



**Purple Loosestrife Performance Task**  
**The affects of Purple Loosestrife on Wetland Functions,**  
**And the impact of biocontrol.**

**Essential Questions:**

1. What is a Wetland? What is the Wetland Protection Act? What are functions of wetlands that the WPA protects? What are threats to wetlands? How have wetlands been impacted historically? How do people protect wetlands?
2. What threats to ecosystems do invasive species pose?
3. How can people help wetlands? How can we help?
4. How can we study whether the beetles are having an impact?
5. How can mapping loosestrife and beetle damage help to develop a plan for purple loosestrife control?

**Learning Goals (What you should know by the end of the unit):**

1. Wetlands have important functions that humans protect
2. Invasive species are a threat to some of the wetland functions.
3. Humans are working to protect and restore wetlands
4. Raising and releasing beetles is a way that students and teachers can contribute to wetland health.
5. Monitoring wetlands is a way to check how successful restoration efforts have been.
6. Mapping invasive species and beetle damage is a way to assess how widespread the problem is, and to begin to plan how to best approach the problem.
7. Plant and beetle life cycles

**Assessment of the Project:**

Students will need to have the following things built into their project

- **6 key terms used correctly and explained** in the project somewhere.
- Either the Poster boards, 3D models, PowerPoint, or Video must contain **solid content**, must **speak to the audience**, and professional qualities should exist (check your spelling and content).
- **All of the learning goals should be addressed** somewhere in the project as a way of proving that you have learned, and can talk about each knowledgably.

All students in the team must contribute **to the creation of the Model/poster/PowerPoint/Video**, and present equal portions **of the presentation**.



### **Purple Loosestrife Unit Project:**

Goal: To protect and improve the wetland functions in local wetland.

You are a wetland consultant in Essex County, Massachusetts. You have been asked to develop a wetland management plan for the school that your daughter attends. Purple loosestrife has invaded the wetland, and you know this is a threat to biodiversity. You have been hearing that *Galerucella* beetles have been used in the region for control of this invasive species, but you do not think they have been released in this particular city. You will need to prepare a plan in the form of a powerpoint presentation. Be sure to inform the conservation commission with critical background information such as the ecological values of the site that have been harmed by this invasive plant. Include a research-based prediction of what wetland functions may be impaired by this invasive species. Include details about specific plant and animal species that may be impacted. Contain a map of the areas currently impacted by the invasive, and other visuals that support the presentation. Explain potential control methods, and explain why biocontrol with *Galerucella* beetles is the best possible control method. Address any concerns people may have about biocontrol. Your presentation should be clear, persuasive, and scientifically accurate.

#### Checklist:

Your presentation should:

- ✓ Inform the conservation commission by telling the ecological values of the site.
- ✓ Include a research-based prediction of what wetland functions may be impaired by this invasive species. Include details about specific plant and animal species that may be impacted.
- ✓ Contain a map of the areas currently impacted by the invasive, and other visuals that support the presentation.
- ✓ Explain potential control methods, and explain why bio-control with *Galerucella* beetles is the best possible control method.
- ✓ Address any concerns people may have about bio-control.
  - Consider how you can respond to possible concerns that may be raised by abutters including:  
A bee-keeper, a local trapper, a Sanctuary Director, and the Conservation Commission who have never considered a project like this before.
- ✓ Be clear, persuasive, and scientifically accurate.

#### 7 Key Terms to use accurately in your presentation:

- *Galerucella*
- Biocontrol
- Invasive species
- Biodiversity
- Wetland
- Wetland Functions
- Wetland Protection Act



### **Presentation options:**

- Create a PowerPoint presenting current information. You should cover each of the goal bullets in some way in your presentation. Each person in the group is responsible for creating equal amounts of slides in the presentation, and each person must also present a portion of the information.
- Create a presentation with several professional poster boards covering the above listed unit goals. Each team member should create a poster board that is of professional quality, and must present the information that is covered on their board.
- Create a presentation using 3D models to demonstrate and explain the phenomena of invasive species and its affects on biodiversity. Each team member must create at least one, if not more than one, quality 3D model, which they will use to assist them in teaching the Conservation Commission about purple loosestrife and its affects on biodiversity.
- Create a video that can be shot in school that could be played to the Conservation Commission presenting the information. Each member must present a portion of the information. The final video product should be of professional quality. Props may be used as long as they are used to support the information you are presenting

Some Useful Web-sites to investigate:

<http://www.npwrc.usgs.gov/resource/plants/loosstrf/index.htm>

[www.mass.gov/czm/wrp/projects\\_pages/loosestrife.htm](http://www.mass.gov/czm/wrp/projects_pages/loosestrife.htm)

<http://www.invasiveplants.net/InvasivePlants/PurpleLoosestrife/PurpleLoosestrife.asp>

<http://www.springerlink.com/content/m8l203167uv7037k/>

### *Biocontrol Resources*

Vermont DEC: gives a detailed account of VT's efforts with loosestrife biocontrol:

[http://www.anr.state.vt.us/dec/waterq/wetlands/docs/wl\\_loosestrife-report.pdf](http://www.anr.state.vt.us/dec/waterq/wetlands/docs/wl_loosestrife-report.pdf)

Scientific article about *Galerucella* host specificity (Kaufman and Landis 2000). Beetle's effect on wild & ornamental plants besides purple loosestrife:

<http://www.landislab.ent.msu.edu/documents/PDF%20Pubs/Host%20Specificity%20Testing%20Galerucella.pdf>

Minnesota Coop. Extension website for *Galerucella* rearing:

<http://www.extension.umn.edu/distribution/horticulture/DG7080.html>

Two more sites with info/control techniques on loosestrife & other invasive plants

<http://www.invasiveplants.net>

<http://tncweeds.ucdavis.edu>

*Lessoning Loosestrife by Elizabeth B. Duff 2008*



### **Student checklist For Unit Project**

Name: \_\_\_\_\_ Date: \_\_\_\_\_ Class#: \_\_\_\_\_

**Please check off the things that you have completed. If there is something that you have not completed please write down which steps you intend to take to complete the given task.**

1. I understand that the unit project is worth 2 test grades as well as several participation grades. \_\_\_\_\_
2. I understand that I should be prepared to present the project on . \_\_\_\_\_
3. The overall project should have at least 7 key terms used correctly and also used properly within the flow of the presentation. My group has discussed how to meet this goal and is prepared to be able to meet this goal. \_\_\_\_\_
4. The words that I will use in my portion are:
  
5. I know that the goal of this project is to present to a Conservation Commission introducing the wetland functions that are impaired by purple loosestrife, possible control methods, and your recommendation to do biocontrol of purple loosestrife using Galerucella beetles.

List the job of each person in your team in the order in which they will present.

6. I also know that within the context of the presentation I must touch on each of the learning goals. I have spoken with my group about this and we have come up with a strategy to address this goal. \_\_\_\_\_
7. I have prepared some flashcards to read during the presentation so that I will know what I need to say. \_\_\_\_\_
8. My Project/Poster/PowerPoint is mainly visuals- I will talk about and explain each as part of my presentation. \_\_\_\_\_

Please address any portion of the project that hasn't been completed or addressed. Tell me what steps you will take to make sure that you are prepared to present. Use the back side of this page if necessary.



**Project Rubric**

**Group Member's names:** \_\_\_\_\_

**Due Date:** \_\_\_\_\_ **Class#:** \_\_\_\_\_

<b>Things I will look for when grading:</b>	<b>Rough Draft First check</b> (Place a check mark in the box if you have done this on your rough draft- be honest.)	<b>Final Draft second check.</b>  <b>Grade your work and substantiate it!</b>	<b>Teacher Check, and comments</b>
Title is present and meaningful			
The overall look of the presentation reflects a high level of effort!			
The message of your presentation is clear, and pictures/materials support that message			
Spelling, and sentence construction are correct.			
You have used your own words 100%			
Visual examples support your statements.			
All team members contributed to project.			
Color and creativity were part of the design process.			
A rough draft was turned in with the final.			
The project was complete and was turned in on-time.			



**Final Event:** Perform a Conservation Commission Hearing with Each Team Taking Turns presenting. Students will rotate between roles. Presenting, Conservation Commission, and Audience. (You may use the questions in the “Mock

Conservation Commission: 5-7 people. (If possible, they sit at the front behind a table. The presenter addresses them. The audience is the class on the other side.

Conservation Agent. (Optional)

Presentation Team

Audience

Optional:

Assign these roles to members of the audience to raise questions:

These roles may be played by “abutters” that attend the meeting.

You are a bee-keeper who lives next to the school. Your bees feed on the purple loosestrife in July, when few other flowers are blooming. You are concerned that your bees will have no food if the purple loosestrife is controlled. If this happens it will be a threat to your livelihood.

You are a trapper. You trap wild animals, and sell their fur. Ever since that pretty purple flower has showed up in your marsh, you’ve noticed there have been fewer and fewer animals in your traps. You are hoping to know more about this so you can continue to make money in this business.

You are a Sanctuary Director at a local Wildlife Sanctuary that is within a mile of this school. You are concerned about invasive species, but want to be sure that the beetle release does not harm any endangered species. Is there evidence that the beetle release will not harm other species, while it is controlling the purple loosestrife?

You are a Conservation Agent and you are charged with protecting the health of the local wetlands, and enforcing the Wetland Protection Act. You are wondering if this type of project has been approved in other towns in this region, how successful they have been, and whether there were any negative consequences.

# Purple Loosestrife competing with cattail



Figure 2. Purple loosestrife invades wetland areas and displaces native plants, such as cattails shown here.



**Photographer:** Mary Hollinger, NODC biologist, NOAA

## Muskrat Lodge made from Cattail

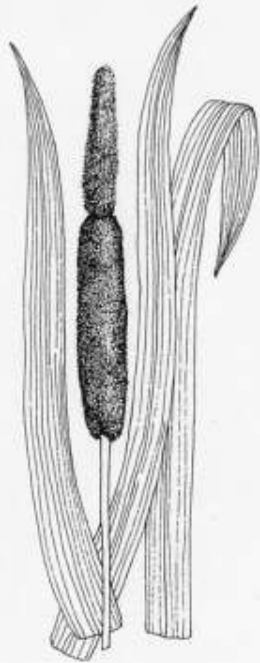


**Credit:** Christine Humphreys/Painet Inc.

Investigate: What other species might be impacted if purple loosestrife invades?



What additional species are impacted when purple loosestrife takes over a wetland?



## Common Cattail *Typha latifolia* L.

### TYPHACEAE (Cattail Family)

#### General Description -

Native perennial herb growing to 10 feet in height.

**Stem;** stiff, growing in dense stands from underground rhizomes.

**Leaves;** upright, linear, 2-6 feet long and up to 1 inch wide arising from the base or are alternating along the stem; leaves have a spongy feel which represents air-filled chambers responsible for channeling air to the roots.

**Flower;** many small flowers, packed into tight clusters creating a lower female spike topped by a smaller male spike with no gap between the two flower types; female spike persists turning into the familiar dark brown "tail" and appearing May-July.

**Habitat;** fresh marshes, also wet swales, stream, pond and lake margins.

**WIS; OBL**

### Common Cattail Interactions

**Community Interactions;** direct relationship between stand loss and bird brooding couple decline, thus implying impacts of wetland destruction; single flooding events can eliminate cattail stands which in turn reduce migrating duck populations and breeding waterfowl on flooded nest sites; impact of changing storm water runoff patterns to wetlands implied; creates ecotonal edge and serves food, shelter, breeding, overwintering, and migratory corridor wildlife habitat functional values; can be representative of a wetland in transition to upland field; an unusually zinc tolerant species through resistance to its uptake; this cattail occupies wetter sites than *T. angustifolia* and is less salt tolerant than the latter which invades brackish waters; plant will hybridize with other forms near coastal areas thereby adjusting to salinity changes; in winter, frozen substrate protects this plant from the effects of compaction by heavy construction equipment being driven over it with growth the next spring not varying significantly from that of the previous year-implications of how to possibly mitigate wetland impacts during construction are suggested by this.



**Mammals;** Muskrats build dens from leaves packed with mud for shelter, sleeping and rearing of young; they also use rootstalks, culms, and leaves as primary food source, consuming up to 10% of stand per year; Chipmunks and mice use fluff from the spike to line nests and the Whitetail Deer and occasionally Mink, will bed down in stands.



**Plants;** Giant Reed out competes Cattail, the favored nesting site of many birds, thus posing a threat to local population diversity; Cattail contains phenolic compounds in leaves which are released upon decay and inhibit germination of its own seeds, thus reducing competition within the stand; competes successfully with sedges and Swamp Loosestrife in or near water but less so further from the water's edge; observations support the contention that the seeds may release substances which limit the growth of blue-green algae; commonly seen growing with duck weed floating between the stalks.




**Birds;** Redwing Blackbird and Long-billed Marsh Wren suspends nest between stalks in dense stands 2-4 feet above the water, needing at least 3-5 adjacent stems for attachment and thus not nesting as readily in sparse stands; Swamp Sparrow attaches nest to stalks 2-4' above water; favored nesting site because it is rigid, an easy perch, and has wide spacing to allow for best defense; Semipalmated Sandpiper eat seeds; Snow, and Canada Goose eat seeds, young stalks, and starchy rootstalks; Least and American Bittern, the Sora, Virginia and King Rail, Common Moorhen, American Coot use leaves extensively for nesting sites and building material;




( continued )


## Common Cattail Interactions




**Birds** (continued); Sanderlings may line nest with material from dried spikes; many other birds including the Boat-tailed Grackle, Common Grackle, Black-crowned Night-Heron, Canada Goose, Mallards, Mute Swan, Blue-winged Teal can be expected to nest amongst these plants; rarely one might see a Green-backed Heron nesting in cattails and in very dense stands you can expect a good nesting site for the Glossy Ibis; if in remote, safe, undisturbed area, small (less than 1/2 acre) Cattail stands support feeding, nesting, and brooding for Canvasbacks.




**Reptiles;** Common hiding and occasional feeding site for Common Snapping Turtle; breeding site for Spotted Turtle; Common Snapping Turtle and Painted Turtle feed on seeds and stems; Northern Water Snake is very selective in its habitat usage, preferring drier vegetative clumps in cattail marshes for sunning- it will hunt for frogs, fish, and invertebrates in the wetter areas, as will Ribbon and Garter Snakes.




**Amphibians;** Northern Spring Peepers, Greenfrogs, Bullfrogs and the Northern Leopard Frogs breed here (look for N. Leopard Frog eggs attached to submerged stems).



**Insects;** Cattail Borer Moth goes through entire life cycle on head-stalk; female lays eggs on the flower in summer, larvae feed on seeds, construct a winter home from the flower cottony hairs, build a cocoon in spring in seedhead and begin the cycle again in summer after pupation, emergence, and mating; Oblong Sedge Borer Moth is common inhabitant of Cattail as are the White-tailed Diver moth and the Pickerelweed Borer Moth; none of these is a threat to cattail nor reduces its energy production; several other moths including Henry's Marsh, the Meal Moth, and the Shy Cosmet use this as a larval food plant; Backswimmers *Notonecta undulata* may attach eggs to stems under water, and the Giant Water Bug *Lethocerus americanus* and Velvety Shore Bug *Ochterus americanus* are found on the plants where they may lay eggs.




**Spiders;** Elongated Long-Jawed Orb Weaver builds orb web among leaves.



**Fish;** serves as cover for Bluegills and Pumpkinseeds, both of which may also hollow out a nest around base of plant; Carp are known to dislodge rootstocks, thus playing a role in the vegetative propagation (reproduction) of Cattail; plant has an associated aquatic insect population which probably serves as food for fish; Northern Pike are known to spawn in waters where this and other emergent marsh grasses grow.

( continued )

## Common Cattail Interactions



**Human/Economic Use;** one of the most famous edible and useful plants in the world, often referred to as the "supermarket of the marsh;" the young leaves are excellent salad greens and can be cooked as potherbs; before the pollen spike is ripe, it can be boiled and eaten much like corn on the cob; the pollen is high in protein and can be added to wheat flour as a nutritional supplement; the hairs of the fruit have been used to stuff pillows and life preservers; the rootstocks are high in starch and quite edible, eaten regularly by Native Americans; Cattail tea from the young spikes is used to stop diarrhea; American Natives including the Algonquin and Fox and early American pioneers used the flower down (fluff) as a wound dressing; dried leaves make excellent material for chair seats; this plant and *Phragmites* have photosynthetic rates comparable to some of our highly managed crops such as sugar beets, corn, and sugar cane; Cattails play an important role in pollution reduction by absorbing excess nitrogen and phosphorous and by slowing down the rate of water flow they allow for the settling out of suspended materials; has been implicated as an aeroallergen resulting in hypersensitivity in some humans.





## Purple Loosestrife *Lythrum salicaria* L.

### LYTHRACEAE (Loosestrife Family)

#### General Description -

Introduced from Europe and naturalized, a perennial herb growing to 5 feet with terminal purple inflorescence.

**Stems;** erect, tall, smooth to hairy.


**Leaves;** lance shaped, opposite to whorled (three) and tending to have clasping leaf bases and hairy surfaces.

**Flower;** insect pollinated, with 5-6 purple petals and green hairy sepals held in a dense terminal spike, appearing July-August.


**Habitat;** fresh marshes, wet meadows, pond and swamp edges, and usually in full sun.

**WIS; FACW+**


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**Community interactions;** research has shown that this plant can take up PCB (polychloro-biphenyls) pollutants, thus implicating it as an environmental filter; this is a highly invasive plant in all marshes where it gets started, propagating not only by seed but also vegetatively through growth of the strong fleshy roots; it normally out competes most other emergent plants, thereby reducing the high species diversity of both plants and animals which is usually characteristic of a marsh; this plant persists for many years and grows successfully in standing water; Loosestrife cheerfully colonizes the upper edges of salt marshes and the entirety of brackish ones; generally considered to be of low value to wildlife.




**Mammals;** the normal movements of Muskrats and Beavers along the water's edge often results in these plants being knocked down where the seeds may then be passively spread by water or become attached to animal coats and carried to new locations.




**Plants;** through rapid growth, it often establishes pure stands at the expense of other emergents.




**Birds;** Red-winged Blackbirds have been seen perching and nesting among these.



**Amphibians;** little information is available on interactions with this plant.



**Insects;** as a plant which produces large amounts of pollen and nectar high in sucrose, Honey bees, flies, beetles, and Bumblebees are often seen visiting the flowers and are probably involved in its pollination; one may chance to see the Water Scavenger Beetle *Hydrobius fuscipes* crawling over the leaves of this and other nearby plants; members of the Snout Beetle family Curculionidae may be involved in pollination; this is also the larval food plant for the Pearly Wood-nymph moth.



**Human/Economic Use;** the leaves can be consumed as a vegetable; infusions or extracts of the herb are reportedly used to control diarrhea; research has revealed that leaf extracts can stop internal bleeding; beekeepers have planted this herb in waterways because it is a valued source of nectar and pollen for their hives.

**Need To Know** about interactions involving amphibians, reptiles, fish, and spiders.

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**Questions: How is purple loosestrife impacting wetlands? Looking at past research.**

(Source From <http://www.springerlink.com/content/m81203167uv7037k/fulltext.pdf> page 4.)

On a separate piece of paper answer these questions:

1. Is purple loosestrife harming the wetland's value as a habitat?
2. If yes, what plants and animals (including birds) have been impacted?
3. Is purple loosestrife impacting biodiversity?
4. What wetland functions have been altered by purple loosestrife?

The chart below summarizes research done by different scientists. Scientists look at the research done by other scientists to learn what is already known. The "reference" column lists the names of the scientist who did the research. The "Field" column means the research was done outside. The "laboratory" column means the research was done inside a lab. Use the chart below to answer the above questions.

Reason	Field	Laboratory, micro- and mesocosms	Reference
Reduction of high quality bird habitat			
Black Tern ( <i>Chlidonias niger</i> )	X		Hickey 1997 Hickey and Malecki 1997
Least Bittern ( <i>Ixobrychus exilis</i> )	X		Lor 2000
Pied-billed Grebe ( <i>Podilymbus podiceps</i> )	X		Lor 2000
Virginia Rail ( <i>Rallus limicola</i> )	X		Lor 2000
Sora ( <i>Porzana carolina</i> )	X		Lor 2000
Long billed marsh-wren ( <i>Cistothorus palustris</i> )	X		Rawinski and Malecki 1984 Whitt et al. 1999
Reduction in plant biodiversity			
Reduction in native plant species	X		Gabor et al. 1996
Domination of seed bank	X		Welling and Becker 1990
Superior competitive ability of purple loosestrife		X	Weiher et al. 1996
Replacement of cattail ( <i>Typha</i> spp.)		X	Mal et al. 1997 Weihe and Neely 1997
	X		Mal et al. 1996 Weiher et al. 1996
Reduction in pollination and seed set of native rare plant <i>Lythrum alatum</i>	X		Brown 1999
Alternation of wetland function			
Changes in decomposition rates and timing	X		Emery and Perry 1996
	X		Barlocher and Biddiscombe 1996
	X		Grout et al. 1997
Changes in porewater chemistry (reduced P)	X		Templer et al. 1998
Increased evapotranspiration rates	X		Yavitt (unpublished data)

**Biodiversity:** Number and variety of living organisms; includes genetic diversity, species diversity, and ecological diversity

**Decomposition Rate:** The speed at which the decomposition occurs, called the "rate of decomposition", depends on the temperature, moisture and chemical composition of the organic matter.

**Evapotranspiration rate** is a value given to help determine the rate at which plants lose water through evaporation.

**Pore water** is the water filling the spaces between grains of sediment.

5. **Follow up:** Investigate whether any of the impacted birds are endangered in MA

[http://www.mass.gov/dfwele/dfw/nhesp/species\\_info/esa\\_list/esa\\_list.htm](http://www.mass.gov/dfwele/dfw/nhesp/species_info/esa_list/esa_list.htm)

## ANSWERS

### Questions: How is purple loosestrife impacting wetlands?

1. Is purple loosestrife harming the wetland's value as a habitat?

*Yes. Purple loosestrife is reducing the quality of bird habitat.*

2. If yes, what plants and animals have been impacted?

*Plants: Native plant species, Cattail*

*Animals: Least Bittern, Pied-billed Grebe, Virginia Rail, Sora, Long Billed marsh-wren,*

3. Is Purple Loosestrife reducing biodiversity?

*Yes. Gabor's research has shown a reduction in native plant species.*

4. What wetland functions have been altered by purple loosestrife?

*Reduction in plant biodiversity, reduction in native plant species, Changes in decomposition rate, Changes in porewater chemistry, Increased evapotranspiration rates.*

5. Least Bittern and Pied-billed Grebe are listed as endangered in Massachusetts.

Chart taken from

Impact and management of purple loosestrife (*Lythrum salicaria*) in North America

Journal	<a href="#">Biodiversity and Conservation</a>
Publisher	Springer Netherlands
ISSN	0960-3115 (Print) 1572-9710 (Online)
Issue	<a href="#">Volume 10, Number 10 / October, 2001</a>
DOI	10.1023/A:1012065703604
Pages	1787-1807
Subject Collection	<a href="#">Biomedical and Life Sciences</a>
SpringerLink Date	Wednesday, November 03, 2004



**Guiding Question to Discuss/Investigate Further:**

If cattail decline as a result of purple loosestrife, what impact might that have on other species?

[http://www.livinglandscapes.bc.ca/prnr/photo\\_journey/wildlife.htm](http://www.livinglandscapes.bc.ca/prnr/photo_journey/wildlife.htm)

Muskrat ( *Ondatra zibethicus* ) make their homes in wetlands as well and depend upon cattails and bulrushes for food and material to build their homes. The top of the muskrat home is often used by water birds for nesting and loafing (Delesalle, 1998).



<http://dnr.metrokc.gov/wlr/waterres/smlakes/winter98.htm>

**Cattails**

*Typha latifolia* have long, flat tapering leaves along with a dense brown spike of a flower at the top of a tall stalk. Total height can reach 1-3 meters. Cattails are typically found together with bulrushes along the lake shoreline. Many species of waterfowl and mammals depend on both plants for food and shelter. **The underground stems provide food for geese, beaver, muskrat and other animals while marsh wrens and redwing blackbirds nest among the upper stems.** Indigenous people used both cattail leaves and bulrush stems to make mats that were hung as screens, used as shelter, or served as mattresses and kneeling pads. Baskets and string can also be made from cattail leaves or bulrush stems.

<http://www.ag.ndsu.edu/pubs/plantsci/weeds/w1132w.htm>

“The most destructive impact of purple loosestrife invasions is on the ecology of aquatic sites. Purple loosestrife forms dense monotypic stands as it displaces native wetland plants (Figure 2). Under optimum conditions, a small isolated group of purple loosestrife plants can spread to cover aquatic sites in just one growing season (Figure 3). **When purple loosestrife replaces native vegetation it also can displace wildlife. For example, songbirds do not consume the small hard seed. Muskrats use cattails to build their homes, and they show a preference for cattail over purple loosestrife for food. Waterfowl, especially ducks, avoid wetlands that have become dominated with purple loosestrife. In addition, overall waterfowl production decreases as suitable nesting habitat is eliminated. The plant's growth is generally too compact to offer cover, and cover may be as crucial to wildlife as food.**“

**Photographer:** Marv



Muskrat Lodge. Muskrats are mammals native to Massachusetts. Many bird species build nests on top of Muskrat lodges, or simply rest upon them.

*Lessoning Loosestrife by Elizabeth B. Duff 2008*