Case Study

Establishing a volunteer group to assist in the eradication of invasive brown treesnakes from Islan Dåno' (Cocos Island), Guam

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Abstract: Islan Dåno' (Cocos Island) is an islet of high conservation value located 2.5 km off Guam, USA, in the Western Pacific. It has long been considered free from invasive brown treesnakes (*Boiga irregularis*; BTS). A recently confirmed breeding population of BTS puts its wildlife populations, including U.S. Endangered Species Act-listed lizard and bird species, at risk. In response, we established Guam's first volunteer group dedicated to BTS eradication, which we named Friends of Islan Dåno'. We provided training to local volunteer snake searchers and organized regular night searches for BTS on Islan Dåno'. We completed 25 searches between June 2021 and January 2022, which were attended by 89 individual volunteers and removed 14 BTS from the island. This case study provides an example of how public participation can be successfully promoted within the context of a complex multi-agency invasive species eradication project.

Key words: *Boiga irregularis*, brown treesnake, citizen science, community engagement, environmental management, eradication, Guam, invasive species, volunteer

Public support is an integral element of successful invasive species management (Shackleton et al. 2019). The importance of engaging communities, stakeholders, and indigenous rightsholders to reach understanding, agreement, and co-management is widely recognized (Reed et al. 2009, Howald 2020). Lack of public support can delay or derail well-intentioned, scientifically sound, and time-sensitive management initiatives (Bremner and Park 2007, Estévez et al. 2015, Walsh et al. 2019). Therefore, public support has been identified as a pillar of successful environmental management and one of the core principles of invasive species eradication projects (Larson et al. 2011, New Zealand Department of Conservation 2021).

Public participation can strengthen links between public and scientific communities and increase public understanding of scientific methodologies (Miles et al. 1998, Galbraith 2013). Participation in natural resource management can also be crucial in developing a relationship of trust between local communities and managers (Wald et al. 2019). Organizers of volunteer efforts should consider potential participants' circumstances, personal attributes, and demographics as well as their motivations in order to understand obstacles to participation and promote inclusivity (West and Pateman 2016).

Examples abound of the pivotal role of volunteers in invasive species management. The pioneering feral cat (*Felis catus*) eradication on Te Hauturu-o-Toi (Little Barrier Island), New Zealand, might not have been possible without the substantial contribution of volunteer track cutters and trappers (Veitch 2001). Volunteers have accelerated the removal of invasive common sun skinks (*Eutropis multifasciata*) in Taiwan (Chao and Lin 2017) and devoted thousands of hours over 20 years to red mangrove (*Rhizophora mangle*) control in Hawai'i, USA (Rauzon and Drigot 2002). In Guam, a U.S. island territory in the Western Pacific, volunteer teams helped remove nearly 70,000 crown-of-thorns starfish (*Acanthaster planci*) between 1968 and 1972 in an effort to prevent their destruction of coral reefs (Cheney 1973). In a recent focus group study, residents of Guam expressed a desire for greater engagement with natural resource managers and increased participation in invasive species management activities (Wald et al. 2019).

Brown treesnakes (*Boiga irregularis*; BTS) are

arguably the most devastating invasive species on Guam and are globally notorious for their role in the rapid extirpation of much of the island's native vertebrate community (Savidge 1987, Rodda and Savidge 1997). Millions of dollars are spent annually on BTS interdiction, mitigation, and scientific research due to the ecological and economic damage they cause and the high risk of invasion they pose to other regions (Engeman et al. 2018).

Local and federal resource management agencies have organized public campaigns to raise awareness about BTS on neighboring islands (Hawley 2007) and on Guam, including a focus on preventing BTS from reaching Islan Dåno' (Cocos Island, hereafter Dåno'), an offshore islet of high conservation value previously thought to be snake-free (Guam Department of Agriculture 2017). There is therefore great impetus for community members to report BTS in areas outside their current range. However, there has been minimal direct public involvement in BTS management on Guam, and most control efforts have been concentrated on military and port facilities (Vice 2011, Engeman et al. 2018). In discussing a bounty contest open to the public that drew limited participation, Rodda et al. (1999) expressed that "it seems that few people are willing to spend their evenings combing jungles for venomous snakes" (12), a sentiment that continues to be echoed by managers today. The BTS are moderately venomous, although defensive bites pose negligible risk to adult humans (Mackessy et al. 2006).

In October 2020, public reports led to the confirmation of an actively breeding population of BTS on Dåno' (Barnhart et al. 2022). We established a volunteer group in response to this incursion, with the main goals of providing an opportunity for community volunteers to be involved in the eradication of BTS from Dåno' and accelerating BTS removals from Dåno' for the benefit of native wildlife. We describe the rationale and process of our group's establishment and the results of our efforts to date.

Study area

Dåno' is a 33.6-ha atoll islet 2.5 km off the southern coast of Guam, within a 1,070-ha shallow lagoon (Figure 1). The lagoon has traditionally been a favored fishing ground for the villagers of Malesso'. For example, during fiestas (communal celebrations), families would camp on Dåno' while tekken (gill nets) were set in the tidal zones around the island (J. Quinata, Guam Preservation Trust, personal communication). These practices were disrupted by the establishment of a military facility on the island following World War II and subsequent chemical contamination in the lagoon (Haddock et al. 2011). During the period of Spanish occupation on Guam, coconut (*Cocos nucifera*) plantations were also cultivated on the island, hence the alternate name Cocos Island (J. Quinata, Guam Preservation Trust, personal communication). While the bulk of traffic to Dåno' in recent decades has been tourism-related, local residents continue to routinely visit the island using private watercraft for fishing, crabbing, and recreation.

Dåno' is currently mostly forested, with a 10- to 20-m-tall canopy composed primarily of gagu (ironwood; *Casuarina equisetifolia*) and niyok (coconut palm; *Cocos nucifera*), and an understory dominated by påpåya (papaya; *Carica papaya*) and ladda (noni; *Morinda citrifolia*). Several hectares of scrub in the interior of the island are covered in dense, tangled growth of gaso'so' (latherleaf; *Colubrina asiatica*). The northeastern 24.8 ha of the islet are privately owned and were managed as a day resort (Cocos Island Resort) until approximately March 2020, when it was closed due to the global COVID-19 pandemic. Approximately 1.5 ha in the center of the island are developed with buildings, a swimming pool, areas of lawn, and a jetty. A network of trails was maintained around the resort property (Figure 1), although some are now becoming overgrown. The southwestern 8.8 ha are administered as a natural area by the Guam Department of Parks and Recreation (Lujan et al. 2010).

Dåno' is an island of outsized conservation importance, particularly with respect to regionally and locally threatened lizard and bird species. Twelve lizard species have been reported from Dåno', the most diverse lizard community in the entire Mariana archipelago (Perry et al. 1998). These include the Micronesia saw-tailed gecko (*Perochirus ateles*) and the Mariana skink (*Emoia slevini*), listed respectively as Vulnerable and Critically Endangered by the IUCN Red List (the latter listed as Endangered under the U.S. Endangered Species Act [ESA]), and both extirpated from the main island of Guam (Allison et

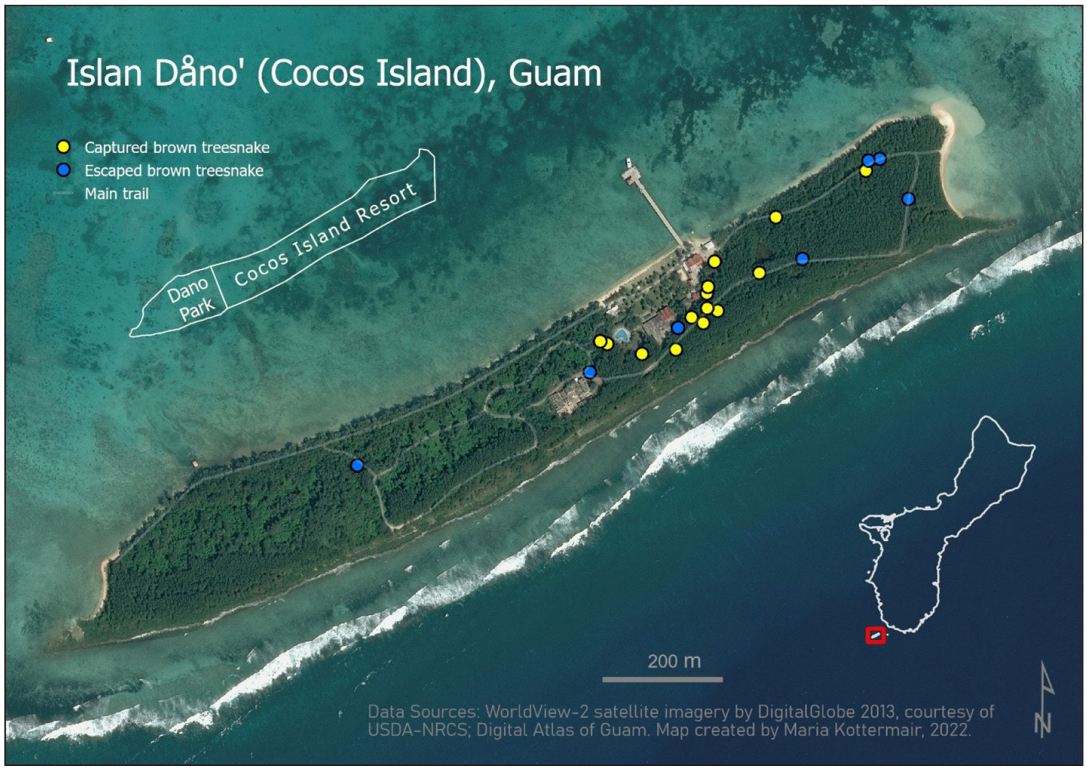

Figure 1. Satellite imagery of Islan Dåno' (Cocos Island), Guam, USA, with its location relative to the main island of Guam indicated by the red box on the map in the bottom right of the image, and the boundary between the government and resort properties outlined in the upper left. Locations of brown treesnakes (*Boiga irregularis*; BTS; *n* = 14) captured by volunteers between June 2021 and January 2022 are marked by yellow circles, escaped BTS (*n* = 7) are marked by blue circles, and the island's main trails are traced in pale gray lines.

al. 2017, Richmond et al. 2022). Dåno' has acted as a refuge for several species of birds that were extirpated, or nearly so, from Guam by BTS in the 1980s and 1990s: såli (Micronesian starling; *Aplonis opaca*), CHunge' (white tern; *Gygis candida*) and fåhang (brown noddy; *Anous stolidus*; Wiles et al. 2003, Pollock et al. 2022). It has also become the site of one of the largest black noddy (*A. minutus*) colonies in the Mariana Islands and regularly attracts migratory seabird and shorebird species (Wiles et al. 1993).

An eradication of Polynesian rats (*Rattus exulans*) in 2009 allowed the translocation of ko'ko' (Guam rail; *Hypotaenidia owstoni*) to Dåno' the following year (Lujan et al. 2010, Pitt et al. 2012). The Dåno' ko'ko' population, which is considered self-sustaining, was the basis for downlisting the species on the IUCN Red List from Extinct in the Wild to Critically Endangered (BirdLife International 2019; Endangered under the ESA). Dåno' has been proposed as an experimental release site for Extinct-in-the-Wild sihek (Guam kingfisher; *Todiramphus cinnamominus*; J. G. Ewen, Zoological Society of London, personal communication). The beaches of Dåno' are also important nesting grounds for the Endangered haggan betde (green sea turtle; *Chelonia mydas*; Maison et al. 2010).

Despite its proximity to Guam and sporadic records of BTS over the past several decades, Dåno' has been considered snake-free until 2020. A probable BTS was reported from the resort grounds in 1988, and in 1989 a backhoe operator killed a large BTS on the island (Fritts et al. 1999). There were 5 additional unconfirmed reports of BTS encounters on Dåno' between 1989 and 2007, as well as at least 1 BTS captured in a trap at an unspecified date, but a breeding population was not confirmed despite occasional trapping and visual search efforts (H. S. Rogers, Iowa State University, personal communication; Stanford and Rodda

Figure 2. Equipment used by Friends of Islan Dåno' volunteers for brown treesnake (*Boiga irregularis*) capture on Islan Dåno' (Cocos Island), Guam, USA, between June 2021 and January 2022: (1) 3-segmented 2.4-m aluminium telescoping pole, extending fully to 7.3 m; (2) 1.8-m wooden broomstick; (3) full/semi-automatic airsoft electric gun; (4) headlamp, ~1000 lumen at maximum brightness; (5) 60-cm paint roller used as a snake hook, can screw onto (1) or (2); (6) tool holder, can screw onto 1) or 2), and used to connect both poles for additional extension; (7) flashlight, ~3000 lumen at maximum brightness; (8) painter's tape, used to strengthen the connection between the poles when they are connected via the tool holder; (9) snake bag; (10) Global Positioning System unit.

2007, Richmond et al. 2022). There were 2 separate public reports of potential BTS on Dåno' in 2020: a snake shed found by 2 biologists conducting surveys in January, and 5 total snakes seen (of which several were killed) by local community members on 2 separate occasions in August and September. In response, the U.S. Geological Survey's BTS Rapid Response Team (USGS RRT) deployed to Dåno' on 19 occasions between October 2020 and January 2021 and captured 28 individual BTS ranging from small juveniles to large adults of both sexes, thus confirming an actively breeding population (Barnhart et al. 2022). Given the devastating effects of BTS on Guam's wildlife, the risks posed by BTS to the biodiversity of Dåno' are severe. The importance of preventing further introductions of BTS and other invasive species to the island cannot be overstated, and therefore commercial and casual visitors must be engaged as part of a broad biosecurity strategy.

Methods

Group establishment and regulatory compliance

In January 2021, we approached the Guam Department of Agriculture's Division of Aquatic and Wildlife Resources (GDAWR) about initiating volunteer BTS searches on Dåno' and began collaborating once we became aware of each other's plans. Officials at GDAWR were supportive of the idea and suggested the possibility of providing funding for the effort. However, they expressed concern at possible regulatory and liability issues due to the presence of ESA-listed species on the island. Uncertainty lingered for several months surrounding the issues of whether volunteers needed a GDAWR permit to search for BTS on the island (due to an existing memorandum of understanding between GDAWR and Cocos Island Resort), if volunteers needed ESA Section 7 and National Environmental Policy Act compliance to search on the island (due to the presence of ESA-listed species and how funding could be provided to the volunteer effort organizers), and how that might affect permitting. While those issues were being resolved, we began recruiting potential volunteers and organized training sessions open to the public. In June 2021, it was resolved that volunteers only needed permission from resort owners, but not GDAWR, to search on resort property (i.e., the northern 2/3 of the island; Figure 1), due to it being privately owned. The U.S. Fish and Wildlife Service (USFWS) provided informal guidance on mitigation measures to avoid any negative impacts on ESA-listed species. Finally, we ran a successful crowd-funding appeal for $3,500 USD to cover costs for purchasing equipment and paying boat fees.

Training and searches

Our informal group, which we named Friends of Islan Dåno', welcomed volunteers regardless of their prior snake-searching experience. We organized 3 large-group (10–20 individuals) training sessions on weekday evenings on the Guam mainland in March, April, and September 2021, each lasting about 2 hours, covering theoretical and practical aspects of BTS searches. In the first hour of the training, we discussed snake-searching techniques, explaining for example the appropriate pace of searching, snake behavior on the ground and in the canopy, and how BTS appear in the beam of a flashlight. We then covered capture and handling techniques, including how to use appropriate tools to aid in capture (Figure 2), how to safely catch and hold a BTS, and how to secure it in a snake bag. We used a live BTS to demonstrate relevant techniques, improve volunteers' search image, and allow them to practice handling the snake. We also discussed how to recognize and avoid ESA-listed wildlife on Dåno', how to collect appropriate data, and the importance of biosecurity. During the second hour of training, we split into small groups to search for BTS along the edge of a wooded area, and if a snake was located, nearby groups were called over to maximize the number of individuals gaining experience in each capture effort.

We presented a realistic picture of searching for BTS on Dåno', emphasizing for example that sightings are generally scarce due to low snake densities and a tall, dense canopy. We discussed relevant eradication principles, such as the need for thorough search coverage to maximize captures. We stressed that each snake may be progressively harder to capture than the last, and that sustained, high-quality effort will be required long after the last snake is seen in order to confirm eradication. The duration of the confirmation period for a BTS eradication is unknown and will inevitably depend on the nature and density of detection tools used (e.g., intensive visual searching, detector dogs, baited cameras), but will likely be on the order of years as is currently standard for rodent eradication attempts (Russell et al. 2017, Yackel Adams et al. 2021). If volunteers were unable to attend one of the training events, we provided a detailed briefing immediately prior to the search, lasting between 15 minutes and 1 hour, depending on the group's level of experience, on the topics listed above. Therefore, some volunteers' first practical snake-searching experience was part of our efforts on Dåno'.

We provided basic snake capture equipment on each search night (Figure 2), including at least 1 high-powered flashlight or headlamp per search group. We paired any novice searchers with those more experienced in navigating the island and capturing BTS. Search groups usually consisted of 2–4 individuals, with 1 designated leader in charge of assigning roles during capture attempts and overseeing data collection. Roles during capture attempts are variable and context-dependent but typically include 1 person (and ideally more) illuminating and tracking the snake, 1 person performing the removal, and 1 person catching the snake once it was knocked to the ground. Other tasks may include calling other groups to request assistance, moving obstructing vegetation, or retrieving equipment stored at the resort buildings. As per USFWS recommendations, searchers walked on cleared, pre-established trails. If a snake was located, captures were made by hand or using hooks and telescoping poles (8 m maximum length), and snakes were kept alive in pillowcases.

In October 2021, we purchased an airsoft electric gun (Evike, Alhambra, California, USA) to use in targeting BTS that were out of reach or with a high probability of escape. Impact from pellets shot from airsoft guns have been demonstrated to induce injuries causing paralysis or mortality and sometimes cause BTS to drop from trees, thus allowing easier capture (Knox et al. 2018). Although they are officially classified as "hobby-grade" and not firearms, airsoft guns were only used by volunteers with previous experience with their safe use or with previous firearms safety training. We collected data on the time, coordinates, height, and perch taxon of any snake captured and/or sighted, as well as notes on search group composition and spatial coverage. We transferred all snakes captured to the USGS RRT and shared relevant data. Invasive cane toads (*Rhinella marina*) are also present on the island (McCoid 1996), and volunteers removed them opportunistically as they were encountered.

Results

Volunteer participation and searches

Between June 19, 2021 and January 6, 2022, we organized 25 night searches on Dåno'. We were joined by 89 individual volunteers overall, with an average of 6.52 (± 4.62) volunteers per search night. Volunteers had diverse cultural (44% CHamoru, 37% Caucasian, 7% Asian, 7% Hispanic, 4% multiracial) and professional backgrounds, were gender-balanced (49% female), and ranged in age from teenagers to septuagenarians. Nearly all were Guam residents, and 17% had prior snake-searching experience. Roughly a third of the volunteers (28 of 89) returned for 2 or more search nights. For logistical purposes, we generally capped participation at 8–10 searchers on a given night. We spent between $100 and $150 USD per night on boat fees and the remainder of our funds on equipment.

We removed 14 BTS from Dåno', averaging 0.56 snakes captured per search night (Figure 3; Supplementary Table 1). These ranged from juveniles (<600 mm snout-vent length [SVL]) to large adults (>1,500 mm SVL), of which 6 were female, 7 male, and 1 of unknown sex (Supplementary Table 2; BTS morphometrics provided by USGS RRT). We located 7 additional BTS that we were unable to capture (i.e., 21 BTS seen overall, averaging 0.84 BTS seen per search night). We captured 87% (13 of 15) of the BTS we encountered below 10 m in the canopy (our maximum reach holding an extended telescoping pole above head height), but only 17% (1 of 6) of the individuals at or above 10 m. We anticipate that continued use of the airsoft electric gun will increase our capture rate, particularly of those snakes that were previously out of reach.

Figure 3. Friends of Islan Dåno' volunteers Olympia Terral, Linda Tatreau, and Jayanika Lawrence with an invasive brown treesnake (*Boiga irregularis*) caught on Islan Dåno' (Cocos Island), Guam, USA, on September 25, 2021. Olympia (left) is holding a telescoping pole that extends to 7.5 m. This snake was spotted at 9 m in the canopy, and thus the fully extended pole had to be held above head height to remove it from its perch (*photo courtesy of P. Boykin*).

Our searches were concurrent with USGS RRT efforts until September 30, 2021, when they ended their response, although they have since returned for intermittent searches during training courses (L. T. Huse, USGS RRT, personal communication). The U.S. Department of Agriculture Wildlife Services (USDA WS) began occasional searches in November 2021, with an aim to increase in frequency in early 2022 (P. D. Barnhart, USDA WS, personal communication). Although numbers of searchers and spatial coverage differed between groups, capture rates were broadly similar during periods of overlap. We published newsletters summarizing our search results, including updates provided from our agency partners. There were also several newspaper articles published about our group's efforts, and we shared media contacts with interagency collaborators in an effort to increase the information available to the public about the eradication project as a whole.

Discussion

We successfully organized a volunteer group dedicated to eradicating BTS from Dåno', which is, to our knowledge, Guam's first volunteer-staffed BTS management project. We demonstrated that volunteers, the majority of whom had little to no prior experience searching for BTS, are capable of making a significant contribution to this effort-intensive eradication. Moreover, we provide further evidence that there is significant enthusiasm among Guam's communities to participate directly in invasive species management for the benefit of the island's wildlife (Wald et al. 2019). With investment, our project or similar ones could increase in scope and expend greater effort into recruiting from groups, such as the indigenous CHamoru population, historically excluded from natural resource management on Guam, and from communities adjacent to Dåno' in particular. Although we experienced significant bureaucratic and regulatory delays in initiating our searches, these can be prevented in the future through a proactive planning process (Boser et al. 2019).

There are many examples of invasive species control or eradication projects that have successfully incorporated volunteer workers, but efforts to involve volunteers in invasive snake control have shown mixed results to date. The California kingsnake (*Lampropeltis californiae*) eradication project on Gran Canaria, Canary Islands, Spain, has held regular structured volunteer days and credits citizen involvement and volunteer drive as major factors in slowing the spread of the invasive snake and reducing its impact on native wildlife (Gallo Barneto et al. 2016). However, in the Florida Everglades, USA, most of the people who participated in voluntary searches for invasive Burmese pythons (*Python bivittatus*) did not capture snakes, and their experiences appeared to decrease their belief in scientific reports of the python's numbers and impacts (Harvey et al. 2015). In 2014, the majority of registrants in a citizen science python removal program did not participate in the program at all, and organizers suspected that low participation rates may be explained by the low likelihood of observing snakes (Falk et al. 2016).

We were concerned that searching for BTS, a species with notoriously low detectability (Amburgey et al. 2021), would be similarly demoralizing for volunteers on Dåno'. We aimed to counteract this possibility by: (1) clearly communicating the realities of low detectability during training, while emphasizing the value of sustained effort in achieving our desired outcome; (2) establishing conditions for success (e.g., providing adequate equipment [Figure 2], balancing levels of experience within search groups); and (3) celebrating captures when they do occur (Figure 3). We were pleased by the relatively high rate of returning volunteers (~30%) and impressed by a number of novice (including first-time) searchers successfully finding and capturing BTS on Dåno'. Our results, together with those from the kingsnake project, suggest that providing basic training and a structured framework for searches may be advantageous in integrating volunteers into invasive snake eradication efforts and management efforts involving cryptic species more generally.

The literature on public involvement in invasive species management emphasizes the role of volunteers as potential citizen scientists, although the value and quality of citizen science data is debated (Crall et al. 2010, 2011; McKinley et al. 2017). In invasive Burmese python management, Falk et al. (2016) suggested that the value of citizen science data "is in collecting search-effort information." Members of the public are seen as particularly beneficial in BTS management as agents of "passive surveillance," that is in providing early warning of potential incursions outside the current BTS range, due to the high cost of active surveillance by paid personnel (Yackel Adams et al. 2021). Indeed, the BTS population on Dåno' was discovered thanks to reports by local community members (Barnhart et al. 2022). Atchison et al. (2017) noted that it is worthwhile to look beyond the contributions of citizen science in terms of its potential for cost-effective data collection, and to consider in human terms the motivations of volunteers and the costs and benefits that their participation may entail. The level of empowerment and satisfaction volunteers derive from their involvement can be directly influenced by the particulars of their relationships with resource management agencies (Pagès et al. 2019). To date, volunteer representatives have been excluded from interagency coordination meetings, which represents a possible lost opportunity based on the recent findings. Inclusion could provide further benefit to planning efforts and results.

The success of eradications, and especially those that involve visual searches, is often said to rely as much from the motivation and dedication of the individuals involved as from the technical planning aspects (Merton 1987, Brown and Sherley 2002, Torr 2002). Maintaining eradication investments requires sustained, long-term biosecurity and vigilance (Kennedy and Broome 2019). The eradication of BTS from Dåno', and its maintenance as a snake-free haven for native and endemic wildlife, will be a formidable test of ability and will for Guam's conservation practitioners and a step toward the ultimate goal of making Guam snake-free. We believe that engaging and empowering the local community, and especially the younger generation, is crucial to making those achievements a reality.

Management implications

Volunteer groups such as ours facilitate the engagement of community members, and un-

derrepresented groups in particular, in natural resource management initiatives. Moreover, volunteer participation can allow a cost-effective increase in capacity for effort-intensive projects such as invasive species eradication attempts. Public engagement will be particularly valuable in ensuring ongoing biosecurity once the eradication project is complete. Providing adequate training, equipment, and structure may be crucial in integrating volunteers into invasive snake control or eradication projects and those targeting similarly cryptic invasive species. Proactive planning is needed to avoid unnecessary delays in allowing public participation in such projects. Including representatives from volunteer groups in interagency coordination efforts would be useful in aligning objectives, comparing results, and harmonizing plans for the future.

Supplemental material

Supplemental material can be viewed at https://digitalcommons.usu.edu/hwi/vol17/iss2/11.

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