Plant Succession, Pest Management and the Role of Herbicides

Kayla Malone

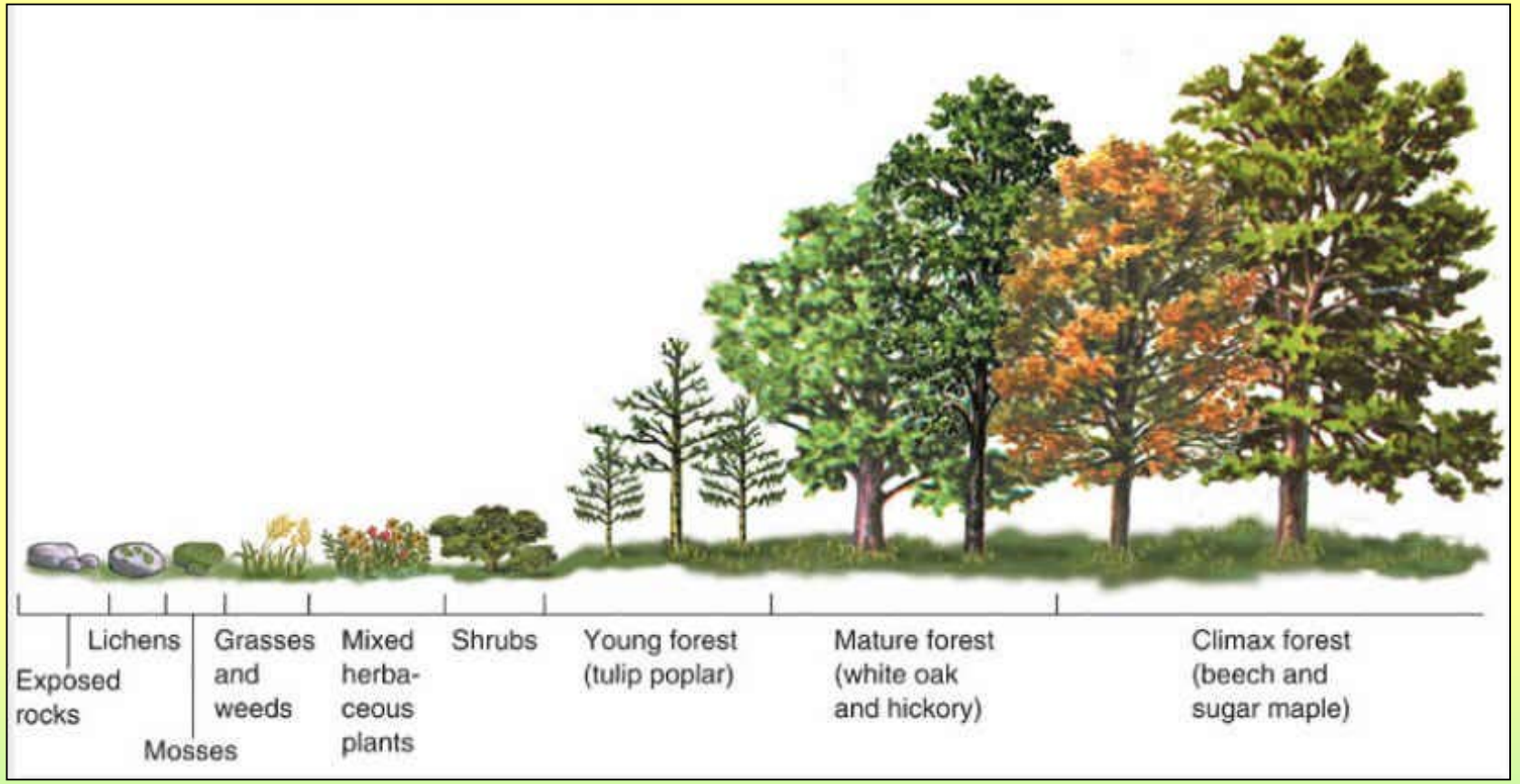
Chaffee County Noxious Weed Program Director

Outline

- What is Succession? (20 Minutes)
- How Invasive Species Impact Succession. (10 Minutes)
- How Management Tools Impact Succession (15 Minutes)
  - Mechanical
  - Biological
  - Chemical
  - Cultural (Prevention)
- Questions and Comments

What is Succession?

Observed, orderly changes in community composition over time.



Successional Pathway Examples

When Fire is removed from a system, grasslands are replaced with shrubs and quick growing trees, which are later replaced with slow-growing trees.

Ex: Mountain meadows are consistently encroached on by aspens and other quick-growing shrub and tree species. This creates a shaded understory. This in turn creates ideal habitat for pine tree germination (mottled shade and protection from drying winds).

Ex: If fire remains an intermittent disturbance, then the ecosystem consistently shift towards tree encroachment, and back to grasslands.

Successional Pathways

- If left undisturbed, the area will pass though different successional stages, called a sere.
- Each new community is better adapted to changed environments which are provided by the previous community.
- Eventually a stable, climax community will develop and succession will not progress further.
- Climax communities are in stable equilibrium with prevailing climate.

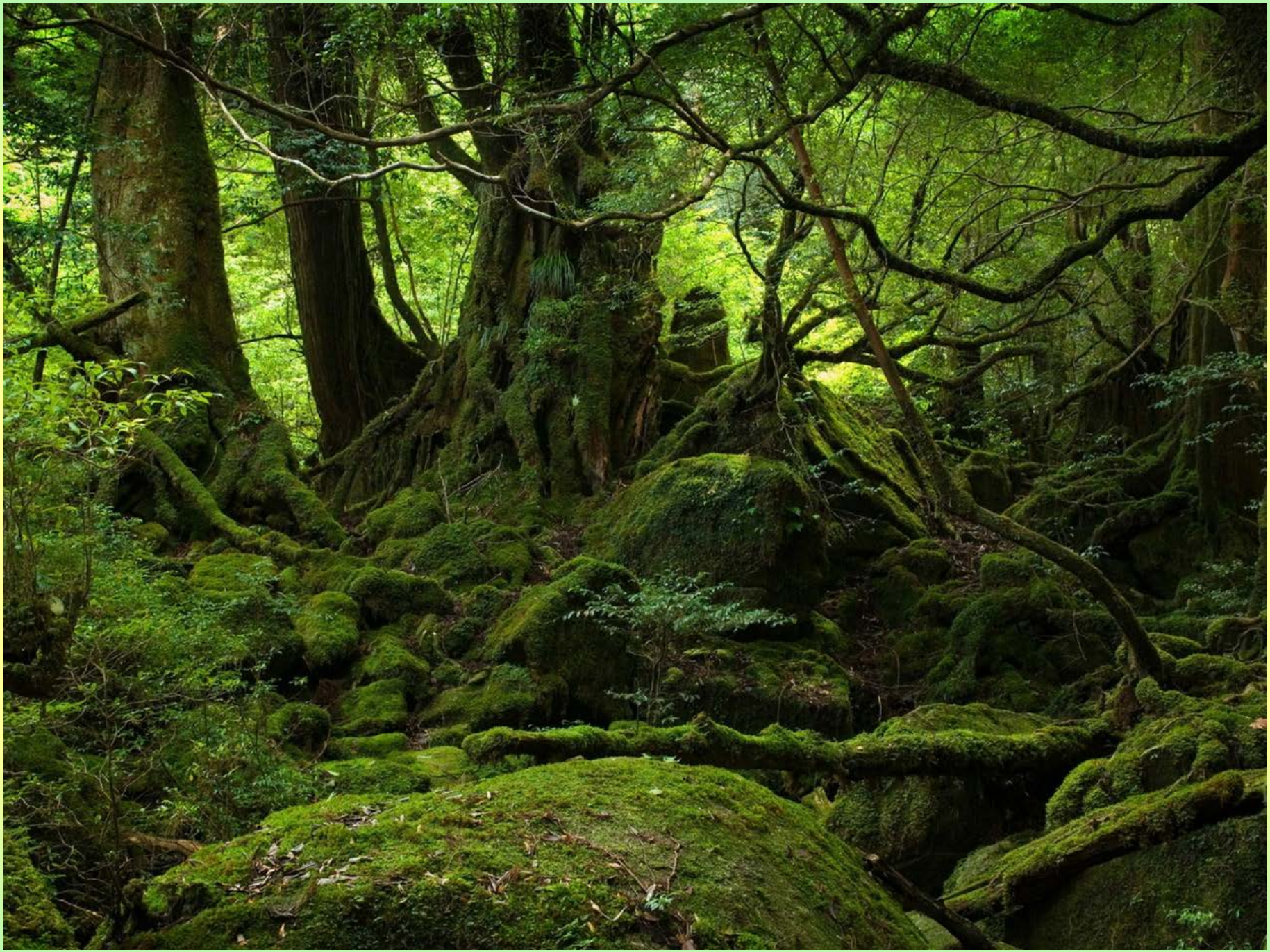
Climax Communities

“A historic term for a biological community of plants, animals, and fungi, which, through the process of succession in the development of vegetation in an area over time, has reached a steady state”

“An ecological community in which populations of plants or animals remain stable and exist in balance with each other and their environment. A climax community is the final stage of succession, remaining relatively unchanged until destroyed by an event such as fire or human interference.”

“Ecosystems that are resistant to colonization by outside species”


Buzzle.com
The Sonoran Desert is widely considered an apt example of a climax community in North America.



CO Climax Communities

- Pine and Spruce forests are climax communities.

Other ecosystems are kept in an earlier state of succession by a range of biological and climatic disturbances.

- Grasslands are NOT climax communities. They develop in regions where forests would be the climax community, but drought and regular fire intervals prevent tree establishment.




Disturbance

Disturbance is any activity or action that impacts vegetation cover.

Natural disturbances:

- Fire, flooding, extreme weather, wind, landslides, avalanche, drought, etc.
- Predation, grazing by ungulates, consumption by insects, and infection by pathogens.

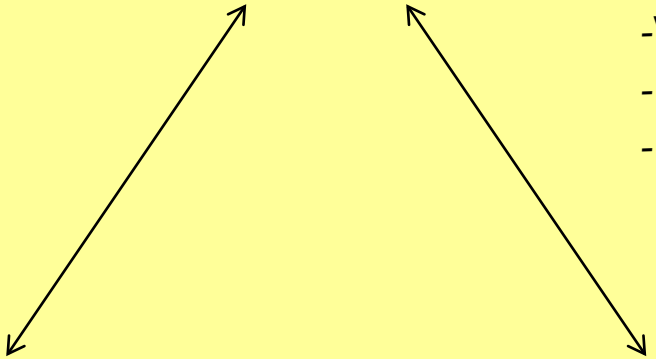
Human disturbances:

- Any activity that impact vegetation cover.
- Tilling, herbicide applications, mowing, seeding, gardening, ornamental plantings, development, road maintenance/development, tree thinning, prescribed fire, or any other action that impacts vegetation!!!

Ecological Succession

Environment

All abiotic characteristics of the site:
-Precipitation levels.
-Slope, aspect & exposure.
-Wind.
-Mineral composition.
-Bedrock structure.



Species

All biotic characteristics of a site:
-Bacteria
-Fungi
-Non-vascular plants
-Vascular plants
-Animals
-Insects

Disturbance

Any action, activity, or organism that can alter vegetation composition:
-Extreme weather events.
-Human Activity
-Invasive Species.

Types of Succession

Primary Succession – occurs on sites that have never had vegetation before.

- EX: Volcanic activity creates new land that never previously existed.
- EX: Glacial melt exposes area of bare rock that vegetation has never colonized previously.

Secondary Succession – occurs on sites that have previously been vegetated.

- EX: Seasonal flooding deposits silt over existing vegetation.
- EX: Hurricane blows down forest canopy.

History of Successional Studies

Early formal scientific work on succession began at beginning of the 1900's, environment-level observations of vegetation change over time.

- (1915-1950) Clements: late-successional species could not occupy the site w/o earlier-successional species occupying the site first.
- (1950-1970) Drury & Nisbet: plant species are sorted along a gradient with changes in resources driving changes in plant composition.
- (1977-1987) Connell & Slatyer: 3 models/mechanisms of succession.
- (1987-current) Pickett: successional pathways are driven by species availability, site availability, and performance of a species within a site.

3 Models of Succession

The key factor distinguishing the three models is how the process of succession affects the original, pioneer species (i.e. their relative success in later-successional stages).

- Facilitation – arrival of early species modify the site to be better suited for later colonizers.
- Tolerance – life-history traits of vegetative species determine order of species dominance.
- Inhibition – early arrival species utilize resources, preventing the establishment of later successional species.

Facilitation (+)

- Observed changes in vegetation composition is actively impacted. Early Successional species modify the environment so that it is less hospitable for the original species and FACILITATES the success of later successional species.
- Species impact on the environment positively drives (Facilitates) changes.
- Early successional, quick growing, species increase soil permeability and add biological material for soil development facilitating the growth of other species.

Tolerance (O)

- Observed changes in vegetation composition over time is passively impacted. Early Successional species neither inhibit nor facilitate the growth and success of other species. Changes over time is driven by the life history traits of the species on the site.
- Species COMPETITION is the mechanism that drives change.
- Short lived annual species are passively replaced by slower-growing perennial species over time.

Inhibition (-)

- A lack of observed changes in vegetation composition over time. Early successional species inhibit the growth of later successional species.
- The only possibility for new growth is a disturbance that leads to the dominating species being destroyed, damaged, or removed.
- Ex: oak brush scrub creates densely shaded sites that inhibit the growth of other successional species.

3 Models of Succession – 1977-1987

These models that can be observed on a landscape-level, the three models provide ultimate causation, not proximate.

Difficult to study, lacks predictive values.

WHAT happens, not WHY it happens…

What variables impact successional change?

- Availability of open sites – niches open for colonization.
- Availability of species - dispersal and establishment.
- Performance of species - ability to survive and compete with species.

Availability of Open Sites

Physical space become available for colonization after a disturbance disrupts established vegetation.

- How many layers of previous vegetation were removed.
- How deeply the substrate is stirred, mixed or buried.

Disturbances effects - the kinds and amounts of available resources that remain after the event; the degree to which biomass is removed or rearranged; and the water & nutrient holding capacity of exposed substrates.

Example: low intensity forest understory fire vs. high intensity forest canopy fire.

Availability of Species

Vegetation structure and compositions post-disturbance depends on the *availability of species* to survive the disturbance or their ability to reach the site after the disturbance.

- Species may persist through a disturbance.
- Species ability to invade from elsewhere.

Example: low intensity forest understory fire vs. high intensity forest canopy fire.

Performance of Species

Intrinsic characteristics that impact its ability to survive and thrive in an ecosystem.

> "the suite of activities that species employ to acquire resources, grow, persist, and reproduce"

- Life history traits
- Relative growth rates
- Age to maturity
- Competitive abilities
- Stress tolerance
- Herbivory & predator defense

Successional Pathway Examples

When Fire is removed from a system, grasslands are replaced with shrubs and quick growing trees, which are later replaced with slow-growing trees.

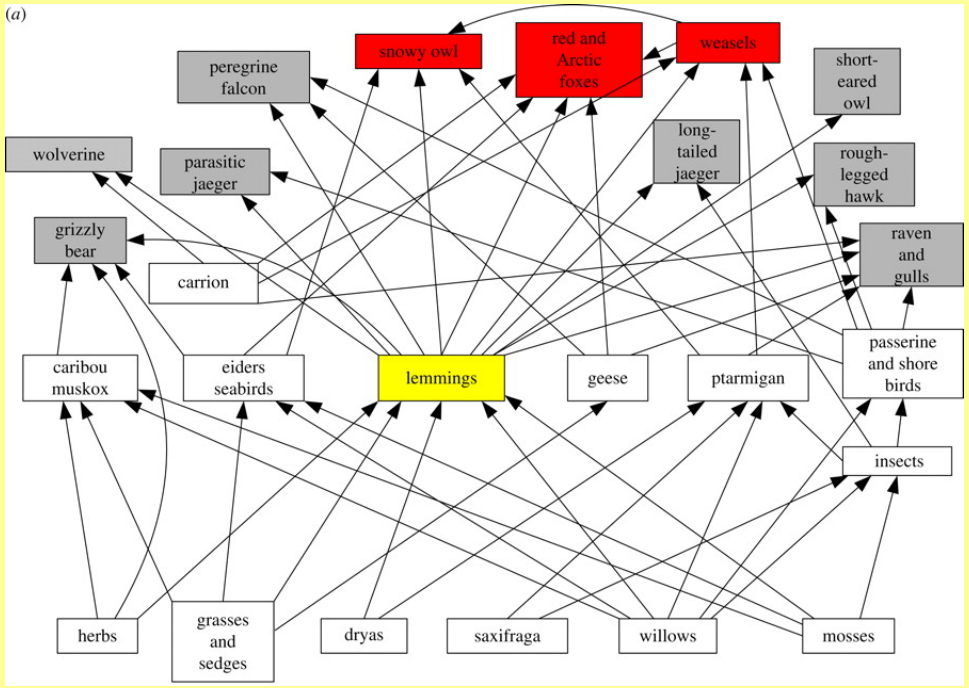
Ex: Mountain meadows are consistently encroached on by aspens and other quick-growing shrub and tree species. This creates a shaded understory. This in turn creates ideal habitat for pine tree germination (mottled shade and protection from drying winds).

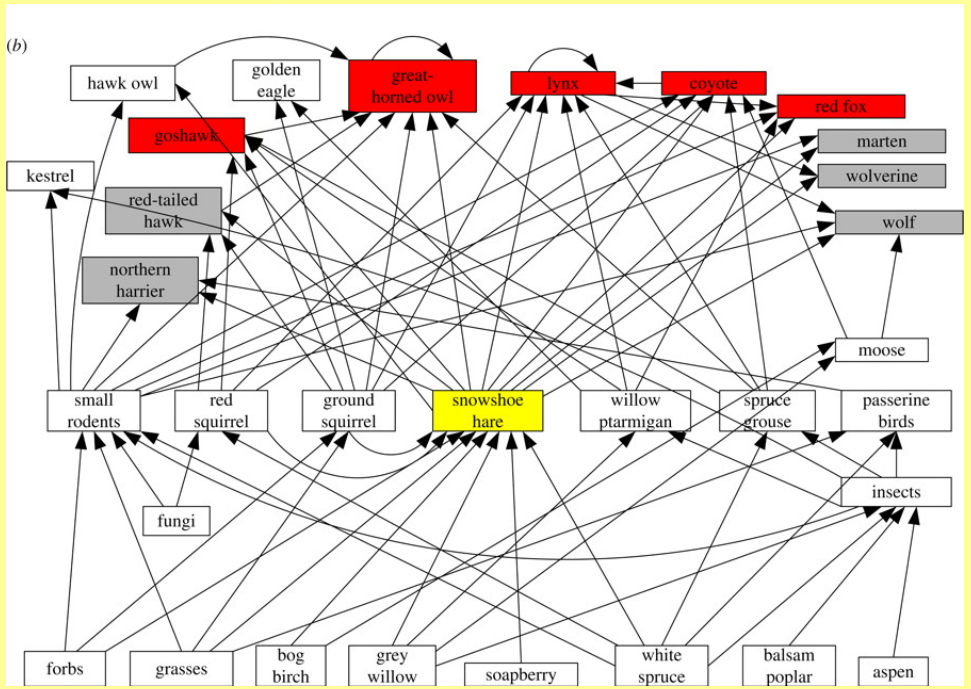
Ex: If fire remains an intermittent disturbance, then the ecosystem consistently shifts towards tree encroachment during years without fire, and reverts back to grasslands after intermittent burning.

What Happened?

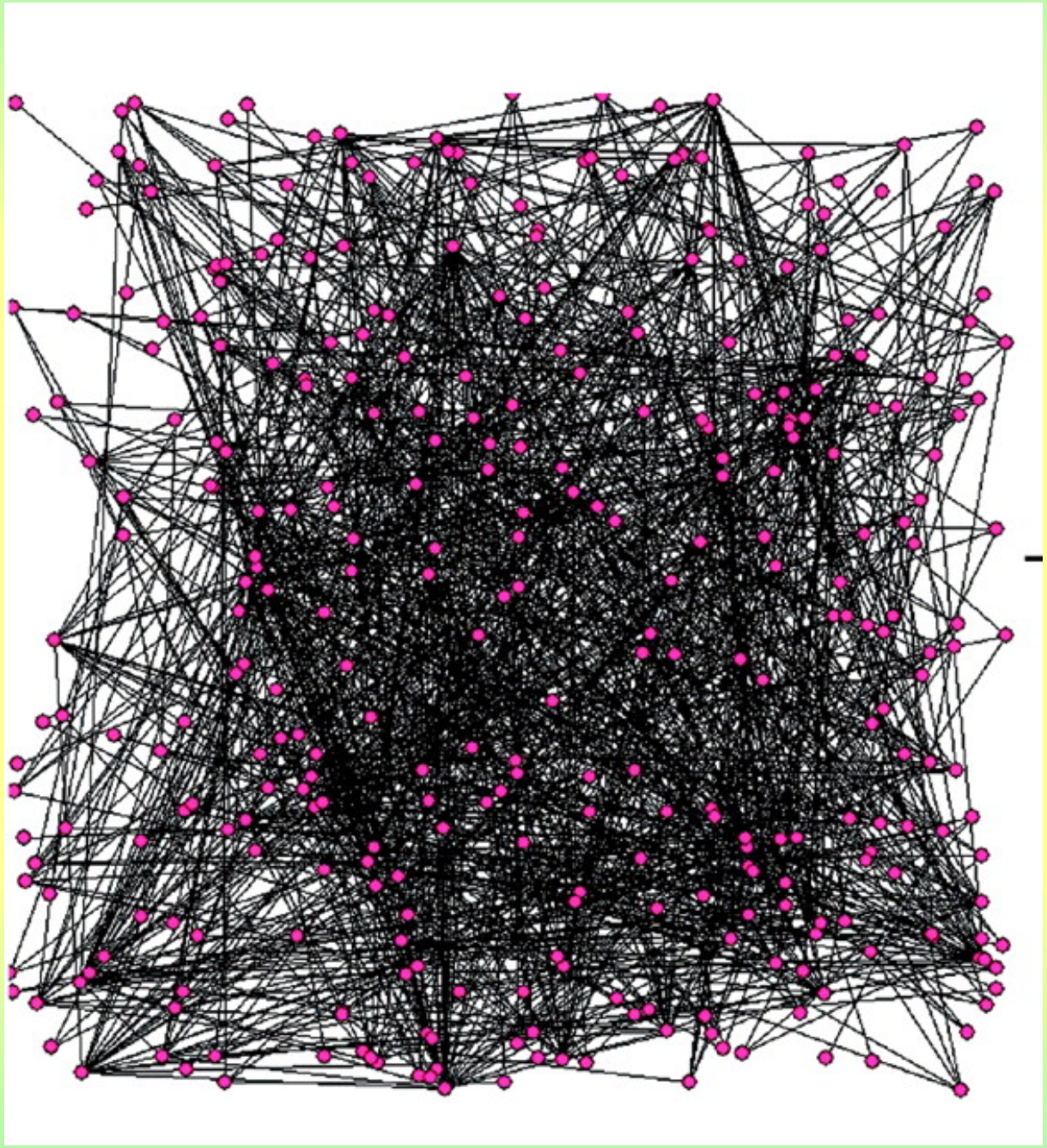
- Grasslands have *open sites* available for colonization by quick-growing, shade intolerant species.
- There is viable material available that will result in the development of the later successional species (*species availability*).
- The *performance of the species* (aspen trees and grasslands) have variable growth rate and potential biomass. Over time, the aspen trees dominate as an intrinsic factor of their growth and development. The ability to produce new shoots from existing root material enhances the advantage.

Food Web





Of lemmings and snowshoe hares: the ecology of northern Canada
Charles J. Krebs
Published 27 October
2010.DOI: 10.1098/rspb.2010.1992



Keystone species and food webs

Ferenc Jordán

Published 18 May 2009.DOI: 10.1098/rstb.2008.0335

Ecosystem Complexity

Dozens of plant species

Six unique habitat types

Many food sources for wildlife

Habitat for wildlife

Surface water for wildlife

Nutrient input for soil

Water holding capacity

Adaptable to environmental conditions

Very Complex Food Web

Invasive Species

- Nonnative, aggressive species.
- Evolved in separate ecosystems and have “escaped” from the predators/competitors of their native system.
- Typically observed after a disturbance occurs and creates open sites.
- Have the ability to impact all aspects of successional change.
  - Site availability
  - Species availability
  - Species performance

Site Availability

Invasive species rapidly take up open and available sites if seeds/viable materials are present.

-Fast germination rates.

-Quick growth rates.

EX: Common Mullein seeds persist though fire events, and rapidly colonize open sites post-fire.

Availability of Species

Many invasive species have intrinsic dormancy mechanisms. This allows for a build-up of viable materials on a site prior to disturbances. Intrinsic mechanisms that enhance the length of survivability for seeds, roots, and other viable materials are species-specific.

-Viable seeds or root materials can be buried and remain dormant for decades until ideal conditions for growth and development occur.

-Many invasive species have mechanisms that allow for the increased availability of the species.

Species performance

Most invasive species have limited or no natural predators or competitors. The individual mechanisms for success are highly variable but can include:

-internal toxins that reduce likelihood of consumption by animals and insects.

-allelopathic components that native species are ill-adapted to.

-adaptation to altered disturbance cycles.

-lack of specialized soil biota to consume/breakdown root structures.

Result: Inhibition

If:

-Viable material (seeds) from Mullen are present, AND

-A disturbance occurs that opens up viable sites, AND

-Conditions are ideal for germination and growth, AND

-There is a lack of plants that can out-compete this species.

THEN:

Mullen populations can create a stable vegetation community that will not change until an additional actions or activities results in a redistribution of available resources.

Summary

Disturbances on the landscape result in available sites which need to recolonized. Recolonization is dependent on the species available to recolonize post-disturbance (ability to persist through the disturbance or ability to disperse to the disturbed site). Changes in ecosystem composition over time are dependent on: availability of other species to disperse to the site and the ability of other species to compete with colonizers.

Invasive species have no natural mechanisms to keep populations in-check. This allows them to continue to colonize additionally disturbed sites unabated.

Ecosystem Complexity

Dozens of plant species

Six unique habitat types

Many food sources for wildlife

Habitat for wildlife

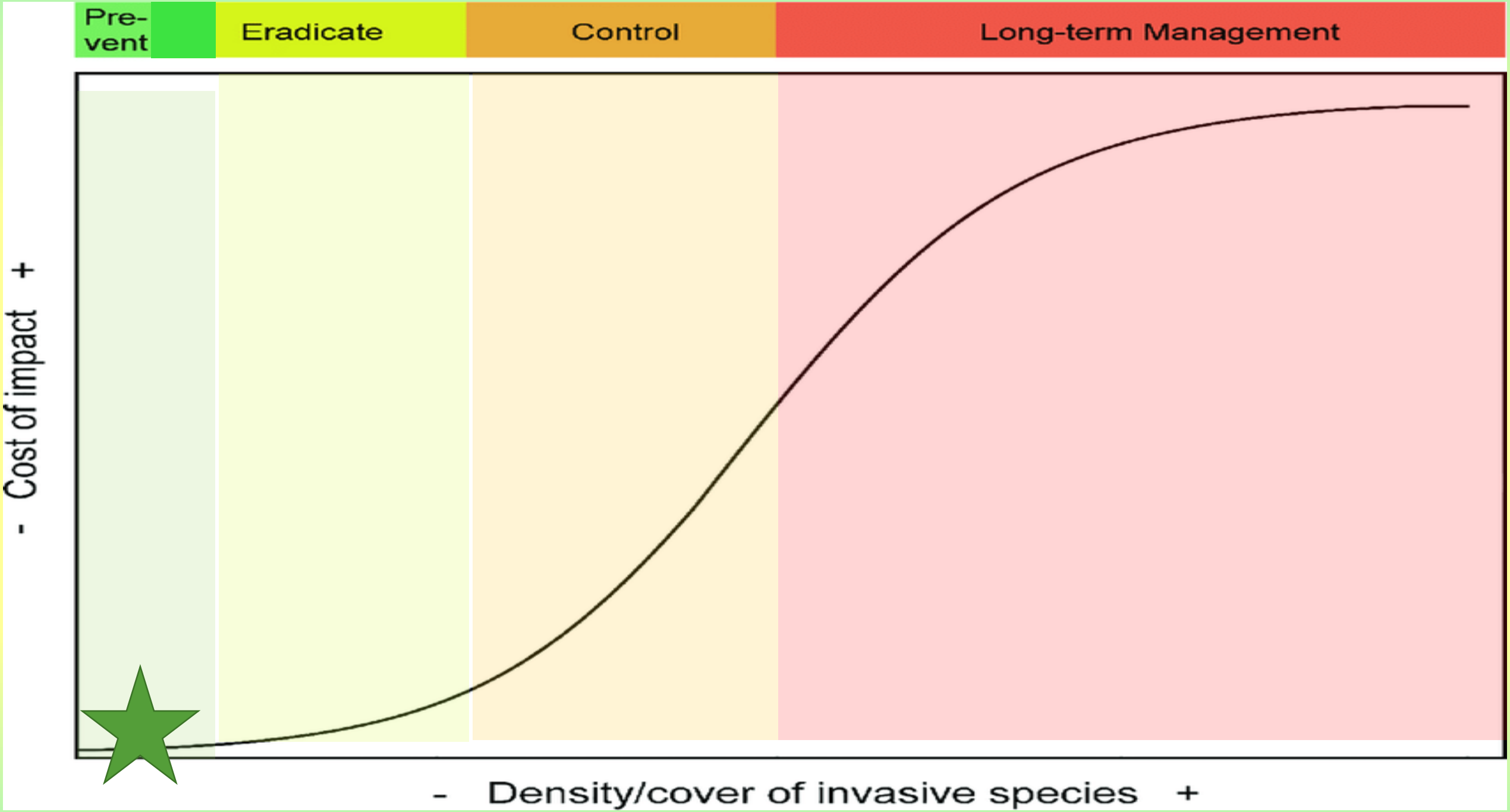
Surface water for wildlife

Nutrient input for soil

Water holding capacity

Adaptable to environmental conditions

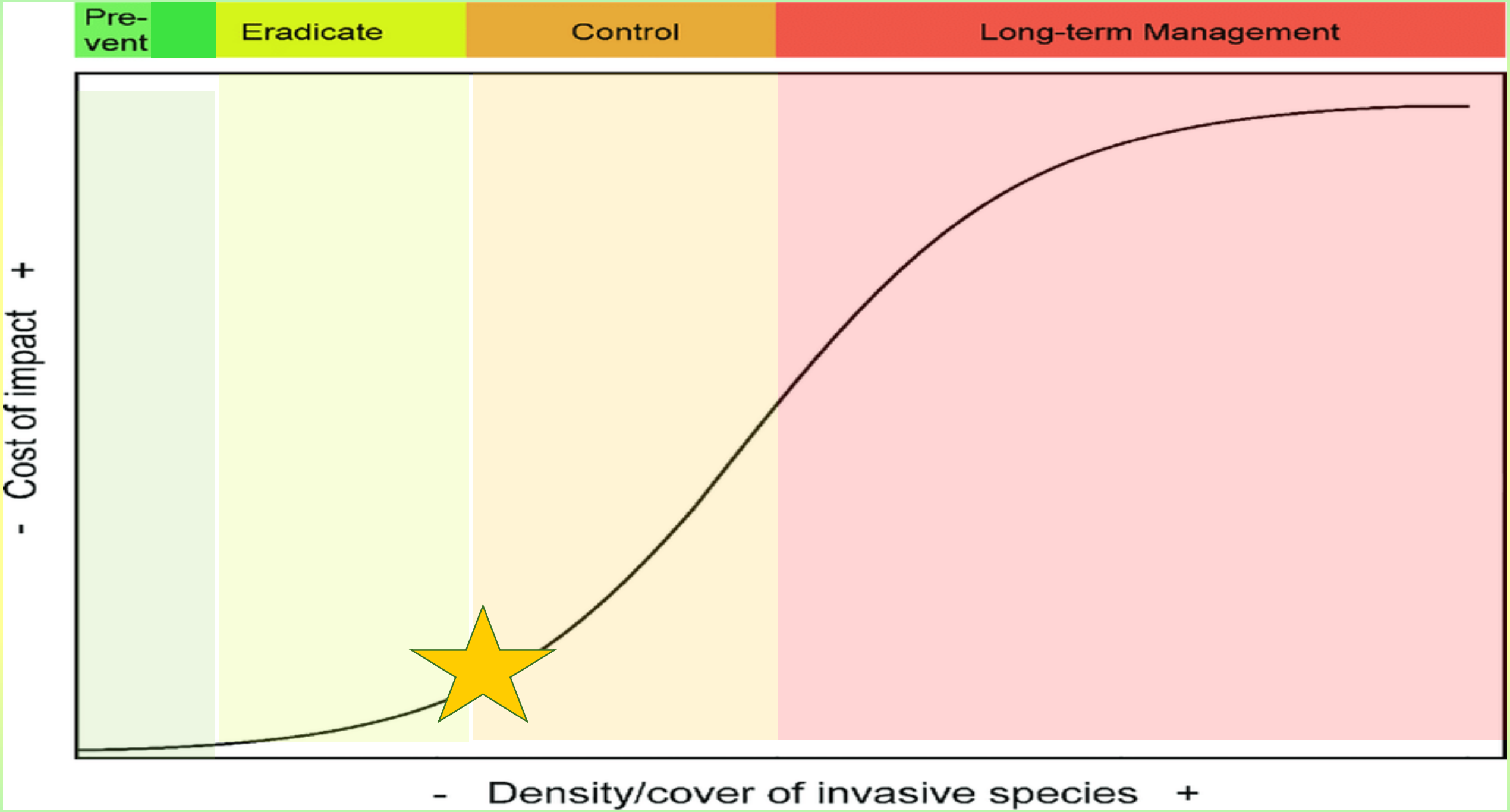
Very Complex Food Web


Pre-vent
Eradicate
Control
Long-term Management
- Cost of impact +
- Density/cover of invasive species +

Ecosystem Invasion

Moderate Stage of Invasion:

1. Viable Leafy Spurge was present in the ecosystem.
2. Grazing pressure resulted in reduced performance of grasses and forbs.
3. Open sites were available for colonization.
4. Leafy Spurge was able to out-compete native grasses and forbs. Lack of predation, disease or consumers drive successful species performance.
5. Naturally occurring disturbances continue to create open site available for colonization.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Ecosystem Invasion

Leafy spurge has taken over!

Limited, or no other vegetation.

Elimination of ecosystem functions.

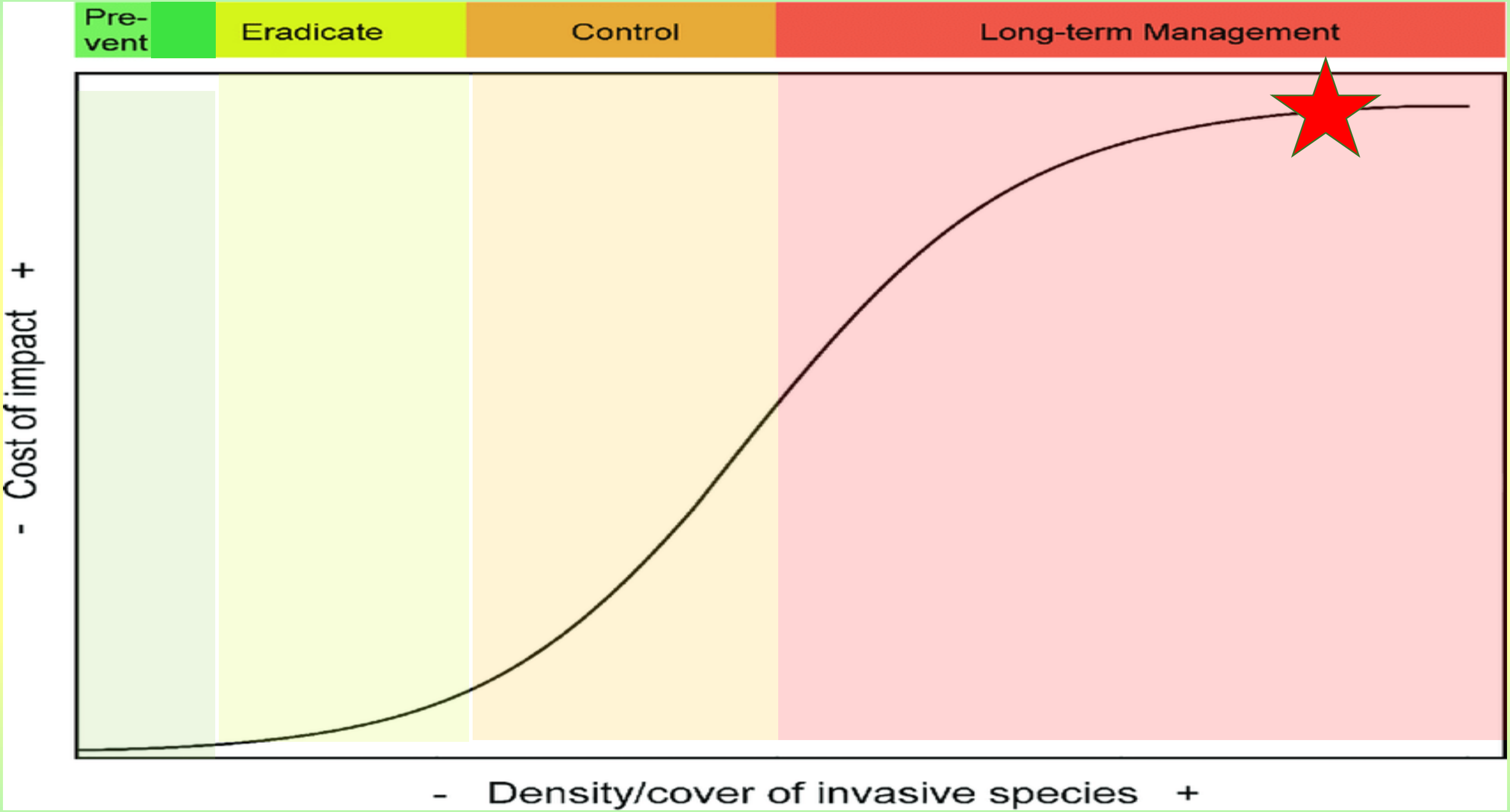
Simplification of food web.

Loss of habitat.

Elimination of wildlife.

Very intensive to restore.

Restoration efforts will be needed to re-establish native successional pathways.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Management Strategy Impacts on Succession

Each tool in the toolbox of weed management has the ability to impact different aspects of successional change over time. In order to develop effective Integrated Management Strategies, managers need to consider all aspects of native and non-native successional pathways.

Ideal management tools will negatively impact invasive species availability and species performance, while positively impacting native species diversity.

Mechanical Options

Mowing

Site availability,

Increases above ground sites for colonization. Does not impact below-ground niches.

species performance,

Negative impacts on species with growth points at tips (annual, biennial, and simple perennial forbs). Positive impacts on species with growth points at the crown (grasses, creeping perennials).

species availability.

Reduces the potential species availability of target and nontarget species if conducted before seeds are viable.

Increases potential species availability if conduced after seeds are viable (enhance dispersal).

Mechanical Options

Tilling

Site availability,	species performance,	species availability.
Increases the sites available for colonization by both target and nontarget species. Both above-ground and below ground impacts. Creates large open niches for re-colonization.	Can eliminate, reduce and/or damage target and non target species with simple root systems.	Can reduce the availability of target and nontarget tap rooted species. Can increase the availability of perennials with the ability to regrow from root fragments.

Mechanical Options

Hand removal of above and below ground materials

Site availability,	species performance,	species availability.
Increases available site by opening above and below ground space.	Eliminates targeted species without eliminating non-target species.	Reduces species availability of target species without reducing the availability of non-target species.

Herbicide

Non-selective, systemic herbicides. Broadcast application. – (Kills everything).

Site availability,	species performance,	species availability.
Increases all available sites by eliminating target and non target species.	Decreases/eliminates species performance of all species present at time of application.	Reduces the species availability of all target and nontarget species.

Herbicide

Non-selective, systemic herbicides. Spot treatment. (Kills everything)

Site availability,	species performance,	species availability.
Increases available sites by selectively removing target species.	Decreases/eliminates species performance of all target plants. No effect on non-target plants.	Reduces the species availability of all target plants by preventing additional seed development. Does not impact existing seedbed.

Herbicide

Selective, systemic herbicides. Broadcast Application.

Site availability,	species performance,	species availability.
Increases available sites by selectively removing target and susceptible non-target species.	Decreases/eliminates species performance of all target plants. Decreased performance on some susceptible species. Improves performance of non-susceptible native species.	Reduces the species availability of all target plants by preventing additional seed development. Does not impact existing seedbed.

Herbicide

Selective, systemic herbicides. Spot Applications.

Site availability,	species performance,	species availability.
Increases available sites by selectively removing target and susceptible non-target species. Reduced non-target effects compared to broadcast applications.	Decreases/eliminates species performance of all target plants. Decreased performance on some susceptible species. Improves performance of non-susceptible native species.	Reduces the species availability of all target plants by preventing additional seed development. Does not impact existing seedbed.

Biocontrol

The use of natural enemies (insects).

Site availability,

Indirect increases in site availability by reducing survivability of target species.

species performance,

Decreases the performance of targeted species by consumption, predation, and impacts on survivability of target plants. No impacts on non-target species.

species availability.

Decreased availability of target species over time due to; reduction in seeds produced, reduction in plants that reach maturity.

Biocontrol

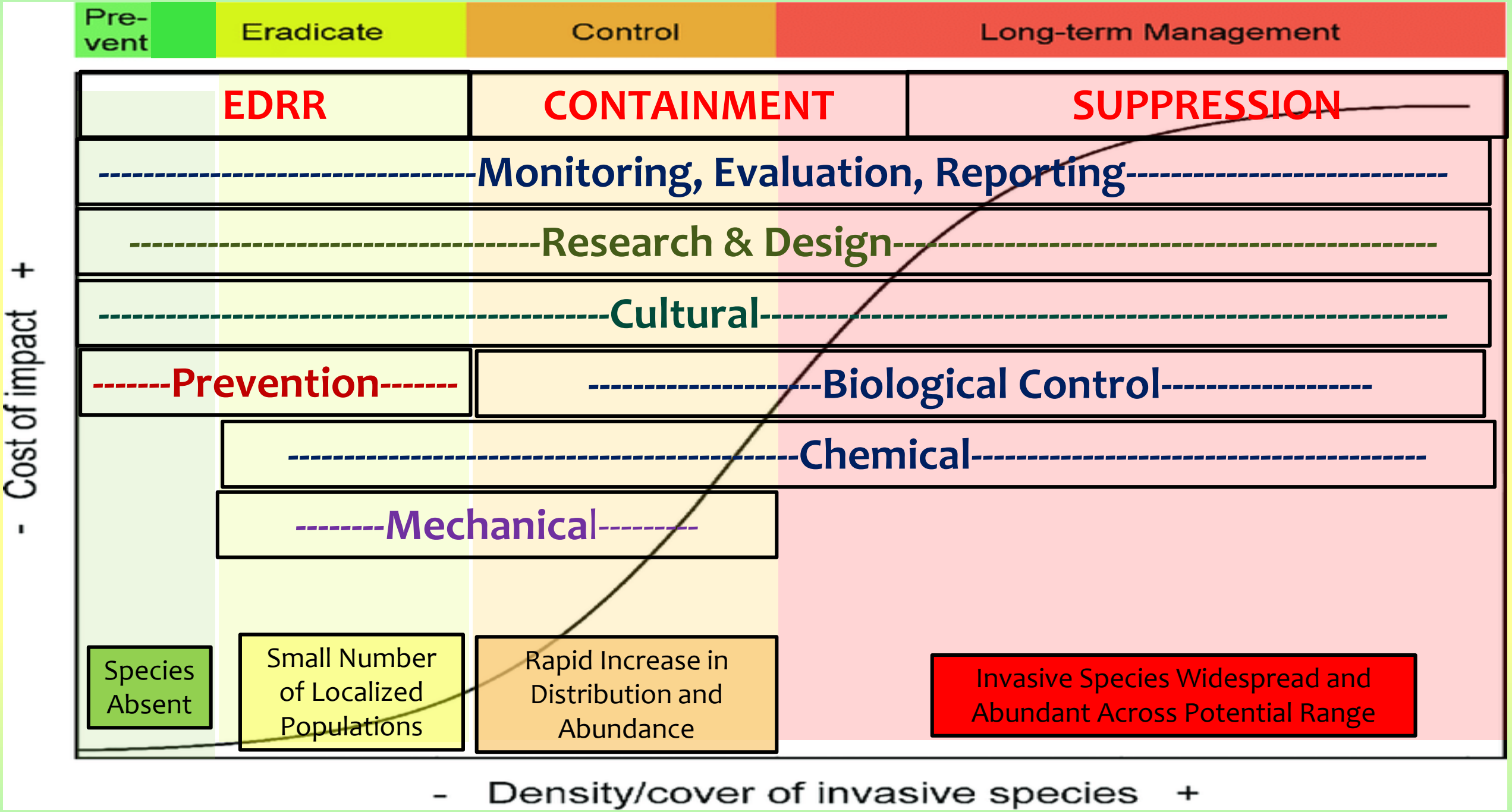
The use of natural enemies (livestock/herbivory).

Site availability,	species performance,	species availability.
Increases in site availability by hoof action and consumption activities (uprooting seedlings).	Decreases the performance of preferred species by consumption, predation, and impacts on survivability of target plants. No impacts on poisonous or non-palatable species. Increases species performance via nutrient input.	Decreased availability of preferred species over time due to; reduction in seeds produced, reduction in plants that reach maturity. Increase in non-preferred plant due to grazing pressure.

Cultural Controls

Thought experiments! How do the following techniques impact the three variables that influence successional change? (Site availability, species performance, and species availability)

- Fertilization.
- Hand broadcast native seed.
- Drill seeding of native seed.
- Washing equipment.


Pre-vent
Eradicate
Control
Long-term Management
EDRR
CONTAINMENT
SUPPRESSION
Monitoring, Evaluation, Reporting
Research & Design
Cultural
Prevention
Biological Control
Chemical
Mechanical
Species Absent
Small Number of Localized Populations
Rapid Increase in Distribution and Abundance
Invasive Species Widespread and Abundant Across Potential Range
- Cost of impact +
- Density/cover of invasive species +

Considerations

Historical (natural) disturbance regimes.

- Are these suppressed? Do they still occur? How did they historically impact native species? Should we re-introduce these disturbances to restore succession?

Human disturbance regimes.

- Are they ongoing? How do they impact site availability, species availability, and species performance of native and non-native vegetation.

Current stage of succession.

- What types of species are present on the site? What resource is the limiting factor? Is the site changing in complexity over time?

Considerations

Natural native community compositions.

- What should the community look like without invasive species? How does it function? What are the limiting resources? What are the factors driving competitive changes? Will native seed be necessary to allow for restoration of succession pathways?

Targeted Species.

- How many targeted species need to be managed? What are the traits that allow these species to dominate over time? Will removal of one targeted species result in a release of another? Are there long-term effects that will need to be managed once targeted species are removed?

Management Strategies.

- Do my management strategies effectively reduce targeted species performance and availability? How do these strategies impact native vegetation?

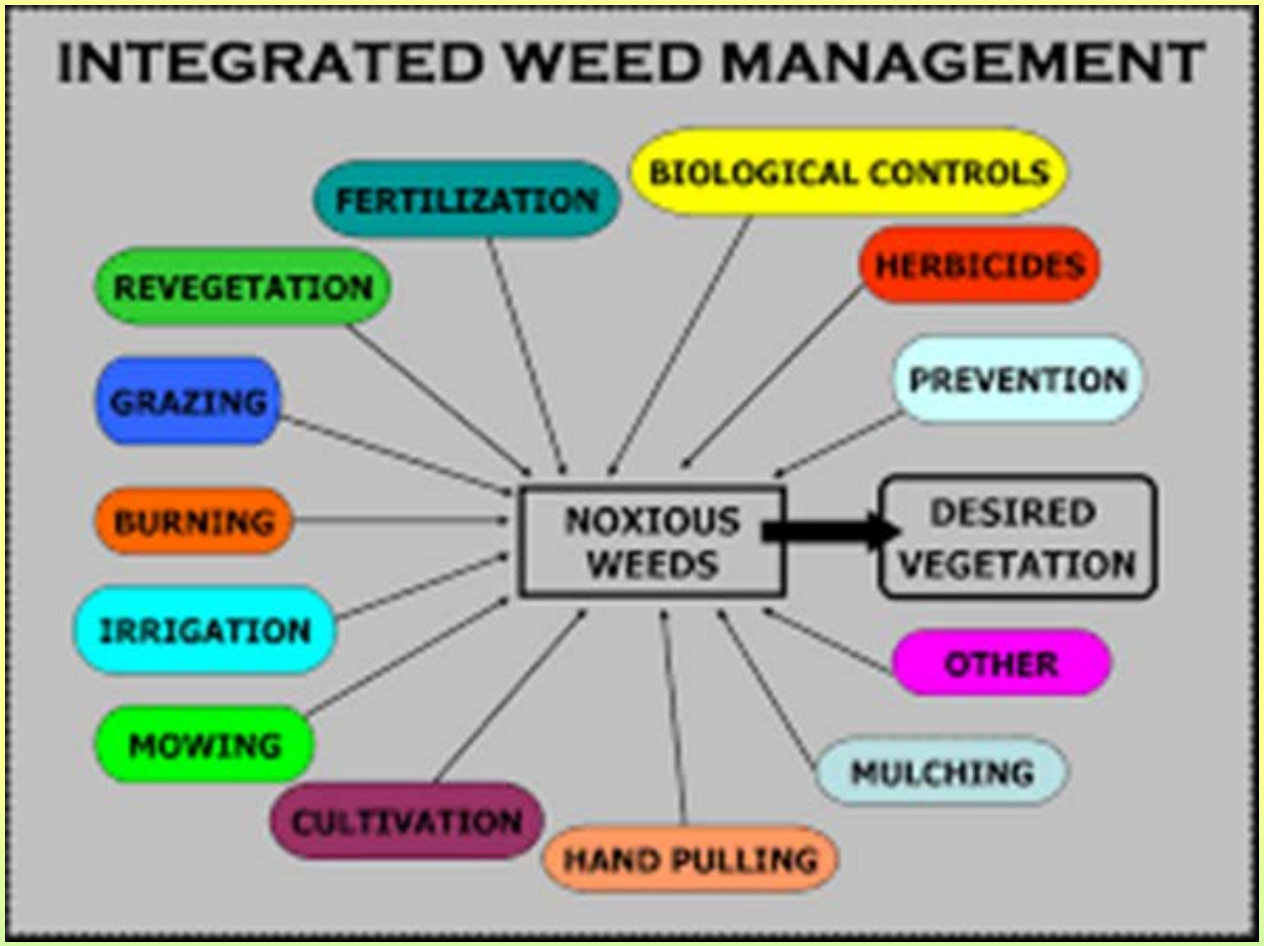
Management Goals

1. Reduce the sites available for colonization.
    - Limit disturbance on invaded sites. Reduce the potential for germination and development.

2. Reduce species performance of target invasive species while increasing species performance of non-target native species.
    - Use of management methods that selectively inhibit the species performance of non-natives.
    - Allow for mechanisms of competition and succession to establish.

3. Reduce the species availability of target invasive species while increasing the species availability of non-target native species.
    - Methods which prevent seed production and remove underground viable materials, without damaging natives are preferred.

Questions? Comments?



"The use of a variety of management strategies to reduce the survivability of pest species."

Kayla Malone
Chaffee County Noxious Weed Program Director
kmalone@chaffeecounty.org