Week 9; Monday

Announcements:
Key Final on Wednesday; Open lab keying practice, Tuesday 10:00 – 1:00
Family ID final next week on Wednesday (no class on Monday – Memorial Day)

Lecture: Parasitic Plants

All organisms can be categorized into two groups on the basis of how they obtain their carbon-based basic sugars for building complex cell structures:
**Autotrophs** (self-nourish) – produce their own food
**Heterotrophs** (other-nourish) – obtain food from other organisms, alive or dead

**Photosynthesis** - characterizes plants from unicellular green algae to the largest trees (as well as many types of bacteria, including cyanobacteria).
This process enables the plant to construct the basic building blocks for growth - sugars and complex carbohydrates (including cellulose) - from energy obtained from the sun.

Chemically it looks like this: \[ 6\text{H}_2\text{O} + 6\text{CO}_2 + \text{E(sunlight)} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]

This process first evolved in bacteria, perhaps 2.5 – 3.0 billion years ago.

**Photosynthetic eukaryotes** (plants and algae) are derived from the **Endosymbiosis** of a cyanobacterium and a non-photosynthetic eukaryotic cell at some point a long time ago.

Plants have many adaptations to enable them to be efficient factories for the production of carbohydrates from sunlight
- **broad, thin leaf blades** with the thickness and pigmentation optimal for capturing sunlight
- **stems, branches, and petioles** enabling the organization of leaves on a plant to be positioned to overlap minimally and capture as much of the light that arrives in the area of the plant as possible. Some leaves even track the sun's movement.
- **Roots that can grow in any direction** to find water - even to a depth of 70 feet!

Some plants have evolved to be heterotrophic - either partially or completely. These are called **parasites**.

**Parasite** - an organism that grows, feeds, and is sheltered on, or in, a different organism at the expense of that organism and contributing nothing to the survival of its host.
This is one type of **symbiosis**. The others are:
**mutualism** - both organisms benefit
**commensalism** - one organism benefits, while the other neither benefits or suffers
Becoming a plant parasite.

Parasitism can be either directly on another plant by connections to the roots or stems, or via a fungal intermediary (mycoparasitism).

A parasite connects to a host plant by means of a **haustorium**. This is a sucker-like swelling on a root or stem, which invades a host root or stem and makes a connection between the vascular tissue of the parasite and host.

In the case of parasites on fungi, the parasite induces the fungus to grow into the root of the plant and then turns the table and sucks the nutrients from the fungus.

Plants that obtain all of their nutrients from the host are called **holoparasites** (or obligate parasites). However some parasites remain capable of photosynthesis, while supplementing their diet with the host plant nutrients. These plants are called **hemiparasites** (or facultative parasites).

**Parasitic Reduction Syndrome** (holoparasites): This combination of traits is repeated in many different groups of parasitic plants. The dramatic difference relative to other related plants that are not photosynthetic often results in segregating them into distinct families (e.g., Orobanchaceae from Scrophulariaceae; Monotropaceae from Ericaceae; Lennoaceae from Boraginaceae; Cuscutaceae from Convolvulaceae; Rafflesiaceae from Euphorbiaceae). Most of these are now included in the originating family.

1) Loss of leaves - leaves reduced to scales
2) Reduced overall size of plant - no need for large plants to hold leaves
3) Loss of roots - reduced to short, stumpy projections with haustoria
4) Loss of chlorophyll
5) Loss of genes needed for photosynthesis – overhead of **Epifagus cp genome**
6) Higher substitution rate (more rapid DNA divergence) in genes that are not lost – overhead of **Cuscuta in Convolvulaceae phylogeny**

Use it or lose it!! A maxim in evolution.

Not all parasites are small. There are many shrubs and trees among them (though not as holoparasites), including the Australian Christmas tree, *Nuytsia floribunda* (Loranthaceae).

However, the **flower** still is necessary for reproduction and usually is similar enough to the non-parasitic ancestors to indicate relationships. Often the only structures left on the plant are those needed to produce the flower and expose it to the insects or other agent needed for pollination.
Parasitism has evolved perhaps 20 times among flowering plants. In each case the plants have become parasitic on either other plants or fungi. These include 4 families we know: Boraginaceae, Scrophulariaceae, Ericaceae, Orchidaceae (overhead - Chase et al. tree; black - plant parasites; green - fungal parasites or mycotrophs)

In Scrophulariaceae/Orobanchaceae parasitism evolved only once, but loss of photosynthesis evolved several times (overheads)

In some cases (eg, Orchidaceae), parasitism probably has evolved many times fairly recently in one family.

There are quite a few families of parasitic plants that probably are quite ancient (Hydnoraceae, Cynomoraceae, Balanophoraceae); Rafflesiaceae once was thought to be ancient, but we now know it is nested within Euphorbiaceae.

They have evolved both very tiny flowers (only a few cells in the case of some Balanophoraceae), but also include the largest flower in the world (*Rafflesia* - 3 feet or more in diameter!) – overhead. In some cases, the closest relatives are of these plants are unknown; perhaps they went extinct long ago. Their positions in the tree are difficult to determine, because either they have no close relatives, or their morphology is unique and doesn't provide a clue to relationships and their DNA sequences have diverged rapidly.

In the case of *Rafflesia* the entire plant consists of thread-like root cells that grow in among the cells of the host plant and the only way one knows the plant exists is when the flower emerges - the ultimate Parasitic Reduction Syndrome.
Week 9; Wednesday

Announcements:
- Key final today; Family ID final in lab next week Wednesday
- Final exam HERE, Tuesday, June 7 (In class review on Friday, June 3)

The Biology and Natural History of Rarity
(Based on past Guest Lectures by Art Kruckeberg)

Why be interested in Rarity?
- **Aesthetic** – innate human interest in things rare
- **Ethics** – humans should be responsible for maintaining biodiversity.
- **Conservation** – rare species as placeholders for conserving the entire ecosystem
- **Biological values** – rare species may be critical to ecosystems

**Biodiversity** – roughly defined, is the number and distribution of species that are found in one place. (**species richness** is just the number of species)

**Biodiversity** – elegantly defined (by E. O. Wilson) is: “the variety of organisms considered at all levels, from species through genera, families, and still higher taxonomic levels and including the variety of ecosystems, which comprise both the communities of organisms within particular habitats and the physical conditions under which they live.” **[Overhead]**

**Phylogenetic diversity** – measure of evolutionary/phylogenetic breadth represented in a flora of a region. Used to assess conservation value.

**Endemism** (derived from word for “native” in greek) - condition of being restricted in distribution to a particular region. When a species is referred to as being “endemic,” a geographic region must be specified (e.g., *Lewisia tweedyi* is endemic to Washington, or *Campanula piperi* is endemic to the Olympic mountains).
Narrow endemic (“restricted species”) - very restricted distribution; population often less than 10,000 individuals
Scarce - broadly distributed and widely separated populations; never very abundant
Common - Regional distribution; abundant somewhere
Cosmopolitan - found everywhere (e.g., Bracken fern); this is unusual - <1% of spp.

In California > 30% plant species endemic to the state; much less in Washington (Hawaii > 90% endemism)

Narrow endemics come in two kinds:

**Paleoendemics** - ancient origin, left over from wider distribution, and typically have no closely related species; usually evidence of ancient ecosystems
Examples: *Sequoia sempervirens* (Coast Redwood) in California
*Microcycas* in Cuba – every plant is known and counted
*Metasequoia glyptostroboides* – first described as a fossil, but then discovered in 1940’s in Hupei province in China

**Neoendemics** - recent in origin (typically post-Tertiary in origin) and typically have closely related species nearby
Allopolyploids (species derived from hybridization and chromosome doubling, so the parent species are still around) and peripherally isolated species from more widespread species
Examples: *Erigeron piperianus* endemic to eastern Washington is a recently derived offshoot of the widespread *Erigeron linearis*, found throughout the intermountain region.
*Stephanomeria malheurensis* known from one very small locality in eastern Oregon, where it is distinguishable from its progenitor species by smaller flowers and self-fertilizing mating system.
*Streptanthus* (“jewelweeds”) - rare species are found on serpentine soils, while their more common relatives are nearby, but off serpentine.

“Spurious Endemism” - result of “Taxonomic inflation”, the splitting of species into many small species of doubtful integrity.
Example: *Pritchardia* – Hawaiian palms – one species with scattered distribution around several islands, or several species, each representing a single population?
The opposite of this is ‘taxonomic extinction’, which results from ‘lumping’ of two species into one.

**Ecotypes** are variations within a single species that have evolved specific differences associated with their ecological conditions – plant ecotypes are not protected under Endangered Species Act (some are for animals – salmon runs).
Kinds of Rarity

<table>
<thead>
<tr>
<th>Geographic Range:</th>
<th>Large</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat specificity</td>
<td>Wide</td>
<td>Narrow</td>
</tr>
<tr>
<td>Local Range</td>
<td>Large</td>
<td>Locally abundant everywhere</td>
</tr>
<tr>
<td>Population</td>
<td>Small</td>
<td>Sparse, but everywhere</td>
</tr>
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</table>

Environmental determinants of Rarity:

**Discontinuity allows for isolation AND isolation results in speciation**

1) Habitat Specificity - geo-edaphic factors; discontinuous distribution of sites favorable to particular plant; isolation can lead to speciation. Serpentine endemics in California and Oregon (and elsewhere around the world) are good examples of this.

2) Islands – this can include oceanic islands (e.g., Hawaii) and mainland islands: For example: Topographic islands - mountain tops – “Sky islands” in Arizona and northern Mexico

   Substrate islands - discontinuous rock/soil types (eg, limestone, or serpentine)

3) Local Climate/Regional Climate - some paleoendemics may occupy “relictual climates” (eg, similar to climates in the Tertiary, before the Ice ages). An example is the Dawn Redwood (*Metasequoia glyptostroboides*), found only in a small valley in China, but once very widespread. The “Arcto-Tertiary flora” is based on this concept. Related plants in eastern North America, Europe, and Eastern Asia represent the remnants of a once widespread flora that covered all of the northern latitudes when the climate was milder.

4) Biotic factors - the interaction between species, including plant dependence on pollinators, that may be rare or extinct. Example is Kincaid’s lupine in the Willamette Valley in Oregon, which is pollinated by a rare butterfly. This is believed to be responsible for some of the rare plants in Hawaii, which no longer have native pollinating birds.

**Ultramafic, or Serpentine rocks**

- high in Fe, Mg, and often Ni, Cr, Co (trace metals toxic to plants); low in Ca
- usually deficient in nitrogen and phosphorus
- this makes them a very difficult substrate for plants to grow on. Serpentine outcrops have very low plant cover, but high plant diversity.
Time also is a factor in development of endemic species. It takes time for new species to evolve. So, older habitats will have more endemic species. The Puget Sound trough has very few endemics, because it was filled with ice 12,000 years ago. The Wenatchee Range is rich in serpentine endemics and is one of the most botanically diverse areas in the state. Some special species include *Claytonia megarhiza* (Portulacaceae) and *Douglasia nivalis* (Primulaceae).

**Endangered Habitats**
- **Old Growth forest** – old growth may be defined as: widely spaced old trees (> 200 yrs) with rich undergrowth. Example at Asahel Curtis grove along I-90 west of Snoqualmie Pass
- **Wetlands** – example Nisqually delta near Tacoma, which was saved from filling and development
  - Bogs are a particularly interesting and valuable type of wetland in the Puget Sound region
- **Puget Sound Prairies** – Near Fort Lewis south of Tacoma. These are being lost due to fire prevention, which used to keep trees out. Now Douglas fir is starting to dominate
- **Alpine parkland** – ‘timbered atolls’; threatened by global warming as tree line goes farther up mountains.
- **Yellow Pine woodlands** (Ponderosa Pine) east side of Cascades
- **Serpentine regions** – soils high in magnesium and heavy metals (eg, nickel) and low in calcium create “serpentine barrens” with few trees, but rich in unusual species often endemic to serpentine.

**Rare Species classifications**

**Federal**
- **Endangered** – in danger of extinction through all or large part of its range
- **Threatened** – likely to become endangered within the foreseeable future
- **Candidate** – current information indicates probable cause for listing
- **Species of concern** – more information is needed to merit classification.

**State of Washington**
- **Endangered** – in danger of becoming extinct or extirpated within Washington
- **Threatened** – likely to become endangered within WA
- **Sensitive** – vulnerable or declining and could become endangered or threatened
- **Candidate** – species under review for listing
- **Review** – plant species of potential concern, but more information is needed, because either 1) additional field work needed, or 2) unresolved taxonomic questions.

Outlying populations of a widespread species may be protected if they fall in another state (e.g., *Fritillaria kamschaticum* has one population in Washington, but is common in Alaska.)
How to preserve rare species?
1) **Preserve habitat** – Most rare species are tied to specific habitats

How to aid in the recovery of endangered species? In order to bring species back from the brink of extinction, it takes more than preserving the habitats that we have left.

1) **Habitat Restoration** – wetlands, old growth forests, and other degraded habitats can be rehabilitated and brought back to health so that they can support rare species.

2) **Ex situ populations** – grow individuals in cultivation to re-establish in nature. “Rare Care” program here at the UW Botanical Gardens

The causes of rarity usually are not considered when the label of “rare” or “endangered” is assigned. Some rare species may be momentary novelties that have never been common and probably will not survive regardless of efforts to preserve them.

For example, *Stephanomeria malheurensis*, now thought to be extinct in the wild despite efforts to save it.

**Efforts to preserve biodiversity**

**Federal Government**
- *Endangered Species Act* first passed in 1973 first included just animals, but was amended one year later to include plants; every state must have a list.
- Many agencies have responsibility for managing federal land and all are required to consider the impact of any use on endangered species and loss of biodiversity.
- “Research Natural Areas” established to preserve biodiversity on a variety of natural ecosystems in National Forests, Bureau of Land Management and other federal lands.

Examples include:
- **Swakane Canyon** north of Wenatchee, where Thompson’s clover (*Trifolium thompsonii*) is found. This was C. L. Hitchcock’s favorite place in Washington.
- **Perry Creek**, East of Granite Falls on the Mt. Loop highway. This area has over 30 species of ferns.
- **Chowder Ridge on Mt. Baker** – Ronald Taylor Research Natural Area (named for botanist who worked to preserve the area)

**State of Washington**
- “**Natural Area Preserves**” are state lands with the highest level of protection for biodiversity.
Private sector

- **Washington Native Plant Society (WNPS)** – established to promote understanding and preservation of native plants in Washington. ([www.wnps.org](http://www.wnps.org))
- **Nature Conservancy** conserves some pieces of land

  Examples:
  - Kings Lake Bog in King Co.
  - Cypress Island in the San Juans.
  - Ellsworth Creek near Willapa Bay in SW Washington

**Art Kruckeberg** contributions to rare plant conservation in Washington

Art Kruckeberg has worked tirelessly for the promotion and conservation of the native flora of the Pacific Northwest. A quick summary of the timeline for some of his most important contributions looks like this:

1972 – Helped lead the movement to create the Washington Natural Area Preserves Act that has led to the establishment of dozens of Preserves in the State of Washington designated with the highest conservation value of all state owned lands.

1973 – Developed the first list of rare and endangered plants species for Washington State.

Ca. 1975 – founded, with wife Mareen, the MsK Rare Plant Nursery, the first nursery specializing in native plants for the garden.

1976 – Founded the Washington Native Plant Society, an organization that has grown to include 11 active chapters and over 2000 members statewide.

1982 – Helped create the Washington Natural Heritage Program, within the WA Department of Natural Resources, to oversee the Natural Areas and rare species management in the state.

1982 – Published “Gardening with Native Plants of the Pacific Northwest”

1970’s-1980’s – Served on US Forest Service, Region Six, Research Natural Areas Commission to identify areas of particular botanical interest and establish RNAs to protect them.

1997 – Established Botany Washington, an annual field trip for professional botanists throughout the state to promote increased understanding of the native flora.

2008 – Kruckeberg Botanic Garden becomes a public Garden in City of Shoreline and operated by non-profit Kruckeberg Botanic Garden Foundation.
Week 9; Friday

Announcements
     Family ID final Wednesday;
     Final exam on June 7 at 8:30 am.

Guest Lecture: Sarah Reichard, UW Botanic Gardens, Center for Urban Horticulture

Alien Invasive plants in the Pacific Northwest.

“Native Plant” – Definition must include reference to time and place. Most people consider ‘native’ to mean pre-European settlement, so we can refer to plants that are native to Washington, the Pacific Northwest, or North America, meaning those plants found in these regions prior to settlement by Europeans.

Invasive, non-native species are those that can or have spread into native wilderness or managed ecosystems, develop self-sustaining populations, and become dominant or disruptive to those systems.

Why the concern with European settlement as a starting point?
• Natural seed dispersal is a very slow phenomenon
• Europeans exploration and colonization represented the beginning of frequent and wide travel by people from one part of the planet to all other parts.
• They purposefully carried many plants with them and accidentally carried many more.

Other terms used sometimes when referring to non-native species:
alien, exotic – these terms have many different uses and should be avoided
weed – strictly a management term and does not necessarily refer to non-native
noxious – legal term for a species that is injurious to human interests

Example – Hawaii
• Native plant colonization rate: 1 species per 100,000 years
• After Polynesian settlement: 1/50,000 years
• After European settlement: 4/year (now more like 5/year)
• 1000 species have arrived in the last 200 years of a total of 5000 estimated colonization events in the entire geologic history of the islands.

How do Invasive plants drive out other species?

By competition for resources.
  1. Light – eg, Kudzu (Pueraria lobata) and English Ivy (Hedera helix/H. hibernica) grow over other plants and cut off their light source
2. Water, nutrients – Many invasive plants can make better use of water and minerals in the soil, thus leaving too little for native plants.

3. Attract pollinators or dispersers away from native species so that the natives do not reproduce as effectively. For example, purple loosestrife (*Lythrum salicaria*) outcompetes native plants, including native loosestrife for bees as pollinators, thus reducing reproduction by natives.

Allelopathy – producing secondary chemical compounds that inhibit, or ‘poison’ other plants. *Geranium robertianum* (Herb Robert or Stinky Bob) is an example.

By engineering communities

1. Adding nitrogen to soils
   - increases rate of succession
   - permits more alien species to colonize
   - makes natives that are adapted to the nutrient poor soils uncompetitive
   Example: *Morella faya* in Hawaii growing on sterile lava flows
   Example: Scot’s broom (*Cytisus scoparius*) in the Puget Sound Prairies, where this legume with nitrogen-fixing bacteria in its root nodules, increases the N content of the soils, permitting more non-natives to colonize and changing the composition of plant communities
   Example: Knotweed (*Polygonum* spp.) has the reverse effect in riparian areas here in Western Washington. It translocates 75% of N from leaves to rhizomes at the end of the growing season and then moves it back into new leaves in the spring. Native plants, alders and willows, only translocate 5% and 33%, respectively, thus depositing lots of N into the streams and streamside ecosystems in the leaves each year contributing to the nutrients available for invertebrates and, indirectly, to trout and other salmon.

2. Sending down deep roots and lowering the water table so native plants can’t get sufficient water. Tamarisk (*Tamarix ramocissima*) is particularly bad for this along rivers in the desert SW, but also now known in eastern Washington. Tamarisk also traps sediments and organic material thus stabilizing banks and channelizing rivers, thus destroying flood plain habitats.

3. Stabilizing habitats in areas that are naturally disturbed
   - beach and salt-marsh grasses, such as *Spartina alterniflora*, can stabilize mud flats and catch sediments, thus converting shallow estuaries into stable land (almost like filling a wetland). Example: Willapa Bay in SW Washington

4. Increasing the frequency and intensity of fires
   - by increasing fuel load (some grasses that die each year) or by being a fast-burning plant (gorse – *Ulex europaeus*), fires can become more common or more intense, thus altering the native plant community. *Pennisetum setaceum* is a grass that invades dry forests in Hawaii and helps spread fires in habitats where fires were rare before.

5. Vines adding weight to tree canopies. English Ivy has thick, evergreen leaves, which adds a lot of weight to deciduous tree canopies in the winter when they don’t usually have the weight of leaves and causes trees to fall in wind storms.
Some invasive plants can be harmful or even deadly. For example, Giant Hogweed - *Heracleum mantegazzianum* can cause harmful burns on the skin from the sap in the stems and leaves. This is a class “A” noxious weed, which means that all means of eradicating it should be taken (this designation is generally used only for weeds that are still limited enough that eradication is feasible). [“Revenge of the Giant Hogweed” by Genesis]

Hybridization with non-native plants also can dilute gene pools and in some cases even extirpate native species (eg, rainbow trout hybridizing with and eliminating cutthroat trout from throughout most of the native range of cutthroat trout).

**Causes of endangerment of imperiled species in the US:**

<table>
<thead>
<tr>
<th>Cause</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat destruction</td>
<td>81%</td>
</tr>
<tr>
<td>Non-native species</td>
<td>57%</td>
</tr>
<tr>
<td>(we’re losing biodiversity due to invasive species!)</td>
<td></td>
</tr>
<tr>
<td>Pollution</td>
<td>19%</td>
</tr>
<tr>
<td>Overharvest</td>
<td>45%</td>
</tr>
<tr>
<td>Disease</td>
<td>1%</td>
</tr>
</tbody>
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**Positive impacts of Invasive plants (these usually are outweighed by their negative impacts)**

- Food or shelter for animals
- Erosion control – many species planted during ‘dust bowl’ in 1930’s have become invasive
- Aesthetically pleasing – many were first introduced for ornamental purposes
- Some species can produce useful goods for people (fruit, wood, etc.)
- Useful for pollination or other ecological services – the Honey bee is an introduced species.

**How do alien introductions occur?**

Estimated source of woody plant invasives:

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landscape plants</td>
<td>82%</td>
</tr>
<tr>
<td>(ca. 2/3 or all alien plants)</td>
<td></td>
</tr>
<tr>
<td>Overall, ca. 65% of invasive plants are introduced this way (herbs are more likely to be seed contaminants introduced with other plants)</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>14%</td>
</tr>
<tr>
<td>Erosion control</td>
<td>3%</td>
</tr>
<tr>
<td>Accidental contamination</td>
<td>1%</td>
</tr>
<tr>
<td>(but this is much higher for many herbaceous plants, especially those that come in as seed contaminants in agricultural shipments)</td>
<td></td>
</tr>
</tbody>
</table>

“The 10s Rule” – Potential for new weed species (estimate by Rappaport 1991)

10% introduced species have capacity to become adventive
10% of adventives are capable of establishing viable populations
10% of those that establish viable populations may become problem species
With ca. 260,000 species of flowering plants and about 10% of those as good colonizers, that makes about 26,000 potential weeds. There are now about 10,000 species recognized as weeds and, of them, about 4,000 have spread to other continents. So even with a conservative estimate of 10% of the remaining species becoming successful weeds, that leaves more than 2,000 more potential weeds.

Cars and people are major vectors of invasive plants, boats and boat trailers are important vectors for spreading aquatic aliens.

Phases of an invasion.
1) Establishment (“lag phase” - slowly spreading; invasives as “sleeper” populations); can be a real or perceived period of time between introduction and expansion
2) Expansion (dramatic take-off in population size)
3) Saturation (this is mostly theoretical and most invasives in the PNW may not have reached this phase)

What triggers the expansion following the lag phase?
1) Major disturbance (e.g., hurricane or forest fire)
2) Staging areas (e.g., new horticultural introductions often are distributed slowly among gardens before they become popular); e.g., *Verbena bonariensis* - “purple top”
3) New genotypes or hybrids (a hybrid between diploid European and North American species of *Spartina* has produced a tetraploid species, *S. anglica*, which has become invasive where the parental species have not)
4) Human perception! It may be that there is no ‘lag phase,’ but only that no one was aware of it until it became quite widespread and then was recognized everywhere. Pampas grass (*Cortaderia selloana*) has been monitored in western Washington for years, but has only recently become self-sustaining. *Arum italicum* has been established for years, but has only very recently started to ‘take off.’

**Q:** Why do aliens succeed?
**A:** They “cheat death” and they are effective migrants

Population sizes of all species can be modeled mathematically by the following simple equation:

\[ N_{t+1} = N_t + B - D + I - E \]

- \( N_t \) = population at starting point (time “t”)
- \( N_{t+1} \) = population after some time has elapsed
- \( B \) = births; \( D \) = deaths (e.g., stress tolerance); \( I \) – immigrants; \( E \) = emigrants

“\( r \)” is the intrinsic growth rate; high ‘\( r \)’ leads to fast population growth
Traits of invasive plant species
• Vegetative growth (e.g., rhizomes of riparian plants may spread by floods)
• Early seed production/fast growth
• Long flowering/fruits times
• Easy seed germination
• Nitrogen fixers
• Semi-evergreen (in western U.S., especially in semi-arid regions); e.g, Scot’s broom (*Cytisus scoparius*) and Himalayan blackberry (*Rubus bifrons*)

Establishing standards to prevent introduction of new invasive species.

In Australia: Australian Weed Risk Assessment (WRA) is a system of 49 questions in 8 categories for evaluating the potential risk for a given species. This has been >80% accurate for species that become invasive, but only 70% effective for predicting non-invaders.

Propagule Pressure (or infection pressure)
This implies that the more propagules are introduced, or the longer they are introduced, the greater the chance that the species will become invasive. Examples include studies that plants that have been sold for more years in Florida nurseries tend to be more invasive and plants in British seed catalogs from the 19th Century tend to be invasive there more often today than other plants more recently introduced to horticulture.

What you can do:
St. Louis Declaration (2001) – identifies what various interest groups can/should do to help prevent the spread of alien plants.
This “Declaration” provides a “Code of Conduct” for nurseries, botanical gardens, landscape architects, government agencies, and the Gardening public.

Gardeners Code of Conduct (from St. Louis Declaration)
• Ask nurseries for non-invasive species
• Don’t trade invasives with other gardeners
• Remove invasives from your property
• Ask gardens to display only non-invasives
• Help educate others about invasives
• Request that garden writers not promote invasive species
• Volunteer with groups to help remove invasive species
• Learn which agencies regulate invasive species in your area and report problem species to them (King Co. Noxious Weed Board: [http://www.kingcounty.gov/environment/animalsandplants/noxious-weeds.aspx](http://www.kingcounty.gov/environment/animalsandplants/noxious-weeds.aspx)).
• Help your garden club create policies about invasive species.
A pilot program in Seattle area asked 5 commercial nurseries to discourage the sale of invasive species and to promote alternatives. A booklet is available “Garden Wise” that describes alternatives to Invasive species.

Be sure to remove seeds from socks and other clothes and clean your hiking boots before leaving an area with weeds.
Don’t drive off road in areas with weed infestations.
Clean your boat well before leaving a lake or river with weeds in it to avoid spreading weeds to other bodies of water.