

POPULATION DYNAMICS FOLLOWING REINTRODUCTION OF *PARTULA* ON MOOREA, FRENCH POLYNESIA

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Abstract. As extinction rates increase, reintroduction efforts of threatened species will become more important. *Partula* snails became extinct on Moorea in 1987 from biological-control-agent-gone-wrong, *Euglandina rosea*, and are now being reintroduced on the island. This study, completed in October and November 2017, examined September 2017-released populations of *Partula taeniata nucleola*, *P. mooreana*, and *P. tohiviana* and a January 2017-released population of *P. tohiviana*. Sites were surveyed every week or every other week for five weeks to look at plant host preference, changes in population size, rates of dispersal, and changes in population age structure over time and between sites. Sites for the September-release populations were also mapped to show the location of snails in the site. Two of the three September-release sites showed snails have a preference for *Freycinetia arborea* over other plants. None of the sites experienced any statistically significant changes in population size over time, but the number of snails at the *P. mooreana* site decreased by nearly half. Age structure analysis revealed no significant differences between the September sites or between the *P. tohiviana* sites. The average distance of snails from the release point increased at all sites, and this increase was statistically significant at both *P. tohiviana* sites. Several *Platydemus manokwari* predatory flatworms were found, indicating that predation may be a threat to the success of these reintroduction efforts. Facilitating snail reproduction may help increase the success of these reintroductions and aid the permanent reestablishment of these organisms.

Key words: *Snail; mollusk; reintroduction; Partula; population biology; dispersal; Moorea, French Polynesia; predation*

INTRODUCTION

Today's extinction rates are calculated to be 100 to 1000 times higher than Earth's estimated average (Rockström et al. 2009). These extinctions are being caused by a wide variety of factors, from abiotic environmental changes to the spread of pathogens to accidental and intentional exotic species introductions. As human impacts on the environment affect more species, understanding how to help ecosystems recover is essential to maintaining global biodiversity.

One way to do this is through the captive breeding and reintroduction of species that have been extirpated in nature. One such effort is being attempted by Paul Pearce-Kelly and Trevor Coote, who reintroduced *Partula* snails to Moorea, French Polynesia after they were declared extinct in the wild in 1987 (Murray et al. 1988).

The family Partulidae has been heavily researched due to its usefulness as an example of extensive adaptive radiation (Clarke and Murray 1969). With more than 70 species in French Polynesia alone, this family has been studied for its unusual intra and inter-species

diversity, and has yielded many discoveries about population genetics and evolution (Clarke and Murray 1969, Coote 2007). In addition to their scientific value, prior to their extinction *Partula* shells were used to make jewelry that once played an important economic role in the lives of some French Polynesians (Coote and Loève 2003).

Before 1977, there were seven known species of *Partula* and two species of *Samoana* on the island of Moorea (Coote and Loève 2003). In 1977, *Euglandina rosea* was introduced in attempt to exterminate the agricultural pest, *Achatina fulica*, an introduced giant African land snail (Coote 2007). Instead of feeding on the invasive land snail, *E. rosea* ate the native partulid tree snails (Coote 2007). By 1987, all nine species of partulid snails on Moorea were believed to be extinct in the wild (Murray et al. 1988).

Five of the seven *Partula* species were maintained in captivity (Coote and Loève 2003). Relict populations of *Samoana attenuata* were rediscovered in 1996, and populations of *Partula taeniata* were rediscovered in 2000 (Coote 2007, Lee 2009). In 1994, three zoo-bred *Partula* species were released into the wild in

exclosures intended to prevent *E. rosea* predation. However, *E. rosea* exclusion failed when the exclosures were not closely monitored, and the effort was abandoned in 1998 (Coote et al. 2004). Adding to the population losses caused by *E. rosea* predation, there have also been recent observations of an introduced flatworm, *Platydemus manokwari*, which has contributed both to *E. rosea* and partulid decline (Gerlach 2017).

Though relict populations have been periodically monitored since their rediscovery, scientists have never had the opportunity to document a large-scale reintroduction of captive-bred snails on Moorea such as that being carried out by Pearce-Kelly and Coote (Lee 2009, Maher 2010, Hardesty-Moore 2014). They have introduced over 1,800 *Partula* snails at 10 sites on Moorea (Coote, pers. comm.). At each site, captive-bred snails from one of the five extant *Partula* species were placed in cups that were tied to trees, and left to disperse.

This study focused on four of these reintroduction sites in the Opunohu Valley near the Belvedere, along the Three Pines Trail. Three sites were composed of snails that were reintroduced on September 18, 2017. Each site had either *P. taeniata nucleola*, *P. tohiviana*, or *P. mooreana*. The fourth site, located at the 1994 *E. rosea* exclosure site, contains *P. tohiviana* reintroduced both in January 2016 and on January 17, 2017 (Table 1).

The goal of this study was to document the changes in demographics and distribution of

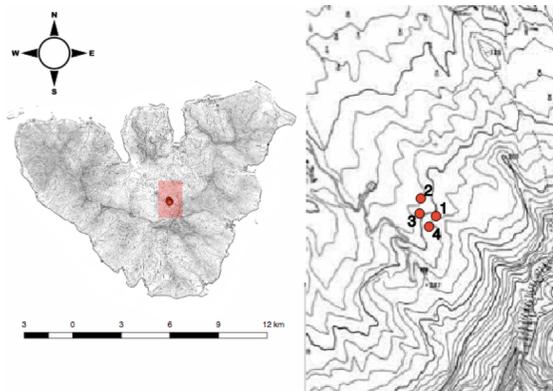


FIG. 1. A map of Moorea and all four study sites (QGIS Development Team 2017).

Partula snails reintroduced at these four sites, and the effect on predator populations. Six questions were addressed: (1) Which plant hosts do *Partula* snails prefer, and how does this affect their distribution? (2) At what rate will *Partula* population sizes change in the two months following reintroduction? (3) At what rate will the snails disperse from the release cups? (4) Using size as a proxy for age, how does demography change over time for each species? (5) Comparing the two *P. tohiviana* sites, how do these populations differ in their age structure and average distance from the release point? (6) Finally, will *Partula* reintroduction result in *E. rosea* or *P. manokwari* population size increases?

METHODS

Study Sites

All study sites were found near the Belvedere on Moorea, French Polynesia. The site number, location, species, and release date of each site are shown in Table 1.

Population Surveys

Between October 10 and November 17, 2017, population surveys were done weekly (every six to eight days) at the three September-release sites (*P. tohiviana*, *P. taeniata nucleola*, and *P. mooreana*). Surveys were done biweekly at the January *P. tohiviana* site, as population changes were expected to be slower there because the snails were released less recently. Sites consisted of the set of 5-18 release cups. Sites were searched for *Partula*, *E. rosea*, *A. fulcia*, and *P. manokwari*.

Snails were found by observing the area around each cup, or set of cups, walking in a spiral to the extent the terrain allowed. Each snail's distance from the nearest cup and shell length was measured using transect tape and a ruler, respectively. Distance was measured only in terms of horizontal distance (transect tape running parallel to the ground), not vertical distance. Shell length was measured from the tip of the shell to the farthest point on the aperture. Based on their size and species,

TABLE 1. Numbers, coordinates, species, and release date of the snails at each site.

Site	Location	Species	Release Cups	Release Date
1	-149.8258, -17.53897	<i>P. tohiviana</i>	18	January 17, 2017; 2016
2	-149.8266, -17.53803	<i>P. taeniata nucleola</i>	6	September 18, 2017
3	-149.8267, -17.52882	<i>P. mooreana</i>	6	September 18, 2017
4	-149.8262, -17.53952	<i>P. tohiviana</i>	5	September 18, 2017

snails were grouped into “juvenile,” “subadult,” and “adult” categories (some species are smaller than others). Cutoffs were determined by observing the snails during the final week and placing lengths into age categories according to the following shell criteria (Gerlach 2017, Coote pers. comm.). A snail was categorized as a juvenile if it had a small ridge halfway down the body whorl, but only a small spire (one to two whorls). Snails with a faint ridge on the body whorl but a larger spire than juveniles were categorized as subadults. Adults lacked the ridge and instead had a lip around the operculum. Using these cutoffs, *P. taeniata nucleola* juveniles were up to 9 mm long, subadults were 10-14 mm, and adults were 15 mm and longer. *P. mooreana* juveniles were up to 9 mm long, subadults were 10-13 mm, and adults were 14 mm and longer. *P. tohiviana* juveniles were up to 12 mm long, subadults were 13-18 mm, and adults were 19 mm and longer.

The snails’ host plant and paint markings were also recorded. Snails were marked with paint prior to release. Blue paint indicated that the snail was part of a 2017 reintroduction, while yellow was used to mark snails released in 2016. Snails that were adults at the time of release were marked on the side of the shell; juveniles were marked at the tip (Coote, pers. comm.). If a snail had no markings, it was assumed that the organism was born in the wild. Surveys were considered complete when the area of the farthest snail’s distance (for that cup) plus two meters had been searched and no snails were found.

This information was used to analyze snail plant preference, each site’s population changes over time, each population’s change in age structure over time, changes in distribution from the release cups over time.

Site mapping

Snail distribution was depicted on a map for the September sites, in order to show the potential paths snails of dispersal from release cups and the impact vegetation may have on snail dispersal rates. Relevant vegetation at each site was mapped during the fourth week of surveys with two methods. A plant was considered relevant if it was taller than knee height (about 0.4 m), but shorter than six meters, or if a snail had been observed on that plant in the past. This worked to exclude tall, canopy trees and understory grasses, which were not surveyed for snails and are not considered common locations for *Partula*. Plant

locations and sizes were hand-drawn to create a vegetation map. Then, the site was surveyed for snails and their location marked by hand on the map. Also, the data collected from site mapping was used to determine the frequency of *F. arborea* and *A. evecta* at each mapped site for comparison to snail host frequencies.

The *P. taeniata nucleola* site was mapped using two perpendicular transect tapes to mark the outer boundaries of each site, similar to axes on a graph. Two more transect tapes were used to measure the distance of each relevant plant in the site from each of these “axis” tapes to give each plant a Cartesian “coordinate” in the site. These tapes were used to approximate the dimensions of each plant as well.

The September-release *P. tohiviana* and *P. mooreana* sites were mapped using the polar coordinate system. A transect tape and compass were used to determine the distance and angle of each relevant plant from each release cup or set of release cups. This method was also used to determine the release cups’ locations with respect to each other. Both mapping methods yielded accurate results as determined by a visual comparison of the sites to the map. Coordinates of both methods were graphed digitally using the computer language R and the package “ggplot 2” in R (Wickham 2009, R Core Team 2017). The January-release *P. tohiviana* site was not mapped.

Statistical Analysis

All analysis and graphing was done using the computer language R (R Core Team 2017). The “plyr” and “dplyr” packages were used for some calculations, and the “ggplot2” package was used to visualize the data (Wickham 2009, Wickham 2011, Wickham et al. 2017).

For plant preference analysis, the percent of snails on each plant for each site every week was calculated. An ANOVA was run on a linear model fitted for the percent of snails at each site and each week on each type of plant. A Tukey HSD test was run to determine which plants were significantly more common host plants. Then, the average proportion of snails across weeks on each plant at each site was taken. The percentage of plants at the September-release sites that were *F. arborea* was also calculated to determine if *F. arborea* host choice was simply proportional to its abundance in the habitat, or due to preference.

To analyze snail population changes, an ANOVA was run on a linear model fitted for changes in the number of snails at each September-release site over time. A Tukey HSD

test was run to determine which sites differed significantly in their population sizes. For the January-release site, a linear regression was done to see if the population size changed significantly over time.

To analyze snail distribution changes, an ANOVA was run on a linear model fitted for the distances of the snails found each week at each site and the week number. A Tukey HSD test was run to determine which sites had significantly different distances of snails, and linear regressions were run for each site to look for significant increases and rates of change in snail distance over time. To explore the hypothesis that *Angiopteris evecta* facilitates snail dispersal, the percent frequency of *A. evecta* in each September-release site was calculated for comparison to the rate of dispersal at each of those sites, and a linear regression on these data was run.

Age structure was analyzed in two separate groups: the September-release sites

and the *P. tohiviana* sites. For both groups, snails were grouped into “juvenile,” “subadult,” and “adult” categories, and summed for each site and each week. The percent that sum represented out of the total number of snails found at each site for each week was calculated. An ANOVA was run on a linear model fitted for each group of sites to determine the effect that site, week, and age group had on this percent. For both groups, a Tukey HSD test was run to determine which age classes differed significantly in their proportions. Finally, to further examine whether there were any differences between the proportion of snails born in the wild between the *P. tohiviana* release sites, an ANOVA was run on a linear model fitted for the proportion of marked snails at each site every week to determine the effect time and site had on this percent.

Information on plant host preference and age structure comparisons were displayed in boxplots. For all boxplots in this study, the horizontal line in the middle of the box indicates the median of the data and the upper and lower horizontal lines of the boxes show the first and third quartiles of the data. The vertical “whiskers” extending from the top and bottom of the boxes show the maximum and minimum values in the data set, except for the points outside the boxes, which represent exceptionally high or low outlying points.

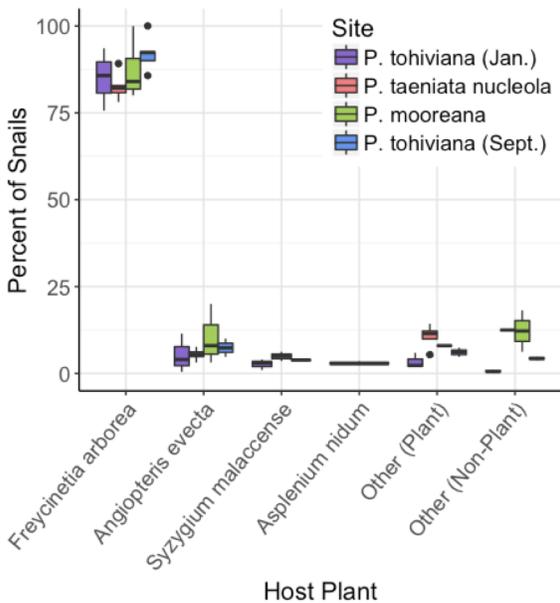


FIG. 2. Boxplot of the average percent of snails each week on each plant for all sites.

TABLE 2. Percent of snails found on each plant type or category for each site, averaged across all five weeks (week was found to be a non-significant factor in plant host preference).

Plant Type	<i>P. tohiviana</i> (Jan.)	<i>P. taeniata nucleola</i>	<i>P. mooreana</i>	<i>P. tohiviana</i> (Sept.)
<i>Freycinetia arborea</i>	84.98±9.00	82.62±4.09	87.29±8.16	92.12±5.19
<i>Angiopteris evecta</i>	5.31±5.59	5.48±1.87	10.37±8.68	7.38±3.70
<i>Syzygium malaccense</i>	2.66±1.53	4.91±1.89	0	3.85
<i>Asplenium nidum</i>	2.93±0.51	0	0	0
Other (Plant)	3.41±2.22	10.66±3.74	8.00	6.08±1.87
Other (Non-Plant)	0.71±0.37	12.50	12.22±8.44	4.30±0.65

RESULTS

Plant Preference and Mapping

Across all sites and weeks, *Freycinetia arborea* made up over 80% of the plants on which snails were found (Fig. 2, Table 2). Plant type had a significant effect on plant host preference (ANOVA, $F_5 = 521.49$, $p < 0.001$). No significant differences between weeks (ANOVA, $F_1 = 0.069$, $p > 0.05$) or sites (ANOVA, $F_3 = 2.63$, $p > 0.05$) were found. *F.*

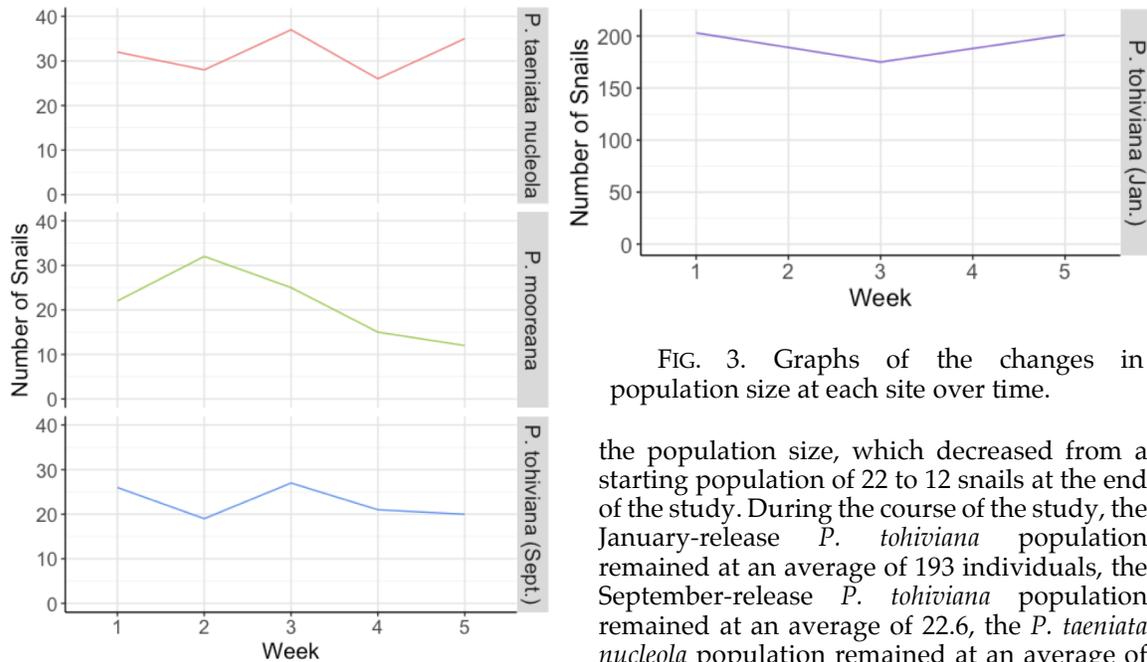


FIG. 3. Graphs of the changes in population size at each site over time.

the population size, which decreased from a starting population of 22 to 12 snails at the end of the study. During the course of the study, the January-release *P. tohiviana* population remained at an average of 193 individuals, the September-release *P. tohiviana* population remained at an average of 22.6, the *P. taeniata nucleola* population remained at an average of 31.6, and the *P. mooreana* population remained at an average of 21.2 snails (Fig. 3).

arborea was the host plant of snails significantly more often than all other plants (Tukey HSD, $p < 0.001$). The September-release sites were also mostly composed of *F. arborea*. The *P. taeniata nucleola* site was 74.12% *F. arborea*, the *P. mooreana* site was 94.29%, and the September *P. tohiviana* site was 64.66%. The ratio of these values to the average percent of snails found on *F. arborea* are as follows: *P. taeniata nucleola*: 0.897, *P. mooreana*: 1.080, and September *P. tohiviana*: 0.702.

Small changes in *P. manokwari* populations were also observed. During the first two weeks, *P. manokwari* was not found, while in the final three weeks of the study, one flatworm was found at the *P. taeniata nucleola* site, and one at the *P. mooreana* site. The following week, these numbers increased to four at the *P. taeniata nucleola* site and three at the *P. mooreana* site. During the week five surveys, no flatworms were found. Of all the flatworms found, three were found on *F. arborea*, and the rest were found on the forest floor. One was found eating a non-Partulid snail. No live *E. rosea* were found throughout the course of this study.

Barring three exceptions, snails were never found on the ground. This aversion is shown on the maps (Appendices A, B, and C). Snails were most frequently found on plants that were touching each other on the map, especially if those plants were touching the release cup's plant.

Distribution

Partula and *P. manokwari* Population Size

Across all sites, snail distance from the release cups increased significantly over time (Fig. 4, ANOVA, $F_1 = 26.72$, $p < 0.001$), and the differences between sites were significant (ANOVA, $F_3 = 32.78$, $p < 0.001$). The January-release site snails were significantly farther from the release cups than they were at any other site (Tukey HSD, $p < 0.001$) and the *P. taeniata nucleola* site snails were significantly farther than the *P. mooreana* snails (Tukey HSD, $p < 0.001$).

In the September-release sites, there were no significant changes over time in population size (ANOVA, $F_1 = 2.04$, $p > 0.05$), but there were significant differences between sites (ANOVA, $F_2 = 4.86$, $p < 0.05$). The *P. taeniata nucleola* site had a significantly higher population than the *P. mooreana* site (Tukey HSD, $p < 0.05$). The January-release *P. tohiviana* site similarly experienced no significant changes in population size over time (linear regression, $R^2 = 0.004$, $p > 0.05$). For the *P. mooreana* site, there was a downward trend in

For the January-release *P. tohiviana* site, snail distance increased significantly at a rate of 0.085 meters per week (linear regression, $R^2 =$

0.024, $p < 0.001$). For the September-release *P. tohiviana* site, snail distance increased significantly at a rate of 0.141 meters per week (linear regression, $R^2 = 0.068$, $p < 0.01$). For the *P. taeniata nucleola* site, snail distance increased non-significantly at a rate of 0.066 meters per week (linear regression, $R^2 = 0.018$, $p > 0.05$). For the *P. mooreana* site, snail distance increased non-significantly at a rate of 0.028 meters per week (linear regression, $R^2 = 0.004$, $p > 0.05$).

Snail dispersal was correlated non-significantly with *A. evecta* frequency at the September release sites (linear regression, $R^2 = 0.929$, $p > 0.05$). Sites with greater *A. evecta* frequency had greater rates of dispersal. The *P. taeniata nucleola* site was 4.71% *A. evecta*, the *P. mooreana* site was 0.95%, and the September *P. tohiviana* site was 7.52%.

Age Structure

Across all the September-release sites, there were no changes in *Partula* age structure over time (ANOVA, $F_1 = 0.026$, $p > 0.05$) or between sites (ANOVA, $F_2 = 0.055$, $p > 0.05$). However, there were significant differences between the proportion of snails in each age category (ANOVA, $F_2 = 12.58$, $p < 0.001$). There were significantly more adults than subadults (Tukey HSD, $p < 0.005$) and juveniles (Tukey

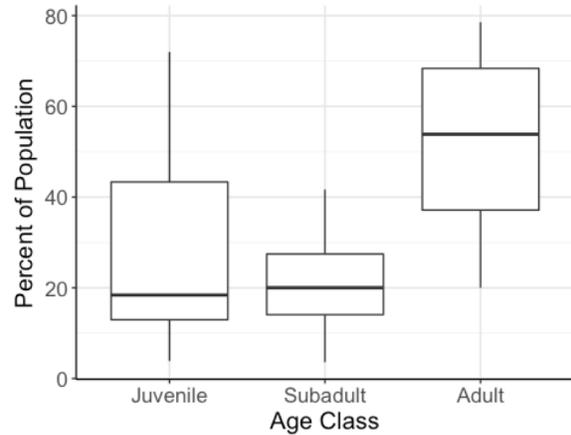


FIG. 5. A graph showing the age structure averaged across time and all of the September-release sites.

HSD, $p < 0.001$). On average, sites were composed of 52.51 ± 19.18 adults, 21.24 ± 11.73 subadults, and 28.12 ± 21.61 juveniles (Fig. 5).

Between the two *P. tohiviana* release sites, there were no significant changes between weeks (ANOVA, $F_1 = 0.039$, $p > 0.05$) or between sites (ANOVA, $F_1 = 0.056$, $p > 0.05$), but again there were significant differences between the proportion of snails in each age category (ANOVA, $F_2 = 109.37$, $p < 0.001$). There were significantly more adults than

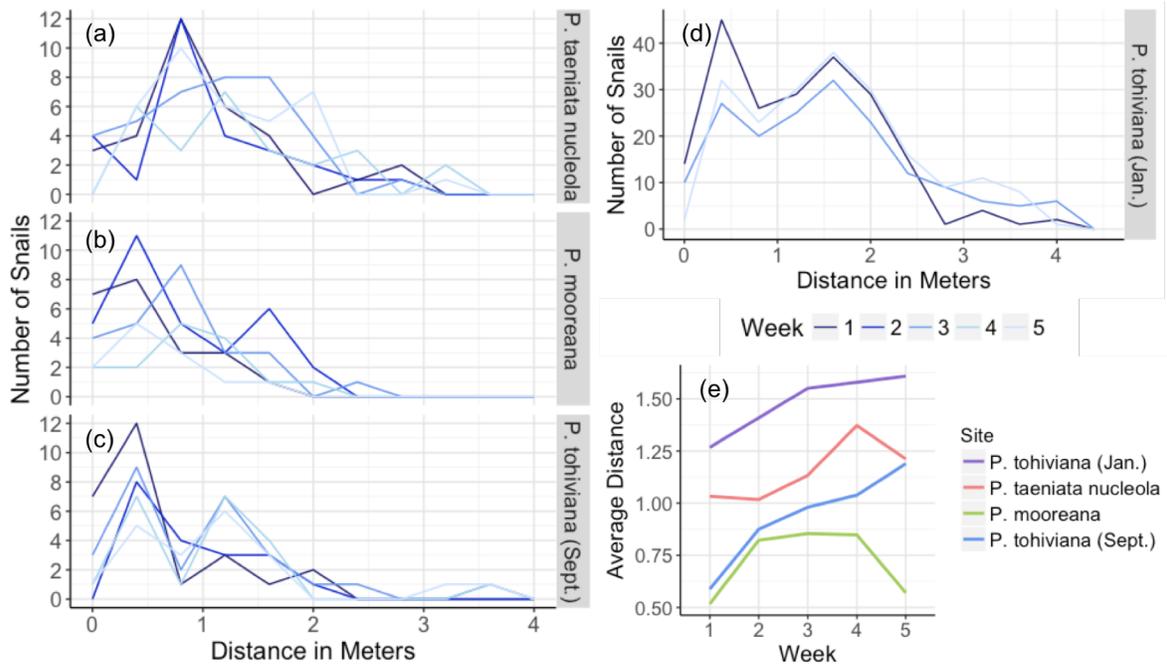


FIG. 4. Graphs displaying the changes in distribution of snails with respect to their release cups over time. Graphs (a)-(d) show the distribution of snails each week for each site. Graph (e) depicts the change in the average distance from release cup over time for each site.

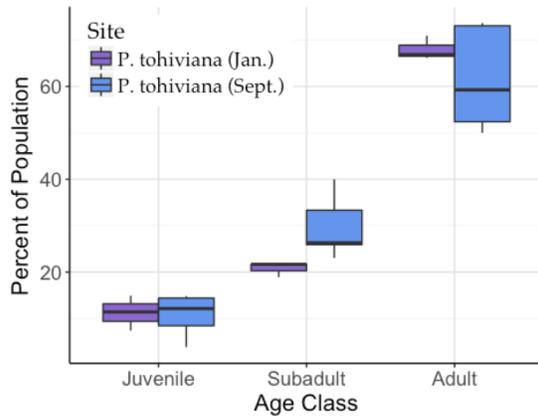


FIG. 6. A graph depicting the age structure differences between the *P. tohiviana* sites.

subadults (Tukey HSD, $p < 0.001$) and juveniles (Tukey HSD, $p < 0.001$), and significantly more subadults than juveniles (Tukey HSD, $p < 0.005$). Also, there were some non-significant differences in the average percent of snails in each age category between sites. On average, the January-release site was composed of 67.99 ± 2.58 adults, 20.76 ± 1.61 subadults, and 11.25 ± 3.77 juveniles, while the September-release site was composed of 61.68 ± 11.21 adults, 29.73 ± 6.87 subadults, and 10.37 ± 5.07 juveniles (Fig. 6). There were no significant differences between the proportion of marked individuals over time (ANOVA, $F_1 = 0.96$, $p > 0.05$) or between the September and January sites (ANOVA, $F_1 = 0.80$, $p > 0.05$).

DISCUSSION

Plant Preference and Mapping

As supported by previous literature, all *Partula* species were found more frequently on *F. arborea* than any other plant (Murray et al. 1993). For the *P. taeniata nucleola* site and *P. tohiviana* site, this frequency exceeded the frequency that this plant occurred in each site, as shown by the less-than-one ratios for these sites, suggesting a preference for *F. arborea*. This effect may be more amplified than suggested by the data, as *F. arborea* is a relatively small plant and therefore its percent cover in relation to other plants may be smaller than shown by its percent frequency. The opposite was true for the *P. mooreana* site, with the frequency of *F. arborea* in the habitat exceeding the average frequency of *F. arborea* as a snail host plant by almost seven percent (a greater-than-one ratio of percent frequency in the site to percent host frequency across weeks). One explanation for

this difference is that certain non-*F. arborea* plants may have been closer to the release cups, making them more opportune hosts than *F. arborea* for *P. mooreana*. Additionally, this population experienced the most dramatic changes over time in population size and average distance from the release cups, suggesting that some other unknown and unaccounted-for factor could be at play.

Partula and P. manokwari Population Size

The lack of change in population size across all four sites, though more successful than a decrease in population, is a less than ideal sign for *Partula* reintroduction. Because there were only non-significant changes to the age structure of any of the sites, this implies that one cause of this stagnation may be due to snails not reproducing. More studies on what factors encourage *Partula* reproduction would be useful.

P. mooreana's decline, though non-significant, is an important trend worth investigating. Flatworm predation may be the cause, as four of the nine flatworms found were found at this site (Sugiura and Yamaura 2009). On one occasion, an empty *P. mooreana* shell was spotted on a *F. arborea* leaf with one flatworm on each of the two leaves directly below this shell. Flatworms also appeared to generally be found on *F. arborea* at this site on rainy days. Though this potential trend needs further research, if flatworms are more active in moist environments, the *P. mooreana* habitat may be particularly hard-hit during the rainy season that began as this study ended because it is located on a temporary stream bed. Future studies will be needed regarding seasonal *Partula* success following the introduction of *P. manokwari*.

The possibility also exists that snails dispersed so rapidly and so widely that they no longer fell into the range detailed in the methods of this study. This is unlikely because on multiple occasions when the population seemed lower than the previous week, a wider area was searched due to this possibility. On only one occasion did this additional searching lead to the discovery of a live snail, and it was at the September-release *P. tohiviana* site. On more occasions, however, this additional searching revealed empty *Partula* shells on the forest floor. This discovery brings about a number of questions: How did these snails get so far away? If snails are capable of travelling that far, why are there no living snails at that distance? Why did they die? One potential

explanation may be that some snails began travelling on the forest floor until they were discovered by *P. manokwari*, and eaten. Snails on the floor are both more likely to be able to travel longer distances, as they would be unhindered by the meandering path created by touching vegetation, as well as more likely to be eaten, because the risk of flatworm predation is higher on the forest floor (Coote, pers. comm.).

Distribution

The increase in average snail distance from the release cups, in addition to the higher average distance of the January-release site than the September-release sites, suggests that as time passes, snails will continue to disperse. However, dispersal without population increase may inhibit population growth. Snails may travel so far from each other that they never encounter a mate (Coote, pers. comm.). More studies need to be done on how much dispersal affects population size. All four sites have a particularly high frequency of *F. arborea* compared to the rest of the forest along the Three Pines trail, and, at the January-release *P. tohiviana* site, snails seemed to remain within the more densely packed *F. arborea* plants. Though this could simply be coincidental, if snails are reluctant to pass into less-densely-packed regions of *F. arborea*, this could facilitate population growth by preventing snails from getting too far from each other. Another way to support snail reproduction could be to simply introduce more snails so they are more likely to encounter a mate, or place the release cups in a way that ensures as snails disperse they still encounter snails placed in other cups.

Additionally, due to its size and long, elevated fronds, *A. evecta* may play an important role in facilitating snail dispersal. For all populations, it was the second-most-common plant host. The positive (non-significant) correlation between *A. evecta* percent frequency and snail dispersal rate suggests an increased number of *A. evecta* at a site may aid dispersal. Because of these preferences, future reintroductions working to increase distribution rates may benefit from placing snails in *F. arborea*-dominated habitats that also contain *A. evecta*. Further research on the effect host plants have on dispersal rates should be done.

Age Structure

In addition to the stagnant population size of all the sites, the lack of significant differences between age structures and percent marked in the January and September-release sites is an indication that successful reproduction events are not occurring the January site in particular. However, the greater percent of adults and smaller percent of subadults in the January site compared to the September *P. tohiviana* site may be an indication that the individuals released in January are surviving and growing into adulthood. Perhaps insufficient time has passed for the January release snails to fully acclimate and devote energy to reproduction, or too few offspring have survived long enough to be found during the surveys in this study. This study was conducted during the dry season, and snails are less active and perhaps less likely to mate during this time. As Moorea enters the wet season, reproduction may increase. Studies need to be done to see if increased time after reintroduction or seasonal changes result in higher reproduction rates in *Partula* snails.

Conclusion

Despite the lack of population growth shown in this study, these reintroductions appear to be moderately successful so far. At the January site, several snails remained from the 2016 reintroduction, showing a potential for snails to establish permanently. If these reintroductions continue, more work should be done on the impacts genetic bottlenecks and genetic drift caused by a reduced population and years in captivity may have on these populations. Because of small genetic changes resulting from captivity, released snails may have different behavior than snails with more recent ancestors born in the wild (Frankham 2008). This may have been an additional factor affecting the trends shown in this study.

The *Partula* genus has helped improve our understanding of speciation processes, evolution, and adaptive radiation. This reintroduction has allowed us to learn even more from this taxon. As extinction rates increase, and reintroduction efforts become more common and important, it is essential that these efforts are closely monitored so future reintroductions can serve as a successful way to preserve biodiversity.

ACKNOWLEDGMENTS

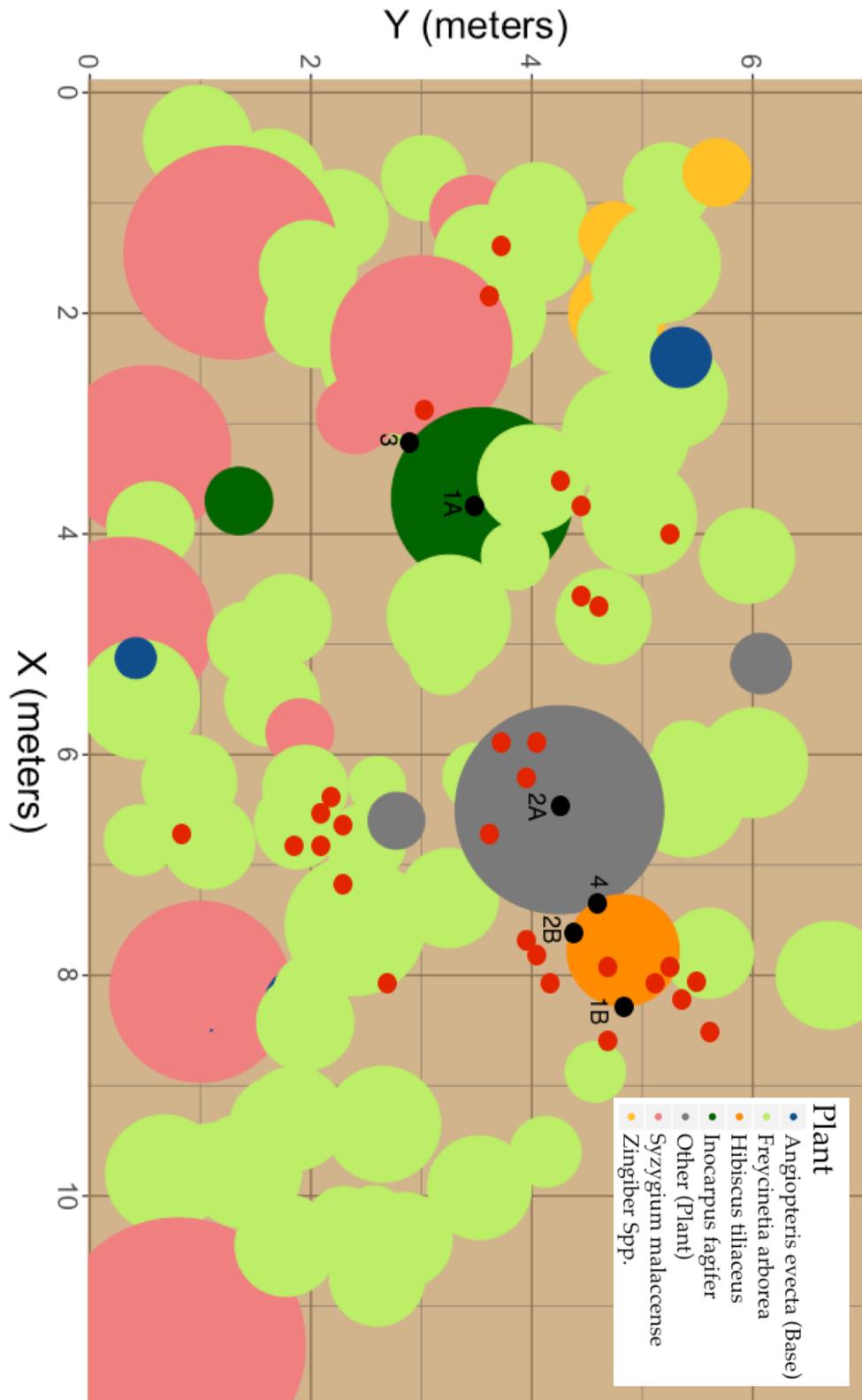
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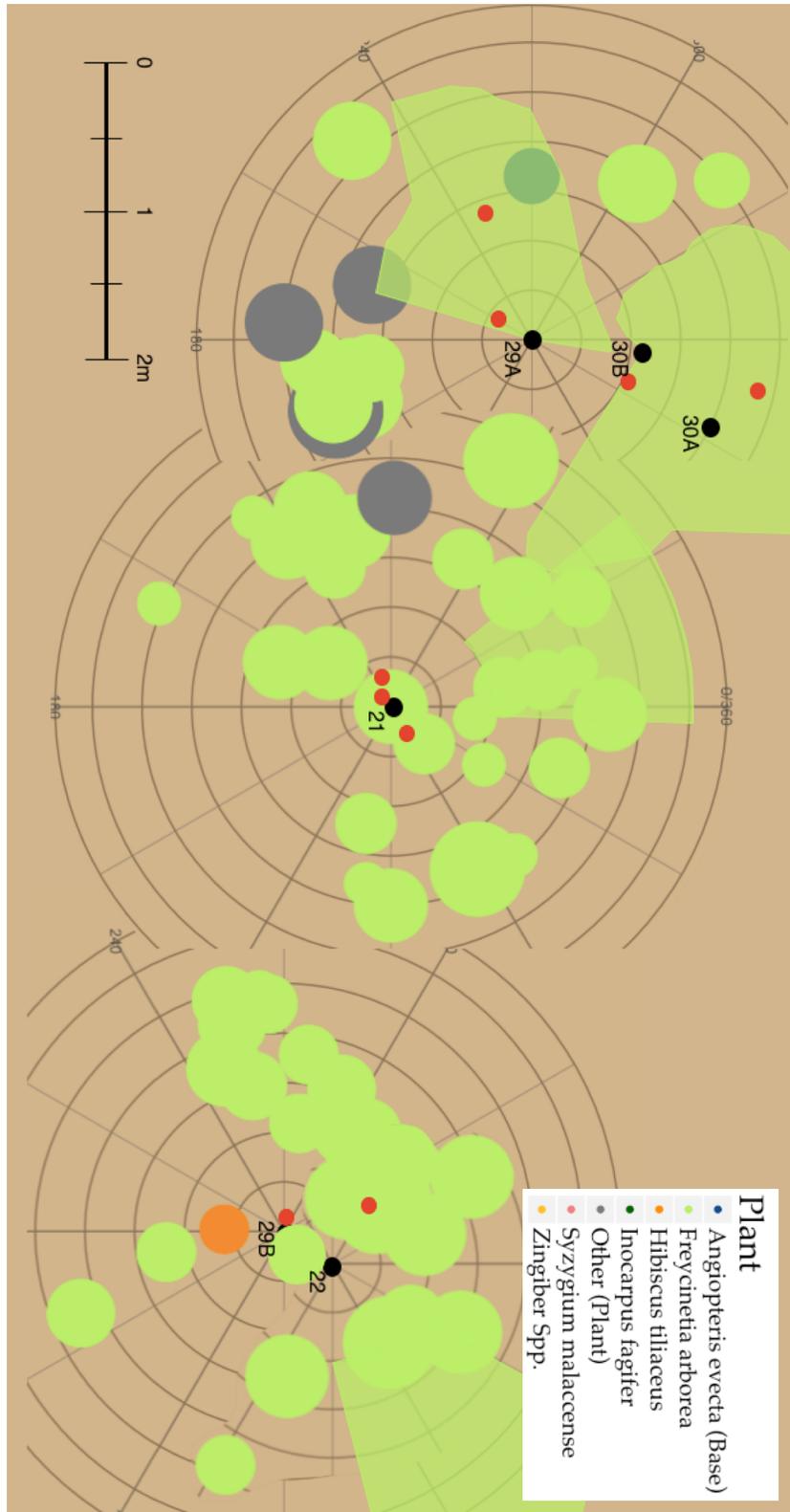
APPENDIX A

Map of the September-release *P. taeniata nucleola* site. Black numbered circles show the 6 release cups at this site, and the red circles represent each snail found during the week five survey.



APPENDIX B

Map of the September-release *P.mooreana* site. Black numbered circles show the 6 release cups at this site, and the red circles represent each snail found during the week five survey.



APPENDIX C

Map of the September-release *P. tohiviana* site. Black numbered circles show the 5 release cups at this site, and the red circles represent each snail found during the week five survey.

