# Impacts of litter manipulation to heathland fauna on Nantucket Island, MA

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## Abstract

Recent ecological changes to Nantucket Island's, MA heathland habitats have lead to a joint restoration effort. Currently three brush-cutting management practices are being studied: (i) cut litter collected and removed ($OM_0$), (ii) cut litter remains on the ground ($OM_1$), or (iii) added to adjacent plots ($OM_2$). Specific characteristics, soil respiration, soil carbon and nitrogen content, organism abundance, richness and diversity, for each litter treatment is compared to the original Scrub Oak Forest (SOF). There were positive relationships between litter disturbance, soil respiration and soil content. Soils with higher carbon and nitrogen contents, relative to litter concentrations, maintained a greater abundance, richness, and diversity of organisms than nutrient poor soils. Soil content thereby increased community complexity. In order to restore heathland habitats it is necessary to minimize soil nutrient content by removing litter and thereby successfully expunge the corresponding connections.

## Introduction

In the past century agricultural practices, specifically domestic animal grazing, on Nantucket Island, MA have reduced significantly. Grazing kept the vegetation low and promoted the growth of heathland plants. However, with the decline in grazing pressures tall shrubs, scrub oaks, and other successional plants have invaded these heathlands. Because of this transformation many of these areas have become unsuitable for rare plants and animals. Active land management practices have been implemented in order to restore the heathland ecosystem. Areas with dense stands of tall shrubs and trees are removed with a combination of mechanical tree removal, hydro-axing, York raking, and brush-cutting. Litter then (i) remains on the ground, (ii) collected and removed, or (iii) added to adjacent plots. Consequently, creating plots with no litter, single litter, and double litter manipulation.

Physical manipulation of soil can often significantly alter the soil ecosystem. Leaf litter fauna can change abundance, distribution, and activities in response to land management practices (Norris, P.,Conroy, B.). Meso and macrofauna, essential for recycling nutrients and transferring energy through food webs, maintain the productivity of soils. Soil microflora and fauna complement each other in the comminuntion of litter, mineralization of essential plant nutrients, and conservation of these nutrients within the soil. Harvesting litter directly affects these processes through the reduction and redistribution of organic matter, changes in plant cover, modification of microclimate, all of which affect the distribution, composition, and activity of soil biological communities (Marshall, V.G.. 1999).

Work in disturbed-forested ecosystems suggests that alteration of soil food web structure can alter the direction of succession. By managing food web structure appropriately, early stages of succession can be prolonged or deleted (Allen.1993). In normal successional sequences the replacement of grasslands with forests requires alteration of soil food web structure from a bacterial-dominated food web in grasslands to a fungal-dominated food web in forests (Ingham, E. et al, 1986). Therefor, any attempt at reversing this succession must focus on altering soil communities.

In soil food webs with increasing complexity nutrient loss is minimized while nutrient cycling and productivity increase. Total ecosystem productivity increases with an increase in soil biodiversity (Moore et al. 1991). Interactions among soil fauna maintain nutrient cycling. Plant growth is dependent on soil food web interactions to mineralize nutrients (Nannipieri et al. 1990). In undisturbed ecosystems, nutrient immobilization and mineralization are closely linked with plant growth. However, with litter disturbance this coupling is diminished or lost (Ingham et al. 1986).

Of three litter disturbance techniques studied on the Calluna heathland, litter raking and removal was the most effective treatment in restoring the heathland (Lowday, J.E.. 1999). Extended periods of litter removal significantly decreased the nutrient content within the soils. Consequently establishing favorable soil conditions, acidic and nutrient poor, for heathland plants. Similarly, it was expected that plots with less litter would have fewer nutrients, support few and less complex ecosystems, and subsequently be more favorable for heathland restoration.

## Site Description

Sandplain grasslands and coastal heathlands are relatively flat, open habitats similar to the prairies found in the midwest. As the name implies, this habitat is dominated by grasses, interspersed with annual and perennial wild flowers such as New England blazing star, ox-eye daisy, trailing arbutus, yarrow, and many species of asters and goldenrods. Patches of low-growing shrubs occur among the grasses and wild flowers. The heathlands contain larger patches of shrubs, including black huckleberry, lowbush blueberry, bayberry, and pasture rose. These low ground cover plants such as bearberry, alpine reindeer moss, and false heather are adapted to growing on these nutrient-poor, gravely soils *(The Conservation Foundation).*

On Nantucket Island, both of these habitats are due to extensive human use, beginning with early Native American settlers, who may have burned extensive portions of the Island. Later, European immigrants, who arrived in 1659, brought large numbers of grazing animals with them. By 1845, there were approximately 15,000 sheep grazing on Nantucket. As the sheep overgrazed the trees and shrubs, low-growing heathland and grassland plants were able to grow. The grasslands and heathlands created by fire, grazing and other human activities now support high concentrations of rare and endangered animals and plants. However, populations of endangered animals and plants are declining, as the large, contiguous areas of open, low-nutrient grassy habitats that they require are permanently lost to development *(The Nantucket Conservation Foundation).*

The decline of grazing pressure has allowed shrub species to grow and out-compete rare grassland and heathland plants. This natural process of succession, if left unchecked, will replace Nantucket's rare plant communities with oak and pine trees, and endangered species will eventually disappear due to lack of suitable habitat. Because these two habitats are the products of human land use practices, active management is needed to prevent them from disappearing. Since 1983, the Conservation Foundation has been involved in cooperative research programs with scientists from the Massachusetts Audubon Society and the University of Massachusetts. In 1996 the Conservation Foundation, the Massachusetts Audubon Society, and The Nature Conservancy entered into a cooperative vegetation management program with the Nantucket Golf Club. The goal of the partnership is to improve habitat for rare plant and animal species. The purpose of this agreement is to decrease the encroachment of shrubs and restore grassland and heathland habitats. Research has shown that prescribed burning, extensive brush-cutting, hydro-axing, and mechanical vegetation removal are effective in maintaining rare grassland and heathland plant communities and providing habitat for their associated wildlife *(The Nantucket Conservation Foundation).*

## Methods

### *Sampling Methods*

Sampling was conducted on litter manipulated plots in the Eastern Moor on Nantucket Island (Fig 1). Each of the litter-manipulated quadrats was chosen at random from the test site (Figure 2). Meso and macrofauna were collected from a no litter ($OM_0$), a single litter ($OM_1$), a double litter ($OM_2$), and three Scrub Oak Forest ($SO_F$) quadrats. In order to minimize disruption to the plots all sampling was contained within a $1m^2$ area.

Two methods were used to collect soil fauna. At the center of each quadrat fresh litter was removed from an area of 20x20cm (.04m$^2$) and stored in litter bags to retain moisture. In order to extract live organisms from the fresh litter, samples were incubated for 120 hours using a modified heat gradient apparatus, Tullgren-Berlese funnels (Schaller,1968).

Pitfall traps were set to collect more mobile fauna. On each of the six test plots, one 350ml plastic cup (8.5cm in diameter) was filled with ~260ml of ethanol and placed into the ground using a bulb corer. So that the traps were level with the litter layer. Traps were set randomly within one meter of litter removal. After 24 hours, traps were collected and contents were sorted by plot.

### *In Situ CO$_2$ Fluxes*

I measured CO$_2$ fluxes with a LiCor Infrared Gas Analyzer (IRGA) 6200 on each of the six plots. On each plot reading were taken every 15 seconds for a total of four minutes on the O/I and Oea layers within the LiCor ring (25 cm diameter).

### *Soil Carbon and Nitrogen Content*

Carbon and nitrogen contents of the soil per plot were determined by grinding the dried soil with a mortar and pestle, wigelbug and Wiley mill, and then analyzing the homogenized soil using a Perkin-Elmer 240 CHN analyzer.

### *Identification and Grouping*

Using Arnett (2000), Behler and King (1995), Borror and White (1970), and Milne and Milne (1996) samples were identified and counted under a dissecting microscope. I organized the organisms into taxonomic categories by morphology. Taxonomic categories were comprised of individuals that appeared to be the same using body shape, size, and color as criteria. I identified organisms into Class and in some cases I was able to identify groups to Order, Suborder and family. Microscope magnification and my limited knowledge of organism anatomy inhibited further identification.

### *Statistical Analysis*

To calculate diversity and equitability of each plot I used two diversity indices, Simpson and Shannon diversity indices (Pielou, E.C.. 1975). These indices provide mathematical measures of the community composition, relative abundance's, and equitability of individuals' distributions.

### *Isotopic Analysis*

Isotopic analysis of fauna was performed by the Stable Isotope Facility at the Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA. Alike samples from each of the plots were combined and isotopically analyzed for δ13C and δ15N. Samples were chosen to represent a variety of trophic levels and the most abundant species. Based on literature I was able to construct a preliminary trophic pyramid and compare it to actual $\delta^{13}$C and $\delta^{15}$N values.

## Results

The meso and macrofauna collected were classified into 12 large taxonomic categories (Table 1). Although most of the faunas were arthropods other invertebrate phylums such as Annelida and Platyhelminthes were also in the soil horizons. With the exception of SOF$_2$ the SOF plots had a greater number of taxonomic groups than the OM plots (Table 2). Of the twelve large taxonomic categories five taxa were predominant in the O/I layer, Oea layer, and the pitfall traps: Acarina, Arustacea, Collembola, Archnomorpha, and Diplopoda in order of abundance respectively (Fig 3 a,b,c,d,e). As expected, the more mobile taxonomic categories have higher abundances in pitfall traps than less mobile organisms. Crustacea, Archnomorpha, Diptera, Protura, Coleoptera, and Lepidoptera were more often located in pitfall traps than in the soil horizons. While the less mobile organisms, Acarina, Collembola, Diplopoda, Hymenoptera, and Platyhelminthes were more prevalent in the soil horizons. Hymenoptera, Oligochaete, Protura, Coleoptera, and Lepidoptera were not well distributed throughout the soil horizons and the plots, as the remaining taxonomic categories appeared to be better distributed among the different plots. However, only three taxa: Acarina, Collembola, and Archnomorpha were found at each plot (Fig 4). This was expected because Acarina and Collembola are distributed throughout the world in almost every conceivable habitat and frequently occur in large numbers.

The Simpson and Shannon Diversity Indices are mathematical measures of species diversity in each plot. The Simpson index characterizes the taxonomic diversity of the community while the Shannon index provides more information about their respective community composition rather than just richness. It takes into account the abundance and equitability or eveness of the different taxonomic categories. If one measures a plots' community diversity simply by taxonomic richness (S), than on average all of the litter manipulation plots have similar richness' (Table 3). However, none of the plots had the same Simpson diversity (D), Shannon diversity (H), or equitability ($E_D$ and $E_H$ respectively).

If the data from the Scrub Oak Forest is averaged, the Simpson diversity index ranks the diversity of the plots as follows: (in descending order) $OM_1$, SOF, $OM_0$, and $OM_2$ (Table 3). The equitability ranking is SOF, $OM_1$, $OM_2$, and $OM_0$. For both D and $E_D$ control and single litter plots are the most diverse and taxonomically even. The Shannon index ranks plot diversity and equitability (in descending order) $OM_1$, $OM_0$, SOF, and $OM_2$. Because the two indices do not test for the same characteristics within a community their rankings for diversity and equitability are different. Regardless, it is obvious that the diversity and equitability indexes for the $OM_1$, $OM_0$, and SOF are similar. Although the double litter manipulation had comparable organism abundance it had substantially lower diversity and equitability indices. In addition, I was able to evaluate community diversity and its relationships with community properties and environmental conditions (Pielou, E.C.1975). In this case, the diversity indices strongly correlated with average soil respiration and carbon and nitrogen content per plot.

Soil organisms alter the physical, chemical and biological properties of soil (Beare, M.H. 1995). On each of the plots, soil respiration tended to increase as the amount of litter increased (Fig 5). There is no real consistency among the SOF plots with regards to soil respiration. However, the average soil respiration value for the SOF is similar to the respiration of the $OM_1$ treatment. In terms of respiration this suggests the SOF resemble the $OM_1$ plots more than the other litter treatments. There seems to be a positive relationship between litter manipulation and soil respiration.

This same relationship also occurs between soil respiration and the abundance, richness (S), and diversity (D, H) (Fig 6). As presumed, soil respiration increased as the number of respiring organisms or abundance increased. This elevation in respiration also corresponds with increases in S. When coupled with increasing abundance, D and H simultaneously increase. There is a strong correlation ($R^2 = 0.5597$, $R^2=0.9595$) respiration and D and H. It can then be assumed that the greater the number of individuals and the richer a community, the greater the rate of respiration. Similarly, a positive relationship occurs among soil carbon and nitrogen content and the absolute number of individuals, the richness (S), H, and D (Fig 7 & 8). $OM_2$, which has the lowest carbon and nitrogen content, also had the smallest H and $E_H$ (Fig 9). Soils with higher carbon and nitrogen contents can maintain greater numbers of individuals than nutrient poor soils. Because of this, nutrient rich soils are more likely to support more species, increasing richness and diversity within the plots. According to McBrayer chemical nutrient availability may impose the most serious limitations on soil animal populations (1997).

The organisms found within the soil horizons and on the surface were also studied as a community. These organisms were grouped broadly as meso and macrofauna. Under this heading organisms were further classified by feeding habits, size, and morphological differences (Table 1). Based in literature, I constructed a preliminary food web that included each of the taxonomic categories (Fig 10). With the isotopic $\delta^{13}C$ and $\delta^{15}N$ values I reassessed and reconstructed my initial diagram (Table 4 and Fig 11). Because Diptera had a higher $\delta^{15}N$ values than expected it was necessary to move Diptera from a $2^o$ consumer to a $3^o$ consumer. From the isotopic analysis it is evident that selectivity of food material varies seasonally and by life stage (Luxton, M. 1982). Although Hymenoptera had a high $\delta^{15}N$ value it remained as a $1^o$ consumer because it principally feeds on soil organic matter (SOM), which $\delta^{15}N$ becomes isotopically heavier overtime (Nadelhoffer, K.J. 1994). No other changes were made to the complete food web.

In addition, I devised plot specific food webs (Fig 12). The SOF diagram, which had the greatest richness (S), most closely resembled the complete food web. It appears that as litter concentrations increase so does trophic complexity. However, it is possible that the lack of complexity is also due to disturbance. It is apparent that the undisturbed SOF is the most rich and complex ecosystem, while the no litter site hosts the least rich and most simple ecosystem. Litter layer removal could increase the amount of disturbance and adversely affect each community. In general, arthropod numbers and diversity will increase with a decrease in disturbance (Kay, F.R. et al. 1999).

## Summary

Meso and macrofauna collected from $OM_0$, $OM_1$, $OM_2$, and SOF plots were classified by morphology and food source into 12 broad taxonomic categories and quantified. From these counts, statistical analysis determined a positive relationship between litter manipulation, soil respiration and soil content. The greater the number of individuals and the richer a community per treatment type, the greater the rate of respiration. Soils with higher carbon and nitrogen contents maintained a greater abundance, richness, and diversity of organisms than nutrient poor soils. Increased litter causes an increase in soil carbon and nitrogen content. These higher nutrient levels supported a greater abundance, richness and diversity of organisms. Thereby increasing the community complexity. In order to restore heathlands it is necessary to minimize soil nutrient content through litter removal and thereby successfully expunge the corresponding connections.

## Acknowledgments:

I am grateful to the Massachusetts Audubon Society and the Nantucket Conservation Foundation, owners of the Nantucket heathlands, to the members of the Partnership for Harrier Habitat Preservation (PHHP), and the University of Massachusets field station, thank you for granting me permission to study the Eastern Morre. Special thanks are extended to Dr. Ernest M. Steinauer, Dr. Gus Shaver, Dr. Knute Nadelhoffer, Dr. Marshal Otter, Dr. Martin Sommerkorn, MaryKay Fox, Pat Micks, Robyn Chiarelli, and Catherine Taylor for valuable help, critiques, and suggestions.

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Figures not available