Egg Predation and Egg Predator Diversity in Forest and Open Habitat of the Monteverde Region

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ABSTRACT

As habitats continue to be destroyed and fragmentation decreases the number of large predators, intermediate predators are expected to thrive. To further investigate whether the intermediate predator hypothesis applies to open areas in addition to edges, the difference in the amount of egg predation and the egg predator diversity in the forest and open habitat of the Monteverde region was tested. Each night three clusters of eggs with three quail eggs and three fake plasticine eggs were placed in each habitat. Results showed a significant difference between the total number of real eggs removed from the two habitats, (Chi-squared test, $\chi^2 = 5.373$, $p = 0.0205$, $n = 2$) but there was no difference between the number of eggs removed each night between the two habitats (Sign test, $p > 0.05$). It is thought that fewer eggs are removed from the open area because other, more preferred food sources such as gardens and compost exist in the open area.

RESUMEN

En tanto que los habitats continúan siendo destruídos y la fragmentación disminuye el número de depredadores grandes, los depredores intermedios se espera que abunden. Con el fin de investigar si la hipótesis de los depredadores intermedios es válida en áreas abiertas además de en bordes, se examinó la diferencia entre la cantidad de depredación en huevos y la diversidad de depredadores de huevos en el bosque y en habitat abierto en la region de Monteverde. Cada noche, se puso tres grupos de huevos con tres huevos de codorniz y tres huevos falsos de plasticina en cada habitat. Los resultados mostraron una diferencia significativa entre el número total de huevos verdaderos quitados de los dos habitats, (Test de χ , $\chi^2 = 5.373$, $p = 0.0205$, $n = 2$) pero no hubo diferencia entre el numero de huevos quitados cada noche entre los dos habitats (Test del signo, $p > .05$). Se piensa que fueron quitados menos huevos del habitat abierto porque existen otras, fuentes de alimento preferidas como jardines y abono.

INTRODUCTION

Habitat fragmentation has increased in many parts of the world including the cloud forest area in Monteverde, Costa Rica. When habitat fragmentation forms edges or islands, it usually results in negative effects on many species and plays a strong role in the rarity of species, the loss of genetic diversity, and extinction. However, not all animals suffer from habitat fragmentation. In fact, many generalist predators prefer open habitats and are likely to penetrate formerly core areas of forests now made accessible by edges, water lines, or roads (Wheelwright 2000).

Habitat fragmentation facilitates the spread of some predators and is an important part of the intermediate predator hypothesis (Conwell 1997). This hypothesis states that the number of medium-sized predators greatly increases in a patchwork of fragments because fragmentation decreases the number of top predators. With fewer top predators, intermediate sized predators will thrive and enter fragments to prey on food sources (Owen 2001). A large number of intermediate predators is problematic for prey like small animals and their eggs. It is thought that in large, continuous forests with few edges, top predators control the populations of the medium-sized predators that often prey on nests, thereby lowering the rate of bird nest predation

(Wilcove et al. 1986). The open areas resulting from deforestation may harbor egg predators, although the kinds and abundances of predators are likely to differ from closed forest habitats. It is thus interesting to quantify egg predation in open and forest habitat. In this study I tested whether egg predation rates differ between the forest habitat and the open habitat of three sites in the Monteverde area.

The intermediate predator hypothesis does not address the composition of predators in open areas. While egg predation is usually higher in forest fragments versus large forest tracts, whether it is higher in open areas versus forest fragments is unknown. The amount of predation in the open habitat should be strongly dependent on the kinds of egg predators that will frequent open areas. It is thought that specific characteristics of each species, besides its intermediate size, will contribute to whether the species thrives in an open area. Hence it is important to couple the comparison of egg predation rates with observations on the identity of egg predators.

The Monteverde area contains 121 species of mammals of 25 families (Timm and La Val 2000). Seven of these mammals have been identified as possible intermediate-sized predators. In addition, these omnivorous predators have been known to prey on most food types, including eggs. The seven suspected intermediate egg predators include: *Didelphis marsupialis* (Common opossum), *Cebus capucinus* (White-faced capucin), *Procyon lotor* (Common raccoon), *Nasua narica* (Coati), *Rattus rattus* (Roof rat), *Urocyon cinereoargentus* (Gray fox), and *Eira barbara* (Tayra). The opossum, raccoon, roof rat, and gray fox are mainly nocturnal, while the capucin monkey, coati, and tayra are mainly diurnal (Reid 1997).

In particular, the opossum has been known to raid chicken houses, kill chickens and eat their eggs (Reid 1997). This marsupial, which usually forages alone, has a modified molar specialized for both crushing and shearing, a feature that allows easy access to eggs (Eisenberg 1989). The raccoon, which prefers disturbed areas, has also been known to raid chicken coops and have a preference for eggs. The tayra belongs to the family Mustelidae, in which several species have adapted a specialized method to open large eggs. The egg predator arches its body, grasps the egg in its forelegs and then hurls it backwards between its legs, sometimes giving it an extra kick from a hind leg (Reid 1997).

Coati males are mostly solitary except during breeding when they are quite social. This mainly diurnal animal locates its food primarily by smell and is often an egg predator (Wainwright 2002). The roof rat is comfortable in both cities and rural areas and will eat anything, including garbage and household materials. The gray fox particularly favors edges and farmland, especially in rocky country. It has an excellent sense of smell and is an opportunistic feeder (Reid 1997). Although brown jays have been seen defending their nests from the social white-faced capucins (Timm and La Val 2000), they are unlikely predators for my experiment because of their arboreal nature and scarceness in the sites I will use. For these reasons, the capucins will no longer be considered as a possible predator.

Based on knowledge of edge effects, the intermediate predator hypothesis, and the habitat and feeding preferences of the seven common intermediate predators of the Monteverde area, I hypothesized that the species composition of egg predators would differ between the forest and open area. My experiment is designed to test whether the amount of egg predation varies and whether the species composition of egg predators varies between the open and forest habitats.

MATERIALS AND METHODS

Study Site
The study was conducted in the Monteverde, Puntarenas area of Costa Rica. Two trials occurred at a farm near the Sapo Dorado Hotel, six trials occurred at the Monteverde Cloud Forest School, and six trials occurred at the Monteverde Biological Station.

Methods
To compare egg predation in two different habitats (the forest and the open disturbed area at various sites in the Monteverde area), each habitat had three clusters of eggs placed at least 50 m apart on the ground under a tree. The clusters consisted of three quail eggs and three plasticine eggs placed together on the ground; no structures such as bowls prevented the eggs from rolling away or being moved. Quail eggs were used to estimate the relative predation levels on small bird eggs, while plasticine eggs are used to obtain markings to help identify the predators (Marni and Melo 1998). The egg clusters were placed in the evening between 1600 hours and1800 hours and collected the next morning by 0800 hours. The egg clusters were placed and observed nine times between July 15th and August 2nd. Three different sites in Monteverde were used; each site had an open and forested area. The location of the clusters changed for each trial to prevent individual predators from learning where the eggs were located.

For each trial, I recorded the number of eggs removed and remaining from each cluster, the number of plasticine eggs with markings, the type of markings on plasticine eggs, the number of predator species identified, and any change to the immediate area such as paw prints, pieces of eggs on the ground, or scratches on trees. Any existing tooth marks or paw prints were sketched for further identification. Using the three field guides of <u>Mammals of the Neotropics</u>, <u>The Natural History of Costa Rican Mammals</u>, and <u>Mammals of Central America and Southeast Mexico</u>, the species of egg predators were identified, if possible from the markings given. If the plasticine eggs had deep markings and/or were seriously altered, they were kept and replaced with a new plasticine egg. Those plasticine eggs with no marks or only slight scratches were smoothed out and reused after data had been recorded.

A Chi-square goodness of fit test was used to analyze the total number of eggs removed and remaining in open and forest habitat. The sign test compared the open and forest habitat in regards to the difference in number of eggs removed per evening, number of eggs with marks, and number of predator species identified.

RESULTS

No significant difference exists between the nightly number of eggs removed from the two habitats (Sign test, $p > 0.05$). In two cases, more eggs were removed from the open than the forest area; in four cases, more eggs were removed from the forest than in the open area; in eight cases no difference occurred (Figure 1). No significant difference exists between the number of plasticine eggs with bite marks in the two habitats (Sign test, $p > 0.05$) (Figure 2). In two cases, more eggs from the open area had marks; in four cases, more eggs from the forest area had marks; in eight cases no difference occurred.

A significant difference does exist between the two habitats in regards to total number of eggs removed (Chi-squared test, $\chi^2 = 5.373$, $p = 0.0205$, $n = 2$) (Figure 3). In each habitat, 126 eggs were placed. Seven eggs were removed from the open area while eighteen eggs were removed from the forest area. Significantly more real eggs were removed from the forest area. In contrast, there was no significant difference in the number of fake eggs with marks between the two microhabitats (Chi-squared test, χ^2 = 0.400, p= 0.53, n = 2). Eleven eggs were marked in the open area and fourteen eggs were marked in the forest area (Chi-squared test, χ^2 = 0.400, p= 0.53, n = 2).

Table 1 shows a comparison of the species of predators found in the respective habitats. Both habitats showed evidence of the coati, rat, and small rodents. The exact species of rat or small rodent could not be identified from the marks left. The open area had evidence of a raccoon and gray fox while the forest area showed evidence of the opossum. The open area had two unidentified species of predators based on the egg marks while the forest had one unidentified predator, for a total of three different unidentified species of egg predator. A coati male was witnessed foraging on plasticine eggs left from the previous night's study despite all of the real eggs having already been eaten or removed. The coati was recorded as the egg predator although the original markings on the eggs suggest a different predator.

Table 2 summarizes any other markings found at the egg clusters that were not bites on plasticine eggs. Three paw prints were found in the open area while only one paw print was found in the forest. Two of the paw prints were identified as raccoon prints. One raccoon print was recorded in each habitat. The other print found in the open habitat was from a gray fox. Six plasticine eggs had small rodent scratches in the open area while seven forest area eggs contained the same scratches.

DISCUSSION

My hypothesis stated that the species composition of egg predators differs between the two habitats and thus I predicted that the kinds of egg predators would differ at the egg clusters in open and forested habitat. However, species composition between the two habitats was similar while the amount of egg predation differed between the two habitats.

These data are both interesting and biologically significant for many reasons. To begin, the data do not support the intermediate predator hypothesis. The intermediate predator hypothesis predicts that predation would be greater along edges like the open area near the forest as opposed to the closed forest area. A study by Wilcove et al. (1986) found that predation rates were higher closer to the forest edge, suggesting that the high predation rate was due to predators living in the surrounding habitat and penetrating the forest fragment (Angelstam & Andrén 1988). The opposite of this study is shown in Figure 3, because a significantly greater number of eggs were removed from the closed forest as opposed to the open area. One explanation for this could be that larger populations of predators exist in the forest. In the recent history of the Monteverde region, populations of large mammals were decimated outside protected areas and populations of many small and medium sized mammals have decreased due to widespread habitat fragmentation and hunting (Timm and La Val. 2000). It is possible that more predators exist in the forests included in my study because these forests are largely protected and have little negative human influence such as hunting and poaching. In addition, the forest area may supply more eggs and contain the most abundant in resources. All of these factors could contribute to a greater abundance of egg predators, resulting in more eggs removed from the egg clusters in the forest.

Abundance of predators and resources does not explain, however, why the difference in number of marks on the plasticine eggs of the two habitats was not significant. Figure 4 shows that the open area received a similar number of bites on plasticine eggs as the forest area. This suggests that the eggs in the two habitats are drawing an equal amount of attention or that the frequency of predator visits is similar. The difference between the two habitats is that the predators in the forest take the eggs more often while the predators in the open area investigate the eggs but take them less frequently. An explanation for this could be that the predators that venture into the open area find other types of food in addition to eggs. This other food may be more preferable and while the predators do find the eggs, they choose not to waste their time with the eggs with more enticing food in the area. The Cloud Forest School, for example, contains organic gardens, fruiting trees, and compost piles. These sources of food may be more desirable for those omnivorous predators, as fruits, vegetables, and organic matter are listed as part of the diets of the seven main predators in the area (Reid 1997). Support of this theory includes the occasion in which I placed a nest where a pile of compost containing watermelon and vegetable matter had been dumped. While I do not know whether any animals ate any of the fresh food, the eggs were clearly ignored that night.

It is somewhat perplexing that although a difference did exist in the number of eggs removed from the forest area, the species composition of predators of the two areas showed little difference. Natural history also shows that these predators all are capable of living in either habitat. Although the gray fox and raccoon were found in the open area, they are also often found in forest areas. Similarly, although the opossum was found only in the forest, these animals are commonly found in open areas. In fact, on many occasions, I walked past a dead opossum on the side of the road (an open area) to get to the Cloud Forest School.

The data can be somewhat misleading when it comes to searching for an explanation as to why no significant difference existed between the amount of egg predation of the two habitats. Of the two events in which more eggs had been removed from the open area, one event occurred when a single egg had been eaten. This egg had accidentally cracked as it was placed and may have been destroyed by a smaller rodent that would not usually be able to break the egg open. This one of two open area predation events involved a single egg being eaten. In many instances in the forest, complete clusters of eggs were removed at once. In every instance in which eggs were removed from the forest, at least three eggs were removed. One evening six of the nine quail eggs were removed from the forest. The sign test only shows that differences occurred and not the magnitude of difference between the two habitats.

Table 2 can be misleading when it shows that three paw prints were found in the open area and only one was found in the forest. It was very difficult to find paw prints in the forest when most of the clusters were placed under trees on top of leaf litter. In the cases of paw prints in the open area, many times the eggs were placed specifically near dirt or sand, which would hold a paw print better. Muddy trails, sandy areas, and riverbeds are excellent track substrates (Wainwright 2002). Since at times an adequate track substrate was specifically searched for in the open area and not the forest area, this creates a bias between the two habitats. The raccoon tracks are very common to find because the raccoon is a plantigrade mammal that presses its toes and heels into the ground while standing, causing it to be more likely to produce a visible print (Wainwright 2002). These plantigrade mammals take food that does not require fast pursuit but which might require some manipulation, such as eggs (Wainwright 2002).

There are many possible avenues of future research based on this study. First, it would be better to increase the length of the study, the number of clusters placed per night, and the number of eggs per cluster. An increase in the number of nights in the study to twenty nights would allow further statistical testing such as a paired t-test, which would be more in depth and accurate. It would also be interesting to incorporate other sites such as the Monteverde Cloud Forest Preserve or the Monteverde Ecological Sanctuary into the investigation. Furthermore, it would help to place eggs even deeper into the forest habitat to avoid any chance of overlap between deep forest and forest edge. Egg placement could be slightly closer to sundown and retrieval slightly closer to sunrise in order to lessen the impact of diurnal predators. In addition, it would be interesting to videotape the clusters to more clearly identify the species of egg predator. To reduce error, it would be best to use new plasticine eggs for each trial and be absolutely sure that the real eggs did not have any cracks in them.

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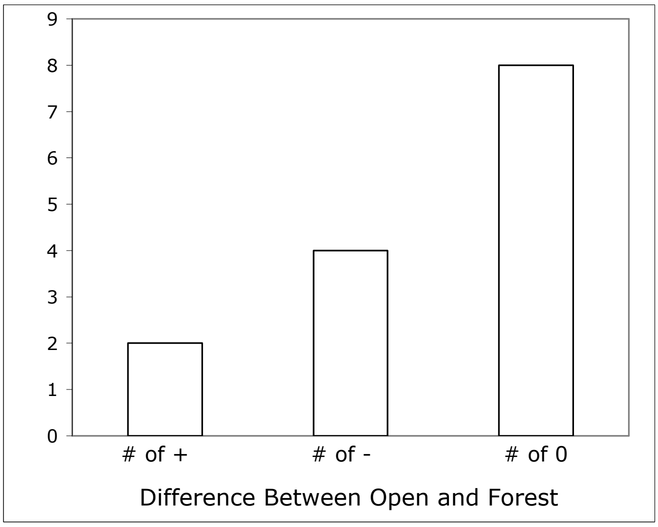

FIGURE 1. The relationship between the number of real eggs removed in open and forest habitats. A + indicates more eggs removed from the open area than the forest area. A – indicates more eggs removed from the forest area than the open area. A 0 indicates no difference. There is no significant difference in the number of real eggs removed in the two habitats (Sign test, $p > 0.05$).

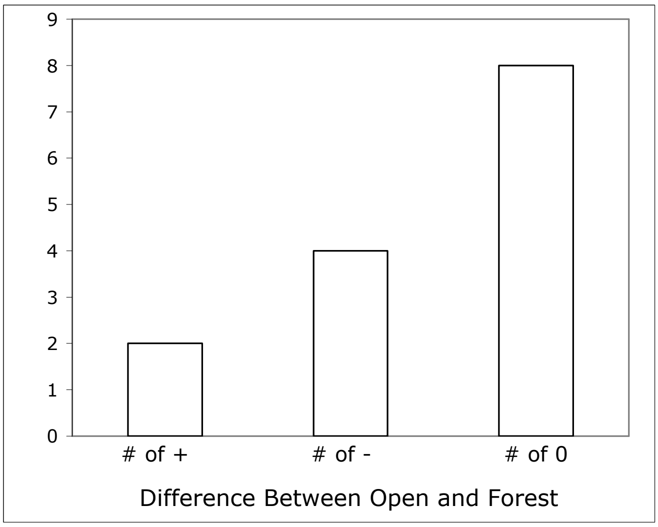

FIGURE 2. The relationship between the number of plasticine eggs with predator marks in open and forest habitats. A + indicates more eggs marked in the open area than the forest area. A – indicates more eggs marked in the forest area than the open area. A 0 indicates no difference. There is no significant difference in the number of plasticine eggs with marks in the two habitats (Sign test, $p > 0.05$).

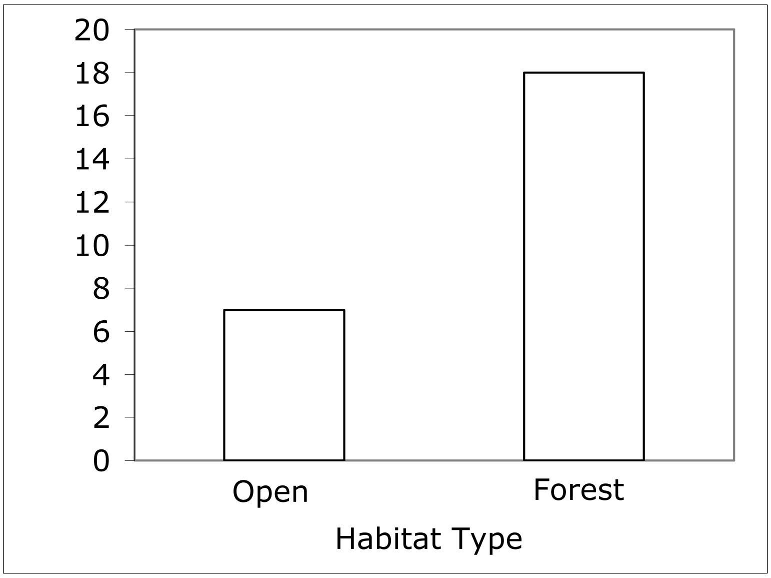

FIGURE 3. The total number of real eggs removed from open and forest habitat. 126 eggs were placed in each habitat with seven being removed from the open area and 18 from the forest area. A significant difference exists between the number of eggs removed in the forest compared to those removed in the open area (Chi-squared test, $\chi^2 = 5.373$, $p = 0.0205$, $n = 2$).

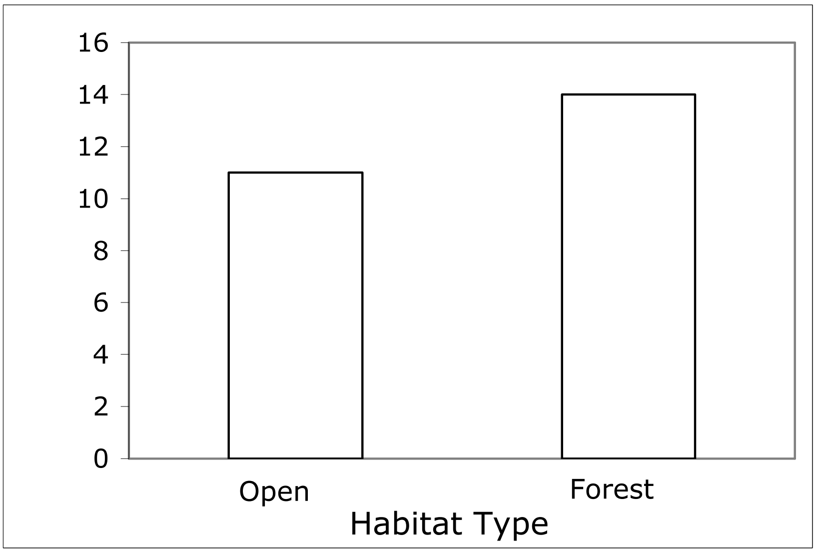

FIGURE 4. The total number of plasticine eggs with marks in the open and forest habitat. Eleven eggs were marked in the open area and fourteen eggs were marked in the forest area. There is no significant difference between the number of fake eggs with marks in the two habitats (Chi-squared test, $\chi^2 = 0.400$, $p= 0.53$, $n = 2$).

TABLE 1. *A list of egg predators identified based upon the bite and scratch marks on the plasticine eggs. The coati, rat and small rodent were found in both areas. The open area had seven different predators while the forest area had only five (Eisenberg (1989), Reid (1997), & Wainwright (2002)).*

Egg Predator	**Open Area**	**Forest Area**
Opossum	No	Yes
Rat	Yes	Yes
Small Rodent	Yes	Yes
Gray Fox	Yes	No
Raccoon	Yes	No
Coati	Yes	Yes
Unknown Medium Sized Animal 1	Yes	No
Unknown Medium Sized Animal 2	No	Yes
Unknown Small Animal	Yes	No

TABLE 2. *This table compares events other than bite marks recorded in the open and forest area. A greater number of paw prints were found in the open area and a slightly greater number of eggs with small scratches were found in the forest area.*

	Open	**Forest**
# of clusters of eggs with paw prints	3	1
# of plasticine eggs with small rodent scratches	6	7