



A human-centered approach to designing invasive species eradication programs on human-inhabited islands



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ABSTRACT

Targeting human-inhabited islands for invasive species eradication campaigns layers social complexity on top of technical complexity. Attaining widespread support and cooperation for eradications requires programs designed to meet diverse stakeholder needs. The Tierra del Fuego archipelago serves as an informative case study and model for understanding and incorporating private landowner preferences into a proposed eradication program. We employed a human-centered approach to characterize landowner perceptions, preferences, and potential support for a large-scale initiative to eradicate the invasive North American beaver (*Castor canadensis*) from Tierra del Fuego. We used a factorial vignette survey to understand how attributes of an eradication program are related to landowners' decisions to participate. Landowners rated four programs that randomly varied by contract length, required level of landowner involvement, institutional administrator, payment, social norms, and probability of a successful eradication. Landowners in Tierra del Fuego were generally more willing to participate under three conditions: (1) increased payments, (2) increased expectations of program success, and (3) low requirements for landowner involvement. Our results suggest that incorporating feedbacks into program design can increase public support, and that landowners in Tierra del Fuego may not express the same preference for autonomy that exists in other regions of the world. Understanding and incorporating stakeholder preferences, perceptions, and beliefs into management strategies is an ongoing challenge for conservation practitioners worldwide. The vignette survey approach provides a cost-effective, rapid, and scalable tool to document and incorporate local values into conservation program design. Programs built using a human-centered approach will complement landowners' land-use objectives, increase cooperation, and ultimately improve conservation outcomes.

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1. Introduction

Although biological invasions have increased in scope and speed with globalization, the technical ability to eradicate certain invasive exotic species from islands has also increased exponentially (Towns and Broome 2003; Carrion et al., 2011). With improved technology, island size is often no longer the limiting factor for eradication campaigns, and large island eradications deemed

impossible a decade ago are now taking place (Veitch et al., 2011). To date, there have been over 1,200 successful vertebrate eradications on islands, the majority of which have been mammals (Glen et al., 2013). High success rates (Howald et al., 2007) and improved techniques have led environmental managers to attempt increasingly complex and extensive eradications, and to begin targeting human-inhabited islands and continental settings (Zabala et al., 2010; Malmierca et al., 2011; Glen et al., 2013).

Targeting human-inhabited islands for eradication campaigns layers social complexity on top of technical complexity. Although invasive species often destroy natural resources (e.g., agricultural crops, forest products), damage built infrastructure, and

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compromise other aspects of human health and well-being (Mooney, 2005), they also create significant material and cultural value for societies (e.g., cuisine, cultural rituals, traditional medicine, sport, ornamentation, cultural icons) (Pfeiffer and Voeks, 2008; Estévez et al., 2015). Consequently, conflicts around invasive species management are often rooted in divergent values, making them “wicked problems” with no clear resolution (e.g., Game et al., 2014). Further, human presence complicates eradication campaigns because it limits the range of feasible and socially acceptable eradication strategies available to practitioners. Eradications often require techniques incompatible with human settlements (e.g., aerial broadcast of toxins) or activities that landowners may not condone or allow on their land (e.g., shooting animals) (Saunders et al., 2011; Wilkinson and Priddel, 2011). Finally, due to the all-or-nothing nature of eradication campaigns, a lack of support or access by a single landowner can delay or completely derail an eradication effort (Biel, 2008; Gardener et al., 2010; Wilkinson and Priddel, 2011). Human-inhabited areas are typically managed by multiple private landowners with heterogeneous land-management objectives; as a result, eradication efforts in these areas are especially challenging because they require collective action and coordination, even when the issue may not be salient or agreeable to residents (Epanchin-Niell et al., 2010).

Given this social complexity, attaining widespread support and cooperation for invasive species eradication on inhabited islands requires programs that are designed to meet stakeholder needs. In some instances, incentives built into the design of an eradication program can increase private landowners' willingness to participate in conservation programs (Sorice et al., 2011). To date, however, efforts to understand landowner preferences for eradication program design have been largely limited to informal stakeholder engagement and community consultations (Glen et al., 2013; Estévez et al., 2015), despite evidence that in-depth stakeholder involvement can improve program design and conservation outcomes (Young et al., 2013).

The Tierra del Fuego (TDF) archipelago in southern Argentina and Chile serves as an informative case study and model for understanding and incorporating landowner preferences into eradication program design for human-inhabited islands. Introduced in 1946, the North American beaver (*Castor canadensis*) population on TDF has increased to over 100,000 individuals (Lizarralde et al., 2004; Skewes et al., 2006) and has recently expanded to mainland Chile (Wallem et al., 2007). Beaver activity directly affects private landowners by destroying grazable pasture and ranch infrastructure (e.g., bridges, fences) (Schüttler et al., 2011). Although beavers behave the same in TDF as in North America, they have no natural predators, and the region's riparian vegetation has not evolved the necessary resilience to recover from the beaver's impacts (i.e., nutritional or palatability defenses, regeneration mechanisms, high species diversity) (Anderson et al., 2009). As an ecosystem engineer, beavers cause long-lasting changes to local hydrology, nutrient cycling, riparian vegetation, food webs, and aquatic and terrestrial species assemblages (Lizarralde et al., 2004; Simanonok et al., 2011; Henn et al., 2014). These changes alter successional patterns by suppressing seedling regeneration, which ultimately leads to the permanent conversion of sub-Antarctic forests to meadows (Wallem et al., 2010). Landscape ecologists characterize the beaver's impact as the largest landscape-scale alteration of the forested areas of this ecoregion in the last 10,000 years (Anderson et al., 2009, 2011), a conclusion that prompted binational support and planning for eradication (Parkes et al., 2008; Funes et al., 2011). In 2008, the Argentine and Chilean governments formalized an agreement to initiate the largest eradication ever attempted—over 7 million hectares across two countries (Menvielle et al., 2010; Malmierca et al., 2011). This eradication effort would require participation and support from over 300 rural landowners in Chile and Argentina who

have varied opinions about beavers, their impacts, and control strategies.

We employed a human-centered approach to understand landowner perceptions, preferences, and potential support for a large-scale eradication and restoration campaign. This approach to program design recognizes that the way a program is structured and administered serves as its own set of incentives from which landowners receive benefits and incur costs (Sorice and Donlan, 2015). Often overlooked, both program structure and implementation can lead to reduced participation, ultimately undermining the collective action needed to achieve conservation goals. Using this framework, we explored the willingness of ranchers on TDF's largest inhabited island to participate in eradication programs that varied based on program structure and expected outcomes. Our study is a first step in an iterative approach to define landowner needs, desires, constraints, and experiences as a means to design an eradication program that integrates their needs and thus achieves widespread, voluntary participation.

We surveyed non-corporate, private landowners in TDF to estimate the importance of program structure and administration, social context, and expected success of the program. We hypothesized that landowners would prefer programs that are less controlling (i.e., allow landowners to do the work on their own and make their own choices), that require shorter commitments, and that provide higher payments. Further, theory about solving collective-action problems suggests that information feedbacks are key signals that drive human behavior (Van Vugt, 2009; Abrahamse and Steg, 2013). We included two such signals in program scenarios: information about the participation of other landowners, and information about the estimated collective efficacy of the eradication program (i.e., the probability of successful eradication if landowners participate). We hypothesized that feedbacks indicating higher participation or collective efficacy would be related to increased participation. Finally, our initial interviews suggested that landowners were heterogeneous regarding the institutions that they trust, so we asked to indicate their preference for government or independent non-profit organization (NGO) program administration. These interviews led us to hypothesize that landowners may prefer an NGO to a government-run program.

2. Materials and methods

2.1. Study area

The Tierra del Fuego archipelago is located south of the Strait of Magellan (52°S, 70°W; Fig. 1). The Chilean-Argentine international border bisects *Isla Grande*, the largest and most populated island of the archipelago. We will hereafter refer to *Isla Grande* as it is conventionally regarded: Tierra del Fuego or TDF. A large majority of the island's inhabitants (97%) live in urban areas, with Argentine inhabitants (~150,000) greatly outnumbering Chileans (<7,000) (DGEC 2010, SDRA 2014). A highly diverse landscape, TDF is characterized by four ecoregions: arid steppe; deciduous southern beech forests (*Nothofagus antarctica*, *N. pumilio*); broadleaf evergreen forests (*N. betuloides*, *Drimys winteri*); and Magellanic moorlands (*Sphagnum* spp. bogs) (Fig. 1; Moore, 1983). The principal economic activities on the Argentine portion of the island are social services, commercial activities (i.e., restaurants, tourism), manufacturing, transportation, construction, fisheries, timber harvesting, real estate, and mining (DGEC 2010), while the Chilean portion relies mostly oil and gas exploration, and ranching (SDRA 2014). Public land makes up about half of TDF. Families or shareholder groups operate large private ranches throughout the island, and forestry companies, conservation NGOs, and governments manage most of the forested areas in southern TDF.

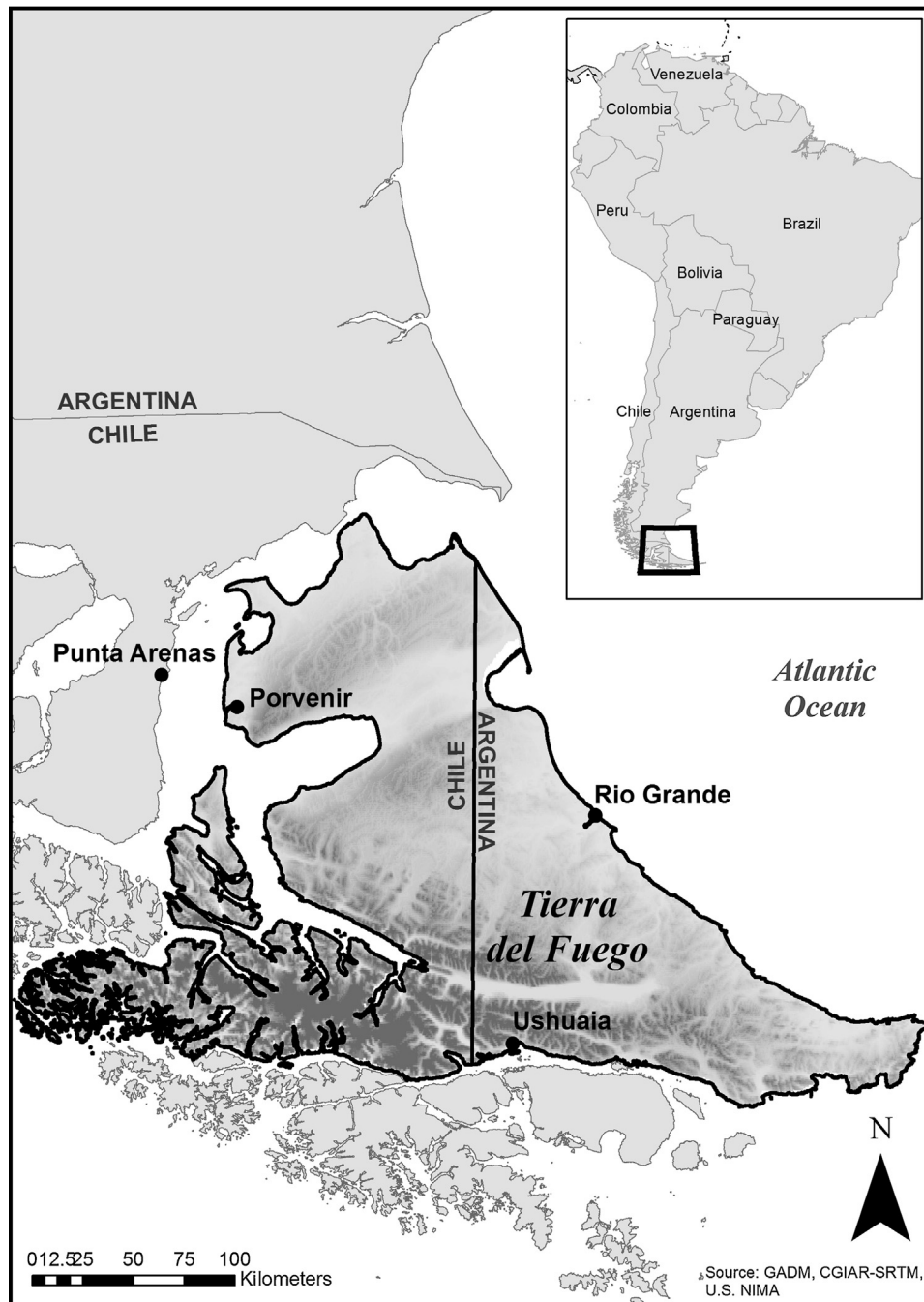


Fig. 1. Map of Isla Grande, the largest most populated island of the Tierra del Fuego Archipelago. The Chilean-Argentine international border bisects the island (Chile $\sim 29,000 \text{ km}^2$, Argentina $\sim 18,000 \text{ km}^2$). Private sheep and cattle ranches dominate the grasslands in the northern portion of the island. The forested south consists of large tracts of state-owned land, private protected areas, and private forestry operations.

2.2. Sampling

The population of interest consisted of all individuals currently serving as the primary decision-maker for ≥ 300 ha of privately-held, non-corporate land on TDF. We limited this sample to non-corporate, private landowners because the decision process for institutions fundamentally differs from individuals. In Argentina, private land parcels are typically $\geq 10,000$ ha. In Chile, various land reforms divided and redistributed land into *estancias* (i.e., ranches $\geq 2,500$ ha), *parcelas* or *chakras* (parcel or tract ~ 100 – $2,500$ ha), and *hijuelas* (plots typically < 100 ha). *Hijuelas* and smaller *parcelas* are typically non-productive land immediately outside of the small town of Porvenir. We focused on landowners with larger properties because many small parcels and plots are unmanaged. The unit of analysis was the landowner, operationalized as the property's primary decision-maker.

We obtained publicly available land registry data for private properties in Argentine and Chilean TDF. For many properties, ownership information was incomplete or outdated; we iteratively triangulated and updated ownership information in consultation with public and private institutions to improve the quality of our landowner lists. Our final sample frame included 49 and 134 landowners in Argentina and Chile, respectively ($N = 183$). We were unable to identify ownership information for one parcel in Argentina and approximately 20 parcels in Chile. We attempted to census all identifiable landowners between March and June 2014. We used professional connections, mutual acquaintances, and participating landowners to introduce us to other landowners. In rare cases when we were unable to locate acquaintances, we called or visited addresses listed on the land registry. We coordinated in-person interviews with landowners in public locations, private homes, or offices. Meetings generally lasted 45–60 min. We used face-to-face, structured interviews because education levels and access to technology among participants were

highly variable, and mail service on TDF is unreliable. Further, in-person interviews ensured all participants were able to ask clarifying questions. We conducted all interviews in participants' native languages, either Spanish ($n = 132$) or English ($n = 1$).

2.3. Survey design

In factorial surveys, vignettes are hypothetical scenarios (i.e., possible eradication programs) that consist of attributes (e.g., program length) with levels that vary randomly across scenarios (e.g., 2, 6, or 10 years). Each vignette is unique and individual respondents are randomly assigned a subset of all possible vignettes (Jasso, 2006). Randomization of vignettes gives factorial surveys the robustness of an experimental design, but unlike many experiments, surveys can be administered to a large sample of respondents to capture socio-economic diversity (Bekkers, 2010; Kinsbergen and Tolsma, 2013). Factorial vignette surveys are thus considered a “quasi-experimental” design. As a respondent evaluates each vignette, they must consider multiple attributes simultaneously. This joint consideration of multiple independent factors can reduce social desirability bias and indirectly reveal preferences for individual program components (Jasso 2006; Andorfer and Otte, 2013). Because respondents may be unaware of conscious and unconscious factors influencing their decisions, this holistic approach can reveal actual determinants of human judgments even when participants are not fully aware of all factors driving their decisions (Wallander, 2009).

Our eradication program vignettes varied based on: contract length, required landowner involvement, participation of other landowners, probability of a successful eradication, institutional administrator, and payment (Table 1). Each dimension had two, three, or four levels. We asked each participant to evaluate a subset of four randomly selected vignettes from the total population of 648 ($3^4 \times 2 \times 4$) possible programs. Adding additional vignettes,

Table 1

Descriptions of vignette attributes and levels in the factorial survey. All participants evaluated four scenarios in which every attribute level appeared randomly in at least one vignette. Text in italics represents working hypotheses based on the literature and initial landowner interviews.

Decision attribute	Description and hypotheses	Levels
Program length	Number of years the landowner is obligated to be in the program. <i>Landowners will prefer short-term conservation programs on their private lands^{a,b}</i>	(1) 2 years (2) 6 years (3) 10 years
Required level of landowner involvement	Responsibilities of participating landowners. <i>Landowners will prefer autonomy (i.e., working on the beaver issue without program intervention)^{b,c,d,e}</i>	(1) You and workers will hunt beavers and report results to program (2) You and workers will hunt beavers and report results to program. Program will verify successes (3) You and workers will notify program of beavers on your land. Program will enter your land and hunt beavers
Participation of other landowners	Perceived level of participation by other landowners. <i>An awareness of higher participation will increase willingness to participate^{a,f}</i>	(1) You have not heard of any other landowners participating (2) You have heard of some landowners who are participating, and others who are not (3) Most of the landowners you know are participating
Probability of program success	Likelihood the program will successfully eradicate beavers if landowners participate. <i>As expectation of collective efficacy increases, willingness to participate will increase^{a,c,g}</i>	(1) 33% chance of success (2) 66% chance of success (3) 99% chance of success
Implementing organization	Organization responsible for administering the program. <i>Willingness to participate will be lower in government administered programs^{c,e}</i>	(1) Non-governmental organization (NGO) (2) Government agency
Monthly payment	Monthly stipend paid to landowners for participation. <i>Higher payments will increase willingness to participate^a</i>	(1) \$200 USD/month (2) \$400 USD/month (3) \$600 USD/month (4) \$800 USD/month

^a Sorice et al. (2011).

^b Sorice et al. (2013).

^c Moon (2013).

^d Cocklin et al. (2007).

^e Peterson and Horton (1995).

^f Epanchin-Niell et al. (2010).

^g Abrahamse and Steg (2013)

vignette dimensions, or dimension levels is cognitively burdensome for the participant and may lead to fatigue that causes error or a break-off in the interview (Jasso and Opp, 1997; Jasso, 2006). To limit cognitive burden, we employed an incomplete block design such that each respondent was exposed at least once to all levels of all vignette dimensions in their four vignettes. The design we used ensured estimability of parameters for 250 landowners, and these effects remained estimable once the final data ($n = 133$ respondents) were collected. Landowners scored each vignette on a 7-point Likert-type scale to indicate their stated intention to participate (1 = extremely unlikely, 4 = unsure, 7 = extremely likely). A typical vignette was constructed as follows:

“The first program I will describe would span 2 years and would rely on you and your workers to kill beavers. You would report them to the program and allow program experts to verify the kills. The eradication program will be run by a Non-Governmental Organization (NGO) that is specifically created to administer this program. You will be paid \$400 each month for your participation, and an additional \$10 for each verified beaver kill. Right now you haven't heard of any other landowners participating, but the program organizers estimate that there is a 66% chance that the program will be successful if private landowners like you participate.”

Our selection of program attributes and levels was based on landowner participation in other conservation programs, expert opinion, personal experience, and preliminary interviews with landowners in TDF (Abel et al., 1998; Cocklin et al., 2007; Sorice et al., 2011, 2013; Moon et al., 2012; Lubell et al., 2013). All program attribute levels were selected to provide adequate variation to require landowners to consider tradeoffs, while remaining realistic. For example, based on the third author's experience, a large-scale eradication effort using hunting and trapping techniques can take a minimum of 2 years of on-the-ground activities. Recognizing that this eradication is complex and could take many years, we selected an upper bound of 10 years. This upper bound distinguishes this effort as a discrete “eradication” attempt, rather than an ongoing “control” effort. We assigned low, middle, and high values that represent the full range of possible scenarios for our variables signaling participation of other landowners and probability of program success. Similarly, levels for landowner involvement and implementing organization reflected the range of

possible options available in TDF based on input from key informants.

Payment levels reflect amounts above and below the average estimated cost of participation in the program. We assumed that the program would require landowners to dedicate 10 workdays per month toward eradication efforts, and that the program would pay above or below 50% of the monthly cost of a worker. We estimated participation costs by asking landowners and landowner association representatives from both Argentina and Chile to estimate the total monthly cost of supporting one ranch worker (e.g., salary, taxes, housing and food, communication, transportation). Our estimated monthly cost for a half-time worker ranged from \$415 USD to \$875 USD (average: \$550 USD). Values were similar between the two countries.

2.4. Data analysis

We used a generalized linear mixed model to estimate the fixed effects of program attributes on participants' stated likelihood of participation, and introduced a random effect to control for error associated with repeated measurements of individuals (West et al., 2007; Kinsbergen and Tolsma, 2013). Our dependent variable was a landowner's rating of their intention to participate in a program. Although social science research often treats 7-point ordinal scales as continuous, our model did not meet linear regression assumptions. Instead, we employed an ordinal model with a logit link. We transformed the reported log odds into odd ratios ($\Omega = e^{\beta}$) to enhance interpretation and discuss the results in terms of percent change in the odds ($\Omega - 1 \times 100\%$) (Long, 1997). We used a pooled dataset because there were no differences across landowners in Chile and Argentina.

Based on the results, we dichotomized the ordinal scale and used the same model predictors to estimate predicted probabilities that an average TDF landowner is: (1) moderately likely or extremely likely to participate, and (2) moderately unlikely or extremely unlikely to participate. Predicted probability curves represent the median responder from the population; this is created by averaging each participant's model prediction, sorting them, and then choosing the median responder. In this case, we estimated predicted probabilities of the median responder belonging to the “likely” or “unlikely” to participate groups when offered various levels of payment and required landowner involvement (Fig. 3a) as well as payments and likelihood of

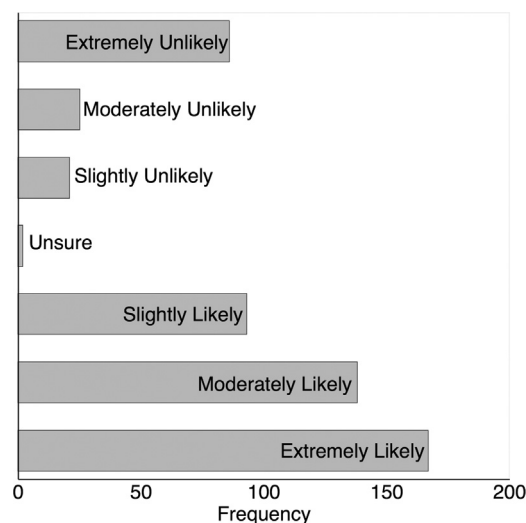


Fig. 2. Distribution of landowner ratings of their intention to participate in an eradication program. Each of the 133 respondents responded to four unique scenarios that varied randomly in program attributes and attribute levels ($n = 532$). Participants were “moderately” or “extremely” likely to participate in 57% of all scenarios.

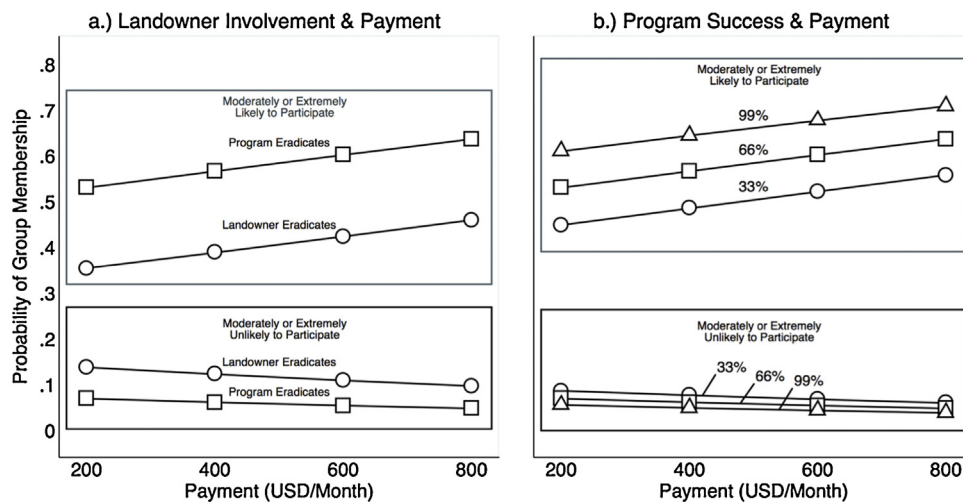


Fig. 3. Predicted probability of belonging to the “likely to participate” group or the “unlikely to participate” group based on: (a) landowner involvement requirements and payments, and (b) expectation of program success and payments. Predicted probabilities were generated holding other program factors constant at representative values.

program success (Fig. 3b) while controlling for other program-related components (control levels set at: 6-year contract, landowner knows of some ranchers participating, and program is administered by an NGO).

3. Results

Of the 183 landowners in our sampling frame, 97 and 37 individuals participated in Chile and Argentina, respectively (raw response rate = 73%). The adjusted response rate was 74% after removing ineligible respondents (e.g., non-contactable due to non-working address) (AAPOR, 2011a,b). One survey with missing vignette data was also excluded. The final sample size used in this analysis was 133.

Overall, landowners expressed high stated willingness to participate in beaver eradication programs on TDF across scenarios (Fig. 2). Landowners focused primarily on payment levels, expected success of the program, and required level of landowner involvement (Table 2). For every \$100-increase in monthly payment, the odds of being more likely to participate increase by 8.9% ($b = 1.08$; $z = 2.19$; $p = 0.03$). Similarly, for every 10% increase in the expected probability that the program would be successful, the odds of a landowner being more likely to participate increase by 12% ($b = 0.01$; $z = 3.42$; $p < 0.01$).

Willingness to participate was also related to required level of landowner involvement ($X^2 = 11.97$, $df = 2$, $p = 0.002$). The reference level of involvement asked landowners to hunt beavers and simply report their kills without external verification by program administrators. There was no difference between this baseline and a requirement that landowners kill, report, and permit the program to verify the kill (Table 2). Further, compared to the reference level, landowners preferred a program in which they simply notify administrators about the presence of beavers and then allow the program to enter their land to kill them ($b = 0.72$; $z = 3.29$; $p = 0.01$). The odds of a landowner participating increase by 106% when the program takes responsibility for hunting, compared to a program in which landowners hunt and simply report their beaver kills. Program duration, social norms associated with participation of other landowners, and implementing organization were not related to willingness to participate.

The predicted probability curves illustrate the effect of payments, landowner involvement requirements, and expected program success for landowners belonging to the “likely to participate” category (i.e., either “moderately likely” or “extremely likely”) (top panel of Fig. 3a and b) and the “unlikely to participate”

category (i.e., either “moderately unlikely” or “extremely unlikely”) (Fig. 3). Controlling for other program components, the feedback related to program success and the eradication efforts assumed by the program result in higher probabilities of being in the “likely to participate” category. Further, the slopes of the predicted probabilities indicate landowners in the “likely to participate” group are more responsive to payment, requirements, and expected program success.

4. Discussion

As a first step in a human-centered approach to designing an eradication program, the factorial vignette survey provides initial insights into private landowner preferences. We found that landowners in TDF were generally more willing to participate under three conditions: (1) higher payments, (2) higher expectation of program success, and (3) a lower required level of landowner involvement. Program length, participation of other landowners, and administering institution were not significant predictors of willingness to participate.

4.1. Program-related influences on landowner participation in eradication programs

We found that higher direct payments increase TDF landowners’ willingness to participate in a beaver eradication campaign. Payments serve two potential purposes (Wunder, 2005). First, they may reduce barriers to participation by compensating landowners for direct or opportunity costs of cooperation. Second, payments may be perceived as rewards that motivate participation. Not surprisingly, payments are an integral part of many conservation incentive programs (e.g., Langpap, 2006; Norden, 2014). However, they are not a panacea and consideration should be given during the design phase to ensure that payments do not unintentionally undermine intrinsic motivations for cooperation (Ryan and Deci, 2000; Frey and Jegen, 2001; Muradian et al., 2013; Sorice and Donlan, 2015).

In addition to payments, a higher expectation of program success can increase participation. In reality, uncertainty surrounding the probability of an eradication program’s success always exists. Although invasive mammal eradications enjoy a low failure rate (Howald et al., 2007; Keitt et al., 2011), eradications in settings with human inhabitants bring additional risks and complications. Because of the hypothetical nature of our research, we were able to provide landowners with feedback on the ability to achieve

Table 2

Ordinal mixed model results with eradication scenario program attributes as fixed effects, respondent as random effect, and intent to participate as the dependent variable ($X^2 = 29.440$, $df = 8$, $p = 0.003$).

Program component	Estimate	Odds ratio	SE	z	$P < z $	95% CI
Program length (years)	0.01	1.01	0.03	0.38	0.70	−0.04 0.06
Required level of landowner involvement						
Kill & Report (reference category)						
Kill, Report, Program Verifies	0.13	1.14	0.21	0.62	0.53	−0.28 0.55
Report, Program Kills	0.72	2.06	0.22	3.29	<0.01	0.29 1.16
Participation of Other Landowners						
Not heard of others participating (reference category)						
Heard of some who are participating	−0.13	0.88	0.22	−0.58	0.56	−0.55 0.30
Most landowners you know are participating	0.01	1.19	0.22	0.80	0.42	−0.25 0.60
Probability of program success	1.15	3.14	0.34	3.42	<0.01	0.49 1.80
Implementing organization						
Non-governmental organization (reference category)						
Government agency	−0.03	0.98	0.17	−0.14	0.88	−0.36 0.31
Monthly payment ^a	0.08	1.18	0.04	2.19	0.03	0.01 0.16
Cut point 1 ^b	−1.00	0.37	0.44	−2.27	0.02	−1.86 −0.14
Cut point 2	−0.53	0.59	0.44	−1.22	0.22	−1.39 0.32
Cut point 3	−0.19	0.82	0.44	−0.45	0.66	−1.05 0.66
Cut point 4	−0.16	0.85	0.44	−0.38	0.71	−1.02 0.69
Cut point 5	1.04	2.84	0.44	2.37	0.02	0.18 1.91
Cut point 6	2.75	15.58	0.46	6.00	<0.01	1.85 3.65
Random effect	3.66	39.00	0.775	.	.	2.42 5.55

^a To facilitate reporting and interpretation, payment was divided by \$100 US.

^b Cut points in ordinal models indicate the thresholds between levels of intention to participate.

eradication at the landscape scale. Our results suggest that cooperation does increase when targeted participants receive signals about the potential for a program's success (Van Vugt, 2009; Abrahamse and Steg, 2013). Incorporating feedbacks into program design can help garner the necessary public support for programs that require widespread and continued participation. The importance of this feedback in enhancing the confidence of potential participants suggests that a key issue and research agenda for applied ecologists may be to strengthen both the scientific foundation for incentive programs and the forecasting of ecological changes brought about by a program. To date, the natural science supporting program design and implementation is arguably inadequate (Naem et al., 2015). To ensure that forecasts are science-based, it is crucial for ecologists to identify and quantify feedbacks between human behavior (participation) and ecological outcomes.

Based on previous research about ranchers' values, we expected TDF landowners to express their desire for autonomy (Cocklin et al., 2007; Putten et al., 2011; Sorice et al., 2011; Lubell et al., 2013; Moon, 2013; Zammit, 2013). Landowners expressed their independence by demonstrating that knowledge of how other landowners were acting did not influence their willingness to participate (van Dijk et al., 2008; Stock and Forney, 2014). However, we also expected autonomy to manifest itself as a preference for hunting beavers themselves, with minimal intervention from the program. The high-autonomy condition was potentially appealing to landowners as it relied simply on the honor system—the landowner culls beavers and simply reports to the program without verification. Instead, landowners preferred that the program have access and complete control over beaver eradication on their land.

We consider a number of reasons why landowners may prefer to grant the program access to their land rather than work on it themselves. First, landowners in TDF may perceive a low level of motivation or self-efficacy for addressing the problem. This could be due to a lack of time, resources, or competing priorities. In interviews we conducted as part of a larger study, landowners often expressed greater concern about invasive mink, muskrat, and feral dogs than beaver. Thus, although the beaver invasion is a significant conservation issue for TDF, it may not be perceived as such at the scale of the individual rancher. Additionally, in further

interviews, some landowners expressed that their personal involvement (i.e., hunting) was “not worth the effort” or “impossible” because of the current extent of the invasion, and the ruggedness the region's terrain. Second, economic and social instability may discourage landowners from committing limited labor to what they may consider non-essential activities. Regional challenges, such as the decreasing demand for Patagonian wool, natural capital depletion (e.g., desertification, soil loss), tax increases, and livestock depredation from feral dog packs have decreased the profitability of TDF's ranches (Ares, 2007; Klepeis and Laris, 2008; Von Thüngen and Lanari, 2010; Livraghi, 2011). Decreased stability and income may be barriers to participation for some landowners. Lastly, there has been a gradual shift in the culture of ranching in Patagonia: younger generations have steered away from an isolated, rural lifestyle in favor of urban settings with better access to jobs and social services. This shift has resulted in a widespread shortage of available, trustworthy, and skilled ranch labor throughout the region (Livraghi, 2011). Due to these changes, a key barrier for landowners engaging in beaver eradication on their own may be the inability to afford the time, labor, or financial burden of participation in non-livelihood activities. The preference for passive cooperation, however, is likely an advantage from the perspective of the eradication program because the threshold of cooperation needed to be successful (i.e., landowners allow access) is easier to achieve than ensuring landowners are themselves endeavoring to hunt beavers on their land.

4.2. Advancing a human-centered approach to conservation program design

Participant preferences regarding conservation program structure and delivery are often overlooked during program design, yet they substantively influence participation. Participants perceive costs and benefits from the ways in which voluntary agreements are structured and implemented (Sorice et al., 2013). A human-centered design (HCD) approach to conservation planning is based on the idea that programs co-designed and adaptively co-managed with local stakeholders will incorporate stakeholder needs and values into program design; this approach can increase voluntary

participation and achieve widespread support (Sorice and Abel, 2015; Sorice and Donlan, 2015).

Designing and implementing conservation programs that complement landowners' land-use objectives is a multi-phase, participatory process. Before conducting this research, we began with landowner interviews, related academic literature, and expert opinion. The goal of our factorial vignette survey was to understand landowner preferences in order to inform the first stage of eradication program design. A number of our results call for pause, reflexivity, and further in-depth investigation. For example, ranchers tend to be cross-culturally known for their characteristic independence and autonomy (e.g., Trevizo, 2003; Fischer and Charnley, 2010; Moon, 2013). TDF ranchers' preference for outside intervention on their land may indicate that the program could meet a latent need for assistance with labor supply.

Additionally, we found no preference for the institution that administers the program despite preliminary interviews that indicated substantial anti-government sentiment. This could be attributed to the fact that landowners focused on other factors they felt to be more important in the decision context (e.g., payment, involvement requirements); or, the landowner population may be truly divided on which institutions they trust to administer a program. Given the critical importance of the role in institutions engendering trust in participants (Van Vugt, 2009; Mackenzie and Larson, 2010), further in-depth research is needed to understand the lack of a definite, population-wide preference in our data. The HCD approach endeavors to identify these key factors that can increase the value of participation for landowners, because they can substantially increase landowner commitment to the program.

Factorial surveys are a cost-effective, rapid, and scalable tool for gaining insight on the preferences of potential participants. The method is especially valuable in the initial stages of program design because it can detect shared or consensual preferences for individual program attributes. Other tools and strategies complement this approach and can provide additional detail regarding stakeholder preferences for program attributes, such as qualitative interviews or focus groups (e.g., Gelcich and Donlan, 2015), stated-preference choice experiments (e.g., Sorice et al., 2013), and participatory mapping (e.g., Brown and Raymond, 2014).

5. Conclusion

As the technical ability to eradicate invasive mammals from islands continues to improve and campaigns target larger inhabited islands (Cruz et al., 2009; Veitch et al., 2011; Glen et al., 2013; Campbell et al. 2015), the challenge of gaining cooperation and coordinating eradication efforts is increasing. People hold diverse views on invasive species from a variety of perspectives: economic, environmental, and individual (cognitive and emotional) (Pfeiffer and Voeks, 2008; Gobster, 2011; Marshall et al. 2011). Human communities create novel challenges to eradication campaigns by imposing regulations, logistics, and socio-political constraints. Due to their all-or-nothing nature, invasive species eradication programs represent an extreme case where widespread buy-in and coordination is critical and consensual support of local landowners (e.g., access to land) is essential to program success.

Conservation programs that use a human-centered design approach are more likely to maximize participation and buy-in (Donlan, 2015; Sorice and Donlan, 2015). This approach can be broadly applied to terrestrial or marine settings, and used to address a number of ecological issues (e.g., biodiversity, water resources, etc.). Many conservation dilemmas, such as invasive species eradications, are fundamentally grounded in place. They occur in different socio-political and ecological contexts, and are based in the value judgments of local communities (Leslie et al.,

2015). The degree to which preferences vary across these contexts is a key question for future social science research. A strength of HCD is that it can be used to reveal sources of value to landowners that were previously unidentified and unknown in each setting. Further, as in our case, HCD is valuable as an approach to examine assumptions and concepts that might otherwise be considered conventional wisdom. Designing a program under the assumption that landowner autonomy means minimizing program intervention and access would lead to suppressed participation.

Understanding and incorporating stakeholder preferences, perceptions, and beliefs into management strategies is an ongoing challenge for conservation practitioners worldwide. By focusing on user needs during the design phase, program administrators can build programs that complement landowners' land-use objectives, enhance cooperation, and thus improve conservation outcomes.

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