

**Implications of land-use change on food resource availability for birds**

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## **Abstract**

Habitat disturbance through anthropogenic development often leads to invasion by exotic species. While studies have examined the influence of non-native species on the breeding habitat of birds, little researched has looked at the importance of plant community composition change on the food resources available at stopover habitat used by migrating species. In order to examine the influence of land-use change, and especially species invasion, I analyzed the plant cover across forest, edge, and rural remnant habitat and assayed nutritional content of fruits from several common species of native and exotic plants in fruit in mid November near Falmouth, Massachusetts. I found that disturbed (edge and rural) habitat had higher total cover and exotic plant cover, while forests contained only native species. Assays of protein, carbohydrate, and lipid indicated that exotic fruits were sugary; natives were fatty. Studies of the preferred nutritional content used by resident and migratory birds indicate that only the lipid-rich natives are a suitable food source for migrating species. I also found that most fruiting plants were exotic, suggesting that they may fruit too late to be available during migration. Together, the availability and nutrition of exotic fruits suggests that they are not a suitable food replacement for migratory bird species. While this has conservation implications, further studies need to be completed in order to better analyze periods of bird migration and fruit production of all plant species in the area.

## **Introduction**

Currently, one of the biggest threats to biodiversity is habitat alteration and loss, which is often a result of coupled human disturbance and exotic species invasion (McKinney and Lockwood 1999). Not only do environmental factors directly support invasion, but often the environmental conditions also dictate where people develop, which causes modification of the environment that leads to subsequent invasion (Seabloom et al. 2002).

Exotic species generally thrive in human-altered habitat, which affords open space (and sometimes nutrient addition), but many invasives spread beyond developed areas to the surrounding natural habitat (McKinney 2002; McKinney and Lockwood 1999). Consequently, exotic populations tend to be highest along edges – which usually occur where disturbed and undisturbed habitat converge (Pauchard and Alaback 2005; Yates et al. 2003).

Although avian use of edges varies, many disturbance-induced edges contain high numbers of exotic species, and the implications that native replacement by exotic species has on bird species is in need of further investigation (Faaborg et al. 1995). So far, numerous studies have addressed the influence of exotic plants on nesting success and breeding habitat use (e.g. Borgmann and Rodewald 2004), but little work has been done on the impacts of migratory food resource change due to disturbance and invasion.

Peak avian migration usually occurs between August and October, which is also the period of highest fruit production for most plants (Schwarzman 2002; Thompson and Willson 1979). Migratory species that are insectivorous during the breeding season supplement their diet with fruit during migration; this allows for fat accumulation and storage while minimizing foraging activity (Parrish 1997; Bairlein and Gwinner 1994; Thompson and Willson 1979). The coordination of migration and fruit production periods is also advantageous for fruiting plants, because migrating species can serve as long distance dispersers (Thompson and Willson 1979;

Thompson and Willson 1978). Due to migrants' high assimilation efficiency and proficient storage of lipids, lipid-rich fruits are the best food source for birds needing to store energy for a long distance flight (Witmer and Van Soest 1998; Bairlein and Gwinner 1994; Johnson et al. 1985).

Unlike migrants, resident bird species generally don't travel long distances. They, therefore, prefer high carbohydrate diets, which are easier to digest and provide plenty of energy for regular foraging activities (Witmer and Van Soest 1998; Bairlein and Gwinner 1994). Similarly, plants that fruit in the winter, once migrants have already left the area, are sufficiently dispersed by the random movements of over-wintering species (Thompson and Willson 1979). Many residents are known to frequently inhabit edge and rural areas, in part because they are urban adaptors that use anthropogenic resources as additional habitat (McKinney 2002; McKinney and Lockwood 1999).

As a food source for birds, it is yet unknown if exotic plants only displace natives spatially, or if they are a functionally equivalent resource as well. If exotic plants either a) don't fruit when migrants are passing through or b) don't provide necessary nutrition for migrants, then the plant community alteration caused by coupled disturbance and species introduction could aggravate food resource loss for migratory bird species. Stopover habitat is crucial to migration success, so any change in the resources available at these sites could have major implications for migrants (Parrish 1997; Bairlein and Gwinner 1994). These changes would mean that food loss could not be quantified by ground area ( $m^2$ ) alone; conservation efforts should be informed and planned accordingly. If not all berries are equally suitable food sources, then conservation areas may need to be carefully selected for and managed for exotic-free habitat.

This study examines the effects of land-use change on food availability for birds, especially the relative importance of native and exotic fruit-bearing species. Most importantly, it analyzes whether exotics can adequately replace natives as a food resource. To address this question, I compared the mass and nutritional value of berry species encountered within the study across origin (native, exotic) and habitat (forest, edge, rural remnant). In order to see the larger impact of each result, I then calculated the land area of each habitat needed for a single bird to complete a full fall migration.

## **Methods**

*Field Methods* – I sampled at four sites: Peterson Farm, Coonamessett Conservation Area, Francis Crane Wildlife Management Area, and Bourne Farm in Falmouth, Cape Cod, Massachusetts from November 13<sup>th</sup> to 20<sup>th</sup>. Within each site there is accessible interior forest, disturbed edge, and rural neighborhood, which I considered three treatments representative of varying degrees of anthropogenic disturbance. Within each treatment I laid out a 100m transect beginning in a representative area. At 10m intervals along the transect (11 plots), I made species cover estimates in a 4m<sup>2</sup> quadrat using pre-assigned cover values (1 =  $\leq$  10%, 2 = 11-30%, 3 = 31-60%, 4 = 61-90%, 5 = 91-100%). When quantifying species cover, I also noted whether each species was currently fruiting or had evidence of having recently fruited (empty berry-bearing stems, etc). I also counted and collected berries from every fruiting species within the quadrat. Where there appeared to be more than 300 berries within the quadrat, counts were conducted within a 1m<sup>2</sup> quadrat nested within the larger one; the corner of the nested quadrat was pre-decided, moving clockwise from the bottom left corner. When necessary, the average number of

fruits per stem was established; then, average number of stems per branch was used to calculate number of fruits per branch and per quadrat.

I also conducted morning (06:30-09:30) bird observations at each habitat within the transect area in order to quantify bird diversity when activity was highest. Birds were identified by sight and sound during a standard 10 minute interval. Two bird observation periods were conducted per habitat.

*Lab methods* – I measured mass and nutrient content (carbohydrates, proteins, lipids) for each species of berry surveyed within the study. Mean mass (g) per berry was established by finding the average of approximately 100 weighed berries per species. A sample of wet berry was then weighed and dried at approximately 60 degrees Celsius before being reweighed to establish dry weight and to develop a species-specific wet:dry mass ratio. Homogenized, ground, dry samples of each species were used in all subsequent analyses.

Lipids, proteins, and carbohydrates were analyzed to develop an average content for each species: carbohydrates were assayed using phenol-sulfuric acid extraction and then read on a spectrophotometer (Dubious et al. 1956). Similarly, proteins were read with a spectrophotometer after being assayed with a biuret reagent consisting of copper sulfate, sodium potassium tartrate tetrahydrate, and sodium hydroxide (Lovrien and Matulis 1995). Lipids were extracted with methanol and chloroform, and then lipid content was established using a dry weight mass ratio (Bligh and Dyer 1959). All nutritional analyses were run in at least duplicate. Carbohydrate samples were diluted 2000:1 and read at 490nm; proteins were diluted 100:1 and read at 550nm. Before extraction, lipid samples were brought to 80% water using DI. Berry samples were also ashed at 500 degrees Celsius for four hours in order to establish indigestible content. All analyses were scaled to g/g berry dry weight.

*Calculations and Analysis* – For cover analyses, midpoints were assigned for each cover value (1 = 5, 2 = 20.5, 3 = 44.5, 4 = 75.5, 5 = 95.5). Berry density counts taken in the field were also scaled to berries/m<sup>2</sup> before analysis. Using the average berry mass established in lab, I was able to calculate grams of berry per m<sup>2</sup> from the berry counts. The birds and plants observed during the study are listed in Table 1; however, only berries found in sufficient numbers were analyzed for nutritional value. Data was statistically analyzed for the influence of species, origin (native or exotic), and treatment (forest, edge, rural) using analysis of variance in SAS (SAS Institute 2005). In order to determine the ground area of each treatment needed to support the lipid needs of a single migratory warbler – as Davis (2001) determined for a 3000km flight, grams of lipid per gram of berry dry weight was multiplied by the grams of berry per meter squared calculated from berry count and mass data and corrected for 89.8% assimilation efficiency of lipids (Witmer and Van Soest 1998).

## Results

*Cover* – Excluding canopy cover, edge habitat had higher total cover than either forest or rural areas ( $df = 2$ ,  $r^2 = 0.09$ ,  $N = 132$ ,  $P = 0.0026$ ). Forests had the highest native cover ( $df = 2$ ,  $r^2 = 0.28$ ,  $N = 132$ ,  $P < 0.0001$ ); while all three habitats had significantly different exotic cover – edges had the most exotic cover, while forests completely lacked exotic cover ( $df = 2$ ,  $r^2 = 0.47$ ,  $N = 132$ ,  $P < 0.0001$ ). The highest rates of exotic plant encounter occurred in edge habitat, while the highest incidence of natives occurred in rural areas. Edges also had the greatest number of fruiting plants, which were mostly exotic (Figure 2).

*Birds* – Analysis of number of bird species across treatments showed that forests had significantly fewer birds than rural areas or edges ( $df = 2$ ,  $r^2 = 0.53$ ,  $N = 8$ ,  $P = 0.0003$ ; Figure 1).

*Berries* – Exotics were the main species in fruit during the study. The mass of berries per m<sup>2</sup> increased with disturbance across habitats ( $df = 2, r^2 = 0.06, N = 132, P = 0.0163$ ; Figure 3). Although there was no difference in mass of native fruits between treatments ( $df = 2, r^2 = 0.01, N = 132, P = 0.4039$ ), edge and rural habitats had a much higher mass of berries per m<sup>2</sup> from exotic species; forest contained no exotics ( $df = 2, r^2 = 0.06, N = 132, P = 0.0227$ ; Figure 4). Native and exotic berries did not significantly differ in protein content ( $df = 1, r^2 = 0.05, N = 8, P = 0.3758$ ; Figure 5a). Exotic fruits had more carbohydrates than native species ( $df = 1, r^2 = 0.46, N = 11, P < 0.0001$ ; Figure 5b). However, exotic fruit species contained lower lipid levels than natives ( $df = 1, r^2 = 0.41, N = 10, P < 0.0001$ ; Figure 5c).

*Migration energetics* – Using the lipid values per gram of berry dry weight within the habitats surveyed at current fruiting, the most forest area would be needed for a single Blackpoll Warbler migration (Table 2).

## Discussion

*Cover* – Many edges are considered thicket habitats, which matches my finding that edges had the greatest total cover (Litvaitis 2003). The high cover of the edge habitat appeared to indicate the replacement of natives by exotics, because the edges also had significantly higher exotic cover than the other habitats; this suggested that its higher cover value originated from the addition of exotics. Numerous other studies have found this and have suggested that the encroachment of non-native species greatly alters the overall plant community composition (Maskell et al. 2006; Frappier and Eckert 2003). On the other hand, the forests had the highest native cover, which is probably a result of non-native species' inability to penetrate undisturbed habitat (Pauchard and Alaback 2006). If exotics are detrimental to the migratory food supply, then undisturbed forest that exotics can't easily invade should be a key target for conservation. Also, the number of plants encountered within a habitat accurately predicted the relative number of bird species present in that area, as McKinney's summary (2002) suggested: rural remnants and edges examined in this study had both more plant and bird species.

*Birds* – Contrary to the expectations of some studies, evidence here indicated that bird use was higher in human disturbed areas (Mills et al. 1989; Germaine et al. 1998). This may be in part because the bird species identified within this study fit into McKinney's (2002) category of urban adaptors, as taken from Blair (2001) – they tend to utilize human subsidized food sources like birdfeeders; they are also typified as mainly omnivores, ground feeders, and seedeaters. Also, since the vast majority of birds recorded during the study were residents, it was not unexpected that the most species were found in edge and rural habitat, which contained high quantities of exotics whose high carbohydrates are the preferred food source for resident species (Witmer and Van Soest 1998).

*Berries* – When the mass of berries per square meter within each habitat was divided between native and exotic origin, it became evident that the greater mass in edge and rural habitat originated from the increase in exotics in those areas, considering that more exotics were in fruit at the time of the study. However, when the nutritional content of each berry was examined, exotics were high in sugars, while natives were higher in lipids. Based on this study and literature, natives that have high lipid levels – favored by migrants – fruit predominantly during peak migration periods (Schwarzman 2002; Thompson and Willson 1979); while exotics with high carbohydrate content, which is residents' preferred form of nutrition, fruit in late fall and winter. Although this study was unable to survey plants throughout the fruiting season, this

still suggests that native and exotic fruits are available when birds favoring their particular nutritional qualities are present.

Based on various studies of frugivorous birds, two key factors dictate the suitability of a food source: the nutritional quality of the berry, and the timing of fruiting (Witmer and Van Soest 1998; Parrish 1997; Thompson and Willson 1979). I found that nutritional quality was significantly influenced by the origin of the fruiting plant. Timing influences whether the fruit produced will be available to migrant or resident species. As seen in this study, exotics are not nutritionally suitable for migratory bird species, and exotic fruiting may generally occur too late to be beneficial for migrating species; thus, exotics may only be a suitable food source for overwintering birds. This relationship concurs with exotics' high sugar levels, which are more palatable for residents that mainly forage and fly short distances. Witmer and Van Soest (1998) also demonstrated this relationship by showing that cedar waxwings (a resident) are adapted to high sugar diets, while thrushes (a migrant) assimilate the most energy from lipid-rich foods. If exotics replace native plants that fruit during periods of migration, then the food available to passing flocks will provide less needed nutrition, even if copious amounts of fruits are produced; so, invasion by exotics may cause net food resource loss for migrating birds, because these new "replacement" plants do not provide adequate food when it is most needed (Schwartz et al. 2006; Frappier and Eckert 2003; Thompson and Willson 1979). This shift in the seasonal availability of food supply implies that the introduction of exotics to disturbed areas could exacerbate food loss for migratory birds. This would mean that disturbance-induced food loss is disproportionately higher than the area of habitat loss.

*Migration energetics* – Although the migration analyses completed here signify that more forest area is needed to provide the lipids necessary for a single migrant, the land area derived from the migration calculations should not be directly applied to conservation policy, because the calculations utilized data gathered after natives had passed their peak fruiting season, which is when most migrants pass through. However, if the high native cover of forest habitat is examined in combination with the high lipid levels of the native fruits assayed, it appears that the least amount of forest area would be required (between August and October) to provide the energy needed for a single migrant. Although several results from this study support this possibility, such a conclusion is out of the realm of this study and requires further investigation over one or more complete seasonal cycles.

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## Appendix

Table 1: All bird and plant species observed during this study on Cape Cod, MA in November. Plant entries include origin classification.

Birds		Plants		
Common Name	Scientific Name	Common Name	Scientific Name	Origin
Gray Catbird	<i>Dumetella carolinensis</i>	Oriental Bittersweet	<i>Celastrus orbiculatus</i>	Exotic
Song Sparrow	<i>Melospiza melodia</i>	Multiflora Rose	<i>Rosa multiflora</i>	Exotic
White-throated Sparrow	<i>Zonotrichia albicollis</i>	Crabapple	<i>Malus angustifolia</i>	Exotic
Blue Jay	<i>Cyanocitta cristata</i>	Japanese Honeysuckle	<i>Lonicera japonica</i>	Exotic
Tufted Titmouse	<i>Baeolophus bicolor</i>	Bush Honeysuckle	<i>Lonicera sp.</i>	Exotic
Black-capped Chickadee	<i>Poecile atricapilla</i>	Privet	<i>Ligustrum sinense</i>	Exotic
Crow	<i>Corvus sp.</i>	English Ivy	<i>Hedera helix</i>	Exotic
American Robin	<i>Turdus migratorius</i>	Autumn Olive	<i>Elaeagnus umbellata</i>	Exotic
Slate-colored Junco	<i>Junco hyemalis</i>	Rhododendron	<i>Rhododendron sp.</i>	Exotic
Hermit Thrush	<i>Catharus guttatus</i>	Shinning Sumac	<i>Rhus copallina</i>	Native
Northern Flicker	<i>Colaptes auratus</i>	Red Cedar	<i>Juniperus virginiana</i>	Native
Hairy Woodpecker	<i>Picoides villosus</i>	Black Oak	<i>Quercus velutina</i>	Native
Downy Woodpecker	<i>Picoides pubescens</i>	White Oak	<i>Quercus alba</i>	Native
Mourning Dove	<i>Zenaidra macroura</i>	Catbriar	<i>Smilax rotundifolia</i>	Native
White-breasted Nuthatch	<i>Sitta carolinensis</i>	Wild Raisin	<i>Viburnum nudum</i>	Native
Cedar Waxwing	<i>Bombycilla cedrorum</i>	Poison Ivy	<i>Toxicodendron radicans</i>	Native
Northern Cardinal	<i>Cardinalis cardinalis</i>	Wild Grape	<i>Vitis sp.</i>	Native
Carolina Wren	<i>Thryothorus ludovicianus</i>	Blue Spruce	<i>Picea pungens</i>	Native
Golden-crowned Kinglet	<i>Regulus satrapa</i>	Sheep Laurel	<i>Kalmia angustifolia</i>	Native
American Goldfinch	<i>Carduelis tristis</i>	Maleberry	<i>Lyonia ligustrina</i>	Native
		Huckleberry	<i>Gaylussacia baccata</i>	Native
		Blueberry	<i>Vaccinium sp.</i>	Native
		Club Moss	<i>Lycopodium sp.</i>	Native
		Wintergreen	<i>Gaultheria procumbens</i>	Native
		Bracken Fern	<i>Pteridium aquilinum</i>	Native
		Eastern White Pine	<i>Pinus strobus</i>	Native
		Pitch Pine	<i>Pinus rigida</i>	Native
		Bayberry	<i>Myrica pensylvanica</i>	Native
		Sweet Fern	<i>Comptonia peregrina</i>	Native
		Raspberry/Blackberry	<i>Rubus sp.</i>	Native

Table 2: The area (m<sup>2</sup>) of each habitat in Falmouth, MA required to provide the 6g of bird fat needed for a single Blackpoll Warbler to migrate from Canada to the Amazon (~3000km).

Habitat	m <sup>2</sup>
Edge	11.4
Forest	436.4
Rural	7.4

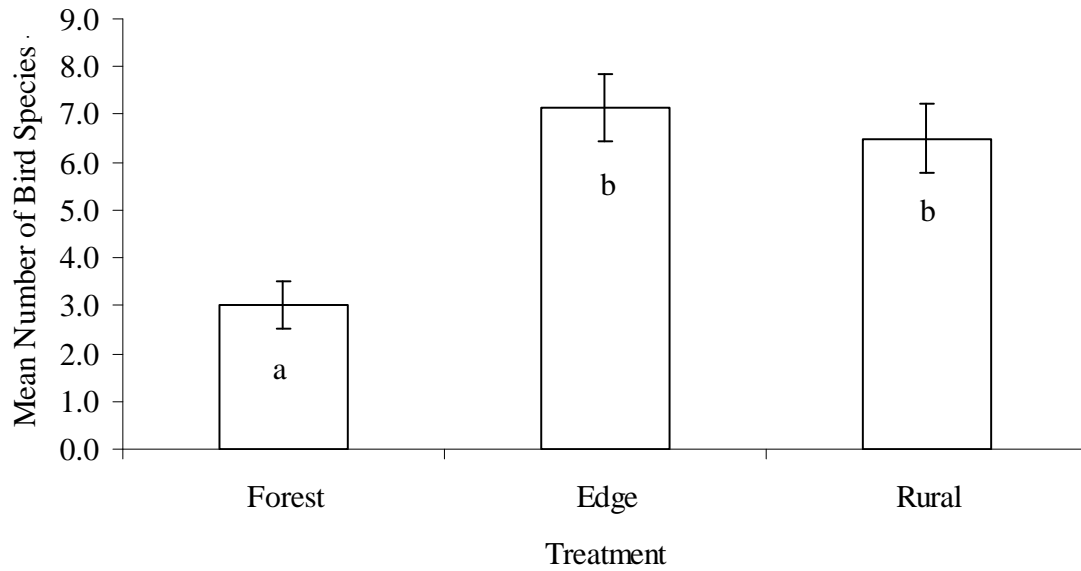
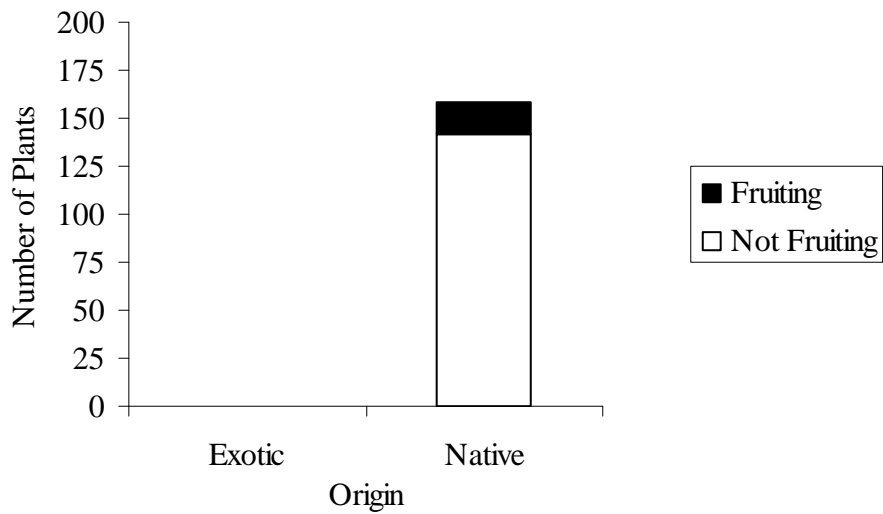
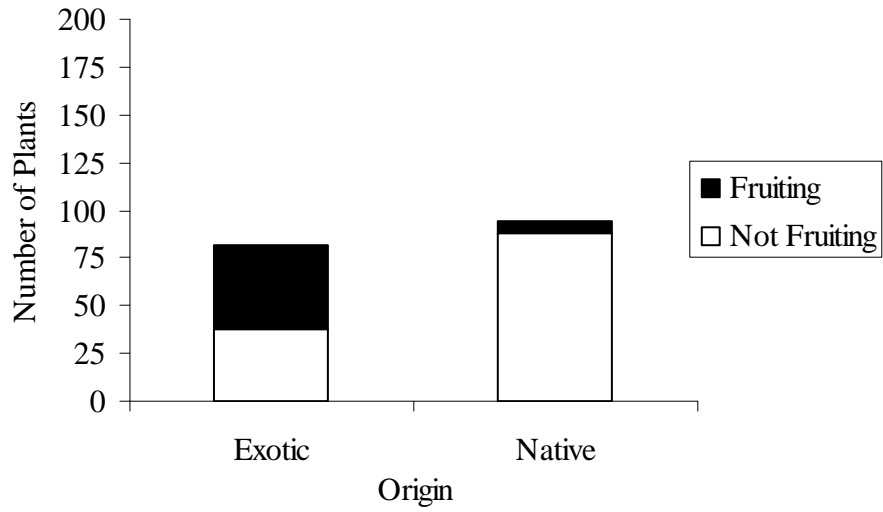


Figure 1: Graph of the mean number of bird species recorded across three treatments during 10 minute sight and sound observations on Cape Cod, MA in November ( $P = 0.0003$ ).

A)



B)



C)

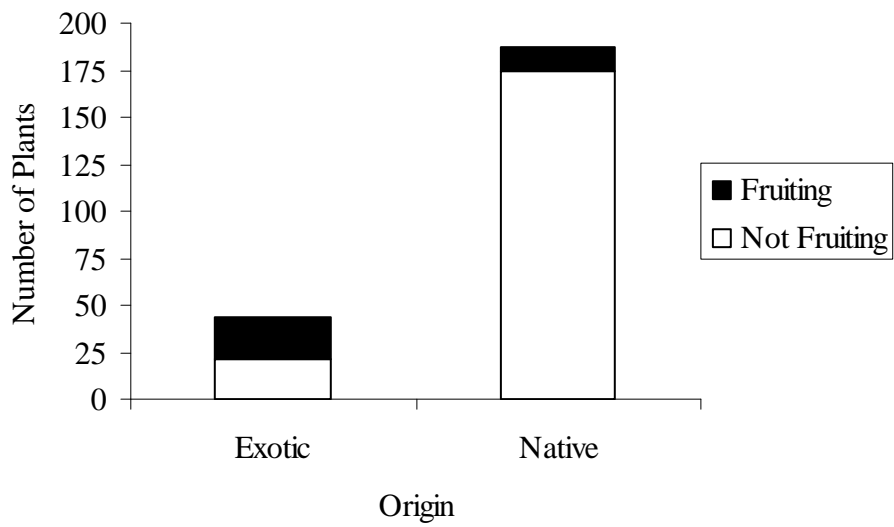


Figure 2: The number of fruiting and non-fruiting native and exotic plants encountered within (A) forest, (B) edge, and (C) rural habitat in Falmouth, MA.

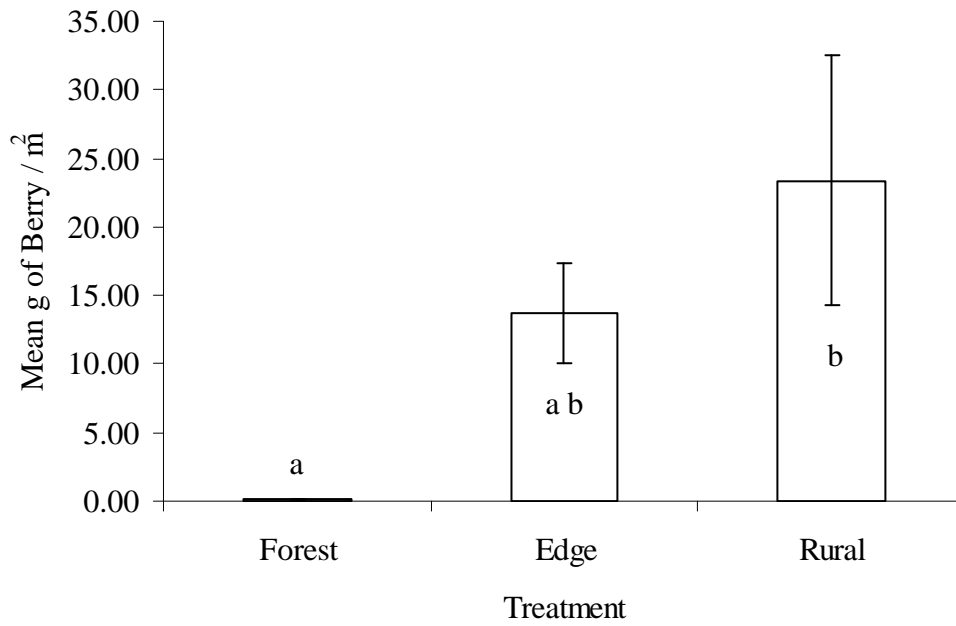


Figure 3: The average mass (g) of berries per m<sup>2</sup> across treatments on Cape Cod, MA. Mass increased with greater levels of disturbance ( $P = 0.0163$ ).

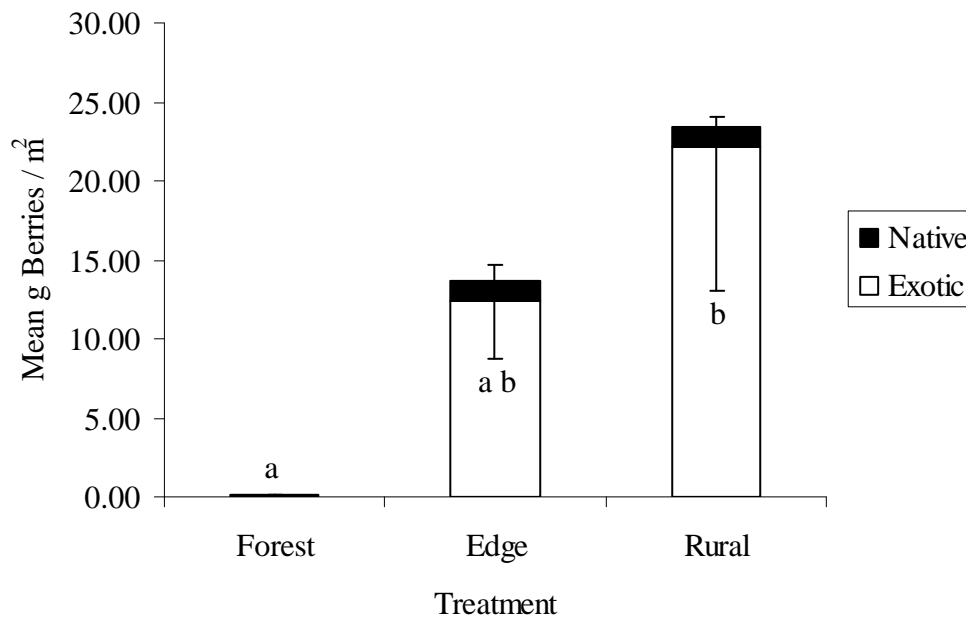
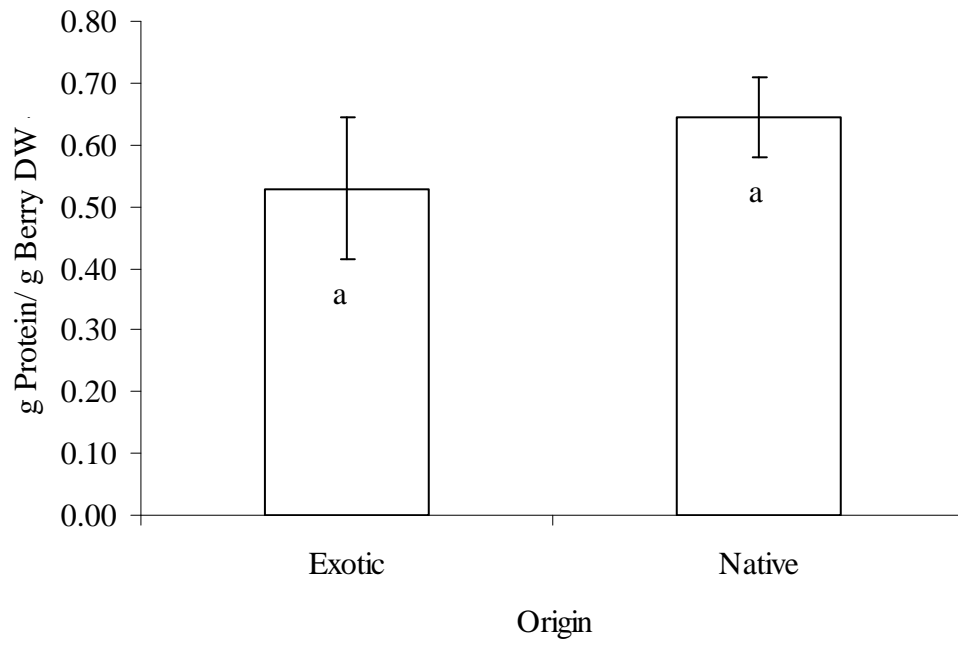
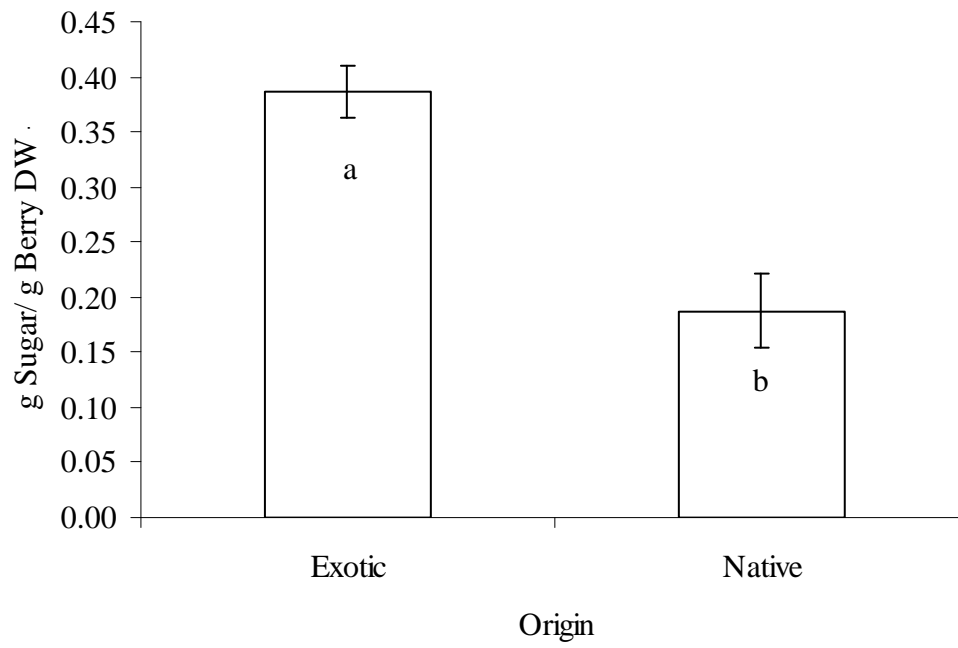


Figure 4: Average mass (g) of berries per m<sup>2</sup> divided by origin across three treatments on Cape Cod, MA in November (exotic,  $P = 0.0227$ ). Only edge and rural treatments had exotics present.

a)



b)



c)

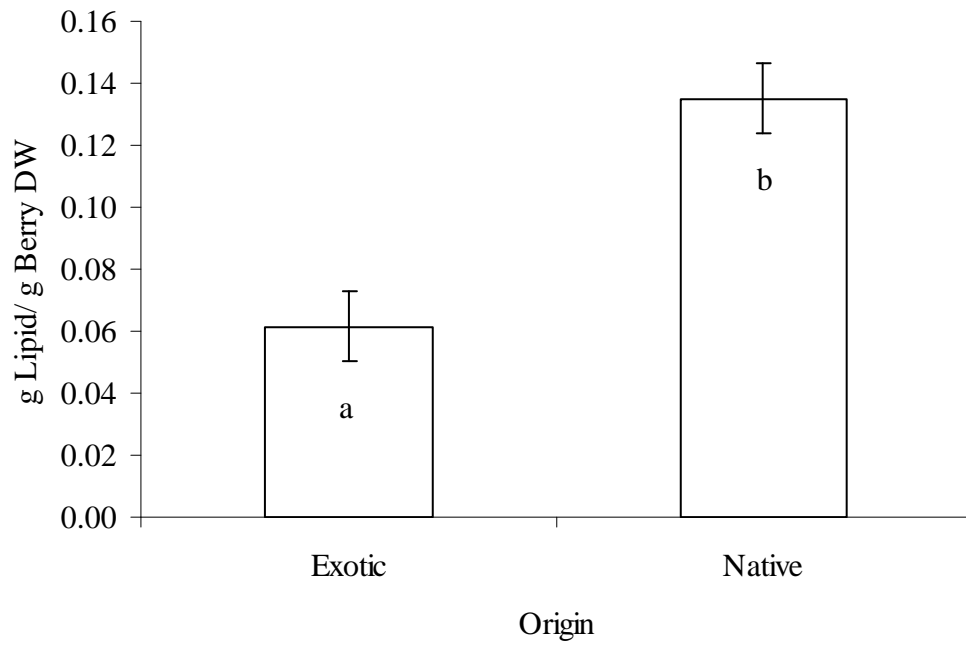


Figure 5: Comparison of protein (a), carbohydrate (b), and lipid (c) content of berry dry weight (g) between plant origins in a study on Cape Cod, MA ( $P = 0.3758$ ,  $P < 0.0001$ , and  $P < 0.0001$ , respectively).