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Successful translocation of Snares Island snipe (*Coenocorypha huegeli*) to replace the extinct South Island snipe (*C. iredalei*)

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Abstract Deliberate taxon substitution is a much discussed but rarely enactioned concept in restoration ecology. We describe the successful establishment of a translocated population of Snares Island snipe (*Coenocorypha huegeli*) on Putauhinu I, which lies alongside Taukihepa (Big South Cape I), the last stronghold of the extinct South Island snipe (*C. iredalei*). Thirty Snares Island snipe were captured on North East I, Snares Is in Apr 2005 and released 3-5 days later on Putauhinu I. A survey on Putauhinu I in Mar 2011 resulted in the capture of 54 descendants of the released birds and a population estimate of at least 320 birds. This is one of few documented translocations of an organism with the specific objective of replacing a closely related extinct taxon. As a result, the Snares Island snipe is probably more abundant than at any time in its evolutionary history.

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Keywords Snares Island snipe; *Coenocorypha huegeli*; taxon substitution; ecological analogue; rewilding; translocation; ecological restoration; island restoration

INTRODUCTION

Taxon substitution or the introduction of ecological analogues both refer to the concept of replacing extinct taxa with close relatives or species that fulfil a similar ecological function (Griffiths *et al*. 2010; Hansen 2010; Parker *et al*. 2010). Despite decades of discussion (Atkinson 1988; Aikman & Miskelly 2004; Cheke 2008; Parker *et al*. 2010), very few deliberate taxon substitutions have been undertaken. Reasons proposed for undertaking taxon substitutions include restoring lost evolutionary potential, restoring ecological processes and regeneration dynamics, advancing understanding of ecological processes, and improving conservation status if threatened species are being used as substitutes (Atkinson 1988; Hansen 2010; Kaiser-Bunbury *et al*. 2010).

The best studied taxon substitutions to date are the introductions of Aldabran giant tortoises (*Aldabrachelys gigantean*) and Madagascan radiated tortoises (*Astrochelys radiata*) to small Mascarene islands, to replace the ecological role of extinct *Cylindraspis* tortoise species (Jones 2008; Griffiths *et al*. 2010, 2011). Within 3 years, giant tortoises released on Ile aux Aigrettes, Mauritius, demonstrably improved seed spread and germination of the endangered ebony tree (*Diospyros egrettarum*) (see Griffiths *et al*. 2011).

We report the outcome of the 1st deliberate taxon substitution of a New Zealand bird (Miskelly

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& Powlesland, *submitted ms*) – the 2005 translocation of Snares Island snipe (*Coenocorypha huegeli*) to replace the extinct South Island snipe (*C. iredalei*) – and compare the demography of the translocated population 6 years after release with that of the source population.

Background to the translocation of Snares Island snipe to Putauhinu Island

The snipe genus *Coenocorypha* (Scolopacidae) includes 5 extant and 2 recently extinct allopatric taxa all endemic to the New Zealand region (Gill 2010; Miskelly & Baker 2010). Due to their reluctance to fly and low productivity (typically a single clutch of 2 eggs pair^{-1} year^{-1}; Miskelly 1990, 1999a, Miskelly, Walker & Elliott 2006), *Coenocorypha* snipe are extremely vulnerable to introduced predators, and all surviving forms have high threat rankings (Miskelly *et al*. 2008).

South Island snipe formerly occurred on the South I, and Stewart I and its outlying islands (Miskelly 1987; Worthy & Holdaway 2002; Worthy *et al*. 2002). It was extirpated from north to south following introduction of Pacific rats (*Rattus exulans*), ship rats (*R. rattus*), feral cats (*Felis catus*), weka (*Gallirallus australis*) or a combination of these to all localities where it occurred (Miskelly 1987, 2012). Despite rescue efforts, the last population became extinct in 1964 after ship rats colonised Taukihepa (Big South Cape I), a muttonbird island south-west of Stewart I (Bell 1978; Miskelly 2012).

The ecological role of *Coenocorypha* snipe is poorly understood. Snares Island snipe consume a wide variety of soil-dwelling invertebrates (Higgins & Davies 1996) in a bird community with no other species that probe deeply in the soil. There is no information on potential cascade effects of the presence or absence of snipe predation on subsoil invertebrates. Snares Island snipe are indistinguishable from South Island snipe in skeletal morphology and proportions (Worthy *et al*. 2002) and so were considered likely to fill a similar ecological niche to the birds formerly present on muttonbird islands around Stewart I (Roberts & Miskelly 2003).

Interest in recovery planning for *Coenocorypha* snipe followed the remarkable discovery of the previously unknown and critically endangered Campbell Island snipe (*C. aucklandica perseverance*) in 1997 (Barker *et al*. 2005; Miskelly & Baker 2010). In addition to replacing the extinct South Island snipe, translocation of Snares Island snipe to an island off Stewart I was proposed to improve the conservation status of Snares Island snipe (Miskelly 1984; Atkinson 1988; Roberts & Miskelly 2003), and to develop translocation techniques that could be used for Campbell Island snipe (Roberts & Miskelly 2003). The muttonbirders on Putauhinu I (adjacent to Taukihepa) sought the return of tutukiwi (snipe) and hakawai (a nocturnal aerial display performed by snipe; Miskelly 1987) to their island; the proposal was developed by the New Zealand Snipe Recovery Group, supported by the muttonbirding community of Putauhinu I, and approved by the New Zealand Department of Conservation, and the Rakiura Titi Islands Administering Body.

STUDY SITES AND METHODS

The Snares Islands Nature Reserve (48°01'S 166°37'E), has never had introduced mammals, and retains its original avifauna including 4 endemic taxa. The archipelago includes 2 vegetated main islands totalling 328 ha and holding ~400 pairs of the endemic Snares Island snipe at densities up to 10 birds ha^{-1} (Miskelly 1999b; Miskelly *et al*. 2001). Both North East I and Broughton I have a monoculture of 5-6 m tall subantarctic tree daisy (*Olearia lyallii*) forest in their interiors and reaching close to sheltered portions of their eastern shorelines. We searched for and captured snipe during 11-13 Apr 2005 in a 12 ha strip between Skua Point and Hoho Bay on the east coast of North East I, centred on the research station at the base of Station Point. Ground covers there included large areas of 1-2 m tall *Polystichum vestitum* fern and broad-leaved *Poa tennantiana* tussock grass, clumps of the megaherb punui (*Stilbocarpa robusta*), and extensive turf-like mats of *Callitriche antarctica* and *Crassula moschata*. Seabirds nesting abundantly in this area included sooty shearwater (*Puffinus griseus*), common diving petrel (*Pelecanoides urinatrix*) (both burrow-nesting) and Snares crested penguin (*Eudyptes robustus*). Snipe were caught with hand-nets both during the day and mostly (aided by headlamps) at night. Birds were held in two 4.8 x 3.0 m tent aviaries (15 birds per aviary) until transfer, and were maintained predominantly on a diet of commercially obtained mealworm *Tenebrio molitor* larvae replenished every 3 hours during daylight (Charteris & Miskelly 2005). The 30 birds translocated comprised 28 adults (13 males, 15 females) and 2 juvenile females; sexes were confirmed using genetic techniques (Baker *et al*. 2010), although all adult birds had been correctly sexed in the field by CMM based on plumage markings, leg colour and measurements.

Birds were weighed and banded before release into an aviary, and weighed again on 16 Apr when recaptured for translocation. Each bird was placed into an individual compartment in 1 of 20 purpose-built wooden bird-transfer boxes for the 40 min, 107 km helicopter flight to Putauhinu I (47°13'S 167°23'E). Each box had closed-cell foam attached to the exterior base to reduce noise and vibration, and non-slip matting attached to the interior base (Charteris & Miskelly 2005). All 30 snipe were

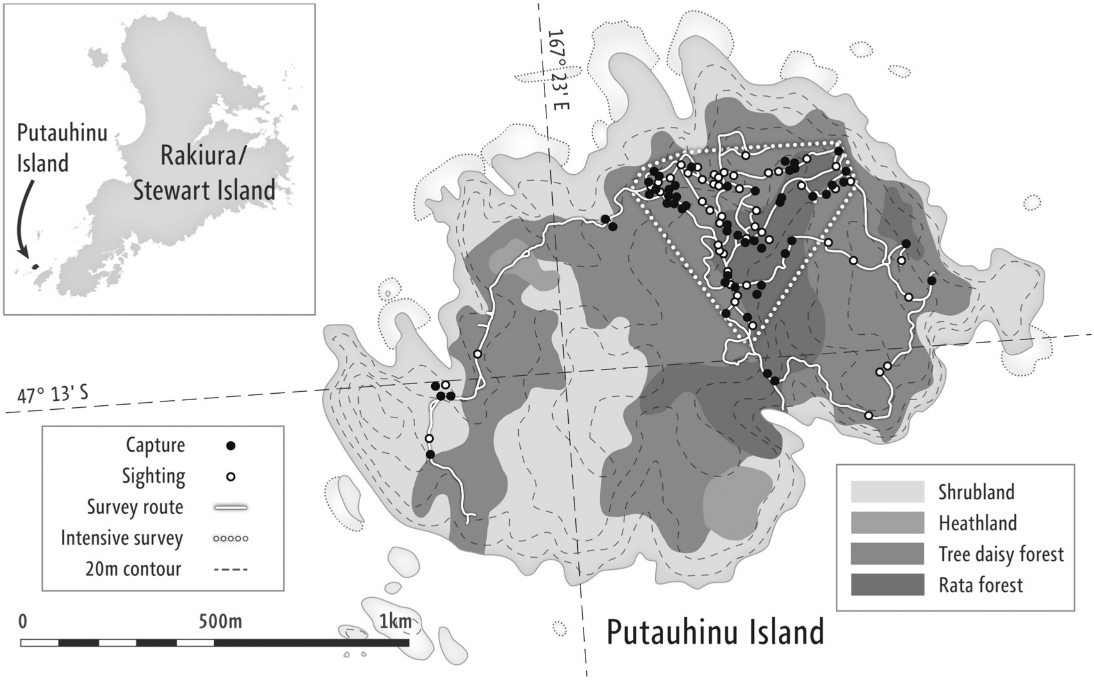

Fig. 1. Map of Putauhinu I showing the spatial extent of 4 vegetation types, the location of the 17 ha intensive survey area (ISA), survey routes taken, and snipe sighting and capture locations. No snipe were detected in the small section of heathland surveyed, and so heathland habitat was excluded from the population estimate. Survey routes and snipe locations were all based on GPS co-ordinates recorded in the field.

released into a fern-filled gully (known as Jane's Gully) on 149 ha Putauhinu I in the late afternoon of 16 Apr 2005.

Putauhinu I is a muttonbird (titi) island off the south-west coast of Rakiura/Stewart I, and is administered by the Rakiura Titi Islands Administering Body. Descendants of Rakiura Maori who are members of Ngai Tahu or Ngati Mamoe iwi (tribes) are permitted to frequent titi islands between 15 Mar and 31 May each year for the purpose of harvesting large chicks (muttonbirds) of the burrow-nesting titi (sooty shearwater). Putauhinu I has 4-8 m tall forest predominantly of tupare (*Olearia colensoi*) and southern rata (*Metrosideros umbellata*), with a coastal fringe of 2-3 m tall teteaweka (*O. angustifolia*) and kokomuka (*Hebe elliptica*) shrubland (Fig. 1). *Polystichum* fern is the predominant ground cover, and punui (*Stilbocarpa lyalli*) is common. Apart from 17 ha of rata forest, the vegetation is similar to that on the Snares Is. Feral cats died out on Putauhinu I by 1970, and Pacific rats were eradicated in 1995 (McClelland 2002), leaving the island free of introduced mammals. Previous successful bird translocations to Putauhinu I were South Island saddlebacks (*Philesturnus carunculatus*) in 1974, 1976 & 1984, Codfish Island fernbirds (*Bowdleria punctatus wilsoni*) in 1997-98, and Stewart Island robins (*Petroica australis rakiura*) in 1999 (McClelland 2002; Miskelly & Powlesland, *submitted ms*).

Six years after the snipe translocation, CMM returned to Putauhinu I with JRF and the latter's bird-locator dog during 22-29 Mar 2011. The same team had previously surveyed for *Coenocorypha* snipe on Enderby I (Auckland Is) and Campbell I (Miskelly 2006; Miskelly & Fraser 2006). Snipe were searched for during daylight hours whenever weather conditions allowed during 23-28 Mar (22 h 45 min searching, 8 h 15 min catching, 11 h 45 min handling). Most were living among dense 2 m tall *Polystichum* under forest and were located by their scent by the dog. All searches were within 50 m of existing tracks; about half the island was surveyed, with *c.*17 ha repeatedly surveyed to facilitate density estimation (Fig. 1). Birds were caught by herding them between the 2 of us until within reach of a hand-net, using the dog to attempt to relocate any birds that flew and/or were subsequently lost among the dense vegetation. All birds caught were blood sampled (for DNA sexing), measured, banded, and marked on the nape with white correcting fluid. If encountered subsequently, birds so marked were not pursued further and were noted as a re-sighting. All capture and re-sighting locations were recorded on a handheld GPS, allowing estimation of search

Table 1. Comparison of body masses of adult snipe from the source population (North East I, Snares Is) in mid Apr 2005 with body masses of adult snipe at the release site (Putauhinu I) in late Mar 2011, 6 years after release.

Sex	Male		Female	
Location	Snares	Putauhinu	Snares	Putauhinu
Sample size	15	16	15	19
Mean mass (g)	100.6	97.1	113.2	112.3
Standard error	1.9	1.3	1.7	1.7
t statistic	1.54		0.37	
P	0.13		0.71	

effort, encounter rates and capture rates. Ages of 11 dependent chicks and 7 independent juveniles captured were estimated from the state of their down and measurements, using growth equations given by Miskelly (1999a). Lay dates for the eggs that produced these chicks were estimated based on an egg-laying interval of 3 days and an incubation length of 22 days (Miskelly 1990).

Possible post-release population growth scenarios were modelled using the deterministic projection of Armstrong & Reynolds (2012, Table 6.3), with varying estimates of female reproductive output, based on incremental adjustments to productivity estimates obtained from the Snares Is population between 1982 & 1987 (Miskelly 1990, 1999b).

RESULTS

All 30 Snares Island snipe were released in good condition on 16 Apr 2005, 3-5 days after capture. Overall, release masses (107.3 ± s.e. 1.6 g) did not differ from capture masses (107.7 ± s.e. 1.6 g; mean mass loss of 0.4%). Individual mass changes ranged from a loss of 11.8% to a gain of 13.9%. Twelve birds were lighter than their capture mass when transferred, and 16 were heavier. Males lost an average of 1.7% of their body mass, while there was no measurable difference in mean female body mass. This sexual difference in mass loss was largely due to 2 males taking a long time to learn where the feed trays were in the aviaries (Charteris & Miskelly 2005).

Over the first 5 years after release the muttonbirders on Putauhinu I reported that snipe were breeding successfully (based on sightings of downy chicks, and unbanded birds), that they had spread over the whole island, and were encountered increasingly frequently (Tane Davis, *pers. comm.*).

Snipe were difficult to survey on Putauhinu I due to their preference for areas of dense *Polystichum* fern growing up to 2 m tall, with intermeshed living fronds that impeded our movement and vision, and dense skirts of dead fronds that provided cover that could conceal birds that were within 1 m of us. The difficulty of seeing snipe and their legs constrained our intention of using mark-recapture population estimates. We therefore estimated the Minimum Number Alive in a 17 ha intensive survey area (ISA) by repeated surveys over 6 days, and calculated a correction factor for density estimates outside the ISA based on relative encounter rates inside and outside the ISA.

We caught 54 snipe on Putauhinu I in Mar 2011: 35 adults, 8 juveniles (*i.e.,* recently independent young), and 11 dependent chicks. Eight parent-chick pairs were caught, and so there were 46 separate capture events. All birds caught plus an additional 14 adult or juvenile birds seen but not caught were unbanded, *i.e.*, none of the snipe released in 2005 was seen in a minimum of 60 independent encounters. The dog indicated a further 17 birds that were not seen, or not seen sufficiently well to determine if they were banded. Birds were encountered at a rate of 3.5 per hour of searching; 83% of birds encountered were seen, and 70% of unmarked birds seen were caught.

Forty-three birds were caught in the ISA (Fig. 1), where a minimum of 8 further adults and 1 juvenile remained uncaught, based on widely-spaced sightings of unmarked birds on the final day of searching. The birds captured or seen in the ISA comprised a minimum of 39 adults, 5 juveniles and 8 chicks (all close to independence) at a minimum density of 3.0 birds ha^{-1}. Encounter rates were 29% lower outside the ISA (2.7 birds h^{-1} cf. 3.8 birds h^{-1}), allowing a minimum estimate of 271 birds in 128 ha of forest and shrubland outside the ISA, and a minimum total population estimate of 323 birds. Based on age ratios of captured birds, the population was estimated to comprise about 209 adults and 114 birds of the year (*i.e.*, ~1.1 fledglings $pair^{-1}$).

The mean body masses of 35 adult snipe caught on Putauhinu I during 23-28 Mar 2011 did not differ significantly from the mean body masses of 30 adult snipe caught on North East I, Snares Is 11-13 Apr 2005 (Table 1). Seven of the adults handled on Putauhinu I were caring for chicks (5 males, 2 females), 20 others had commenced wing moult (6 males, 14 females), and 8 were neither caring for a chick nor moulting (4 males, 4 females). Comparative figures from the

Table 2. Comparison of potential population growth scenarios for Snares Island snipe translocated to Putauhinu I in 2002 (13 adult males, 15 adult females, 2 juvenile females). Row 1 ("Snares Is") uses known female survival and productivity estimates from the Snares Is (Miskelly 1990, 1999b); Scenario 1 has the mean reproductive success of 1-year-old females equal to that of older females; Scenarios 2-5 keep survival of all female age classes at the level recorded from the Snares Is, but with mean productivity increasingly incrementally by 0.5 juveniles year^{-1} from 1.0 to 2.5 juveniles year^{-1}; Scenario 6 had mean productivity adjusted iteratively (to 2.67 juveniles per female) to model an adult female population of similar size to that estimated on Putauhinu I in 2011 (104 adult female snipe). Population growth was modelled using the deterministic projection model provided by Armstrong & Reynolds (2012, Table 6.3). Increased population growth could also be projected by increasing annual survival; we chose not to model this due to our failure to locate any of the 30 banded birds released in 2005, suggesting that adult snipe survival was not exceptional on Putauhinu I.

	Probability of juvenile survival to breeding	Probability of adult female surviving 1 year	Mean juveniles per 1st-year female	Mean juveniles per adult female	Projected 2011 adult female population
Snares Is	0.51	0.88	0.22	0.52	11.4
Scenario 1	0.51	0.88	0.52	0.52	11.8
Scenario 2	0.51	0.88	1.00	1.00	21.0
Scenario 3	0.51	0.88	1.50	1.50	35.8
Scenario 4	0.51	0.88	2.00	2.00	58.0
Scenario 5	0.51	0.88	2.50	2.50	90.0
Scenario 6	0.51	0.88	2.67	2.67	103.7

Snares Is in Apr 2005 were 9 caring for chicks or carrying an egg (2 males, 1 female, 6 uncaught birds of unknown sex), 23 moulting (11 males, 12 females, including 1 male caring for a chick), 2 females neither caring for a chick nor moulting, and 3 males that had completed their moult.

All 12 family groups encountered on Putauhinu I comprised 1 adult and a single chick. The 11 dependent chicks measured ranged in age from 31 to 60 days old, and 7 independent juveniles were estimated to be 53 to 60 days old; all chick and juvenile measurements indicated a synchronous laying period 28 Dec to 31 Jan. No nests were found.

The minimum population estimate of 209 adults within 6 years of translocation greatly exceeded expectations for population growth. Based on reproductive rates and survival estimates from the Snares Is measured between 1982 & 1987 (Miskelly 1990, 1999b), the translocated population was predicted to decline slightly to about 11 adult females after 6 years unless productivity or survival rates increased relative to the Snares Is (Table 2). As we failed to locate any of the 30 banded birds released in 2005, it is unlikely that survival rates on Putauhinu I greatly exceeded the 83% per annum (88% for females) recorded for adult snipe on the Snares Is (Miskelly 1999b). We therefore modelled population growth holding survival rates at Snares Is levels, but varying productivity of 1st-year females (initially, to match adult female productivity), then continued to increase female productivity estimates for both age classes in increments until the modelled population size was similar to the estimated population size recorded in 2011 (Table 2). Assuming that survival rates of fledglings and adults were similar to those measured on the Snares Is, productivity (fledglings per female per annum) would have had to have been ~5 times that recorded on the Snares Is (2.67 fledglings female^{-1} year^{-1}, cf. 0.52) to achieve a population of 200+ adults within 6 years (Table 2).

DISCUSSION

Translocated Snares Island snipe were well established on Putauhinu I in 2011, with a population estimated at more than 10 times the number of birds released in 2005. Our population estimate is considered conservative as at least 17% of birds within the ISA remained uncaught and unmarked (*i.e.*, there were likely to be more than 3 birds ha^{-1} present there), plus we did not include areas of heathland in our population estimate as we failed to detect any snipe during the brief time spent surveying heathland. It is likely that snipe were present in the 3.8 ha of heathland on Putauhinu I, as this was the preferred habitat formerly occupied by snipe on adjacent Taukihepa (Guthrie-Smith 1936; Miskelly & de Lange 2006).

The rapid growth of the population from 30 birds to an estimated 320+ birds 6 years later indicates that productivity rates (at least) greatly increased in the colonising population compared to the source population. In order to reach a population of *c.*100 pairs after 6 breeding seasons, productivity probably exceeded 2.5 fledglings pair^{-1} year^{-1} (enlarged clutches and/or double-brooding) and/or survival of adults and fledglings exceeded levels recorded on the Snares Is. Paradoxically, we failed to find any of the 30 banded birds released in 2005, yet would expect at least 10 to be alive in 2011 (at 83% mean annual survivorship; Miskelly 1999b). Our failure to find any banded birds among the minimum of 60 adult and juvenile snipe encountered provides further support for a population estimate in excess of 320 birds.

Unfortunately no-one was able to study the breeding ecology of the colonising snipe population on Putauhinu I during the first 5 breeding seasons, and so we do not know whether the apparent extraordinary increase in productivity was due to increased clutch sizes (*Coenocorypha* snipe occasionally lay 3 or 4 eggs per clutch; Miskelly 1990, Miskelly, Walker & Elliott 2006) and/or a prolonged breeding season allowing 2 or more broods to be raised per year, nor was it possible to measure survival rates over this time. We believe that there was no possibility of additional snipe colonising from the Snares Is 107 km away during this period, as no individuals of any *Coenocorypha* taxon has crossed a water gap greater than 3 km in historical times (Miskelly, Bester & Bell 2006).

By the time of our 2011 survey, demographic parameters of the Putauhinu I snipe population were similar to those recorded on the Snares Is. Two apparent differences were the higher proportion of juveniles present at the end of the breeding season (35% of the population on Putauhinu I *cf.* a mean of 16% over 6 years on the Snares Is; Miskelly 1999b), and a surprisingly short breeding season (laying apparently ceased after 31 Jan 2011 on Putauhinu I, based on our failure to detect eggs or young chicks, *cf.* laying continuing until at least Apr on the Snares Is; Miskelly, Walker & Elliott 2006).

Before this project, the Snares Island snipe was endemic to a single, small relatively unmodified island group and had a total population of about 400 pairs (Miskelly *et al*. 2001). In 2011, Putauhinu I held approximately 20% of the world population (*i.e.*, 100 pairs out of a total of 500 pairs), providing an insurance population in the event of a catastrophe affecting the Snares Is population. This is a rare example of conservation management resulting in a species probably becoming more abundant than at any time in its evolutionary history.

The establishment of a dense population of Snares Island snipe on Putauhinu I was the 1st successful deliberate taxon substitution in New Zealand, and one of few recorded in the world (Hansen 2010; Parker *et al*. 2010; Seddon *et al*. 2012; Miskelly & Powlesland, *submitted ms*). As Putauhinu I is situated within an archipelago of highly fertile islands with similarly high densities of burrow-nesting seabirds, it is expected that Snares Island snipe will naturally colonise nearby islands. Putauhinu I could also be used as a source population for further translocations of snipe to sites formerly occupied by South Island snipe. Blood samples collected from 53 birds on Putauhinu I in 2011 will be used to compare the genetic structure of the new population with that of the source population (Baker *et al*. 2010), to determine where future translocations are best sourced from. Future translocations to more accessible sites may provide opportunities for natural experiments to better understand snipe breeding ecology and demography following translocation, and allow comparisons of soil invertebrate diversity and abundance before and after translocation, and at nearby sites without snipe.

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