A population is a group of organisms of the same species in the same area.

Population Ecology—the study of population growth and distribution and the factors that affect these things.
Populations can be made up of individuals, clones or colonies.
The boundaries and distribution of a population are scale dependent.
How individuals within a population are distributed gives us information about how the individuals interact with each other and what environmental factors affect the individuals.
Distribution can be a function of how an organism can disperse. Plants are restricted by seed movement.
Animals are more mobile and thus can be more widely distributed in a short period of time.

Some animals are very widely dispersed depending on the time of year.

Arctic terns travel 40,000 miles in a year!
Red knots in NJ migrate from Patagonia to Hudson Bay. They depend on horseshoe crab eggs to give them the energy to make it to Hudson Bay and to be able to breed.
We tend to think of populations as being in one place with everybody being in that place. But, everybody may not be in the same place. There may be several local populations that together make up the total population. This group of local populations together form a metapopulation. When looking at a metapopulation, immigration and emigration or extinction play important roles in regulating population size.
When possible, individuals will move away from their area/population or move into a new area/population. The movement in and out of populations determines the density or the number of possible areas occupied.
Populations can spread over time. Invasive species are aggressive spreaders.
Assuming that individuals in a population cannot leave or enter, the number of individuals in a population is $N(t)$. The population changes in size as a result of births (B) and deaths (D).

Population size is given as: $N(t_2) = N(t_1) + B - D$ or: $N(t_2) - N(t_1) = B - D$

Birthrate $b = \frac{\#births}{dt} \times N(t_1)$  Deathrate $d = \frac{\#deaths}{dt} \times N(t_1)$

$\#births = B = \text{birthrate} \times dt \times N(t_1)$ and $\#deaths = D = \text{deathrate} \times dt \times N(t_1)$

$N(t_2) - N(t_1) = (\text{birthrate} \times dt \times N(t_1)) - (\text{deathrate} \times dt \times N(t_1)) = (\text{birthrate} - \text{deathrate})(dt \times N(t_1))$

Change in population size over time: $\frac{\Delta N}{\Delta t} = (b - d)N(t_1)$; $r = b - d$; $\frac{\Delta N}{\Delta t} = rN(t_1)$
Remember: \( r = b - d \) \( \Delta N/\Delta t = rN(t1) \)? This equation assumes that there is no limit to population growth. However, that is not generally the case once the population reaches a certain density. At that point, population growth declines until the population stays at a steady number. Thus, we need a new equation!!!

\[
dN/dt = rN(1-N/K)
\]
Density can affect population growth by changing reproductive output. In plants, this can mean fewer seeds and smaller seeds. In animals, it can mean fewer offspring or fewer females having offspring.

The presence of a predator can also change population growth. Some studies have shown that tadpoles will mature faster when a predator is present.


But, other studies show that the presence of a predator can slow down growth due to avoidance of the predator (this will be discussed at a later time)
Density is directly a result of numbers of individuals in a population and the area over which the population is spread.

Larger animals need larger areas or in other words, area is more limiting for larger organisms.

Behavior can influence population density and the effects of population density. For example, if density is high, certain female birds will stop producing eggs.
Density can be regulated by territorial behavior. Males of certain bird species will claim territories by the loudness or complexity of their calls. When males are removed, others will move in to their territories either from adjacent areas or from outside the immediate area.
The environment also plays a role in controlling population size. This is called density independent control.
Age and age distribution are important characteristics of a population. The question is: what proportion of a population is the reproducers? How often are they reproducing?
Population growth is a function of reproduction which can be sexual
Or, asexual
Sexual reproduction can happen between different organisms or within the same organism.
Worms are hermaphroditic, but mate with other worms.
Some organisms can change sex depending on environmental conditions.

Parrot fish can change from female to male.

Jack-in-the-pulpit can change from asexual to male to female.

Communal insects can change sex ratios depending on colony needs.
Sexual selection:
Either females select males with greatest chance of success or males with greater chance of success select females. It’s all about resources and immune systems and ??.
Different species may invest more or less energy in their offspring. Species that produce many offspring are termed r-strategists and those that produce few offspring are termed K-strategists (we will return to these terms later).
From an evolutionary point of view, reproduction is a matter of reproductive success which is a function of trade-offs between access to resources (energy), allocation of resources (growth vs sex), parental care.

\[ r \text{ vs } K \text{ selection} \]

Production of offspring requires energy and thus there are trade-offs between size and numbers.
On the other hand, larger organisms can produce more offspring.
Habitat selection can influence reproduction
Northern birds may have larger clutches because:
1. They have more food available
2. They live in a less predictable environment
3. They have higher mortality in the winter (and thus fewer competitors for food in the spring)
Once reproduction occurs, numbers of offspring and care of them is important
Attack of the plant invaders: A special case of population and ecosystems ecology

Fact is worse than fiction!!
THE REGIONAL IMPACT OF AN INVASIVE SPECIES, JAPANESE KNOTWEED, ON SURFACE WATER SYSTEMS

Dirk Vanderklein
Josh Galster
Montclair State University

Acknowledgements:
• Karina Schäfer (Rutgers-Newark), Rob Scherr, Kiryl Bychkouski, Anita Trajkovska, Kim Vanderklein, Ian Vanderklein, Nicole Bujalski, Hyun Kho, Jared Lopes
Why do invasive plants matter?

1. Non-native invasive plants account for about 26 billion dollars worth of damage to American agriculture every year.

2. Non-native invasive plants can take over a complete ecosystem.

3. Non-native invasive plants displace native animal and plant species.


!! Not all non-native plants are invasive (but may still cause problems indirectly – Liebold et al. 2012 Frontiers in Ecology and the Environment) !!
Number of exotic plants by state

Mac et al. 1998

www.fs.fed.us/ne/delaware/biotrends/biological_trends.html#Biodiversity/T&E%20Species/Species%20Abundance
### Plant species losses by state

<table>
<thead>
<tr>
<th>State</th>
<th>Number of native species</th>
<th>Native species extirpated or extinct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
</tr>
<tr>
<td>Maine</td>
<td>1,500</td>
<td>84</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1,700</td>
<td>53</td>
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<td>59</td>
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<td>49</td>
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<tr>
<td>Ohio</td>
<td>1,800</td>
<td>84</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>1,700–1,800</td>
<td>13</td>
</tr>
</tbody>
</table>

1/7/2002

Mac et al. 1998

www.fs.fed.us/ne/delaware/biotrends/biological_trends.html#Biodiversity/T&E%20Species/Species%20Abundance
How do invasive species alter ecosystems?

- Outcompeting native species for resources (light, nutrients, water, pollinators)
- Altering the physical environment (soil properties, water flow, soil moisture)
- Altering the chemical environment (salt, oxygen, acidity)
- Altering natural sources of disturbance (effects of wind, fire, flood)
- Altering species interactions & food webs

Ehrenfeld, 2007
Outcompeting native species for resources (light, nutrients, water, pollinators)

Norway maple
Honeysuckles, vines

- compete for light
- inhibit germination & growth of seedlings of native trees & understory herbs → loss of biodiversity, forest health

Ehrenfeld, 2007
Altering the physical environment

**Tamarix**
- Removes large amounts of water
- Causes large amounts of sediment to accumulate → damages water resources for agriculture, human use

**Phragmites**
- Accumulates sediments
- Eliminates refuges (pools) for young fish → reduce sport fish & commercial fish populations

Ehrenfeld, 2007
Altering the chemical environment

Ice plant (*Carpobrotus edulis*)
- concentrates salt at the soil surface → discourage native species

Salt-lover (*Halogeton*)
- Takes up salts from the soil → poisonous to cattle and sheep on rangelands
- Makes surface soils too salty for other plants → eliminates desirable forage plants

Ehrenfeld, 2007
Nutrients: alteration of flux rates

**Berberis thunbergii**
Increase nitrification rates
(Japanese barberry)

**Lantana camara**
Increase decomposition rates
(Ham 'n Eggs)

Ehrenfeld, 2007
Pueraria montana - Kudzu

The plant that ate Georgia. Introduced for animal food and to reduce soil erosion. Grows 1 foot per day. Completely overgrows everything.

www.nps.gov/plants/alien/fact/pulo1.htm
www.nps.gov/plants/alien/fact/img/pulo1b.jpg
www.nps.gov/plants/alien/fact/pulo1.htm
overstated.net/photos/kudzu/kudzu-car.jpg
Hedera ilex - English Ivy

Introduced as an ornamental plant. Still used that way. Completely overgrows everything. Toxic to animals and people.

www.nps.gov/plants/alien/fact/hehe1.htm
Lythrum salicaria - Eurasian purple loosestrife

Is spreading at a rate of 270,000 acres per year. It has displaced 44 native plant species and is threatening the bog turtle. It costs the US Government about 45 million dollars per year to control. Newest control is a non-native beetle that eats the plant (Pimental et al. BioScience 50: 53-65).

www.nps.gov/plants/alien/fact/lysa1.htm

www.npwrc.usgs.gov/resource/1999/loosstrf/cover2.jpg
A few local non-native invasive plants:

- Japanese knotweed
- Japanese honeysuckle
- Japanese barberry
- Multiflora rose
- Lesser celendine

[www.nps.gov/plants/alien/fact/]
[http://berkeley.edu/news/media/releases/2009/05/26_exoticpests.shtml]
More importantly, invasive plants impact hydrological processes.

1. Tamarisk removes more water than native vegetation under low baseflow conditions in US SW

1. Invasive plants in South Africa remove between 7% - 15% of surficial flow. Impact is exacerbated during low baseflow conditions

- Little research in temperate areas like northeastern U.S.
- Little knowledge of watershed-scale impacts

http://el.erdc.usace.army.mil/aqua/apis/PlantInfo
We need to know how invasive plants are affecting water resources in temperate regions because:

Human water use is increasing (i.e., demand is increasing)

Cities and agriculture

http://site.recy-cal.com/blog/2011/08/02/recycle-your-plastic-water-bottle-containers/
In NJ Highlands region, 62% of sub-watersheds have been experiencing water shortages

5.4 million people depend on this water

(i.e. supply has decreased)

Van Abs & Hutzelmann, NJ Highlands Council 2010
Global climate change scenarios for the US NE predict increased ET and decreased streamflow

(i.e., supply will continue to decrease)

OK, maybe not this past summer

Water-using invasive species are a problem even in “water-rich” areas

A plant of concern: Japanese knotweed (Polygonum cuspidatum)
Japanese knotweed:

- Declared “New ornamental plant of the year” in 1848
- Now is declared highly invasive plant in NY and top invasive plant in NJ and banned in several other NE states
- Can be found in 41 states and half of Canadian provinces
Eco-hydrology of Japanese knotweed

- Can use as much water as tamarisk (salt cedar)
- Is extensively distributed along river corridors
- Has high leaf area and extensive root system
- Known presence in source areas for drinking water
Global climate change scenarios for the US NE predict increased ET and decreased streamflow coupled with concentrated rainfall events (i.e., supply will continue to decrease despite flooding events)
Importance of knotweed water use

low flows are biologically critical

- Aquatic habitat impacted
- Hydrologic connectivity of headwater streams threatened
- Duration is increasing
So,
-We need to know how invasive plants may be affecting water resources in mesic (i.e. wet) environments such as the US NE

-Knotweed is a good candidate to consider because of its invasiveness and association with riparian environments

Enter Vanderklein and Galster and a multi-year study to assess the eco-hydrological impact of Japanese knotweed on the Third River, NJ.
Part One: The site-specific impact

Location: Bonsal Preserve, Montclair, NJ
About 20 acres in size
Experimental approach – Hydrological:

- Installed pressure sensors (levelogger junior, Solinst) in stream bed to measure water levels upstream and in-patch (adjusted for air pressure changes). Sensors were installed in June 2008.
Experimental approach – Hydrological:
- Determined diurnal maxima and minima during baseflow conditions
- Measured stream levels one month prior to and post knotweed harvest.
Experimental approach – Physiological:

Physiological measurements were collected on knotweed plants for two days before being harvested.

Leaves were measured across the canopy from left to right and front to back.

Measurements were recorded every hour from dawn to dusk.
Measured transpiration with a LiCor 6400 IRGA

Data were integrated over each measurement period (dawn to dusk) to get total daily water loss from the stand.
Harvested all plants within patch.

"Seriously, how are you NOT going crazy right now?"

Determined total leaf area for the patch (744 m$^2$) and total ground area (150 m$^2$) to give us leaf area index (LAI) of ca. 5 (m$^2$/m$^2$).
Results - Hydrology

Average Daily Minimum Stream Depth In Patch

Average Daily Maximum Stream Depth In Patch

Above the patch, change in stream depth was in opposite direction
Results - Physiology

Sunlight intensity at the measured leaves from dawn to dusk (and beyond).

Water loss from the leaves from dawn to dusk. Total average water loss for the day is 1556 liters. This translates into 10.4 mm of transpiration or the equivalent of 3 people’s water use for one day.
Part two: Extrapolating local impact to regional impact

Third River, New Jersey

- Manageable size (third order)
- Representative of land use in northern NJ
- Site of intensive physiological measurements
• Knotweed patches mapped with laser range finder
• Length and width of patches measured and recorded
• 5.7 km of river mapped
Unmanaged vs. Managed

- 2.3 km river length
  - 4.2 m² of knotweed per meter of stream

- 3.4 km river length
  - ~0 knotweed found
Stream areas classified in GIS

- 28.1 km total stream length
- 10.6 km classified as managed
  - No knotweed
- 17.5 km classified as unmanaged
  - 4.2 m² of knotweed per meter of stream

Stream areas classified in GIS

[Map showing stream lengths and knotweed classification]
Water use in the unmanaged 17.5 km of river channel

- 17,500 m stream length x 4.2 m$^2$ of knotweed per meter of stream = 73,570 m$^2$ of knotweed

- 73,570 m$^2$ of knotweed x 10.4 L water/m$^2$/day = 1,030,000 liters per day = 1030 m$^3$ water/day used by knotweed (=2060 people without water for one day)

- Average discharge of Third River is 51,000 m$^3$/day
- Water use by knotweed is 2% of average discharge

- Low flow discharge of 8500 m$^3$/day measured by USGS
- Water use by knotweed is 12% of low flow discharge
Implications of Japanese knotweed water use

- Knotweed uses significant amounts of water in “water-rich” areas (10% or more of low flow discharge)
- Negative impact on aquatic habitat amount and connectivity
- Negative impacts on water supply coupled with projected warmer and drier future climate
- However, this is extrapolating from a small area
- Need for more mapping of invasive species distribution and measure their physiological characteristics
Can we do anything to reduce the impact of Japanese knotweed on our water supply?

1. First and foremost, do not plant it or distribute it!!

2. Removal is almost impossible. Multiple doses of herbicide are needed along with mechanical removal.

3. Annecdotally, this does not guarantee permanent removal

   So....
One option is to find an economic use for it. For example:

We could discover a highly lucrative desire for it such as happened to the freshwater mussels in the Third River, once known as Pearl Brook.

This is most likely the Queen pearl which was discovered in Notch Brook (possibly the Third River) in a freshwater mussel. After its discovery, pretty much all freshwater mussels were decimated from the river in an effort by many people to make their fortunes.

Solution: convince Tiffany Co. to make jewelry out of knotweed plants
Option 2: Find an economic use for the plant.

1. It has medicinal uses: laxative, diuretic, soothes burns and rashes, anti-oxidant (resveratrol).

2. It can be eaten: like rhubarb.
In the meantime, we need to get more accurate data on the distribution of the plant in New Jersey and we need to get better estimates of its water removal and where the water is coming from (soil and/or river).

This is where you can come in (if you are interested):

Citizen Science: mapping knotweed distribution throughout the state.

Research this summer.
Invasive plant data bases:

1. www.nps.gov/plants/alien
