Measuring behavioral social learning in a conservation context: Chilean fishing communities

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Abstract

In the sustainability and conservation sciences, “social learning” is defined as a group process which depends on trust and social capital and tends to boost conservation outcomes. We term this “collaborative social learning.” Meanwhile, the behavioral sciences define social learning as the individual use of socially acquired information and seek to explain how individuals employ social learning as part of adaptive behavior. We term this “behavioral social learning.” However, the influence of behavioral social learning on ecological outcomes is poorly understood. We conducted a study of behavioral social learning among fishers in seven communities in Chile’s Region V to probe its connections with ecological outcomes and collaborative social learning. We develop and employ a novel behavioral measure of individual social learning in a simple fishing game in which fishers may pay a portion of their game earnings to observe and learn from other fishers in the game. We explore the internal and external validity of the instrument. The self-consistency of game play, learning, and participant reflections reveals strong internal validity of the learning game. Additionally, game behavior is correlated with factors such as migration history, and the perceived availability of peers from whom to learn, suggesting the method also holds external validity. We then test whether factors associated with collaborative social learning, such as social capital, are related to social learning behavior as measured by the experiment. Interestingly, many correlates of ‘collaborative social learning’ are not strongly correlated with ‘behavioral social learning’ in our sample. We argue that this disconnect can help improve our understanding of the emergence of community-based conservation and positive ecological outcomes as well as ‘collaborative social learning’ itself. Finally, we provide guidance on how behavioral measures of social learning could benefit community-based natural resource management and conservation.

Keywords

behavioral game, community natural resource management, conservation, social learning
INTRODUCTION

Social science research in conservation, sustainability and natural resource management has identified social learning as a process that can lead to beneficial social and ecological outcomes. It has been suggested that social learning can increase engagement between stakeholders (e.g., Pelling, High, Dearing, & Smith, 2008), change environmental attitudes (Glasser, 2007), and increase collective action (Reed et al., 2010; Webler, Kastenholz, & Renn, 1995). Social learning may therefore be useful for community conservation (Barrow & Murphree, 2001) by helping to balance resource conservation with economic needs (Rodríguez-Izquierdo, Gavin, & Macedo-Bravo, 2010) and cultural factors (Gavin et al., 2015). Thus, social learning holds significant promise as a social process and applied approach in development of conservation science and policy.

Social learning in the environmental management literature is typically defined as a multi-party process of mutual social exchange (e.g., Keen, Brown, & Dyball, 2005). Here, we refer to this process as collaborative social learning. However, a proliferation of research on the topic has come at the expense of definitional clarity and operationalization (Reed et al., 2010; Cundill & Rodela, 2012; Rodela, 2011). While social learning is widely recognized as important, there have been a dearth of standardized methods to measure it, especially with quantitative and objective approaches (Reed et al., 2010; Rodela, 2011), hindering our ability to understand when and how social learning operates or produces certain outcomes. For example, one problem is that social learning overlaps with other processes such as deliberation and governance that may also help solve conservation problems and engender learning (Reed et al., 2010). Additionally, social learning is often considered (implicitly or explicitly) to be positively associated with social capital and positive relationships. This perspective may rest on a foundational assumption that learning should occur given the “right” spaces for the “right” people to engage with one another (e.g., Pelling et al., 2008). While such an association may often be true, assuming such a connection causes a problem of inference which conflates positive outcomes and processes that lead to them. For example, Murti and Mathez-Stiefel (2019) define social learning as an “iterative, collective learning process that can convene the wide range of stakeholders support co-creation of knowledge, enhance collective understanding of what action is needed as well as strengthen the willingness for joint action and advocacy.” This raises the question, is the social learning method to achieve a beneficial outcome, or a beneficial social process itself? If the latter, what is required to achieve that beneficial social process?

Reed et al. (2010), identify three major challenges in the study of social learning: (a) understanding what factors lead to social learning; (b) conflation of social learning and its hypothesized outcomes, such as trust and social capital; and (c) differentiation between social scales of organization. In summary, conceptual development of the causes, structure and outcomes of “social learning” may be useful.

Interestingly, there is another process called “social learning” in evolutionary biology and the behavioral sciences which may be of use in conservation science and policy. In psychology and the behavioral literature, social learning is defined as the individual use of socially acquired information (Bandura, 1971) and is contrasted with individual learning in which individuals learn independently from the environment through trial and error. We refer to this as behavioral social learning. Social learning of this sort is thought to have evolved as a flexible system for acquiring context-specific adaptive behaviors (Morgan, Rendell, Ehn, Hoppitt, & Laland, 2012), has been identified in many animal species (Heyes & Galef Jr, 1996), and is most extensive in humans. Behavioral researchers have developed and refined a set of quantitative methods for measuring social learning including simple surveys, laboratory experiments (McElreath et al., 2005; Mesoudi, 2009; Mesoudi & Whiten, 2008) and field experiments (e.g., Efferson et al., 2007).

Behavioral social learning is typically considered to be a strategic process (Laland, 2004) in which individuals use cues about the learning context and content to select effective and adaptive behaviors to adopt (McElreath et al., 2008; Rendell et al., 2011). For example, strategic social learning may utilize characteristics of the learner (e.g., learner uncertainty), characteristics of the role model (e.g., kinship, knowledge, success, age, gender), or the frequency of a behavior across multiple models (e.g., via conformity or copying rare behaviors) (Rendell et al., 2011). Naturally, learning cues are more valuable if they are more clearly linked to the impact of the focal behavior on the role model. So the most fundamental cue is the success behavior for the role model, and the most important social learning strategy may be success-biased social learning (Baldini, 2012); the imitation of a given behavior based on the observed success of the person who practiced it. We focus on success-biased social learning in this study.

By allowing humans to transmit beliefs, values, norms, behaviors, and other cultural traits behavioral social learning is at the heart of human cultural evolution, the emergence of technology and the accumulation of social structure (Richerson & Boyd, 2005), and is considered a signature human adaptation (Boyd, Richerson, & Henrich, 2011). The evidence suggests that
many human behaviors are transmitted via social learning, including, for example, moral judgements (Bandura, 1969), mate preferences (Little, Jones, DeBruine, & Caldwell, 2011), consumer preferences (O’Hara & Stagl, 2002; Yang & Allenby, 2003), and even conservation behavior and attitudes (Horsley, 1977). Social learning has been shown to influence the acceptance of climate change science (Guilbeault, Becker, & Centola, 2018), and may be important in sustainable water management (Pahl-Wostl et al., 2008), and fisheries conservation (Waring & Acheson, 2018). Moreover, cultural evolutionary theory suggests that behavioral social learning may be a key driver in the evolution of cooperation in environmental social dilemmas (Richerson, Boyd, & Paciotti, 2002; Richerson & Henrich, 2012; Waring et al., 2015). However, human social learning research has not been adequately harnessed in the applied sciences of conservation and sustainability.

It is likely that behavioral social learning plays an important role in determining conservation behavior. For conservation efforts to work, individual behavior must often change, sometimes even in the absence of institutional change. But we know that humans learn much of their behavior from each other. So, simply understanding how conservation relevant behaviors diffuse is of value. Social learning, therefore, offers a framework to understand behavior change that is distinct from and sometimes contrary to economic predictions based on self-interest. Behavioral social learning may be most important when individuals must conserve voluntarily. In such cases cooperative conservation will not emerge via economic self-interest but may yet spread via some types of behavioral social learning, and influence conservation outcomes. Thus, behavioral social learning can be seen as a target of larger, goal-directed processes of collaborative social learning (Figure 1).

This paper seeks to cross-pollinate these two strains of research by measuring behavioral social learning among individuals in the domain of natural resource exploitation, typically associated with collaborative social learning. Our goals were (a) to develop and test a novel measurement of behavioral social learning (specifically success-biased social learning) for use in conservation, sustainability and natural resource management, and (b) explore how measures of behavioral social learning might be used to better understand how social-ecological outcomes (such as the conservation of biodiversity and natural resources) emerge, and why. To satisfy these two goals, we first develop a novel measurement of behavioral social learning that is easy to administer and logistically feasible for field study. We then test the validity of this behavioral game as a measurement of real-world outcomes.

**FIGURE 1** Two conceptual models of the process of collaborative social learning: (a) as typically represented in the conservation literature and (b) restructured to include the social learning behavior of individuals as represented in the behavioral literature as a determinant of conservation behavior and outcomes.
behavior patterns. Secondarily, we explore how measurements of behavioral social learning can be of value in studying collaborative social learning. To accomplish this, we test how factors hypothesized to be related to collaborative social learning (i.e., social capital, trust, shared perceptions) (Reed et al., 2010) are related to behavioral social learning. In so doing, we add social and behavioral complexity to the idea of collaborative social learning.

2 | METHODS

A behavioral game was deployed as part of a survey of 122 fishers in seven fishing communities in Chile. In addition to the behavioral game, the survey provided self-reports of social learning in context and a variety of factors hypothesized to be associated with social learning. The supporting research is described in Tam (2016), and the social learning game and survey is detailed in the Appendix.

2.1 | Study site

We studied behavioral social learning among fishers in seven communities in Chile’s Region V (Figure 2). Fishing communities are spread along the Chilean coast. Within Chile, areas of coastal land designated as “coves,” (caletas in Spanish) are strips of land above the high tide mark that provide certain rights to users such as right to access to the sea, land a boat, remove catch, and erect certain buildings. Currently there are approximately 450 such caletas in Chile. Caletas are typically managed by a single fishing association within a given village. These associations have the rights to manage and develop caletas. In addition, fisher associations can be granted marine concessions through a national common property governance system for benthic resources (Castilla & Fernandez, 1998; Gelcich et al., 2010). This co-management regime allows for a degree of autonomy so that fishing associations may tailor their operations to local conditions while maintaining alignment with

FIGURE 2 The study focused on members of fishing associations in each of seven Chilean fishing communities in Region V, near Valparaiso. For additional fishing association details, see Table S1
national policies, leading to differentiation between how associations manage their caletas and marine concessions. As such, we expect unique cultures to emerge from individual communities (Aburto et al., 2013). Thus, Chilean artisanal fishing communities represent a useful natural experiment in which to test the presence and influence of social learning on resource use behavior.

Fishing for a livelihood also presents an interesting case study to examine behavioral social learning because although fishers included in this study are members of organizations with common objectives and have a vested interest in the wellbeing of communally owned resources, high social learning is not a given. Fishers themselves may be loath to share valuable information with one another, for example regarding new fishing grounds, business ventures, and fishing techniques that are not immediately tied to benthic resources. However, payoffs in sharing may also be great, and repaid in-kind or through other favors. Thus, we expect individual variation in the degree of social learning to be partially independent of the community characteristics.

2.2 | Social learning game design

Although much social learning research seeks to understand which social learning strategies individuals employ under which conditions (Brand, Heap, Morgan, & Mesoudi, 2020; Claidière & Whiten, 2012; Morgan & Laland, 2012), our goal is much more basic. We seek to develop and test a lightweight measure of social learning with relevance for conservation and sustainability research. We adapted a group-based experimental social learning methodology from Efferson et al. (2007) for this purpose. The simplest measure of behavioral social learning is the choice to observe the behavior of others. Our game is framed as a simple fishing scenario. Players are first presented a fishing choice between two decks of cards (red and blue) representing two types of fish, one of which is more valuable on average. Players are then given the opportunity to observe the behavior of the “most successful player” for the round just played. Social learning can thus be measured as social information access (Figure 3).

**Learning task:** Our behavioral game builds on a workhorse learning task called a “two-armed bandit,” in which players repeatedly select between two alternatives which offer varying payoffs that have different long-run averages (Robbins, 1952). The goal is to learn which alternative is most rewarding on average, so as to maximize one’s total payoff. The decks were designed so that uncertainty about which deck paid more was reduced over successive rounds regardless of player choices (Figure 4). The high payoff (HP) deck has payoffs 21% greater on average than the low payoff (LP) deck, but the HP deck might be either red or blue. Payoffs were drawn from truncated normal distributions with an SD of 57 pesos (HP: μ = 133, max = 275, LP: μ = 103, max = 245). If a player chose the HP deck exclusively, their final payoff was 3,760 pesos compared to 2,720 pesos for the LP deck.

**Social information:** After each fishing choice, players had an opportunity to observe the behavior of the “most successful player” for the round just played. The most successful player was selected from seven fishers who played a pilot game. The range of winnings among pilot players was 2,910 to 3,490 pesos (mean = 3,204.3, SD = 198.5), and the player with the highest payoff (3,490 pesos) was selected as the social information model. The model selected the HP deck only half of the 30 rounds. So that the value of social information was not correlated with the round, the order of the rounds was randomized for each pilot participant. So, because the model’s choices were made based on rounds in a different (randomized) order, the social information does not pertain to the amount of knowledge a subsequent player has access to through their experience of the game. Thus, the value of the social information varies between choices, but does so only randomly. Players have the option to purchase this “social” information starting in the third round, when it costs 15 pesos. The price of
social information increases by 15 pesos each round to 420 pesos in the final round.

Payoffs were calculated as the total earned from fishing minus the amount spent on social information. Payoffs were real, and payoff values, in Chilean pesos, were designed so that total earnings would be approximately equivalent to earnings from 1 hr of fishing work.

Ultimately, the game provides two different metrics of a respondent's social learning propensity: the number of times a player purchased social information, and the total they spent. The amount spent (game cost) may be considered a better metric if we assume that respondents are sensitive to price. Conversely if respondents are not very price sensitive, the buying frequency (buy count) may be a better measure. Using the game cost metric, an individual may be considered more of a social learner even if they purchased social information fewer times but did so later in the game, at higher prices.

### 2.3 Data collection

Two surveys were administered in each of the seven fishing associations between January and March 2013. The first surveyed 100 individuals as part of a larger study (Tam, Chan, Satterfield, Singh, & Gelcich, 2018) and included extensive demographic information. The second survey, the focus of this study, included 122 participants and was built to test the behavioral measure of social learning. Only 37 people took both surveys. Within caletas individuals were sampled on an availability basis, constituting a convenience sample. Of the 122 people to take the survey, 119 completed it.

A set of factors have been hypothesized to be related to collaborative social learning, whether as a precursor or an outcome. These include improved environmental attitudes (Glasser, 2007), common perception and understanding of environmental dynamics (e.g., Pelling et al., 2008), positive social relations (Rodela, 2011; Pahl-Wostl et al., 2007), greater collective action (Reed et al., 2010; Webler et al., 1995), and greater “adaptive capacity” (Pelling et al., 2008; Folke, Colding, & Berkes, 2003; Pahl-Wostl, 2009; Fazey et al., 2007). The survey measured factors associated with environmental attitudes, shared understanding, positive social relations, locus of control, quality of life, willingness to take risks, and collective action. These were measured as follows.

**Environmental attitudes**: Three questions adapted from the New Ecological Paradigm Measure of pro-environmental worldviews (Dunlap, Van Liere, Mertig, & Jones, 2000).

**Common understanding**: Shared perceptions among respondents and their communities were assessed using a 22-question true or false test based on statements regarding local environmental dynamics. These statements were created based on conversations with fishers in the first survey and administered in the second. Using cultural consensus theory (CCT) methodology (Romney, Weller, & Batchelder, 1986; Weller, 2007), the test allows the computation of a “competence score”—the degree to which respondents answers cohere with those of their peers—for each respondent.

**Positive social relations**: Many scholars have emphasized that social learning is likely to be associated with enhanced trust, social capital, and strengthened social relations (Reed et al., 2010; Cundill & Rodela, 2012). Thus, we include the following: two questions on trust of colleagues and outsiders (adapted from Veenstra, 2002); two questions related to social capital, specifically the perception of a capable leadership and valuing of
friendships with colleagues (Obst, Smith, & Zinkiewicz, 2002); and two questions related to the perceived need to belong to the fishing association (adapted from (Leary, Kelly, Cottrell, & Schreindorfer, 2013).

Locus of control: Social learning is frequently associated with adaptive capacity (e.g., McClanahan et al., 2008; Moser & Ekstrom, 2010). An essential component of adaptive capacity is the will and perceived ability to effect change. We included five questions pertaining to locus of control—or the perceived ability to affect personal outcomes and circumstances around fishing adapted from (Mueller & Thomas, 2001).

Quality of life: Social learning is by and large touted as having an overall positive influence. As a measure to assess one specific manifestation of this claim, we also include a measure of overall wellbeing as depicted by quality of life. This was a single-item measure from 1 to 10, with 10 indicating the most positive rating (World Value Survey Association, 2005).

Risk taking: Two measures of risk perceptions were included (adapted from (Dohmen et al., 2005): one general and the other specific to monetary risks. Both questions ask the degree to which respondents are willing to take risks on a scale of 0 to 10 with 10 being very willing to take risks.

Collective action: Lastly, 10 measures of collective action are included; five of which pertain to Ostrom’s collective action institutions (Cox, Arnold, & Villamayor-Tomas, 2010; Ostrom, 1990), and another five related to social norms related to fishing.

In addition, one environmental factor that is thought to influence behavioral social learning generally is the novelty of the environment. Evolutionary theory suggests that if experienced role models are available individuals should employ social learning in order to thrive in new or unknown environments (Boyd & Richerson, 1985; Kameda & Nakanishi, 2002). Thus, a lack of familiarity with the present context might increase individual’s use of social information. Historical migration of fishers along the Chilean coast (Aburto, Thiel, & Stotz, 2009) therefore suggests that learning from others might be important among Chilean fishers. Thus, we assessed whether a person was born in the local community or not as a way to measure local experience and need for social learning. The survey also included variables that may be related to behavioral social learning, including the percentage of income derived from marine extraction (+), number of years fishing (−), number of years respondents have been members of the local fishing association (−), and the average number of days spent fishing per month (−), as well as a standard suite of demographic variables including age, years of formal education, and income.

2.4 Analysis

Our analysis consists of three distinct steps. Primarily, we examine whether the game is a valid measure of individual efforts to learn socially, especially via success-biased social learning. To do so we assess the convergence with self-reported personal knowledge seeking behaviors and perceptions of knowledge sharing and knowledge availability. Second, we test whether there is a statistically significant correlation between our social learning measures and variables hypothesized as outcomes and/or enabling variables. We use basic bivariate one-tailed correlations in the first and second steps.

We used a CCT approach to measure common ecological understanding. CCT is based on the concept of individual “competence” as a measure of conformity between an individual’s answers and that of their peers in the same community, and not of the environmental accuracy of their responses. We constructed competence measures for each individual and community from 22 true and false questions on environmental dynamics and change. CCT analysis was conducted using UCINET 6. Although methods such as structural equation modeling may be desirable in a case where causality is unclear and much understanding could be gained, we deemed such methods unsuitable due to the small sample size to predictor ratio and the associated risk of unstable results. Analyses were conducted using the statistical packages R 3.6.1 (Team, 2013) and R packages “hier.part” (Walsh, Mac Nally, & Walsh, 2003) and “tidyverse” (Wickham et al., 2019).

3 RESULTS

3.1 Descriptive statistics

Social information use varies over time and between players. Of 119 players, most bought (i.e., paid for) some social information, while 20% of players (n = 24) did not buy any information and one person bought information all 28 times. Access of social information declined over time as the game progressed (Figure 5). Use of social information starts high and declines to an average frequency of 14% above round 10.

3.2 Validity of the learning task

Our first methodological question was if learning occurs in the game. Three different measures confirm that learning does occur (Figure 6). First, performance in the game improves 8% on average, from 48 to 56%. As this was the
first trial of the social learning game, we asked two reference questions every fifth round: “What color pays more?” and “How certain are you?” Self-reports of best option improve 22% on average (from 45 to 67%), and self-reported certainty improves 10% on average, from 65 to 75%. Therefore, players learn the higher paying deck, are aware of that learning, and choose the higher paying deck accordingly.

A subsidiary methodological question is whether social information improves game outcomes. We do not find evidence that it does. Social information use is negatively correlated with net earnings, fishing payoffs, and correct choices of the HP deck (Figure S1). In addition, the choice to buy social information in the previous round is associated with improvements in mean correctness in the present round of 5% or greater in only five rounds across the entire dataset (Figure S2). Thus, overall, social information use did not help player performance, but reduced overall correctness. However, the purpose of the instrument is to measure the strength of social learning, not the benefit of social learning.

Participants also reported their strategies verbally following the game, in terms of deck choice and use of social information. Deck choice strategy could be characterized into four groups of players (Table 1). The majority of players pursued a conscious testing strategy \((n = 65)\), while others chose randomly \((n = 22)\), used a fixed preference \((n = 17)\), or relied on instinct \((n = 5)\). Of the players who reported on social information most found it unhelpful \((n = 33/55)\). These verbal responses clearly show that not only were many players strategic in their choices, but that there was great variation in choice strategy. More importantly, these open-ended questions provide the first and most important validation of the social learning game in that we can confidently confirm that players (a) made use of the social information (b) evaluated the quality and value of that social information for their own benefit, and (c) varied significantly in their approach to the use of social information. These qualitative results show that many players may have used the information about the “best fisherman” in an attempt at success-biased social learning. That many of the players decided that the social information was either not useful, or not worth the cost is also a significant finding. It means that players closely attended to the value of social information. Therefore, the social learning game...
(both learning task and social information use) can be said to have internal validity in that it makes sense to players as intended, and players seem to consciously treat the game as an opportunity for success-biased social learning.

### 3.3 Validity of the social learning measure

With a measure of internal validity established, our most important methodological question is whether the game measures social learning in a manner that reflects other measures of social learning from the survey. Our methodological hypothesis was that perceptions of availability of information worth learning should be positively correlated with the use of social information as measured by the frequency of social information access. We did not use the cost of social information because it was perfectly colinear with round and therefore conflated with individual learning. We used three questions from the first survey to test game validity. These questions assessed personal knowledge seeking, the availability of teachers, and willingness of teachers. Because of sample size restrictions, we performed simple 1-tailed bivariate correlations to test these relationships. Tests required the overlap of Surveys 1 and 2 ($n = 37$). The frequency of social learning behavior was correlated with perceptions of the availability of useful social information. Social learning frequency was moderately and positively related to the perception that there were many people in the community from whom they could usefully learn ($r = .30, p = .04$), and significantly and positively correlated with the perception that peers are willing to give advice when asked ($r = .23, p = .09$). Social learning was not strongly correlated with preferences for independent learning ($r = .17, p = .16$) (see Table 2). Thus, the frequency of behavioral social learning in the game exhibits patterns expected of individuals if they were truly learning socially in the context of fishing in their real lives.

### 3.4 Social learning correlates

Among the suite of predictors, only 10 variables were notably correlated with behavioral social learning, three of which were the validity variables discussed above. The remaining predictors of note included age (a positive correlation), migrant status (the strongest correlation at $r = 0.5$), days fishing per month, monetary risk propensity; confidence in monitoring; agreement that organization rules are clearly defined (Table 2).

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**Table 1** Verbal self-reported player strategies for deck choice and use of social information with representative examples

| Choice strategy       | $n = 109$ | Examples                                                                 |
|-----------------------|-----------|--------------------------------------------------------------------------|
| Test                  | 65        | “I was comparing each color over the other,” “trying to find the color that paid more. Just as when looking for fishing water goes groping to find the part where there are fish.” |
| Random                | 22        | “I chose randomly. There is no ambition for winning. It did not matter which one to choose as long as I was winning money.” “only randomly. Follow a pattern sometimes red, sometimes blue. Two and two.” |
| Fixed preference      | 17        | “Blue, because red is communist,” “Chile soccer team, that’s way I chose blue,” “I bought more in the red because it’s my favorite color.” |
| Instinct              | 5         | “By instinct,” “I did it by instinct as I do like to fish. I am not interested to know what I had done the other, I am guided by my instincts.” |

| Social information use strategy | $N$ | Examples                                                                 |
|---------------------------------|-----|--------------------------------------------------------------------------|
| SI used                         | 45/56 | “I used the information to contrast with what I chose” “Bought when I was doubtful which color to choose.” |
| SI not used                     | 11/56 | “I did not buy information, because I wanted to do it my way” “Did not buy information because I was sure [of] red.” |
| SI useful                       | 22/55 | “[I] would buy information when I was not sure what it was that was paying more,” “comparing with the best player” |
| SI not useful                   | 33/55 | “The information was more a loss than a gain, it was not very useful” “Do not agree to pay for information that I would reduce my earnings since the information was not accurate. I would not benefit.” |

*Note: All but four players offered a strategy explanation, but detail varied. Only 109 reported choice strategies that could be classified, 56 reported their use of social information, and 55 reported its usefulness.*
The correlations were not strong, overall. The strongest correlation whether the participant was a migrant to the community ($r = .50, p = .00$), and it was positive, as might be expected for someone who needs to learn local lifeways. Other behavioral predictors displayed directions of correlation as would expected, while some did not. For example, we expected the number of days fishing per month to be negatively associated with social learning, as more experience might obviate the need for social learning. However, the correlation was weakly positive ($r = .21, p = .11$). Predictor variables from the collaborative social learning survey questions were also largely uncorrelated at this sample size. The strongest of these included institutions for collective action, which were positively correlated as expected; confidence in monitoring ($r = .23, p = .09$), rule clarity ($r = .32, p = .03$). Lastly, monetary risk propensity, for which we did not have a prior expectation, was weakly positively correlated with social learning ($r = .26, p = .06$). However, bivariate correlations with a small sample size should not be taken as strong evidence.

| TABLE 2 | Individual-level bivariate Pearson correlations (1-tailed) between social learning (buying frequency) and predictor variables, by category |
|----------|----------------------------------------------------------------------------------------------------------------------------------|
| Pearson’s $r$ | $t$ | $p$ value | df | CI- | CI+ |
| **Demographic** | | | | | |
| Age | 0.15 | 0.87 | **0.19** | 35 | −0.13 | 1 |
| Education | −0.12 | −0.70 | 0.76 | 35 | −0.38 | 1 |
| Income | 0.05 | 0.30 | 0.38 | 35 | −0.23 | 1 |
| **Validity** | | | | | |
| Many useful teachers (+) | 0.30 | 1.83 | **0.04** | 35 | 0.02 | 1 |
| Teachers willing (+) | 0.23 | 1.37 | **0.09** | 35 | −0.05 | 1 |
| Prefer individual learning (−) | 0.17 | 1.01 | **0.16** | 35 | −0.11 | 1 |
| **Behavioral** | | | | | |
| Migrant (+) | 0.50 | 3.40 | **0.00** | 35 | 0.26 | 1 |
| % life resident (−) | −0.42 | −2.71 | 0.99 | 35 | −0.62 | 1 |
| % income fishing (+) | 0.08 | 0.45 | 0.33 | 34 | −0.21 | 1 |
| Years fishing (−) | 0.01 | 0.06 | 0.48 | 35 | −0.27 | 1 |
| Years as member (−) | 0.01 | 0.05 | 0.48 | 35 | −0.27 | 1 |
| Days fishing per month (−) | 0.21 | 1.24 | **0.11** | 35 | −0.07 | 1 |
| **Collaborative** | | | | | |
| Locus of control: Luck$^a$ | −0.18 | −1.11 | 0.86 | 35 | −0.44 | 1 |
| Quality of life | −0.03 | −0.15 | 0.56 | 35 | −0.30 | 1 |
| Enviro attitude: Ecol catastrophe | −0.32 | −1.98 | 0.97 | 35 | −0.55 | 1 |
| Enviro attitude: Humans abuse enviro | 0.05 | 0.32 | 0.38 | 35 | −0.22 | 1 |
| Belonging: Desire to be accepted | 0.09 | 0.55 | 0.29 | 35 | −0.19 | 1 |
| Social capital: Number of friends | −0.26 | −1.59 | 0.94 | 35 | −0.50 | 1 |
| Social capital: Org. Friends important | −0.16 | −0.94 | 0.82 | 35 | −0.41 | 1 |
| Monetary risk propensity | 0.26 | 1.57 | **0.06** | 33 | −0.02 | 1 |
| Institution: Confident in monitoring | **0.23** | 1.39 | **0.09** | 33 | −0.05 | 1 |
| Institution: Clear rules of behavior | **0.32** | 1.98 | **0.03** | 35 | 0.05 | 1 |
| Institutions: Approve of poaching | −0.13 | −0.78 | 0.78 | 35 | −0.39 | 1 |
| Institutions: Approve of risk taking | −0.18 | −1.06 | 0.85 | 35 | −0.43 | 1 |
| Shared ecological knowledge (CCT) | 0.03 | 0.20 | 0.42 | 34 | −0.25 | 1 |

Note: Expected direction of correlation in parentheses. Tests required the overlap of Surveys 1 and 2, for which $n = 37$.

$^a$Reverse coded. Correlations with $p$-values less than .20 are boldfaced.
4 | DISCUSSION

This work is exploratory because the method is novel. Nonetheless, our methodological aim has been satisfied. The evidence suggests that the social learning game provides a simple, replicable and valid quantitative tool for assessing behavioral social learning in field contexts where collaborative social learning may be a research object or management goal. We believe this connection may benefit both research domains.

In addition to strong evidence of internal validity of the method, we found that social learning frequency was related to perceptions of the number and willingness of peers to learn from. These results add confidence that the game is measuring social learning as conceptualized in the behavioral and evolutionary sciences. The strongest correlation, between social learning frequency and migration, suggests that relative newcomers engage in more learning behaviors in the game. This finding is also consistent with social learning research and theory (Boyd & Richerson, 2009; Boyd & Richerson, 1988; Henrich & Boyd, 2008; Kameda & Nakanishi, 2002). That our measure of behavioral social learning conforms to predictions from social learning theory is further confirmation of the domain validity of our measure.

Interest in collaborative social learning or the “social learning approach” (Keen et al., 2005) has been fuelled, in part, by hopes that it can deliver positive outcomes in natural resource management contexts, by improving environmental attitudes (Armitage et al., 2008; Olsson et al., 2004), collective action (Reed et al., 2010; Weblcr et al., 1995), adaptive capacity (Pelling et al., 2008; Folke et al., 2003; Pahl-Wostl, 2009), and mutual understanding between stakeholders (Folke et al., 2003; Olsson et al., 2004; Pelling et al., 2008). But how do these factors relate to behavioral social learning? When do resource users choose to learn from each other, and is that process important in social-ecological outcomes? Our results provide some hints of this possibility in the sense that our behavioral measure appears to be related to some of the variables associated with collaborative social learning (such as collective action institutions), even with a small sample size. Thus, it may be that behavioral social learning plays an intermediary role in determining social-ecological outcomes, and therefore have value in the study of collaborative social learning.

Unpacking what we have called collaborative social learning is of pressing importance for conservation science and policy. For example, behavioral social learning can lead to the spread of destructive behaviors such as overharvesting, polluting, or poaching, as well as conservation behaviors including behavioral alternatives, voluntary reductions in consumption, and the like. Therefore, social learning is important in its own right, and may significantly alter the positive outcomes associated with collaborative social learning.

4.1 | Limitations and considerations for future research

Our study was successful as a methodological pilot but can be improved upon in many regards. Two design errors hindered this study: the increasing price of social learning information and the low accuracy of the social information model. Our social information model only selected the highest deck 50% of the time. This severely limited the value of social information, and most probably reduced the use of it as well. Thus, future studies might select (or even construct) a social learning model to provide a certain specified information content. Social learning models could be made intentionally useful or useless depending on the needs of the study.

It is also clear that the price of social information should be held constant and probably kept low in studies of this basic design. Multiple participants reported that the price was too high to consider using social information. And, the choice to increase costs each round altered the value of the choice to buy social information change over time, confounding the value of the information itself with its escalating costs. Thus, future studies of this sort should make social information accessible at a constant low cost, unless seeking to determine price sensitivity. Our study showed only an 8% average improvement in the high-deck pick rate, increasing to a final value of only 56%. Thus, the choice task itself could be made easier (or harder) to fit the needs of future research.

Our application of cultural evolutionary methods here is somewhat shallow. What types of cultural evolutionary mechanisms should we find in this case? What cues should guide social learning in our study context, or in conservation or natural resource use in general? These questions are as important for cultural evolution as they are for conservation, but they are beyond the scope of this exploratory research. Ideally, future research would first conduct evolutionary modeling to identify the types of social learning which might be expected to evolve under certain circumstances, so that such an empirical investigation could inform cultural evolution research as well.

Despite these limitations, this new tool for measuring success-biased social learning has methodological value for conservation research. First, the game is not limited to fishing, or resource extraction but can be used to study any natural resource use, conservation, or sustainability behavior in context. Second, as a behavioral measure, it
has the usual advantages over self-reported data. Behavioral data are typically more reliable than self-reported data, they enable much greater scope for between-case comparison, and they can be systematically modified to answer different questions and used as the basis for experimental study.

The behavioral study of social learning compliments the use of field experiments in conservation science and policy. For example, a robust literature uses field experiments to explore the factors controlling cooperation in environmental dilemmas (Cárdenas, Gómez, & Mantilla, 2019; Cardenas & Ostrom, 2004; Cavalcanti, Schläpfer, & Schmid, 2010; Gelcich, Guzman, Rodriguez-Sickert, Castillo, & Cárdenas, 2013). Other field experiments have been used to evaluate and design policy approaches to conservation goals, such as exploring the effect of injunctive norms (Bhanot, 2018), or social compensation (Ferraro & Price, 2013) on conservation behaviors, evaluating the most effective policy options for conservation (Kurz, Donahgue, & Walker, 2005), or exploring the impact of political attitudes on the efficacy of conservation interventions (Costa & Kahn, 2013). This literature is already extremely valuable for informing conservation policy. However, understanding how social learning determines behavioral diffusion in conservation efforts remains under explored. For example, future research could explore the role of success-biased learning in other conservation contexts, or draw on the other social-learning strategies and cues from the behavioral literature (Rendell et al., 2011), such as prestige-biased social learning (Brand et al., 2019; Henrich & Gil-White, 2001), conformity (Bardsley & Sausgruber, 2005; Morgan & Laland, 2012), and explore how these social learning mechanisms might be used to achieve more effective policy interventions. Research by Atkisson, O’Brien, and Mesoudi (2012) suggests that adult learners in novel environments use prestige cues to target their social learning efforts. Does this finding hold up for adult learners in environmental resource use generally, or after migration in adulthood? Can that insight be used to inform policy approaches? We believe that understanding the mechanisms that transmit conservation-relevant behavior must be a primary goal for conservation science and policy alike. These findings beg for more research.

### 5 CONCLUSION

Despite this study’s limitations, this investigation appears to be one of the first to connect behavioral social learning with collaborative social learning with an eye toward better understanding the latter. If research on social learning in conservation is to progress, the field will require continued development of theories, definitions, and measures, many of which can be drawn from other fields such as cultural evolution and psychology. Thus, we hope to help to uncover the mechanisms of social learning rather than focusing on outcomes (Rodela, 2011). Finally, our method is simple and applicable to many research contexts and can be delivered in the field or laboratory either in person or online. Materials for replicating or modifying our methods are available at https://doi.org/10.7910/DVN/6QJU01.

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### CONFLICT OF INTEREST

The authors declare no conflict of interest.

### AUTHOR CONTRIBUTIONS

**Jordan Tam:** Designed the research project; designed the behavioral social learning measure; conducted the surveys and behavioral game in Chile; analyzed the data and wrote the manuscript.

**Timothy Waring:** Designed the behavioral social learning measure; analyzed the data and wrote the manuscript.

**Stefan Gelcich:** Designed the research project; facilitated field research in Chile.

**Kai M. A. Chana:** Designed the research project.

**Terre Satterfield:** Designed the research project.

### DATA AVAILABILITY STATEMENT

The survey and game instrument, data, and analysis code in R necessary for inspecting, replicating, or modifying our study are available at https://doi.org/10.7910/DVN/6QJU01.

### ETHICS STATEMENT

The research was approved by the University of British Columbia’s Behavioural Research Ethics Board (certification number: H12-03130).

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Additional supporting information may be found online in the Supporting Information section at the end of this article.

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