on Antarctic ecosystems (Tin et al. 2009). Indeed, the capacity to disperse into novel habitats is the most vital factor for plant survival in response to global changes (Parker, 2001).

In this context, mathematical models of a plant species environmental requirements can predict its potential to spread into a novel region under different scenarios of environmental change (Owens et al. 2012). Species distribution models (SDMs) are numerical tools that combine observations of species occurrence with environmental variables and have been particularly useful in the context of biological invasions to predict potential distributions as well as to hypothesize stages of species establishment (Elith & Leathwick, 2009; Gallien et al. 2012). The prediction of a species distribution outside its native location has long been based on the principle of niche conservatism which argues that a species will tend to survive and expand under the same environmental conditions of its native range (Wiens & Graham, 2005). Yet, it excludes the possibility to detect niche shifts to non-analogous environments that could be occupied by non-native species in the introduced range (Peña-Gómez et al. 2014). To address this issue and to project the potential range of a non-native species in an introduced area, Gallien et al. (2012) proposed to use a combination of both global and regional models as they provide information on the general biotic and abiotic niche requirements of the species as well as on the local specificities (e.g. Roura-Pascual et al. 2009; Taucare-Ríos, Bizama & Bustamante, 2016). Scheme of Gallien et al. (2012) also compares presences between the two models which provides information on four theoretical scenarios regarding the establishment status of a species (i.e. stable, colonizing, adapting, sinking).

Recognizing non-native species current and potential distributions as well as delineating hotspots would enable ecosystem managers to prioritize resources (Catford et al. 2011). Here, we use the term "hotspot" to refer to areas with high potential for non-native species occurrences, as also defined by O'Donnell et al. (2012). Thus, SDMs are tools that have been widely used in conservation, especially for biodiversity inventory, predicting new occurrences and prioritizing areas for conservation (Franklin, 2013) and therefore could help to prevent the introduction and spread of non-native species.

This paper aims to assess the establishment stage, the niche dynamics and the hotspots areas of four abundant non-native plant species, namely (i) *Bellis perennis*, (ii) *Cerastium fontanum*, (iii) *Taraxacum officinale* and (iv), *Trifolium repens* using the case of Navarino, a remote sub-Antarctic island in southern Chile, where no research of this kind has been carried out before. More specifically, we aim to answer the two following questions: (i) have the four species conserved their climatic niche on Navarino Island? and (ii) have the four species reached a geographical equilibrium or can we expect them to spread further throughout the island?

Primarily, this paper aims to fill the knowledge gap on potential distribution of non-native herbaceous plant species in the sub-Antarctic. Expected changes in the sub-Antarctic southern Chile (e.g. growing tourism, infrastructure development, increase in temperature and precipitation (IPCC, 2013)) could facilitate the establishment of non-native species (Lebouvier et al. 2011). No studies have yet investigated specific effects of those four plants in the subantarctic and the Antarctic, but a lag can often be observed between the effect and its detection (Simberloff et al. 2013). As Navarino should be considered a stepping stone between the South American continent and Antarctica, it is therefore particularly relevant for conservation efforts to monitor non-native plant distribution.

3.2. Materials and methods

3.2.1. Local setting

The study was carried out on Navarino Island, southern Chile (55 º S) located within the Cape Horn Biosphere Reserve (CHBR) (fig.3). The local vegetation consists of an assemblage of southern breech (*Nothofagus* spp.) evergreen and deciduous forest, treeless Patagonian steppe dominated by fescues (*Festuca* spp.), low shrubs and hard-cushion species and Magellanic moorlands, a matrix of peatlands (Arroyo et al. 1996; Godley, 1960; Pisano, 1981). The hyperhumid climate is dominated by the surrounding oceans, with cool temperatures and a strong precipitation gradient between west and east areas of the CHBR (Tuhkanen et al. 1990). The permanent westerly winds create a continuous stress factor for plant life throughout the area (Molina et al. 2016). Currently, several non-native plant species are found on Navarino Island (Rozzi et al. 2004), four of which (*B. perennis*, *C. fontanum*, *T. officinale* and *T. repens*) are found outside human-impacted areas in addition to being in the list of the 15 plant species with the highest invasive potential in the Antarctic and sub-Antarctic regions (McGeoch et al. 2015). Three of them (*B. perennis*, *T. officinale* and *T. repens*) have also been characterized as particularly abundant by local stakeholders (Crête et al. Unpublished data).

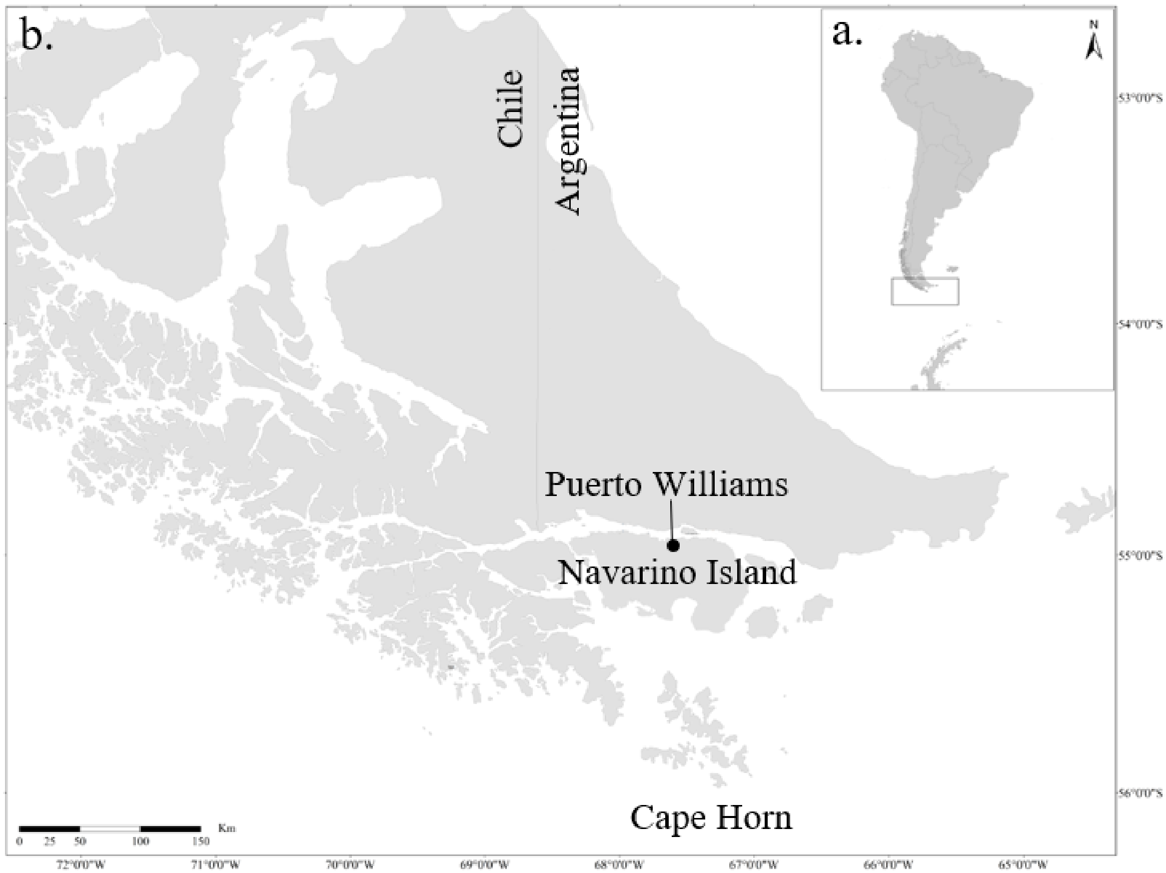

Figure 3. a. South America and Antarctica with focus on study site at the southern tip of Chile; b. Sub-Antarctic Navarino Island with Puerto Williams as the capital of the Chilean Antarctic Province.

3.2.2. Data collection

To assess the global distribution of the four species, we used the Global Biodiversity Information Facility (GBIF; http://www.gbif.org/). Presence data from before 1960 were filtered and excluded to correspond to the time range of the bioclimatic variables of the WorldClim database (http://worldclim.org/). The totality of occurrences collected for the species worldwide can be viewed as a proxy of the species' fundamental niche (Vetaas 2002) and corresponds in this study to the native range, whether the species is found in its actual native range or not. To assess the regional distribution of the four species, we built a monitoring scheme adapted to the limited logistics and access of Navarino Island. That way, we sampled on fourteen random transects starting from the one main road to the south and 13 starting from the three main hiking trails, all with a minimum distance of 500 m between each other and on alternating sides of the trails. Plots of 4 m^2 were sampled every 10 m along those transects until reaching 50 m and then sampled at 100 m, 250 m and 500 m. We also obtained opportunistic presence-only data through our walks between the transects. The regional occurrences on Navarino Island correspond to the non-native range.

To reduce the effect of spatial autocorrelation in the models, data points within the same ~1 km^2 grid cell were remove and spatial filtering were applied (Boria et al. 2014). The total number of filtered presence records was 14 928 for *B. perennis*, 17 560 for *C. fontanum*, 10 579 for *T. officinale* and 23 609 for *T. repens*.

3.2.3. Niche dynamics

We performed a principal component analysis (PCA) using environmental data extracted from occurrence data and available climate (PCA-env) following Broennimann et al. (2012) as PCA-env has demonstrated its ability to accurately detect niche overlaps. This method compares the environmental conditions of both native and non-native range available for a species with its observed occurrences and calculates the available environmental space defined by the first two axes from the PCA (Kumar et al. 2015). Then, the two-dimensional environmental space was projected onto a 100×100 PCA grid of cells and the occurrence points were converted into densities of occurrences using a kernel function to smooth the distribution (Broennimann et al. 2012). Based on these values, an occupancy index was estimated, a metric that allows the unbiased comparison of occurrence densities when environments are not equally available. Finally, the values of the occupancy index were incorporated in the environmental space to delimit the niche of the species. The Schoener's D metric was used to measure the niche overlap, which ranges from no 0 (no overlap) to 1 (overlap). We also calculated the three metrics stability, unfilling and expansion following Guisan et al. (2014). Niche unfilling (U) corresponds to the percentage of the native niche not shared with the non-native niche; it is presumed that this zone has not been occupied yet or it does not exist in the invaded range. Niche stability (S) corresponds to the percentage of the niche conserved in the non-native range. Finally, niche expansion (E) corresponds to the percentage of the non-native niche not shared with the native niche and represents the occupation of novel environments not predicted from the native niche.

Niche analyses were performed with the "ecospat package" in R (https://www.r-project.org/).

3.2.4. Data modelling

We used MaxENT for species distribution modelling, a software that evaluates the distribution probability of a species using a function of maximum entropy (Phillips, Anderson & Schapire, 2006). We selected MaxENT for our analyzes because it requires presence-only data and because it performs better in modelling low number of occurrences (Wisz et al. 2008). We selected the bioclimatic variables from Worldclim with a spatial resolution of 2.5 arc seconds. Of the 19 bioclimatic variables that summarize the information on temperature and precipitation, we selected a subsample of four bioclimatic variables after performing a correlation test using the software ENM-Tools version 1.3 (Warren et al. 2008). When the correlation of a pair of variables exceeded 0.7, we selected the variable that was more relevant based on physiological and ecological requirements of the four plant species. That way, we used annual mean temperature (BIO1), monthly temperature range (BIO2), annual precipitation (BIO12) and precipitation seasonality (BIO15) for modelling. 75% of the data were used to build the SDM model, while the remaining 25% were used to test it. We selected an average model obtained from 50 replicates for the regional models and 20 for the global models. We used the $\beta = 1$ parameter to regulate an excess of parametrization (Phillips & Dudík, 2008) and the "do-clamping" option to prevent environmental extrapolations outside the range of the training data. We used 10 times more pseudoabsences than the number of occurrences to build the models (Beaumont et al. 2009). To test the accuracy of the models, we used the area under the curve in a ROC curve analysis (AUC index) (Hirzel et al. 2006).

We adopted a theoretical framework suggested by Gallien et al. (2012) to identify the establishment stage of the four species based on a comparison of the global and regional models' predictions at the regional scale for each observed presence. This framework allows us to identify four stages of establishment (Gallien et al. 2012) i.e. (i) when most presences are found in a suitable area shared by both regional and global models, the population is considered stable, (ii) when most presences are found in a suitable area of the global model, but are absent from those of the regional models, the population is engaged in the colonization process, (iii) when most presences are found in the suitable areas from the regional models but are absent from those of the global models, the population is adapting to its new biotic and/or abiotic conditions not predicted from the fundamental niche and (iv) when most presences fall outside suitable areas predicted by both models, the population is sinking.

3.2.5. Hotspots mapping

The combination of global and regional models provides a risk map highlighting the hotspots areas of invasion probability in relation to the fundamental niche requirements of the species, but also in relation to local specificities. The hotspots assessment method that was developed and used in this study is fundamentally a simple raster algebra operation of the two geospatial rasters: the rasters of both global and regional models that contains the probabilities of a species being in a certain cell area. The raster that shows hotspots areas of the four non-native plant species on Navarino Island is obtained by the product of these two rasters. The final hotspots map was then reclassified in four categories of risk: null, low, average, high, extreme.

All GIS analyses were performed using ArcGIS version 10.6.1 (ESRI).

3.3. Results

3.3.1. Species niche dynamics

The first two principal components of the PCA correlation circles explained all between 79,6% and 81,1% of the variation of the data (fig.4). The principal component analysis (PCA) results were similar for all four species. Overlap between species non-native and native niche was small (Schoener's D= [0,013-0,400]) which is also demonstrated by the small niche fraction conserved in the non-native range (S= [0,005-0,011]). Moreover, a high proportion of species densities in the non-native niche was found in different environmental conditions to the native niche (E= [0,982-0,995]) and results indicate that there is no potential space of the non-native niche that has not yet been occupied in the native range (U= 0).

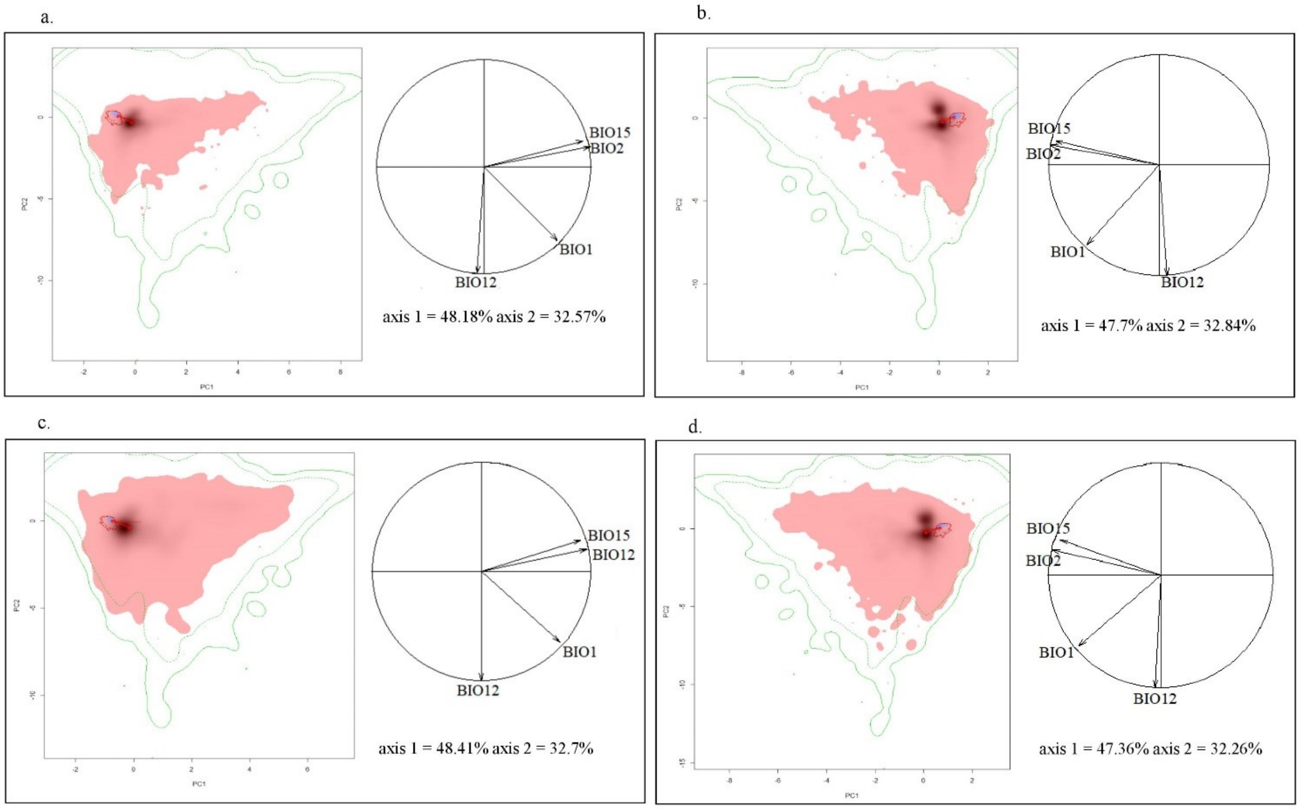

Figure 4. Principal Component Analysis of the climatic niche of the a. *Bellis perennis*; b. *Cerastium fontanum*; c. *Taraxacum officinale*; d. *Trifolium repens* in their non-native range (red). Blue area corresponds to niche areas shared in both native and non-native ranges. Solid and dashed lines show 100% and 75% of the climatic envelope from the native (green) and from the non-native range (red), respectively. Red area is the expanded niche in the non-native range. Red arrow shows the niche centroid shift and dark cells represent zones with higher occurrence densities in the non-native niche (Navarino Island). Correlation circles show the correspondence between annual mean temperature (BIO1), monthly temperature (BIO2), annual precipitation (BIO12) and precipitation seasonality (BIO15) along the two principal components axis.

3.3.2. Species stage of establishment

Regional and global models revealed that all four species are mostly stabilized populations (stabilized population rate = [65% - 84%]), but also revealed a significant regional colonization percentage for all four species ([9% - 35%]) (fig.5). Only *B. perennis* showed a percentage of sink population (6%) while no species presented local adaptation.

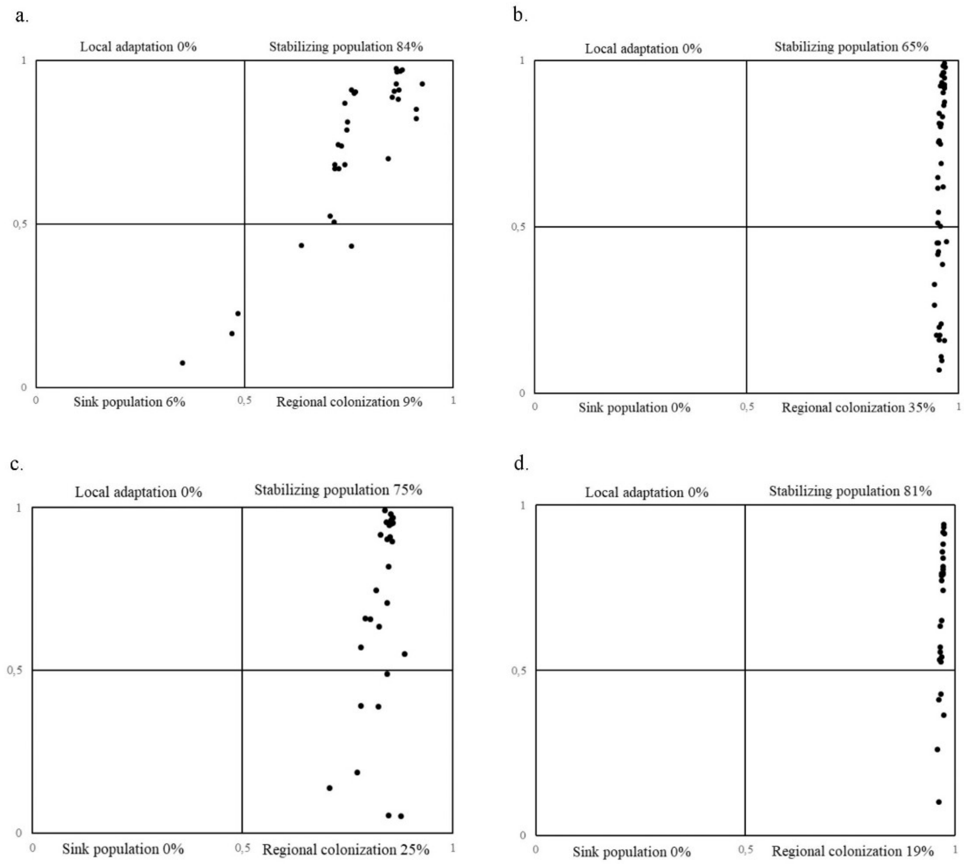

Figure 5. Niche space showing the establishment stage (i.e. local adaptation, stabilizing population, sink population, regional colonization) of a. *Bellis perennis*; b. *Cerastium fontanum*; c. *Taraxacum officinale*; d. *Trifolium repens* on Navarino Island, southern Chile.

3.3.3. Models performance and hotspots mapping

We found a good performance for each model, with AUC values ranging from 0,895 to 0,981 for regional models and from 0,846 to 0,901 for global models. The relative contributions of each environmental variables to the MaxEnt model are shown in Table 1. BIO1 (annual temperature) ($\bar{x}$ regional = 39,7%; $\bar{x}$ global = 38,1%) and BIO12 (annual precipitation) ($\bar{x}$ regional = 53,9%; $\bar{x}$ global = 38,8%) were the most important environmental variables determining the distribution of the four species. BIO2 (monthly temperature range) ($\bar{x}$ regional = 1,8%; $\bar{x}$ global = 3,1%) and BIO15 (precipitation seasonality) ($\bar{x}$ regional = 4,6%; $\bar{x}$ global = 23,8%) were the least contributing variables for the species.

Table 4. Relative contribution of each environmental variables of *B. perennis*, *C. fontanum*, *T. officinale* and *T. repens* to MaxEnt global and regional models on Navarino, southern Chile.

Species	**Regional models**				**Global models**			
	BIO1	BIO2	BIO12	BIO15	BIO1	BIO2	BIO12	BIO15
B. perennis	38,5	1,7	56,7	3,1	47,9	3,6	17,4	31,1
C. fontanum	25,8	2,5	67,8	3,8	30,8	6,2	47,4	30,8
T. officinale	42,9	1,7	49,2	6,1	40,9	1,2	39,9	17,9
T. repens	51,5	1,1	42	5,3	32,8	1,4	50,4	15,2
Average ($\bar{x}$)	**39,68**	**1,75**	**53,93**	**4,58**	**38,10**	**3,10**	**38,78**	**23,75**

The combination of global and regional models showed that the four species hotspots are located on the southern coast of the island and extend north way depending on the species (fig.6). Species with wider distribution potentials are *C. fontanum* and *T. officinale*. *B. perennis* is the species with the smallest distribution area but shows higher probabilities of presence compared to *T. repens* (fig.6).

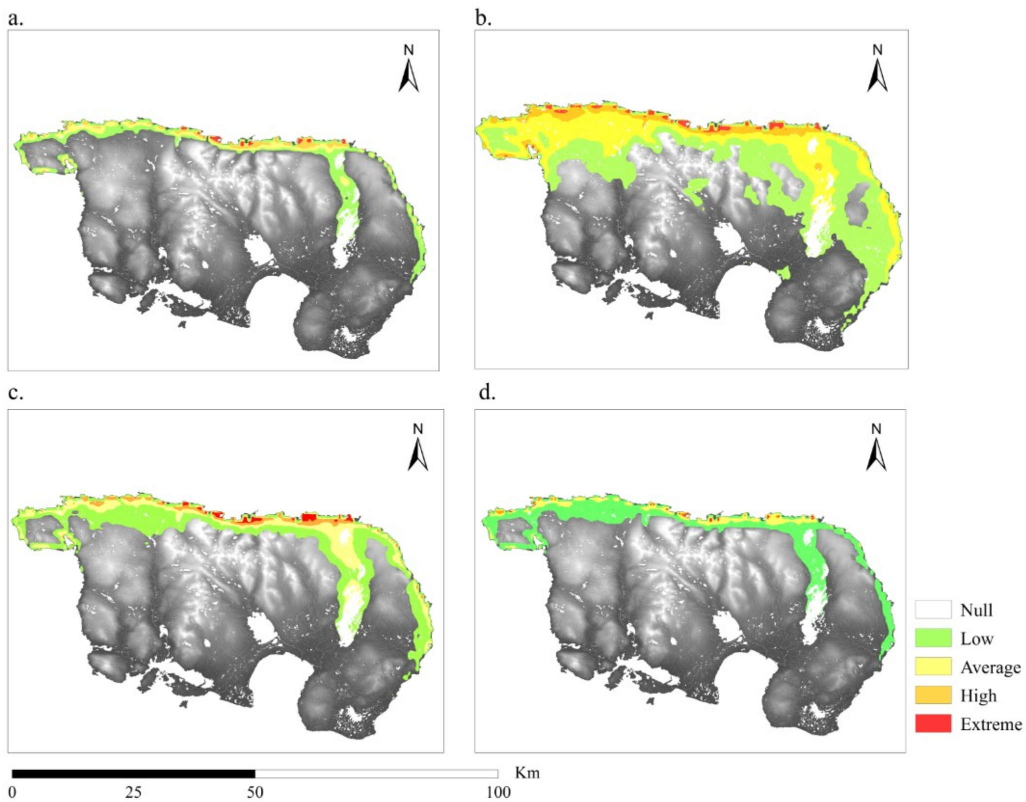

Figure 6. Hotspots mapping of a. *Bellis perennis*; b. *Cerastium fontanum*; c. *Taraxacum officinale*; d. *Trifolium repens* showing species occurrences risk areas (null, low, average, high, extreme) in Navarino, southern Chile.

3.4. Discussion and conclusion

We investigated niche dynamics, establishment stage, and hotspots of four non-native plant species (*Bellis perennis*, *Cerastium fontanum*, *Taraxacum officinale* and *Trifolium repens*) in a remote sub-Antarctic island within the Cape Horn Biosphere Reserve. To the first initial question "have the four species conserved their climatic niche on Navarino Island?", this study has shown that *B. perennis*, *C. fontanum*, *T. officinale* and *T. repens* all occupy a different niche on Navarino Island compared to their native range. Niche stability measures also indicated a small proportion of the environmental conditions present in both native and non-native ranges and thus showed that niche were not conserved on Navarino. Moreover, niche expansion measure showed that the four species have established in non-analog climates relative to the native range and demonstrated a strong plasticity. Plasticity is the ability of a plant species to modify its physiology or morphology in response to environmental conditions changes (Donoghue and Edwards, 2014). It should be noted, however, that results should be interpreted guardedly because our models do not account for microclimates available to the species. Indeed, as we also model global distribution, we selected a dataset of spatial resolution easier to manipulate and thus illustrate macroclimate responses at the population-level of the four species rather than individual responses (Kumar et al. 2015). We also recognize the bias induced by the sampling method, largely determined by the accessibility of the sites, adding, perhaps, uncertainty to the models. Yet, it has been widely argued that non-native plant species are much more common in human-impacted areas (Early et al. 2016; Lodge, 1993; Mack et al. 2000; Mullin, Anderson, Ditomaso, Eplee & Getsinger, 2000). Consequently, model results should be used as an informative tool for preventive measures.

Detecting significant deviations from niche conservatism may highlight non-native species that exhibit evolutionary or ecological changes which is a key indicator in an era of rapid climate change (Petitpierre et al. 2012). Along with plasticity, some other functional traits could also drive niche shifts. Over the last few decades, researchers have searched for trait differences between widely dispersed non-native species and native species (Hamilton et al. 2005; Kolar & Lodge, 2001; Thompson et al. 2001), but it has not been possible to draw generalizable conclusions since it seems that the traits that favor establishment and dispersion are context-dependent (Daehler, 2003). These idiosyncrasies of non-native species make it difficult to predict accurately their possible dynamics (Ibáñez et al. 2009). Other factors such as novel biotic interactions between species may play a more important role in shaping the outcomes of species establishment and dispersion (Gallagher et al., 2010). Studies on positive interactions between non-native and native species focusing on sub-Antarctic contexts are scarce, but Anderson et al. (2006) found that North American beavers (*Castor canadensis*) could facilitate the establishment of *B. perennis*, *C. fontanum*, *T. officinale* and *T. repens* along with other non-native plant species in creating meadows on Navarino. Moreover, a study of Cavieres, Quiroz & Molina-Montenegro (2008) showed that native nurse cushion species in the high Andes of central Chile could facilitate the establishment of *T. officinale*. As one of them (*Azorella monantha*) also reach 55°S, it is critical to monitor the distribution of non-native plant species and assess possible positive interactions between species in a sub-Antarctic context.

To the second initial question "have the four species reached a geographical equilibrium or can we expect them to spread further throughout the island?", this study has shown that *B. perennis*, *C. fontanum*, *T. officinale* and *T. repens* all presented an unfilling rate of 0% which indicates an absence of suitable unoccupied sites in the non-native range. Moreover, establishment stage of the four species all showed mostly stabilized populations. Stabilizing occurs when non-native populations hit dispersal barriers, reach unsuitable abiotic conditions or face biotic resistance (Araújo and Pearson 2005). Literature also suggests a positive association between the residence time in a novel range and the degree of equilibrium of the species (Pyšek, Richardson & Williamson, 2004; Wilson et al. 2007). Indeed, residence time could be a useful predictor for determining the degree of stability of the four non-native plant species on Navarino. In Tierra del Fuego, southern Chile, the earliest records of non-native plants species date back to 1882, thirteen years after the first resident Europeans arrived, but there is evidence that some may have arrived earlier (Moore & Goodall, 1977). No such early records have been established specifically for Navarino, however the establishments of farms on Navarino in the early twentieth century contributed to the intentional introduction of many herbaceous species for the creation of grazing meadows, as well as contributed to the unintentional introductions of seeds through animals' fur (Rozzi et al. 2004). Such a range could have left enough time for the species to reach the equilibrium. In this case, this would indicate the need to monitor new introductions on Navarino that could evolve with different dynamics, especially in a context of climate change.

While it is true that spatial distribution of plant species depends on a range of abiotic and biotic factors, especially in cold and remotes areas such as sub-Antarctic, human intervention has proven to account significantly to non-native species distribution (Lembrechts et al. 2016). Navarino currently face several anthropogenic disturbances that could confer competitive advantages to non-native plant species and thus facilitate their establishment and dispersal, such as the exponential growth of the tourism industry through cruise ships (García, 2004), the construction of new roads and infrastructures (Sernatur, 2014) and the spread of *Castor canadensis*, which create forest corridors and open habitats (Anderson et al. 2006). Even if this study showed that populations are stabilized, growing anthropic activities could lead into the introduction of new non-native plant species or could create new pathways throughout Navarino Island. Then, it should not be assumed that *B. perennis*, *C. fontanum*, *T. officinale* and *T. repens* or other non-native plant species will not have impacts on Navarino Island because they have not been detected yet. As Simberloff et al. (2013) mentioned: "certain extremely consequential impacts, particularly at the ecosystem level, are not readily detected", which reinforces the need for a long-term monitoring of non-native species on Navarino island where little data on non-native plants are available. Since even widespread non-native species may have negligible effects (Hulme, 2012) and because most of the impacts from non-native species are context-dependent (Bartz & Kowarik, 2019), it cannot be alleged that these species will cause impacts on Navarino, but it is imperative that some form of monitoring system be in place so that invasions can be detected in the earliest phases. Yet, most non-native species policies focus primarily on addressing only detrimental invasive species (Puth & Post, 2005).

Because it has been shown that human influence associated with rapid social and economic changes at different scales can significantly influence the fate of local and regional biological diversity (Cerda, Barkmann & Margrraf, 2014), it is particularly important to incorporate stakeholders' participation into prevention and monitoring actions. As Novoa et al. (2015, p. 308) mentioned: "The key challenge is to find ways of regulating movements of non-native species that are effective, are based on objective, transparent, and defendable criteria, enjoy support from most stakeholders and are aligned with international, national, and regional policies and priorities." As previously said, this is particularly relevant since the island represents a stepping stone between the South American continent and the Antarctic and non-native propagules might be transported from the CHBR further south (Rozzi et al. 2007). Currently, *B. perennis*, *C. fontanum*, *T. officinale* and *T. repens* are all found along the sub-Antarctic islands in different densities (Frenot et al. 2005; Lebouvier et al. 2011) but remain absent from the Antarctic. Careful attention should be paid to the Fildes Bay maritime station, which is owned by the Chilean Navy, as it is the most important air strip used for station supply and personnel transportation, as well as for tourist transfers from South America to cruise ships (Peter et al. 2008).

Our study therefore contains important points for decision-makers and managers of the Cape Horn Biosphere Reserve with respect to niche dynamics, establishment stage and hotspots of *Bellis perennis*, *Cerastium fontanum*, *Taraxacum officinale* and *Trifolium repens* which will need to be considered to prevent further spread or new establishments of non-native plant species through Navarino, other sub-Antarctic islands and the Antarctic.

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References

Anderson, C. B., Griffith, C. R., Rosemond, A. D., Rozzi, R., & Dollenz, O. (2006). The effects of invasive North American beavers on riparian plant communities in Cape Horn, Chile. *Biological Conservation*, *128*(4), 467–474. https://doi.org/10.1016/j.biocon.2005.10.011

Andrewartha, H. G., & Birch, L. C. (1986). *The Ecological Web: More on the Distribution and Abundance of Animals*. University of Chicago Press.

Araújo, M. B., & Pearson, R. G. (2005). Equilibrium of species' distributions with climate. *Ecography*, *28*(5), 693–695. https://doi.org/10.1111/j.2005.0906-7590.04253.x

Arroyo, M. T. K., Riveros, M., Peñaloza, A., Cavieres, L., & Faggi, A. M. (1996). Phytogeographic Relationships and Regional Richness Patterns of the Cool Temperate Rainforest Flora of Southern South America. In R. G. Lawford, E. Fuentes, & P. B. Alaback (Eds.), *High-Latitude Rainforests and Associated Ecosystems of the West Coast of the Americas: Climate, Hydrology, Ecology, and Conservation* (pp. 134–172). https://doi.org/10.1007/978-1-4612-3970-3_8

Bartz, R., & Kowarik, I. (2019). Assessing the environmental impacts of invasive alien plants: A review of assessment approaches. *NeoBiota*, *43*, 69–99. https://doi.org/10.3897/neobiota.43.30122

Beaumont, L. J., Gallagher, R. V., Thuiller, W., Downey, P. O., Leishman, M. R., & Hughes, L. (2009). Different climatic envelopes among invasive populations may lead to underestimations of current and future biological invasions. *Diversity and Distributions*, 409–420. https://doi.org/10.1111/j.1472-4642.2008.00547.x@10.1111/(ISSN)1472-4642.species-distribution-models-in-conservation-biogeography

Bennett, J. R., Shaw, J. D., Terauds, A., Smol, J. P., Aerts, R., Bergstrom, D. M., … Possingham, H. P. (2015). Polar lessons learned: Long-term management based on shared threats in Arctic and Antarctic environments. *Frontiers in Ecology and the Environment*, *13*(6), 316–324. https://doi.org/10.1890/140315

Boria, R. A., Olson, L. E., Goodman, S. M., & Anderson, R. P. (2014). Spatial filtering to reduce sampling bias can improve the performance of ecological niche models. *Ecological Modelling*, *275*, 73–77. https://doi.org/10.1016/j.ecolmodel.2013.12.012

Broennimann, O., Fitzpatrick, M. C., Pearman, P. B., Petitpierre, B., Pellissier, L., Yoccoz, N. G., … Guisan, A. (2012). Measuring ecological niche overlap from occurrence and spatial environmental data. *Global Ecology and Biogeography*, *21*(4), 481–497. https://doi.org/10.1111/j.1466-8238.2011.00698.x

Catford, J. A., Vesk, P. A., White, M. D., & Wintle, B. A. (2011). Hotspots of plant invasion predicted by propagule pressure and ecosystem characteristics: Hotspots of plant invasion. *Diversity and Distributions*, *17*(6), 1099–1110. https://doi.org/10.1111/j.1472-4642.2011.00794.x

Cavieres, L. A., Quiroz, C. L., & Molina-Montenegro, M. A. (2008). Facilitation of the non-native Taraxacum officinale by native nurse cushion species in the high Andes of central Chile: Are there differences between nurses? *Functional Ecology*, *22*, 148–156. https://doi.org/10.1111/j.1365-2435.2007.01338.x

Cerda, C., Barkmann, J., & Marggraf, R. (2014). Non-market economic valuation of the benefits provided by temperate ecosystems at the extreme south of the Americas. *Regional Environmental Change*, *14*(4), 1517–1531. https://doi.org/10.1007/s10113-014-0591-2

Chown, S. L., & Convey, P. (2016). Antarctic Entomology. *Annual Review of Entomology*, *61*(1), 119–137. https://doi.org/10.1146/annurev-ento-010715-023537

Daehler, C. C. (2003). Performance Comparisons of Co-Occurring Native and Alien Invasive Plants: Implications for Conservation and Restoration. *Annual Review of Ecology, Evolution, and Systematics*, *34*(1), 183–211. https://doi.org/10.1146/annurev.ecolsys.34.011802.132403

Donoghue, M. J., & Edwards, E. J. (2014). Biome Shifts and Niche Evolution in Plants. *Annual Review of Ecology, Evolution, and Systematics*, *45*(1), 547–572. https://doi.org/10.1146/annurev-ecolsys-120213-091905

Early, R., Bradley, B. A., Dukes, J. S., Lawler, J. J., Olden, J. D., Blumenthal, D. M., … Tatem, A. J. (2016). Global threats from invasive alien species in the twenty-first century and national response capacities. Nature Communications, 7, 12485. https://doi.org/10.1038/ncomms12485

Ehrenfeld, J. G. (2003). Effects of Exotic Plant Invasions on Soil Nutrient Cycling Processes. *Ecosystems*, *6*(6), 503–523. https://doi.org/10.1007/s10021-002-0151-3

Elith, J., & Leathwick, J. R. (2009). Species Distribution Models: Ecological Explanation and Prediction Across Space and Time. *Annual Review of Ecology, Evolution, and Systematics*, *40*(1), 677–697. https://doi.org/10.1146/annurev.ecolsys.110308.120159

Faúndez, E. I., & Carvajal, M. A. (2014). Bed Bugs Are Back and Also Arriving Is the Southernmost Record of Cimex lectularius (Heteroptera: Cimicidae) in South America. *Journal of Medical Entomology*, *51*(5), 1073–1076. https://doi.org/10.1603/ME13206

Franklin, J. (2013). Species distribution models in conservation biogeography: Developments and challenges. *Diversity and Distributions*, *19*(10), 1217–1223. https://doi.org/10.1111/ddi.12125

Frenot, Y., Chown, S. L., Whinam, J., Selkirk, P. M., Convey, P., Skotnicki, M., & Bergstrom, D. M. (2005). Biological invasions in the Antarctic: Extent, impacts and implications. *Biological Reviews*, *80*(1), 45–72. https://doi.org/10.1017/S1464793104006542

Gallagher, R. V., Beaumont, L. J., Hughes, L., & Leishman, M. R. (2010). Evidence for climatic niche and biome shifts between native and novel ranges in plant species introduced to Australia. *Journal of Ecology*, 790–799. https://doi.org/10.1111/j.1365-2745.2010.01677.x@10.1111/(ISSN)1365-2745.GLOBWA

Gallien, L., Douzet, R., Pratte, S., Zimmermann, N. E., & Thuiller, W. (2012). Invasive species distribution models - how violating the equilibrium assumption can create new insights: Beyond the equilibrium assumption of SDMs. *Global Ecology and Biogeography*, *21*(11), 1126–1136. https://doi.org/10.1111/j.1466-8238.2012.00768.x

García, M. (2004). Ecotourism in Cape Horn. In R. Rozzi, F. Massardo, & C. Anderson (Eds.), *The Cape Horn Biosphere Reserve: A Proposal for Conservation and Tourism to Achieve Sustainable Development at the Southern End of the Americas.* (pp. 177–204). University of Magallanes Press.

Godley, E. J. (1960). The Botany of Southern Chile in Relation to New Zealand and the Subantarctic. *Proceedings of the Royal Society of London. Series B, Biological Sciences*, *152*(949), 457–475. Retrieved from JSTOR.

Guisan, A., Petitpierre, B., Broennimann, O., Daehler, C., & Kueffer, C. (2014). Unifying niche shift studies: Insights from biological invasions. *Trends in Ecology & Evolution*, *29*(5), 260–269. https://doi.org/10.1016/j.tree.2014.02.009

Hamilton, M. A., Murray, B. R., Cadotte, M. W., Hose, G. C., Baker, A. C., Harris, C. J., & Licari, D. (2005). Life-history correlates of plant invasiveness at regional and continental scales. *Ecology Letters*, *8*(10), 1066–1074. https://doi.org/10.1111/j.1461-0248.2005.00809.x

Hirzel, A. H., Le Lay, G., Helfer, V., Randin, C., & Guisan, A. (2006). Evaluating the ability of habitat suitability models to predict species presences. *Ecological Modelling*, *199*(2), 142–152. https://doi.org/10.1016/j.ecolmodel.2006.05.017

Hulme, P. E. (2012). Weed risk assessment: A way forward or a waste of time? *Journal of Applied Ecology*, *49*(1), 10–19. https://doi.org/10.1111/j.1365-2664.2011.02069.x

Ibáñez, I., Silander Jr, John. A., Allen, J. M., Treanor, S. A., & Wilson, A. (2009). Identifying hotspots for plant invasions and forecasting focal points of further spread: Hot spots for plant invasions. *Journal of Applied Ecology*, *46*(6), 1219–1228. https://doi.org/10.1111/j.1365-2664.2009.01736.x

IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* (T. F. F. Stocker, D. Quin, G.-K. Plattner, M. M.B. Tignor, S. Allen K., J. Boschung, … P. M. Midgley, Eds.).

Kolar, C. S., & Lodge, D. M. (2001). Progress in invasion biology: Predicting invaders. *Trends in Ecology & Evolution*, *16*(4), 199–204. https://doi.org/10.1016/S0169-5347(01)02101-2

Kumar, S., LeBrun, E. G., Stohlgren, T. J., Stabach, J. A., McDonald, D. L., Oi, D. H., & LaPolla, J. S. (2015). Evidence of niche shift and global invasion potential of the Tawny Crazy ant, *Nylanderia fulva*. *Ecology and Evolution*, *5*(20), 4628–4641. https://doi.org/10.1002/ece3.1737

Lebouvier, M., Laparie, M., Hullé, M., Marais, A., Cozic, Y., Lalouette, L., … Renault, D. (2011). The significance of the sub-Antarctic Kerguelen Islands for the assessment of the vulnerability of native communities to climate change, alien insect invasions and plant viruses. *Biological Invasions*, *13*(5), 1195–1208. https://doi.org/10.1007/s10530-011-9946-5

Lembrechts, J. J., Pauchard, A., Lenoir, J., Nuñez, M. A., Geron, C., Ven, A., … Milbau, A. (2016). Disturbance is the key to plant invasions in cold environments. *Proceedings of the*

National Academy of Sciences, *113*(49), 14061–14066. https://doi.org/10.1073/pnas.1608980113

Liao, C., Peng, R., Luo, Y., Zhou, X., Wu, X., Fang, C., … Li, B. (2008). Altered ecosystem carbon and nitrogen cycles by plant invasion: A meta-analysis. *New Phytologist*, *177*(3), 706–714. https://doi.org/10.1111/j.1469-8137.2007.02290.x

Lodge, D. M. (1993). Biological invasions: Lessons for ecology. Trends in Evolution and Ecology, (8), 133–137.

Mack, R. N., Simberloff, D., Lonsdale, W. M., Evans, H., Clout, M., & Bazzaz, F. A. (2000). Biotic Invasions: Causes, Epidemiology, Global Consequences, and Control. Ecological Applications, 10(3), 689–710. https://doi.org/10.1890/1051-0761(2000)010[0689:BICEGC]2.0.CO;2

McGeoch, M. A., Shaw, J. D., Terauds, A., Lee, J. E., & Chown, S. L. (2015). Monitoring biological invasion across the broader Antarctic: A baseline and indicator framework. *Global Environmental Change*, *32*, 108–125. https://doi.org/10.1016/j.gloenvcha.2014.12.012

Molina, J. A., Lumbreras, A., Benavent-González, A., Rozzi, R., & Sancho, L. G. (2016). Plant communities as bioclimate indicators on Isla Navarino, one of the southernmost forested areas of the world. *Gayana. Botánica*, *73*(2), 391–401. https://doi.org/10.4067/S0717-66432016000200391

Moore, D. M., & Goodall, R. N. (1977). La flora adventicia de Tierra del Fuego. *Anales Del Instituto de La Patagonia*, *8*, 263–274.

Mullin, B. H., Anderson, L. W. J., Ditomaso, J. M., Eplee, R. E., & Getsinger, K. D. (2000). Invasive plant species. Council for Agricultural Science and Technology, 13, 1–18.

Novoa, A., Kaplan, H., Kumschick, S., Wilson, J. R. U., & Richardson, D. M. (2015). Soft Touch or Heavy Hand? Legislative Approaches for Preventing Invasions: Insights from Cacti in South Africa. *Invasive Plant Science and Management*, *8*(3), 307–316. https://doi.org/10.1614/IPSM-D-14-00073.1

O'Donnell, J., Gallagher, R. V., Wilson, P. D., Downey, P. O., Hughes, L., & Leishman, M. R. (2012). Invasion hotspots for non-native plants in Australia under current and future climates. *Global Change Biology*, *18*(2), 617–629. https://doi.org/10.1111/j.1365-2486.2011.02537.x

Ott, S., Hughes, K. A., Bölter, M., & Convey, P. (2006). Colonization processes. In D. M. Bergstrom, P. Convey, & A. H. L. Huiskes (Eds.), *Trends in Antarctic Terrestrial and Limnetic Ecosystems: Antarctica as a Global Indicator* (pp. 35–54). Retrieved from https://www.springer.com/gp/book/9781402052767

Owens, H. L., Campbell, L. P., Dornak, L. L., Saupe, E. E., Barve, N., Soberón, J., … Peterson, A. T. (2013). Constraints on interpretation of ecological niche models by limited environmental ranges on calibration areas. *Ecological Modelling*, *263*, 10–18. https://doi.org/10.1016/j.ecolmodel.2013.04.011

Parker, V. (2001). Listening to te Earth: a call for protection and restoration of habitats. In J. A. McNeely (Ed.), *The Great Reshuffling: Human Dimensions of Invasive Alien Species* (pp. 43–54). IUCN.

Peña-Gómez, F. T., Guerrero, P. C., Bizama, G., Duarte, M., & Bustamante, R. O. (2014). Climatic Niche Conservatism and Biogeographical Non-Equilibrium in Eschscholzia californica (Papaveraceae), an Invasive Plant in the Chilean Mediterranean Region. *PLoS ONE*, *9*(8), e105025. https://doi.org/10.1371/journal.pone.0105025

Perrings, C., Mooney, H., & Williamson, M. (2010). *Bioinvasions and Globalization: Ecology, Economics, Management, and Policy*. OUP Oxford.

Peter, H.-U., Buesser, C., Mustafa, O., & Pfeiffer, S. (2008). *Risk assessment for the Fildes Peninsula and Ardley Island, and development of management plans for their designation as Specially Protected or Specially Managed Areas.* (p. 344 p.). Dessau: German Federal Environment Agency.

Petitpierre, B., Kueffer, C., Broennimann, O., Randin, C., Daehler, C., & Guisan, A. (2012). Climatic Niche Shifts Are Rare Among Terrestrial Plant Invaders. *Science*, *335*(6074), 1344–1348. https://doi.org/10.1126/science.1215933

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*(3), 231–259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Phillips, S. J., & Dudík, M. (2008). Modeling of species distributions with Maxent: New extensions and a comprehensive evaluation. *Ecography*, *31*(2), 161–175. https://doi.org/10.1111/j.0906-7590.2008.5203.x

Pisano, V. E. (1981). Bosquejo fitogeográfico de Fuego-Patagonia. *Anales Del Instituto de La Patagonia*, *12*, 159–171.

Puth, L. M., & Post, D. M. (2005). Studying invasion: Have we missed the boat? *Ecology Letters*, *8*(7), 715–721. https://doi.org/10.1111/j.1461-0248.2005.00774.x

Pyšek, P., Jarošík, V., Hulme, P. E., Pergl, J., Hejda, M., Schaffner, U., & Vilà, M. (2012). A global assessment of invasive plant impacts on resident species, communities and ecosystems: The interaction of impact measures, invading species' traits and environment. *Global Change Biology*, *18*(5), 1725–1737. https://doi.org/10.1111/j.1365-2486.2011.02636.x

Pyšek, P., Richardson, D. M., & Williamson, M. (2004). Predicting and explaining plant invasions through analysis of source area floras: Some critical considerations. *Diversity and Distributions*, *10*(3), 179–187. https://doi.org/10.1111/j.1366-9516.2004.00079.x

Roura-Pascual, N., Brotons, L., Peterson, A. T., & Thuiller, W. (2009). Consensual predictions of potential distributional areas for invasive species: A case study of Argentine ants in the Iberian Peninsula. *Biological Invasions*, *11*(4), 1017–1031. https://doi.org/10.1007/s10530-008-9313-3

Rozzi, R., Charlin, R., Ippi, S., & Dollenz, O. (2004). Cabo de Hornos: Un parque nacional libre de especies exoticas en el confin de America. *Anales del Instituto de la Patagonia*, *32*, 55–62.

Rozzi, R., Massardo, F., Mansilla, A., Anderson, C. B., Berghöfer, A., Mansilla, M., … Barros, E. (2007). La Reserva de Biosfera Cabo de Hornos: Un desafio para la conservacion de la biodiversidad e implementacion del desarollo sustentable en el extremo austral de America. *Anales del Instituto de la Patagonia*, 16.

Sernatur. (2014). *Plan de Acción Región de Magallanes y Antarctica Chilena Sector Turismo 2014-2018*. Santiago de Chile: Sernatur.

Simberloff, D., Martin, J.-L., Genovesi, P., Maris, V., Wardle, D. A., Aronson, J., … Vilà, M. (2013). Impacts of biological invasions: What's what and the way forward. *Trends in Ecology & Evolution*, *28*(1), 58–66. https://doi.org/10.1016/j.tree.2012.07.013

Taucare-Ríos, A., Bizama, G., & Bustamante, R. O. (2016). Using Global and Regional Species Distribution Models (SDM) to Infer the Invasive Stage of *Latrodectus geometricus* (Araneae: Theridiidae) in the Americas. *Environmental Entomology*, *45*(6), 1379–1385. https://doi.org/10.1093/ee/nvw118

Thompson, K., Hodgson, J. G., Grime, J. P., & Burke, M. J. W. (2001). Plant traits and temporal scale: Evidence from a 5-year invasion experiment using native species. *Journal of Ecology*, *89*(6), 1054–1060. https://doi.org/10.1111/j.1365-2745.2001.00627.x

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., … Snape, I. (2009). Impacts of local human activities on the Antarctic environment. *Antarctic Science*, *21*(1), 3–33. https://doi.org/10.1017/S0954102009001722

Tuhkanen, S., Kuokka, I., Hyvönen, J., Streenroos, S., & Niermelä, J. (1990). Tierra del Fuego as a target for biogeographical research in the past and present. *Anales Del Instituto de La Patagonia*. Retrieved from http://bibliotecadigital.umag.cl/handle/20.500.11893/1433

Vanbergen, A. J., Espíndola, A., & Aizen, M. A. (2018). Risks to pollinators and pollination from invasive alien species. *Nature Ecology & Evolution*, *2*(1), 16. https://doi.org/10.1038/s41559-017-0412-3

Vetaas, O. R. (2002). Realized and potential climate niche: A comparison of four Rhododendron tree species. *Journal of Biogeography*, *29*(4), 545–554. https://doi.org/10.1046/j.1365-2699.2002.00694.x

Vilà, M., Williamson, M., & Lonsdale, M. (2004). Competition Experiments on Alien Weeds with Crops: Lessons for Measuring Plant Invasion Impact? *Biological Invasions*, *6*(1), 59–69. https://doi.org/10.1023/B:BINV.0000010122.77024.8a

Warren, D. L., Glor, R. E., & Turelli, M. (2008). Environmental Niche Equivalency Versus Conservatism: Quantitative Approaches to Niche Evolution. *Evolution*, *62*(11), 2868–2883. https://doi.org/10.1111/j.1558-5646.2008.00482.x

Westphal, M. I., Browne, M., MacKinnon, K., & Noble, I. (2008). The link between international trade and the global distribution of invasive alien species. *Biological Invasions*, *10*(4), 391–398. https://doi.org/10.1007/s10530-007-9138-5

Wharton, T. N., & Kriticos, D. J. (2004). BIODIVERSITY The fundamental and realized niche of RESEARCH the Monterey Pine aphid, Essigella. *Diversity and Distributions*, 10.

Wiens, J. J., & Graham, C. H. (2005). Niche Conservatism: Integrating Evolution, Ecology, and Conservation Biology. *Annual Review of Ecology, Evolution, and Systematics*, *36*(1), 519–539. https://doi.org/10.1146/annurev.ecolsys.36.102803.095431

Wilson, J. R. U., Richardson, D. M., Rouget, M., Procheş, Ş., Amis, M. A., Henderson, L., & Thuiller, W. (2007). Residence time and potential range: Crucial considerations in modelling plant invasions. *Diversity and Distributions*, *13*(1), 11–22. https://doi.org/10.1111/j.1366-9516.2006.00302.x

Wisz, M. S., Hijmans, R. J., Li, J., Peterson, A. T., Graham, C. H., Guisan, A., & NCEAS Predicting Species Distributions Working Group†. (2008). Effects of sample size on the performance of species distribution models. *Diversity and Distributions*, *14*(5), 763–773. https://doi.org/10.1111/j.1472-4642.2008.00482.x

Woodward, F. I. (1987). *Climate and Plant Distribution*. Cambridge University Press.

Conclusion

Dans la littérature scientifique, un nombre élevé d'études emploient inexorablement la formule « invasive alien species are a major threat to global biodiversity » (voir p.ex. Chornesky & Randall, 2003 ; Early et al. 2016; Mullin et al. 2000; Simberloff, 2005). À l'heure où le clivage entre l'humain et la nature s'amenuise, la question des espèces non-natives est intéressante, car elle questionne plusieurs principes qui n'ont traditionnellement pas été remis en question. D'une part, dans un contexte de changements socio-environnementaux tel que nous les connaissons aujourd'hui, les espèces non-natives, que Pearson (2015) a nommé « the new wild », pourraient témoigner de l'adaptabilité des écosystèmes à de tels changements. En ce sens, vouloir préserver certaines espèces « fragiles, natives et vulnérables » dans un écosystème dynamique et en changement pourrait sembler problématique. Cette valorisation, voire même imposition, d'une « authenticité » à travers la « nativité » fait-elle preuve d'une forme de paternalisme, nostalgique d'une époque révolue? La façon dont est traité la question des espèces non-natives serait-elle représentative d'un comportement typiquement *blanc*? Évidemment, le but n'est pas de répondre exhaustivement à ces questions dans cette section, mais plutôt de questionner des principes « scientifiques » que l'on considère parfois acquis et qui reproduisent des structures de pouvoir.

En gardant conscience des privilèges intrinsèques à ma condition et de ce que tout cela implique, ce mémoire s'est ainsi questionné sur l'enjeu des espèces végétales non-natives en contexte insulaire en intégrant les observations locales aux savoirs scientifiques dans une perspective multidisciplinaire. Plus précisément, ce mémoire a tenté de comprendre comment se construisent et se façonnent les relations et interactions humains-plantes non-natives sur l'île Navarino ainsi que d'identifier l'état actuel ainsi que les zones de points chauds de quatre de ces espèces.

Le second chapitre du présent mémoire a révélé que bien que les parties prenantes de Navarino soient majoritairement capable de définir le concept général d'espèces non-natives, l'application de celui-ci au contexte local et plus particulièrement végétal présente des lacunes. En effet, il y a un manque d'informations disponibles pour les parties prenantes en ce qui a trait aux plantes non-natives sur l'île Navarino. Les résultats d'entrevues ont néanmoins révélé plusieurs valeurs positives associées aux plantes non-natives à Navarino, parmi lesquelles la valeur esthétique était la plus mentionnée. Tandis que certaines plantes étaient strictement associées à des valeurs positives (i.e. la pâquerette et le trèfle blanc), la plupart des espèces étaient associées à la fois à des valeurs positives et négatives. Toutefois, ce chapitre a servi à mettre en lumière que la majorité des parties prenantes était indifférente à la gestion des espèces herbacées non-natives présentes sur l'île de Navarino.

Le troisième chapitre du présent mémoire a révélé un changement dans la niche réalisée de quatre espèces particulièrement abondantes sur l'île de Navarino (i.e. la pâquerette, le céraiste commun, le pissenlit et le trèfle blanc) comparativement à leur niche fondamentale. Ces résultats mettent en lumière leur plasticité substantielle permettant de survivre dans des fourchettes climatiques variées. Les analyses en composantes principales faites dans ce chapitre ont servi à démontrer que les températures et précipitations annuelles étaient les variables les plus déterminantes de la distribution des espèces sur l'île. Bien que les résultats indiquent que les populations des quatre espèces sont présentement stables à Navarino, la cartographie des points chauds pourrait servir d'outil pour les parties prenantes impliquées dans la gestion de la RBCH.

Au cours de la maîtrise, je me suis questionnée sur comment et pourquoi le savoir circule-t-il? Je me suis également questionné sur la manière efficace de faire circuler « le mien ». Fazey et al. (2013) définissent l'échange de connaissances comme un processus consistant à générer, partager et/ou utiliser des connaissances au moyen de diverses méthodes adaptées au contexte, aux objectifs et aux parties prenantes. En ce sens, à l'hiver 2019, un retour sur le terrain a été effectué dans le but de partager les résultats de la présente étude à la communauté. Une activité de bingo des plantes a été organisée avec le camp de jour afin que les jeunes puissent venir avec nous sur le terrain et identifier les plantes non-natives et natives de leur environnement. Une autre activité de transfert de connaissances sur laquelle nous travaillons présentement est un court document explicatif et illustré montrant les différents résultats obtenus. Puisqu'il a été démontré que les barrières linguistiques peuvent entraîner des lacunes dans la disponibilité de l'information (Amano, González-Varo & Sutherland, 2016), toutes les activités de transfert des connaissances ont été et seront faites en espagnol. Ainsi, ce mémoire n'aurait pas trouvé son sens sans le partage bilatéral des connaissances duquel il a profité.

En somme, il s'agit d'une première recherche sur les espèces végétales non-natives d'une île subantarctique chilienne intégrant les observations locales aux savoirs scientifiques dans une perspective multidisciplinaire. Compte tenu du peu d'études faites sur le sujet, du manque d'informations disponibles sur les plantes non-natives sur l'île de Navarino ainsi que sur l'importance d'intégrer les parties prenantes aux activités scientifiques, il pourrait être particulièrement intéressant d'élaborer un projet de « citizen science » (i.e. science participative) à Navarino. En plus de contribuer à l'avancement des connaissances relatives au sujet, la science participative permet d'outiller les parties prenantes à reconnaître les espèces (Bonney et al. 2009). Puisqu'un nombre croissant d'études se penche maintenant sur les espèces non-natives à Navarino tels que vertébrés (Schüttler et al. 2019) et invertébrés (Rendoll-Cárcamo et al. 2016; 2017), un projet de science participative qui intégrerait plusieurs espèces non-natives pourrait être pertinent dans ce contexte.

Bibliographie

Adams, W. M., & Hutton, J. (2007). People, Parks and Poverty: Political Ecology and Biodiversity Conservation. *Conservation & Society*, *5*(2), 147–183.

Agrawal, A., & Gibson, C. C. (1999). Enchantment and Disenchantment: The Role of Community in Natural Resource Conservation. *World Development*, *27*(4), 629–649. https://doi.org/10.1016/S0305-750X(98)00161-2

Alpert, P., Bone, E., & Holzapfel, C. (2000). Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants. *Perspectives in Plant Ecology, Evolution and Systematics*, *3*(1), 52–66. https://doi.org/10.1078/1433-8319-00004

Amano, T., González-Varo, J. P., & Sutherland, W. J. (2016). Languages Are Still a Major Barrier to Global Science. PLOS Biology, 14(12), e2000933. https://doi.org/10.1371/journal.pbio.2000933

Anderson, C. B., Griffith, C. R., Rosemond, A. D., Rozzi, R., & Dollenz, O. (2006). 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*(4), 467–474. https://doi.org/10.1016/j.biocon.2005.10.011

Anderson, L. G., Rocliffe, S., Haddaway, N. R., & Dunn, A. M. (2015). The Role of Tourism and Recreation in the Spread of Non-Native Species: A Systematic Review and Meta-Analysis. *PLOS ONE*, *10*(10), e0140833. https://doi.org/10.1371/journal.pone.0140833

Arroyo, M. T. K., Mihoc, M., Pliscoff, P., & Arroyo-Kalin, M. (2005). The Magellanic moorland. In L. H. Fraser & P. A. Keddy (Eds.), *The World's Largest Wetlands: Ecology and Conservation* (Cambridge University Press, pp. 424–445).

Auray, J.-P., Bailly, A., Derycke, P.-H., & Huriot, J.-M. (1994). *Encyclopédie d'économie spatiale : Concepts - comportements - organisations* (Economica). Paris.

Balmford, A., & Whitten, T. (2003). Who should pay for tropical conservation, and how could the costs be met? *Oryx*, *37*(2), 238–250. https://doi.org/10.1017/S0030605303000413

Barry, T., Secretariat, C., & Dickson, C. (2010). *Steering committee members*. 12.

Bartuszevige, A. M., & Endress, B. A. (2008). Do ungulates facilitate native and exotic plant spread? Seed disperal by cattle, elk and deer in northeastern Oregon. *Journal of Arid Environments*, *72*, 904–913.

Bennett, N. J., & Dearden, P. (2014). Why local people do not support conservation: Community perceptions of marine protected area livelihood impacts, governance and management in Thailand. *Marine Policy*, *44*, 107–116. https://doi.org/10.1016/j.marpol.2013.08.017

Berdoulay, V. (1974). Remarques sur la géographie de la perception. *L'Espace géographique*, *3*(3), 187–188. https://doi.org/10.3406/spgeo.1974.1480

Berkes, F., Folke, C., & Colding, J. (2000). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press.

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. BioScience, 59(11), 977–984. https://doi.org/10.1525/bio.2009.59.11.9

Brandon, K. E., & Wells, M. (1992). Planning for people and parks: Design dilemmas. *World Development*, *20*(4), 557–570. https://doi.org/10.1016/0305-750X(92)90044-V

Brockington, D., & Duffy, R. (2010). Capitalism and Conservation: The Production and Reproduction of Biodiversity Conservation. *Antipode*, *42*(3), 469–484. https://doi.org/10.1111/j.1467-8330.2010.00760.x

Buschmann, A. H., Riquelme, V. A., Hernández-González, M. C., Varela, D., Jiménez, J. E., Henríquez, L. A., … Filún, L. (2006). A review of the impacts of salmonid farming on marine coastal ecosystems in the southeast Pacific. *ICES Journal of Marine Science*, *63*(7), 1338–1345. https://doi.org/10.1016/j.icesjms.2006.04.021

Carroué, L., Collet, D., & Ruiz, C. (2005). *Les mutations de l'économie mondiale du début du XXe siècle aux années 1970*. Editions Bréal.

Castree, N. (2015). Geography and Global Change Science: Relationships Necessary, Absent, and Possible. *Geographical Research*, *53*(1), 1–15. https://doi.org/10.1111/1745-5871.12100

Chapuis, J.-L., Frenot, Y., & Lebouvier, M. (2004). Recovery of native plant communities after eradication of rabbits from the subantarctic Kerguelen Islands, and influence of climate change. *Biological Conservation*, *117*(2), 167–179. https://doi.org/10.1016/S0006-3207(03)00290-8

Charles, A. (2007). Adaptive co-management for resilient resource systems: Some ingredients and the implications of their absence. *Adaptive Co-Management: Collaboration, Learning and Multi-Level Governance*, 83–102. Retrieved from Scopus.

Chartier, D., & Rodary, E. (2007). Géographie de l'environnement, écologie politique et cosmopolitiques. *L'Espace Politique. Revue en ligne de géographie politique et de géopolitique*, (1). https://doi.org/10.4000/espacepolitique.284

Chornesky, E. A., & Randall, J. M. (2003). The Threat of Invasive Alien Species to Biological Diversity: Setting a Future Course. *Annals of the Missouri Botanical Garden*, *90*(1), 67–76. https://doi.org/10.2307/3298527

Chown, S. L., & Smith, V. R. (1993). Climate change and the short-term impact of feral house mice at the sub-Antarctic Prince Edward Islands. *Oecologia*, *96*(4), 508–516. https://doi.org/10.1007/BF00320508

Claval, P. (1974). La géographie et la perception de l'espace. *L'Espace géographique*, *3*(3), 179–187. https://doi.org/10.3406/spgeo.1974.1479

Clavero, M., & García-Berthou, E. (2005). Invasive species are a leading cause of animal extinctions. *Trends in Ecology & Evolution*, *20*(3), 110. https://doi.org/10.1016/j.tree.2005.01.003

Contreras, E. (2019, March 26). Polémica destitución de director del Museo Martín Gusinde: Acusan despido por participar en marchas. Retrieved May 29, 2019, from BioBioChile - La Red de Prensa Más Grande de Chile website: https://www.biobiochile.cl/noticias/artes-y-cultura/actualidad-cultural/2019/03/26/polemica-por-destitucion-de-director-del-museo-martin-gusinde-acusan-despido-por-asistir-a-marchas.shtml

Convey, P. (2006). Antarctic Climate Change and its Influences on Terrestrial Ecosystems. In D. M. Bergstrom, P. Convey, & A. H. L. Huiskes (Eds.), *Trends in Antarctic Terrestrial and Limnetic Ecosystems: Antarctica as a Global Indicator* (pp. 253–272). https://doi.org/10.1007/1-4020-5277-4_12

Convey, P., & Lebouvier, M. (2009). Environmental change and human impacts on terrestrial ecosystems of the sub-Antarctic islands between their discovery and the mid-twentieth century. *Papers and Proceedings of the Royal Society of Tasmania*, *143*(1), 33–44. https://doi.org/10.26749/rstpp.143.1.33

Cottet, M. (2013). Caractériser les valeurs environnementales au cours du temps : Une étape indispensable à la gestion des patrimoines naturels : Le cas de la restauration des bras morts de l'Ain et du Rhône. *VertigO*, (Hors-série 16). https://doi.org/10.4000/vertigo.13558

Crutzen, P. J. (2002). Geology of mankind. *Nature*, *415*, 23. https://doi.org/10.1038/415023a

Curnow, J., & Helferty, A. (2018). Contradictions of Solidarity. *Environment and Society*, *9*(1), 145–163. https://doi.org/10.3167/ares.2018.090110

Di Méo, G. (1998). De l'espace aux territoires : Éléments pour une archéologie des concepts fondamentaux de la géographie. *L'Information Géographique*, *62*(3), 99–110. https://doi.org/10.3406/ingeo.1998.2586

Dorrepaal, E., Aerts, R., Cornelissen, J. H. C., Callaghan, T. V., & Logtestijn, R. S. P. V. (2004). Summer warming and increased winter snow cover affect Sphagnum fuscum growth, structure and production in a sub-arctic bog. *Global Change Biology*, *10*(1), 93–104. https://doi.org/10.1111/j.1365-2486.2003.00718.x

Dumont, G.-F. (2001). *Globalisation, internationalisation, mondialisation: Des concepts à clarifier (Globalisation, Internationalisation and Global Business: Concepts to Be Clarified)* (SSRN Scholarly Paper No. ID 2560731). Retrieved from Social Science Research Network website: https://papers.ssrn.com/abstract=2560731

Dupré, S. (2006). Perceptions et représentations géographiques : Un outil pour aménager les forêts touristifiées ? *Téoros. Revue de recherche en tourisme*, *25*(25–2), 53–61.

Early, R., Bradley, B. A., Dukes, J. S., Lawler, J. J., Olden, J. D., Blumenthal, D. M., … Tatem, A. J. (2016). Global threats from invasive alien species in the twenty-first century and national response capacities. *Nature Communications*, *7*, 12485. https://doi.org/10.1038/ncomms12485

Everett, R. A. (2000). Patterns and pathways of biological invasions. *Trends in Ecology & Evolution*, *15*(5), 177–178.

Facon, B., Genton, B. J., Shykoff, J., Jarne, P., Estoup, A., & David, P. (2006). A general eco-evolutionary framework for understanding bioinvasions. *Trends in Ecology & Evolution*, *21*(3), 130–135. https://doi.org/10.1016/j.tree.2005.10.012

Fazey, I., Bunse, L., Msika, J., Pinke, M., Preedy, K., Evely, A. C., … Reed, M. S. (2014). Evaluating knowledge exchange in interdisciplinary and multi-stakeholder research. Global Environmental Change, 25, 204–220. https://doi.org/10.1016/j.gloenvcha.2013.12.012

Firn, J., Moore, J. L., MacDougall, A. S., Borer, E. T., Seabloom, E. W., HilleRisLambers, J., … Buckley, Y. M. (2011). Abundance of introduced species at home predicts abundance away in herbaceous communities. *Ecology Letters*, *14*(3), 274–281. https://doi.org/10.1111/j.1461-0248.2010.01584.x

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, *16*(3), 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Frenot, Y, Gloaguen, J. C., Massé, L., & Lebouvier, M. (2001). Human activities, ecosystem disturbance and plant invasions in subantarctic Crozet, Kerguelen and Amsterdam Islands. *Biological Conservation*, *101*(1), 33–50. https://doi.org/10.1016/S0006-3207(01)00052-0

Frenot, Y., Gloaguen, J.-C., & Tréhen, P. (1997). Climate change in Kerguelen Islands and colonization of recently deglaciated areas by Poa kerguelensis and P. annua. In B. Battaglia, J. Valencia, & D. W. H. Walton (Eds.), *Antarctic Communities: Species, Structure and Survival* (pp. 358–366). Cambridge, UK: Cambridge University Press.

Frenot, Yves, Chown, S. L., Whinam, J., Selkirk, P. M., Convey, P., Skotnicki, M., & Bergstrom, D. M. (2005). Biological invasions in the Antarctic: Extent, impacts and implications. *Biological Reviews*, *80*(1), 45–72. https://doi.org/10.1017/S1464793104006542

Frenot, Yves, Lebouvier, M., Gloaguen, J.-C., Hennion, F., Vernon, P., & Chapuis, J.-L. (2006). Impact des changements climatiques et de la fréquentation humaine sur la biodiversité des îles subantarctiques françaises. *Belgeo. Revue belge de géographie*, (3), 363–372. https://doi.org/10.4000/belgeo.12097

García, M. (2004). Ecotourism in Cape Horn. In R. Rozzi, F. Massardo, & C. Anderson (Eds.), *The Cape Horn Biosphere Reserve: A Proposal for Conservation and Tourism to Achieve Sustainable Development at the Southern End of the Americas.* (pp. 177–204). University of Magallanes Press.

Gilbert, A. (1986). L'idéologie spatiale: conceptualisation, mise en forme et portée pour la géographie. *L'Espace Géographique*, (1), 57–66.

Godley, E. J. (1960). The Botany of Southern Chile in Relation to New Zealand and the Subantarctic. *Proceedings of the Royal Society of London. Series B, Biological Sciences*, *152*(949), 457–475. Retrieved from JSTOR.

Gore, A. J. P. (1983). *Mires: swamp, bog, fen and moor* (Elsevier Scientific). Amsterdam: Gore, A.J.P.

Grawitz, M. (1994). *Lexique des sciences humaines* (6e ed.). Paris: Dalloz.

Hall, C. M. (2015). Tourism and biological exchange and invasions: A missing dimension in sustainable tourism? *Tourism Recreation Research*, *40*(1), 81–94. https://doi.org/10.1080/02508281.2015.1005943

Hall, M., & Wouters, M. (1994). Managing nature tourism in the Sub-Antarctic. *Annals of Tourism Research*, *21*(2), 355–374. https://doi.org/10.1016/0160-7383(94)90051-5

Harkin, M. E., & Lewis, D. R. (2007). *Native Americans and the Environment: Perspectives on the Ecological Indian*. U of Nebraska Press.

Hattingh, J. (2001). Human dimensions of invasive alien species in philosophical perspective: towards an ethic of conceptual responsibility. In J. A. McNeely (Ed.), *The Great Reshuffling: Human Dimensions of Invasive Alien Species* (pp. 183–194). IUCN.

Hayes, K. R., & Barry, S. C. (2008). Are there any consistent predictors of invasion success? *Biological Invasions*, *10*(4), 483–506. https://doi.org/10.1007/s10530-007-9146-5

Holdgate, M. W., & Wace, N. M. (1961). The influence of man on the floras and faunas of southern islands. *Polar Record*, *10*(68), 475–493. https://doi.org/10.1017/S0032247400051858

Holmes, G. (2015). Markets, Nature, Neoliberalism, and Conservation through Private Protected Areas in Southern Chile. *Environment and Planning A: Economy and Space*, *47*(4), 850–866. https://doi.org/10.1068/a140194p

Hornborg, A., & Crumley, C. L. (Eds.). (2007). *The world system and the earth system: Global socioenvironmental change and sustainability since the Neolithic*. Walnut Creek, Calif: Left Coast Press.

Hough, J. L. (1988). Obstacles to Effective Management of Conflicts Between National Parks and Surrounding Human Communities in Developing Countries. *Environmental Conservation*, *15*(2), 129–136. https://doi.org/10.1017/S0376892900028939

Hulme, P. E. (2009). Trade, transport and trouble: Managing invasive species pathways in an era of globalization. *Journal of Applied Ecology*, *46*(1), 10–18. https://doi.org/10.1111/j.1365-2664.2008.01600.x

Hulme, P. E. (2012). Weed risk assessment: A way forward or a waste of time? *Journal of Applied Ecology*, *49*(1), 10–19. https://doi.org/10.1111/j.1365-2664.2011.02069.x

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (R. K. Pachauri & L. Meyer, Eds.). Retrieved from https://epic.awi.de/id/eprint/37530/

King, J. C., Turner, J., Marshall, G. J., Connolley, W. M., & Lachlan-Cope, T. A. (2013). Antarctic Peninsula Climate Variability and Its Causes as Revealed by Analysis of Instrumental Records. In *Antarctic Peninsula Climate Variability: Historical and Paleoenvironmental Perspectives* (pp. 17–30). https://doi.org/10.1029/AR079p0017

Kleunen, M. V., Weber, E., & Fischer, M. (2010). A meta-analysis of trait differences between invasive and non-invasive plant species. *Ecology Letters*, *13*(2), 235–245. https://doi.org/10.1111/j.1461-0248.2009.01418.x

Kolar, C. S., & Lodge, D. M. (2001). Progress in invasion biology: Predicting invaders. *Trends in Ecology & Evolution*, *16*(4), 199–204. https://doi.org/10.1016/S0169-5347(01)02101-2

Lake, J. C., & Leishman, M. R. (2004). Invasion success of exotic plants in natural ecosystems: The role of disturbance, plant attributes and freedom from herbivores. *Biological Conservation*, *117*(2), 215–226. https://doi.org/10.1016/S0006-3207(03)00294-5

Larson, B. M. (2005). The war of the roses: Demilitarizing invasion biology. *Frontiers in Ecology and the Environment*, *3*(9), 495–500. https://doi.org/10.1890/1540-9295(2005)003[0495:TWOTRD]2.0.CO;2

Larson, B. M. H. (2011). Embodied Realism and Invasive Species. In K. deLaplante, B. Brown, & K. A. Peacock (Eds.), *Philosophy of Ecology* (pp. 129–146). https://doi.org/10.1016/B978-0-444-51673-2.50005-4

Lee, J. R., Raymond, B., Bracegirdle, T. J., Chadès, I., Fuller, R. A., Shaw, J. D., & Terauds, A. (2017). Climate change drives expansion of Antarctic ice-free habitat. Nature, 547(7661), 49–54. https://doi.org/10.1038/nature22996

Lodge, D. M. (1993). Biological invasions: lessons for ecology. *Trends in Evolution and Ecology*, (8), 133–137.

MacDonald, I., Loope, L., Usher, M., & Hamman, O. (1989). Wildlife conservation and the invasion of nature reserves by introduced species: a global perspective. In J. Drake, H. Mooney, & F. Di Castri (Eds.), *Biological invasions: A global perspective* (pp. 215–256). New York: John Wiley & Sons.

MacDonald, K. I. (2010). The Devil is in the (Bio)diversity: Private Sector "Engagement" and the Restructuring of Biodiversity Conservation. *Antipode*, *42*(3), 513–550. https://doi.org/10.1111/j.1467-8330.2010.00762.x

McNeely, J. A. (2001). *The Great Reshuffling: Human Dimensions of Invasive Alien Species*. IUCN.

Mooney, H. A., & Cleland, E. E. (2001). The evolutionary impact of invasive species. *Proceedings of the National Academy of Sciences*, *98*(10), 5446–5451. https://doi.org/10.1073/pnas.091093398

Moore, P. D., & Bellamy, D. J. (1974). *Peatlands* (Elek Science). London.

Mulkay, F. (2006). Les représentations sociales: étudier le social dans l'individu. *Cahiers Internationaux de Psychologie Sociale*, *61*, 57–62.

Mullin, B. H., Anderson, L. W. J., Ditomaso, J. M., Eplee, R. E., & Getsinger, K. D. (2000). Invasive plant species. *Council for Agricultural Science and Technology*, *13*, 1–18.

Nadasdy, P. (2005). The Anti-Politics of TEK: The Institutionalization of Co-Management Discourse and Practice. *Anthropologica*, *47*(2), 215–232.

Octobre, S., & Cicchelli, V. (2018). Pour une approche cosmopolite de la globalisation. *Sociétés plurielles*, *Épistémologies du pluriel*. Retrieved from https://societes-plurielles.episciences.org/4246/pdf

Oldekop, J. A., Holmes, G., Harris, W. E., & Evans, K. L. (2016). A global assessment of the social and conservation outcomes of protected areas. *Conservation Biology*, *30*(1), 133–141. https://doi.org/10.1111/cobi.12568

Patt, A. G., & Weber, E. U. (2014). Perceptions and communication strategies for the many uncertainties relevant for climate policy. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(2), 219–232. https://doi.org/10.1002/wcc.259

Paulet, J.-P. (2002). *Les représentations mentales en géographie*. Paris: Anthropos.

Piaget, J., & Inhelder, B. (1948). *La représentation de l'espace chez l'enfant*. Paris: PUF.

Pyhälä, A., Fernández-Llamazares, Á., Lehvävirta, H., Byg, A., Ruiz-Mallén, I., Salpeteur, M., & Thornton, T. F. (2016). Global environmental change: Local perceptions, understandings, and explanations. *Ecology and Society : A Journal of Integrative Science for Resilience and Sustainability*, *21*(3). https://doi.org/10.5751/ES-08482-210325

Reaser, J. K. (2001). Invasive alien species prevention and control: the art and science of managing people. In J. A. McNeely (Ed.), *The Great Reshuffling: Human Dimensions of Invasive Alien Species* (pp. 89–104). Cambridge: IUCN.

Redford, K. H., Brandon, K., & Sanderson, S. (1998). Holding ground. In K. Brandon, K. H. Redford, & S. Sanderson (Eds.), *Parks in Peril: People, Politics, and Protected Areas* (pp. 455–464). Island Press.

Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, *141*(10), 2417–2431. https://doi.org/10.1016/j.biocon.2008.07.014

Rejmanek, M. (1989). Invasibility of plant communities. In J. Drake, H. Mooney, & F. Di Castri (Eds.), *Biological invasions: A global perspective* (pp. 369–399). New York: John Wiley & Sons.

Rendoll Cárcamo, J., Contador, T., Crego, R. D., Jordán, N. I., Schüttler, E., Gañán, M., … Kennedy, J. H. (2016). First record of Vespula vulgaris (Linnaeus 1758) (Hymenoptera: Vespidae); on Navarino Island, Chile. Gayana, 80(1), 133–136.

Rendoll-Carcamo, J. A., Contador, T. A., Saavedra, L., & Montalva, J. (2017). First record of the invasive bumblebee Bombus terrestris (Hymenoptera: Apidae) on Navarino Island, southern Chile (55°S). Journal of Melittology, (71), 1–5. https://doi.org/10.17161/jom.v0i71.6520

Ricciardi, A., & Cohen, J. (2007). The invasiveness of an introduced species does not predict its impact. *Biological Invasions*, *9*(3), 309–315. https://doi.org/10.1007/s10530-006-9034-4

Richardson, D. M., & Pyšek, P. (2006). Plant invasions: Merging the concepts of species invasiveness and community invasibility. *Progress in Physical Geography: Earth and Environment*, *30*(3), 409–431. https://doi.org/10.1191/0309133306pp490pr

Richardson, D. M., Pysek, P., Rejmanek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: Concepts and definitions. *Diversity <html_ent Glyph="@amp;" Ascii="&"/> Distributions*, *6*(2), 93–107. https://doi.org/10.1046/j.1472-4642.2000.00083.x

Rintoul, S. R., Chown, S. L., DeConto, R. M., England, M. H., Fricker, H. A., Masson-Delmotte, V., … Xavier, J. C. (2018). Choosing the future of Antarctica. Nature, 558(7709), 233–241. https://doi.org/10.1038/s41586-018-0173-4

Robic, M.-C. (1992). *Du milieu à l'environnement: Pratiques et représentations du rapport homme/nature depuis la Renaissance*. Paris: Economica.

Rokeach, M. (1973). *The nature of human values*. New York, NY, US: Free Press.

Royles, J., & Griffiths, H. (2015). Invited review: Climate change impacts in polar regions: lessons from Antarctic moss bank archives. *Global Change Biology*, *21*(3), 1041–1057. https://doi.org/10.1111/gcb.12774

Rozzi, R., Armesto, J. J., Gutiérrez, J. R., Massardo, F., Likens, G. E., Anderson, C. B., … Arroyo, M. T. K. (2012). Integrating Ecology and Environmental Ethics: Earth Stewardship in the Southern End of the Americas. *BioScience*, *62*(3), 226–236. https://doi.org/10.1525/bio.2012.62.3.4

Rozzi, R., Charlin, R., Ippi, S., & Dollenz, O. (2004). Cabo de Hornos: Un parque nacional libre de especies exoticas en el confin de America. *Anales del Instituto de la Patagonia*, *32*, 55–62.

Sauvé, L., & Machabée, L. (2000). La représentation: point focal de l'apprentissage. *Éducation Relative à l'environnement*, *2*, 183–194.

Schüttler, E., Crego, R. D., Saavedra-Aracena, L., Silva-Rodríguez, E. A., Rozzi, R., Soto, N., & Jiménez, J. E. (2019). New records of invasive mammals from the sub-Antarctic Cape

Horn Archipelago. *Polar Biology*, *42*(6), 1093–1105. https://doi.org/10.1007/s00300-019-02497-1

Sernatur. (2014). *Plan de Acción Región de Magallanes y Antarctica Chilena Sector Turismo 2014-2018*. Santiago de Chile: Sernatur.

Sharp, P. A., & Leshner, A. I. (2014). Meeting Global Challenges. *Science*, *343*(6171), 579–579. https://doi.org/10.1126/science.1250725

Smith, V. R. (2002). Climate Change in the Sub-Antarctic: An Illustration from Marion Island. *Climatic Change*, *52*(3), 345–357. https://doi.org/10.1023/A:1013718617277

Soto, D., & Norambuena, F. (2004). Evaluation of salmon farming effects on marine systems in the inner seas of southern Chile: A large-scale mensurative experiment. *Journal of Applied Ichthyology*, *20*(6), 493–501. https://doi.org/10.1111/j.1439-0426.2004.00602.x

Steffen, W., Sanderson, A., Tyson, P. D., Jäger, J., Matson, P. A., Moore III, B., … Wasson, R. J. (2004). *Global Change and the Earth System*. Berlin: Springer.

Terkenli, T. (2004). Tourism and Landscape. In A. A. Lew, C. M. Hall, & A. M. Williams (Eds.), *A Companion to Tourism*. John Wiley & Sons.

Thorpe, J. (2011). Temagami's Tangled Wild: The making of Race, Nature, and Nation in Early-Twenthieth-Century Ontario. In A. Baldwin, L. Cameron, & A. Kobayashi (Eds.), *Rethinking the Great White North: Race, Nature, and the Historical Geographies of Whiteness in Canada* (pp. 193–210). UBC Press.

Turner, J., Colwell, S. R., & Harangozo, S. (2012). Variability of precipitation over the coastal western Antarctic Peninsula from synoptic observations. *Journal of Geophysical Research: Atmospheres*, 13999–14007. https://doi.org/10.1029/96JD03359@10.1002/(ISSN)2169-8996.SMWS1

Valenzuela, A. E. J., Anderson, C. B., Fasola, L., & Cabello, J. L. (2014). Linking invasive exotic vertebrates and their ecosystem impacts in Tierra del Fuego to test theory and determine action. *Acta Oecologica*, *54*, 110–118. https://doi.org/10.1016/j.actao.2013.01.010

Valéry, L., Fritz, H., Lefeuvre, J.-C., & Simberloff, D. (2008). In search of a real definition of the biological invasion phenomenon itself. *Biological Invasions*, *10*(8), 1345–1351. https://doi.org/10.1007/s10530-007-9209-7

Vaughan, D. G., Marshall, G. J., Connolley, W. M., Parkinson, C., Mulvaney, R., Hodgson, D. A., … Turner, J. (2003). Recent Rapid Regional Climate Warming on the Antarctic Peninsula. *Climatic Change*, *60*(3), 243–274. https://doi.org/10.1023/A:1026021217991

Vedwan, N. (2006). Culture, Climate and the Environment: Local Knowledge and Perception of Climate Change among Apple Growers in Northwestern India. *Journal of Ecological Anthropology*, *10*(1), 4–18. http://dx.doi.org/10.5038/2162-4593.10.1.1

Vitousek, P. M., D Antonio, C. M., Loope, L. L., & Westbrooks, R. (1997). Introduced species: a significant component of human-caused global change. *American Scientist*, *84*(5).

Warren, C. R. (2007). Perspectives on the `alien' versus `native' species debate: A critique of concepts, language and practice. *Progress in Human Geography*, *31*(4), 427–446. https://doi.org/10.1177/0309132507079499

Weber, E. U. (2010). What shapes perceptions of climate change? *Wiley Interdisciplinary Reviews: Climate Change*, *1*(3), 332–342. https://doi.org/10.1002/wcc.41

West, P., Igoe, J., & Brockington, D. (2006). Parks and Peoples: The Social Impact of Protected Areas. *Annual Review of Anthropology*, *35*(1), 251–277. https://doi.org/10.1146/annurev.anthro.35.081705.123308

Whinam, J., & Copson, G. (2006). Sphagnum moss: An indicator of climate change in the sub-Antarctic. *Polar Record*, *42*(01), 43. https://doi.org/10.1017/S0032247405004900

Wilshusen, P. R., Brechin, S. R., Fortwangler, C. L., & West, P. C. (2002). Reinventing a Square Wheel: Critique of a Resurgent "Protection Paradigm" in International Biodiversity Conservation. *Society & Natural Resources*, *15*(1), 17–40. https://doi.org/10.1080/089419202317174002

Annexe 1. Liste des espèces végétales non-natives retrouvées le long des transects lors de l'échantillonnage de terrain de 2018 sur l'île Navarino, au Chili.

Noms latin des espèces
Achillea millefolium
Agrostis capillaris
Agrostis stolonifera
Bellis perennis
Capsella bursa-pastoris
Cerastium arvense
Cerastium fontanum
Cirsium vulgare
Dactylis glomerata
Holcus lanatus
Hypochaeris radicata
Leucanthemum vulgare
Matricaria discoidea
Poa annua
Poa nemoralis
Poa pratensis
Rumex acetosella
Rumex crispus
Sagina procumbens
Senecio vulgaris
Stellaria media
Taraxacum officinale
Trifolium aureum
Trifolium dubium
Trifolium repens
Veronica serpyllifolia

Annexe 2. List of non-native herbaceous plant species found on Navarino Island, southern Chile, adapted from Rozzi et al. (2004) from which the photographs showed to the participants during the interviews were created.

Latin name	English name	Chilean Spanish name
Achillea millefolium	Yarrow	Milenrama
Agrostis capillaris	Common bent	Chépica
Agrostis stolonifera	Creeping bentgrass	Chépica
Alopecurus geniculatus	Water foxtail	-
Alopecurus pratensis	Meadow foxtail	-
Anthoxanthum odoratum	Sweet vernal grass	Pasto oloroso
Bellis perennis	Common daisy	Primavera
Capsella bursa-pastoris	Shepherd's purse	Bolsita del Pastor
Cerastium fontanum	Mouse-ear chickweed	Oreja de ratón
Cirsium vulgare	Spear thistle	Cardo
Coronopus didymus	Lesser-swine cress	-
Dactylis glomerata	Cock's-foot	Pasto ovillo
Holcus lanatus	Yorkshire fog	Pasto miel
Hypochaeris radicata	Catsear	Hierba del chancho
Juncus bufonius	Toad rush	Junquillo
Leucanthemum vulgare	Oxeye daisy	Margarita
Linum catharticum	Purging flax	-
Matricaria discoidea	Pineappleweed	Manzanilla
Mentha sp.	Mint	Mentha
Myosotis discolor	Forget-me-not	No me olvides
Papaver somniferum	Opium poppy	Amapola
Plantago lanceolata	Ribwort plantain	Llantén
Plantago major	Broadleaf plantain	Llantén
Poa nemoralis	Wood bluegrass	-
Poa pratensis	Kentucky bluegrass	Pasto azul
Poa trivialis	Rough bluegrass	-
Ribes grossularia	Gooseberry	Grosella
Rubus idaeus	Raspberry	Frambueso
Rumex acetosella	Sheep's sorrel	Vinagrillo
Rumex crispus	Curly dock	Romaza
Sagina procumbens	Procumbent pearlwort	-

Senecio vulgaris	Groundsel	Hierba cana
Stellaria media	Chickweed	Quilloi-quilloi
Taraxacum officinale	Dandelion	Diente de león
Thlaspi arvense	Field pennycress	Maleza Común
Trifolium aureum	Large hop trefoil	Trébol amarillo
Trifolium dubium	Lesser trefoil	Trébol enano
Trifolium repens	White clover	Trébol blanco
Urtica dioica	Common nettle	Ortiga mayor
Veronica serpyllifolia	Thyme-leaved speedwell	Verónica

Annexe 3. Certificat d'éthique provenant de l'Université de Montréal (CERAS).

Université de Montréal

Nº de certificat
CERAS-2016-17-203-D

Comité d'éthique de la recherche en arts et en sciences

CERTIFICAT D'APPROBATION ÉTHIQUE

Le Comité d'éthique de la recherche en arts et en sciences (CÉRAS), selon les procédures en vigueur, en vertu des documents qui lui ont été fournis, a examiné le projet de recherche suivant et conclu qu'il respecte les règles d'éthique énoncées dans la Politique sur la recherche avec des êtres humains *de l'Université de Montréal.*

Projet		
Titre du projet	**Espèces invasives dans la réserve de la biosphère du Cap Horne: état actuel, prévisions et intégration des observations locales/Invasive species in the Cape Horn Biosphere Reserve: actual state, forecast and local perceptions in order to improve management policies**	
Étudiante requérante	**Gaëlle Crête**	Étudiante à la maîtrise, FAS-Département de géographie
Sous la direction de	Thora Martina Herrmann, professeure agrégée, FAS-Département de géographie, Université de Montréal	

Financement	
Organisme	Non financé
Programme	
Titre de l'octroi si différent	
Numéro d'octroi	
Chercheur principal	
No de compte	

MODALITÉS D'APPLICATION

Tout changement anticipé au protocole de recherche doit être communiqué au CÉRAS qui en évaluera l'impact au chapitre de l'éthique.

Toute interruption prématurée du projet ou tout incident grave doit être immédiatement signalé au CÉRAS.

Selon les règles universitaires en vigueur, un suivi annuel est minimalement exigé pour maintenir la validité de la présente approbation éthique, et ce, jusqu'à la fin du projet. Le questionnaire de suivi est disponible sur la page web du CÉRAS.

Martin Arguin, Président Comité d'éthique de la recherche en arts et en sciences Université de Montréal	**20 septembre 2017** Date de délivrance	**1er octobre 2019** Date de fin de Validité

Annexe 4. Certificat d’éthique provenant de l’Université de Magallanes, Chili.

UNIVERSIDAD DE MAGALLANES
DIRECCIÓN DE INVESTIGACIÓN

COMITÉ DE ÉTICA CIENTÍFICO
UNIVERSIDAD DE MAGALLANES

Punta Arenas, 21 de Agosto de 2017

CONSTANCIA

Nombre del Proyecto: “Especies de plantas exóticas en la Reserva de la Biosfera Cabo de Hornos: estado actual, tendencias futuras y observaciones locales”.

Investigador responsable: Gaëlle Crête, Universidad de Montreal

Institución patrocinante: Universidad de Montreal

Institución responsable: Universidad de Montreal

De nuestra consideración:

Se deja constancia que fue recepcionado en la Secretaría del Comité de Ética Científico de la Universidad de Magallanes el Proyecto **“Especies de plantas exóticas en la Reserva de la Biosfera Cabo de Hornos: estado actual, tendencias futuras y observaciones locales”**, el cual será entregado al Comité de Ética Científico para su revisión y evaluación.

UNIVERSIDAD DE MAGALLANES
COMITÉ DE ÉTICA CIENTÍFICO
CHILE

Dr. Manuel Manríquez F.
Director de Investigación

Dra. E. Mariela Alarcón Bustos
Presidenta Comité Ética Científico