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Identifying corridors, refuges and entry points for starlings, *Sturnus vulgaris*, at an invasion front.

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NATURAL RESOURCE MANAGEMENT INC

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The project 'Identifying corridors, refuges and entry points for starlings, *Sturnus vulgaris*, at an invasion front' was carried out in accordance with the Objectives, Key Performance Indicators and Milestones as detailed in the following report.

Signed **Date** 11 January 2013

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Fig. 3: Example sonograms displaying the two most distinctive starling call types identified from a reference collection of calls of starlings from various locations in South Australia. Shown are two examples each of the ‘descending whistle’ and the ‘variation on whistle’ call types.

Overview

In a bid to prevent the establishment of one of the World's top 100 worst invasive species, the West Australian Government has facilitated starling (*Sturnus vulgaris)* control operations in the southern coastal region of this State since the 1970s. Consequently, the number of starlings established in Western Australia (WA) remains low. Ongoing research coupled with sustained control aims to facilitate rapid response to new incursions. However, efficiently detecting cryptic, wary starlings that are present at low density in a challenging and expansive field environment presents a significant challenge to the starling control program.

Through the support of the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), the West Australian Department of Agriculture and Food (DAFWA), the South Coast Natural Resource Management organisation (SCNRM) and the University of Auckland investigated the application of remote audio detection technology to the starling program. Twelve consecutive months of field recordings were successfully collected from strategic locations on the south coast. To efficiently scan through this large volume of data, researchers from the University of Auckland developed an automated software filter to detect potential starling calls. Currently, this software has a high success rate (> 76%) for detecting starling calls amongst background recordings and is now available for use by the DAFWA for future remote surveillance.

Results

Field placement

A total of 50 Song Meter (SM) Terrestrial Packages were acquired from Wildlife Acoustics™ in May 2010. Direct consultation with on-ground biosecurity staff resulted in the selection of 12 sites that could potentially provide favourable habitat to starlings. These recommendations were informed by numerous years of on-ground starling surveillance. All of the sites chosen have a history of starling invasion, varying from recent evidence of occupation at the easterly sites to the more westerly sites where starling have not been sighted for several years. Table 1 outlines the placement of each of the SM units into the field in June 2010.

Song Meter units were typically fixed with elastic straps to the northern aspect of trees at head height (Fig. 1). Each SM unit was placed 300 m from neighbouring SM units. In winter, several sites were inundated with water, but the SM units were placed high enough up the trees to stay dry. From June 2010 to June 2011, SM units continuously collected sound recordings according to a pre-programmed schedule outlined in Figure 2. Over 57 600 hours of field recordings were collected during eight field trips (approximately 20 terabytes of data). Data was downloaded at the end of each trip onto the iVEC Informatics Super Computer storage facility at Murdoch University, Perth prior to upload to collaborators in New Zealand.

Some issues with field operations

We encountered some initial problems with several of the SM units early on during the field recordings. Primarily, the lids provided did not initially seal adequately and consequently moisture entered the units and condensation built up on the electrics board and also in the battery compartment. This issue was related to a particular production batch of the SM units and the manufacturer immediately sent out replacement lids for all 50 units which were fitted once we received them. In the interim, we were able to improve the water-proofing of units by applying gaffa-tape around the seal. The result of these early malfunctions was that some units ceased recording early (reduced battery function) and some did not record at all (malfunctioning electrics board). Any units which had malfunctioned as a result of moisture damage were either repaired or replaced by Wildlife Acoustics at no cost. Therefore for the majority of the project all SM units were operating satisfactorily.

A few of the SM units were invaded by ants which entered through the vent and built nests inside the units. Depending on the extent of invasion, some units continued to function normally with ants present, whereas others required repairs to the electrical board. We manually removed all ant colonies when they were discovered and moved cleaned SM units to nearby trees to minimise the likelihood of re-invasion.

The foam covering on the small microphones was apparently quite attractive to possums and stock and a small proportion had to be replaced periodically and the SM units moved out of reach of any cows. The microphones were also sensitive to deterioration from prolonged UV exposure and most were brittle and disintegrated by the end of the project. The elastic straps attaching the SM units to trees also disintegrated significantly in the field and were discarded at the end of the project.

Finally, two SM units were lost when the tree they were attached to fell over and became submerged in the lake at Mason's Bay (see Table 1 for details).

Fig. 1. Song Meter units were affixed to trees (alive and dead) at each site with elastic straps. Data was downloaded and batteries replaced every six to seven weeks over a period of 12 months.

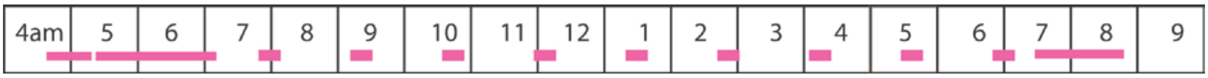

Fig. 2. The recording schedule programmed into each Song Meter unit consisted of actively recording (pink bars) for 15 minutes before sunrise, one hour after sunrise, for 10 minute intervals throughout the day and for 30 minutes before sunset. Exact recording times varied depending on seasonality and consequent day length.

Table 1: Site description and information on the number of Song Meter recording units that were deployed and the number that failed during 12 month survey for starlings commencing June 2010.

Site	Location (Lat –S, Long – E)	Habitat type	Number of units deployed	Number of units failed	Comment
Diamond Downs	33.87522, 120.26767	Swamp with dead & live standing trees surrounded by pasture.	3	0	Previous history of starling eradication from this, the most westerly, site included in the current project.
Mason's Bay	33.88892, 120.39871	Swamp with dead and live standing trees surrounded by blue gum plantation.	4	2	Two units were lost under water when tree they were attached to collapsed between field trips.
Minnikin	33.81789, 120.95957	Swamp with predominantly dead standing trees surrounded by mix of pasture and cropping.	5	0	Strong prior history of starling occupation and breeding at this site.
Stuart Downs	33.75879, 120.93207	Swamp with dead & live standing trees surrounded by pasture.	3	0	Strong prior history of starling occupation and breeding at this site.
Willanjay	33.70200, 120.96600	Swamp with dead & live standing trees surrounded by	2	0	Strong prior history of starling occupation and breeding at this site, plus contemporary (2012)

		pasture.			record of starling trapped on this property.
Stokes Inlet	33.79821, 121.14481	Bushland corridor	1	0	Represents a potential riparian habitat corridor that starlings may use to disperse throughout the agricultural landscape.
Young River	33.77151, 121.16486	Riparian remnant vegetation corridor	4	0	Represents a potential riparian habitat corridor that starlings may use to disperse throughout the agricultural landscape.
Coomalbidgup	33.71532, 121.37714	Swamp with predominantly dead standing timber surrounded by small amount of remnant bushland	9	3(4)	Very large swamp with strong record of historical and contemporary starling nesting activity. Over 12 month period, four units malfunctioned, one was repaired and re-deployed.
Omega	33.66741, 121.37218	Swamp with dead & live standing trees surrounded by cropping.	4	0	Large swamp with prior history of starling occupation.
Glen Carriber	33.79639, 121.40305	Swamp with dead & live standing trees surrounded by pasture.	3	0	Historical records of starlings at this site.
Beef Machine	33.78242, 122.34238	Dry swamp with predominantly live trees, surrounded by blue gum plantations and pasture	6	0(3)	Large treed habitat with strong record of starling activity. Three units malfunctioned during the project but all were repaired and re-deployed (one reserved for extension work with Munglinup Primary School).
Geovon	33.67275, 122.52173	Dry swamp with predominantly live trees, surrounded by	6	0(1)	Most easterly site (~300km from Diamond Downs). Large treed habitat with strong

		pasture			record of starling activity. One unit malfunctioned during the project but all were repaired and re-deployed.

Reference library

At the time of this project, it was not possible to locate and approach starlings on the south coast region of WA to collect reference calls as birds were present at very low density and are extremely wary of humans. Therefore, three field trips to collect reference calls (funded by the DAFWA and conducted in accordance with Standard Operating Procedures; Appendix 1a and approved by the DAFWA's Animal Research Committee and Animal Ethics Committee; Appendix 1b) were conducted at the Turretfield Research Station near Lyndoch in the Barossa Valley region outside of Adelaide, South Australia. In addition, SM units were sent on separate occasions to Turretfield (2 units) and Eucla (5 units) to expand the reference library. Calls were also collected from starlings nesting near Fowler's Bay (130 km west of Ceduna).

Reference calls from starlings were collected using both direct and remote recording techniques. A hand-held NAGRA^{BB+} digital recorder with Sennheiser shot-gun directional microphone was used to collect high quality calls from starlings in situations where they could be approached relatively easily (e.g. in the township and immediate surrounds of Lyndoch where starlings are acclimated to human presence). These types of reference calls were incredibly valuable as they allowed us to identify two distinctive and unique call types that help distinguish starlings from other species. These call types were labelled 'variation on whistle' and 'descending whistle' and the features of these two call signatures can be seen in Figure 3. Multiple examples of these calls, from different individuals in different habitats and locations were collated from the recordings of the SM units and the hand-held digital recorder and supplied to Drs Stuart Parsons and Victor Obolonkin at the University of Auckland, New Zealand.

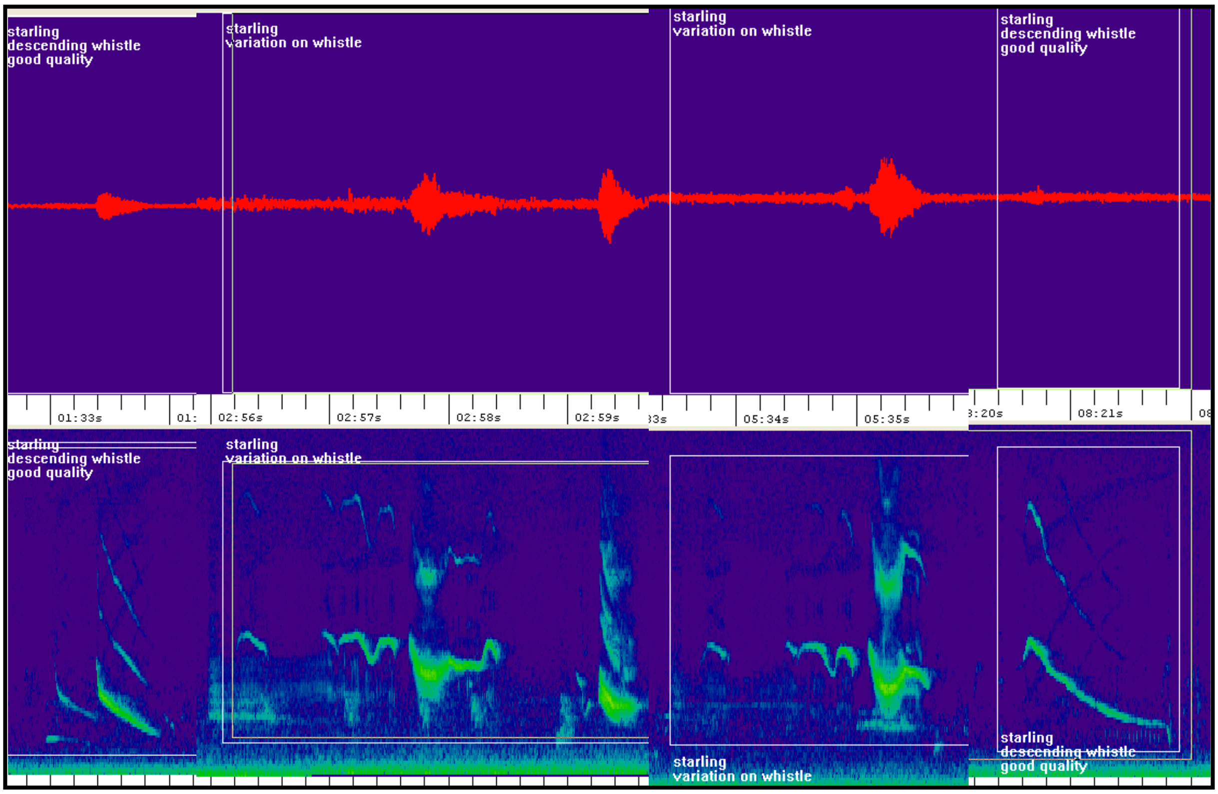

Fig. 3: Example sonograms displaying the two most distinctive starling call types identified from a reference collection of calls of starlings from various locations in South Australia. Shown are two examples each of the 'descending whistle' and the 'variation on whistle' call types.

Eucla recordings

From the 16th November 2011 to 7th January 2012, five SM2 units were placed on a property (32.44077S, 134.16194E) in remote South Australia between Streaky Bay (32.79558S, 134.21140E) and Ceduna (32.12623S, 133.67370E). These units were placed in areas known to be occupied by starlings, including stock watering points and feed stations, and were set to record at dawn, dusk and throughout the day to collect additional reference calls. Initially, these recordings were scanned manually to identify any starling calls that could assist in developing the automated detection filter. The 620 hrs of data from these five units were transferred to Auckland University to test and refine the automated filter.

Automated filter development

Drs Stuart Parsons and Victor Obolonkin from Auckland University in New Zealand were contracted to develop an automated filter that could be applied to field recordings to detect the presence of any starling calls. This work was necessary as it quickly became impractical to manually scan through 1000s of hours of field recordings to visually detect starling call signatures. To facilitate the development of an automated filter, Dr Susan Campbell (DAFWA) provided Drs Parsons and Obolonkin with an extensive reference library of starling calls.

Progress report from Drs Parsons and Obolonkin – 25/5/2011

Library familiarisation and coding

- Became familiar with recordings including marked starling calls, other bird calls, noise, etc
- Transferred SongScope annotations to Raven and selected all individual syllables of all starling calls
- Transferred Raven selection tables to syllable coding for HTK toolkit
- Four main SongScope annotation groups were identified: “decreasing whistle”, “electric buzz”, “variation of whistle”, “chick calls”. Chick calls were not used for model training due to the purpose of the detector (invasion front detection).
- The resultant starling library consists of 1991 starling syllables consisting of: 639 decreasing syllables, 293 electric buzz syllables, 1059 variations of whistle syllables.
- Syllables classified as being low, medium or high quality based on visual assessment of signal to noise ratio.

Initial model run with default HTK parameters, raw signal (no filtering)

- The starling library was slit 50:50 into training and testing datasets.
- HTK was able to find all sound events in the testing data above 4 kHz in frequency.
- HTK detected 97% of starling syllables of high and medium quality.
- HTK detected large number of false positives (i.e. not starling syllables identified as starlings). Within the testing file 63 selections that did not contain starling calls were detected by the HTK.
- This result is extremely positive as the HTK, with no optimisation, is able to detect starling calls.

Processing time:

- A 20 m 40 s recording was used to measure how long it takes to process testing file.
- The parameterisation (measuring variables from the recording) took 1m 35s, giving a parameterisation rate of 1 min for every 15 min of recording.
- The detection processing time was 11s. Detection speed is 1m 00s for every 2 hours of field recording.

Next stage

- Filter recording and change the parameterisation scale (Mel-scale) of the HTK to focus on the frequency band in which most of the starling calls are produced.
- Split components of individual whistles into sub-units and songs into syllable units to develop a language model to detect starlings. This is similar to recognising a word based on the syllables it contains, or a sentence based on the words it contains (and their order)
- Convert HTK scripts to run on the UoA cluster (rather than a single PC) to improve training time.
- Quantify the effectiveness of SongScope and Raven’s built-in detectors so they can be used as benchmark for comparison with results of the HTK model.

Improve test file parameterisation (mainly) and detection times.

Final report from Drs Parsons and Obolonkin – 21/12/2012

Western Australia Starling Detection Project

Summary of work completed

- The collections of files sent by Susan Campbell were analysed and calls added to the detector system.
    - o Two different approaches were implemented and tested one that represents a single model for all starling calls and another separate models for each of three call types: “electric buzz”, “decreasing whistle”, “variation of whistle”.
- To improve processing speed of the detector, scripts were developed to run in a multiprocessor environment (cluster, multiple/n-core CPU(s)). This reduced parameterisation and training time of the model re-estimation linearly.
    - o The multiprocessor system allows for new correctly detected calls to be fed back into the model, allowing immediate adaptation/updating of model parameters. This potentially will increase the number of true positives and decrease false detections. Running simultaneously on multiple processors will decrease processing time
- Scripts were implemented that automatically split long recordings (the size of the recording file can’t be greater than total memory available.
    - o The size of the file is now analysed “on the fly” and is cut into desired portions. Default file size is set to 200MB.
- Different parameterisation techniques were tested to determine which gave the best detection results.
    - o Different number of MFCC coefficients and resolutions of the parameterization window, and its size, were tested. Increases in the size and the resolution of the window, as well as the number of parameters extracted, creates a linear increase in the in the size of the parameter file. At the moment 1GB of the recording equals to 7.5GB of parameter file, i.e. 1 to 7.5. The size of the parameter file can be reduced, but only at the cost of detector performance.
- Filtering of the recordings was checked, but due to the poor detector performance on filtered data and an unacceptable increase in processing time, we chose instead to manipulate the spectral window from which parameters were extracted. The window that gave the best results was between 4 and 14.5 kHz.
    - o It was decided that filtering of the original recordings will not be implemented. Filtering led to a massive number of recordings being rejected. Instead, only the frequency band where most of the starling calls are produced is parameterised. The downside of this approach is calls falling outside this

frequency band will not be detected (**Figure 1**). However, these represent rare calls such as chick-begging and contact calls produced by mothers near the nest.

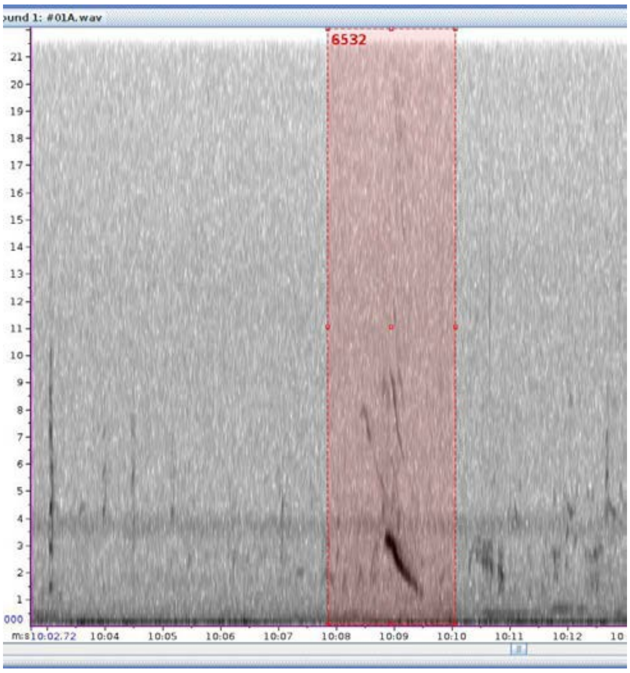

Figure 1 Call that would be missed by the system due to the frequency band manipulation

- Leave-one-out cross validation algorithm was implemented to utilize the most from the data available.
    - o This algorithm removes one file from the training dataset, and subsequently uses it to test a trained model. This process is then repeated for the entire dataset. Overall performance is deduced from the average of all iterations. This algorithm is computationally intense and requires a lot of human- processing time. However, it makes best use of the data available.
- An automated system to test for true/false positives/negatives was implemented to decrease "result-output" processing time.
- Scripts were developed to deal with false positives (initial parameters are derived from the existing data). Three approaches were implemented implemented.
    - o The first approach allows the user to set the log-likelihood outputs of the detector – essentially a threshold for acceptable detection. Having a high threshold will mean that only starling calls are detected, but some may also be missed. Having a threshold set too low will result in all starling calls being detected, but the number of false positives will also be high.
    - o The second approach uses a second layer classifier, where detected calls are passed on to another system to be "double-checked". The Markov Toolkit we are using allows recognition from continuous recordings and from isolated segments. Initial detection of starling calls is from continuous recordings. As soon as a segment in the recording is recognised as "starling" it is sent to an isolated segment

procedure using the same parameters. This system is good for reducing the number of false positives.

- o A second type of second classifier, an artificial neural network, was developed and tested. However, this increased parameter preparation and classification time. The classifier was developed but not implemented the application
- o The third uses a simple duration threshold. As described more in the results section, the majority of false positives are short in duration and so easily be discarded. A minimum acceptable “starling” call duration will be set by the user.

Results

Identification of starling calls:

- The system detects approximately 98% of high-and medium-quality calls. The detection rate for low-quality calls is between 60 – 70%. Detection rates for the “decreasing whistle” call of starling is highest. Starling calls masked by the calls of another bird or species will be detected if the starling call has a higher signal-noise ratio (**Figure 2**).

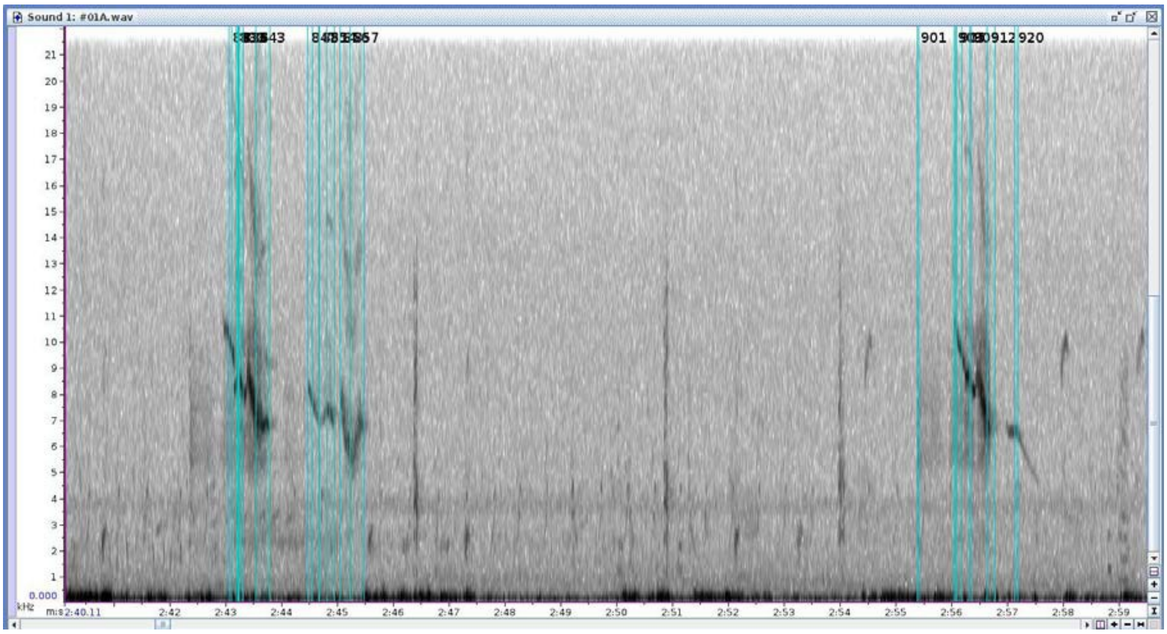

Figure 2: Raw output of the detector system. Starling calls are detected as a number of small segments. The results are shown in Raven software.

- All (99%) of starling high-medium quality songs (i.e. a series of calls) are detected. (A song is classified as detected if at least one call from the song is correctly identified, **Figure 3**).

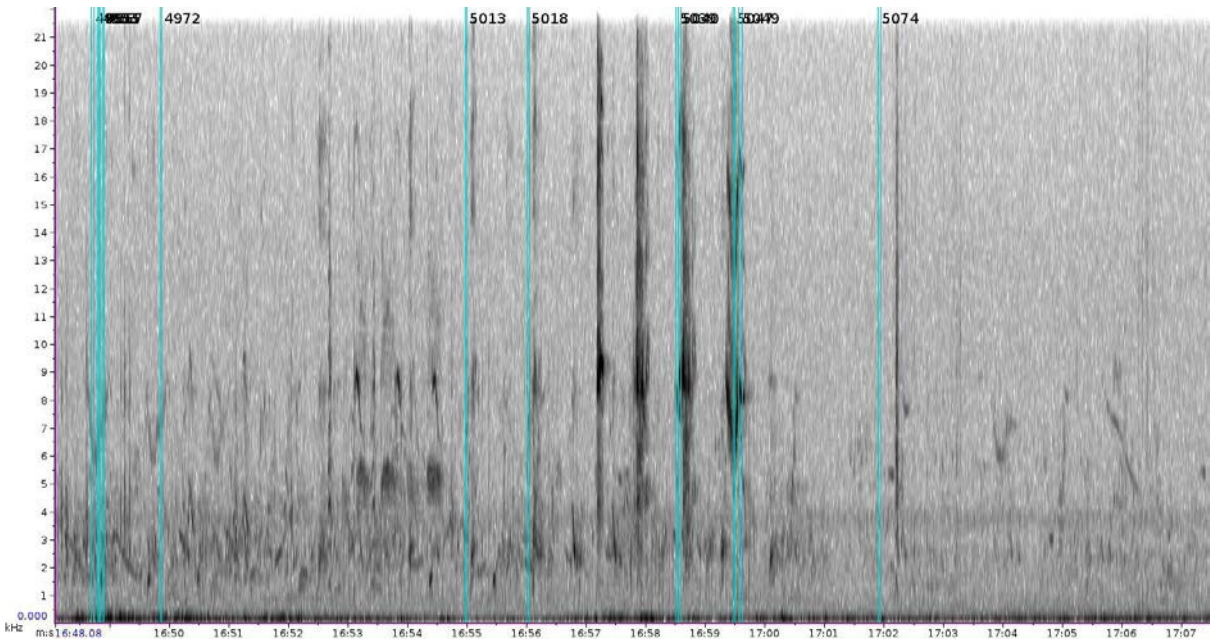

Figure 3 Starling "song". The "song" is the sequence of starling syllables in short period of time. Not all syllables were detected, but the "song" as a whole was.

- As an initial test of the system, we analysed a 30-minute recording made near Auckland. The recording was visually inspected to ensure it contained no starling calls. The model detected no starlingcalls.
- A file sent from Western Australia, and known to contain no starling calls, was also tested using the model. Two calls were identified by the system as "starling" (**Figure 4**).

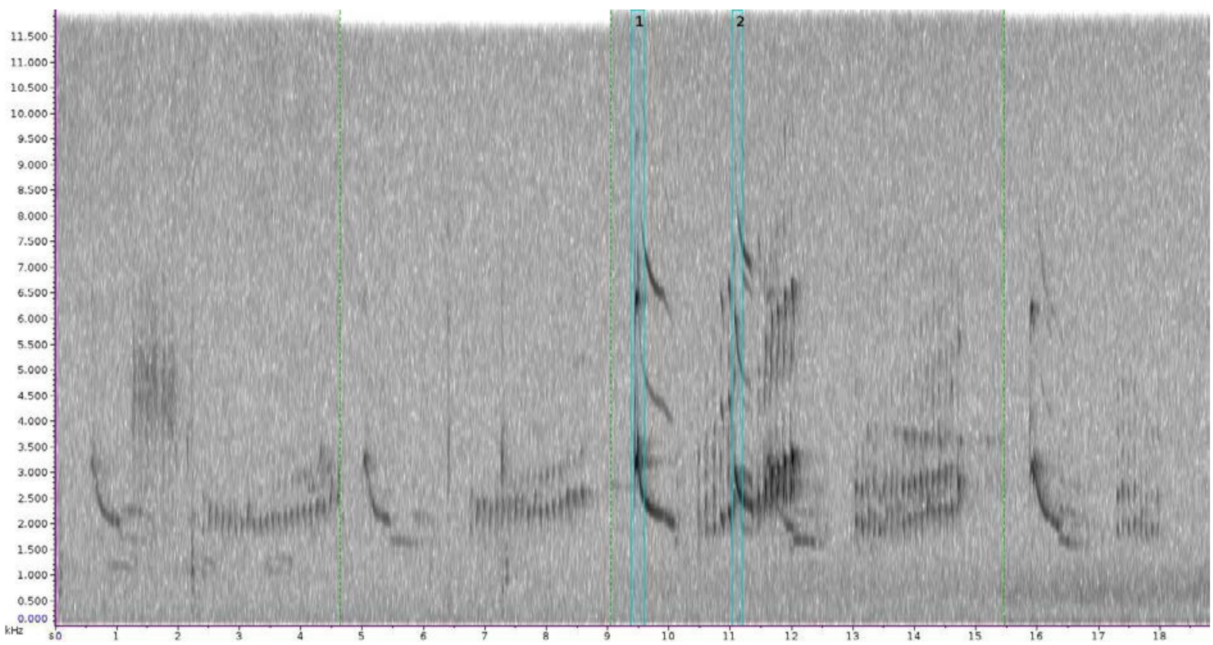

Figure 4: False positive detections of non-starling calls. This test file did not contain any true starling calls.

False identifications:

49% of all calls detected by the raw model (i.e. with no attempt to remove false positives) were false positives.

Log-likelihood threshold:

- Results were poor for the log likelihood threshold system. The system was “certain” in it’s decision (**Figure 5**)

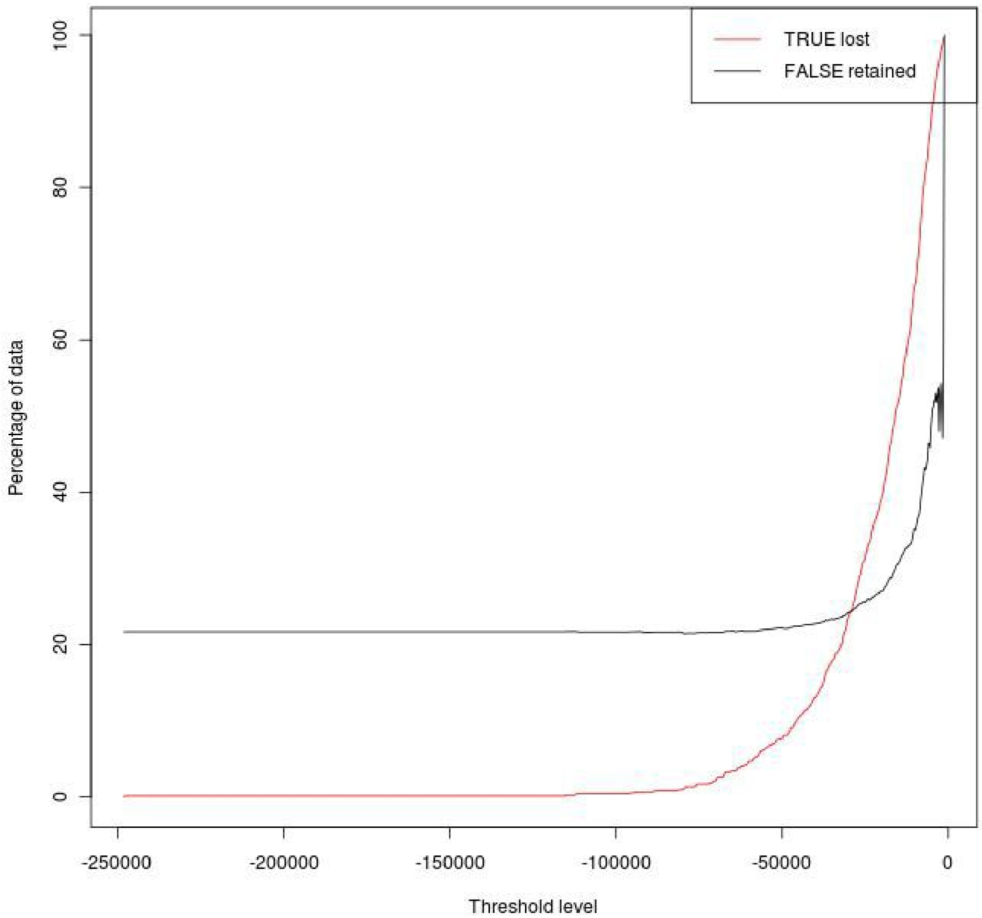

Figure 5: Log-likelihood threshold. Percentage of true starling calls lost and false starling detections retained over the log-likelihood threshold levels

- Following implementation of the threshold, the percentage of false positives does not decrease with increasing threshold level. Also note that as the threshold increases, the percentage true positives lost increases rapidly.

Second Level classifier (isolated segment classification with HMM):

- Results were very similar to those achieved using the log-likelihood threshold.

Second Level classifier (Artificial Neural Networks classifier):

- Separate Neural Network classifier was developed. Overall detection rate falls down to 89% due to the ANN, but we have the decrease in the false positive detection to 15%. The calls that are not recognized as starling are all from the "variation of whistle" category.

Duration threshold

- 49% of all calls detected by the raw model (i.e. with no attempt to remove false positives) were false positives.
    - o After the call duration threshold (0.065s) was implemented the percentage of false-positives dropped to represent 25% of all detections. This threshold also reduced the proportion of true positive calls detections by 11% (to 87% from 98%), i.e. 11% of the correctly detected starling calls do not pass the length threshold (**Figure 6**).

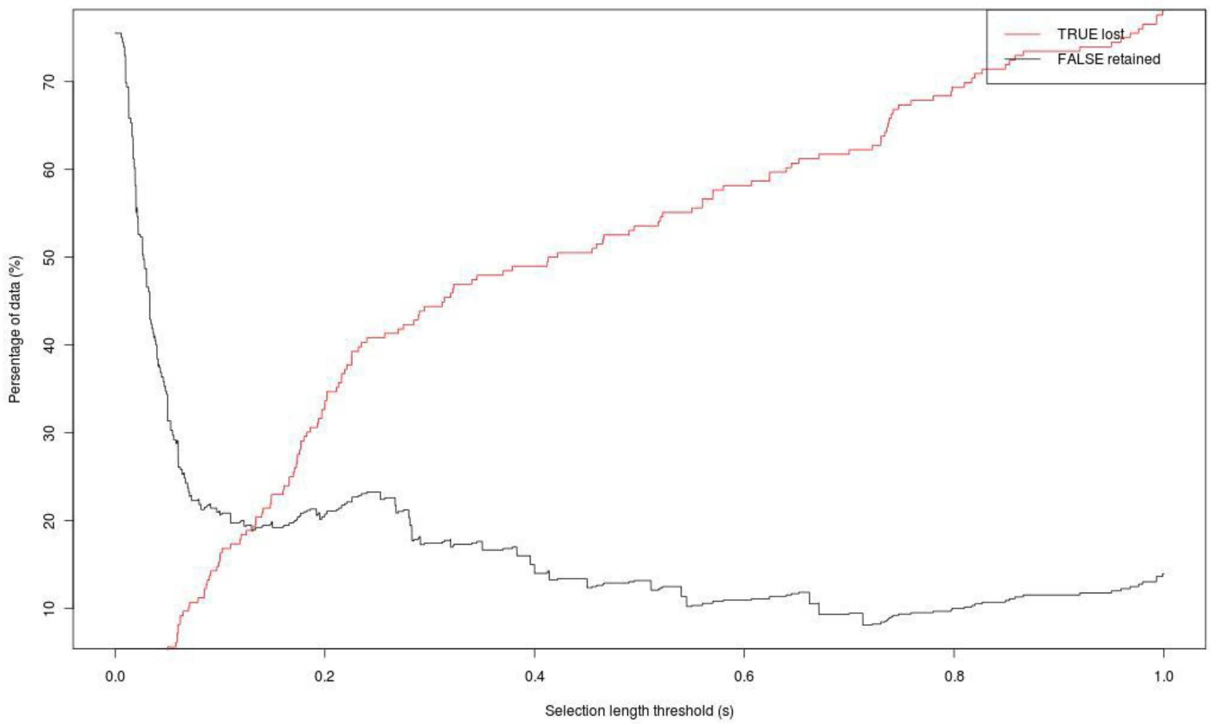

Figure 6 The relationship between the threshold call duration and the number of false positives detected, and number of true positives lost

- As the aim of the model is to detect invasion "events", we altered the way the system classified the detection of an event (previous results refer to detecting individual syllables or songs).

- We defined three types of event.
  - Low: 3 starling calls are detected in 60 seconds of recording
  - Medium: 5 starling calls are detected in 30 seconds
  - High: 5 starling calls are detected in 15 seconds (high).
- The raw (i.e. with no duration threshold) results are (%):

	Event Type		
	High	**Medium**	**Low**
True Positive	27	62	100
False Positive	73	38	0

- After the implementation of the duration threshold the results are (%):

	Event Type		
	High	**Medium**	**Low**
True Positive	46	82	100
False Positive	54	18	0

The percentage of TRUE events missed due to the threshold was 33% (high), 13% (medium) and 0% (low).

Two main types of false detections were identified:

- Random unknown call (**Figure 7**)

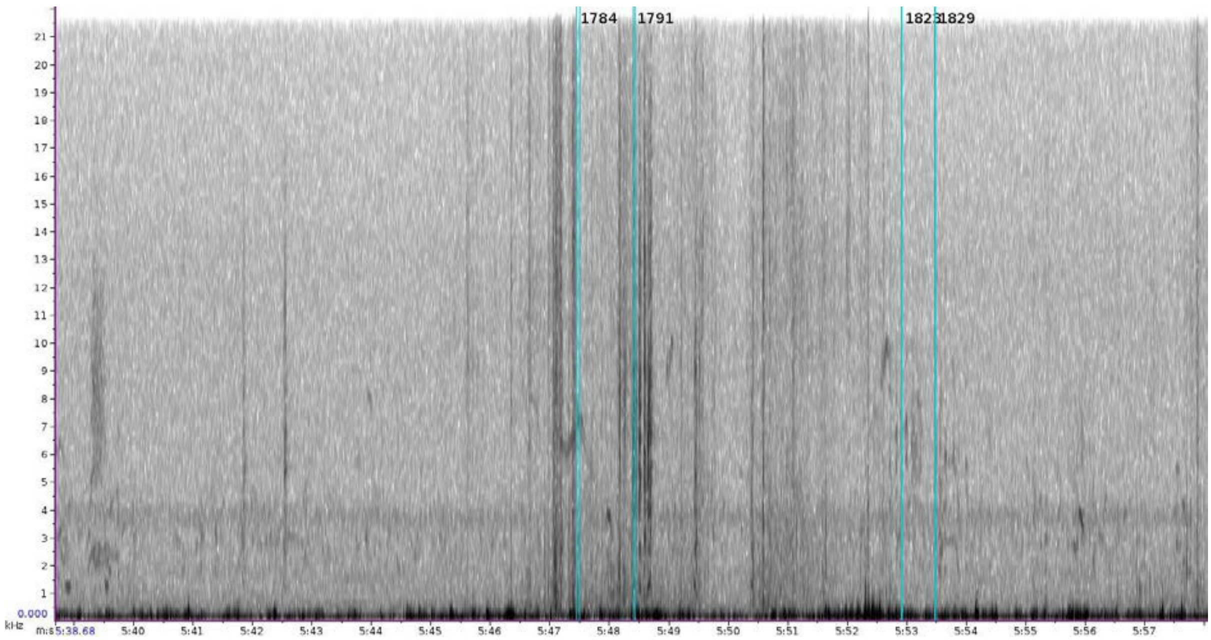

Figure 7 False-positive calls detected by the system

- Call of a particular bird, which represent a very common misidentification (**Figure 8**)

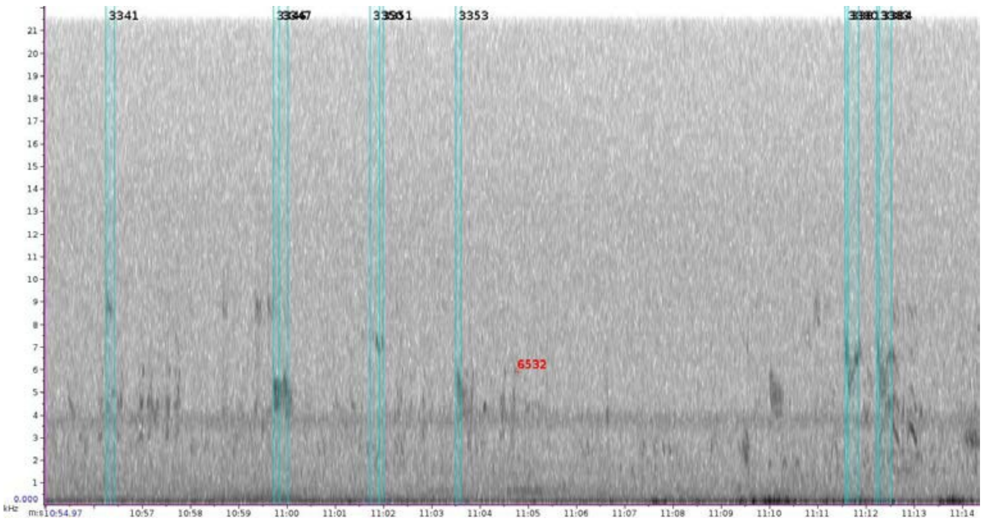

Figure 8 Very common false-positives detected by the system. Due to the low signal to noise ration it is difficult to decide whether the calls are starlings or not.

- Duration threshold significantly reduces the number of false identifications.

Windows based application:

- Combined all different parts of the program into one GUI-based program.
- Processing speed is much greater for GUI application then Linux scripts (1:3 ratio)
- Application uses 3rd party libraries (R; http://www.r-project.org/)
- Second level classifiers were not implemented due to the long processing time
- More work needed to develop commercial software based on this detector

Automated filter testing

A 30-min test file was compiled consisting of known starling calls placed amongst numerous other species' calls, including species commonly encountered in the agricultural setting of WA's south coast region such as ravens (*Corvus coronoides*) and magpie-larks (*Grallina cyanoleuca*). The test file also included the calls made by starling chicks begging at the nest and the sounds of mothers attending to these chicks. Neither of these call types were used in the training of the automated filter.

The first run of the automated filter through the test file resulted in:

- 150 false positives (not starlings)
- 24 detected starlings (true positives)
- 22 false negatives (missed starlings, all call types)
    - 13 descending whistles missed
    - 1 electric buzz missed
    - 8 chicks begging + attending mother calls missed

As the filter was not trained on calls associated with chicks and attending mothers, the system effectively missed 14 starling calls, however 7 of these were of a very poor quality that we could not expect the filter to detect (i.e. they had a very low signal to noise ratio). Therefore, there were 7 starling calls of suitable quality out of a total of 27 possibilities that went undetected. This equates to a 76% likelihood of the filter detecting a single starling call (descending whistle, electric buzz or variation on whistle) if it is recorded at medium – high quality. In reality, birds will produce more than just a single call; therefore the likelihood that we would detect an incursion by a starling(s) is greater than 76%.

The number of false positives was larger than desired, and consisted predominantly of raven, magpie-lark and willy-wag tail (*Rhipidura leucophrys*) calls. Reducing the occurrence of false positives, and thereby reducing staff time in verifying results, is easily achieved by re-training the algorithms. This process requires additional time and funding to fulfill prior to the adoption of remote surveillance in WA's starling control campaign.

Analysis of field recordings

Given the significantly greater time period required to develop and, importantly, refine the algorithm, at the time of writing, the analysis of the 12 months of field was still being processed. The work required by the DAFWA to determine the proportion of true positives, false positives and missed calls (if any) is consequently ongoing and will be used to feed back into the re-training of the final algorithms that will be adopted in any future remote surveillance. Unfortunately this scenario impacts on our ability to address some of the outcomes and milestones associated with this project at the current time.

Immediate outcomes

- *Use extensive knowledge base to identify prime areas to place units*

As detailed in the Acknowledgements, the DAFWA Biosecurity Staff with extensive prior knowledge of starling occurrence and behaviour on the south coast of WA were consulted with regards to field placement of the SM units. All sites selected have a history of starling occupation. Sites located east of Esperance are areas where starlings may still be present, whereas the western most sites near Hopetoun have not had confirmed sightings of starlings for several years. The majority of units were placed near the local of Munglinup, which represented the core of the control area for the 2006 – 2009 eradication campaign. Consideration was also given to placement of some of the units on the agricultural / remnant bush interface, and sites (e.g. along Young River and near Stokes Inlet) that could represent habitat corridors that may facilitate starling dispersal.

- *Expand the area of starling surveillance*

During the 2010/11 starling control campaign, the number of on-ground field staff declined from previous years, and consequently the area that was surveyed for starling presence also was reduced. Little to no on-ground surveillance was carried out at any of the sites that had Song Meters present, with the exception of Coomalbidgup and Minnikin swamps. Consequently, this project greatly expanded the area of active surveillance, with units spaced strategically along a ~300 km stretch of the south coast.

- *Strengthen surveillance at current operation sites*

As noted above, two swamps actively targeted for on-going ground surveillance are Coomalbidgup and Minnikin swamps. These are large swamps, with 100s of potential nesting sites for starlings. Conditions (surface water, snakes, mud, areas of thick vegetation) at both sites are not conducive to easy and efficient on-ground surveillance. Therefore, placement of units around the entire boundary of both these locations, helped strengthen surveillance at both these current operational sites. On-ground surveillance in the 2010-11 season did not detect any starling activity at these sites. Analysis of the field recordings from all sites is ongoing.

- *Extend temporal period of starling surveillance*

SM units recorded continuously from June 2010 to the end of June 2011. During this period, on-ground staff operated within the control area from the end of October 2010 through to February 2011. This project therefore extended the temporal period of starling surveillance to include the non-breeding season and results on whether any starlings were detected are to be forthcoming.

- *Facilitate rapid response to new groups of starlings*

The analysis of field recordings could not occur in real time due to the onerous nature of manual review of the data. Successful development of the automated filter occurred more than 12 months after the collection of field data, therefore we were unable in this project to facilitate real time responses to any positive starling recordings. However, we now have the tools and the potential to pursue this goal using upgraded recording units that can be accessed remotely to download data. Combining remote download with our existing software will achieve this goal of facilitating rapid response to new incursions.

- *Identify habitat corridors used as dispersal routes by starlings*

No starlings were seen in the study area during the period this project was undertaken by on-ground Biosecurity staff, nor by the research staff that attended to the SM units every 7 – 8 weeks. To confirm this absence of starlings in all habitats, including during the winter months when starlings may be sheltering, dispersing and / or prospecting for future breeding sites, we will need to manually screen the results from the automated filter analysis of the field recordings and determine the occurrence of any true positives. This work is ongoing, but will be fed back to management immediately upon completion.

- *Prevent spread of starlings throughout the south coast*

Our work through this project has enabled us to reinforce the DAFWA's presence throughout the south coast region of WA and has greatly helped to communicate the risks associated with a starling incursion in this area to numerous stakeholders and audiences. This project represented a novel approach to starling detection and allowed us to re-visit areas that would otherwise be overlooked for on-ground surveys. By continuing to inform the public, landholders, students, management and the greater scientific community on the importance of reporting suspected starling sightings, we have certainly helped prevent the spread of starlings into WA. Ultimately, the findings from this project will help to improve the efficiency of the starling control campaign and will increase the extent of surveillance conducted in remote areas of the south coast.

Long-term outcomes

- *Remotely survey for starlings with minimal on-ground intervention*

Incorporating remote surveillance into WA's starling control campaign is the highest priority goal associated with the current project. Wildlife Acoustics™ have developed a new model of the SM2 units (referred to as 'SongStream') that enable remote downloading of data. Combining this new technology with the automated starling detector developed during the current project means that we can remotely survey for starlings with minimal on-ground intervention.

- *Maintain constant monitoring presence in strategic areas*

'SongStream' units are currently commercially available in Australia and the DAFWA is investigating the logistics of their application to the starling control campaign. These units rely on 3G mobile coverage so that data can be downloaded remotely. Currently, the Royalties for Regions program (Regional Mobile Communications Project – www.commerce.wa.gov.au/scienceinnovation/Content/Programs/Regional_Mobile_Communications_Project/index.html) is funding the placement of several new mobile towers along the South-West highway in WA, which may result in improved mobile coverage in remote areas. This suggests that we should be able to successfully access sufficient mobile coverage in a wide area to enable a constant monitoring presence for starlings in strategic areas.

- *Develop computer algorithms to automatically detect starling calls*

As outlined above, we achieved this long-term outcome during the second year of this project. The software has been supplied to the DAFWA and has been designed with an interface that is simple to operate and allows the user to input different thresholds that the algorithms can run with

- *Develop algorithms to detect and identify other bird species*

The Department of Environment and Conservation (DEC) have a good reference collection of Western Ground Parrot calls. This library can be used to develop an automated filter for this species should the manual review of call files become too onerous. Currently however, the length of field recordings generated from targeted Western Ground Parrot surveys are short enough to be reviewed manually (see Appendix 2). The techniques outlined above by Drs Parsons and Obolonkin can be readily applied to any other species of interest provided a sufficient reference library of calls is obtained.

- *Protect agricultural and community assets along the south coast from the impact of starlings.*

The most efficient and cost effective management of any pest animal is to act before they become established. Provided that the opportune time has not lapsed, *preventing* successful pest invasions should initially be the primary goal of any control and/or eradication campaign. Therefore, by investing in the detection and control of starlings in WA *before* this pest has become established, management is providing the best possible protection for agricultural and community assets along the south coast. The current project has paved the way for the application of remote starling surveillance using recording units, enabling rapid response to new incursions over an area greater than could be covered by on-ground staff. This combination of on-going control and early detection will further ensure that at-risk agricultural and community assets are protected from the potential impacts of establishment of starlings in WA.

Media / Extension

- *"Detecting bird songs"* – page 2 of Starling Spotter **Newsletter**, January 2009*.*

  Starling_Spotter0109
  .pdf

- *"Efforts step up as starling eradication looms"* – page 25 of Biosecurity in Agriculture **Newsletter**, June 2010.

  bia_jun10sm.pdf

- *"Sounding out starlings"* – page 8 of Agriculture and Resource Risk Management **Newsletter**, December 2010.

  ARRM Newsletter -
  December 2010.pdf

- *"New Remote Sound Records Trialled to Detect Western Ground Parrots"* – Page 2 of Friends of the Western Ground Parrot Inc. **Newsletter**, May 2012

  Final report_May
  WGP Newsletter 201

- *"Automated Recording Units at Cape Arid National Park – The Results!"* – Page 5 of Friends of the Western Ground Parrot Inc. **Newsletter**, June 2012

  Final report_June
  WGP Newsletter 201

- Vertebrate Pest Conference – Sydney June 20-24 2011. **Spoken presentation** "*Applying remote audio technology to Western Australia's starling eradication campaign*".
  Authors: Susan Campbell, R. Parr, G. Gray, G. Martin, A. Woolnough.

- **Spoken Presentation** to the Agriculture and Resource Risk Management Group, DAFWA, South Perth, July 2011. "*Applying remote audio technology to Western*

Australia's starling eradication campaign".
Authors: Susan Campbell, R. Parr, G. Gray, G. Martin, A. Woolnough.

- **Presentation** to staff and students of Munglinup Primary School, November 2010.

  Susan Campbell gave a class room presentation to the senior students on the use of applying remote technology to detect birds in the environment. The students were also given a workshop on how an SM2 unit functions and were left with one set up in a tree at the back of their school (see photo in article 2c above). Follow up analysis of the data collected by this particular unit revealed common farmland fauna, including magpies, yellow throated miner birds, western gerygones, magpie-larks, wattle birds, ravens and galahs. These findings were communicated (via email) back to the students.

- Wildlife Sound Recording Workshop, Wellington Lodge Conference Centre, Wellington Mill, 18 – 23 September, 2011. **Spoken presentation** and **participation** in workshop by Dr Malcolm Kennedy, DAFWA. "*Applying remote audio technology to Western Australia's starling eradication campaign*". Participants at this workshop were very interested in the SM2 technology and could see the technology being applied to a range of applied research areas, including avian and amphibian surveys.

Objectives & Milestones

Objective	Milestone Date	Date achieved	Performance description
Determine presence/ absence of starlings in novel habitat.	Feb. 2010 & monthly thereafter	Jan. 2013+	SM2 units were placed in areas that would otherwise not have been surveyed by ground staff. Therefore we have the ability to achieve this objective, however due to the unforseen delays in the development of the sophisticated analysis software, we are currently processing and reviewing results from the analysis of field recording data. Findings will be immediately reported to management and also fed back into refining the algorithms used in the automated filter.
Identify potential habitat corridors used by starlings for dispersal.	Feb. 2010 & monthly thereafter	Jan. 2013+	As above, results from recordings made at Young River and Stokes Inlet will provide interesting insight into the potential use of habitat corridors during the winter period and also pre-breeding when starlings are likely to be dispersing and / or prospecting for nest sites.
Continually monitor for starling activity on the south coast of WA throughout the year.	May – Sept. 2010	May – Sept. 2010	We successfully collected 74 GB of field recordings that represent continuous monitoring for any starling activity over a 12 month period.
Inform management and guide strategic response(s) to starling incursions.	Jan. 2010 monthly thereafter	Nov. 2012+	The knowledge and tools gained from this work allow informed management decisions concerning future starling surveillance and the efficient use of limited resources.
Report on the detection of other significant fauna.	Feb. 2010 & monthly thereafter	Nov. 2011 – Sept. 2012	The Department of Environment (DEC) has successfully applied the SM2 technology to surveys of the Western Ground Parrot (WGP). The loan of 30 SM2 units to the DEC has proved invaluable in assessing their effectiveness for WGP surveys. A detailed report on the outcome of this

			objective is provided in Appendix 2.
Identify the use by starlings and other conservation significant fauna of habitat on the boundary of agricultural and remnant areas.	Feb. 2010 & monthly thereafter	Nov. 2011 – Sept. 2012	Western Ground Parrot calls detected by an SM2 unit in Fitzgerald River National Park, located 3.6km from farmland.
Encourage community monitoring of specific units.	Jan. 2010 & monthly thereafter	Nov. 2010	A single SM2 unit was erected on the ground of Munglinup Primary School, located in the heart of the 2006/07 starling incursion into the southern coastal region.
Produce education and extension material relevant to the project.	Feb. & Nov. 2010	2009 - 2011	Newsletter articles, progress reports, conference presentations and workshop presentation and participation details are outlined in Appendix 2. During the project, four spoken presentations have been made and five Newsletter (3 DAFWA, 2 DEC) articles published – exceeding the initial performance indicators stated in the application. A broad range of audiences (e.g. primary school students through to International academics at Vertebrate Pest Conference) have been presented with information on the application of remote detection to WA's starling control campaign. The DEC have produced two Newsletter articles relevant to the project: • Friends of the Western Ground Parrot Newsupdate No. 54 – May 2012 • Friends of the Western Ground Parrot Newsupdate No. 55 – July 2012 (Both available online at http://wgpnewsletters.blogspot.com.au/)

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