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Review

Applying behavioral theories to invasive animal management: Towards an integrated framework

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ABSTRACT

Invasive species wreak an estimated $1.4 trillion in damages globally, each year. To have any hope of reducing this damage, best-practice control strategies must incorporate behavior change interventions. Traditional interventions, based on the *knowledge-transfer* model, assume that if land managers are properly educated about risks and strategies, they will develop supportive attitudes and implement appropriate control strategies. However, the social sciences have produced a large number of behavioral models and frameworks that demonstrate that knowledge transfer, by itself, fails to change behavior. The challenge then lies in knowing which behavioral model to choose, and when, from a potentially overwhelming 'universe'. In this paper, we review nine behavior theories relevant to invasive species management. We then introduce the *Behavior Change Wheel* as a tool for integrating these theories into a single practical framework. This framework links drivers of and barriers to behavior change with intervention strategies and policies, in what we consider, from an applied perspective, to be an important advance.

1. Introduction

Invasive animal species significantly impact the environment, economy and society. Managing invasive species is an important global priority; estimated damages total more than $1.4 trillion per year (Pimentel et al., 2001) and millions of dollars are spent annually on research and development of best-practice methods (Fitzgerald and Wilkinson, 2009; Gong et al., 2009). To ensure land managers adopt these new methods and integrate them into everyday practices, behavior change interventions are required.

Research into human behavior is extensive; a large number of social science models provide a deeper understanding of factors that promote and prevent behavior change. However, most of behavior change research related to invasive animal management has not explicitly linked to any specific behavioral theory.

Instead it has been widely and erroneously assumed that values and attitudes directly influence human behavior (Fitzgerald, 2009; Homer and Kahle, 1988). Thus, the focus of research, to varying degrees, has been on the knowledge, values and attitudes of individuals towards invasive species and their impacts (Fitzgerald, 2009; Fitzgerald et al., 2007; Miller, 2003; Miller and McGee, 2001; Southwell et al., 2013). In this context, providing information has been at the forefront of invasive species management intervention strategies, the misplaced assumption being that if individuals are adequately informed they will develop supportive attitudes, and consequently modify their behavior (Burgess et al., 1998; Kollmuss and Agyeman, 2002).

Furthermore, behavioral models can help identify the most important drivers of behaviors, but they do not specify how to bring about behavioral change. For that we need to explicitly link drivers of behavior to interventions designed to change behavior.

To that end, many theories of change have improved our understanding of how change occurs, and helped identify leverage points to initiate and sustain change. Also, several frameworks for developing and evaluating behavior change interventions have been proposed (e.g., Darnton, 2008; Jackson, 2005; Michie et al., 2011). However, to date there has been no direct application of these frameworks in invasive animal management.

In this paper, we review nine behavior theories relevant to invasive species management. We group these theories into four

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broad and sometimes necessarily overlapping categories: (1) expectancy-value models, (2) models emphasizing normative influences, (3) models that incorporate effect, and (4) broader contextual models.

We then introduce the *Behavior Change Wheel* (Michie et al., 2011) as a tool for integrating these theories into a single practical framework for: (1) identifying and understanding the drivers of and barriers to land-managers adopting best-practices for invasive species management, and (2) linking these drivers and barriers to specific behavior change interventions and policies.

2. Behavioral theories

Decision making in invasive species management to date has relied heavily on the notion that rational choice assumptions underpin behavior. That is, individuals will always make prudent and logical decisions to act based on benefits and costs, and will select the behavior that is in their highest self-interest and maximizes their net welfare (e.g., Gong et al., 2009; Hone, 1994; Meurk, 2014).

Rational choice underpins a broad class of decision making theories known as expectancy-value (EV) theories – the first of our four broad categories. These theories are based on the idea that action is motivated by the expectations of the consequences of our behavior, and the values and probabilities attached to those outcomes (Darnton, 2008). Attitudes are then a result of the function between beliefs about behaviors and the value of outcomes arising from that behavior (Fishbein, 1963; Fishbein and Ajzen, 1974). Numerous behavioral theories have expanded on this basic attitude-behavior assumption by either adding other factors to improve the predictability of the model, or changing the combination and/or specificity of the determining factors. We review three EV theories in the following sections, highlighting applications to invasive species management.

2.1. Health belief model

The health-belief model (HBM) was developed in the 1950's to explain and predict health-related preventive behavior (Janz and Becker, 1984; Rosenstock, 1966, 1974). Based as it is on EV theory, HBM assumes that behavior is completely determined by anticipated outcomes. The constructs used in HBM are: (1) perceived susceptibility or risk of developing a problem, (2) perceived severity of the problem and its consequences (the combination of susceptibility and severity are often referred to as perceived threat), (3) perceived benefits of taking action, and (4) perceived barriers to taking action. HBM also hypothesizes that a cue or trigger is necessary for prompting engagement in the behavior. Such cues to action can be internal (e.g. pain, symptoms), or external (e.g. visual materials like brochures and posters, or verbal information from family or professionals). The notion of self-efficacy, an individual's perception of their competence to successfully perform a behavior (Bandura, 1977), was added later to HBM to improve the predictive power of the model (Rosenstock et al., 1988).

Although developed for preventive health behavior, the constructs behind HBM can easily be imagined as determining participation in invasive species management. If individuals perceive they are susceptible to negative impact from invasive species, if there is a severe negative outcome if they don't participate in management activities, if the benefits of participation are likely to reduce the negative impacts and/or the barriers to adopting the management activities are low, then they are more likely to adopt the required management activities. An individual's perception of their ability to successfully perform a management action, such as set a trap for an animal, would also influence their participation. Cues to action could include actual observations of negative impacts (e.g. damaged crops or injured livestock), or information presented at field days or provided by government.

This model attempts to predict behavior by only accounting for individual differences in beliefs and attitudes, and as such it suffers from the similar limitations of rational choice theory in general. For example, HBM is unable to explicitly account for the influences of other factors, such as the impact of emotions, habitual behaviors, and social or environmental factors (Glanz et al., 2008; Janz and Becker, 1984; Rosenstock, 1966). It also does not specify how the constructs of the model interact with one another, making it difficult to define and evaluate (Carpenter, 2010; Glanz et al., 2008).

2.2. Protection motivation theory

The protection motivation theory (PMT) is another EV based-theory, and as is the case with the theory of planned behavior (section 2.3), a mediating intention variable exists between attitude and behavior: the protection motivation construct.

This theory was initially developed by Rogers (1975) in order to better understand fear appeals on attitude and how people cope, although it has now been expanded to include a broader range of information sources, and has become a more general theory of persuasive communication that could be applied to any situation involving threat (Maddux and Rogers, 1983; Rogers, 1983). It is based on the fundamental ideas of cognitive appraisal processes and how they relate to coping with stress (Lazarus and Folkman, 1984), and proposes that individuals protect themselves (protection motivation) based on the interactions between the threat appraisal process and the coping appraisal process.

Threat appraisal evaluates maladaptive behaviors (i.e. behaviors that are harmful), and is a function of the perceived severity of a threatening event, the perceived probability of the threatening event occurring (personal vulnerability), and any maladaptive response rewards (both intrinsic and extrinsic). The coping appraisal process evaluates the ability to cope with and avert the threatened danger, and is a function of the efficacy of the recommended response behavior, the perceived self-efficacy, and the response costs (Floyd et al., 2000; Milne et al., 2000; Rogers, 1983). These appraisal processes are initiated from two main sources of information; environmental (e.g. verbal persuasion, observational learning), or intrapersonal (e.g. personality variables, feedback from prior experience) (Rogers, 1975, 1983).

PMT has not explicitly been applied to invasive animal management, however persuasive communications, containing some form of threat message to the individual's livelihood, lifestyle, or the natural environment, are commonly used to increase participation in invasive animal management.

According to PMT, the decision to take protective action (i.e. conduct a management activity) becomes a positive function of the perceived severity of the invasive animals impact, and the feelings of vulnerability to this harm. These considerations must override the rewards of not conducting a management activity, and/or tolerating or actually increasing the prevalence of these animals for other purposes. This appraisal of threat supplies the motivation to initiate some form of positive management action. To decide to adopt the recommended management practices, a person must believe that performing this action will reduce the impact, and that they have the ability and will to perform the action. These considerations must outweigh the costs (e.g. monetary, time and effort, indirect effects on other animals) of performing the management activity.

PMT conventionally has been applied in the personal health contexts, where it has been shown to be a viable model on which to base individual and community health intentions (Floyd et al., 2000; Milne et al., 2000), and has provided an understanding of

why attitudes and behavior can change when people are confronted with various health threats. This model has also found support in a variety of other contexts; e.g. earthquake preparedness (Mulilis and Lippa, 1990), however the results have been mixed from the small number of environmental examples in the literature. Kantola et al. (1983) did not find any influence on water conservation behavioral intentions after manipulating the severity and efficacy messages in water conservation communications, whereas Shelton and Rogers (1981) found that messages either highlighting the noxious scenes of industrial whaling or the pro-environmental actions to successfully save the whales strengthened intentions to help this endangered animal species. Hass et al. (1975) found that increments in the perceived severity of an energy crisis strengthened intentions to reduce energy consumption, however increases in the perceived likelihood of an energy shortage had no effect.

2.3. Theory of reasoned action and theory of Planned Behavior

Two well-known general behavior models based on EV theory are the theory of reasoned action (TRA), and its extension, the theory of planned behavior (TPB). Unlike HBM, both these models propose that anticipated outcomes have only an indirect impact on behavior, being mediated by behavioral intentions. The TRA adds to the attitude-behavior construct of EV theory to incorporate normative social influences on behavioral intention (Fishbein and Ajzen, 1975). These social norms are defined as the product of an individual's personal beliefs about how 'important others' want them to behave, and their motivation to comply with those expectations. The TPB expands TRA to incorporate a third component, perceived behavioral control (PBC) (Ajzen, 1991). This factor is very similar to Bandura's (1977) concept of self-efficacy and refers to the individual's perception of personal control over the outcomes of the behavior. It can include both internal factors (e.g. skills, knowledge) and external factors (e.g. availability of resources, facilitating conditions), and is thought to influence behavior both indirectly, through the mediating role of intentions, as well as directly (Ajzen, 1991).

There has been some research exploring the factors underlying invasive species management behavior based on TPB. Kilvington et al.'s (1999) model of the intention to undertake pest control for the purposes of controlling bovine tuberculosis in New Zealand identified a wide range of attitude-belief, social normative and PBC factors. Major influences for the adoption of a new wild dog management tool as identified by Southwell et al. (2013) included the individual's beliefs toward the role of wild dogs in the ecosystem, and the participation of all neighboring land managers across all land tenures (normative beliefs). Research in Europe and North America has also highlighted the important role that these social factors play in wildlife management actions (Delibes-Mateos et al., 2013; Zinn et al., 1998).

Both TRA and TPB were developed as general behavior models, based on the most immediate and proximal causes of a specific behavior, and focused on intrapersonal and social factors involved in individual decision making. They are useful in understanding some intentional behavior but offer no insight into the influence of other important social and intrapersonal factors such as role beliefs, personal norms (morals), emotions, and habits. Also they do little to explain the causes or long-term roots of a specific behavior, or reflect the importance of external, contextual, or situational variables.

2.4. Focus theory of normative conduct

The attempt by TRA and TPB to account for some social influences on individual behavior by incorporating social norms leads us to our second broad category of behavioral theories: models emphasizing normative influence.

Social norms are the accepted standards of behavior of social groups. Research has shown that these norms can be a powerful force in inhibiting and encouraging an individual's own behavior, and can act at all levels of influence from immediate to more distal causes.

The confusion in the early literature over the concept of social norms was clarified with the publication of Cialdini's Focus Theory of Normative Conduct. This theory differentiates between two kinds of social norms: (1) injunctive norms – behaviors that are perceived to be approved by other people – that is, beliefs about what should be done, and (2) descriptive norms – perceptions of how other people are actually behaving – that is, what is actually being done (Cialdini et al., 1990). Injunctive social norms reflect the moral rules and guidelines of the social group, and tend to motivate or constrain certain behaviors by promising social rewards or sanctions. Descriptive social norms play an adaptive role in human behavior, functioning as a kind of mental shortcut for guiding behavior when individuals are unsure of how to act in social situations (Jackson, 2005).

The practical implication of this theory to invasive animal management becomes apparent when information campaigns seek to persuade an audience to behave in a particular way according to existing norms. Research across many areas has shown that messages containing normative information increases behavioral modification (Cialdini et al., 1990; Nolan et al., 2008; Schultz et al., 2008). In most cases descriptive norms are more persuasive than injunctive ones. That is, people will tend to conduct a management activity if their peers are doing likewise, rather than if the government regulates their behavior. However these two types of social norms can be contradictory in their outcomes, depending on the circumstances. For instance if you wish to prevent a socially disapproved conduct by depicting it as regrettably frequent (e.g. "many land managers in your area bait with unregistered toxins"), you risk inadvertently installing the counterproductive and undercutting descriptive normative message "Look at all the land managers who are baiting illegally".

Another problem with descriptive norms is that if you depict the norm as a lower level than what individuals are already performing (e.g. "80% of land managers check their traps every second day). In such situations the audience should not be focused on what is done but instead, on what is approved/disapproved i.e. the injunctive norm (e.g. "You should not use unregistered toxins when you bait" or "traps should be checked at least once a day") (Cialdini et al., 2006; Schultz et al., 2007).

2.5. Theory of interpersonal behavior

Triandis's theory of interpersonal behavior (TIB) is another model emphasizing normative influence. This theory proposes that behavioral intentions are influenced by: (1) personal normative beliefs (a function of morals and self-efficacy), (2) social normative beliefs (a function of social norms and role beliefs), (3) attitudinal beliefs (a function of perceived consequences and affect), (4) facilitating conditions (such as external barriers and situational contexts), and (5) habit, which can be a primary determinant on both intention and behavior, as well as have an influence on attitudinal beliefs (Triandis, 1977).

TIB is distinct from the models in our first broad EV category in that it includes (1) personal norms (feelings of moral obligation which are free from social expectations (Schwartz, 1977)), (2) role beliefs (the appropriateness of a person's behavior for their perceived social role and self-definition), (3) an affective measure of attitude which is distinct from the more cognitive EV measure of

attitude, and (4) most importantly, highlights habit (an automatic 'situation behavior' carried out with very little cognitive deliberation (Triandis, 1977)) as one of the important determinants of behavior. Furthermore, facilitating conditions are conceptualized as objective moderators of the influence of intention and habit on behavior.

TIB has not yet been applied to invasive animal management behaviors and the inclusion of these new influential variables are likely relevant. For example, management actions for most invasive animal species are usually not just one-off events, but must be repeatedly performed to ensure success (e.g. laying and checking of baits or traps). Therefore some behavior may become habitual and guided mostly by automated cognitive processes and past behaviors. This concept needs to be explored because habitual behaviors are more difficult to influence and modify by traditional education and persuasive techniques (Aarts et al., 1998; Ouellette and Wood, 1998; Verplanken and Aarts, 1999).

EV models have been criticized for neglecting moral considerations, particularly in situations when self-interest and the interest of others are at odds with each other (Manstead, 2000). By including this factor, TIB may be beneficial in understanding management behaviors because situations like this commonly occur in invasive species management. For example, an individual land manager, who does not suffer directly from the impact of a particular invasive animal, may not take part in a group control program that would benefit the other participants, thereby reducing its overall effectiveness. Also, these moral standards and their associated moral emotions are particularly relevant when considering people's treatment of animals. Emotional responses play an important role in animal management decisions, being strongly linked to people's values and value orientations (Manfredo, 2008), and should not be overlooked.

2.6. Norm activation theory

Schwartz's norm activation theory (NAT) – another model emphasizing normative influence – is one of the most widely applied models for understanding pro-social and altruistic behaviors (Darnton, 2008; Jackson, 2005). This theory postulates that pro-social behaviors are the result of an internalized personal norm to act in a particular way.

A personal norm is a feeling of strong moral obligation, and is activated by the awareness of the consequences of actions on others and the acknowledgment of personal responsibility for them (Schwartz, 1977). This model assumes that people have a general value orientation toward the welfare of others, that is, that they are motivated to prevent harm to others. In particular NAT has been applied to gain an understanding of pro-environmental behaviors (behaviors that are judged to attribute to a healthy environment).

As discussed in the TIB section, investigating the influence of personal norms (morals) on invasive animal management participation may be particularly beneficial in understanding situations where the interest of others takes priority over self-interest. NAT predicts that 'helping' behavior (e.g. participation in group management programs) will be strongest among people who are aware of the negative consequences of not helping and feel some responsibility for these consequences than among those people who deny negative consequences and/or responsibility. NAT has gained some support from studies investigating recycling behavior (Hopper and McCarl Nielsen, 1991; Thogersen, 1996), however it has met with varying success with other behaviors, mainly because alternative factors, particularly external social or institutional constraints, are thought to influence the expression of personal norms e.g., (Bamberg and Schmidt, 2003; Stern et al., 1985).

2.7. Value belief norm theory

The final theory in our broad category of normative influence, Stern et al.'s value-belief-norm theory (VBN), also proposes that personal norms and morals are the ultimate predictors of pro-environmental behaviors. This theory adjusts NAT to clarify a more sophisticated relationship between values and the emergence of attitudes and personal norms to behave in a pro-environmental way (Stern et al., 1999). VBN is presented as a linear linking of three levels of analysis: personal values, beliefs, and personal norms.

The first level of the causality chain in the VBN model starts with personal values, which reflect an individual's personality and concept of self, and serve as standards for individual behavior across contexts and time (Ibtissem, 2010). Of particular interest are the concepts altruism and egoism, which are thought to influence the motives behind preparedness to act collectively (Stern and Dietz, 1994). A positive correlation exists between altruistic motives and pro-environmental behavior, while egoistic values are traditionally oppositional (Stern, 2000; Stern and Dietz, 1994).

The second causal level incorporates beliefs, beginning with the perception of the relationship of people with nature (ecological worldview), which corresponds with the new environmental paradigm (NEP) described by Dunlap and Van Liere (1978) and Dunlap et al. (2000). The adoption of NEP determines the beliefs regarding the negative consequences of the behavior and the individual's perceived capacity to lessen the danger, creating the feeling of obligation to act in order to protect the environment in terms of the third link in the causality chain, personal norms.

We found one recent study in the literature that has applied a VBN-like theory to an animal management issue. In their research on stakeholder preference for lethal cat management in the US, Wald and Jacobson (2014) developed a multivariate model based on the framework of cognitive hierarchy, which is grounded in VBN theory. They hypothesized that specific attitudes towards various lethal control practices would mediate the effect of general attitudes, personal beliefs, and values, including NEP, (the second level of the VBN model) on lethal management support. Their final model explained 74% of the variance in lethal cat management support, with positive attitudes towards lethal management having the largest direct effect.

VBN has been shown to apply for other pro-environmental behaviors in specific contexts, such as energy conservation (Ibtissem, 2010). However, in other cases TPB accounted for more of the explained variances: e.g. conservation behavior (Kaiser et al., 2005) and willingness to pay for park conservation (López-Mosquera and Sánchez, 2012).

2.8. Affect heuristic

Most EV models assume that rational behavior is the result of deliberative cognitive processes and mostly ignore affective (emotional) responses, either viewing them as irrational or including their effect explicitly as part of self-interest (Jackson, 2005; Slovic et al., 2004). Similarly, models based on social and personal normative influence emphasize that normative influence over affect. In practice, however, many of our behaviors are a combination of controlled cognitive deliberation and automatic responses, in varying degrees, which brings us to our third broad category of behavioral theories: models that incorporate affect.

The automatic system is thought to account for a large proportion of human behavior, as people tend to unconsciously rely on a variety of decision and emotional heuristics (mental short-cuts), biases (rules of thumb) and habitual behaviors to shorten everyday decision-making processes (Tversky and Kahneman, 1974; Zajonc, 1980). Research has shown that affect can play an

important role in guiding decisions and judgments (Finucane et al., 2000; Loewenstein et al., 2001; Mellers and Schwartz, 1997; Peters and Slovic, 1996, 2000; Shiv and Fedorikhin, 1999).

Slovic's concept of the 'affect heuristic' was developed to explain the role of emotions in attitude formation (Finucane et al., 2000; Slovic et al., 2002). It is described as a mental shortcut where people subconsciously base a decision on their feelings rather than cognitive deliberation, particularly in cases of complex problems or when problems require solving quickly (Slovic et al., 2004).

Research on the affect heuristic has its origin in risk perception. Zajonc first noted that affective reactions to stimuli were often the first reaction, occurring automatically, and subsequently influencing the judgment of information (Zajonc, 1980). Finucane et al. (2000) then showed that perceived risk and perceived benefit were negatively correlated, i.e. if feelings towards a situation were positive, then people were more likely to judge the risks as low and the benefits high, even when this seemed counter intuitive. The implication of the affect heuristic theory is that judgment can be influenced not only by what people think about a situation, but also by how they feel about it.

Animals can evoke strong positive or negative emotions in humans (Jacobs, 2009; Searle, 2000), and emotional responses have been shown to play an important role in many wildlife management decisions (Manfredo, 2008; Slagle et al., 2012; Wieczorek Hudenko, 2012). Emotional responses drive wildlife tourism, zoo visitation, pet ownership, animal welfare, and wildlife conservation groups, so their impact on invasive animal management should be not overlooked.

The use of affect, especially negative emotions, is a common tool in behavior change interventions. Fear, as already discussed, is often used to instigate behavioral change by the use of 'fear appeal' communications. Positive emotions can also play a part. Howard (1999) noted that the positive affective component of tourist-wildlife education programs encouraged long-term conservation behavior. More broadly, Milton (2002) expanded upon the importance of emotion to commitment, motivation and action in caring for the natural world.

2.9. Needs, opportunities and abilities model

Our fourth and final category of behavioral theories – broader contextual models – is encapsulated in the Needs, Opportunities, and Abilities (NOA) model. The NOA model was developed by Vlek, Jager and Steg in 1997 to describe the environmentally relevant behaviors of individuals, households and business companies (Vlek, 2000). The authors believe that an essential characteristic of environmental problems is the inherent conflict between the individual, social and economic benefits of pro-environmental behaviors against the collective costs and risks (a 'commons' dilemma). Management of these commons dilemmas should be approached from a macro-level, involving problem diagnosis/risk assessment, decision making and risk control (Vlek, 1996), and it is these macro-level developments that act upon the three main components of the NOA model: (1) needs, (2) opportunities, and (3) abilities of the actors. These three constructs do not operate independently and their effect on behavior is mediated by two further components: 'motivation to perform' and 'behavioral control'. Needs and opportunities influence the motivation to perform a given behavior, while opportunities and abilities determine the behavioral control over a given activity.

According to the NOA model, to change a particular behavior would require not only modifications to relevant needs and/or relevant opportunities and/or relevant abilities that underlie that particular management behavior, but also an understanding of the interaction between the needs and opportunities (and how this influences motivation), and the interactions between opportunities and abilities (and how this influences behavioral control).

Therefore, to encourage participation in a particular invasive animal management activity (e.g. a group baiting program), it may not be enough to supply pre-made baits (a need), arrange a local group pick-up point (an opportunity) and conduct some training in laying baits (ability), if these components have no influence on the motivation and/or behavioral control of the land managers.

3. Towards an integrated framework of behavior change

The behavioral theories grouped into four broad categories (EV, normative influence, affect, and contextual) in the previous section provide a useful overview of the main drivers of and barriers to behavior change. They also guide practitioners about optimal leverage points for interventions. However, for the most part, they fail to make explicit connections between drivers/barriers, behavior change intervention tools and public policy. Thus, it is often unclear to practitioners which intervention and policy tools are most appropriate for specific contexts and populations.

Michie et al. (2011) have developed a *Behavior Change Wheel* (BCW) that links the behavioral factors to interventions and policy. The BCW enables practitioners and policy makers to understand the mechanisms underlying problematic behaviors, such as land manager disengagement, and select appropriate interventions and policies to invoke behavior change. In this section of the paper, we describe the main elements of the BCW and explore how it can be applied to invasive species management.

3.1. Behavior change wheel and the COM-B system for understanding behavior

An overarching, integrative model of behavior, the COM-B (Capability, Opportunity, Motivation – Behavior) system, lies at the hub of the BCW (Michie et al., 2011). COM-B can help invasive animal practitioners understand behavior in context by identifying the main causes of problematic behaviors such as non-participation in recommended animal control activities. It also helps identify what exactly needs to change to increase the probability that desirable behaviors will occur. According to the model, behavior is determined by three main factors:

(1) Capability – an individual's physical and psychological capacity to engage in the behavior of interest. COM-B distinguishes between two types of capability. *Physical capability* refers to the extent to which an individual can engage in the behavior. For example, does the land manager have the financial resources, equipment and physical ability to install a fence to exclude wild dogs or pigs or a fox-proof enclosure? *Psychological capability* refers to the capacity to engage in the necessary mental activities (risk assessments, mental simulation of possible outcomes, decision making etc.) to select an appropriate course of action. Mental health issues, such as depression, can substantially undermine psychological capability.

(2) Opportunity – factors external to the individual that prompt or enable the behavior to occur. COM-B distinguishes between two types of opportunity. *Physical opportunity* refers situational factors such as having relevant equipment or supplies readily available that are need to address an invasive animal problem. It can be difficult to lay bait if bait is not available. *Social opportunity* refers to cultural or community values and norms that may make engaging in recommended best practices more or less likely. For example, if most land managers within a region are baiting, this creates a social

norm that increases that likelihood that others in the region will also engage in this practice.

(3) Motivation – factors internal to the individual that energize or direct behavior. COM-B distinguishes between two types of motivational factors. *Reflective motivation* consists of conscious deliberation and reasoning, and often involves evaluating threats, planning, goal setting, and mentally simulating possible outcomes associated with various types of actions. For example, prior to deciding to rip out a rabbit warren, a land manager may make a list of the costs and benefits of engaging and not engaging in this activity, and select the option that he or she believes is most likely to produce the most positive outcome. *Automatic motivation* refers to mental processes that operate largely outside conscious control of the individual, including habits, impulses, and emotionally driven behavior. For example, a land manager's decision to participate in wild dog control may be driven by their negative emotional experiences resulting from the sight of their mutilated stock rather than logical deliberation.

According to the COM-B model, capability, opportunity, motivation influence and are influenced by behavior. For example, land managers who perceive many benefits and few costs associated with laying bait for wild pigs (high motivation), have the relevant knowledge and skills (high capability), and reside in a community where baits are readily available and baiting is a common practice (high opportunity) are more likely to engage in this practice. In turn, engaging in baiting can have a reciprocal reinforcing effect, increasing motivation, capability and opportunity in both self and others.

Importantly, all of the individual components of the behavioral theories reviewed in the first part of this paper can be classified into the COM-B system (see Table 1). From an applied perspective, we consider this to be an important advance. As Darnton (2008) noted, social psychology and behavioral economics have produced over 60 theories outlining the determinant of behavior. This is a very large number that is likely to overwhelm most practitioners, not to mention many social scientists.

The COM-B system provides a mechanism for integrating a highly disparate behavioral science literature into a single manageable framework that will enable practitioners to identify behavioral drivers and barriers that are most relevant to the invasive animal issue they wish to resolve. In addition, the COM-B system, as part of the behavioral wheel, enables practitioners to explicitly link drivers and barriers operating in a given context to specific behavior change strategies, a topic we turn to next.

3.2. Linking drivers and barriers to interventions

The middle ring of the BCW consists of nine intervention functions for changing behavior: education, persuasion, training,

Table 1
Translating behavioral theories into COM-B system.

COM-B Categories	Definition	Model factors
Capability – Physical	Capacity to physically engage in the behavior.	HBM – Perceived physical barriers TPB – Perceived behavioral control PMT – Perceived efficacy NOA – Behavior control; Abilities
Capability – Psychological	Capacity to engage in the thought processes (comprehension, reasoning, etc.) than underlie the behavior.	HBM – Self-efficacy PMT – Perceived self-efficacy TPB – Perceived behavioral control TIB – Self-efficacy NAT, VBN – Awareness of consequences; Ascription of responsibility NOA – Behavior control; Abilities
Opportunity – Physical	Features of the physical environment prompting or making possible a behavior.	HBM – Cues to action PMT – Response rewards; Response costs TIB – Facilitating conditions NOA – Behavior control; Opportunities
Opportunity - Social	Features of the socio-cultural environment prompting or making possible a behavior.	PMT – Response rewards; Response costs TIB – Facilitating conditions NOA – Behavior control; Opportunities
Motivation – Reflective	Conscious brain processes that energize and guide the behavior (e.g., evaluations and plans)	HBM – Perceived threat; Perceived benefits; Perceived seriousness; Perceived susceptibility PMT – Perceived severity; Perceived vulnerability; Threat appraisal; Coping appraisal; Protection motivation; Environmental and Intrapersonal information TPB – Attitudes; Normative beliefs; Subjective Norms; Outcome beliefs; Outcome evaluations; Motivation to comply; Intention FTNC – Injunctive Norms; Descriptive Norms TIB – Behavioral intention; Social normative beliefs; Personal normative beliefs; Perceived consequences; Role beliefs; Normative beliefs; Personal norms; Professional norms NAT – Personal norms VBN – Personal values; Personal beliefs; Ecological worldview (paradigm); Personal norms; Altruistic values; Egoistic values; Traditional values NOA – Motivation to perform; Behavioral processing; Needs
Motivation – Automatic	Automatic brain processes that energize and guide behavior (e.g., emotions, impulses, etc.)	HBM – Cues to action TPB – Subjective Norms; Normative beliefs FTNC – Injunctive Norms; Descriptive Norms TIB – Affect; Habit; Affective attitudinal beliefs NAT – Personal norms AH – Affect heuristic NOA - Needs

Note: HBM (Health Belief Model), PMT (Protection Motivation Theory), TPB (Theory of Planned Behavior), FTNC (Focus theory of Normative Conduct), TIB (Theory of Interpersonal Behavior), NAT (Norm Activation Theory), VBN (Value Belief Norm Theory), AH (Affect Heuristic), NOA (Needs Opportunities and Abilities Model).

incentivisation, coercion, restriction, environmental restructuring, modeling, and enablement. Definitions and examples are provided in Table 2. A key strength of the BCW is that it provides a useful framework for linking identified causes of behavior (from COM-B analysis) to specific intervention types. Practitioners need to be aware of the wide range of behavior change interventions available to them, and understand that, depending on the behavioral drivers and barriers operating within a given context, different types of interventions may be required. For example, if the COM-B analysis indicates that land managers are failing to bait because they lack the requisite skills (physical capability) and fail to see the benefits (reflective motivation), the BCW suggests an optimal intervention could include training (to provide relevant skills), and one or more of education, persuasion, incentivisation, and coercion (to increase reflective motivation). On the other hand, if the main barrier to land manager participation is a lack of readily available baits (physical opportunity) interventions related to environmental restructuring and enablement would be more beneficial.

By understanding the mechanisms that drive and prevent target behaviors within a given context, practitioners are in a much stronger position to select an appropriate set of behavior change intervention strategies. Table 3 summarizes how the components of the COM-B model link to the nine intervention functions.

3.3. Linking interventions to policy

The outermost ring of the BCW focuses on policies – plans of action and strategies to help governments and organizations achieve goals. The BCW distinguishes between seven policy types: communication/marketing, guidelines, legislation, regulation, fiscal, environmental/social planning and service provision.

Just as the BCW provides a means for linking behavioral causes to intervention types, it also provides a bridge between interventions and policy tools. The BCW provides a common framework for practitioners and policy makers to jointly identify which policy tools will support the delivery of specific types of behavior change initiatives. For example, interventions aimed at restricting land managers from engaging in counterproductive management practices would be best supported by a policy mix involving one or more of the following: guidelines, regulation and legislation. On the other hand, interventions aimed at increasing land manager participation rates through modeling would be best supported by policies related to communication/marketing and service provision. A complete summary of the types of policy tools that are best matched to intervention types are summarized in Table 4.

4. Future directions

As discussed, much work in the behavioral sciences is not only applicable to invasive animal management but has the potential to significantly improve pest control outcomes. That said, the application of theory is in its infancy and many questions remain unanswered, including some fundamental dilemmas.

Most notably, the common means of applying behavioral science to invasive animal management is to choose and apply a single theory. We believe this could represent an important mistake. Each of the theories reviewed in this document is limited, and all the elements within a single theory may or may not be applicable in a given context. While it is possible that the models may be generalizable to the core behavior of 'participation', that is, undertaking recommended control practices, specific drivers and barriers may vary significantly across contexts.

Species, audience segment and geographical location are all contexts that could give rise to varied patterns of mediation and different expressions of moderation. Effective behavioral tools for wild pig control, for example, may vary widely between progressive audience segments and more conservative populations that tend to be more suspicious of government. In turn, could a water-based invasive, such as carp, pose different etiologies (compared to pigs) for practitioners seeking to capitalize on affect or protection motivation theory?

COM-B and the Behavior Change Wheel strikes us as an optimal way for practitioners to increase understanding of behavior in context, but the BCW is no panacea. Significant effort will be required to organize and evaluate potential influence factors, informed by all-important context.

5. Conclusion

Social psychology has produced a large number of behavioral theories relevant to invasive animal management. These theories can help practitioners understand the underlying causes of problematic behaviors, and identify leverage points for eliciting behavior change. Michie et al.'s (2011) BCW provides a single, integrated framework for understanding behavioral causes in context, and explicitly linking these causes to interventions and policy tools. Applying the framework to invasive animals will provide practitioners and policy makers with a common 'mental

Table 2
Definitions and examples of interventions.

Intervention functions	Definitions	Invasive animals examples
Education	Increasing knowledge and understanding	The use of written factsheets, technical manuals and video clips, or practical courses to disseminate information and demonstrate invasive animal management techniques.
Persuasion	Using communication to induce positive or negative feelings or stimulate action	The use of fear appeals such as the impacts on native animals to get people to act against invasive animals
Incentivisation	Creating expectation of reward	The use of a bounty system to increase involvement in fox shooting activities.
Coercion	Creating expectation of punishment or cost	Introducing legislation which makes control mandatory with heavy fines for non-compliance
Training	Imparting skills	Running intensive courses to provide theoretical and practical instruction for people implementing vertebrate pest management for agricultural protection and conservation.
Restriction	Using rules to influence the engagement in the target behavior	Introducing regulations to control the supply and use of pesticides so it remains safe and effective.
Environmental restructuring	Changing the physical or social context	Declaring a particular species as a pest species to define it as a social problem and create a situation that is in need of a solution.
Modeling	Providing an example for people to aspire or imitate	Setting up a 'demonstration site' on a local property to display best-practice methods and validate the results in a particular area.
Enablement	Increasing means/reducing barriers to increase capability or opportunity	Developing new technology or improving current methods such as new bait delivery systems, new toxins with more humane action or new monitoring tools with remote sensing abilities.

Based on Michie et al. (2011).

Table 3
Links between COM-B components and intervention functions.

COM-B	Education	Persuasion	Incentives	Coercion	Training	Restriction	Environmental restructuring	Modelling	Enablement
Capability									
Physical					☑				☑
Psychological	☑				☑				☑
Opportunity									
Physical						☑	☑		☑
Social						☑	☑		☑
Motivation									
Reflective	☑	☑	☑	☑					
Automatic		☑	☑	☑			☑	☑	☑

Based on Michie et al. (2011).

Table 4
Links between intervention functions and policy tools.

Policy tool	Education	Persuasion	Incentives	Coercion	Training	Restriction	Environmental restructuring	Modelling	Enablement
Communication/Marketing	☑	☑	☑	☑				☑	
Guidelines	☑	☑	☑	☑	☑	☑	☑		☑
Fiscal			☑	☑	☑		☑		☑
Regulation	☑	☑	☑	☑	☑	☑	☑		☑
Legislation	☑	☑	☑	☑	☑	☑	☑		☑
Environmental/Social Planning									☑
Service Provision	☑	☑	☑	☑	☑			☑	☑

Based on Michie et al. (2011).

model' for conceptualizing and communicating about behavior change. This will provide the foundation for a more coordinated and effective approach for addressing the 'human element' that lies at the heart of many invasive animal management problems.

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