



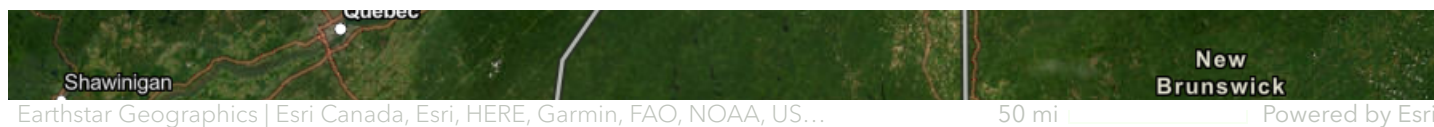
Invasive Changes

How species both invasive and native have changed over time, and why does that matter to Mainers?

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Cover: Invasive Japanese Knotweed

Invasive species are those species is introduced to an area that is not its native habitat. it then goes on to harm the ecosystem that they are placed in. Although some researchers choose to distinguish non-native or exotic as those who do not create harm, in our common discourse the difference doesn't matter. This word choice makes it hard to acknowledge when invasives are neutral or even beneficial. Here in Maine we might not always have invasives creeping up our doorsteps. By looking at the larger world, we can see how we might need to rethink our own misconceptions. Invasives are changing along with the world, and its time own ideas also catch up.



1

What is the issue?



Above: Fiddlehead Fern, native species which is edible

Invasive species have lived in some locations for many generations. As the world changes due to climate change and other human effects, how these species live is beginning to vary.

The first difficulty in the discussion of invasive species is that untouched nature is no longer a possibility. Fred Pearce in *The New Wild* makes the case that

"There is no pristine ecosystems and no blueprints for what they might be."¹

This means attempts to "restore" what was there before become a constantly shifting line that has no actual success. Justin Schlawin, an ecologist who works in Maine on monitoring at-risk habitats notes "we're not worrying about things that have been here a very long time, [that] have caused a lot of problems and are impossible really to do any management to tackle."² Invasive species are also increasingly common. When he works on native trees, there are almost none that don't have some invasive affecting it. Since management of invasive species often focuses on removal, this is a shock. The world has changed to the point that a eradication-based perspective is outdated. So how are worldwide invasives relevant to Mainers?

The first thing Schlawin suggests for us is the removal of toxic language. The way the public talks about invasives often uses rhetoric of anti-immigration, blame and warfare. Thinking of invasives as threats in this way creates many issues. For one, it does not allow for the nuance needed in management where total removal is not possible. Another is that it brings in blame on the invasive species as the cause of any destruction of an ecosystem. Schlawin denounces this as an unfair villainization, as it is clear that the invasive is simply acting as any other species. Furthermore, invasives are often found in disturbed areas. As they indicate current or past disturbance, human impact can often be the true source of the issue. This move of seeing invasives as indicators of disturbance is a key evolution of the scientific view that the public needs to become aware of.

Biocontrols, which is using organisms to control species instead of chemicals, is another way the science is developing. As native species evolve new bodies and behaviors we can expect this practice to increase.

Another shift in view is acknowledging how our environment is impacted by invasives. This topic is not only a concern for ecologists. As Schlawin explains, species like Japanese knotweed impact both culture and ecology. It takes away rare floodplains by changing water flow. This removes areas that are for activities like upland bird hunting and the traditional harvesting of fiddlehead ferns for food. When our culture is at risk, we need everyone's cooperation in order to succeed.

Even when the invasive species are not evolving, the science of how they interact in their new environment does evolve. Lets catch up on some of the ways that both the native and invasive species have been evolving by looking at some examples!

2

Beneficial Changes



Above: Omiodes blackburni, one of the endemic species of Hawaii

There are times where after many generations the introduction of the invasive species lessens its negative impact. Therefore beneficial relationships are those that promote the native species while curtailing the invasive to act more in sync with the native ecosystem. This can be through changes to the local species to

better live with the effects of invasives, or with the invasive forming helpful relationships.

3

Beneficial Relationships with Invasives



Above: African tulip tree, Spathodea campanulata

Invasive species can play a role in the reintroduction of native species, as their heightened ability to succeed can change conditions to better suit the natives. In Puerto Rico, introduced species paved the way for reintegration of former farmland. The African tulip tree became a colonizer of the floodplains and became home to the coqui tree frog and native reptiles and birds.¹⁶ Commensal relationships are ones where one species benefits and the other is not impacted, seen often with trees being habitat for birds. Because invasive species can also create commensal relationships, they can expand the habitable areas for native species, even in their own native lands. Therefore, invasives could significantly strengthen the survival of native species, especially with their ability to assist reclamation of human modified territories.

On Seychelles island, a native fruit bat now roosts primarily in non-native trees.¹⁷ Through the many changes in habitat alteration, invasive species can create scenarios where either preferring or avoiding invasives can mean either greater success or failure for the native species.

4**Defending through Predation**



Above: Rostrhamus sociabilis, snail kite

Native species often face great selective pressures when dealing with invasive species. As they can greatly disrupt the local environment, those species that will interact with the invader can go through rapid shifts represented by morphological changes. Morphological changes are those that change the structure of the organism's body. Many invasive species thrive by not having predators suited to them. However there can be a renewal of the arms-race between predator and prey. In the Everglades, the endangered snail kite *Rostrhamus sociabilis* is able to prey upon the invading island apple snail, *Pomacea maculata*. As the invader was larger than native prey, their introduction meant that they became a preferred prey. Because the invasive snail is larger than the typical prey, both bill size and body mass of the bird

increased in 10 years.³ In longer-lived species the researchers assumed that they would not be able to respond in time. However, this case showed that even long-living species respond to an invader's introduction, especially if the interaction is beneficial.

Other species can also develop a preference that was not there before. There are also ways in which the introduction of an invasive changes the behavior of the native species. Species of host-specific moths were able to evolve to the introduction of bananas in Hawaii about 1000 years ago.⁴ This means that regardless of the initial lack of exposure, local species can exploit new plants. This can require a significant change in behavior, as they must adapt to this invasive to keep up with the sudden change in local populations. The moths are particularly unique in this, as their host-specificity has to be overcome in the relatively short period of 1000 years. This shift can also be intensified if the invading plant begins to outcompete the local ones or disrupts the food web. In these cases, the evolution of new behavior might be a necessity for the local species to survive.

5

Trendsetter-body and behaviors are ready to change





Above: Soapberry bug, Leptocoris tagalicus

Invasive species' success in new habitats can be curtailed as the native species evolve to exploit the new resource. Invasive species are often able to overwhelm the local population as they do not have any native competitors nor population-limiting relationships like predation. Over 30-40 years, the native Australian soapberry bugs have seen a 5-10% increase in their mouthparts, allowing for the consumption of an invasive balloon vine's seeds.⁵ With this larger mouth, the insects also tend to prefer the vine's seeds, suggesting a possible behavioral change. Through selected genetic changes, a native species can quickly adapt to exploit the new invasive and curtail a previously uncontrolled population. This is vital as the Australian soapberry bug is the only species to exploit this invading vine, meaning that even in a short time native species can overcome the risks of not having any previous relationships with the invader.



Defensive Actions by Native Species



Above: Iberian Water frog, Pelophylax perezi

Since the introduction of an invasive species might intensify and wane as the invading population struggles to gain a foothold, the defensive responses can shift as well. Plastic traits are a response to a previous and variable predation risk and begin to confer resistance for the next attack. Plastic means the traits are changed by the habitat and not genetically. This allows a genetically

identical organism to be flexible in its traits based upon location. In Iberia, the invasion of the red swamp crayfish caused tadpoles of the native water frog to have shorter and deeper tails when exposed to the chemical signature of the invader. Those populations which had been exposed for 20 or 30 years as opposed to none had differing responses. Those with more exposure in the natural environment before testing showed a greater variation of responses. This included both a decrease in activity to avoid detection as well as these morphological changes. Those experiment populations which were not exposed in nature had a plastic response of antipredator behavior, but not morphological changes. The longer exposed population kept a lower activity level regardless of if there were chemical signatures, suggesting that the trait is becoming more permanent.⁶ By being able to develop defenses against a predator that it was initially naïve of, local populations can evolve multiple defensive strategies in a short period of time.

Predators do not always succeed at integrating invading species into their food web. The native Australian black snake evolved resistance to the invasive cane toad's poison. It also saw a decreasing behavioral preference for the toad, and a smaller head size.⁷ This morphological and behavioral change means that it is evolving to avoid this invasive species, as even its resistance to the poison is not enough to make it a viable prey. This could be reversed, but only if the poison no longer keeps negatively selecting against the cane toad as a prey type. When some invasives are not suitable to be prey, the native predators might evolve in order to avoid them and their defenses.

The ecosystem as a whole can also repel invasives. Biotic resistance is the ability for a community to check the continued expansion of an invasive species. For plants, biotic resistance can come through competitive exclusion. This means the

local species is so competitive that the invasive is removed entirely. The invasive snakeroot in South Korea is better repelled by a functionally diverse ecosystem.⁸ This, along with niche partitioning, made it possible to resist invasion as there are no resources for the invasive to exploit. If these competitors evolve traits that make them more suitable at repelling the invader, such as quicker growth, they might repel the invasive species entirely through exclusion.

7 Prey Naïveté and Changing Local Species Behavior



Native prey are initially vulnerable to predation by invasive predators. This is through the ecological mismatch, as the prey is unable to recognize the predator nor properly respond. This “prey naïveté” can vary greatly, as the invasive might be similar or different to the local predator types. In Australia, the northern brown bandicoot populations were at times exposed to the invasive red fox. Those which live with the red fox recognize and respond to fox odors. Those who have few interactions with the foxes do not, exposing themselves to predation.⁹ The time-frame for this change in naïvete can be short, yet for that time the native species can go through a great population decline or even face extinction. In Australia, the ability to overcome an initial prey naïvete determined if a species could survive the introduction of an invasive predator.

Prey naïvete is a threat to native species across the world, and only a select few are able to evolve beyond it. In a meta-analysis of global prey naïvete, research found naïvete is less influential in different biomes. Native prey were more naïve in marine and freshwater biomes, but not in terrestrial ones. Furthermore, it takes about 200 generations for antipredator behavior to sufficiently overcome naïvete.¹⁰ This means species with a long lifespan will have significant difficulty with invasives as they will have to survive for much longer in order to finally adapt. As certain biomes and species are slower at evolving against prey naïvete, those with short lifespans will have a much higher chance of resisting invasives, removing the vulnerability that typically makes invasive species so harmful to a local ecosystem.

Foraging habits can also be modified in order to accommodate the change in resources. The foraging of native species such as frugivores and herbivores need to change rapidly with the onset of an invasive plant that outcompetes the local

fruits. Herbivores also go through this behavioral shift. The Bison and deer in North America avoid the toxic latex of an invasive *Euphorbia esula*. In order to avoid this toxin, the herds also change their grazing locations.¹¹ Whether the invader is a food source negative or positive, local species are forced to change when and where they forage as an invasive species gains success. Pollinators can also be impacted in a similar way. The number of visitations to native compared to invasive plants might shift.¹² This can be either due to a preference for the new plant, or because the native species has been out crowded to the point that native pollinators do better by changing preference. When the pollinators shift to the invasive species, they create competition not only within the plant community, but this gives those pollinators who adapt an advantage. Through the changing of native species' behavior, invasive species disrupt the impact each species has on the local ecosystem.

8

Invasives strengthen their Foothold



Above: spiny water flea, Bythotrephes cederstroemi

While native pressures can be a challenge, some invasives are able to adapt. Local predators can place pressure on the invading species if they are viable prey. Canadian lakes have been invaded by zooplankton, which are preyed upon by fish. For fish, the size of their mouth can play a vital role in which prey is viable. The fish can be gape-limited, meaning that the size of their mouths do not change. Therefore, the zooplankton have developed a longer spine as defensive morphology. Those zooplankton in lakes with or without gape-

limited fish had a spine length difference of 17%.¹³ When native species are able to predate the invasive, the invasive species can return to the typical prey-predator evolutionary arms race. Through predation, some invasive species still need to evolve predator defenses regardless of their new ecosystem.

9

Resilience in Invasives



Above: Golden Apple snail, Pomacea canaliculata

Invasive species often have an explosive population boost if they are able to establish. One surprise is that being able to evolve new tolerances might help invasive species get to areas they might not seem suited for. Salinity is a factor that often limits the ability for invasive species to overtake freshwater areas. However, invasive species from brackish waters have been able to succeed in these hostile conditions. The copepod *E. affinis* is not as tolerant of freshwater as some studies suggest, but is able to evolve during an invasion. In Lake Michigan the copepod is able to develop tolerance for freshwater. Furthermore, there were odd changes in life-history such as accelerated metamorphosis.¹⁴ This trade-off of high salinity tolerance for low salinity reveals the difficulties of invasive populations going into a new environment, which requires massive evolutionary changes. regardless, the species is able to evolve, meaning invasive species can become tolerant and overtake even hostile environments.

Invasive species can quickly adapt morphological traits that suit their new habitat. Invasive freshwater snails are more plastic in their defenses when presented with predation stress. In China the waterways of a university had invasive snails. After 30 days of exposure to a local turtle, the snails saw a difference in shell growth. Both males and females were able to adapt a shell morphology that is better at resisting crushing and entry, making their species particularly adaptable compared to the native snails. The growth also varied across the sexes, as males gained more morphological defenses.¹⁵ Through a sexual dimorphic change in shell growth, the defenses might have trade-offs based upon reproduction. In such a scenario, the ability for invasives to be more plastic at evolving these traits means that their continued exposure to predation might not be much of a hurdle for their introduction. The evolved traits will

develop quickly, and already follow such principles such as sex that lead to better results for the invasive species as a whole.

10 Human impact



Above: Sea Lamprey, Petromyzon marinus

Many species now survive in environments that are impacted by humans, putting new pressures on survival.

Human impact is a more modern source of selective pressures. As humans overtake a significant amount of land for their use, some species have evolved to take advantage. In agriculture, farmers must take care that foreign plants besides the crop do not survive. This has created a new form of mimicry, as weeds mimic the crops to avoid culling. The lentil mimic *Vicia sativa* has evolved to better appear like the lentil crop and avoid detection.¹⁸ Such anthropogenic focus also reconsiders the question of what is considered “invasive,” as humans perceive species that are without use to be a nuisance and treat them the same as an invasive species. This can come after agriculture has artificially created the dominance of a non-native crop and pushed out native plants.

Humans can also exploit evolutionary processes to make gains against invasive species. Humans can push native predators to evolve in order to oppose an invasive species. *Drosophila suzukii* is a fruit fly that is a pest for agriculture. Through lab experimentation, researchers were able to evolve native pupal parasites to better develop on the invasive fly. In three generations, the native pupae were able to increase their developmental success to 88% and 259%.¹⁹ In the wild, the native species do not attack the invasive at a very high rate. The ability to quickly evolve a much greater attack pattern and developmental success means that the species can be used as a biocontrol. Humans are able to easily evolve native species to favor invasives, making their evolution a possible form of invasive population control.

Invasive species also face great selective pressure from human attempts to remove the invasive. While humans are often the ones to bring invasives to a new habitat, great efforts are also put in place by governments and other institutions in order to limit the damage an invasive species can do. The hope is often the total eradication of the invasive from the location, but this is rarely possible except on island habitats. Pesticide and herbicide resistance is one example of the difficulties as these culling attempts do not gain success, and then the population becomes more and more resistant. The sea lampreys in Laurentian great lakes have gained resistance to a pesticide used since the 1950s. Although the pesticide has been used for so long, the lamprey population persists, suggesting a resistance. Throughout 57 years, there was not an increase in lethal concentrations, even with a high mortality rate.²⁰ A high mortality rate creates a strong selective pressure, making an ideal scenario for rapid evolution. If an invasive population is able to persist regardless of the massive population decline, those left will strongly influence the genetics of the next generation and allow for rapid evolution.

Other organisms such as insects can also develop both behavioral and physiological resistances, such as moving to other locations or ceasing feeding in areas with insecticide. There are also morphological traits as well, such as the delaying of ovulation in the presence of pesticide or slowing the penetration of the pesticide through the cuticle.²¹ Through rapid evolution, invasive species can begin to show traits that allow for resistance to chemical attempts to control populations. Even with high mortality, the remaining populations are selected for both morphological and behavioral traits. Human management can greatly alter the evolutionary course of an invasive population.

Culling attempts change the behavior of invasive species similarly to normal predation. The invasive lionfish is one example in which humans cull their numbers through direct hunting. Lionfish have a behavioral shift in response to the constant culling, keeping lower activity levels during the day and keeping concealed.²² Such a behavioral shift could impact their hunting patterns, making the lionfish hunt differing species. Through human hunting, invasive species can develop new behaviors that can change their impact on the local ecosystem, and also allow the species to survive human's purposeful eradication plans.

11

Interview



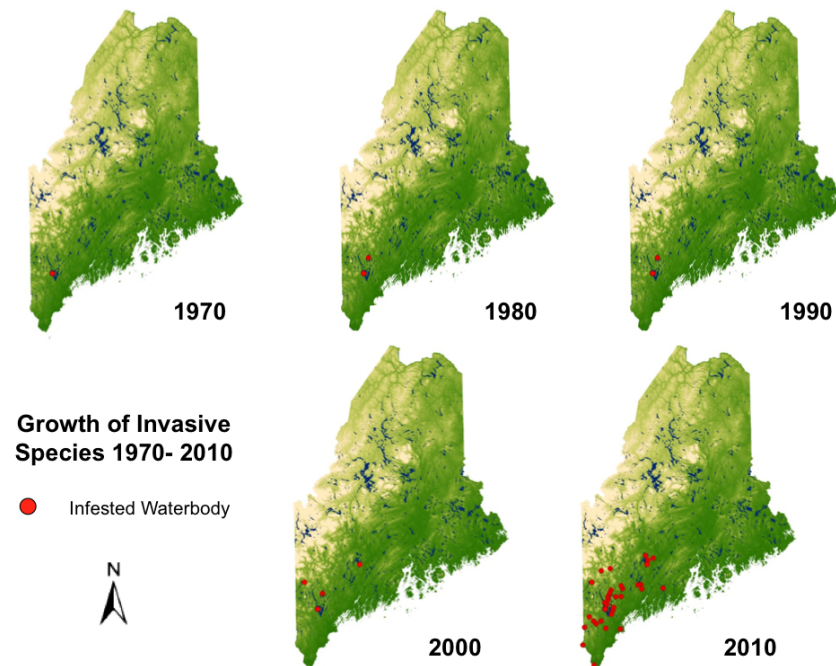
Below is my interview with Justin Schlawin, ecologist for the Maine Natural Areas Program. His work is in tracking rare plant species and protecting vital ecosystems like old growth forests. He describes protecting at-risk areas as "we track the last of the least, and the best of the rest." His job in that is "converting the science we're collecting to conservation outcomes."

In terms of invasive species, his institution helps organizations like the Maine Forest Service with "early detection, rapid response," and assisting in the response through data.²³



Summary of Interview-

1. Discussions of invasive species use problematic language of anti-immigration stances and warfare.
2. Areas with invasive species are indicators of previous disturbance.
3. Humans are culturally impacted by invasives as habitats or species they value are harmed.
4. The public plays a huge role in keeping a sharp lookout for invasives, so learning how to identify invasives is important.
5. Extreme removal measures for invasives are not always effective e.g. garlic mustard- its allelopathic chemicals eventually harm its own growth as native microbes cannot break it down, so it restricts its own growth after becoming established in an area for a long time. An allelopathic chemical is one that effects other plants, for garlic mustard they make a toxin to harm others.
6. Natural area preserves in New Jersey have stopped removing Japanese barberry as the deer are out of control and the barberry is to hostile to deer so it creates an area for native trees to regenerate. This is in spite of barberry creating an non-suitable area of shading that makes recruitment difficult.
7. Disturbed areas like mines in West Virginia have lots of invasives, so they might play a role in reclaiming that land.



A map showing how waterbodies with in invasive species

Invasives are going to remain in many locations. All around the world, it is becoming clear that rapid evolution is driving invasive species to new interactions. What the public can do is clear: stop using toxic wording, be aware of your environment to help track invasives, and recognize how we will treat invasives has to change as they themselves evolve. We can all find ways to connect on this topic through cultural connections to our environment. But the news is not all bad. The changes cannot be reversed, but they might be a new way for nature to adapt to disturbances. In some ways we will be able to use evolution to heal ecosystems, in others it is a risk to be wary of.

Keeping a sharp eye on these as people in Maine is important to everyone as we face the uncertain future.

Organizations

These organizations play important roles such as citizen science and monitoring invasive species. Maybe they can be the way you wish to help Maine!

Maine Invasive Species Network

<https://earthwatch.org/>

<https://masna.org/>

Footnotes

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