# Banana Slugs Unpeeled:

Island biogeography and patterning of *Ariolimax columbianu*s

in the Hakai Luxvbalis Conservancy (Banana Slug)

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Biodiversity & Conservation of Coastal British Columbia

2013

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**Abstract**

With Island Biogeography Theory providing a broad conceptual framework, this paper examines the distribution, density, and patterning of *Ariolimax columbianus* within and between islands surrounding the North end of Calvert Island on the central coast of British Columbia. Through intensive short-term surveying, we documented and described presence of this species on all islands studied, as well as population density and population estimates for islands surveyed. Differences between three main islands were analyzed and provide a preliminary understanding of the differences in slug patterning. Results show that slugs on Baby Island on average are darker (greater average proportion black) than both the slugs on the mainland and slugs on 5th Beach Island. Thorough observation and analysis, this study provides important baseline information about the distribution and variation within and among populations of *A. columbianus* in the Hakai Luxvbalis Conservancy area, which lays a foundation for as well as ideas about potential future studies of this species.

**Keywords**: *Ariolimax columbianus*; Island Biogeography; slugs; phenotypic variation; pattern; distribution

## 1.0 Introduction

### *1.1 Island Biogeography*

First articulated by MacArthur and Wilson, island biogeography theory provides a model to explain and predict species richness in isolated communities, particularly on islands (Ehrlich *et al.,* 1988). The two main drivers affecting the number of species on islands are immigration rate and extinction rate (Ehrlich *et al*., 1988). When these two population curves (immigration per unit time and extinction per unit time) are overlaid, they create an equilibrium model for species richness. The point where the extinction and immigration curves cross in this model demonstrates the equilibrium number of species supported by an island at any given time, providing the factors controlling those two rates remain constant (Losos & Ricklefs, 2009). This equilibrium number of species represents a dynamic equilibrium; the identity of species present fluctuates with time as new species immigrate and already established species go extinct (Ehrlich *et al.,* 1988). This theory predicts that species richness will increase with island size and decrease with distance from mainland (Ehrlich *et al*., 1988).

The goal of island biogeography theory was to provide a foundation upon which the field of population ecology could develop in a logical, bottom up fashion (Losos & Ricklefs, 2009). It accomplished this and remains an extremely influential foundation in ecology. However, the large scale of the theory, despite being the reason for its general success, restricts it from looking at specific factors impacting islands or at an individual species and how it might differ between islands.

Using this theory as a broad conceptual framework, especially the idea that island size and distance from mainland are important factors influencing species on islands, we designed a study distribution between islands. In order to create a measurable study we chose one specific species to observe, *Ariolimax columbianus.* This study focuses on the differences and similarities within and between populations of this species. This means that although our project does use Island Biogeography Theory as a broad conceptual framework, it extends beyond the reaches of this theory to focus on specific island characteristics and their impact on a single species.

### *1.2 Overview of Banana Slugs*

*Ariolimax columbianus* (Pacific banana slug) is one of five species in the group of terrestrial gastropods in this genus, known commonly as banana slugs (Pearson, Pearson, & Ralph, 2006).The other four types of banana slug have ranges which are restricted to California, where populations of all banana slugs are the most dense. From here on, the terms *A. columbianus*, banana slug, and slug all refer to the species *Ariolimax columbianus,* unless otherwise stated. *A. columbianus* is native and endemic to the Pacific Northwest and despite its prevalence there has been comparatively few studies of this benign species compared to the number of studies concerning slugs which are agricultural pests (Pearson *et al*., 2006). The range of this species extends along the entire coast of North America from Sitka, Alaska to Salinas Valley, California (Morrow, 2000).

*A. columbianus* is the only dimorphic species of banana slug, meaning it has two distinct colour morphs. The first morph is monochromatic (unicolour) and has a solid base that ranges in colour from near white to yellow to an olive green (for clarity, we refer to the base colour as green) (Pearson *et al*., 2006; Pilsbry & Vanatta, 1896). The second morph is maculated (two colours) and has black spotting (amount varies widely) in addition to a solid green base. Cody (2006) studied how patterning varied within and between islands, both passively through observation and actively through experiments. He concluded that moisture and vegetation height were correlated with patterning of slugs. He also found that 0.1 hectares was the critical habitat area necessary to support this species.

The diet of *A. columbianus* is varied they are often considered herbivores, but have been known to consume fecal matter, carrion, and even other dead slugs, in addition to a range of green plants and fungus (Rollo, 1983). This species, like other slugs, prefers cool and moist areas. For this reason they are usually found in forests. The predictable climate in the large forests of the Pacific Northwest (cool and moist with low variability), provide a more suitable environment for slugs than open fields which are nearly constantly in a state of successional and environmental flux (Rollo, 1983). When placed in fields adjacent to forests, slugs move from more sparsely canopied areas to areas of denser vegetation, like forests (Hamilton & Wellington, 1981). Although *A. columbianus* do not necessarily live in the same location throughout their entire lives, several studies have shown that they do have a strong homing instinct. An observational study of *A. columbianus* found that home sites typically remained in the same area for months or even years at a time (Rollo and Wellington, 1981). During this time most slugs did not venture much more than 4.5 m from their home site. One potential reason for their fairly small home ranges is that the cost of locomotion is energetically expensive for slugs (Morrow, 2000). This species, like other slugs, propels itself forward by muscular waves running through its large foot. The mucus it produces helps to protect its body and to glide smoothly across the ground. However, using this slime locomotion method is problematic in that the slug must overcome the adhesive powers of its own slime to travel anywhere and that it takes more energy to replace slime lost while travelling (Morrow, 2000).

### *1.3 Research Objectives*

*A. columbianus* is an understudied species, with most existing studies focused on home range, physiology, and reproduction of this species. Relatively few studies have looked at phenotypic variation of this species, with the exception of Cody (2006) and Pearson et al. (2006). We were interested in:

A) Gaining a preliminary understanding of the density and distribution of *A. columbianus* on several islands within the Hakai Luxvbalis Conservancy Area. To do so, we measured slug density on mainland and islands in order to create populations estimates and a measure of population density for these sites. Based on the Theory of Island Biogeography, we hypothesized that larger islands and islands closer to the mainland would have higher populations of *A. columbianus.*

Ha: Slug densities are not equal on all islands

Ha: Slug populations are not equal on all islands

Ha: Island size is correlated with slug population

Ha: Distance from mainland is correlated with slug population

B) Gaining a better understanding of pattern variation of *A. columbianus* within and between islands. Based on work by Cody (2006), we hypothesized that soil moisture would influence the proportion of black of slugs on different islands.

Ha: Average proportion black is not equal across all islands

Ha: Soil moisture is correlated with average proportion black

## 2.0 Methods

### *2.1 Materials*

-Ruler (precision to 1mm)

-Transect tape (30m)

-Transect tape (50m)

-Flagging tape

-Notebook and pencil

-Camera

-Compass

-GPS

-ProScout scale (precision 0.1g)

-FieldScout TDR 300

-Tote

-Sticky notes

-Bug nets

-Work gloves

### *2.2 Site Selection*

We selected seven islands to survey based on size, accessibility, and distance from the mainland (which we considered to be the northern end of Calvert Island) (Figure 1). Based on Cody's (1996) research we did not select any islands less than 0.1 hectares as this size as was the minimize size he found could support this species. Quadrat location was initially determined by random generation of GPS coordinates on each island. This method proved to be unrealistic as some sites chosen were not accessible (steep cliffs, impassible understory, delicate bogs). To modify this method, we generated two lists of random numbers (10m-50m, 0m-20m) (RANDOM.ORG, 2012), went to each island or distinct habitat type and walked to the forest edge closest to where we arrived. From here, we took a bearing perpendicular to the beach into the forest and used a transect tape to walk this bearing for the number of meters dictated by the by first number on the list (10m-50m). We then walked the number of meters dictated by the second number on the list (0-20m) parallel to the beach (+90 degrees to first bearing). If this led to an inaccessible area, we restarted at the forest line using the next set of numbers (Figure 1).

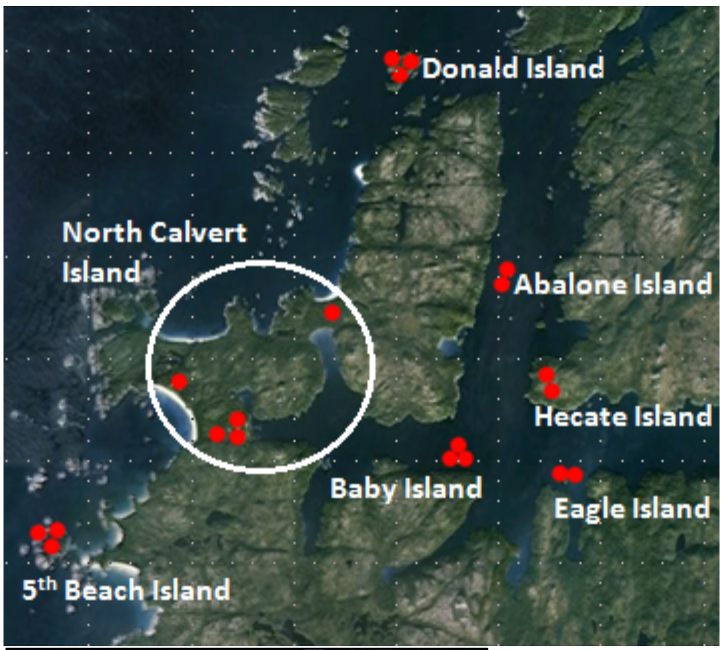



Figure 1. Map of survey sites. Each dot represents one sampling event (dots not to scale).

Left) All survey sites. Right) Close up of North Calvert Island sites.

### *2.3 Surveys*

#### *2.3.1 Initial Surveys*

We made an effort to sample at the same time of day (08:00-12:00) days with similar weather conditions (overcast). Sampling during weather extremes or at different times during the day could potentially affect slug behaviour and bias our results. For example, slugs often hide in soil compressions in extreme weather conditions (too hot or cold) (Rollo and Wellington 1980). This was not always possible, however, due to the short time frame of the study and consideration of tides for accessing some islands.

Two 12m x 12m quadrats were surveyed on each island except Calvert (Figure 2). We thought this was a sufficient area as most slugs do not venture much more than 4.5 m from their home site (Rollo and Wellington 1981). Due to the large size and heterogeneous landscape of the mainland (Calvert Island), we stratified the sites to include four distinct habitat types and surveyed one 12m x 12m quadrat in each: Hakai Beach Institute (HBI) Lawn, West Beach Dunes, West Beach Forest, and Wolf Beach Forest (Figure 1). The area within the quadrat was thoroughly searched for *A. columbianus* in a systematic "lawn-mower" fashion starting at the corner determined by site selection and sweeping along the transect edge and back. The species was commonly found near decaying logs, on the underside of salal leaves, tucked into moss cover, and buried beneath leaf litter on the forest floor. Once a slug was found it was transferred to a "holding pen" outside of the quadrat near the scale and measurement tools. The slugs were each gently handled which caused them to contract and enabled an accurate reading of their length to one millimeter. Weight was measured using a scale to to one tenth of a gram and a tote was used to keep any rain, wind or falling debris from affecting the weight reading.

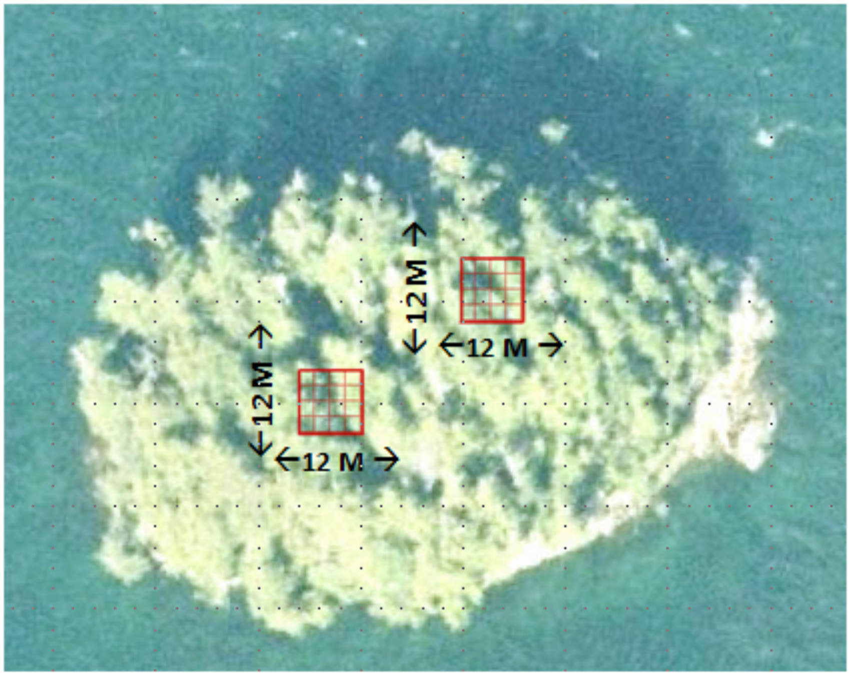


Figure 2: Image of “Baby Island” over-layed with two 12x12 quadrats (not to scale).

One photograph was taken of each side of each individual (n=300) to document the proportion black of each individual (Figure 3). A ruler was placed behind the specimen for scale (approx. 15cm width) and the site number and slug number were present in each photo. Additional field observations recorded include unique field observations, GPS coordinates, and canopy, understory, and ground cover descriptions and photographs.

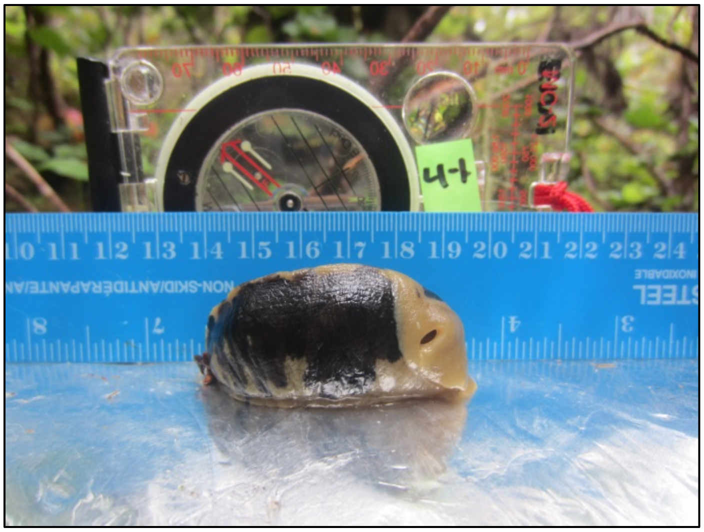


Figure 3. Example A. columbianus photograph (Site 4 - Slug Number 1, right side). The slug is contracted and the photo is scaled to approx. 15cm across (range, 10-25cm).

Moisture readings were taken using a moisture meter (FieldScout TDR 300). The points measured for moisture were chosen using a random number generator (bearing 0°- 180°, meters 0-12). We stood at the 6m mark on one of our quadrat edges, took a bearing from the first randomly generated number, and walked this bearing for the number of meters specified from the second randomly generated number using a transect tape and compass. Four points were measured at each location and this method was repeated five times to obtain 20 moisture readings in each quadrat. If the number of meters along the random bearing passed the edge of the quadrat, we stopped at the edge and walked the same line back towards the start point for the remaining number of meters.

*2.3.2 Secondary surveys*

Due to low success rates in the initial two quadrats on each island, three islands (Baby, 5th Beach, and North Calvert) were selected for further intensive surveys. These sites were chosen based on observed density (sites with more slugs found initially were re-sampled) and accessibility. When re-surveying, we covered as much area as possible and searched until at least 30 individuals were found. To increase efficiency, plastic containers were used to hold multiple slugs while searching away from the weighing station. Slugs were measured and documented in batches (by principle observers only) throughout the survey.

*2.4 Analysis*

*2.4.1 Proportion Black*

Slug photos were organized and imputed into the GNU Image Manipulation Program (GIMP 2, 2012). Grids were overlaid on each photo and the squares were individually counted using Click Counter (Click Counter 1.3.2. N.D.) to determine the proportion black on each individual (Figure 4). Both sides of each individual were assessed (n=310) and an average of the two sides was obtained. Grid size was approximately 200 squares on the slug foot (range 150-300). If more than one colour was present in any square, only the colour that occupied more than 50% of the square was counted. Only squares containing at least 50% slug foot were counted.

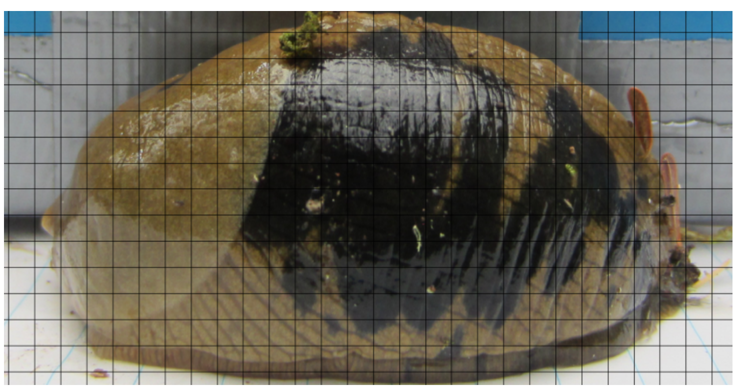

Figure 4. Example gird overlay for measuring proportion black.

*2.4.2 Precision and Inter-observer reliability*

To measure precision, each observer re-assessed 5% of the  slug photographs that they had previously assessed. This 5% subset was chosen using a random number generator. Researchers also re-assessed each other's results to measure inter-observer reliability. The secondary assessments for both tests were compared to the original calculations.

*2.4.3 Recaptures*

As a consequence of doing secondary surveys in or near existing quadrats, individual slugs were potentially recaptured. Based on studies by Pearson et al. which found that weight of *A. columbianus* fluctuated between 0.2 and 3.0g over the period of a month. Given that there was up to a week between first and second surveys, we use +/- 2g as the threshold for cross-examining the photographs for potential recaptures. Photographs were compared between all slugs from the primary survey that were within 2g grams of an individual from the secondary survey at the same site (Figure 5). We used weight as our comparison because the scale was considered more accurate (0.1g) than length from a ruler measurement (1mm), which also has potential for human error. Further, slug length varies greatly in individuals when they are contracted compared to stretched out.

Figure 5. Example recaptured individual. Left) Slug 10-1, June 24, weight 12.0g Right) Slug 1-10, June 20, weight 11.5g

### *2.4.4 Statistical Analyses*

Statistical analyses were conducted in Microsoft Excel (2010) and RStudio (2012). Exploratory analyses in Microsoft Excel directed the subsequent analysis in RStudio. Descriptive statistics (mean, mode, range etc.), Pearson correlations, scatterplots, and histograms, were created in Microsoft Excel. Our data did not meet the assumptions of normality or balance for a parametric Analysis of Variance, even when the data were transformed. Consequently, we used RStudio to run Kruskal-Wallis rank sum tests, a non-parametric alternative to ANOVA (Whitlock & Schluter, 2009). Notably, this test is only able to analyze single-factor ANOVAs, which limited the analyses we were able to perform. Frequency histograms and post-hoc Kruskal-wallis tests were also conducted in RStudio.

## 3.0 Results

### *3.1 Population density and distribution*

Slugs were present on all 7 islands surveyed and were observed in 19 of 20 sites. Between June 20$^{th}$ and June 28$^{th}$, we spent 85 person-hours intensively surveying 9936m$^2$. This survey effort yielded a total of 155 slugs, 150 of which were unique individuals. As survey effort was unevenly distributed, absolute number of slugs found at each site is not indicative of slug density. The number of slugs found per square meter at each site does, however, provide some insight into relative slug density across sites (Figure 6). From this measure of density, a crude estimate of slug population was calculated (Figure 6) Island size is not correlated to slug density on islands surveyed (Pearson product-moment correlation coefficient, $r(5)=0.02$). Island size and slug population do however, show a strong positive correlation, (Pearson correlation, $r(5)=0.72$).

We also found that islands further away from the mainland tended to have lower slug densities than islands close to the mainland (Pearson correlation, r(5)=0.56) (Figure 7).

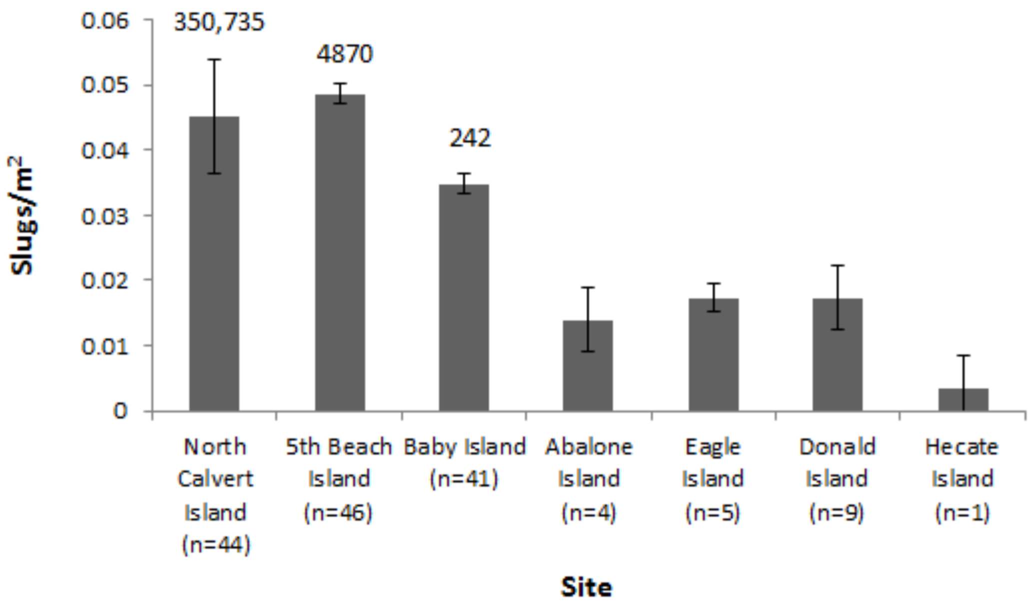


Figure 6. Number of slugs per $m^2$ at each site (average across the four habitat types for North Calvert Island). Numbers above sites refer to total population estimates for these three sites.

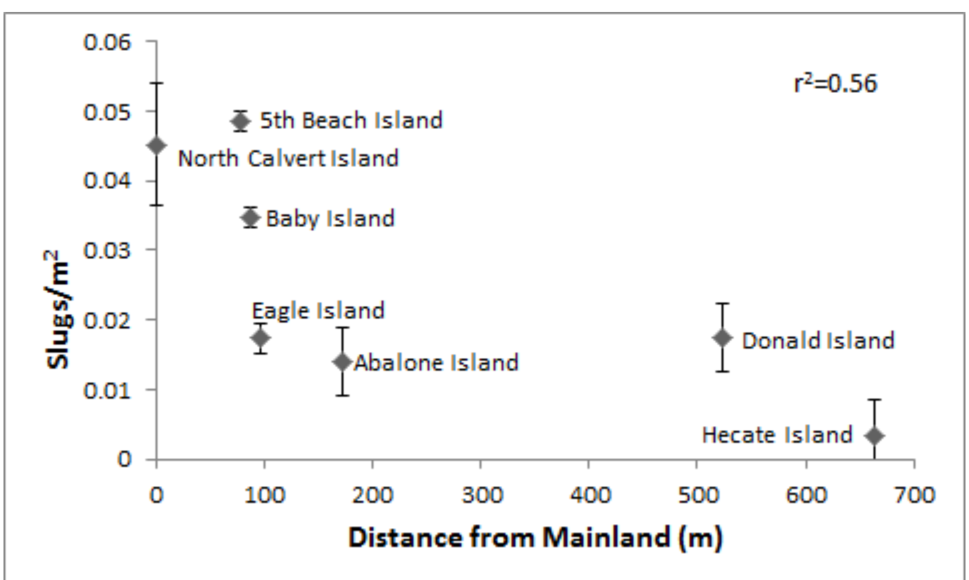


Figure 7. Correlation between slug density (slugs/$m^2$) and distance from mainland (meters from North Calvert Island). Error bars show one standard error from the mean.

*3.2 Pattern Variation*

We observed slugs with a variety of patterns and varying proportions of black, from 0 to 1. The distribution of slug patterning in the study area is bimodal, with the majority (n=108) of slugs following a slightly left skewed distribution with an average proportion black of 0.58 (+/- 0.02 1SE), which forms a mode frequency between 0.6 and 0.7 (Figure 8). The second mode is made up of completely green slugs (0.0 proportion black, n=42).

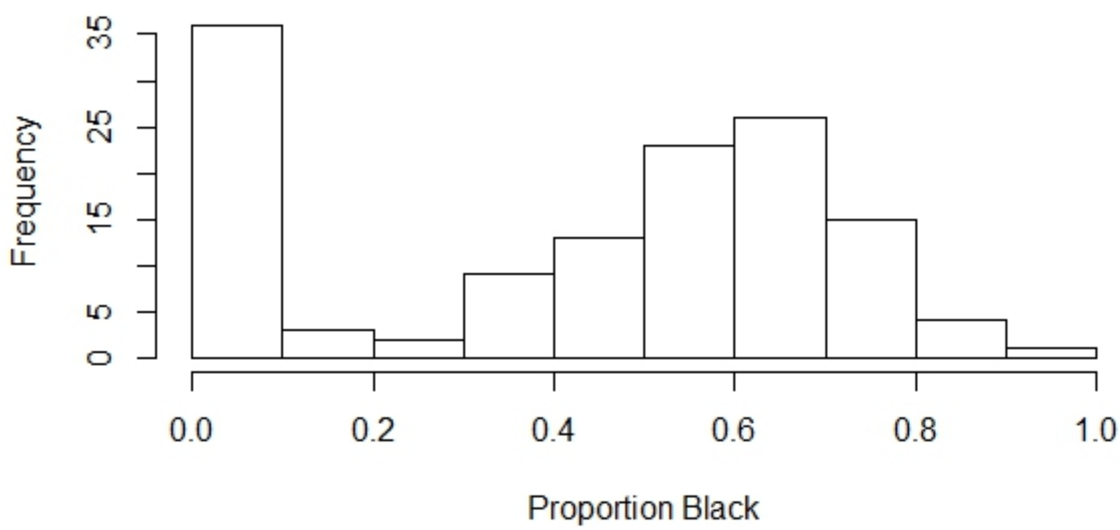


Figure 8. Frequency distribution of slug patterning, described by proportion black. All sites combined.

There was also considerable variation when comparing the mean proportion black among slugs on different islands (Figure 9). Hecate Island is excluded because the number of samples (n=1) does not give any estimation of pattern variation within the island. When comparing the three islands with sufficient sample sizes, the slugs on Baby Island on average have significantly greater proportions of black than slugs on either 5$^{th}$ Beach Island or Calvert Island (Kruskal-Wallis chi-squared test with Kruskal-Wallis post-hoc comparison test, $p < 0.01$,) (Table 1 & 2). Within island variation was also the least on Baby Island, with a complete absence of green slugs and the minimum proportion black on any individual being 0.50 (Figure 9; Table 3). Contrary to our hypothesis, soil moisture was not correlated with proportion black on slugs (Pearson correlation, r(148)=0.08).

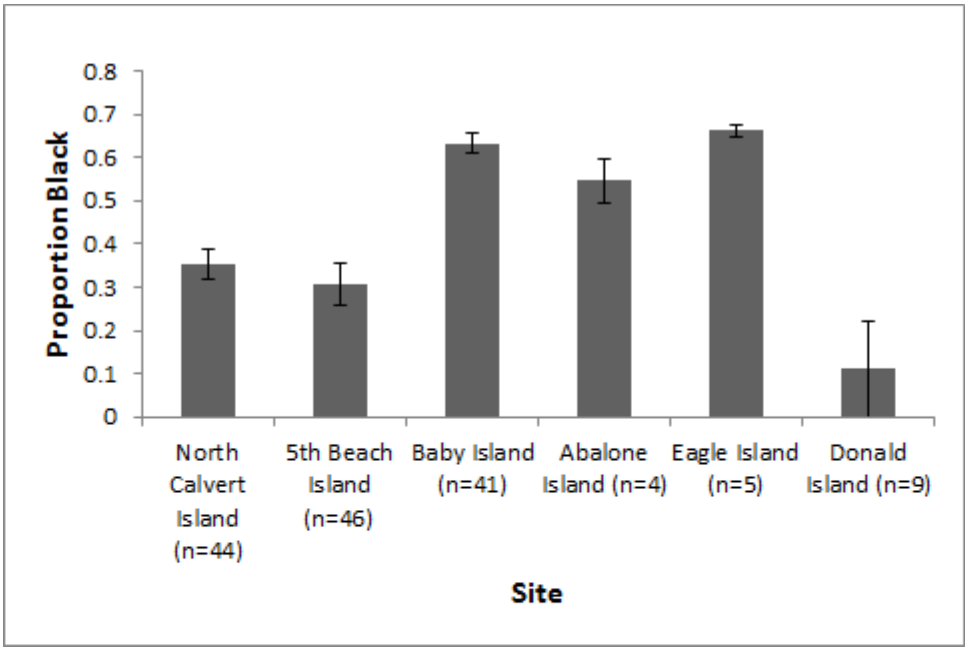


Figure 9. Mean proportion black by study site. Error bars show within island variation as +/-1 Standard Error.

Table 1. Kruskal-Wallis rank sum test.

| Kruskal-Wallis chi-squared | Df | P-value |
|---|---|---|
| 32.4058 | 2 | 9.187e-08 |

Table 2. Kruskal-Wallis post-hoc comparison test.

| Site | Observed Difference | Critical Difference | Difference |
|---|---|---|---|
| North Calvert Island-Baby Island | 41.722284 | 19.87622 | Yes |
| North Calvert Island-5th Beach Island | 2.348646 | 19.20826 | No |
| $5^{th}$ Beach Island- Baby Island | 39.373638 | 19.56785 | Yes |

Table 3. Measures of central tendency

| Site | Mean P(Black) | Min P(Black) | Max P(Black) | SD | N |
|---|---|---|---|---|---|
| North Calvert Island | 0.35 | 0.00 | 0.71 | 0.24 | 49 |
| $5^{th}$ Beach Island | 0.30 | 0.00 | 0.79 | 0.33 | 49 |
| Baby Island | 0.63 | 0.50 | 0.91 | 0.16 | 44 |

To determine whether variation in proportion black is a due to slugs from the black colour morph gaining more spots as they age, we measured the correlation between slug weight and proportion black from this subset of slugs with some black (n=108). Weight and length are highly correlated (Pearson correlation, r(148)=0.76) so only one measure of size was necessary. Weight was used as the proxy for age because the scale was considered more accurate (0.1g) than length from a ruler measurement (1mm), which also has potential for human error. Weight was not correlated with proportion black on slugs (Pearson correlation, r(106)=0.09).

*3.3 Recaptures*

We found 5 recaptured slugs, 3 on the HBI Lawn, 1 on Baby Island, and 1 on 5th Beach Island. The mean difference in weights for the recaptured individuals was 0.7g +/- 0.25g (1se), which indicates that comparing the photographs of potentially recaptured slugs that were within 2.0g of each other was likely sufficient. The mean difference in length from first capture to recapture was 4.8mm +/-0.73mm (1se).

*3.4 Precision & Inter-observer Reliability*

Our average precision for calculating proportion black on slugs was within 1% (n=9). The average interobserver reliability was within 6% (n=6). Although the interobserver reliability score was higher than we would were aiming for (5% or less), these scores were acceptable. We could have increased the number of squares on the grid overlay to improve this score.

## 4.0 Discussion

*4.1 Population density and distribution*

Consistent with our hypothesis, population density and distribution was not equal across all islands. Slug density ranged from 0.003slugs/m$^2$- 0.049slugs/m$^2$, which is a 16 fold increase in density between Hecate Island and 5th Beach Island. Similarly, there was a large range in the estimated populations on islands, from 102 on Abalone to 350,735 on the north end of Calvert Island.

*4.1.1 Population and Island Size*

Island size was correlated with population size. This result is consistent with our hypothesis, which was based on the species-area relationship put forth by the Theory of Island Biogeography. This theory suggests that a larger area is able to support higher species richness. The same principle holds true for abundance within those species. Larger islands have a greater amount of resources and thus can support more individuals of each species represented (Mittelbach, 2012). Having a higher number of individuals in a given population also results in higher genetic diversity, which increases the populations resilience to extinction (Mittelbach, 2012). Although island size is by no means the only factor influencing slug populations on these islands, our data suggest that the the larger the island, the number of slugs will increase. For example, 5th Beach Island is larger than Baby Island and has more slugs on it (4,870 vs. 242). This does not hold for population density. For example, while Calvert island slug density is similar to that of 5$^{th}$ Beach Island (0.045slugs/m$^2$ vs. 0.049slugs/m$^2$) the total population on the north end of Calvert island is an order of magnitude greater than 5$^{th}$ Beach Island (350,735 vs. 4,870). From this we can conclude that of the three islands with greater than 30 individuals, Baby Island, which has a smaller total area than either 5th Beach Island and Calvert, has the lowest number of slugs and thus would likely be the most prone to extinction. It also has the lowest density of these three sites which means there are even fewer individuals, further reducing genetic variation and thus the overall resilience of the population.

### *4.1.2 Density Changes with Distance from Mainland*

We found that slug density decreases with increasing distance from mainland. This finding is consistent with our hypothesis, which was loosely based on island biogeography. Island biogeography states that islands which are farther away will experience lower immigration rates because species transfer to islands is less frequent and in lower numbers and thus colonization is less likely. While this theory explains this concept in the context of number of species colonizing islands, our results suggest that this principle is also applicable to *A. columbianus* as an individual species. Given its fairly slow travel pace(12-19cm/minute) and a tendency to remain close to a home site (Pearson et al. 2006), *A. columbianus* has a low natural dispersal rate, which further supports the idea that slug colonization of islands is low. A further barrier to slug dispersal is the fact that slugs are highly intolerant to saltwater (Cody, 2006). Despite these barriers to colonization, we did find slugs on all seven islands that were surveyed. Although the chances are small and it is unlikely that dispersal to these islands was frequent or in large numbers, it is possible that they travelled to the islands on floating debris or attached to the leg of a bird (Cody, 2006). Given the long history of human occupation in this area, it is also possible that transfer was facilitated by humans (McLaren & Christensen, 2013). During fieldwork, we observed *A. columbianus* crawling on boats on a number of occasions. It should also be noted that because *A. columbianus* is a hermaphroditic species and can self-fertilize (Cody, 2006) it is possible that a new island population could be started by a single individual.

## 4.2 Pattern variation

*4.2.1 Moisture and Canopy Cover*

We found evidence supporting our hypothesis that the proportion of black slugs varied across islands. On Baby Island in particular, we found only darker slugs. However, contrary to our hypothesis, which was based on Cody's research regarding soil moisture, we did not find a correlation between moisture and the proportion black. Our average moisture readings had little variation across island sites. This could be because we surveyed a much smaller variety of islands than Cody did and if we had surveyed a larger area over a longer period of time our results might be more significant.

Qualitatively, the canopy photos we took from the center of our quadrats on Baby, North Calvert, and 5th in particular seem to suggest a correlation between canopy cover and the proportion of back *A.columbianus*. This is consistent with Cody's (2006) study which found a relationship between vegetation cover and slug color. Specifically he found that small, open islands with shorter vegetation had less black slugs while small islands with damp climates and thicker, higher vegetation favoured blacker slugs. However, we did not quantify canopy cover so are not able to comment on the significance of this observation.

4.2.2 Genetic Variation and Geological History

Unlike most of the other islands studied, which had predominantly black slugs, only one out of the nine individuals found on Donald Island had any black patterning. One potential explanation of this divergent result could be the founder effect. The founder effect is the phenomenon whereby a small subset of a population becomes isolated and begins a new colony descended only from that subset. If certain genetic variations happened to be over or under represented in that isolated population compared to the original group, then those genes, or phenotypes created by them, would be similarly over or under represented in the new colony compared with other individuals (Rotimi, n.d.). It is possible that the result we found of nearly all individuals from the green colour morph is due to the fact that slugs with this phenotype were the ones that colonized Donald Island. If this were the case, it would explain the general homogeneity of phenotypes we discovered at this site.

Although unknown, it is highly improbable that sea level has risen  29.2m since the last glaciation, the maximum of which was 18,000 years BP (Eamer, 2013). From this we can presume that slugs were absent from this island at the time of glacial melt, which was after it became separated from Calvert Island. This means that all slugs currently on the island must be descended from individuals which were transported there by other means. Although we were not able to quantify the likelihood of slugs being transported by either natural or human means they must have used one of these dispersal mechanisms.  As previously mentioned, a new population could potentially be started by a single individual. There are no documented midden sites on Donald Island (McLaren and Christensen 2013). This indicates that human dispersal to Donald Island may have been less likely than for some of the other surrounding islands.

While not significant, distance from mainland and sea level could potentially have an effect on slug color.  According to Andrews and Retherford (1978), sea level in this area had dropped until the last few hundred thousand years BP. Land emergence was rapid and the present sea level was reached between 8000 and 7000 BP and then continued to drop to -4km (Andrews and Retherford). Baby Island and 5th Beach Island all have surrounding sea levels at less than 4 meters which according to this research means these islands were all once connected, potentially allowing slugs to travel between them. It is interesting to speculate based on our results that 5th Beach Island and North Calvert Island have similar proportions black due to similar sea level history; 5th Beach Island is the lowest (currently walk-able at low tide) which might allow for similar diversity and mixing between populations. Perhaps then, the reason why Baby Island has such a homogeneous and distinctly black slug population is because it has been isolated from the mainland for a longer period than 5th Beach Island. Slugs generally stay clear of salt water as it causes them to essentially dissolve into froth, making it very unlikely that they were able to immigrate to different islands (Cody 1996). Fewer habitat types and food options could also have led to extinctions of less black color varieties on Baby Island once the sea level rose and and isolated it from the mainland. This is a speculation stemming from research and analysis of our results and would be a fascinating area for future research.

*4.3 Recaptures*

We identified 5 recaptured individuals from our secondary surveys using weight and photograph comparisons. Based on our observations of the variability of length within individual slugs, we were surprised that the length measurements were so precise (<6mm). We calculated proportion black for the same individual twice, before identifying them as recaptures. The mean difference in our two assessments of proportion black was 0.02+/- 0.01 (1se), which is comparable to our precision and inter-observer assessments. Given the consistency of these measurements we believe the methods used were precise and could be effectively used in similar studies in the future. The five recaptures found in our study gained weight between our first and second samples (4-6days). This weight difference could be due to growth of individuals, water gain, or scale error. Cody (2006) analyzed slug weight loss in forest and open habitats on both wet and dry days and found that slugs lost the most weight in the open habitat on dry days and the least loss in forested habitat on dry days. This suggests that the weather between our sampling times was likely not very hot which is congruent with the actual weather which was mostly overcast with some heavy rain and a little sun.

**5.0 Conclusion**

While our study does provide a good basis for further research of this understudied species we did encounter a number of limitations which future studies should work to control for or mitigate. Our fieldwork on this species was significantly hampered by dense forests and thick understory. In this regard, selecting sites to represent a variety of habitat types was a major challenge. It is also possible that weather conditions could have biased our sampling as well. We might have found larger numbers of slugs on rain days as they are generally more active from the moisture, and less slugs on extremely hot or cold days as they could have burrowed in shallow soil. A future study could measure weather as a variable over time in the same places to address this issue.

In regard to our population measures it was difficult to get an accurate measure for density as we did not a have enough time or manpower to survey more than two quadrats per island. If we had been able to do more replicates on each island it would have yielded a more precise measure of density. Given our small sample size we simply averaged the data for each of the quadrats to create an estimation of density for the whole island. Thus, the measure of variation within islands was based on only two replicates and is therefore not statistically comparable or reliable. For future studies it would be beneficial to survey over a longer time period and obtain larger sample sizes with a greater number of replicates on each island. This data would allow for more complex multivariate analysis and fascinating queries into genetic variation as it relates to the founder effect. In addition, it would be interesting to look at *A. columbianus* in interior forest habitats versus edge habitats as we observed a significant number of slugs on the perimeter areas. This is perhaps due to a preference for early succession annuals for food, which would explain them straying from the dense forest in search of tastier food (Cody 1996).

It was a challenge to draw any definitive conclusions from our results due to our small sample size. Anecdotal evidence and field observations do, however, provide insight into numerous opportunities for future studies. Further, the preliminary findings from this study provide a basis for future research on this understudied species as well as some important baseline data on the density, distribution, and pattern characteristics of *A. columbianus* in the Hakai Luxvbalis Conservancy Area. Slugs are an important creature within forest environments; there are over a dozen species of them in coastal forests worldwide and they can comprise up to 70 percent of the animal biomass (Cannings & Cannings, 1996). These decomposers play a major role in forest ecology and further research on this species could provide valuable insights into their role in ecosystems.

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