House sparrow eradication attempt on Robinson Crusoe Island, Juan Fernández Archipelago, Chile

E. Hagen[1], J. Bonham[1] and K. Campbell[1,2]

[1]Island Conservation, Las Urbinas 53 Santiago, Chile. <erin.hagen@islandconservation.org>.[2]School of Geography, Planning & Environmental Management, The University of Queensland, St Lucia 4072, Australia.

Abstract House sparrows (*Passer domesticus*) compete with native bird species, consume crops, and are vectors for diseases in areas where they have been introduced. Sparrow eradication attempts aimed at eliminating these negative effects highlight the importance of deploying multiple alternative methods to remove individuals while maintaining the remaining population naïve to techniques. House sparrow eradication was attempted from Robinson Crusoe Island, Chile, in the austral winter of 2012 using an experimental approach sequencing passive multi-catch traps, passive single-catch traps, and then active multi-catch methods, and finally active single-catch methods. In parallel, multiple detection methods were employed and local stakeholders were engaged. The majority of removals were via passive trapping, and individuals were successfully targeted with active methods (mist nets and shooting). Automated acoustic recording, point counts and camera traps declined in power to detect individual sparrows as the population size decreased; however, we continued to detect sparrows at all population densities using visual observations, underscoring the importance of local residents' participation in monitoring. Four surviving sparrows were known to persist at the conclusion of efforts in 2012. Given the lack of formal biosecurity measures within the Juan Fernández archipelago, reinvasion is possible. A local network of citizen observers is the best tool available to detect house sparrows at low density, however ongoing, dedicated eradication funding does not exist. Opportunistic removals via shooting have been possible from 2013–2016, but elusive individual sparrows were seen during a small number of days each year suggesting remnant group(s) exist in yet unknown forest locations.

Keywords: invasive bird, management, *Passer domesticus*, trapping

INTRODUCTION

House sparrows (*Passer domesticus*) have a wide range of negative impacts in areas where they have been introduced. They affect native bird species, pushing eggs and nestlings from nests and chasing adults (McGillivray, 1980; Gowaty, 1984); they consume crops and ornamental plants; and are vectors of at least 29 diseases affecting people, livestock and wildlife (Clergeau, et al., 2004; Fagerstone, 2007). This species is an effective invader owing to its generalist diet; rapid rate of increase, facilitated by colonial-communal nesting, large clutch sizes and extended breeding seasons; effective range expansion in human-altered landscapes; and aggression against similar and smaller sized birds (MacGregor-Fors, et al., 2010). The risks of house sparrows are often underestimated and delays in rapid responses to incipient or small localised populations can result in much more complex and costly future actions for their management once population growth and negative impacts on native species are documented (Clergeau, et al., 2004). Complete removal of invasive house sparrow populations should be considered to eliminate risk for negative impacts arising from the species' invasion.

House sparrow eradication attempts on other islands have demonstrated that the effectiveness of some methods may decline over time, if sparrows learn to avoid them (Bednarczuk, et al., 2010) emphasising the importance of using a variety of techniques in an adaptive management approach. Campaigns for house sparrow eradication should employ multiple methods and aim to remove the entire population within as short a time as possible. Otherwise, given the species' reproductive potential, there is a risk that house sparrows will breed faster than they are removed. To maintain naïveté of the population to methods for as long as possible and reduce the likelihood of house sparrows dispersing in response, methods should be implemented strategically. The detection and removal of the last individuals must be considered in planning the deployment of the multiple alternative methods available (Morrison, et al., 2007). To increase likelihood of successful eradication, some methods should be deployed consecutively and others sequentially with attention to maintaining sparrows naïve to methods.

The Juan Fernández Archipelago in Chile is comprised of three islands (Robinson Crusoe (4,790 ha), Alexander Selkirk (4,950 ha),) and Santa Clara (220 ha)) with globally significant biodiversity and endemism due to its isolation and topographic variation. However, invasive species continue to drive catastrophic changes to these unique natural values including species extinctions and massive erosion, as well as precipitous declines in plant and animal species and loss of native vegetation cover (Sanders, et al., 1982; Bourne, et al., 1992; Arroyo, 1999; Hahn & Römer, 2002). Feasibility of the complete removal of invasive species has been explored and participatory planning with the islands' inhabitants and varied stakeholders continues to advance as benefits of invasive species removals and restoration are prioritised (Saunders, et al., 2011; Glen, et al., 2013; Ministerio del Medioambiente, 2017).

House sparrows have been present on Robinson Crusoe Island (RC) since 1943 as a wild population (Hahn, et al., 2006) and none are kept as pets. The population appeared stable at around 80 individuals and to be restricted to the island's only human settlement of San Juan Bautista (Hahn, et al., 2006; Hagen pers. obs.); however, observations in 2011–2012 indicated population expansion within San Juan Bautista into new home construction areas following a tsunami in February 2010. The potential increased risk from this species to single-island endemic birds and local food production prompted a review of control and eradication options within a local multi-stakeholder group focused on animal issues related to conservation and local development.

The study reports on an attempt to eradicate the local house sparrow population within an experimental framework to examine the efficacy of methods for house sparrow eradications and protect local biodiversity. The

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objectives of the study were to keep house sparrows naïve and eliminate the potential for survivors to learn to avoid methods (e.g. escape from traps).

METHODS

A range of potential methods for use in house sparrow eradication from RC were considered (see Table 22 of Saunders, et al., 2011). Removal techniques were evaluated and prioritised based on previous success in bird removals, permissibility in this urban setting, and likelihood to contribute to sparrow learning. Toxicants were assessed, but none were considered suitable for house sparrow eradication (Fisher, et al., 2012). Trapping was identified as having the greatest potential to provide a large reduction in the house sparrow population on RC while minimising risks to native birds and poultry. Pre-baiting was initiated one month before removals began (15 June 2012) at 10 sites to allow house sparrows to become accustomed to feeding at a given location on provided crushed maize (1.6–3.2 mm diameter) and to confirm minimal attraction of non-target species to these sites.

Passive removal techniques were employed in the first phase of this trial, to minimise education of house sparrows to future methods (10 July 2012–14 September 2012). Active removal techniques were added to the trial beginning 27 July 2012.

Passive removal techniques

To minimise education of house sparrows in the population, passive traps were employed in the initial phase of removals.

Elevator multi-catch traps have demonstrated good capture and low escape rates (Fitzwater, 1981). House sparrows enter a compartment alone to feed on bait, their body weight causes an “elevator” to lower the individual to its “escape” into a closed cage. Without the bird’s weight, the counterbalanced “elevator” springs back into the original position ready for another passenger. Birds trapped in the closed cage act as live decoys. We purchased traps without the central mesh body for ease of transport, and then assembled the mesh over a plywood base forming the holding cage once on the island. Trap dimensions were 60 × 40 × 20 cm (<http://www.sparrowtraps.net/index.htm>). Elevator traps were placed on an elevated platform, approximately 2 m in height, to reduce the potential for trap interference by domestic animals and private citizens. We added a covered plywood compartment with a perch within each elevator trap’s holding cage to provide protection from the elements for live decoys. Decoys had primary flight feathers on one wing clipped so that they couldn’t fly in the event of escape. Food and water were provided.

Trio multi-catch traps are comprised of two compartments which each function as a single-catch trap, whose sprung doors must be manually reset after each catch (Nature-House ST1 Trio house sparrow trap http://www.amazon.com/Nature-House-ST1-Trio-Sparrow/dp/B001GIP2MG). The bird drops into the compartment, onto a perch over the feed tray which triggers the compartment door to close. Captured individuals can freely move into the third compartment, where they act as live decoys. Three trio traps were deployed, mounted at least 1.5 m above the ground to reduce potential for trap interference by domestic animals and private citizens. We provided flooring in each compartment to increase bait retention and partial roofs to decrease interference from natural elements.

Modified Australian crow (MAC) traps function when birds drop into the MAC trap to access bait and are unable to fly through the trap entrance to escape as their wingspan exceeds the diameter of the entrance. Captured individuals alight on perches in the higher parts of this trap (Clark & Hygnstrom, 1994). Exclusive use of a ‘mini’ MAC trap has enabled local populations of house sparrows to be entirely removed (McGregor & McGregor, 2008). We constructed two mini MAC traps, retaining traditional width of slats and height of centre board to avoid birds jumping to escape, reducing overall length (82 × 137 × 71 cm). MAC traps were placed on the ground given their robust size.

Nest box traps were made from nest boxes which were converted into single-catch traps (http://www.vanerttraps.com/urban.htm) to capture house sparrows investigating nest cavities. In areas where house sparrows were seen entering and exiting cavities, known cavities were covered to exclude sparrows and nest box traps were deployed with small feathers and fine nesting material added to the entrances to encourage investigation.

Traps were placed within open areas where birds could easily see them, and near frequented flyways, perches and feeding areas. For 2–3 days before arming traps, wired-open traps were placed at pre-baiting sites, with crushed maize on and around the open traps, to permit birds to explore them without risk of capture. When birds were trapped, the trap would be covered with a bed sheet to assist calming the birds during transport and reducing visibility to the general public. Covered traps were then transported to a room where any escapees could be recaptured, prohibiting escape. Within this facility birds were removed from traps and either selected for use as live decoys, or euthanised. Euthanasia was via cervical dislocation; possibly the easiest means for this species and a practical means for mass euthanasia (Sharp & Saunders, 2005; AVMA, 2007).

Active removal techniques

As capture rates declined with passive traps, active removal techniques were added to the trial. We continued using passive traps simultaneously with active removal techniques.

Walk in cage traps were used to target individual sparrows unable to be trapped in other trap types. A wooden box with mesh sides was set up as a walk-in cage trap by propping open a door that opens from the bottom. When the prop is pulled out by a nearby observer (Sharp & Saunders, 2005), bungee cords add to downward force to close the door quickly.

Clap traps utilise a spring-loaded throw net triggered remotely by the trapper, which is placed on the ground and pre-baited with crushed maize (<http://pestbarrier.com/store/itemdesc.asp?xCc=8u4u3>). The trap was not triggered unless all birds in a flock were able to be captured.

Mist nets are a common ornithological capture technique for small birds and were deployed on flyways to capture house sparrows that had avoided traps. Continual monitoring was required to quickly remove any house sparrows or non-target species.

Nest destruction can be used during the breeding season to slow or halt recruitment, and may make adult birds more susceptible to other techniques such as clap traps baited with nest material (Fitzwater, 1994). Eggs are crushed and nestlings euthanised (Sharp & Saunders, 2005). Nest destruction, although planned, was not needed in our trial.

Shooting was employed in specific scenarios where traps were proving ineffective. A 0.177 caliber air rifle with 4–12 times magnification scope (Beeman R9, Weirauch, Germany) was utilised, targeting only individuals alone or in pairs, to avoid wariness. Adult females were targeted first, to limit potential growth of the local population. After 2012, shooting was employed opportunistically.

Detection techniques

Eradication campaigns rely on effective detection of the target species to indicate when individuals of the target species no longer exist and the campaign can conclude. We assessed potential detection techniques for house sparrows throughout the trial, to examine their efficacy at varying house sparrow population densities. We anticipated that some detection methods may become innefective at low population densities as changes in flocking, calling and movements may result from individuals. Therefore we deployed multiple detection techniques simultaneously in order to ensure at least one technique was effective at even low population densities.

Autonomous recording units (ARUs) were deployed at 15 sites within San Juan Bautista. Ten ARUs were co-located with pre-baiting locations while the remaining units were in locations without pre-baiting. We programmed ARUs to record every other day for a 4-hour period around dawn (starting 30 minutes before sunrise) when house sparrows are known to be acoustically active. In addition, each sensor was programmed to record one of every 10 minutes throughout the rest of the day until 30 minutes after sundown. Data from these recordings was available only after post-processing in a sound laboratory. Automated analysis of all field recordings was carried out with the eXtensible BioAcoustic Tool (XBAT, <http://www.xbat.org>) using an image processing technique known as spectrogram cross correlation to detect and classify sounds on our field recordings that were correlated with the spectral qualities of typical house sparrow calls. Sensitivity in the detection analysis was increased to improve the probability of detecting house sparrow calls when few individuals remained, which led to manual review of all events to confirm accuracy of detecting true house sparrow calls (McKown, 2013).

Visual observations were conducted over the same period to provide alternative detection methods in the case that a given method failed to detect individuals even though a population remains present. Fixed radius point counts (Bibby, 2000; Buckland, et al., 2001) were conducted weekly beginning 15 June 2012. Project personnel conducted point counts 14 times throughout the trial period at 21 locations throughout San Juan Bautista, 15 of these locations were co-located with ARU deployment sites and six of which were not located with acoustic sensors or pre-baiting locations. Point counts were analysed using the fixed-radius point count equation as detailed by Buckland, et al. (2001), generating density estimates by habitat type, based on the estimated total surface area of coverage class occupied by sparrows (settlement and cultivated *Eucalyptus, Cupressus* and *Pinus* per Greimler, et al., 2002). Point count density estimates were compared to recorded call rates and sparrow removals each week.

In addition to point counts, citizens were encouraged to report opportunistic sightings of house sparrows, which were all investigated by project staff. Multiple reports of the same individuals, as well as uncorroborated reports prevented clear calculations of the number of individuals remaining.

Camera traps (Reconyx, Holmen WI) were deployed opportunistically at pre-baiting and passive trapping locations. Camera traps were used as an additional technique for visual confirmation of surviving individuals.

After the intensive 2012 campaign, an early observer's network attempting to harness the interest and participation of island residents was developed. This network has grown, and has become a formalised early detection network for invasive species, with individuals' observations of invasive species combined with a common smartphone application (WhatsApp) which allows researchers to capture reports within a database.

Stakeholder communications

Throughout the project, a communications campaign was undertaken to highlight the threats that house sparrows pose to local endemic species. Announcements via radio, signs, fliers, and a booth at a children's day event, were complemented with active participation in the local conservation committee, opportunistic presentations for local institutions and a nest box design contest for local endemic bird species. We also promoted the needs for biosecurity and a municipal ordinance to be established to regulate entry and possession of invasive species.

RESULTS

Methods to maximise personnel efficiency were deployed while reducing the risk of educating animals. Passive multi-catch traps (elevator, trio and mini-MAC traps) were deployed first. As nest-building behaviour was observed, passive single-catch nest box traps were deployed. As the number of individual sparrows was reduced, specific individuals were targeted with more time-intensive active multi-catch traps (mist net, clap trap and walk-in trap). Shooting (active, single-catch technique) was reserved for specific scenarios once other methods appeared ineffective.

Personnel contributed a total of 2,600 person hours across two months of sustained effort. A total of 814 trap days were conducted during the trial, resulting in 89 house sparrows removed. The majority of removals resulted from elevator traps (46 individuals, 275 trap days), followed by mist nets (22 individuals, 22 trap days) and trio traps (15 individuals, 70 trap days). Additional methods did not capture birds (modified MAC, walk-in cage, and clap traps) or were used in specific situations, after the population was reduced, and thus removed fewer birds (nest box trap, 1; shooting, 5). At the conclusion of the trial, four house sparrows were known to remain on the island (two males and two females).

Mist nets and shooting were the most effective removal techniques when effectiveness is assessed as the number of individual sparrows removed as a function of the days the technique was deployed. However, both of these active methods can educate individuals in the target population and require much higher personnel effort as compared to passive trap deployment (for example elevator traps and trio traps), demonstrating that this calculation of effectiveness is incomplete. Also, house sparrows captured in traps appeared to be useful as decoys; however, data specific to differential capture rates is not available.

Detection techniques

Both point counts and automated surveys detected a decline of house sparrows after house sparrow removals occurred. Point count density estimates showed abrupt declines after 60 individuals had been removed from the population, while call rates estimated from ARUs varied more gradually over the trial period (McKown, 2013; Fig. 1). Point count observers did not detect house sparrows

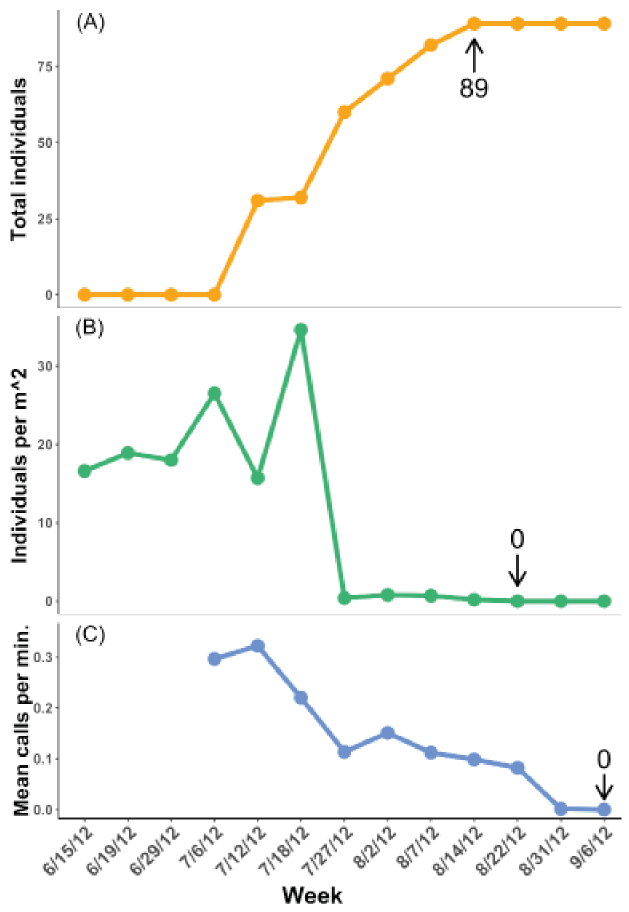

Fig. 1 Results of house sparrow removals over time (month/day/year), as well as detections from point count estimates and acoustic recordings. The cumulative total of house sparrows removed is presented (A) over the same time period that weekly density estimates were calculated from point count observations (B) and mean call rates by house sparrows (C), reported as averages over the previous survey week (McKown, 2013).

after 15 August 2012, while ARUs continued to detect house sparrow activity for 10 additional days. Both point counts and automated surveys failed to detect individual house sparrows known to be present by opportunistic observations on the island in early September 2012; neither point counts nor automated acoustic surveys were effective detection methods at low sparrow densities. Reports and observations made by community members were initiated in July 2012 and continue to date. These observations are a critical component of visual observations as they increase the effective coverage of the dedicated eradication team in area as well as time. In 2014 observations were also being made through the smartphone network, as well as through personal communications.

A total of 1,179 hours of acoustic recordings were collected and analysed from July to September 2012. All 79,822 events detected as potential house sparrow vocalisations were manually reviewed to confirm accuracy. Mean house sparrow acoustic activity, at all surveyed sites with data, declined from an average of 0.3 calls per minute in July 2012 to no calls by the end of August when a low number of individual house sparrows remained on the island (McKown, 2013).

Camera traps effectively captured images of house sparrows visiting known food sources. Given the trial setting in San Juan Bautista, some sites were inefficient for house sparrow detections via camera given that domestic animals, people, and objects moving in the wind would trigger the camera traps resulting in a significant number of images without the target species present. Camera traps did not capture images of individuals when population density was lowered by removals (after 15 August 2012), demonstrating ineffectiveness as a detection method for sparrows at low population densities.

The remnant house sparrows were infrequently detected within the town area between 2012 and 2016 and were reported by residents. Observations were limited to isolated localities and dates (20–23 June 2013, one individual detected and removed; 14 and 23 November 2015, one individual detected; 1 November 2016, five individuals detected; 19–30 October 2016, six individuals detected, three removed). Remaining house sparrows successfully avoided removal techniques and, based on inability to detect them, are thought to spend most of the year outside of the town area. It is uncertain whether or not house sparrows have continued to arrive via cargo ships from mainland Chile.

In addition to house sparrow detections, shiny cowbirds (*Molothrus bonariensis*) have been detected through the citizen observers network (15 March 2016, two individuals detected and removed; 20–24 April 2017, two individuals detected, one removed; Hagen, unpublished data).

Stakeholder communications

Dedicated efforts for regular, personalised and transparent communications about the trial and its goal to benefit native biodiversity were invested before, during and after the trial. Emphasis was given towards communications with homeowners at or near removal sites, as well as broad community-wide communications to minimise misinformation. Project personnel questioned while working always provided community members their attention, answering questions and continuing conversations as needed. A dedicated outreach coordinator led interactions with site owners and local institutions, served as primary point of contact for stakeholder concerns and provided regular updates to stakeholders regarding trial status and advances.

DISCUSSION

The house sparrow has aggressive foraging and nesting behaviour towards native bird species and is one of the most widespread invasive bird species throughout the world (Anderson, 2006). The house sparrow population expansion on Robinson Crusoe Island caused concerns for impacting vulnerable island endemic birds such as the Juan Fernández firecrown (*Sephanoides fernandensis*) and the Juan Fernández tit-tyrant (*Anairetes fernandezianus*), species which already co-occur with house sparrows (Hahn, et al., 2005). Given that house sparrows were pro-actively eliminated from neighbouring Alejandro Selkirk Island in 1994 (Hahn, et al., 2009), there was local interest in their removal from Robinson Crusoe Island while they were still restricted to one area of the island.

Worldwide, invasive bird eradications have received criticism for perhaps not being the highest need or having substantial evidence related to their impacts (Strubbe, et al., 2011). The precautionary principle may be invoked in decisions of eradicating potential threats before ecological damage is documented and the invasive bird establishes a population; in fact, this early action may be the only option for removing highly mobile bird species in some places and can definitely be the most economical option (IUCN, 2000; Baker, et al., 2014; Martin-Albarracin, et al., 2015). On Robinson Crusoe Island, house sparrow eradication and related activities as a community engagement and invasive species awareness-building technique for a broader invasive species programme (Glen, et al., 2013) were used. By working within the island's only town and with dedicated transparent communications focused on native species conservation, a coalition of homeowners was built that not only actively asked questions about invasive species management, but also contributed observations regularly to an early observer's network. This network has grown and today is formalised as an early detection network, continuing to rely on individuals' observations of invasive species by word of mouth, phone and smartphone application as a critical part of invasive species management (Ministerio del Medioambiente, 2017).

At the conclusion of the trial in late 2012, local decision-makers were interested in completing the house sparrow eradication, however the only detection techniques effective at low population densities are opportunistic visual observations. A wide network of citizen observers has successfully indicated presence and locations of house sparrows on Robinson Crusoe in following years; however detailed observations that lead to successful removals require effort-intensive follow-up by specialized personnel. Follow-up trapping has not been successful, however removals by shooting have occurred. It is unclear how many individuals remain, however they tend to be reported in the period from October to January. Multiple methods were ineffective at detecting the presence of remaining house sparrows at low population density, complicating the ability to assess eradication success probability without considerable observer effort across the island. Statstical frameworks developed to assess the probability of eradication confirmation success for other species may lend themselves to adjustments for invasive bird eradications and should continue to be explored (Ramsey, et al., 2011; Samaniego-Herrera, et al., 2013). There is no local institution able to dedicate staff to responding to observations, and so reported sparrow sightings and opportunistic removals are recorded in an exotic species database, including detections and removals from Alejandro Selkirk Island in 2016. The complete removal of house sparrows from the Juan Fernández Archipelago is possible with continued observations and removals; however, the arrival of additional individuals from continental sources via cargo boats is likely as no formal biosecurity measures exist and established municipal ordinances cannot restrict these movements. Persistent threats to native avifauna from introduced species continue to exist in the absence of formal biosecurity and environmental protection legislation.

Worldwide we are aware of at least 23 documented bird eradication attempts (DIISE, 2016, using data classified as good or satisfactory quality, and whole island eradications only). Bird eradication projects are more challenging compared to mammal eradications because volant birds fly more readily between adjacent islands, leading to higher rates of reinvasion (thus necessitating definition of eradication units for eradication planning, e.g. Robertson & Gemmell, 2004; Abdelkrim, et al., 2005) and it is often harder to define if treatment of the whole island or only part of the island is required. Recently, six successful bird eradications in the Seychelles were implemented (Bunbury, et al., 2019) adding to the global knowledge pool for planning and implementing invasive bird eradications. We are aware of only two other attempts to eradicate invasive house sparrows from island habitats, an unsuccessful attempt on Round Island in Mauritius (Bednarczuk, et al., 2010), and a successful attempt of a restricted range population on Mahe in the Seychelles, where repeated invasions (due to international ship traffic) are treated on an ongoing basis (Beaver & Mougal, 2009).

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