Ecological Niche Modeling for *Erythrina herbacea* and *Lonicera sempervirens* and their Projected Response to Climate Change

Anthony Liao, JT Miller, Douglas E. Soltis, Pamela S. Soltis, and Makenzie E. Mabry

ABSTRACT

Florida hardwood forests host numerous plant and animal species, many of which are endangered. Florida's unique geography and geology provide habitats for many temperate as well as tropical species, allowing for numerous, diverse ecosystems. Studying these ecosystems helps in conserving biodiversity. The goal of our project is to find occurrences of specific hardwood forest species, create niche models, and use those models to estimate what their distributions might look like in the future given current projections for climate change. That is, where will the suitable niche space for these species be located in the future? The two species discussed here are *Erythrina herbacea,* a thorny shrub with brilliant red flowers and *Lonicera sempervirens*, an understory vine with red trumpet-shaped flowers. For *Erythrina herbacea*, we predicted that its niche would expand within Florida hardwood forests, but would be much less suitable overall in the United States than currently. For *Lonicera sempervirens*, we found that its niche would decrease in Florida hardwood forests; however, overall its suitability doesn't change much across the United States. These findings combined with similar projections for other hardwood forest species will allow us to better understand how Florida plant communities may change; certain species may become more narrowly distributed and others may expand or alter their range.

INTRODUCTION

Florida is a part of the North American Coastal Plain, the world's 36th biodiversity hotspot. It contains 1,816 endemic plant species with greater than 70% habitat loss [1]. Florida itself has a wide range of climates and geology from the southernmost point to the northern regions, which lead to very diverse ecologies and species throughout Florida. Our plant community of focus for this project is upland mixed hardwood forests in Florida. These regions are defined by mesic or xeric forest dominated mainly by hardwood trees, with well-draining, sandy soil that has more organic matter and moisture relative to adjacent communities. They are usually found on slopes between upland pinelands and lake margins, floodplain forests and marshes, or uplands protected from fire. This individual project focuses on two species found in hardwood forests, *Erythrina herbacea* and *Lonicera sempervirens.*

Figure 1. A) *Erythrina herbacea*, B) *Lonicera sempervirens*

Erythrina herbacea (Figure 1.A), also known as Coral Bean or Cherokee Bean, is a flowering shrub or small tree found through the Southeastern US, Northeastern Mexico, and parts of South America. It grows the best in sandy soils and is found in open woods, forest clearings, hammocks, and disturbed areas. It is a herbaceous perennial around 3' to 4' tall with a woody base and sharp prickly stems, and is sometimes vine-like and multi-stemmed. The leaves are compound, tri-foliate, or spade-shaped, around 6" to 8" long and alternately arranged. The leaves are yellowish-green and smooth. The leaf margins are entire. Stems are thin with tiny spines. The flowers are bright red tubular blossoms that are clustered on long stalks, and they bloom around May. It creates aa dry pod about 4" to 6" long that contains reddish-orange seeds. Other synonyms for this species include *Erythrina arborea, Erythrina hederifolia, Erythrina humilis, Erythrina rubicunda, Corallodendron herbaceum,* and *Xyphanthus hederifolius.*

Lonicera sempervirens (Figure 1.B), also known as Coral Honeysuckle or Trumpet Honeysuckle, is found from Northeastern America to Florida, and as west as Texas. It grows as a climbing vine that needs support and grows well in various soil types from sandy to clay but prefers rich and well-drained soil. It is a big pollinator attractor. As a climbing vine, stems can grow up to about 20 feet long. It has smooth, glossy, paired, and semi-evergreen leaves with rolled down margins. Flowers are two inch long showy trumpet-shaped flowers that are red outside and yellow inside, with tubular blooms. Other synonyms for this species include Lonicera sempervirens L. var. hirsutula Rehder, Lonicera sempervirens L. var. minor Aiton, and Lonicera sempervirens L. var. sempervirens. Phenianthus sempervirens (L.)

As climate change progresses into the future, certain species may find it harder to survive in certain areas they were originally endemic in. Florida hardwood forests support a diverse range species, however as temperatures rise and rainfall patterns shift due to climate change, these ecosystems may face significant disruptions. Species that are adapted to specific temperature and moisture conditions may struggle to survive or migrate to more suitable habitats, leading to shifts in biodiversity and potential species loss. To address this, we use environmental niche modeling (ENMs) to predict the habitat suitability of certain species in regions using climate modeling predictions and knowledge of current species distribution. Looking into the future, we can model certain species habitat suitability and use this information to direct conservation efforts.

METHODS

Downloading records and taxonomic names

We used all the accepted synonyms for each species, put them in the lists, and passed them through the gators_download function to download all occurrence records from iDigBio and GBIF into a CSV. The data was downloaded on 2/12 and 2/14. The synonyms used for each species was found from Florida Atlas [2]. R version 4.3.2 (2023-10-31), the libraries devtools, dplyr tidyr, plyr, spocc, ridigbio, tibble, and gatoRs was used.

Occurrence record cleaning and mapping

We used the R libraries dplyr, tidyr, raster, sf, spThin, fields, lubridate, gatoRs, CoordinateCleaner, and R version 4.3.2. We read in all the raw data points for *Erythrina herbacea* and *Lonicera sempervirens* into two dataframes. We then filtered it to remove every sample it found that wasn't part of our accepted species synonyms list for both species. We filtered N/As, changed the precision of the latitude and longitude, and removed latitude and longitude values that were zero. We removed Cultivated, Outlier, and Centroid coordinates. We then removed duplicates, did spatial thinning based on nearest neighbor, and spatial correction to keep only one sample per pixel. We did a basis of record check to exclude certain samples that came from non-accepted, cleaned points that were out of the native distribution found on POWO [3], and wrote the final table out to a csv. Using this table, we generated maps that displayed occurrence points.

Environmental variables and species training layers

We used the R libraries raster (V 3.6-26), gtools (V 3.9.5), dplyr (V 1.1.2), sp (V 2.0-0), rangeBuilder (V 2.1), sf (V 1.0-15), caret (V 6.0-94), usdm (V 2.1-7), dismo (V 1.3-14), stringr (V 1.5.1), rJava (V 1.0-6), gatoRs (V 1.0.1), and ggpubr (V 0.6.0), along with R version 4.3.2. We first loaded climate and soil data rasters and stacked them together. We then read in our cleaned records, and for each species we created a data frame that holds all the spatial points for each occurrence. Using this data frame, we created an alpha-hull that encloses all our occurrence points including a buffer of the 80th percentile of the max range between two occurrences from the outer points- 6606 meters for Erythrina herbacea and 10,918 meters for Lonicera sempervirens as buffer distances. This is the area that we defined as our accessible area for each species. We then applied this accessible area to our climate and soil rasters so that they would only have data in the region we are considering for each species. The next step we used the VIF function to look through all the environmental variables and select the variables that have the least amount of collinearity between each other to use for our ENM model. We used a threshold of 10, meaning that anything that is above 10 has significant multicollinearity and shouldn't be used in our model. After the VIF function we saved the environmental variables that had multicollinearity less than 10 from VIF.

Ecological niche modeling

We used the R libraries ENMeval (V 2.0.4), gtools (V 3.9.5), dplyr (V 1.1.2), dismo (V 1.3-14), ggplot2 (V 3.4.4), viridis (V 0.6.4), devtools (V 2.4.5), kuenm (V 1.1.10), rJava (V 1.0-6), and R version 4.3.2. Our steps were to read in the maxent ready file with all the endemic occurrences and create ENMs for both species. The models we tested were ("L','LQ""LQH""H"), meaning linear, linear quadratic, linear quadratic hinge, and hinge. These models feature classes from the environmental variables to generate the ENMS. Our partitions are blocks, which are geographical folds that section occurrence points into training and testing sets grouped by geographic blocks. We used 10,000 background points randomly distributed in our accessible area for the specific species. The algorithm we are using is maximum entropy, which predicts the suitable range for the species given the occurrence's environmental variables and the environmental variables of other areas. We generated ecological niche models for our defined accessible areas from the previous step.

Current and future model projections

We first the R libraries tidyverse 2.0.0, raster 3.6-26, gtools 3.9.5, dplyr 1.1.2, dismo 1.3-14, devtools 2.4.5, kuenm 1.1.10, ggplot2 3.4.4, ggspatial 1.1.9, and viridis 0.6.4. We then loaded our endemic maxent species file and bioclim layers. Then, for both species we got the rasters that were used for species models from VIF and got the rasters for the hardwood upland areas. We used dismo predict to the suitble area, and plotted the maps. We then looked to see how many pixels/species were within the defined hardwood regions. We projected to 2041-2060 and 2081-2100 using ssp126 and ssp585 climate models for both Florida upland hardwoods and the entire United States. We generated maps that display each species' habitat suitability in Florida hardwoods and the United States, and predicted ranges they would lose or gain in Florida hardwoods compared to current distributions.

RESULTS

Downloading records and taxonomic names

Table 1. describes each species and how many records were originally pulled from the gatoRs function. After cleaning as described in the previous methods section, we ended up with significantly less data points that were usable. All modeling following used the Endemic only data points.

Table 1. Number of occurrence records before and after cleaning.

Species	Raw Records	Cleaned records	Endemic only records
Erythrina herbacea	8142	3331	3331
Lonicera sempervirens	12407	4659	4598

Occurrence record cleaning and mapping

Figure 2.A refers to the distribution of *Erythrina herbacea*, which is found throughout the southern US and along the east coast. Figure 2.B refers to the distribution of *Lonicera sempervirens*, which is found along the southern US and along the coast into Mexico. These are found in the endemic range for both species.

Figure 2,A

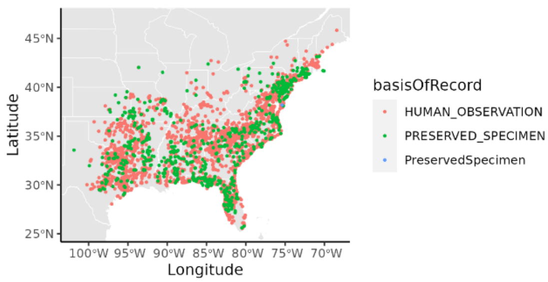

Figure 2.B

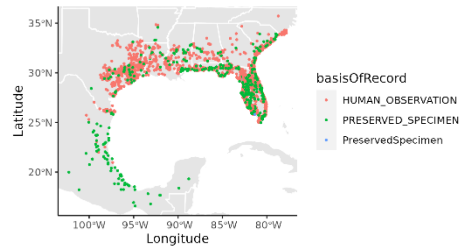

Figure 2. Cleaned endemic records, mapped by basis of record. A) *Erythrina herbacea* B) *Lonicera sempervirens*

Environmental variables and species training layers

Species training layers were used from WorldClim [4] and SoilGrids [4] to develop robust ENMs. WorldClim provides comprehensive climate data variables for each pixel. SoilGrids offers essential soil-related variables like soil pH, organic carbon content, and soil texture for each pixel. As described in the methods, we used VIF to find the environmental variables from both WorldClim and SoilGrids for each species that had a multicollinearity less than 10. The environmental variables came from the accessible area based on where species were found as seen above in Figure 2.

For *Erythrina herbacea* our climate variables are bio2-mean diurnal range, bio5-max temperature of warmest month, bio8-mean temperature of wettest quarter, bio9-mean temperature of driest quarter, bio13-precipitation of wettest month, bio18-precipitation of warmest quarter, bio19-precipitation of coldest quarter.

For *Lonicera sempervirens* our climate variables are bio2-mean diurnal range, bio4-temperature seasonality, bio8-mean temperature of wettest quarter, bio9-mean temperature of driest quarter, bio13-precipitation of wettest month, bio14-precipitation of driest month, bio18-precipitation of warmest quarter.

Ecological niche modeling

For Erythrina herbacea, the optimal model was found to use all three feature classes linear, quadratic, and hinge. The optimal regularization multiplier was 4.5. For Lonicera sempervirens, the optimal model was found to use linear and quadratic feature classes, and a regularization multiplier of 0.5.

Table 2. Optimal models.

Species	**Optimal model**
Erythrina herbacea	fc.LQH_rm.4.5
Lonicera sempervirens	fc.LQ_rm.0.5

For *Erythrina herbacea*, the top two variables that contribute to the models are total nitrogen, which increases habitat suitability as there is more nitrogen, and volumetric fraction of coarse fragments, which decreases habitat suitability as it increases. For *Lonicera sempervirens*, the top two variables are precipitation in the coldest quarter, which decreases habitat suitability as it increases, and proportion of silt particles, which has a sweet spot around 230g/kg and declines as it increases.

A) B) C) D)

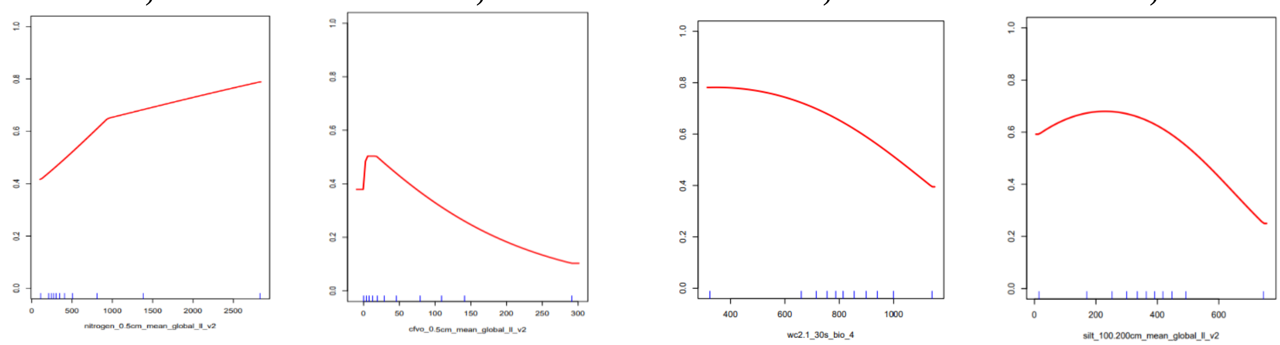

Figure 3. Top two variables that contributed most to the model for *Erythrina herbacea*, A) Total Nitrogen at 0.5cm depth (cg N/kg soil), B) Volumetric fraction of coarse fragments (> 2 mm) (cm^3/ dm^3 (vol‰)), and *Lonicera sempervirens* C) Precipitation of Coldest Quarter (mm), D) Proportion of silt particles (≥ 0.002 mm and ≤ 0.05 mm) (g/kg)

Current and future model projections

Current projections for both species in Florida upland mixed hardwood forests show high habitat suitability, with most regions being above 75% for *Erythrina herbacea*, and most areas above 50% for *Lonicera sempervirens*. For *Erythrina herbacea* there were 151 records found within this region, with a suitability score from 0.5477841 to 0.9416704 with an average of 0.7563864. For *Lonicera sempervirens* there were 66, with a low range of 0.500488 and a high range of 0.8553108 and an average of 0.6999264. Both species are currently well distributed within this community.

A) B)

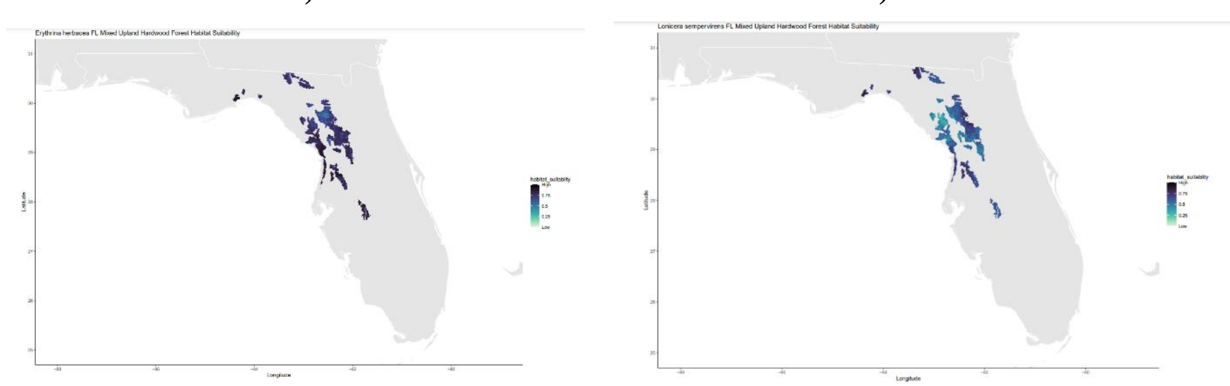

Figure 4. Current habitat suitability of A) *Erythrina herbacea* and B) and *Lonicera sempervirens* in Florida upland mixed hardwood forests.

From our modeling shown in Table 3, Figure 5, and Figure 6, we can see that *Erythrina herbacea* is predicted to gain range in the coming future in all models, however it will have low habitat suitability in Florida hardwood forests. *Lonicera sempervirens* on the other hand is predicted to decrease in range in Florida hardwood forests. It shows lower habitat suitability within Florida hardwood forests compared to the current model, and it is predicted to do poorly and lose range in all models. It seems to still be relatively medium habitat suitability.

Table 3. Suitable habitat changes from current projection to future projections.

Species	Year	SSP	% loss	% gain	Species Range Change
Erythrina herbacea	2041-2060	SSP126	24.128%	37.263%	13.134%
Erythrina herbacea	2041-2060	SSP585	26.562%	38.195%	11.633%
Erythrina herbacea	2081-2100	SSP126	24.37%	37.349%	12.979%
Erythrina herbacea	2081-2100	SPP585	29.099%	39.61%	10.511%
Lonicera sempervirens	2041-2060	SSP126	34.301%	22.835%	-11.466%
Lonicera sempervirens	2041-2060	SSP585	34.591%	22.835%	-11.756%
Lonicera sempervirens	2081-2100	SSP126	34.398%	22.787%	-11.611%
Lonicera sempervirens	2081-2100	SPP585	35.849%	22.206%	-13.643%

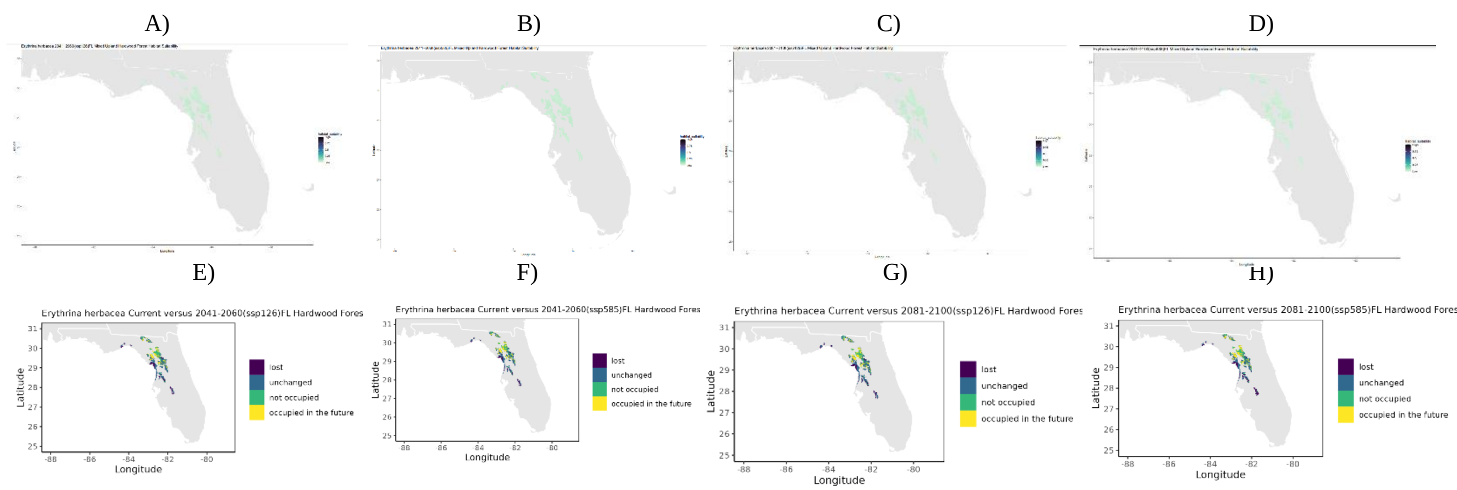

Figure 5. Future habitat suitability in FL hardwood forests for *Erythrina herbacea* in A) 2041- 2060 (ssp126), B) 2041- 2060 (ssp585), C) 2081 – 2100 (ssp126), and D) 2081- 2100 (ssp585). E – H) Corresponding maps of habitat suitability changes.

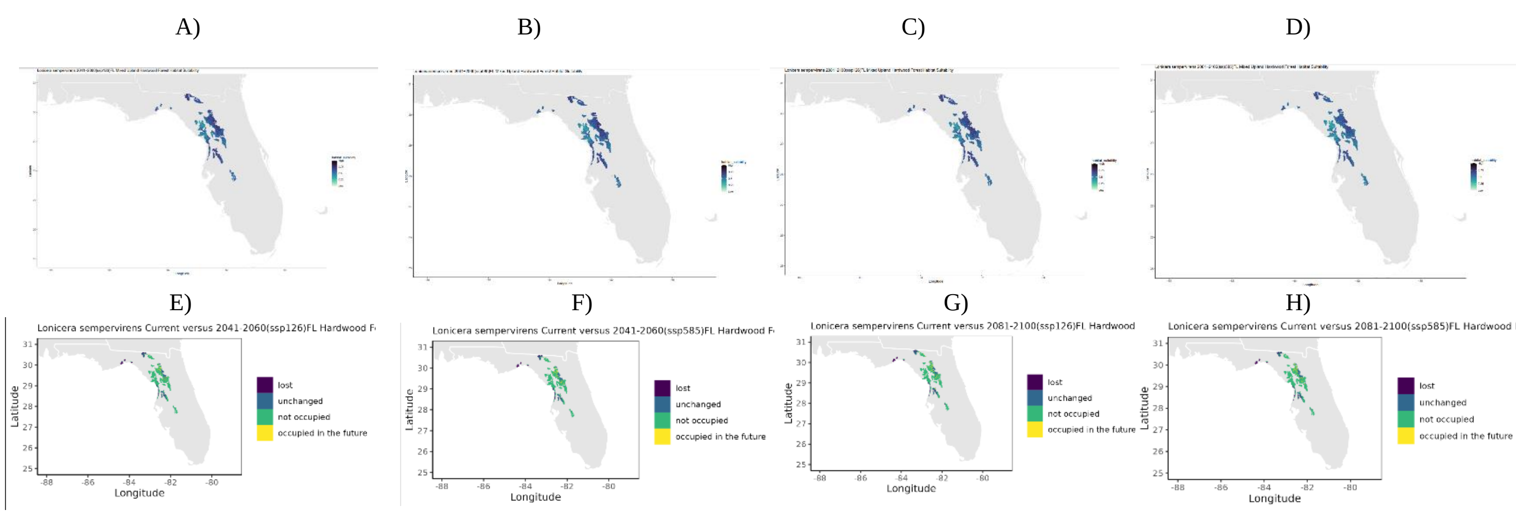

Figure 6. Future habitat suitability in FL hardwood forests for *Lonicera sempervirens* in A) 2041- 2060 (ssp126), B) 2041- 2060 (ssp585), C) 2081 – 2100 (ssp126), and D) 2081- 2100 (ssp585). E – H) Corresponding maps of habitat suitability changes.

Overall in the continental United States, both species are predicted to do poorly in their endemic regions. *Erythrina herbacea* does not seem to have a new area it can find a niche in the United States, possibly being able to survive if it moves closer towards the great lakes, however it has very low habitat suitability everywhere, especially in its endemic area. *Lonicera sempervirens* has a better chance of surviving in the future, with lots of areas with higher habitat suitability in the northeastern and northwestern United States. As it is endemic along the east coast, these regions are not as drastically influenced as *Erythrina herbacea*, and it is likely that *Lonicera sempervirens* will survive well in the coming future and may spread to newer areas with higher habitat suitability.

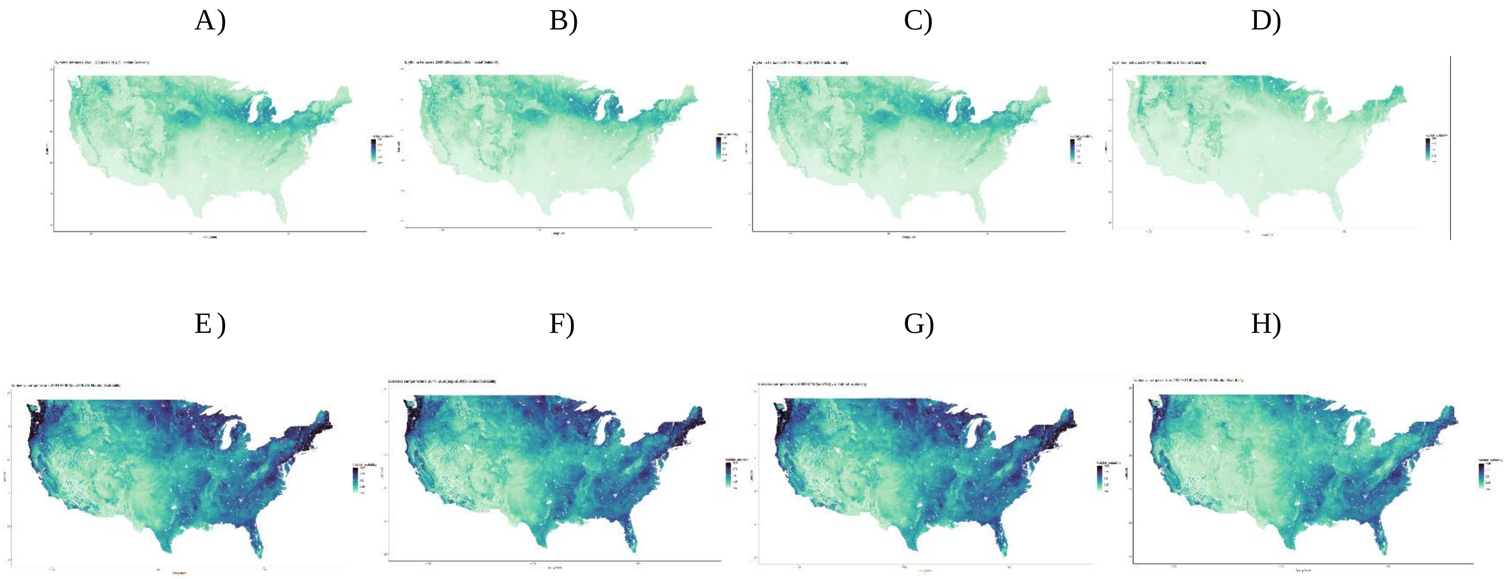

Figure 7. Future habitat suitability for *Erythrina herbacea* in the Continental United States, A) 2041-2060 (ssp126), B) 2041-2060 (ssp585), C) 2081-2100 (ssp126), and D) 2081-2100 (ssp126) and *Lonicera sempervirens*, E) 2041-2060 (ssp126), F) 2041-2060 (ssp585), G) 2081-2100 (ssp126), and H) 2081-2100 (ssp126).

DISCUSSION

According to our models in Florida hardwood forests, both species are not expected to change their distribution very drastically. *Erythrina herbacea* is predicted to gain around 10-13% range and *Lonicera sempervirens* is predicted to decrease around 11-13% range in Florida hardwood forests in the future 40 to 80 years. Interestingly, looking at the maps of *Erythrina herbacea* seem to show very low habitat suitability everywhere, and especially in Florida where the models predicted it to gain range. This species is a low shrub, so it may be more mobile than other species such as trees, however it will be slower to move than a vine such as *Lonicera sempervirens.* There doesn't seem to be a suitable niche anywhere near its current distribution, as it is mostly distributed in the south as shown in Figure 2.A. This may be a species to pay attention to in the coming future, or it may become very endangered or extinct. The most habitable area is near the great lakes, however this species is not endemic to the area, and there may be consequences in the future for trying to relocate it to a non-native area. It is also possible that the species will adapt to different climate and soil conditions and keep its current distribution. The variables with highest contribution were related to the soil, and then related to precipitation. In the future projections, we held the soil layers constant and only used climate data as it was the only future prediction data available, so other changes to soil that are unknown to us may help the species survive better in its endemic areas.

For *Lonicera sempervirens*, it is predicted that the range will decrease within Florida hardwood forests. Looking at the maps across the continental United States and the Florida hardwood forests, it doesn’t seem like this species is one to worry very much about. Looking at Figure 2.B, it is widely distributed across the eastern United States, and has a very large range of distribution for it to spread to if needed, and being a crawling vine it can spread faster into other areas. Its current endemic regions also keep relatively high habitat suitability throughout each model. As for *Erythrina herbacea*, we held soil grid data constant, so it is possible that changes to these variables may affect *Lonicera sempervirens’s* distribution in the future, however most of the variables with high contribution to the model and predictions were based on climate variables.

For both species, their gain and loss seem to contradict their map of habitat suitability. *Erythrina herbacea* shows a very low habitat suitability, however it gains range within Florida hardwood forests. *Lonicera sempervirens* seems to do better in comparison, yet it loses range within Florida hardwood forests. For *Lonicera sempervirens,* the current model for the species within Florida hardwood forests seems to show slightly more habitat suitability than the future projections. The opposite is true for *Erythrina herbacea,* where the average value is 0.7563864 for the current ENM. While the map may seem to show low habitat suitability, in the future projections the average value is not the same, so more areas have a higher value in the future compared to the future average. Using this metric to determine loss and gain of area may be flawed, and other metrics such as minimum of all species considered or a lower quartile of all species or the individual species may need to be further investigated to see if the models make more sense.

CONCLUSION

Of all species found in Florida upland mixed hardwood forests, some species showed favorable projections of expanding or keeping suitable habitats under future climate scenarios, while others showed a concerning trend of losing suitable niches and facing potential range contractions. These changes suggest that this plant community will undergo transformations in the next 80 years. Species that currently thrive in these ecosystems may face challenges in adapting to changing environmental conditions, potentially leading to shifts in species composition and distribution. This could have cascading effects on ecosystem dynamics, diminishing biodiversity, community structure, and ecological functions. *Erythrina herbacea* may be a species that struggles, while *Lonicera sempervirens* may survive well in their current niche. For Florida upland mixed hardwood forests, the findings of this project may predict the opposite effect in this ecosystem and different metrics and models should be further tested to further determine how each species may expand or shrink in this community. This community may see a decrease in biodiversity as some species expand their range and others shrink. These changes underscore the importance of conservation and management strategies to enhance the resilience of Florida's hardwood forests and monitor changes that may occur in the coming future as climate change progresses.

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