Important notes from Rob:

*King and Tschinkel, 2008, our model PNAS paper is 3,500 words. Keep it short and to the point.*

Title(s):

Not all non-native shrubs provide equally poor food resources to insectivorous songbirds

Abstract:

Biological invasions threaten biodiversity by outcompeting native species and disrupting food webs. Invasive species are highly ranked as causal agents in the decline of endemic populations. Non-native woody plants now occupy nearly every conceivable habitat in terrestrial ecosystems as a result of human activity, either through intentional or unintentional introduction. Removal of invasive shrubs to improve habitats costs conservation organizations xxx million dollars a year. In eastern North American temperate forests, understory plant communities are now dominated by exotic species, in many cases being more numerous that native plants. As the base of forest food chains, it stands to reason that wildlife would be significantly and negatively impacted by the prevalence of invasive plants. For many species of insectivorous birds and mammals, invasive plants threaten populations by provided less food resources and food resources of lower quality. From the plant-insect interaction literature there are several mechanisms proposed: first, invasive plants have lower densities of herbivores compared to native congeners. Second, invasive plants have lower nutritional quality, so herbivores that do feed on them have lower nutrient density. Third, invasive plants have traits not seen in native habitats, such as distinctive architecture, and this provides microhabitat for insects resulting in highly modified insect community composition. As such, it is predicted that wildlife, like migratory insectivorous songbirds, will face significant challenges in meeting nutritional needs in habitats dominated by invasive shrubs. In this project, we tested the hypothesis that food availability and food quality for insectivorous songbirds is lower on inside woody plants compared to native woody plants in the same habitat. Using a wide range of host-plant species, including 6 native species and 4 invasive species, we quantified the prey being taken by birds and the nutritional content of those arthropod guilds. Contrary to predictions from other systems, non-native plants did not have lower abundance or quality of insect prey overall compared to native plants overall. Instead, we saw a wide range of nutritional quality among our exotic host plants, suggesting that not all species are equally detrimental to songbird food availability. These results do not suggest that invasive plants are not worth removing, but it instead suggests that management efforts need to prioritize removal of invasive species over others. Invasive plant management needs to take a more nuanced approach for improving habitat for wildlife given the food quality of some invasive plants is on par or superior to native woody plants in the same habitat.

Keywords:

Invasive species, invasive plants, insectivores, songbirds, forests, food webs, habitat improvement

Introduction:

*P1 – The impacts of invasive plants and cost of removal*

Invasive species are the leading cause of biodiversity decline globally, and to address this challenge over xx billion dollars is spent every year to manage invasive populations. Removal of invasive species is costly, but it can also be a highly effective way to conserve endangered species or maintain ecosystem services. Invasive woody plants are particularly challenging to manage in terrestrial ecosystems, with xxx million dollars spent removing them from forested habitats (find data from the invasive species management database). These management decisions are based on the goals of resource management, whether it’s facilitating the growth of native trees for forestry, improving habitat for native wildlife (some southwestern stuff), or preserving habitat for endangered species (phragmites stuff I think), or even reducing disease risk for humans (tick + barberry stuff). However, there are case studies in which invasive plants do not have as negative impacts on environments as other invasive species. Consequently, effective management should prioritize invasive species that (a) are most damaging and (b) contribute to the management goals. However, despite the importance of invasive plant management, comprehensive data on how to prioritize invasive plant removal is lacking.

*P2 – Negative impacts on wildlife as a case study in invasive plant biology*

Plant invasions have cascading impacts on all higher trophic levels by altering above-ground and below-ground food webs. Changes to food chains as a result of plant invasions has been documented in nearly every terrestrial ecosystem, and it is particularly prevalent in habitats experience frequent anthropogenic disturbance (meta-analysis citations). To ameliorate these negative impacts, invasive plant removal if a central feature of habitat improvement plans. In some systems, removal of invasive plants has promoted healthy wildlife populations and facilitate the recovery of declining species (find case studies). In many cases, invasive plant removal plans suggest removal of all non-native woody species. Frequently non-native co-occur and have overlapping impact areas (citation on co-occurring invasives).

*P3 – Motivations for invasive plant management and the implicit assumptions about lower food quality in habitat restoration efforts*

The mechanisms by which invasive plants disrupt forest food webs has been well documented, but broad patterns still differ among host species. Typically, invasive plants are lower quality food sources for insect herbivores compared to native conspecifics (there are a million citations on this, a few from stuff like Norway maple would be ideal). As a result of lower nutritional quality, these invasive plants can host dramatically lower herbivore abundance and fewer species of herbivores. In cases where invasive plants have displaced natives, prey availability for insectivorous birds and mammals are significantly reduced. However, nutritional quality for herbivores is just one of multiple traits of invasive plants that impacts food webs. Allelopathic compounds released from invasive plants through roots and decaying leaves can impact soil food webs and insect prey. Furthermore, invasive plants have atypical architecture compared to native plants (spider paper citations), leading to different compositions of arthropods independent of the host plant quality (more of the spider paper citations).

*P4 – Hypotheses and predictions (this paragraph is not in other PNAS papers, but its important to me to use it as a narrative tool)*

At the community level, non-native plants are expected to have significantly lower prey available for insectivores compared to native plants in the same environment. Furthermore, the insect prey found on non-native plants expected to have lower nutritional quality for these insectivores as well (citation on N content of bugs on invasives). Due to lower abundance and quality of prey, it is generally anticipated that vertebrate insectivores will make optimal foraging decisions and invest less effort into finding food on invasives. As a consequence, the predatory effects of these insectivores should be weaker overall on non-natives vs. native plants. In our system, we tested these three paired hypotheses & predictions. First, that in a shared habitat a group of native woody plant species should have more insect prey than non-native woody species. Second, predation effects will be weaker on native vs non-natives plants overall in the same habitat where insectivore habitats overlap. Third, the nutritional quality of herbivores and other arthropods should be lower on natives vs. natives within these same managed habitats as well.

Methods:

*In PNAS Methods are presented at the end. To save space some methods are put into the supporting information documents*

Results:

P6 – Arthropod biomass across the ten species and bird treatments

P7 – community composition reporting what taxonomic groups birds are removing from native and non-native plants

P8 – Nutritional quality data (again, only 2 paragraphs in King and Tschinkel, 2008)

Discussion:

P9 –

P10 –

P11 –

P12 –

Methods:

P13 – bird exclusion and great hollow habitat information

We performed a selective predator exclusion treatment on ten woody host plant species at Great Hollow Nature Preserve & Ecological Research center (Fairfield Co., Connecticut, USA). This 834-hectare forest preserve follows a USDA forestry conservation plan aimed at managing for outdoor recreation and wildlife habitat. In April and early May 2021, we applied mesh netting to indidual branches or entire shrubs and paired each invidual plant with an unmanipulated control (Methods following Singer et al. 2012 – amnat paper). All pairs of predator exclusions occurred in areas where the overstory tree composition is dominated by *Betula lenta* and *Fagus grandifolia*). We intentionally chose locations that would typically be targeted for invasive shrub removal, with a dense understory including *Berberis thunbergii*, *Lonicerna* spp (Bush honeysuckles), *Eunonymous alatus*, and *Eleagnus umbellata*. Native understory shrubs and include *Acer pennsylvanicum*, *Amelanchier arborea*, *Carpinus caroliniana*, *Hamamelis virginiana*. Reflecting this community composition, our predator exclusion occurred on this pool of ten common species: two overstory trees (saplings were manipulated), four native understory woody plants, and four invasive species. [**I know this is written oddly, but I want to make the point that we didn’t pick the plants, we picked the habitat. We worked with the species actually in the forest here in locations that would typically be managed for invasives. I believe that is critical to highlight -I’m open to ways to highlight this more.]**

P14 – arthropod id and processing

All invertebrates collected in the field were transferred immediately to 7 × 3cm plastic vials or 16 × 8cm plastic zip-top bags and preserved in a –18° C lab freezer. Afterwards, specimens collected on entire experimental branches were weighed (wet mass) on a 10^-4 g microbalance. All invertebrates were identified to class. Common arthropod species (those observed > 25 times) were then identified to order, and all insects in the orders Lepidoptera, Hemiptera, Hymenoptera were identified to family. True spiders (Araneae) and Opiliones were identified to family as well. All invertebrate sorting and taxonomic identification was completed from June 2021 to August 2021. Once identifications were complete, all taxonomic groups from each individual branch sample and placed into 0.6mL and 2mL Eppendorf tubes kept in the lab freezer for later processing.

P15 – nutritional quality methods

Frozen arthropod samples were assayed for nitrogen % using xxx method. [Can you guys write up the C:N methods in detail?]

P16 – stats methods 1

We employed a series of Generalized Linear Mixed Models (GLMMs) using the lme4 package (citation) in R version 4.1.2 (citation). These univariate analyses use the following as response variables: (1) total arthropod biomass sampled per plant in grams, (2) spider abundance (Araneae), (3) caterpillar abundance (Lepidoptera), (4) Hemiptera abundance, and (5) aquatic insect abundance (Stoneflies and Mayflies), (6) C:N Content of spiders, and (7) C:N content of putative herbivores. Arthropod biomass (1) was fitted as normally distributed variable after a log-transformation. All abundance models were fitted using the negative binomial distribution (citations). C:N ratio models were fit using the xxx distribution (or this fitted as % mass that is N). Related to these GLMM’s, we performed a set of diagnostic tests to determine the impact of leaf counts on arthropod biomass among host-plant species (Appendix 1). Posthoc tests comparing changes in biomass, spider abundance, true bug abundance, caterpillar abundance, and tree cricket & katydid abundance were run using the emmeans package in R (Lenth 2009). Differences were investigated across all groupings using Scheffe’s method (following Midway et al. 2020) for P-value adjustment in unplanned contrasts.

P16 – stats methods 2 **[overflow for field methods information if needed. We probably want more about the experimental design and location, maybe each in their own paragraph]**

P18 – **(K&T had 6 short methods paragraphs, but I don’t think we need that much, save the space for the intro or results)**

Fig. 1a. & 1b.

Diagram

Description automatically generated

Figure 2a & 2b & 2c & 2d

Chart

Description automatically generated

Figure 4: (Not table like in K&T)

Nutritional quality plot (C:N ratio), this should only be a clustered bar chart with the 2 groups among the 10 species if possible.

Supporting information:

GLMM table 1

GLMM table 2

GLMM table 3

Variation in insect abundance among native and non-native plants plots from seminars