Evaluation of a long- term integrated management program on the activity of peri-urban wild dogs in Hunchy, Sunshine Coast

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Table of Contents

Abstract

Invasive species threaten human and animal welfare, environment, community (Salb et al., 2008, Macpherson 2005) and industry (Martin et al., 2019, Please et al., 2018, Department of Agriculture, Water and Environment, 2021). The locality of Hunchy on the Sunshine Coast has a history of wild dog impacts. This project critically assesses if an integrated long-term pest management program can be effective in reducing wild dog activity at both a localised level and on an overall landscape level. There are two hypotheses relating to the effectiveness of the integrated management program that were tested. Firstly, the effectiveness of the program on wild dog activity at the localised level. It is hypothesised that there will be a change in the Passive Activity Index of wild dogs and native wildlife following the integrated pest management program. Secondly, the effectiveness of an integrated management program to influence the community regarding public requests for assistance at a landscape level. It is hypothesized that there will be a change in the number of requests for assistance from the public relating to wild dogs following wild dog control measures. This project is an example of how participating properties, native wildlife, livestock and the wider community can benefit from integrated pest management programs. It is important that integrated pest management programs conduct long-term monitoring as part of the process to be able to evaluate the progress and adapt to changing circumstances. The outcomes of this program will help inform future pest management approaches to peri-urban wild dogs by local governments and the community in similar peri-urban environments.

Introduction

Invasive species exist beyond their normal distribution and threaten the environment, human and animal welfare, community (Salb et al., 2008; Macpherson, 2005) and industry (Martin et al., 2019; Please et al., 2018; Department of Agriculture, Water and Environment, 2021). Invasive species include feral animals, insects and other invertebrates, weeds, introduced marine pests, disease, fungi and parasites (Department of Agriculture, Water and Environment, 2021). Most Australian states have legislation requiring landholders to reduce impacts of invasive species on their property (Please et al., 2018; Thomson, 1984). Under the Biosecurity Act 2014, all Queensland residents are responsible for mitigating the risk of invasive species on lands under their control as part of their General biosecurity obligation (GBO) (State of Queensland, 2021).

Wild dogs (*C. familiaris*, *C. dingo*, and hybrids) (Pacioni et al., 2018) and European Red Fox (*Vulpes vulpes*) can invade peri-urban areas including school grounds, parklands and suburban backyards (Gil-Fernández et al., 2021; Allen et al., 2013; McNeill et al., 2016). With densely populated urban areas increasing, the potential for human-wild dog interactions also increases (Gil-Fernández et al., 2021; Please et al., 2018). Wild dogs are considered one of largest vertebrate threats in Australia (Jackson et al., 2017), with predation threatening both native species, including local populations of koalas in peri-urban environments and livestock (Kennedy et al., 2021; Please et al., 2018; Allen et al., 2016; Fleming et al., 2014; Allen and Fleming, 2012; Young et al., 2011). In Australia wild dogs cause significant economic losses annually to agricultural production with recent estimates ranging between

$40M AUD (Pacioni et al., 2018; Gong et al., 2009) and $89M AUD (McLeod, 2016). The predation impacts on sheep and goats are so significant it is considered that these industries simply cannot exist in presence of wild dogs (Fleming et al., 2014; Newsome et al., 2001; Thomson, 1984). Furthermore, wild dogs' impact the community in other ways including maiming and killing domestic pets, threatening people (Gentle et al., 2017), transmission of disease (Davidson et al., 2021; Pacioni et al., 2018) and stock harassment (Kreplins et al., 2018; Pacioni et al., 2018; Fleming et al., 2014).

Local governments assist landholders to meet their general biosecurity obligation, by assisting with the creation a biosecurity plan for their property. Invasive animals can impact heavily on communities by causing financial stress, disruption of community cohesion, mental health of individuals, lack of empowerment and sense of fear within the community (Howard, 2019; Please et al., 2018; Ecker et al., 2017; Allen et al., 2016; Gentle et al., 2016; Harriott et al., 2019).

An effective management program for wild dogs needs to be intensive, continuous, and applied across different tenures (Howard 2019; Martin et al., 2019; Kreplins et al., 2018; Almeida-LeÑEro et al., 2017; Hillier, 2017; Young et al., 2015). There are many challenges in implementing an integrated coordinated management program such as understanding the target species ecology (Martin et al., 2019), cost of ongoing control, community perceptions on animal rights and pest species, social equity and environmental sustainability (Howard, 2019; Almeida-LeÑEro et al., 2017; Hillier, 2017; Young et al., 2015). Furthermore, many invasive species may adapt and learn to actively avoid control (Martin et al., 2019). Wild dogs and their impacts have been widely managed utilising one or a combination of the following best practice controls: baiting, trapping, fencing, shooting and utilising guardian animals (Kennedy et al., 2021; Allen, 2017, Binks et al., 2015; Fleming et al., 2014; Olivera et al., 2010; Gentle et al., 2007; Fleming et al., 2006; Short et al., 2002; Eason et al., 1993).

The Canid pest ejector (CPE) formerly known as the M-44 ejector has been proven to effectively deliver toxins to both introduced canid species in Australia: the European red fox (Marks et al., 2002; Marks et al., 1999) and the wild dog (Kreplins et al., 2018; Connolly, 1988; Busana et al., 1998; Mallick et al., 2016). Canid pest ejectors consist of a housing that is driven into the ground, a spring-loaded piston and trigger, a poison capsule and a lure head (Kreplins et al., 2018). When the lure head is pulled upwards, the trigger hits the piston and the capsules' contents is ejected into the animals' mouth (Kreplins et al., 2018). As the CPE housings are driven into the ground this reduces the risk of bait caching or translocation (Kreplins et al., 2018). The design of the ejector also reduces the risk to non-target species as it requires a minimum 1.6-kilogram vertical pull which limits the number of species capable of this action (Mallick et al., 2016; ACTA, n.d.). Sodium fluoroacetate (compound 1080) has been the principal toxin utilised in the control of many invasive species in Australia (Koertner, 2007). Native animals including mammals, birds and reptile species have developed a tolerance to sodium fluoroacetate over time having evolved alongside with native Australian plant species (Twigg and King, 1991).

Councils can assist in initiating management programs on properties impacted by invasive species. Upon request of a landholder, council officers will respond using a strategy

depending on a variety of factors: proximity to a town, proximity to neighbours, has free roaming animals either livestock or domestic pets and the frequency of invasive species presence. On the Sunshine Coast, Council officers will generally turn to three available management tools to assist landholders, 1) canid pest ejectors, 2) soft-jawed foothold traps or 3) cage traps. Based on the factors above, officers will determine the suitability of control.

This project aims to assess the effectiveness of wild dog management activities coordinated by Sunshine Coast Council in the Hunchy district of the Sunshine Coast, south-east Queensland. This area has a history of known wild dog impacts, and measures undertaken to manage wild dogs, and is thus considered a suitable area for assessment. The project will critically assess if the integrated pest management program conducted has been effective in reducing wild dog activity, at the localised level and an overall landscape level. The outcomes from the project will help to inform optimal pest management approaches to peri-urban wild dogs by local governments and the community in similar peri-urban environments.

There are two hypotheses relating to the effectiveness of an integrated management program that will be tested. Firstly, the effectiveness of the program on wild dog activity at the localised level will be examined. It is hypothesised that there will be a change in Passive Activity Index of wild dogs and native wildlife following integrated pest management program. Secondly, the effectiveness of integrated management program to influence the community regarding public requests for assistance at a landscape level. It is hypothesized that there will be a change in the number of requests for assistance from the public relating to wild dogs following wild dog control measures.

Methodology

This research project uses historical data collected from a wild dog pest management program conducted by Sunshine Coast Councils' Feral Animal Officers in the locality of Hunchy, on the Sunshine Coast, south-east Queensland. The field component of this research was completed by the student by implementing and managing the CPE and trapping program at Hunchy through the years 2018-2021 during employment at the Sunshine Coast Council.

Ethics

This project will use historic data for which the field work has already been completed. This work was conducted ethically by trained operators and under the approval of councils' Feral Animal Prevention and Management program and legislated Biosecurity Act 2014. The University of Queensland Animal Ethics Committee approved the conduct of this research as per certificate 2021/AE000826.

Hunchy Project Area Methodology

Geographical description

The locality of Hunchy (1158 hectares, ha) and surrounding suburbs Landers Shoot (470 ha), Palmwoods (2389 ha), West Woombye (1196 ha), Dulong (1121 ha), Montville (1760 ha), Flaxton (1164 ha) a total area of 9,258 ha has been historically impacted by wild dogs (see Appendix 1). These suburbs have experienced increased urbanisation, evident through a general decrease of property sizes which limits options for wild dog control. In addition, the topography can be inaccessible, further increasing barriers for control. The coastal environment has a mean annual rainfall of 1712.2mm, mean maximum temperature of 25.8 C and mean minimum temperature of 14 C (Nambour DPI State, 040282; (Australian Government, 2021). The natural habitat of the area was sub-tropical rainforest before selective clearing for farming and grazing.

Site description

In 2018, four larger landholders in the Hunchy area were approached by a Feral Animal Officer for collaboration of a joint coordinated integrated management program. These four private properties (Property A: 11Ha; Property B: 65Ha; Property C: 24 Ha; Property D: 16 Ha) are situated at the foothills of the Blackall Range, Sunshine Coast, Queensland (see Appendix 1). Properties A, B and C are all adjoining with Property D separated by approximately 1km. Properties A, C and D are situated within the Hunchy locality boundaries and whilst Property C is adjoining A and C it is classed as West Woombye. Properties A, B and D all are currently running breeding cattle. All properties have conducted opportunistic field shooting in the past. Properties B and D had conducted additional wild dog control previously including foot hold trapping. A natural waterway forms a boundary between Property B & C. Property C holds no stock, is being revegetated to a natural state and has participated in cage trapping previously. None of the properties hold small livestock (sheep, goats, alpacas, pigs). One of the four properties have domestic pets (two miniature fox terriers). Properties A, B and D all experienced impacts from wild dogs. Property C despite not having stock, upholds good neighbour morals and observed impacts on wildlife. Due to proximity of these properties to one another and the home ranges of wild dogs, individual properties were not considered independent from each other. Thus, all data collected was pooled for analysis.

Camera monitoring

Camera trapping as a means of monitoring animal activity and presence is now widely utilised (Bengsen et al., 2011; Tobler et al., 2008). Monitoring cameras were installed on all four properties before and during the management program (see Appendix 2). Each property had two Scout guard® SG560K-18mHD motion detection cameras for the entire duration of the program 2018-2021. The two cameras were placed between 120-1055m apart (an average of 395m). Cameras were set along tracks likely to be visited by wild dogs to increase chance of target captures. The represented sampling should not be expected to be independent nor spatially random. This should not be a limitation as it is not the area

itself that is being sampled but the wildlife populations within the area that is the subject (Bengsen et al., 2011; Engeman, 2005; Wilson and Delahay, 2001).

Each camera is motion sensored with infra-red capability and mounted horizontally on either a tree or fence post 0.3-1m above the ground and directed towards a track. The camera settings were set to record a burst of three images per event with a delay of one minute. The batteries and the SD cards were retrieved and replaced each month. The cameras used the same station locations (±15m) for the entirety of the survey period 2018-2021.

Canid Pest Ejector Deployment

A risk analysis was conducted prior to CPE installation to identify suitable locations for their deployment on the properties. This was done in conjunction with the regulatory distance restrictions: at least 150m from any dwelling, 20m from permanent or flowing water, 50m from centreline of a road and 5m from a property boundary must be established (Queensland Government, 2009). The proximity of neighbouring registered pets is also taken into consideration as is the topography, lack of phone reception, activity of invasive species and their impacts. Owners and occupiers of adjacent neighbours to a CPE program were notified in writing no more than 10 days and no less than 72 hours prior to installation of CPEs. In addition, residents within close proximity of the control properties were also notified if they were deemed a high-risk location.

CPEs were installed and maintained by council officers (see Appendix 2). Under Sunshine Coast Council policy, CPEs are checked and serviced at least every four weeks. This includes noting any activations, servicing the actuator for sound operation, checking condition of the capsule, and replacing the lure head with fresh lure. Different types of lures were used in conjunction with CPEs to increase visitation and elicit a response leading to activation by wild dogs. Canid Pest Ejectors were deployed with 6mg of sodium fluoroacetate (compound 1080) capsules for wild dog control. The housing of the CPEs included an extension of 30cm reinforced steel to increase the depth to which the device is held in the ground. The housing is then hammered into the ground removing the risk of translocation. CPEs were placed no closer than 60m apart, along tracks with high wild dog activity, identified by monitoring cameras placed several months prior to CPE installation. CPEs were placed as close to a monitoring camera as possible whilst still abiding by the distance restrictions required for 1080.

Trapping

Soft jawed foot hold trapping was conducted in areas that were deemed to have high invasive species presence, low risk to domestic pets (including neighbouring pets) and preferably without the presence of livestock. Livestock, whilst unharmed by trapping often set off traps making it a labour-intensive control method for officers. Telemetry cameras, motion-sensor activated cameras that send photos to a designated phone number via MMS

were utilised to monitor traps throughout this project. Telemetry cameras were utilised to ensure animal welfare is not compromised therefore phone reception becomes a requirement. The traps were serviced on average every 2 weeks, depending on frequency of invasive species presence, weather, telemetry camera battery life and the result of any captures requiring attendance. As part of this project Victor-3 soft jawed foot-hold traps were installed (see Appendix 3). Trapping was undertaken during high impact periods to calves as well as in response to the presence of pups.

Cage trapping is also utilised for wild dogs and foxes and are often provided to landholders that do not meet the requirements of the other two forms of control. Opportunistic cage trapping was conducted by landholders as a supplementary control method to the CPEs. Control results by landholders by means of cage trapping was recorded by SCC officers but dates of installation and removal of cage traps are unavailable.

Field Shooting

Opportunistic field shooting by all properties were conducted by landholders as a supplementary control method to the CPEs. Control results by landholders by means of field shooting was recorded by SCC officers but dates of all efforts resulting in no control are unavailable.

Localised Integrated Management 2016-2021

In addition to the control efforts in the Hunchy project area, foothold and cage trapping and use of CPEs were used in general areas surrounding Hunchy (Flaxton, Mapleton, Montville, West Woombye, Palmwoods and Lander shoot) as an extension of the integrated management program.

Community Reporting

Council receives requests for assistance by landholders that are experiencing impacts by invasive species. Every request is recorded in the council database. These records (de-identified-for privacy reasons) were collated as a measure of wild dog impacts on the community (see Appendix 4). These requests for assistance can be monitored over time, by locality and by individual pest species.

Statistical Analysis

Three different analytical models were utilised to test the before mentioned hypotheses. The monitoring of changes in abundance and activity of wild ranging animal populations is a critical component to research and wildlife management programs (Bengsen et al., 2011). Monitoring of population densities or absolute numbers for many free ranging species are often difficult to obtain, few have been validated and often unnecessary for management purposes (Allen and Engeman, 2015; Caughley, 2005). Camera surveys are more commonly utilised to generate indexes of animal population abundance (Bengsen et al., 2011). Indices

that calculate population abundance are beneficial to invasive species management and rapid population assessments (Bengsen et al., 2011; Jarnemo and Liberg, 2005). Passive Activity Indexes (PAI) can be utilised to follow variations of a target population that can go on to inform management decisions (Engeman et al., 1999). These methods can not only be utilised to index the activity of target species (Wild dogs) but simultaneously all other species (Engeman et al., 2000; Gese et al., 1996; Allen and Engeman, 1995). Another advantage of using an activity index is that it is able to be applied quickly and easily in the field whilst still able to track changes in populations over time (Bengsen et al., 2011; Engeman et al., 2000). Indirect abundance measures or activity levels are of greatest value where the population is monitored from the same or similar locations at the same time (Engeman, 2005; Lancia et al., 2005; Pollock, 1995).

Images were manually assessed for the presence of all animals of interest. Each observation of the following taxa was added into a Microsoft Excel spreadsheet: wild dog, fox, cat (*Felis catus),* European hare (*Lepus europaeus),* large macropod, small macropod, small mammal, Australian brush turkey (*Alectura lathami*), small bird and reptile.

An animal event was classified as the number of specific species in a shot over burst of three photos (i.e. each set of bursts of three was classified as a separate event). For example, if one dog was seen in each shot over burst of three images this was considered one dog event. If two dogs were identified in the first of three bursts but only a single dog in following two shots, then it was considered as two dog events. If an animal happened to still be in front of camera in the second burst of three shots it was classified as a second separate event.

The events data were then tabulated based on date in Microsoft excel. The data was then collated by month and the Passive Activity Index (PAI) was calculated monthly (Bengsen et al., 2011). The Passive Activity Index is based on a simple count of the number of times an animal crosses a series of plots or a camera over a known number of days (Allen et al., 2016; Bengsen et al., 2011; Negro˜es et al., 2010; Kawanishi et al., 1999).

Here, data is collected from the cameras over consecutive days, the events are tabulated daily then from here and overall mean was calculated for the month.

$$PAI\ utilised = \frac{The\ sum\ of\ events\ for\ that\ species\ for\ the\ month}{The\ sum\ of\ operational\ camera\ nights\ in\ the\ month} \text{ x } 100$$

This was then replicated for each of the eight cameras then averaged across all eight cameras for the period of 2018-2021.

Seasonal PAI was calculated using the below method to determine if there were difference in wild dog activity throughout the year (see Appendix 5). These tests were used to assess if wild dog PAI decreased between years and if there were seasonal variation in activity

$$PAI\ utilised = \frac{The\ sum\ of\ events\ for\ that\ species\ for\ the\ season}{The\ sum\ of\ operational\ camera\ nights\ in\ the\ season} \text{ x } 100$$

In this analysis the response variable is PAI, and the predicators were either year or season. A linear model with a log transformation and analysis of variance (ANOVA) was utilised via the statistical program R (R Core Team, 2020). The ANOVA was utilised to confirm if a significance existed of the year or season in the model. The residuals and normality were visually checked which suggested a log transformation was most appropriate.

Community Request

The aim of this analysis was to determine if requests decreased over time (year to year) or if more (or less) requests were received in a particular season. The community request data was compiled from the council database, categorised to show the number of wild dog and fox requests per month between 2016-2020 (2021 was not a full complete year and was not included). Where no complaint was recorded for a particular month (per year) it was assigned the value 0. The number of requests by year and by season were compared. Both wild dog and fox species were included for comparison. A Generalised Liner Model (GLM) with a Poisson distribution (family) was utilised via the statistical program R (R Core Team, 2020).

Results

Hunchy Project Area Results

Table 1 shows the results gathered for the Hunchy project area from the four participating properties including: Canid pest ejector, foot hold trapping, cage trapping, field shooting and the analysed camera monitoring data. Table 1 displays the results gathered as part of the project from 15 May 2018 till 12 February 2021. The ten CPE activations in Table 1 lead to the removal of wild dogs, five from the Hunchy properties and five from the West Woombye property. Whilst foxes accounted for eight of the CPE activations two of which occurred on West Woombye property while the others were accounted for on the Hunchy properties. Foothold trapping saw the removal of two wild dogs and one fox from the West Woombye property. Table 1 also shows landholders removed five wild dogs from their properties, two from West Woombye and three from Hunchy properties.

Canid Pest Ejectors, Trapping, Field Shooting

Table 1: Hunchy Project area control results for period of 2018-2021

Species	Date Activated	Locality	Control
Wild Dog	15/05/2018	Hunchy	CPE Activation
Wild Dog	15/05/2018	West Woombye	CPE Activation
Wild Dog	3/07/2018	West Woombye	CPE Activation
Wild Dog	17/08/2018	West Woombye	CPE Activation

Wild Dog	20/08/2018	West Woombye	CPE Activation
Wild Dog (J)	24/08/2018	West Woombye	Trap
Fox	17/09/2018	Hunchy	CPE Activation
Wild Dog (M)	29/09/2018	West Woombye	Field Shot
Wild Dog (F)	29/09/2018	West Woombye	Field Shot
Wild Dog (J)	5/10/2018	West Woombye	Trap
Fox (M)	10/12/2018	West Woombye	Trap
Wild Dog	26/02/2019	Hunchy	CPE Activation
Wild Dog	23/04/2019	Hunchy	CPE Activation
Wild Dog (F)	23/04/2019	Hunchy	Field Shot
Wild Dog (J)	15/02/2020	Hunchy	Field Shot
Wild Dog (F)	18/03/2020	Hunchy	Field Shot
Fox	3/06/2020	Hunchy	CPE Activation
Wild Dog	26/06/2020	Hunchy	CPE Activation
Fox	26/06/2020	Hunchy	CPE Activation
Fox	16/07/2020	Hunchy	CPE Activation
Fox	21/08/2020	West Woombye	CPE Activation
Fox	21/08/2020	Hunchy	CPE Activation
Fox	18/09/2020	Hunchy	CPE Activation
Wild Dog	18/09/2020	West Woombye	CPE Activation
Wild Dog	26/09/2020	Hunchy	CPE Activation
Fox	13/11/2020	West Woombye	CPE Activation

J; Juvenile, F; Female, M; Male

The management program removed 17 wild dogs, nine foxes between 15 May 2018 and 12 February 2021. Most (55 %) were from within the Hunchy locality, with the remainder from the nearby West Woombye locality.

Statistical Analysis

Figure 2 was compiled utilising Passive Activity Index in conjunction with an ANOVA. The PAI data included monitoring data from 2018-2021. The Passive Activity of wild dogs decreases over time ($p= 0.04386$) more significant from 2018 to 2020 ($p = 0.0145$) and 2018 to 2021 ($p =0.0294$). In comparison to Passive Activity between seasons which were not statistically significant ($p > 0.05= 0.25297$).

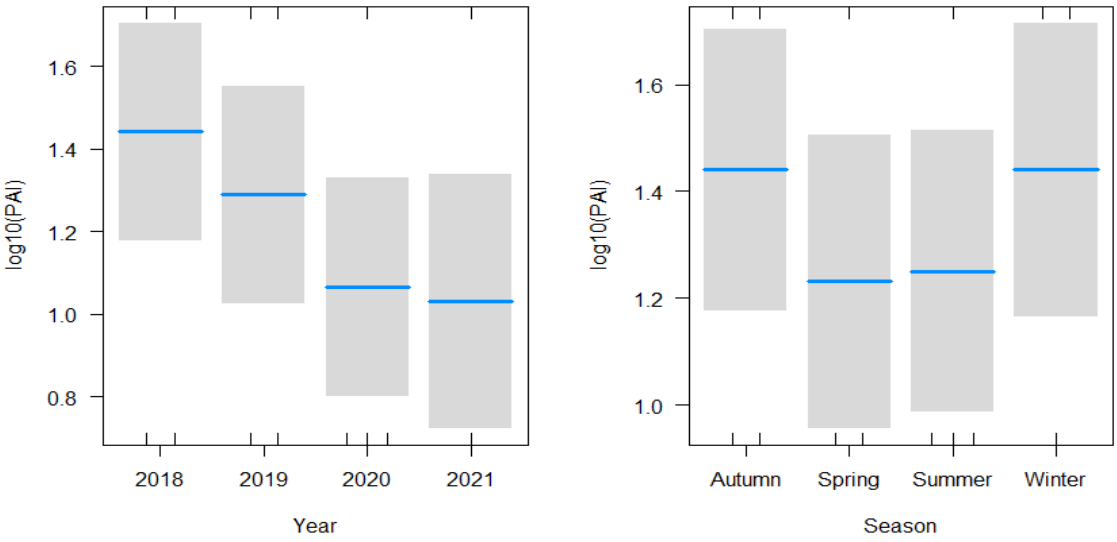

Figure 1: Box Plots displaying (left) decreasing trend in wild dog PAI 2018-2021, and (right) but no difference in wild dog PAI across differing seasons.

Community requests

The following data was compiled from the council data base of community requests for assistance for wild dogs and foxes from 2016-2021. The customer requests (CR) for wild dogs decreases across the years from 2016 till 2021 (Table 2). In comparison the number of wild dogs and foxes removed from the region across the years do not appear to have a pattern. Table 2 also shows the amount of CRs and results for foxes from 2016-2021. The total number of fox and wild dog CR combined is tabulated in Table 2 along with results. The full data leading to Table 2 can be found in Appendix 4.

Table 2: Comparison of customer requests and results from 2016-2021 from Hunchy and surrounds.

	2016	**2017**	**2018**	**2019**	**2020**	**2021**
CR Wild Dogs	23	23	18	13	9	3
Results Wild dogs	0	9	22	6	8	0
CR Foxes	12	19	11	14	4	7
Results Foxes	2	4	3	4	10	2
Total CRs	**35**	**42**	**29**	**27**	**13**	**10**
Total results	**2**	**13**	**25**	**10**	**18**	**2**

CR; Customer requests for assistance *For full data on Customer Requests see Appendix G

The analysis suggests that there was an observed decreasing trend in community requests for assistance with wild dogs and / or foxes from 2016-2020. The analysis showed a statistically significant decrease in 2020 compared to 2016 ($p < 0.001 = 0.000502$). Whilst the other years were not significantly different there appears to be a decreasing trend over this time period. Seasonally, there was no difference in requests received ($p > 0.05$). There was no difference found comparing requests received for wild dogs versus fox therefore these

were combined. For full data leading to trapping and CPE results in Table 2 see Appendix 6 and 7.

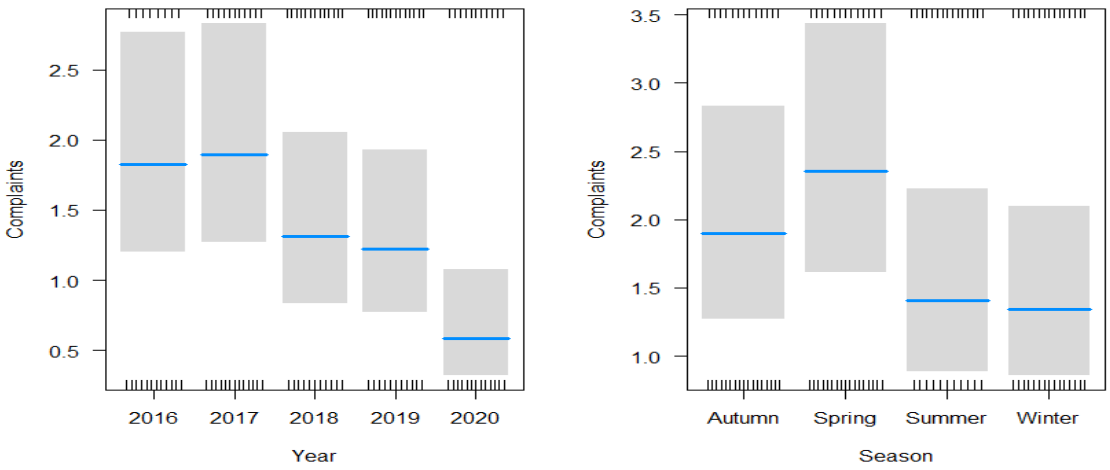

Figure 2: Box Plots showing (left) decreasing trend in community requests 2016-2020 and (right) no difference in community requests across differing seasons.

Discussion

This integrated management program utilised CPEs, foothold trapping, cage trapping and field shooting to effectively remove several invasive species from the four participating properties. The removal of these animals not only had a beneficial impact on the four participating properties but a flow on effect to the wider area. The evaluation of the program's effectiveness was undertaken through monitoring cameras and requests for assistance to council. Both showed declines in wild dog activity (see Appendix 8) and a reduction in community requests (see Table 2). These findings are supportive of this management program and discussed in more detail below.

Passive Activity Index was applied to the camera trapping survey data to generate activity indices from photo observations of wild dogs at repeated survey sites over a continuous period. Other studies that have utilised cameras to monitor animal populations concluded that changes in capture frequencies was an indicator in changes in population abundance as capture frequencies strongly correlated with activity indices that were independently calculated (O'Brien et al., 2003; Kawanishi & Sunquist, 2004). As with other studies it was found that passive activity index models can be easily applied to wildlife management programs in conjunction with the use of camera traps without the need to change sampling protocols (Bengsen et al., 2011). This project also verified that analytical analysis can be coupled with passive activity indexes to provide a useful tool for following statistically significant changes in wildlife abundance (Bengsen et al., 2011).

Statistically there was an observed decreasing trend of wild dog activity from 2018 to 2021. This supports the first hypothesis that there will be a change in Passive Activity Index of wild dogs following an integrated pest management program. There was no difference found seasonally for either wild dog PAI nor in community requests for assistance. Which is a curious result as it has been widely published that wild dog activity is generally influenced by season (McNeil et al., 2016). As seasonal variability was not considered to be statistically significant

in the case of wild dog activity it suggests that the integrated management program was effective for the management of wild dogs. Anecdotally, once the identified original wild dog pack (all but one) was removed from the area an immigration of new individuals was observed. This is a common occurrence when animals are removed from an area, with neighbouring individuals moving in to take up occupancy in an effort to the take advantage of vacant territory and available resources within (Efford et al., 2000). As predators (wild dogs and foxes) were continuously removed from the area over the program period, increases in native species abundance were observed (see appendix 9). The Passive Activity Index of small macropods, brush turkey, small birds and reptiles over time all show an increasing trend (see Appendix 9). This suggests that integrated pest management programs have had a beneficial effect on native species.

An effective integrated management plan needs to be continuous and strive for nil-tenure (Howard, 2019; Martin et al., 2019; Kreplins et al., 2018; Almeida-LeÑEro et al., 2017). Community involvement and nil-tenure approach to pest management programs are heavily dependent on trust, interpersonal relationships, reciprocity, shared purpose (e.g. protect livestock) and in most cases a conduit person to assist networking, communication and encourage community led actions (Howard et al. 2018). Limitations to community involvement include cost, understanding target species ecology, lack of resources and skills, attitudes towards government and preference of non-lethal methods (Please et al. 2018; Howard, 2019; Almeida-LeÑEro et al., 2017; Hillier, 2017; Young et al., 2015). Other studies have found that when a community integrated pest management program is supported by local government the community comes together, and better outcomes are achieved (Howard et al., 2018). This program may have only included four properties but the whole community was aware and supportive of this program. This program has seen a decrease in the number of requests for assistance from the public following wild dog control measures. This supports the claim that integrated wild dog control can reduce the impacts of wild dogs on the community over time. Figure 2 showed there to be a decreasing trend of community requests from 2016-2020 with a statistically significant decrease in 2020 in comparison to 2016. The second hypothesis was verified in Figure 4 with the confirmation of a decreasing trend in the number of requests for assistance from the public following wild dog control measures.

As with any 'in the field' program there were limitations to this study. First limitation of this project was the absence of non-treatment sites in which a comparison could have been made. This doesn't allow for a comparison of data from the treatment area to a site without integrated control. Secondly, access to the properties was sometimes hampered by wet weather. During these times CPEs were serviced a week later than scheduled and required servicing on foot. Wet weather also influenced the operation of the CPEs. Some actuators were found seized and inoperable. Cattle and brush turkeys on the properties lead to false activations. Cattle also caused soil erosion impacting the ability of CPEs to fire as soil built up around the trigger mechanism. Cattle also made it difficult to provide other options of control including trapping due to inquisitive behaviour and setting off traps constantly. The topography often determined control locations due to accessibility. Towards the end of the

program, native birds (i.e. Torresian Crow- *Corvus orru*) had learnt to attack the sensor lenses on two of the cameras leading to potential camera data loss.

Despite the limitations, they are all real-world occurrences that can happen in any management program around the world. Some instances cannot be controlled and accounted for, unlike in laboratory conditions. In a controlled experiment one can control many variables such as the climate, off target species, and location. Under field conditions, conducting real applied science the above limitations were unable to be controlled. A larger scale replication of this project, with a non-treatment site for comparison, would help to verify conclusions and see if it can be duplicated. Implementing set pre-during-post control time frames may also be useful to see outcomes of integrated pest management programs more clearly.

Conclusions

This project aimed to assess the effectiveness of wild dog management activities coordinated by an Officer of the Sunshine Coast Council in the Hunchy district of the Sunshine Coast, south-eastern Queensland. The project critically assessed whether the integrated pest management program was effective in reducing wild dog populations at both the localised level and an overall landscape level. The project utilised a combination of Passive Activity Index, ANOVA and a generalised linear model to confirm both hypotheses that effective integrated pest management programs can reduce wild dog activity and impacts, whilst providing a benefit to native wildlife and community. The project had limitations including topography, absence of non-treatment sites, off target interactions and weather. All these limitations accompany real life pest management programs for which not all factors can be controlled. Despite this future research could benefit from a larger scale replication, non-treatment sites, and clearer pre-during-post control time frames.

This project is an example of how participating properties, native wildlife, livestock and the wider community can benefit from integrated pest management programs. It is important that integrated pest management programs conduct long-term monitoring as part of the process to enable evaluation of the progress and adapt to changing circumstances. This program will go on to assist future pest management approaches to peri-urban wild dogs by local governments and the community in similar peri-urban environments.

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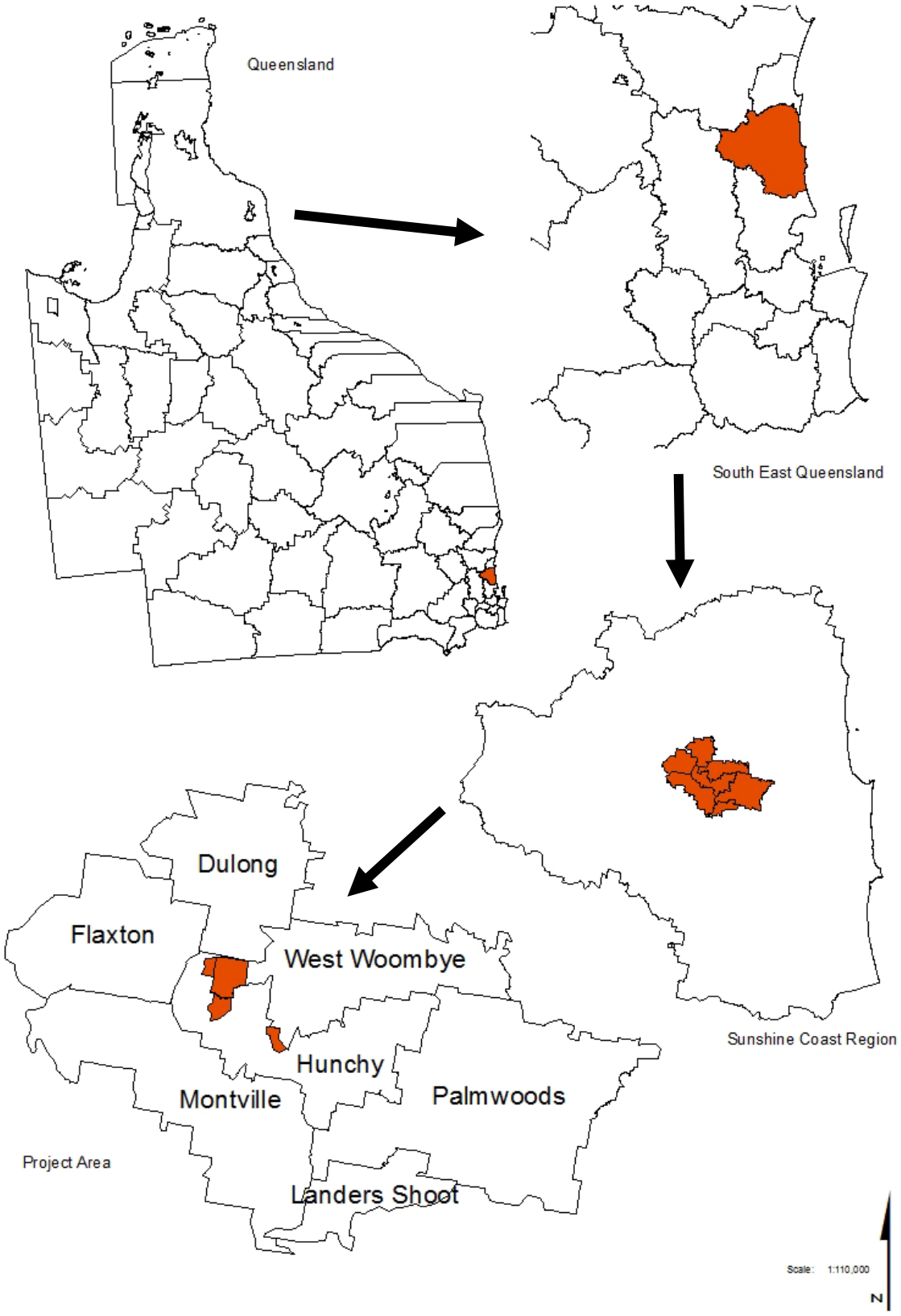
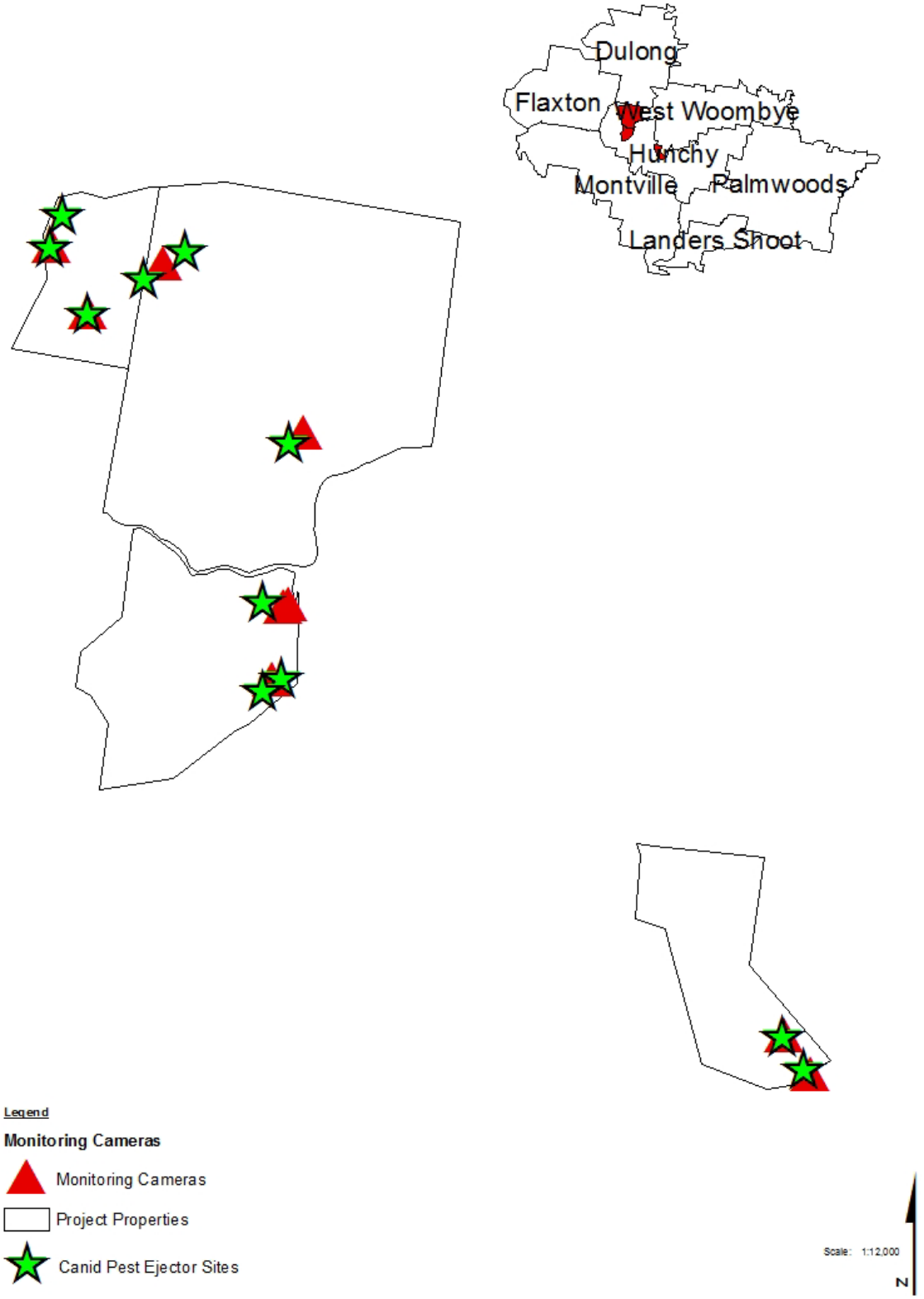
Appendices

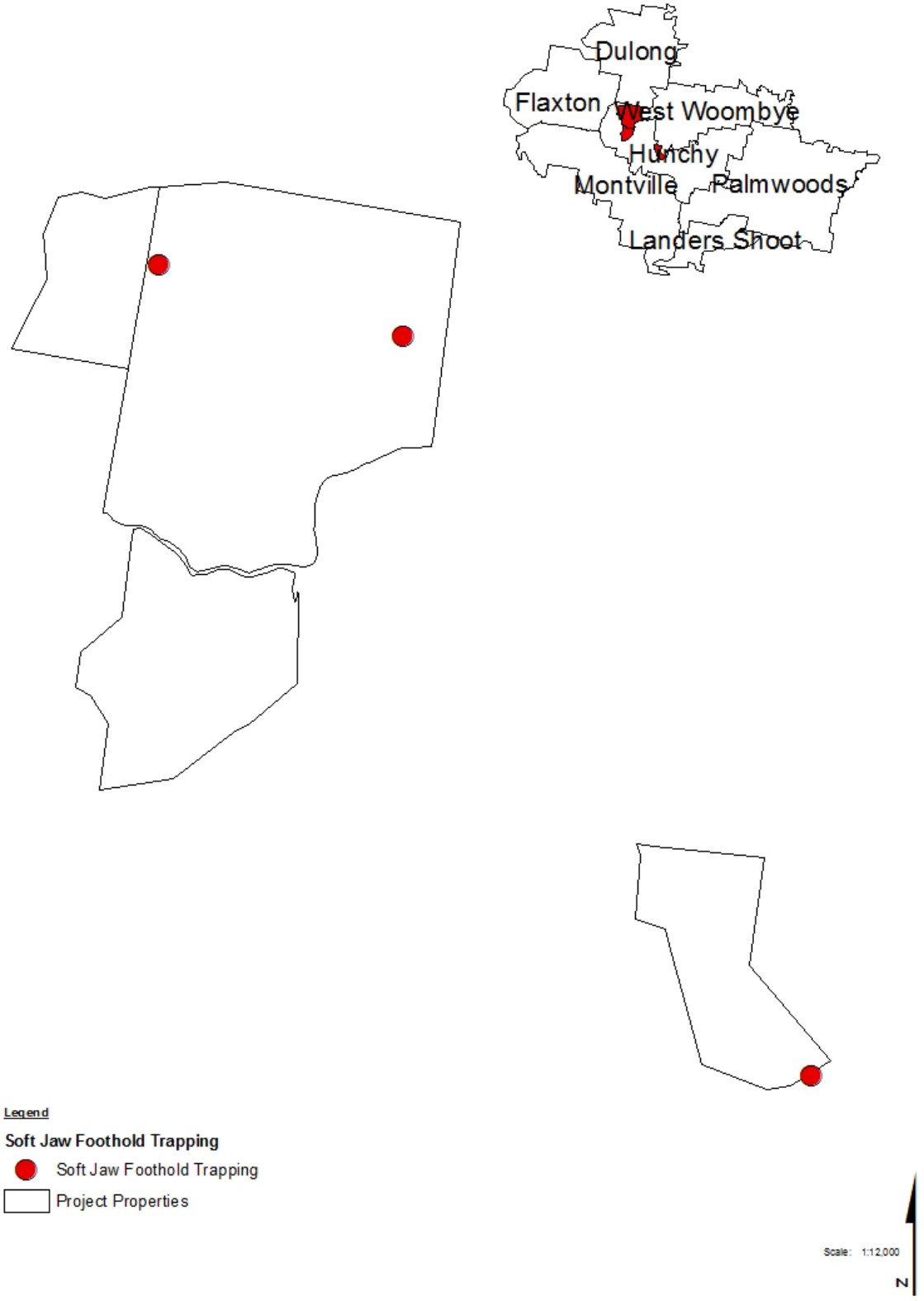
Appendix 1: Land area of Hunchy and surrounds including 4 core project properties.



Appendix 2: Cameras and CPE locations on participating properties



Appendix 3: Locations of foothold trapping on participating properties



Appendix 4: Total combined Community Requests for Assistance 2016-2021

Complaint Species	Date Recorded	Locality	Core Control Centre
Fox	10/03/2016	Palmwoods	Extension
Wild Dog	14/03/2016	Flaxton	Extension
Wild Dog	29/03/2016	Flaxton	Extension
Wild Dog	29/03/2016	Flaxton	Extension
Fox	18/04/2016	Hunchy	Yes
Wild Dog	20/04/2016	Lander shoot	Extension
Wild Dog	26/04/2016	Flaxton	Extension
Wild Dog	30/04/2016	Montville	Extension
Wild Dog	3/05/2016	Palmwoods	Extension
Fox	3/05/2016	Palmwoods	Extension
Fox	23/05/2016	Montville	Extension
Wild Dog	8/06/2016	Palmwoods	Extension
Fox	21/06/2016	Dulong	Extension
Wild Dog	7/07/2016	West Woombye	Yes
Wild Dog	8/07/2016	West Woombye	Yes
Fox	25/07/2016	Montville	Extension
Wild Dog	28/07/2016	West Woombye	Yes
Wild Dog	28/07/2016	Dulong	Extension
Fox	28/07/2016	Dulong	Extension
Wild Dog	3/08/2016	Palmwoods	Extension
Wild Dog	30/08/2016	Lander shoot	Extension
Wild Dog	6/09/2016	Dulong	Extension
Fox	19/09/2016	Lander shoot	Extension
Wild Dog	22/09/2016	Palmwoods	Extension
Wild Dog	27/09/2016	Palmwoods	Extension
Fox	6/10/2016	Lander shoot	Extension
Fox	19/10/2016	Montville	Extension
Wild Dog	20/10/2016	Dulong	Extension
Wild Dog	21/10/2016	Montville	Extension
Fox	28/10/2016	Montville	Extension
Wild Dog	16/11/2016	Montville	Extension
Wild Dog	16/11/2016	West Woombye	Yes
Fox	30/11/2016	Palmwoods	Extension
Fox	2/12/2016	Flaxton	Extension
Wild Dog	16/12/2016	Hunchy	Yes
Fox	6/01/2017	Flaxton	Extension
Wild Dog	1/02/2017	Dulong	Extension
Wild Dog	20/02/2017	Dulong	Extension
Wild Dog	2/03/2017	Dulong	Extension
Wild Dog	6/03/2017	Flaxton	Extension
Wild Dog	7/03/2017	Flaxton	Extension
Fox	10/03/2017	Palmwoods	Extension
Wild Dog	20/03/2017	Flaxton	Extension
Fox	3/04/2017	Montville	Extension
Wild Dog	6/04/2017	Palmwoods	Extension
Wild Dog	6/04/2017	Montville	Extension

Wild Dog	7/04/2017	Montville	Extension
Wild Dog	10/04/2017	Montville	Extension
Fox	21/04/2017	Montville	Extension
Wild Dog	21/04/2017	Montville	Extension
Fox	15/05/2017	Palmwoods	Extension
Wild Dog	1/06/2017	Flaxton	Extension
Fox	12/06/2017	Flaxton	Extension
Fox	27/06/2017	Palmwoods	Extension
Fox	3/07/2017	Palmwoods	Extension
Wild Dog	31/07/2017	Montville	Extension
Fox	11/08/2017	Palmwoods	Extension
Wild Dog	11/08/2017	Flaxton	Extension
Fox	14/08/2017	Hunchy	Yes
Wild Dog	16/08/2017	Montville	Extension
Fox	4/09/2017	Flaxton	Extension
Wild Dog	5/09/2017	Palmwoods	Extension
Wild Dog	5/09/2017	Dulong	Extension
Wild Dog	8/09/2017	Montville	Extension
Wild Dog	8/09/2017	Flaxton	Extension
Fox	14/09/2017	Lander shoot	Extension
Fox	17/10/2017	West Woombye	Yes
Wild Dog	25/10/2017	Hunchy	Yes
Fox	26/10/2017	Palmwoods	Extension
Fox	2/11/2017	Lander shoot	Extension
Fox	3/11/2017	Lander shoot	Extension
Wild Dog	10/11/2017	Hunchy	Yes
Wild Dog	17/11/2017	Hunchy	Yes
Fox	21/11/2017	West Woombye	Yes
Wild Dog	22/11/2017	Flaxton	Extension
Fox	20/12/2017	Palmwoods	Extension
Fox	27/12/2017	Dulong	Extension
Fox	16/01/2018	Dulong	Extension
Wild Dog	25/01/2018	Dulong	Extension
Fox	13/02/2018	West Woombye	Yes
Wild Dog	16/02/2018	Palmwoods	Extension
Wild Dog	22/02/2018	Hunchy	Yes
Fox	7/03/2018	Palmwoods	Extension
Wild Dog	13/03/2018	Montville	Extension
Wild Dog	15/03/2018	Montville	Extension
Wild Dog	4/04/2018	Montville	Extension
Fox	23/04/2018	Flaxton	Extension
Wild Dog	2/05/2018	Flaxton	Extension
Wild Dog	23/05/2018	Flaxton	Extension
Fox	23/05/2018	Hunchy	Yes
Wild Dog	7/06/2018	Montville	Extension
Wild Dog	7/06/2018	Montville	Extension
Fox	18/06/2018	Hunchy	Yes
Wild Dog	17/08/2018	Montville	Extension
Wild Dog	12/09/2018	Montville	Extension
Wild Dog	14/09/2018	Montville	Extension

Wild Dog	3/10/2018	Dulong	Extension
Wild Dog	25/10/2018	Dulong	Extension
Fox	6/11/2018	Palmwoods	Extension
Fox	13/11/2018	Palmwoods	Extension
Fox	15/11/2018	Palmwoods	Extension
Fox	20/11/2018	Palmwoods	Extension
Fox	28/11/2018	Hunchy	Yes
Wild Dog	7/12/2018	Flaxton	Extension
Wild Dog	7/12/2018	Hunchy	Yes
Wild Dog	7/12/2018	West Woombye	Yes
Fox	16/01/2019	Dulong	Extension
Wild Dog	25/01/2019	Dulong	Extension
Wild Dog	25/01/2019	Hunchy	Yes
Fox	11/02/2019	Hunchy	Yes
Wild Dog	11/02/2019	Dulong	Extension
Fox	18/02/2019	Palmwoods	Extension
Wild Dog	1/03/2019	Flaxton	Extension
Fox	20/03/2019	Montville	Extension
Wild Dog	21/03/2019	Flaxton	Extension
Fox	28/03/2019	Dulong	Extension
Wild Dog	2/05/2019	Dulong	Extension
Fox	9/05/2019	Palmwoods	Extension
Fox	30/05/2019	Palmwoods	Extension
Fox	28/06/2019	West Woombye	Yes
Wild Dog	9/08/2019	Flaxton	Extension
Fox	15/08/2019	Montville	Extension
Fox	4/09/2019	Palmwoods	Extension
Wild Dog	1/10/2019	Dulong	Extension
Wild Dog	1/10/2019	Dulong	Extension
Fox	3/10/2019	Hunchy	Yes
Wild Dog	14/10/2019	Palmwoods	Extension
Fox	24/10/2019	Hunchy	Yes
Wild Dog	29/10/2019	Hunchy	Yes
Fox	29/10/2019	Hunchy	Yes
Wild Dog	6/11/2019	Dulong	Extension
Fox	18/11/2019	West Woombye	Yes
Wild Dog	17/12/2019	Flaxton	Extension
Wild Dog	17/01/2020	Hunchy	Yes
Fox	28/01/2020	Dulong	Extension
Wild Dog	5/02/2020	Hunchy	Yes
Wild Dog	9/03/2020	Flaxton	Extension
Wild Dog	16/04/2020	Hunchy	Yes
Fox	1/06/2020	Palmwoods	Extension
Fox	17/07/2020	Palmwoods	Extension
Wild Dog	12/08/2020	Palmwoods	Extension
Fox	3/09/2020	Palmwoods	Extension
Fox	7/09/2020	West Woombye	Yes
Wild Dog	12/10/2020	Montville	Extension
Fox	14/10/2020	Palmwoods	Extension
Wild Dog	21/10/2020	Montville	Extension

Fox	6/01/2021	Palmwoods	Extension
Fox	15/01/2021	Palmwoods	Extension
Fox	1/02/2021	Palmwoods	Extension
Fox	3/02/2021	Palmwoods	Extension
Wild Dog and Fox	17/03/2021	West Woombye	Yes
Wild Dog	16/04/2021	Dulong	Extension
Wild Dog	29/04/2021	Flaxton	Extension
Fox	24/05/2021	Hunchy	Yes

Appendix 5: Passive Activity for all species observed categorised seasonally for period of 2018-2021.

Year	2018				2019				2020				2021	
Season	**S**	**A**	**W**	**Sp**	**S**	**A**	**W**	**Sp**	**S**	**A**	**W**	**S**	**Sp**	**A**
Samples	16.00	47.00	40.88	47.50	70.63	74.88	85.13	82.38	82.13	84.88	88.50	89.13	67.00	24.13
Dog	13.76	19.14	31.31	27.93	18.92	25.47	14.58	8.08	7.23	11.38	13.61	6.48	6.17	12.05
Fox	2.41	5.04	36.46	1.04	1.10	3.46	6.57	3.30	2.46	3.89	18.49	6.05	3.09	2.68
Cat	0.00	0.43	16.67	1.16	0.93	1.28	0.74	1.38	0.58	0.14	0.42	0.00	0.00	0.45
Hare	0.00	6.62	10.99	29.58	10.70	9.54	22.18	19.25	13.44	9.24	31.21	15.20	8.83	6.70
L Mac	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14	0.13	0.00	0.00
Sm Mac	0.00	0.43	35.79	3.06	3.43	4.31	7.37	6.22	6.04	4.30	7.07	10.55	5.69	3.13
Sm Mml	0.00	1.74	353.72	3.96	10.53	14.37	15.72	20.10	10.99	6.20	9.76	14.67	11.78	4.91
B/Turk	0.00	2.10	185.19	22.73	40.58	20.74	9.15	14.26	23.21	25.85	29.69	16.48	11.60	2.68
Sm Bird	0.00	1.23	51.57	14.27	3.69	3.94	3.59	9.79	7.30	2.26	5.07	14.23	24.19	9.82
Reptile	0.00	0.00	0.00	1.18	0.86	0.33	0.52	1.62	1.54	1.12	0.14	1.96	1.39	0.45

S; Summer, A; Autumn, W; Winter, Sp; Spring, L Mac; large Macropod, Sm Mac; Small Macropod, Sm Mml; Small Mammal, B/Turk; Bush Turkey, Sm Bird; Small Bird

Appendix 6: Total combined trapping results from 2016-2021 from Hunchy and surrounds.

Species	Date Captured	Sex	Locality
Fox	9/10/2016	Male	Palmwoods
Fox	20/11/2016	Female	Montville
Wild Dog	12/09/2017	Female	Flaxton
Wild Dog	20/12/2017	Female	Flaxton
Wild Dog	27/8/2018	Juvenile	West Woombye
Wild Dog	5/10/2018	Juvenile	West Woombye
Fox	28/11/2018	Juvenile	Palmwoods
Wild Dog	6/12/2018	Male	Flaxton
Wild Dog	8/12/2018	Juvenile	West Woombye
Wild Dog	9/12/2018	Male	Flaxton
Fox	10/12/2018	Male	West Woombye
Fox	4/04/2019	Male	Dulong
Wild Dog	27/07/2019	Female	Montville
Fox	30/11/2019	Male	Dulong
Wild Dog	1/12/2019	Female	Dulong
Fox	18/03/2020	Female	Montville
Wild Dog	7/09/2020	Female	Palmwoods
Fox	15/10/2020	Female	Palmwoods
Feral Cat	12/02/2021	Female	Hunchy

Appendix 7: Total combined Canid Pest Ejector activations by Wild dogs or foxes from 2016-2021 from Hunchy and surrounds.

Species	Date Captured	Locality
Wild Dog	26/06/2017	Flaxton
Wild Dog	3/07/2017	Flaxton
Wild Dog	31/07/2017	Flaxton
Wild Dog	28/08/2017	Flaxton
Wild Dog	4/09/2017	Flaxton
Wild Dog	15/05/2018	Hunchy
Wild Dog	15/05/2018	West Woombye
Wild Dog	19/06/2018	Flaxton
Wild Dog	19/06/2018	Flaxton
Wild Dog	3/07/2018	West Woombye
Wild Dog	9/08/2018	Flaxton
Wild Dog	9/08/2018	Flaxton
Wild Dog	9/08/2018	Flaxton
Wild Dog	9/08/2018	Flaxton
Wild Dog	9/08/2018	Flaxton
Wild Dog	14/08/2018	Flaxton
Wild Dog	17/08/2018	West Woombye
Wild Dog	20/08/2018	West Woombye
Fox	17/09/2018	Hunchy
Wild Dog	20/11/2018	Flaxton
Wild Dog	4/12/2018	Flaxton
Wild Dog	26/02/2019	Hunchy
Wild Dog	23/04/2019	Hunchy
Fox	3/06/2020	Hunchy
Wild Dog	26/06/2020	Hunchy
Fox	26/06/2020	Hunchy
Wild Dog	16/07/2020	Hunchy
Fox	21/08/2020	West Woombye
Fox	21/08/2020	Hunchy
Fox	18/09/2020	Hunchy
Wild Dog	18/09/2020	West Woombye
Wild Dog	26/09/2020	Hunchy
Fox	13/11/2020	West Woombye

Appendix 8: Wild Dog Passive Activity Index on the study sites per month between January 2018 and April 2021

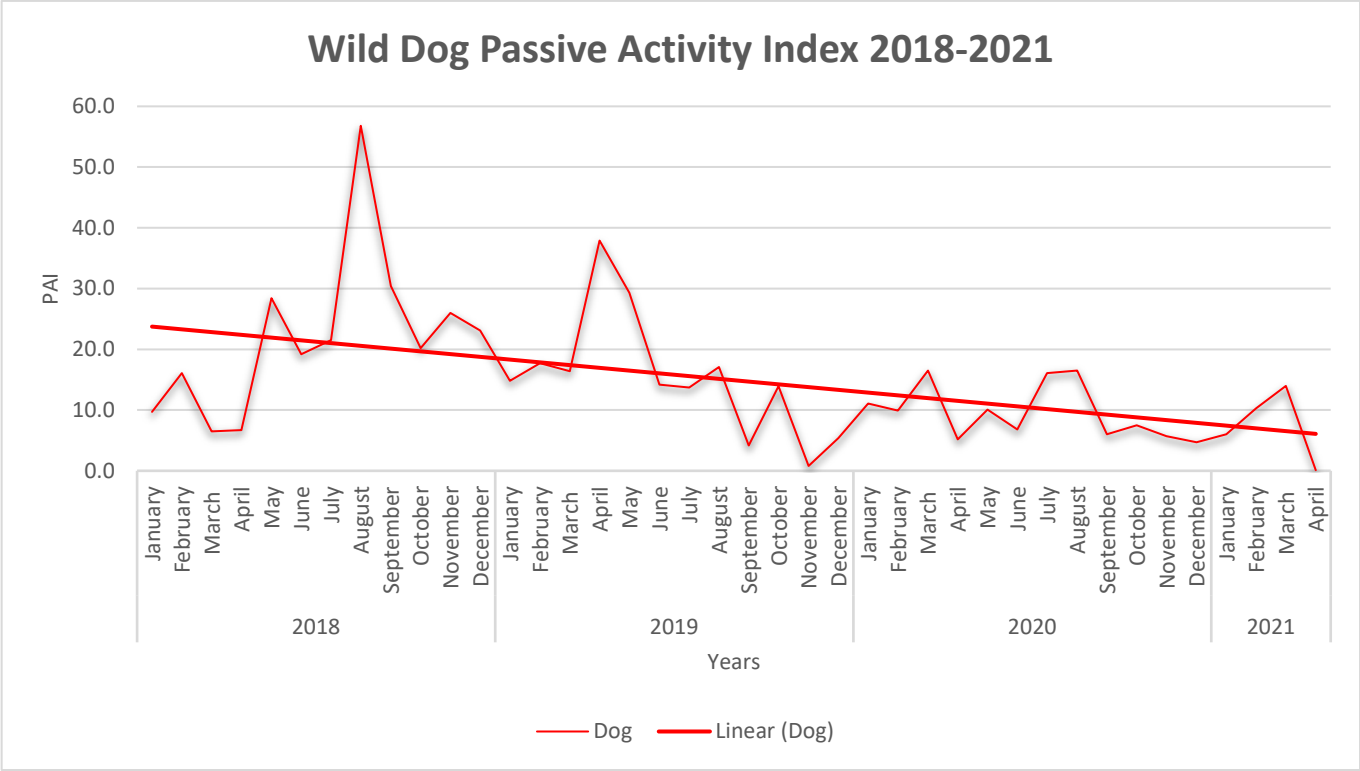


Figure 1: Passive Activity for Wild Dogs categorised monthly with linear trends for period of 2018-2021

Appendix 9: Native Animal Passive Activity Index on the study sites per month between January 2018 and April 2021

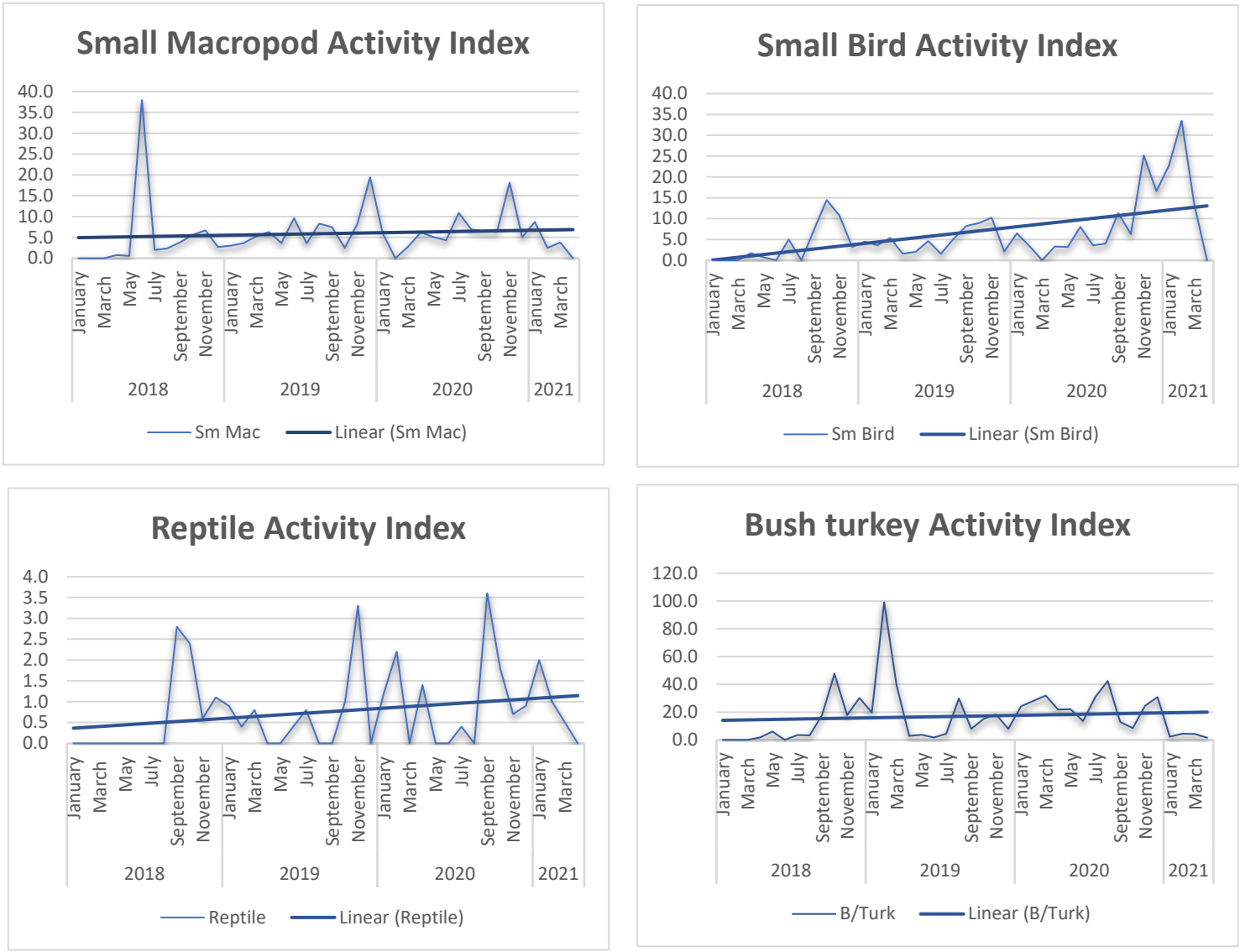


Figure 2: Passive Activity for small macropod (Sm Mac), small birds (Sm Bird), reptiles and bush turkeys categorised monthly with linear trends for period of 2018-2021