Invasive Animals Cooperative Research Centre

Understanding the drivers and barriers towards the adoption of innovative canid control technologies: a review

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"Together, create and apply solutions"

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Summary

Wild dogs (*Canis lupus familiaris*) and foxes (*Vulpes vulpes*) are considered major pests in Australia. To reduce the impact of these pests, a variety of control techniques are available to private and public land managers. Despite the availability of these techniques, many land managers do not participate in canid control because of concerns over non-target risks, humaneness, and cost and effectiveness. There is a need for new canid control technologies that pose fewer risks to non-target animals or other assets, cause minimal contamination of soil, crops and waterways, and are perceived as humane by those who use them and the public at large.

A number of agencies led by the Invasive Animals Cooperative Research Centre (IA CRC) are assessing para-aminopropiophenone (PAPP) as a new chemical for canid control. PAPP and its associated antidote, BlueHealer®, are not yet available for commercial use in Australia but in a number of environments should pose fewer risks to non-target species, especially pet dogs, while being a highly effective chemical active for wild canid control. These desirable attributes should translate into the uptake of this pest control innovation. This paper reviews a selection of innovation diffusion models to better understand the probable drivers and barriers to end users adopting innovative pest control strategies in general and more specifically PAPP products as best practice integrated wild dog management.

There is a growing body of literature in natural resource management examining how the diffusion of innovations can be influenced and how community engagement programs may benefit the adoption of new technologies. The literature suggests that a participatory approach to stakeholder engagement and extension improves rates of adoption. Extension programs should target syndicates or workshops, through champions or trusted intermediaries. The effectiveness, specificity and humaneness of PAPP should be communicated and demonstrated in a transparent, repeatable and easily understood manner. The antidote to PAPP, BlueHealer®, is likely to be the most attractive benefit of the product because of strong concerns over accidental poisoning of farm and working dogs when using existing poisons.

Uptake of PAPP products is complicated by the beliefs, values and perceptions towards both canid management and existing control technologies. The drivers and barriers that influence both participation in, and choice of canid control techniques, are poorly understood. A community survey structured across different stakeholder groups and across geographic space would help quantify key perceptions towards canid management. Adoption of PAPP products may be benefited by focusing research and extension programs on key features of PAPP and on products containing this new chemical active that are poorly or misunderstood by the suite of potential adopters.

1. Introduction

1.1 Impact of wild dogs and foxes in Australia

Wild dogs, which include feral domestic dogs (*Canis lupus familiaris*), dingoes (*C. l. dingo*), their hybrids, and the European red fox (*Vulpes vulpes*) are considered major pests in Australia. Although there is considerable debate as to whether these species play an important role in regulating populations of other species, such as kangaroos, wallabies and rabbits (Fleming et al. 2001), attacks on livestock in rural areas by these pests impact economically, environmentally and socially on farming systems and land managers. In addition to direct losses of stock, increased stress posed on livestock through attacks can result in mismothering of sheep, reduced weight gains, poor wool growth and low quality meat in both sheep and cattle (Mitchell and Balogh 2007). In 2005, the Australian Government House of Representatives Standing Committee on Agriculture, Fisheries and Forestry considered that wild dogs were the most serious pest animal problem facing Australian sheep and cattle farmers; and that they are also one of the most significant pest animal problems for Australian agriculture generally (Parliament of the Commonwealth of Australia 2005).

A number of authors have attempted to estimate the economic cost associated with wild dogs and foxes in the agriculture sector (Bomford and Hart 2002; McLeod 2004; Gong et al. 2009; Hewitt 2009). However, as indicated by Bomford and Hart (2002), it is difficult to quantify accurately the agricultural cost attributable to wild dogs and foxes in Australia on a national, state or regional level. As a result, the estimated economic cost of these species on Australian agriculture varies significantly between authors. McLeod (2004) estimated that the fox costs Australian agricultural industries and the environment more than $227 million annually and that the value of production losses caused by wild dog attacks to livestock, as well as the associated management costs, to be in excess of $66.3 million per year. More recently, Gong et al. (2009) estimated that the overall annual loss in agriculture (including horticulture) nationally due to wild dogs at $48.5 million and foxes at $21.2 million. In Queensland, a report issued by AgForce in 2009 estimated that wild dogs cost agriculture almost $70 million annually through predation, disease and control (Hewitt 2009).

In addition to direct financial costs, wild dogs and foxes increase physical and emotional stress to producers, impact on native wildlife and transmit disease. Wild dogs and foxes can transmit many forms of bacteria, viruses and disease to both humans and animals, particularly at the peri-urban interface where they are increasingly becoming a problem (Allen 2008b; Henderson 2009). The most significant disease spread by canids, *Echinococcus granulosu,* is a hydatid tapeworm known to infect both humans and animals. Reduced agricultural production from wild dog impacts can lead to a decline in employment and services in rural towns. Fitzgerald and Wilkinson (2009) found that farmers can suffer significant emotional distress and frustration associated with a wild dog attack on their livestock. Continual attacks from wild dogs and foxes, and the inability to control their impacts sufficiently, leaves many land managers considering moving to an alternative production system, or at worst selling the farming entity altogether.

1.2 Management of wild dogs and foxes

The management of wild dogs is complicated by inconsistencies as to the pest-status of these species. Each state and territory has specific guidelines and regulations that must be adhered to in controlling feral plants and animals. Current legislation protects pure dingo populations in National Parks whilst supporting their control in surrounding agricultural enterprises (Davis and Leys 2001; Burns 2008). Management of wild dogs and dingoes in protected areas is complicated by difficulties distinguishing pure dingoes from hybrids. A number of techniques are available to distinguish between the two (i.e. measuring differences in skull dimensions); however, none can be used on sighting the animal and such techniques are time consuming and impractical in large-scale operations (Hytten 2009). Consequently, it is difficult to manage dingoes and hybrids separately, which means that many hybrids effectively receive the same legislative protection as pure dingoes.

To reduce the impact of canids, private and public land managers apply a wide variety of control techniques. Principal canid control techniques include exclusion fencing, shooting, guarding animals, trapping and poisoning, usually with sodium fluoroacetate (also known as 1080). Other chemicals such as cyanide, strychnine and phosphorus have previously been used. The choice of control technique used by land managers depends on many factors including; beliefs about the economic impact and behaviour of wild dogs, the role of neighbours, beliefs about the time and effectiveness of control technologies and costs of control. Despite the costs incurred by wild dogs and foxes and the significant landholder and State Government investment in on-farm and regional wild dog control programs, some land managers do not participate in canid control due to concerns over cost, effectiveness and humaneness of current techniques.

As a result, a number of agencies led by the Invasive Animals Cooperative Research Centre (IA CRC) have developed a range of pest control technologies that in general pose fewer risks to non-target animals or other assets, cause minimal contamination of soil, crops and waterways, and are humane. Para-aminopropiophenone (PAPP) and its associated antidote BlueHealer®, is one such technology recently developed as an additional tool for canid control (Fleming et al. 2006). Although not yet available for commercial use in Australia, field trials suggest that PAPP products will be an excellent complement to existing canid control techniques (Fleming et al. 2001). However, despite the apparent advantages of some recent pest control innovations, adoption by land managers can sometimes be slow, leading to poor market outcomes and ultimately reduces innovation in the field. Slow rates of adoption in this market will cause loss of potential benefits to agriculture, communities and the environment (Llewellyn et al. 2007). Understanding what factors are likely to lead to increased rates of adoption are therefore of great potential benefit for both Australian agricultural production and biodiversity conservation.

1.3 Aims of research

The aim of this research is to conduct a literature review and critically analyse the complex influences on individual stakeholder decisions about the adoption of new pest control technologies. More specifically, this review examines:

- The current methods of canid control, specifically 1080 use.
- The benefits and potential risks of PAPP products in integrated wild dog management.
- What the values and beliefs that will drive/limit uptake of PAPP products are.
- How the diffusion of information regarding PAPP products can be influenced to the benefit of end user adoption.

The review begins by summarising current methods of canid control in Australia and why new and innovative control methods are needed (Section 2). Specific attention is given to the most common and cost effective method of pest control—baits containing compound 1080—and how the launch of new PAPP products could enhance the effectiveness and scale of wild canid management (Section 3). After discussing why innovative pest control technologies are needed, the review then examines how the diffusion of new technologies and ideas can be influenced by developers and marketers of an innovation (Section 4). Lessons learnt from the adoption of past innovations such as PIGOUT® are examined. By analysing and understanding a selection of innovation diffusion models and how these feed into what we understand is needed for effective community engagement, the report reviews what factors might drive/limit change in practice in pest control management and what efforts are most effective in encouraging the uptake of PAPP products and innovative pest control technologies in general (Section 5).

2. Current management techniques

2.1 Managers of wild dogs and foxes

A number of stakeholder groups participate in canid control. Fitzgerald (2009) divides invasive species managers into three categories; private land managers, public land managers and Indigenous managers. Private land mangers primarily consist of farmers who participate in canid control to prevent impacts on cattle and sheep production. Public land managers typically have responsibility for managing crown lands or reserves that have some intrinsic natural value that is worth preserving. They include wildlife managers and conservation organisations and generally participate in canid control to prevent or reduce the impact of these species on native wildlife. In contrast, the management of wild canids by Indigenous land managers may be highly influenced by their local history, past experience and relationship to animals.

2.2 Methods of canid control

There are a variety of methods available to land managers to manage and reduce the impact of canids, including: trapping, shooting, guarding animals, exclusion fencing, poisoning; and in the case of foxes, den destruction and fumigation (Saunders et al. 1995; Fleming et al. 2001). Trapping is considered an effective means of wild dog and fox control, but it can be costly when setting and monitoring traps are taken into account. Shooting is often used opportunistically for individual animals and is not considered as being overly effective given the time and effort required to control large populations. The use of guardian animals, such as Alpacas, Marama dogs and donkeys, has proven successful in reducing livestock loss, although there is concern in relation to their capacity to range over a wide area in guarding sheep (Fenton 2009). Despite the relative low maintenance costs of guardian animals, initial expenses to purchase and train such animals are high. Exclusion fencing has been used to protect livestock; however, one of the main impediments to the use of netting or electric fencing is the time and expense required to establish and maintain fence boundaries. Poisoning remains one of the most widely recognised options for canid control and the most cost-effective, particularly in the more remote rangeland areas or at regional scales (Fleming et al. 2001).

2.3 Sodium monofluoroacetate (1080)

Sodium monofluoroacetate (hereafter referred to as 1080) is the most widely used poison in Australia and New Zealand to control pest animals. 1080 poison is considered the most economical control method currently available, and the only practical means for achieving population control in remote and inaccessible areas (Sharp and Saunders 2004). The use pattern for 1080 varies across Australia and is tailored to optimise target specificity and efficacy for the specific ecosystems and regions. During strategic baiting programs, 1080 baits are either applied by aerial or ground distribution (Sharp and Saunders 2004). Aerial baiting is generally regarded as an efficient and cost effective canid control technique and is used where ground baiting is impractical, unduly costly or where terrain is inaccessible. Strategic ground baiting involves placement of baits at sites selected to maximise their uptake by wild dogs and minimise non-target disturbance.

1080 is applied at relatively small rates, is readily degraded on/in soils, surface waters and by micro-organisms and is somewhat targeted compared to other available poisons (Eason et al. 1999; Meenken et al. 1999). For example, dogs, foxes and cats are highly susceptible, followed by all the herbivores (rabbits, cattle, sheep, deer, possums), while quolls, Tasmanian devils, and mice have a relatively high tolerance to 1080 poison (APVMA 2008). Most of the 1080 that is ingested by animals is rapidly metabolised and/or excreted, with only low levels retained in the carcass. The usual scavengers on carrion such as birds have a high tolerance to 1080 and would need to eat large quantities of the meat to receive a lethal dose (APVMA 2008). The chemical does not bio-accumulate in top predators or scavengers with multiple sub-lethal ingestion (APVMA 2008).

2.4 Barriers of participation in 1080 baiting programs

2.4.1 Non-target impacts

Despite the effectiveness of 1080 for canid control, barriers towards participation in baiting programs have been reported. Fitzgerald (2009) found that while farmers are generally accepting of its cost effectiveness and necessity for control of some pest animals, they appear to be increasingly concerned about the environmental impact of 1080. However, many land managers choose to use 1080 because they value its capacity to mitigate canid impacts over concerns regarding its potential impact on native wildlife. A review by the Australian Pesticides and Veterinary Medicines Authority (APVMA) that commenced in 2002 bolstered this paradigm, reporting that although poisoning of non-target animals occurs, it is limited to individual animals and does not adversely affect overall populations of non-target species.

2.4.2 Accidental poisoning of farm and working dogs

Perhaps the greatest barrier to participation in 1080 baiting programs by land managers is concern over accidental poisoning of farm and working dogs. Research suggests that the potential to inadvertently poison farm dogs is a significant factor that deters farmers from using 1080 baits (Allen 2008b; Allen 2008a; Goh et al. 2008; Fitzgerald 2009; Hewitt 2009). Allen (2008a) conducted an assessment of large scale, community based 1080 baiting programs and found that the principal reason given by farmers who do not participate in coordinated baiting programs was their reliance on working dogs to manage their livestock and the hazard 1080 baits posed to these dogs. This belief is supported in the AgForce survey (Hewitt 2009) which found 32 per cent of respondents did not conduct 1080 ground baiting, due to the direct concern about baiting their pet or working dogs. Similarly, 84 per cent of respondents in a survey by Fitzgerald (2009) did not use 1080 due to fear of poisoning farm dogs. This is indicates there is a powerful impetus for an additional chemical control with an associated antidote.

2.4.3 Humaneness

There are concerns, although not universal, in regard to the humaneness of 1080 for canid control. After a canid ingests 1080, there is latent period of around four hours before initial signs of poisoning such as hyper-excitability, vocalisation, manic running and retching occur. Carnivores experience nervous system disturbances and convulsions before dying of respiratory failure (APVMA 2008). Although the symptoms of 1080 poisoning can be distressing to observe, it is difficult to determine if poisoned animals are experiencing pain or whether the symptoms simply reflect central nervous system disturbances (APVMA 2008). As 1080 impairs neurological function, it is difficult to interpret the behaviour of affected animals, or to assess their ability to experience pain or discomfort (Sherley 2007; Twigg and Parker 2010). Death generally occurs two hours after the onset of clinical signs (Sharp and Saunders 2004; Goh et al. 2008). The signs of 1080 poisoning can be distressing to an observer (Marks et al. 1999). The Royal Society for the Prevention of Cruelty to Animals (RSPCA) do not support the use of 1080 to control feral animals; however, they recognise that there are no suitable alternatives presently available and encourage research into more humane, alternative methods of canid control (RSPCA 2010).

2.4.4 Administration and supply of 1080

Extensive regulation of the administration and supply of 1080 is a significant barrier to participation in canid management. All 1080 pesticide products, including baits, are classified as restricted pesticides (Schedule 7—Dangerous Poison) under the *Agricultural and Veterinary Chemicals Code Act 1994* (Cth) (the ‘AgVet Code’), and as such can only be used in accordance with directions given in (for example) a state Pest Control Order or equivalent state agency authority. 1080 products are available only to authorised persons who have the skills and knowledge to handle them safely, which requires training to obtain (Victorian Government Department of Primary Industries (VIC DPI) 2007). An authorised person is generally an officer from local government or state government departments and also includes the relevant state government public authority boards, such as the Livestock Health and Pest Authority in NSW (Department of Environment and Conservation NSW (DECC) 2010).

Regulatory compliance extends to the end-user. When 1080 bait is supplied to land managers, they themselves are required to be appropriately trained and must agree to a number of constraints on the application and use of 1080 baits. For instance, baits must be distributed only on the nominated land, must not be laid within two kilometres of any human habitation and must not be laid within five kilometres of a town area. Further, land managers within two kilometres of the bait site must be notified of the intention to lay baits at least 72 hours beforehand, baits are not to be used within five metres of a fenced property boundary and no baits can be laid within 50 metres of the centreline of a declared road. Warning signs must be placed at the entrance to all properties where baiting occurs.

3. A new chemical active for canid control: para-aminopropiophenone (PAPP)

Since mid-2003 a number of agencies led by the Invasive Animals Cooperative Research Centre (IA CRC) have investigated para-aminopropiophenone (PAPP) as an additional chemical for canid control because of benefits that the poison possesses (Fleming et al. 2006). The chemical has been developed for canid control with target selectivity and humaneness as priority features (Fleming et al. 2006). At present, the chemical is not yet commercially available for wild dog and fox control; however, research and development programs are well advanced in both Australia and New Zealand and the registration dossiers have been filed with both APVMA and New Zealand's Environmental Risk Management Authority (ERMA). Due to the commercial development of this technology and the early stage of registration assessment, published literature on the effectiveness, humaneness and non-target effects of the product are scarce, although PAPP products appear to have desirable attributes for a lethal chemical active, including:

- ease of formulation and manufacture as attractive and palatable baits
- oral bioavailability and reliability of effectiveness
- humane mode of action (anoxia)
- readily biodegraded
- effective antidotes for use by vets and dog owners
- selectively more toxic to mammalian carnivores than most non-targets.

3.1 Effectiveness and humaneness of PAPP

The few published studies on PAPP suggest that it is an effective and humane poison. The toxic effects of PAPP are associated with the clinical condition methaemoglobinaemia whereby the carrying capacity of oxygen in red blood cells is reduced. Death results from a lethal deficit of oxygen in cardiac muscles and the brain due to excessive conversion of haemoglobin to methaemoglobin (Vanderbelt et al. 1944). Marks et al. (2004) concluded from pen trials that PAPP is a highly effective and humane toxin for fox control. In their study, M-44 ejectors were used to deliver a standard dose of 226 milligrams of PAPP in a formulation with dimethylsufoxide and condensed milk to five foxes. The authors reported that the onset of symptoms in foxes was considerably faster than that observed with 1080, with foxes showing abnormal behaviour 10 – 24 minutes after consumption and death occurring after 30 – 43 minutes. As well as concluding PAPP was fast acting and effective, Marks et al. (2004) suggested PAPP was humane, with poisoned foxes showing few clinical signs of toxicosis.

3.2 Non-target impacts of PAPP

PAPP is relatively less toxic to the suite of Australian non-target species when compared to wild dogs and foxes. Non-target risk assessments commissioned for the new active (PAPP) registration submission examined how sensitive 16 iconic Australian native species *(brown antichinus, brush tailed possum, bush rat, eastern quoll, fat tailed dunnart, little raven, lab rat, long nosed potoroo, pademelon, sand goanna, southern brown bandicoot, spot tailed quoll, silver gull, swamp rat, tasmanian* *devil)* were to the effects of orally administered PAPP. A total of 14 species (more than 85% of species tested) required at least 2.9 times an equivalent lethal dog dose (relative to body weight). Only two species were more sensitive (goannas and southern brown bandicoot) than wild dogs. This targeted toxicity was also demonstrated by Savarie et al. (1983), Schafer et al. (1983) and Fisher et al. (2005) who all observed lower PAPP toxicity in birds than in mammalian carnivores when delivered in solution. Eason et al. (2010) tested the toxicity of PAPP when presented in a formulated product in four bird species: Australian magpies (*Gymnorhina tibicen*); blackbirds (*Turdus merula*); mallard ducks (*Anas platyrhynchos*, Pekin breed) and weka (*Gallirallus australis*). Their results agreed with previous studies suggesting PAPP has a lower toxicity to birds and may present a lower risk to a majority of birds than baits containing 1080. This is most likely due to different metabolic pathways that occur in eutherian carnivores compared to other animals (Wood et al 1991). Eason et al. (2010) reported high inter-specific variation in response to PAPP by birds, with mallard ducks the most susceptible of the bird species studied.

3.3 An antidote for PAPP: BlueHealer®

Perhaps the greatest attribute of PAPP products is the availability of an effective antidote, BlueHealer®. BlueHealer® contains the chemical methylene blue, which reverses the methaemoglobinaemia induced by PAPP (Humphrys 2010a). A number of studies have reported the demand for an antidote to accompany baiting technologies. Hewitt (2009) found that 61 per cent of producers interviewed would be more likely to use 1080 baiting if there was an antidote available for their pet or working dogs. Similarly, Fenton (2009) reported that the availability of an antidote would be an important incentive for many land managers to undertake a baiting program on their properties. However, due to the rapid onset of symptoms to time of death following consumption of PAPP bait, land managers will need to seek veterinary assistance or treat animals promptly for BlueHealer® to be effective (Marks et al. 1999). A project that was recently completed by the IA CRC assessed an intravenous administration of the antidote that can now be approved as a vet only product. An oral formulation of methylene blue that dog owners can treat accidently poisoned animals with, under veterinary direction, is also currently being worked up and assessed for efficacy and safety so that rapid treatment of accidentally poisoned animals is possible in the absence of veterinary attention (Humphrys 2010b).

3.4 Adoption of new pest control technologies: lessons learnt from PIGOUT®

The available literature on PAPP suggests that the product is well placed as an additional tool for land managers to use alongside existing baiting methods and in integrated management programs. PAPP products can be laid in baiting programs in a similar manner to 1080, but pose fewer risks to a number of non-target species, particularly farm dogs. However, improvements to pest control methods do not necessarily ensure adoption by land managers. There have been examples in the past where the uptake of innovations in pest management has been slow, leading to market failure. The product PIGOUT® provides a good example of a new technology that, despite a market need, lagged forecast uptake estimates. When the market was critically analysed, sales of PIGOUT® in New South Wales (a key state for feral pig control sales) were not possible due to the omission of PIGOUT® on the relevant pest control order. This meant that most government agency staff responsible for advising end-users were not aware of this new product for controlling feral pigs. Staff aware of the product did not know that they could sell it and as a result, the product was not promoted as a management option to end-users. This example demonstrates how critical it is to understand the value chain with respect to restricted pesticide supply. A description and critical analysis of the value chain is presented in Section 5 of this review.

The remainder of the review will focus on a selection of innovation diffusion models within appropriate community engagement approaches to identify how the roll-out of pest animal PAPP products can be influenced to enhance their ultimate adoption. Adoption of innovations, or practice change is complex, and is not a simple linear process of learning, but a complicated iterative process influenced by social, environmental and economic processes. It requires understanding the fields of information management, multi-stakeholder processes, social learning, behavioural change, marketing, environmental management, conflict management (Rogers 1962), community engagement approaches (Hashagen 2002; Tamarack 2003; Aslin and Brown 2004; Flora 2004), agricultural extension (Pannell et al. 2006; Land & Water Australia n.d), and scientific citizenship (Irwin 2001). By analysing and understanding innovation diffusion models, and how these models integrate within overarching community engagement principles and where transactional friction in these systems is likely greatest, the factors that might limit and conversely drive change in practice and the uptake of PAPP products are discussed.

4. Models of practice change and technology adoption

Diffusion models attempt to explain the spread of an innovation through a social system and the members of that social system who contribute to its spread. Many mathematical and conceptual models describing diffusion of innovation have been developed in the fields of marketing, management, consumer behaviour and natural resource management (e.g. Mansfield 1961; Bass 1969; Mahajan et al. 1990; Pannell et al. 2006). Diffusion models vary in their structure, assumptions and explanation of the diffusion process. They have been used for descriptive purposes and/or to predict how diffusion can be influenced. A comprehensive analysis of all diffusion models is beyond the scope of this review (for more information see Baudisch and Grupp (2006)). Instead, one of the most widely discussed and long-standing models is analysed—diffusion of innovation theory (Rogers 1962)—as well as innovation diffusion models in natural resource management. The context of these models in understanding the uptake and adoption of new canid control control technologies (such as PAPP baits) is also discussed.

4.1 Diffusion of innovation theory

Diffusion of innovation theory (Rogers 1962) attempts to explain how an innovation spreads through society, who are the first to adopt, and how the rate of adoption can be influenced. Diffusion of innovation theory is under-pinned by the assumption that interaction exists between members of a social system. Rogers (1962) suggests that the frequency of individuals successfully adopting an innovation will follow a typical bell-shaped normal distribution curve over time (Figure 1). At first, a minority of individuals or groups adopt, before a tipping point occurs, whereby the rate of adoption rapidly increases. As the rate of adoption increases so does the level of interpersonal influence on non-adopters so that eventually, even individuals who are cautious about the innovation adopt as they succumb to social and economic pressures. According to innovation of diffusion theory, innovators are the first to adopt an innovation, followed by early adopters, the early majority, late majority and laggards (Figure 1). Adoption of an innovation is best influenced by targeting the innovators and early adopters in the target market. Marketing programs should first focus on making these individuals aware of an innovation, and as the innovation gains acceptance, be progressively tailored to appeal to each new adopter category targeted.

There have been many well documented cases where new technologies—such as the use of tractors, hybrid seed and synthetic fertiliser—have been diffused quite widely using diffusion of innovation theory (Korsching 1993; Ruttan 1996a). However, the model of diffusion has been criticised by many authors. Firstly, targeting innovators and/or early adopters will only increase the rate of adoption in social systems where inter-personal communication exists between members of the target market (Wright and Charlett 1995). If interpersonal communication between members is limited, targeting innovators and early adopters first is likely to be much slower than had the whole market been approached (Wright and Charlett 1995). Secondly, many authors suggest that in practice, identifying innovators and early adopters from others in the target market is difficult (Russell et al. 1989; Wright and Charlett 1995). Innovators and early adopters in a target market are likely to be case-specific. Individuals who adopt one innovation early are not necessarily early adopters of all innovations, meaning that marketing strategies should be treated on a case-by-case basis.

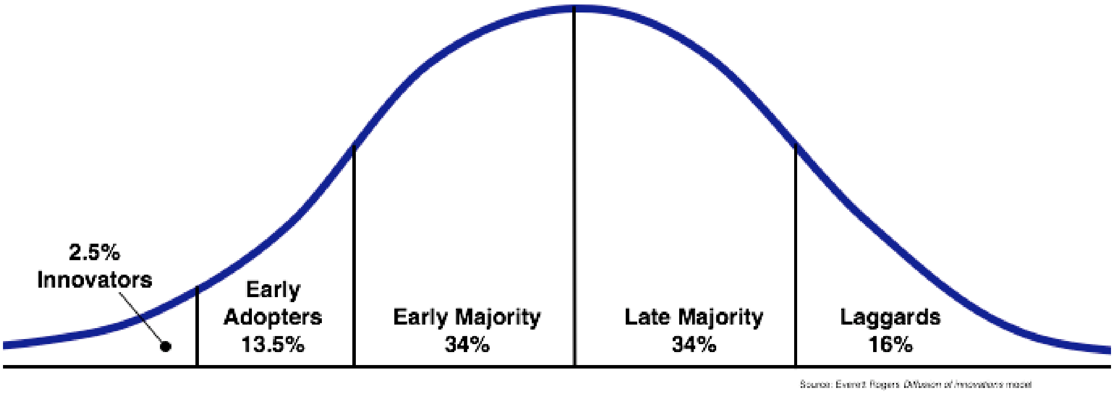

Figure 1: Frequency of individuals successfully adopting an innovation according to Rogers (1962).

4.2 Traits and characteristics of innovators and early adopters

A significant body of literature focuses on quantifying the characteristics of individuals who adopt first so that the people or individuals with these traits can be targeted. Individual characteristics, such as income, age, education and cultural backgrounds, have been shown to be associated with adoption (Pannell et al. 2006). Griliches (1957) and Mansfield (1961) both identified the size of the business, and hence the expected return from the new innovation, is related to earlier and faster rates of adoption. Empirical evidence also suggests that innovators and early adopters have the common traits of being less risk adverse, have the highest social status, are active on an interpersonal level and are more likely to be financially secure (Bond and Wonder 1980; Bardsley and Harris 1987; Ghadim and Pannell 1999). Associations between some characteristics and adoption, such as age, are not so clear. For example, Itharat (1980) proposed that older land managers have more experience, larger amounts of land and are therefore more inclined to adoption in innovation. In contrast, Warner (1981) found that adopters of conservation practices were relatively young, having farmed for a few years on smaller blocks of land.

4.3 Engaging with potential adopters

There is a growing body of literature examining engagement between developers of innovations and potential adopters. Traditionally, engagement programs tend to involve one-way, top-down communication or information exchanges. Recent research into agricultural extension and the use of community engagement indicate that top-down, one-way approaches are less effective in generating lasting change than collaborative or participatory engagement programs (Marsh and Pannell 1998; Pannell et al. 2006; Thompson et al. 2009). Engagement programs should be dynamic so that the flow of information is two-way (Rogers 1962). Participatory programs have the potential to be longer-term and self-sustaining and are believed to improve the impact and effectiveness of engagement processes. Engagement programs should follow through the adoption decision process until adoption is maintained.

The manner in which engagement programs are developed is crucial to effective and successful adoption. Thompson et al. (2009) suggest that developers of engagement programs should recognise the context specificity of activities and information and the diverse perspectives that may exist between groups of potential adopters. All stakeholder groups involved should develop a collective vision of the engagement process. Kruger et al. (2010) suggest that for effective engagement, information must be communicated so that potential adopters understand how they will benefit from the innovation and they must be flexible and responsive to changing circumstances. During a community engagement program, stakeholders should be motivated by highlighting program achievements and be reminded that their involvement is making a difference to the problem at hand. Challenges for those seeking to use community engagement include when expectations about engagement differ between groups of potential adopters and when adopter groups are sceptical about the engagement process due to precious engagement experiences.

Understanding potential adopter groups provides valuable insight into how to develop and implement engagement processes. Kruger et al. (2010) state that marketers should gain insight into the level of interest that stakeholders may have in an innovation. Research should identify who influences decision-making in these groups, their knowledge, attributes, skills and aspirations and which stage of the engagement process is most relevant to them. Effective engagement should not only target relevant stakeholders, but also identify the most suitable individuals within these groups. A range of tools and approaches are available to understand these considerations and ultimately involve and engage potential adopters (Aslin and Brown 2004). For example, network analysis can be used to better understand target groups and the relationships that exist between and within them (Allan and Curtis 2002). Understanding the linkages between individuals and other members in the target market can help engage marketers to identify where people are sourcing information and who they trust to provide relevant and valid information.

4.4 Champions and channelling information

There has been relatively little research on how land managers become aware of innovations and thus how information should be channelled. The community engagement literature highlights how champions and trusted intermediaries can play an important role in creating a shared vision that motivates people to co-operate for change. Effective and successful adoption relies heavily on building trust between engagement facilitators, government representatives, industry groups and land managers. A common issue arising between researchers, government representatives and land managers is the failure of these groups to communicate effectively such that they understand each other (Wynne 1989). Community champions help build contacts between stakeholders who might not typically interact and share ideas or information. A champion should be a well recognised figure who is viewed with respect and trust by the target audience. In the context of promoting PAPP related products the National Wild Dog Facilitator is an example of a suitable champion who might play an important role in channelling information to potential adopters. Other potential intermediaries include state government agency staff responsible for the supply of restricted pesticides to farmers and other end-users to protect biodiversity. Local government and private pest control officers may also be suitable individuals responsible for providing information to land managers on PAPP related products.

Several studies have examined farmers preferred approaches for learning and the implications of these for the design and conduct of planned learning activities (Napier and Scott 1994; Johnson et al. 1996; Bamberry et al. 1997). Changes to practice are influenced by interaction with, and information from, more than one source (Kilpatrick 1996; Black 2000). This means that marketers of PAPP related products may seek to channel information through sources other than champions and intermediaries. In a survey of Australian broad-acre farmers, Oliver et al. (2009) reported where and how farmers source information regarding their farming practices. The authors found that the most common source of information (more than 70 per cent) were the general media, agriculture sector specific media and other farmers/family and friends. Accountants (53 per cent), agribusiness agents (42 per cent) and the internet (37 per cent) were other important information sources. Courses and training activities were reported as the most common way for farmers to keep abreast of current management practices and technical advances. While livestock farmers used a variety of training activities, Oliver et al. (2009) reported that demonstration sites/field days are the most favoured activity (reported by 53 per cent of farms). Workshops and short courses were reported as being slightly less popular at 24 per cent. Similar findings regarding the source of information by farmers have been reported by Reeve and Black (1998).

4.5 Syndicates and learning groups

The adoption of PAPP related products may be influenced by targeting syndicates or informal management/industry groups. Although syndicates are no longer formalised, or required under legislation, numerous voluntary syndicates continue to operate throughout Queensland. Fenton (2009) reported that syndicates exist in some regions to improve the management of wild canids by promoting co-ordination amongst neighbours. Groups provide opportunities for regular interactions and a sharing of ideas with people who share a common interest. Participation in group activities also enhances social networks, which have been shown to affect adoption decisions (Sobels et al. 2001). One of the benefits of targeting syndicates is that local government authorities and marketers of PAPP are able to make groups of individuals aware of the product rather than dealing with individuals. Members of syndicates or groups are more likely to communicate the benefits of PAPP to other managers and land managers, which would possibly increase the rate of adoption.

4.6 Communicating the benefits of PAPP products

The benefits of innovations such as PAPP need to be communicated by intermediaries in a manner that is easily understood by land managers (Gray 1993). Information must be communicated in a clear, straightforward, transparent and plain language (Fisher et al. 2007). Marketers of PAPP related products must communicate the risks and benefits of the toxin objectively. Pannell et al. (2006) suggest that farmers are wary of outside experts telling them what is best for them and instead have to see results for themselves to be convinced. For this reason, trials of an innovation would likely contribute substantially to adoption decision-making (Johnson et al. 1996). However, while practical demonstrations can be convincing, land managers may remain sceptical if the demonstration is in a situation that is too different from their own. Farmers are understandably wary that results from a remote trial may not apply to them. This could be due to factors such as soil differences, topography, labour, scale, machinery, and enterprise mix and or management.

Potential adopters will base a large part of their decision to adopt on the characteristics of an innovation, and these characteristics should be effectively communicated and/or demonstrated. Rogers (1962) suggests that there are five broad characteristics of a technology or practice that drive its adoption or non-adoption: trialability, compatibility, complexity, observability and relative advantage. Trialability refers to how easy it is to move from non-adoption to adoption via a learning phase. The learning phase is influenced by the characteristics of individual stakeholders, their families and broader scale social environments and by the characteristics of the innovation (Rogers 1962). To increase the likelihood of being successfully adopted, innovations must be compatible with an individual's everyday life, be easy to use and results must be observable. The complexity of an innovation determines how easily an innovation may be experimented with as it is being adopted. If a user has a hard time trying an innovation, this individual will be less likely to adopt it (Bangura 1982; Vanclay 1992). Observability is the extent that an innovation is visible to others. An innovation that is more visible will drive communication among the individual's peers and personal networks and in turn create further awareness and consideration (Rogers 1962).

Relative advantage refers to the degree to which an innovation is perceived to be better than what it supersedes, measured in terms that matter to those users, such as economic advantage, social prestige, convenience or satisfaction. In the context of pest control management, there will probably be differences of view about the relative advantages of PAPP related products. For example, wildlife managers are often driven by cost and effectiveness of pest control methods, while some land managers are more concerned with non-target effects, especially with respect to pet and working dogs. In contrast, the general public are more concerned with specificity and humaneness of new technologies (Fitzgerald et al. 2007; Fitzgerald 2009). As such, the relative advantage of PAPP related products will probably be different for each stakeholder group and marketing programs should be tailored to accommodate these differences of views. Quantifying how perceptions towards the benefits of PAPP related products is an important area of future research.

Profit has been found by many to be a key advantage of an innovation (Griliches 1957; Ruttan 1977; Feder and Umali 1993; Oliver et al. 2009). The more profitable and cost-effective an innovation is, the more likely it is to be adopted. Conversely, those innovations for which adoption is slow or low are more likely to be of low or negative profitability. Guerin and Guerin (1994) state that potential adopters must be able to see the long-term benefits of making the adoption. This is illustrated by the fact that the end user adopting best practice pest animal management may not necessarily be rewarded for their investment, which due to wild canid mobility might be enjoyed by neighbouring land managers. This reality highlights the value in coordinated control programs, where integrated management of wild canids is a shared responsibility with the results of the intervention also being shared amongst a community.

5. Influences on adoption decision making

5.1 The influence of beliefs and capacity on decision making

When potential adopters are made aware and are shown the benefits of an innovation, they then make a decision about whether to adopt that innovation. Decision-making in pest management, such as the adoption of PAPP, is particularly complex. Potential adopters will not only consider the advantages and disadvantages of the innovation, but will also be influenced by social, environmental and economic factors. Fitzgerald and Wilkinson (2009) report that there is often much debate between stakeholder groups of different enterprises about the perceived extent of the problem caused by canids and the measures that must be taken to control them. Not only do attitudes vary between stakeholder groups, they are also likely to differ between demographic and gender subsets. Furthermore, decision-making is often not conducted by individuals, but is shared between family members, each who may have differing views (Chamala 1987). Such attitudinal differences may act as barriers to the flow of information between members of society and may mean different marketing approaches are needed for different stakeholder groups.

A good example of conflicting beliefs towards canid management is attitudes by groups of stakeholders towards the role that canids play as top-order predators. Being at the top of the food web, canids prey on a diverse range of species, including: wallabies, kangaroos, goats, rabbits and cats. It is the belief of some that canids control populations of these species that may otherwise have a negative impact on agricultural production and natural ecosystems (Burbidge and McKenzie 1989; Denny 1992). As such, canids are valued by some people for the role they might play regulating populations of other pests. This topic has attracted substantial debate and constitutes an important area of future research. Fleming et al. (2001) also found that a majority of Indigenous people hold dingoes, and to some extent wild dogs, with very high regard as they have cultural significance to them. For some Indigenous people, dingoes are associated with sacred sites and dreamtime mythology (Fleming et al. 2001), and consequently they are seen as a resource and not as a species that must be controlled. Applying chemical control to these animals is outside the experience and beliefs of many land managers and this must be taken into account in planning any nil-tenure approach to canid control across relevant Australian landscapes.

A number of authors have attempted to illustrate the complex influences on decision-making in natural resource management (Feder and Umali 1993; Ruttan 1996b; Ellis 2000; Nelson et al. 2006; Pannell et al. 2006). Nelson et al. (2006) combines Ellis' (2000) rural livelihoods framework with Rogers (1962) diffusion of innovation model to describe factors influencing the decision-making process regarding the adoption of new technologies. Decision-making is influenced by the attributes of the innovation (i.e. relative advantage), the goals, values and beliefs towards both the innovation and problem, and the capacity of potential adopters (Figure 2). Capacity refers to the factors limiting potential adopters to adopt. Ellis (2000) lists five types of capital assets: human, social, natural, financial and physical. Human capital is an important asset of a rural household and consists of the available labour, education, skills and health of members of the household. Social capital refers to social status in terms of social networks, trust and shared values. Potential adopters are most likely influenced by social pressures if social capital is large. Natural capital refers to a household's natural environment, including land, water and biological resources. Access to money, or assets that can be readily turned into money, are referred to as financial capital.

Physical capital refers to any manufactured asset that is applied production, such as machinery, buildings or vehicles. This framework can be used to understand how adoption may be influenced by these five assets and how access to these assets may be influenced by social relations and ties with institutions and organisations (Ellis 2000).

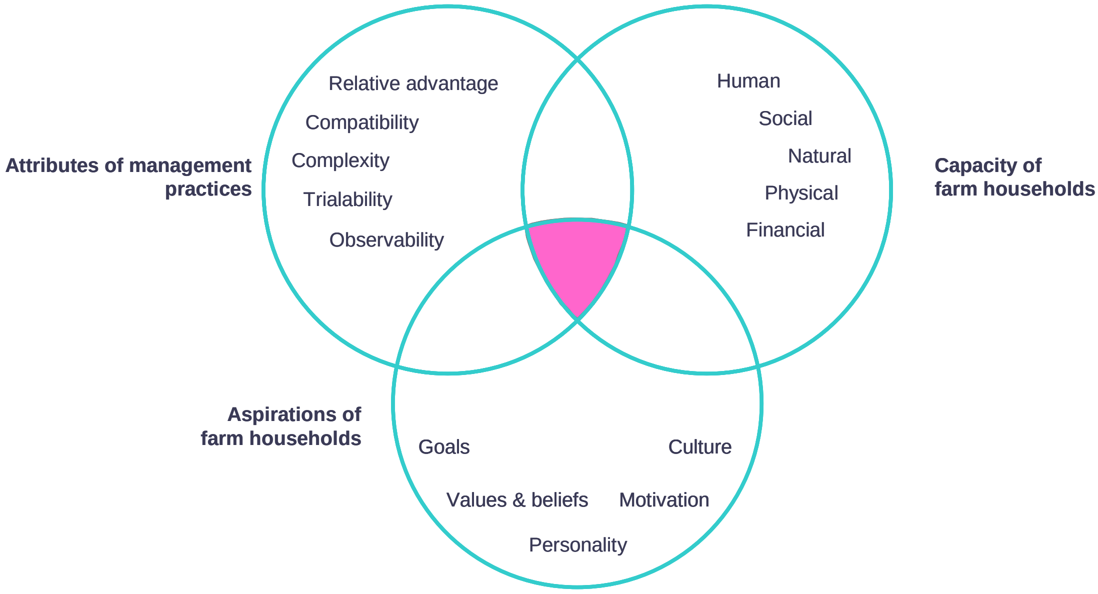

Figure 2: Interaction between aspirations and capacity of farm households, and the attributes of management practices. Source: Nelson et al. (2006).

5.2 The value chain and decision-making

In the context of a new predacide, capacity will be heavily influenced not only by the five types of capacity listed by Ellis (2000), but also by the high degree of regulation that surrounds the use of pesticides. Before any end user has the capacity to adopt the use of PAPP products the APVMA will need to assess and approve both the new chemical and its use in pesticide products. State government agencies will need to determine how the nationally approved product use patterns will fit within state-specific pesticide use frameworks and pest control orders. These will dictate who can supply pesticide products to end users, what level of training end users need to use the products safely and where and how pesticide products will be used. This level of regulatory compliance means the bulk of end users (private land managers) will not be able to directly purchase PAPP pesticide products. Instead they will have to contact authorised agents (such as state or local government agency staff) who can supply the product to end-users. The value chain for PAPP products is illustrated in Figure 3.

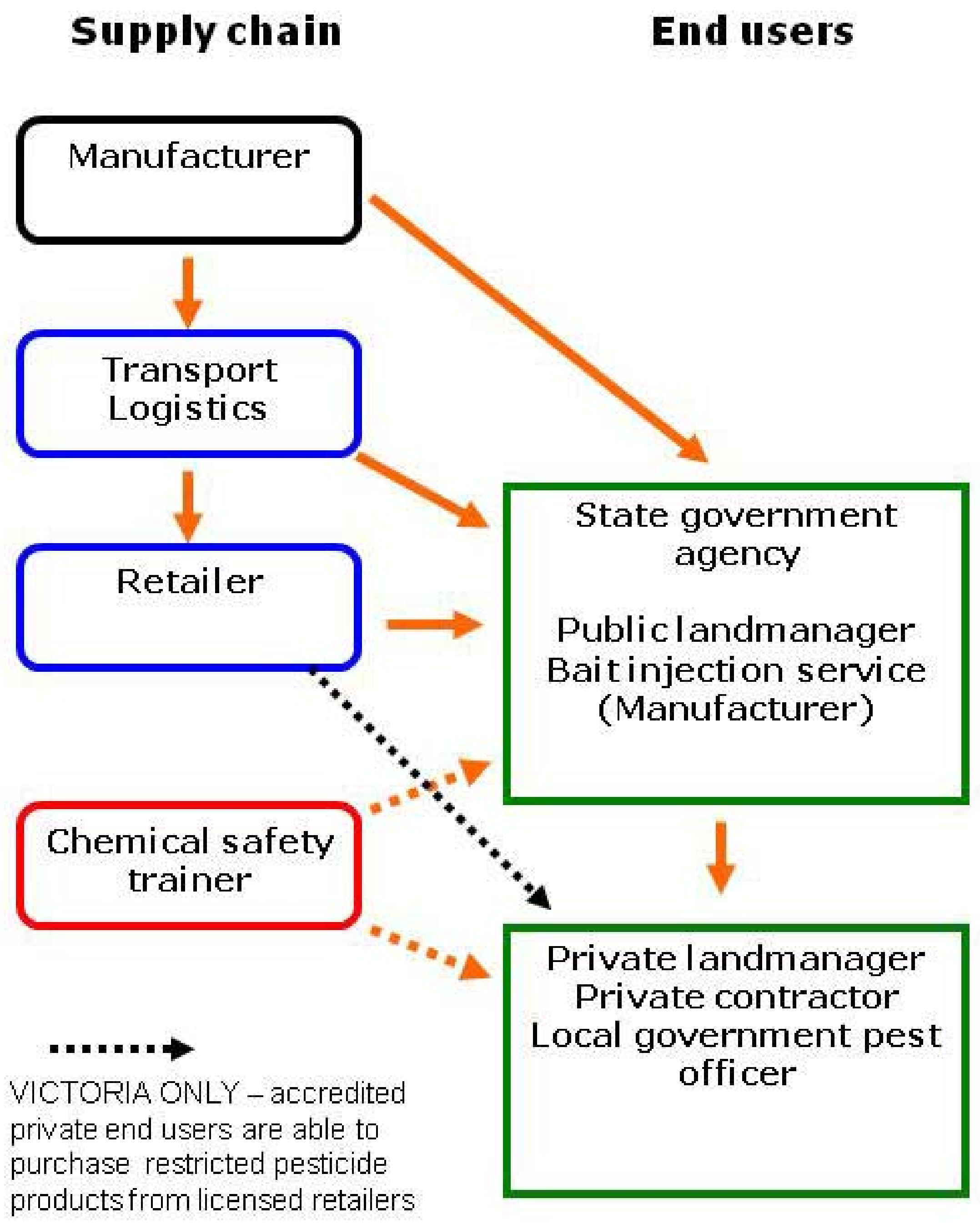

Figure 3: A conceptual model of the value chain for PAPP.

5.3 Factors influencing the choice of wild dog control methods

Few studies have identified the factors that influence participation in, and choice of control method in wild dog and fox management. After conducting unstructured group discussions with 33 land managers in western Queensland, Fenton (2009) reports on the beliefs and attitudes to wild dog control and specifically why land managers choose to control wild dogs and what determines their decision to adopt a specific control method (Figure 4). Fenton (2009) developed a conceptual framework to identify variables important in determining decisions about wild dog management. Although the sample size of this particular study was small (n=33), the author concludes that decision-making about wild dog control is very much dependent upon whether the landholder is a cattle or sheep producer, with sheep producers on the whole appearing more concerned about the impact of wild dog attacks on their enterprise.

Decisions to participate in wild dog control were reported to be influenced by the beliefs about the economic impact of wild dogs. Land managers were more likely to participate in wild dog control if they believed wild dogs have a negative impact on their business. Relationships with neighbours were found to influence participation in wild dog management programs. Working with neighbours was found to be important in coordinating wild dog control strategies. Whether neighbours were cattle or sheep producers, had working dogs, or whether neighbouring properties were managed by caretakers or vacant, were reported as important factors influencing decision-making. Fenton (2009) reported that many land managers did not participate in wild dog management because it was believed to be time consuming. The land managers who participated in the unstructured surveys expressed they were more likely to participate in control programs when information about wild dog behaviour was communicated to them at meetings and workshops. This demonstrates the importance of community engagement processes to successful adoption where groups of potential adopters are encouraged and supported to act in a co-ordinated manner.

In addition to these factors, Fenton (2009) found that a further four variables influence decisions to participate in wild dog management. The size, physical characteristics, location or properties and proximity to national parks were found to influence wild dog control, as well as beliefs about the environmental impacts of wild dogs. A number of respondents were reported to believe that the removal of wild dogs from the environment has allowed many native species to survive and develop, while a few respondents believed wild dogs were native and an integral part of the natural environment. Concern was also expressed by a small number of land managers as to whether a wild dog was a pure dingo or hybrid. This is particularly relevant to wildlife managers aiming to control wild dogs, whilst conserving dingoes within national parks and adjoining land. Finally, Fenton (2009) found that decisions to participate in wild dog control was influenced by beliefs about the costs of wild dog control.

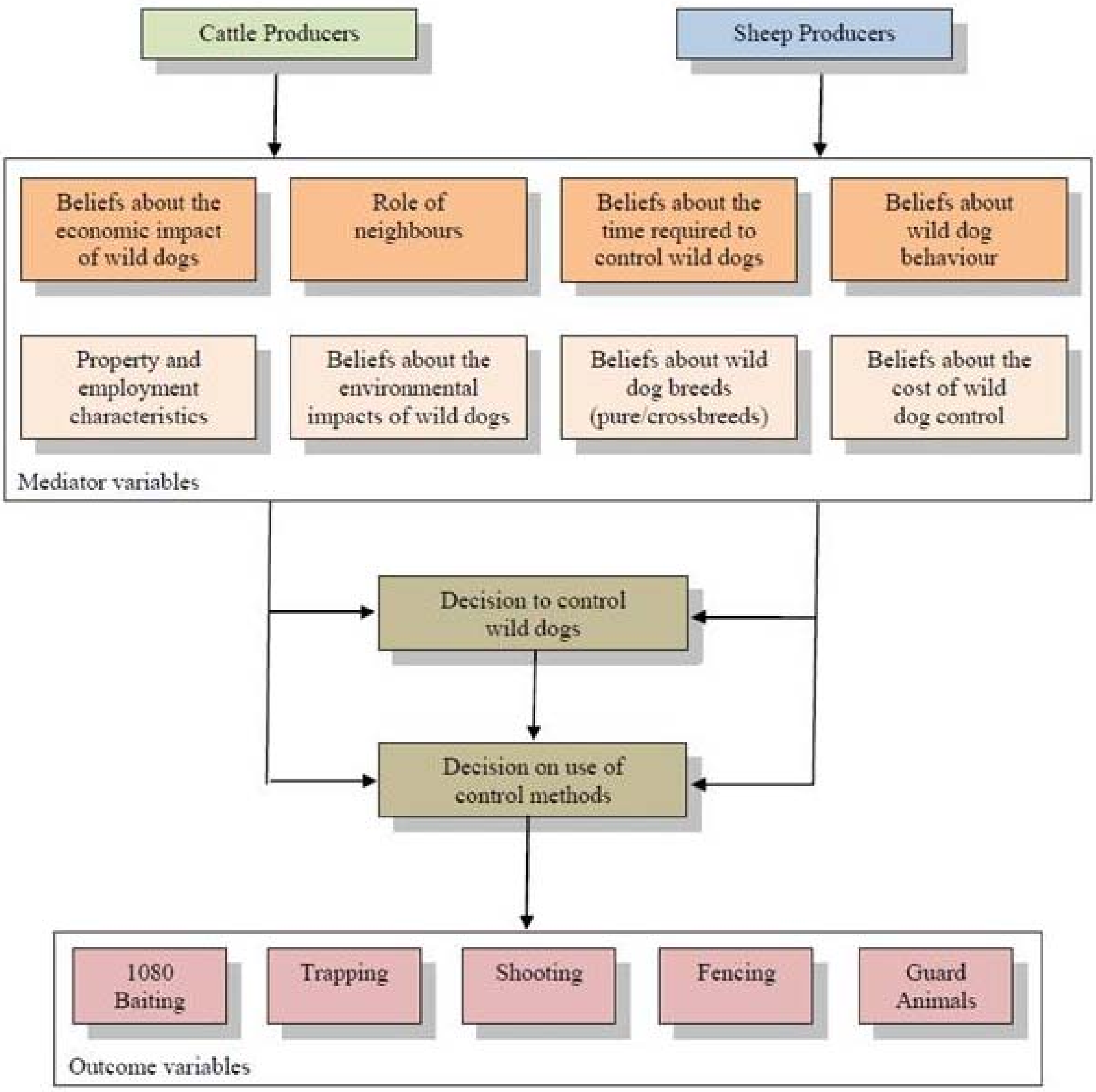

Figure 4: A conceptual framework for decision-making in relation to wild dog control.
Source (Fenton 2009).

5.4 Eliciting the key goals, beliefs and values towards PAPP

Although Fenton (2009) identifies factors that influence the participation in, and choice of control methods in wild dog and fox management, the influence of each of these factors on adoption is not quantified. As stated by Llewellyn et al. (2005) there are a large number of adoption studies in the literature, but few identify the influential perceptions in adoption decisions and even fewer consider the consistency or inconsistency of adopter decisions. Determining the key perceptions influencing adoption can be valuable in focusing research and extension. Learning activities can be targeted at perceptions known to be associated with adoption. Focusing extension information on aspects of an innovation that are already well understood and accurately perceived by potential adopters is unlikely to be beneficial (Llewellyn et al. 2005).

For example, Llewellyn et al. (2005) undertook a survey-based study to determine how extension programs for the adoption of integrated weed management (IWM) by Western Australian grain growers should be focused. Grain growers faced resistance problems to their herbicide dependent cropping systems. Through large scale research and extension initiatives, growers were encouraged to adopt IWM practices to reduce selection pressure for further herbicide resistance. After surveying 132 randomly selected grain growers, the authors found that adoption of IWM practices was most influenced by grower perceptions of herbicide related factors and of the economic value of IWM practices in the farming system. From these results, they concluded that extension programs should focus on communicating the short-term cost effectiveness of IWM practices for weed control. The importance of grower perceptions of the economic value of IWM practices in influencing adoption suggested that was a potential role for extension to lead a management change.

Measuring changes in key perceptions towards an innovation has also been identified as important for influencing adoption (Lacy 1996; Llewellyn et al. 2005; Fisher et al. 2007). Fisher et al. (2007) provide a framework for identifying and monitoring the key perceptions on adoption of innovations. In a case study to quantify public perceptions towards the management of pest mice, the authors conducted a value survey based on the concept of a value tree. The value of controlling pest mice was modelled in terms of the most important characteristics driving the support for management. Using this approach, the authors identified which drivers and attributes carried the most weight in explaining the value of pest mice control. Results showed a substantial base of public support for doing something about mouse plagues; however, respondents did not have a particular preference about the technology used. The survey results informed where extension programs should focus effort and when repeated over time, can be used to monitor the relative importance of different perceptions, values and beliefs in response to extension programs (Llewellyn et al. 2005).

6. Conclusion

Wild dogs and foxes impact significantly on Australian agriculture, communities and native wildlife. New control techniques are needed to reduce the economic, social and environmental impact of these pests. Few published studies have reported the benefits of PAPP products and how these benefits can be integrated with existing control methods in integrated management programs. The studies that are available in the literature suggest that the poison is highly effective, more humane than existing chemical controls and will under most scenarios be able to be used in concert with 1080 to more effectively reduce the refugia available to wild dogs, making control programs more effective. New wild dog and fox management technologies such as PAPP provide opportunities to challenge long held beliefs and perceptions about current pest control use patterns and effectiveness and provide an opportunity to fill currently existing gaps in canid management plans.

There is a rich body of literature from a variety of fields describing how the diffusion of innovations or practices, such as the adoption of PAPP, can be influenced and how effective community engagement can be used to implement behavioural change. Many studies have focused on the adoption of technologies in agriculture and natural resource management; however, factors influencing the adoption of pest control technologies have received relatively little attention. This is surprising given the impact that some pests have on communities, agriculture and the environment. Community engagement programs should move from communication programs to participatory programs. Targeting innovators and early adopters is one way to influence the spread of an innovation provided inter-personal communication exists between potential adopters, although identifying who these individuals or groups are in the target market is problematic. Focusing extension programs towards syndicates, workshops or wild dog management groups, through champions or intermediaries, may increase rate of adoption of PAPP.

Extension programs should communicate the effectiveness, specificity and humaneness of PAPP in a manner which is transparent, repeatable and easily understood. Trials and demonstrations have proven to be effective means of transferring information to potential adopters. The perceived benefits of PAPP will vary between stakeholder groups. Some groups will be more concerned with the cost and effectiveness while others might be more interested in humaneness and non-target impact of the product. The importance of the advantages of PAPP should be quantified for each stakeholder group so that extension programs can be tailored accordingly to suit the interests of the audience. The antidote to PAPP, BlueHealer®, is likely to be the most attractive advantage to livestock farmers because of strong concerns over accidental poisoning of farm and working dogs when using existing poisons such as 1080.

Uptake of PAPP will be complicated by the capacity of potential adopters as well as the beliefs, values and perceptions towards both canid management and existing control technologies. Adoption of PAPP will also be influenced by regulation that surrounds the use of the toxin. A handful of studies have identified factors that influence participation in, and choice of control methods for canid management; however, the number of participants and stakeholders surveyed has been small. A community survey structured across different stakeholder groups and geographic space would help quantify key drivers and barriers of participation in baiting and pest control management. Assuming that PAPP receives the appropriate regulatory approval from APVMA, extension programs should target effort towards communicating the benefits of PAPP that are poorly or misunderstood by respondents. Repeated community surveys would quantify changes over time in key perceptions towards PAPP in response to extension and marketing programs.

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